Process Report

be careful be

cleen

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Trine Thylkjær Asp

MSc4 ID, Group 7, AAU, May 2015

0.0

PREFACE

This report documents the process of the 10th semester Master Thesis projct Cleen in Industrial Design at Aalborg University. The project is documented through the process report, a product report, technical drawings that are printed seperatly. The USB stick contains appendices and electronic copies of the reports.

Title	Cleen
Project theme	Hand hygiene at hospitals
Study programme	Master Thesis
Project period	03.02.15 - 27.05.15
Project group	MSc4 ID - 7
Company cooperations	Ideklinikken, Aalborg University Hospital
Project client	Aalborg University Hospital
Main supervisor	Christian Tollestrup
Technical supervisor	Erik Appel Jensen
Appendices	16
Printing - Process report	7
Printing - Product report	7
Number of pages - Process report	100
Number of pages - product report	24
USB Stick	3

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0.1
SYNOPSIS

This report is a master thesis in Industrial Design from Aalborg University. The subject of the report is the design and development of a hand hygiene solution for Danish hospitals. In collaboration with Idéklinikken at Aalborg University Hospital, the point of departure is a series of interviews and observations that showed a series of critical problems with current solutions.
Through an integrated design process, a new hand sanitizer is developed. The product is called Cleen, and focuses on creating a better and safer experience for both hospital visitors and daily staff. By using an atomizer instead of a regular spout, the product creates a new user experience as well as solves a series of problems regarding drip, splashes and uniform spread. To make guarantee correct use by first-time users, the project has had a deep focus on mockups, prototypes and user-testing. Through this process, valuable insight is gained, and different means have been developed to guide the users to understand and use the product within few seconds.
Throughout the project every stakeholder has been considered, and the feasibility of the concept has been evaluated. It has been estimated that there is a large potential in developing even very small improvements within hand hygiene.

0.2
TERMINOLOGY

HAI: Hospital Acquired Infection

HCW: Health Care Workers e.g. doctors and nurses

Endogenous infection: Infection caused by the patient's own microorganismsl flora

Exogenous infection: Infection caused by the microorganismsl flora from the surroundings

AUH: Aalborg University Hospital

RN: The North Denmark Region

0.3
TABLE OF CONTENT

0.4 INITIAL MEETING AT THE HOSPITAL

Before the beginning of the project period a meeting with two nurses from the Infection Hygiene and our initiating contact at Ideklinikken Pernille Woller Jensen is established.
At the meeting the problem of hospital acquired infections is presented. The hygiene nurses encourage us to focus upon how to make visitors use disinfective alcohol since they assume it is a large reason for the high number of HAI.
The nurses explain how HAI are not just a problem for the affected patients, it is also a problem of political interest. In 2014 17 m DKK was provided to the health care sector for initiatives aiming at decreasing the number of HAI. [sum]

0.5 INTRODUCTION

PROJECT THEME

Every year approximately 100.000 patients are infected by a hospital-acquired-infection in Denmark alone. We would like to reduce this yearly expense through a product that increases the use of hand sanitization, resulting in fewer patients getting the infections. [sdu]

Correct hand hygiene has proven to be the most efficient way of decreasing the occurrence of hospital-acquired infections. [pri1] Within the healthcare sector there is a large focus upon the hand hygiene of employees. In an attempt to improve their hand hygiene a lot of money is spend upon information campaigns resulting in short-lived improvements within hand hygiene. Several studies show that close to no visitors utilize the disinfective alcohol facilities when they are at the hospital. [Wolfe, R. (2012)] This is problematic since the visitors are also spreading the microorganisms leading to hospital-acquired infections. As a visitor at the hospital there are no rules concerning your hand hygiene. It is only when visiting a patient in isolation the visitor gets instructions of hand hygiene.

0.6 PARTNERS AND EXPERTS

PROJECT TEAM

Anders Klitgaard, Louise Christensen, Trine Thylkjær Asp

PARTNER

Throughout the master thesis Ideklinikken at Aalborg University Hospital is used as a sounding board.

IDÉ KLINIKKEN

EXPERTS

HYGIENE NURSES:

Birgitte Todberg & Ingeborg Buus
Introduced the overall problem.

WORK ENVIRONMENT ADVISER:

Ove Willadsen
Has been helping with e.g. fire regulations.

CLEANING DEPARTMENT:

Annette Blok-Olesen
Has answered questions concerning cleaning.

TECHNICAL DEPARTMENT:

Lars Sloth
Has helped understanding the problem from thechair of the technical department.

FINANCE DEPARTMENT:

Heidi Bertelsen
Has anwsered finance questions.

PROCUREMENT DEPARTMENT:

Birgitte Fjeldgaard
Has explained the procurement process concerning new products.

GASTROENTEROLOGICAL DEPARTMENT:

Lise Thylkjær

NEONATAL DEPARTMENT:

Christina Skoda

1.0

RESEARCH

The research section is an overall description of hospital-acquired infections and its prevalence in The North Denmark Region. Secondly the level of hand hygiene is described since a raise of this will be the success criteria of the project.

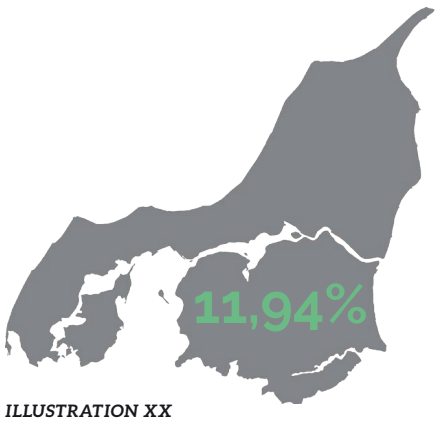


ILLUSTRATION XX
The North Denmark Region percentage of the danish HAI [vest]

1.1
HOSPITAL ACQUIRED INFECTIONS IN DENMARK

THE SCALE OF THE PROBLEM

Every year 8-10% of the patients at Danish hospitals are infected by a hospital-acquired infection, which is approximately 100.000 patients, 3000 of these ends up dying. Numbers show that these infections amounts to approximately 1 billion DKK in Denmark per year, which is more than 2% of the overall hospital expenses. [sdu]

THE FOUR HAI

There are four different kind of HAI.
The four infections are:

- Urinary infections
- Inflammation of the lower respiratory tract
- Postoperative wound infection
- Blood poisoning

ROUTES OF INFECTIONS

Infections are contagious in different ways. The four routes of infections associated with hospital-acquired infections are:

Direct contact

Airborne infection

Indirect contact

Dropborn infections

It is only infections contagious through direct- and indirect contact, which can be decreased through better hand hygiene. Due to this post operative wound infection and respiratory infections will be the focus throughout this project.

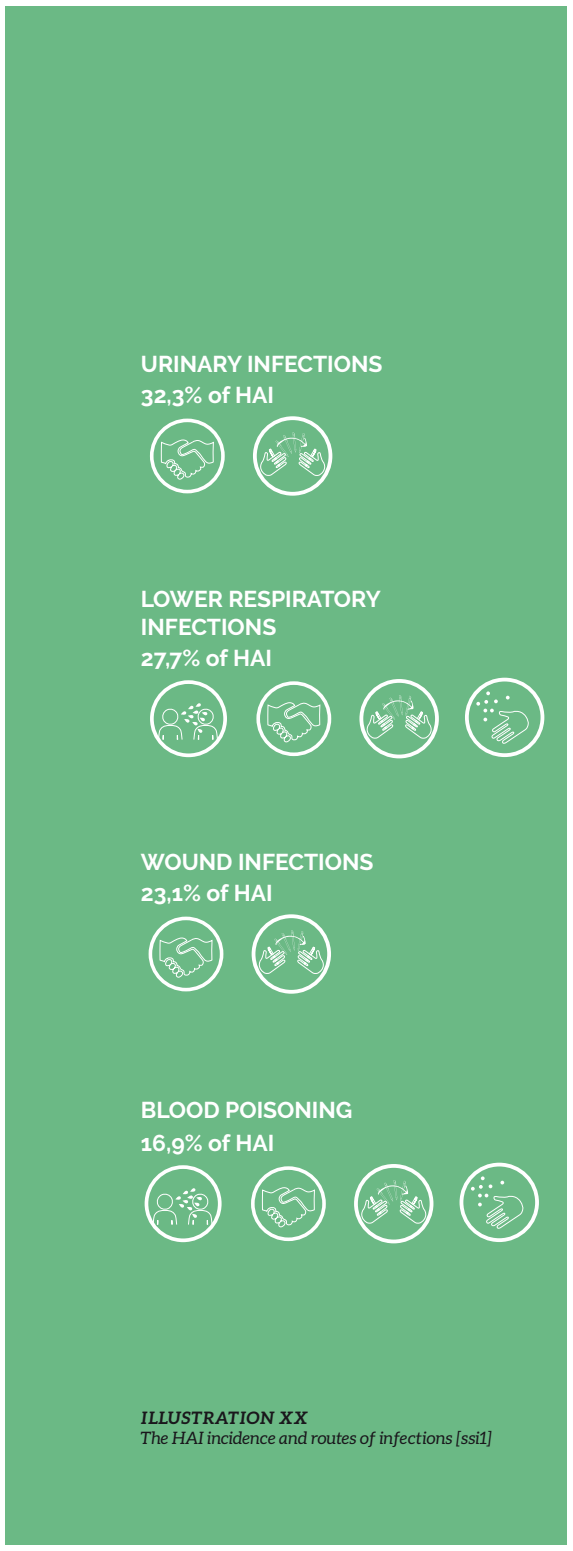
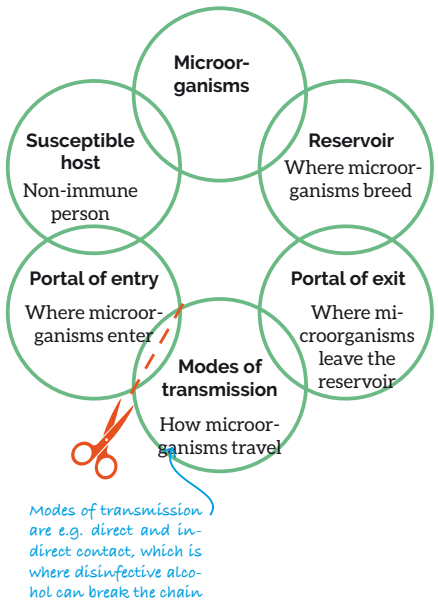


ILLUSTRATION XX
The HAI incidence and routes of infections [ssi1]

1.2
HOW TO AVOID HAI

THE CHAIN OF INFECTIONS

To decrease the incidence of an infection one must break the chain-of-infection. The chain-of-infection consists of the six steps shown at the illustration below. Through correct disinfective alcohol the link "route-of-infection" can be removed for the infections that are spread through direct- and in-direct contact, and by that the patients will not catch the HAI. [ssi2]



1.3
CONTACT WITH PATIENTS

DAILY CONTACT

To be able to decrease the number of HAI through hand hygiene one must know who is in contact with the patients during their hospitalization and how much contact they have.
During an interview with a nurse at the gastroenterological department she estimated that a patient in average is in contact with 9 HCW and 1 relative each day. Statistically this implies that the HCW pose a higher threat of transmitting HAI to the patients than the relatives have.

HAND HYGIENE COMPLIANCE

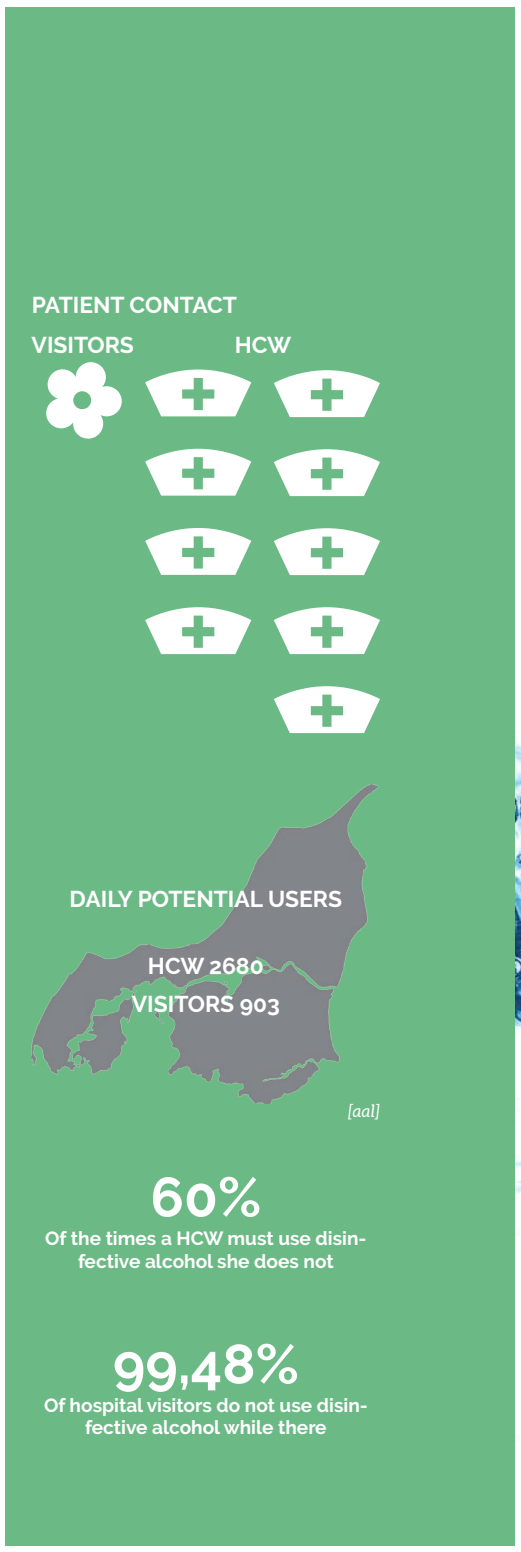
Several studies show that HCW do not use disinfective alcohol nearly enough. In the article *Systematic Review of Studies on Compliance with Hand Hygiene Guidelines in Hospital Care*, 96 studies upon hand hygiene compliance are analyzed to derive a gathered approximated level of compliance at hospitals in the western world.
This study shows that HCW have a 40% hand hygiene compliance meaning that they only wash hands or use disinfective alcohol 40% of the times they must use it. [sdu] Probing the hand hygiene compliance among patient relatives is much worse. Here it is only 0,52% that use disinfective alcohol during their time at the hospital. [pri1]

CAMPAINS

HCW are constantly reminded of the importance of good hand hygiene during their education, courses and information campaigns. Scientific work although shows that only have a short-term effect at the hand hygiene compliance. [Wolfe,R. (2012)]

CONCLUSION

Due to the low hand hygiene compliance of only 40% among HCW, the users in focus of the project, will not only be the relatives of the patient but also the HCW.
This implies that there will be an expert user group who are using the product several times every day and a non-user group who rarely – if ever, use the product.
The implication of these two very different types of users is that the product should be able to teach new users how to use it and still not slow down the HCW in their daily work.

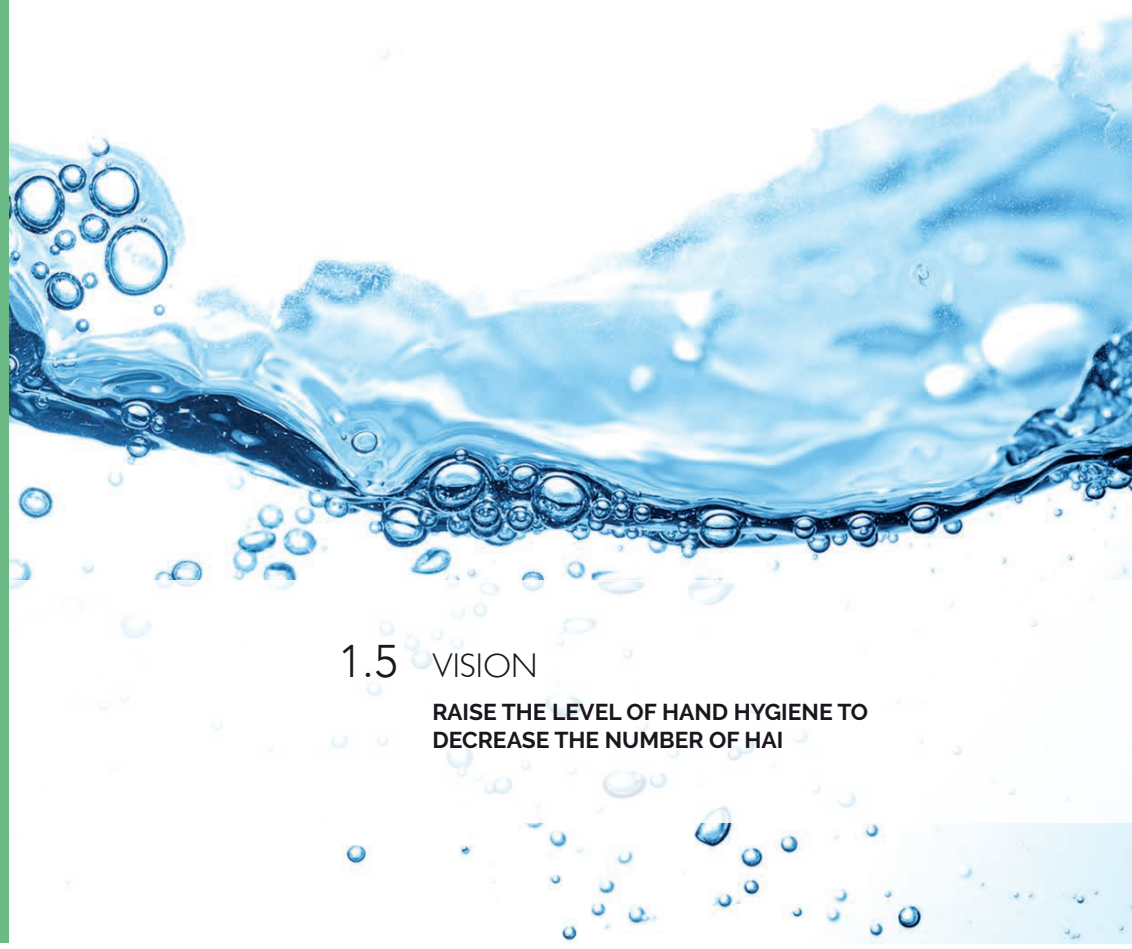


1.4
PROJECT FOCUS

From the initial meeting with the hygiene nurses we are encouraged to focus upon a hand sanitizer. Before beginning the research into the current use of hand sanitizers it must be clarified if there is a better solution to avoid HAI than a better hand hygiene.
From the World Health Organisation it is quickly experienced that there is not.

> Hand hygiene is the single most important element of strategies to prevent health care–associated infection [app1.4]

Disinfective alcohol can be used several times a day without drying out the hands and it kills 99% of the microorganisms when used correctly. [sun] Due to this, the focus of the project is to develop a product providing people with disinfective alcohol. From here the product will be refered to as a hand sanitizer.



1.5 VISION

RAISE THE LEVEL OF HAND HYGIENE TO DECREASE THE NUMBER OF HAI

2.0

CONTEXT INSIGHTS

The key issues concerning hand sanitizers are primarily found through interviews of relevant stakeholders and observations of the use of the hand sanitizers. The following section describes the insights and their impact upon the project framing.

2.1
HAND HYGIENE REQUIREMENTS

HEALTH CARE WORKERS

Within the healthcare sector there are several situations where the HCW must use disinfective alcohol. This is before clean processes and after dirty processes. These are presented at the figure below to show what the ideal hand hygiene for a HCW is.

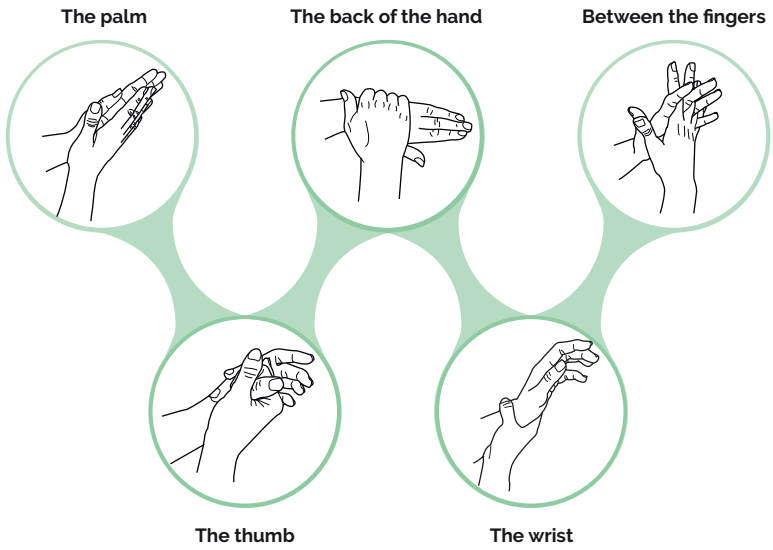
VISITORS

With regards to the relatives of the patients there are no requirements concerning hand hygiene. However if the patient is in isolation they are provided with a booklet encouraging them to wash their hands after the visit. [app2.1]

A HCW must use disinfective alcohol several times in a nursing situation.

HOW TO USE DISINFECTIVE ALCOHOL

To obtain the desired effect of killing 99% of the microorganisms there are two important aspects to consider.
The hands must be wet with disinfective alcohol for at least 30 seconds
The areas that must be covered are illustruted below, the order is insignificant



NATIONAL HAND HYGIENE GUIDELINES

From the hand hygiene requirements some further criteria for the product occur.
The disinfective alcohol must not be contaminated due to use or refill
The hand sanitizer must be hands free or elbow operated
It should be visible if it contains soap or disinfective alcohol
The hand sanitizer must be cleaning-friendly with the biocide directive
Expiration date must be visible [nir]

Sum up

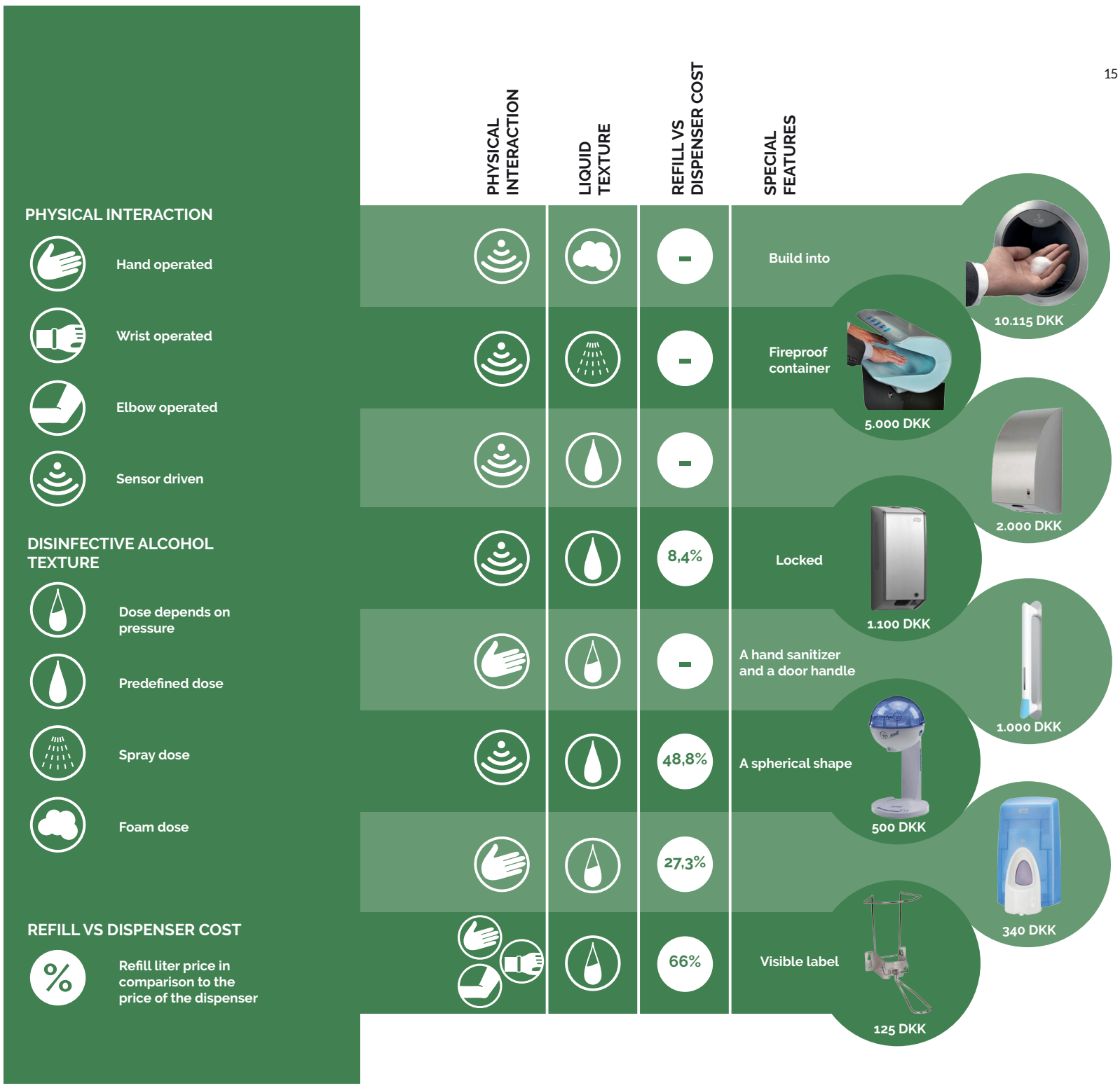
- Humid hands for 30 seconds
- HCW must use disinfective alcohol several times during a nursing situation
- The disinfective alcohol must be spread all over both hands

2.2
MARKET RESEARCH

The market of hand sanitizers is clearly a red ocean with a high number of competing products aiming at fulfilling the same purpose of providing people the best possible microorganisms free hands. The aim of this market research is to get an insight into the price level and features offered at the current hand sanitizer market.
The market research is based upon products of varying complexity, the only entry requirement of being a part of the research is that it must be possible to find the cost price of the hand sanitizer.
Throughout the research it occurs that most brands have their own disinfective alcohol refills. The price of these refills varies from 70-142 DKK. For some of the hand sanitizers the refills cost approximately the half of the dispenser it self. This makes the disinfective alcohol refills an important part of the business case in the process of buying new dispensers.
From the market research mapping at the adjacent figure it occurs that for 500 DKK you can get a sensor driven hand sanitizer. With exception of Handmate the automatic hand sanitizers are battery-powered.
In the group we find the Pull-Clean sanitizer really interesting since it forces the hospital to place the hand sanitizer where people are actually walking and hereby encourage them to use it more frequently.

FINDINGS

The market research shows that there are not large varieties in the features of the hand sanitizers with a cost price between 125-340 DKK and between 500-2000 DKK. While the difference between these two groups is merely that the one group is operated mechanically and the other is sensor driven. When looking for features enhancing the user experience like dosing the disinfective alcohol differently or indicating time like the features at Handmate the cost price is 5000 DKK.
None of the mechanically operated hand sanitizers fulfil the requirement of being impossible to operate with the hand. This leaves an opportunity for the later product development process.
Concerning the disinfective alcohol refills there might also be an opportunity in making a cheap refill solution, which could lead to a better business case compared to existing products in the long run.



2.3 EXPERT INSIGHTS

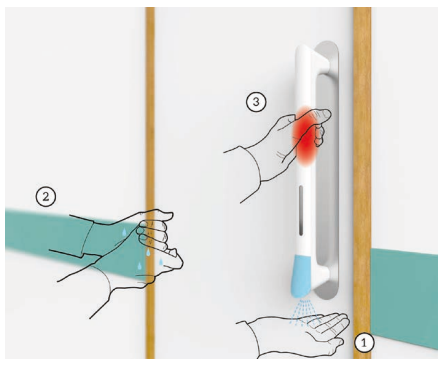
In the procurement processes of hand sanitizers the opinion of the infection nurses plays a large role, when deciding which dispensers to buy. This research is conducted to get insights into what makes them prefer some dispensers above others.

THE EXPERIMENT

Pictures of eight dispensers with varying features and shapes are given to two infection nurses who write their comments to each of them. The comments are visible at the adjacent figure.
It is surprising that the infection nurses are very critical towards Pull-Clean, which is a hand sanitizer incorporated in a door handle. In the group this feature is found quite smart since it makes disinfective alcohol a part of the natural flow when entering a room. It is the risk of using the product in the wrong way and hereby re-contaminating the hands when opening the door that alarms the nurses. See the figure below.

CONCLUSION

In the evaluation of hand sanitizers the infection nurses primarily pay attention to cleaning-friendliness, hands free interaction and if there is a danger of breeding ground for microorganisms.



The hollow shape is a reservoir for microorganisms

You are only capable of operating it with the hand is really bad.

There are a lot of edges which are difficult to clean.

It is a problem that the patients cannot see the nurse using disinfective alcohol. The signalling effect disappears.
People get contaminated hands when opening the door afterwards.

The upward nozzles are a breeding ground for microorganisms.

The product must be

- Cleaning friendly surface with as few cracks as possible
- Hands free interaction no matter if it is a mechanical or automatic solution
- A difficult breeding ground for microorganisms

2.4 THE PROCUREMENT PROCESS

When designing for a public sector like the healthcare sector there are some specific rules concerning the purchase situation.

REGULATIONS

All expenses in the public sector exceeding 500.000 DKK should be announced in a public procurement. [udb]
In these procurements there are some specific requirements the products must fulfill. In the case with hand sanitizers the relevant hospital staff determines these requirements. Their interest in the hand sanitizer differs from economic aspects over user friendliness, aesthetics, maintenance, whether it is easy to clean and it's ability to decrease the spread of microorganisms. In public procurements for new build the architects have a saying concerning the aesthetics and placement of some products, this will then be a part of the procurement too.

PROCUREMENT COORDINATOR

From the interview with Birgitte from the Public Procurement Department it is learned that there are two sorts of procurements. There is a normal procurement and a functional procurement.
In the normal procurement there are no specific requirements for the product. It is then up to the chosen stakeholder team to evaluate the products. In the end the products primarily compete upon price.
For the functional procurement some minimum requirements are the foundation of the evaluation. These minimum requirements must be verifiable. The chosen stakeholder team then evaluates products fulfilling these minimum requirements. This procurement is less dependent on price and more upon functionalities. As a new product challenging the existing products the functional procurement is the recommended approach.
Birgitte also inform that the procurement for hand sanitizers for the Super Hospital in Aalborg will be written in 2017. With the proper strategy and a targeted product development there is a possibility for us to address this procurement.

2.5 HOSPITAL STAKEHOLDERS

All the different stakeholders participating in the procurement process are interviewed, to get to know their needs and wishes for a new hand sanitizer.

INDIGO GROUP

The Indigo group is responsible for the design of the future Super Hospital east of Aalborg. The group was contacted to get a view of the future of modern hospitals, and how they are currently planning to incorporate hygiene and hand sanitizers. The most radical change is the switch to private wards instead of the current wards that are shared with up to 2 other patients. This takes care of the already observed problem, which is described at page 24, where visitors may have to break the private sphere of another patient to use the shared hand sanitizer.
Future hand sanitizers are still collected in the group of other hygiene products called hygiene stations. These standard configurations consist of a sink, soap and sanitizer, disposable gloves and a garbage can. Examples of these are visible in appendix 2.5.

- The hand sanitizer procurement will be decided in 2017
- The product solution must fit in a typical hygiene station
- The hygiene station is still placed beside the door, and those entering the room, should turn away from the natural route towards the patient, to use disinfective alcohol

TECHNICAL STAFF

The main concern for the technical staff is the mechanical upkeep of the dispensers. A new dispenser should be durable, but service and troubleshooting will be too costly if the dispenser cost less than 500 DKK. In that case, they will just replace it.

- Service is only a concern on more expensive equipment
- They want batteries to be replaced by the cleaning staff

WORKING ENVIRONMENT STAFF

It is important that products that are used several times a day, is not affecting the joints and muscles of the users. When discussing alternative disinfective alcohol textures like gas- and spray based concepts there is a concern that people might inhale the aerosoles.

CLEANING STAFF

The cleaning staff has the most interaction with the dispenser when it comes to practical functions like cleaning and refilling, so it is important to consider their needs.
One aspect is the act of removing and refilling the bottles in the dispensers. Through our own experiments, it is apparent that the sanitation refills are difficult to remove when they are empty. Because of the vacuum inside the bottles, they become flat and presses up against the sides of the steel frame.
Another aspect is the cleaning of the dispensers themselves, which is done daily. Even though the dispenser is a busy node for indirect contact, it is only cleaned on the handle.
According to the cleaning staff, drip at the floor is a large problem, because it leaves permanent stains at the organic linoleum floors.
Some cleaning staff uttered frustration with how difficult it is to clean the other parts of the dispenser. They do not have to clean these parts, but at some departments they even put the dispenser in the dishwasher.

FURTHER FINDING

One of the difficulties appearing through the interviews is; who should be allocated with the task of exchanging the batteries if the hand sanitizer ends up being battery driven? The technical staff thinks it is a task for the cleaning staff and vice versa.

- Ethanol in the form of aerosols is a working hazard due to a risk of inhaling
- It must not be physically tasking to use the dispenser many times a day

- Only handles and drip trays are cleaned daily with universal cleaning detergent
- A ward with a patient in segregation is cleaned in a chlorine dissolution. That includes the hand sanitizer
- Disinfective alcohol refills can be difficult to remove when empty

2.6 OBSERVATION OF HEALTH CARE WORKERS

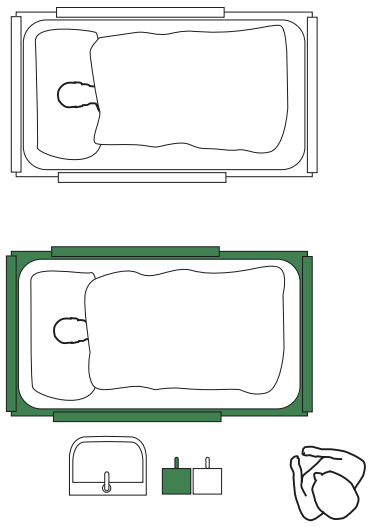
To obtain insights into the HCW use of disinfective alcohol two nurses are shadowed for several hours.

OBSERVATIONS

MACRO STUDIES

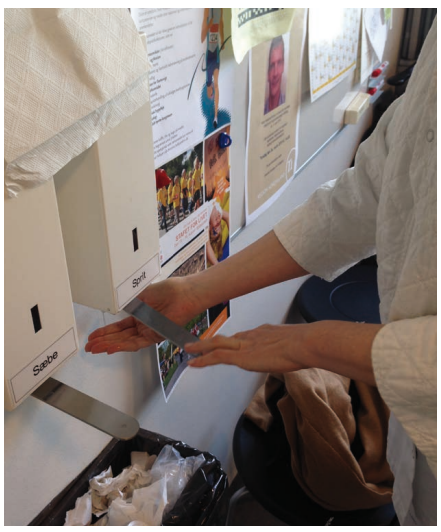
The HCW often carry stuff when entering a ward

The HCW cannot get access to the hygiene station by the sink during hospital overcrowding



MICRO STUDIES

The HCW are constantly operating the hand sanitizer by hand instead of using the elbow as required



The HCW must pump the dispenser twice to obtain enough hand sanitizer

CONCLUSIONS

It must be possible to operate the dispenser carrying stuff under one arm

The dispenser must be able to be placed away from the hygiene station

It must be inconvenient to operate the dispenser by hand

One interaction must deliver the necessary amount of hand sanitizer

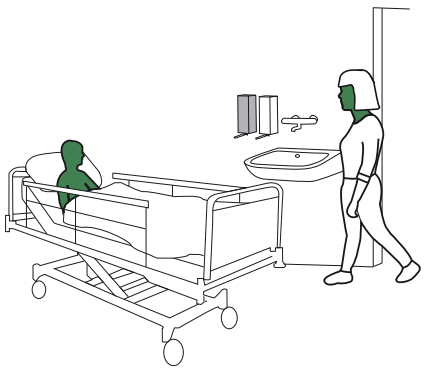
2.7
OBSERVATION OF VISITORS

Observations upon visitors are made for insights into the use of disinfective alcohol – or lack thereof. The macro studies are based upon own experiences since it has not been possible to observe actual relatives at the hospital. The micro studies upon inexperienced users use of the product is conducted at the university, by observing our fellow students using the existing hand sanitizer.

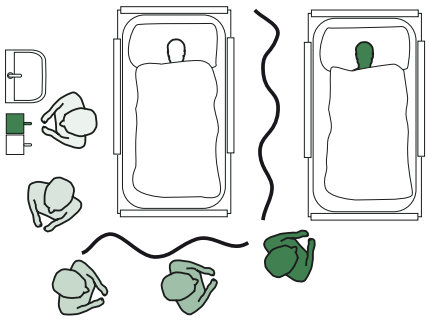
OBSERVATIONS

MACRO STUDIES

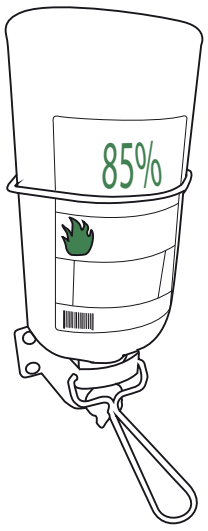
The relatives do not see the hand sanitizer when entering the ward. They are focused upon the patient and want to go greet them.



The relatives should break a domestic sphere to use disinfective alcohol, when the dispenser is placed closest to another fellow patient.



The dispenser looks professional and visitors doubt whether they are allowed to use it.



A lot of emotions are involved when visiting the hospital. In this situation the importance of hand hygiene is forgotten or even opted out consciously because of an urge to go greet the patient.

CONCLUSIONS

Make it natural for the visitor to use disinfective alcohol before greeting the patient.

The future product should be able to be placed away from the hygiene station.

Make it clear that it is a hygiene product that everyone is allowed to use.

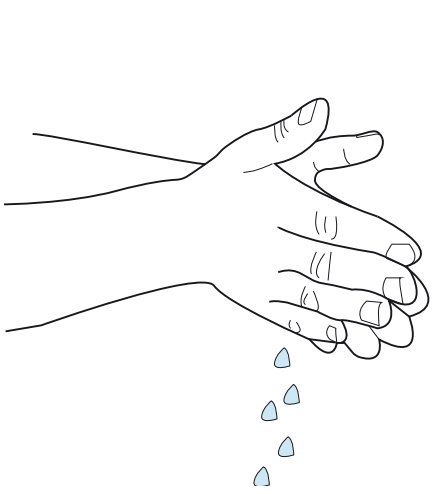
The product must not force people to stay by it during the 30 seconds they should maintain humid hands. This will entail a queue, which reduces the excitement around the visiting situation.

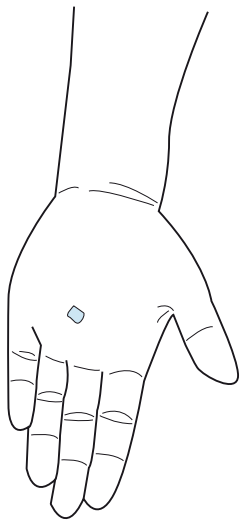
OBSERVATIONS

MICRO STUDIES

There is a lot of drip at the floor when people clasp the hands together to spread the disinfective alcohol at both hands.

Several of our fellow students took a very small portion of disinfective alcohol the second time using the dispenser. They thought their hands were wet for an eternity the first time.





CONCLUSIONS

Alternative ways of dispensing the disinfective alcohol must be considered to reduce drip at the floor

The users should not be able to determine the dosage themselves since they will take too little and think that their hands are clean

CONCLUSION

VISITORS

When addressing the relatives there is a need of a three-step plan.

The visitor should see the disinfective alcohol product.
The product should make aware of its existence through different means like for instance through colours, noises, lights or the like.

The product should communicate that everyone are supposed to use it
It should be clear that the product is a hygiene product and attract people to go and use it without fearing that it is for professional use only.

The visitor should go and use it.
The product should be easy to operate correctly for inexperienced users.

Concerning the visitors the first step of the plan will be of the highest priority in this project since they do not know that they are supposed to use disinfective alcohol.

HEALTH CARE WORKERS

When asking the HCW why they do not use disinfective alcohol as often as supposed to, their only answer is that it is due to a pressure of time in emergency situations. They have no explanation to why they misses it several times throughout the nursing situation. Due to this we must assume that it is because of an oversight. Those opting out the use of disinfective alcohol delibaretely will not be a focus of this project.

Concerning the HCW the focus of the project will be to make them remember to use disinfective alcohol and to make them use it correctly e.g. without touching the hand sanitizer.

THREE-STEP PLAN

SEE IT

ITS FOR YOU

USE IT CORRECTLY

TWO-STEP PLAN

REMEMBER IT

USE IT CORRECTLY

PROBLEMSTATEMENT

SCOPE

IN SCOPE

1st priority

The centre of rotation in this project is the daily use of the hand sanitizer, in the hospital context, focusing on both visitors and HCW who are the primary users of the hand sanitizers. The primary focus will be to improve the user experience.

2ND PRIORITY

The secondary user group is other employees at the hospital. In the procurement process the opinions of the secondary users have an equal status to the opinions of the primary users and are therefore important to include.

3RD PRIORITY

In the project patients are not considered as a user of the hand sanitizer and are therefore not included as a direct user. However there is a hand sanitizer at every ward and the patients will be the ones looking at it most of the time. Consideration of the patients will be taken in the process of attracting attention to the product since it must not be a source of irritation for the patients.

OUT OF SCOPE

The project is delimited from:

As previously described the persons deselecting disinfective alcohol deliberately is not a focus of this project.

There are some specific requirements for the disinfective alcohol. These requirements have not been questioned and the design of the disinfective alcohol has only been touched briefly.

The amount of disinfective alcohol used and the importance of using it vary between the different hospital departments. These differences are not considered in this project since the aim is to develop a product suitable for all departments with no add-ons.

The psychiatric department is not considered as a target group for this project since there are explicit rules concerning security, which will be a bit over the top for the somatic hospital departments.

PREREQUISITES

The project is solely focusing upon the hospital, which is why the project will respect the required regulations like e.g. that the hand sanitizer must be wall mounted.

The business case of the project is based upon the public hospitals in the North Denmark Region. Through the collaboration with Ideklinikken, data upon disinfective alcohol consumption and expenditures for this region are available.

MISSION

MAKE THE HCW

Remember to use disinfective alcohol

Use disinfective alcohol correctly

MAKE THE VISITORS

See the hand sanitizer

Decode that the hand sanitizer is for them

Use disinfective alcohol correctly

2.9 VALUE VISION

For the identity of the hand sanitizer it is decided that it should encourage a professional feeling for the HCW while still resembling an inviting and hygienic product for the visitors.

INVITING

Metaphor: Inviting like a bench in the park

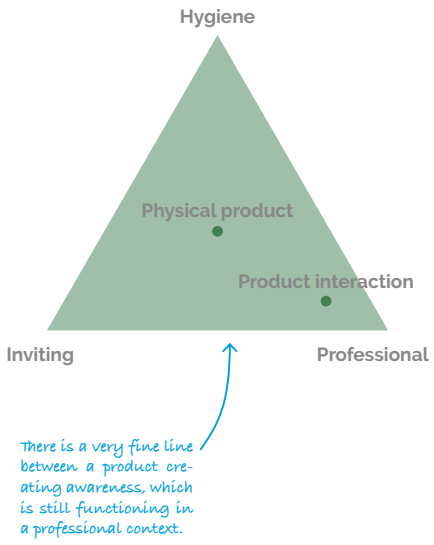
PROFESSIONAL

Metaphor: Someone making it look easy

HYGIENE

Metaphor: The feeling of a freshly made bed

TENSION FIELD



THE CHALLENGE

The fundamental challenge of this project is to make the visitors see the hand sanitizers and make them realise that they are supposed to use them. However it is important that the HCW still takes the hand sanitizers seriously and do not feel like entering a circus whenever using the dispenser. It is important to find the balance between these two aspects to develop a product satisfying the need of both visitors and HCW.

2.10 REQUIREMENT SUM-UP

REGULATIONS
Must contain disinfective alcohol
The disinfective alcohol must not be contaminated due to use or refill
Expiration date must be visible
Must be wall mounted
Should not increase calorific load

HCW
It must not be physically tasking to use the dispenser many times a day

It must be possible to operate the dispenser carrying stuff under one arm

HCW + VISITORS
It should be visible if it contains soap or disinfective alcohol

Humid hands for 30 seconds

OUR FINDINGS
One interaction must deliver the necessary amount of hand sanitizer
The dispenser must be able to be placed away from the hygiene station
Make it clear that it is a hygiene product that everyone is allowed to use.
The product must not force people to stay by it during the 30 seconds they should maintain humid hands.
The users should not be able to determine the dosage themselves
Must be feasible economically for a large hospital with at least one at each ward
Remain functional until last drop
The dispenser must not cause disinfective alcohol on the floor

CLEANING STAFF
The hand sanitizer must be cleaning-friendly with the biocide directive
Cleaning friendly surface with as few cracks as possible
Must show when it must be refilled

HYGIENE NURSES
Hands free interaction no matter if it is a mechanical or automatic solution
The hand sanitizer must be hands free or elbow operated
A difficult breeding ground for microorganisms

THE INDIGO GROUP
The product solution must fit in a typical hygiene station

WISHES
Indicate the critical areas to sanitize
Flexible mounting

3.0

CONCEPT DEVELOPMENT

In the following section concepts for the sub components are developed, tested – mainly through user experiments and finally it is determined which concept to bring to the detailing phase of the project.

A hand sanitizer consists of several sub-components with a specific purpose. These components should all undergo a careful design process to create the best possible product. The priority between the components is different. Some components depend on the functionalities of others and are therefore adapted afterwards.
Throughout the concept development the ideas will be evaluated upon some predefined criteria. When a concept fulfils a criterion the icon will be blue and if it does not fulfil the criterion the icon will be orange.

SUB-COMPONENTS

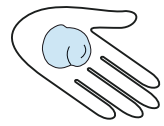
- Shell
- Reminder
- Refill
- Pump
- Physical interaction
- Chamber
- Delivering to hand
- Dose

3.1
ALTERNATIVE TEXTURES

Alternative disinfective alcohol textures are considered to expand the project focus. However they are deselected due to unfeasible production and inconveniences.

FOAMING OF THE DISINFECTIVE ALCOHOL

- Easy to control compared to liquid disinfective alcohol
- Unfeasible as to production due to the requirement of at least 70% ethanol in the hand sanitizer.



HAND SANITIZER NAPKIN

- There will be no drip at the floor
- People would be left with a useless napkin to get rid of.
- People might consider it ever clean and use it repeatedly

HAND SANITIZER CAPSULES

- The users are prepared of the volume of the disinfective alcohol
- A possibility of an eye catching dispensing mechanism
- A quick dispensing allowing people to burst it walking away from the dispenser

- The hand sanitizer must not decompose the capsule and the solution would therefore leave the user with the capsule, which they should then get rid of.

3.2 DOSAGE

To achieve the desired effect of killing 99,9% of the microorganisms when using disinfective alcohol ones entire hands must be wet from it for at least 30 seconds. The point of departure regarding the disinfective alcohol dose is that the required dose depends on the size of the hand.

CRITERIA

The right amount:
Ensure people receive the right amount of disinfective alcohol. By observing HCW and our fellow students using disinfecting alcohol it is experienced that they do not take enough of it.

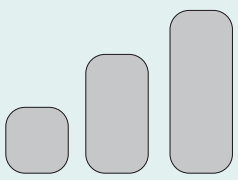
Recontermination:
The hand sanitizer may not be a reason for spreading microorganisms.

Price/complexity:
The product must be feasible economically to implement at hospitals with at least one dispenser at each ward.

Adaption to context:
The hand sanitizer must correspond to the requirements from the context like cleaning-friendliness and working environmental aspects.

Positive assessment

Negative assessment



DIFFERENT DISPENSER SIZES

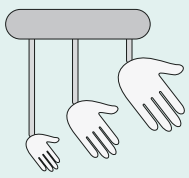
The HCW tend to take too little disinfective alcohol, which might happen with this solution too.
Visitors will not know whether they are a e.g. small, medium or large hand size.

It is possible to make a solution where the users cannot operate the dispenser by the hand.

There is a need of three dispensers, which will roughly be three times as expensive as a single dispenser solution.

The solution will be impossible to incorporate in any of the hygiene stations, when a dispenser should contain at least 1000 ml of disinfective alcohol.

DIFFERENT INTERACTION SIZES

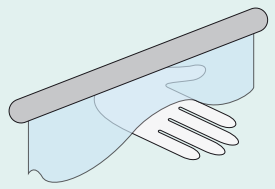


The same argumentation as the idea above.

The same argumentation as the idea above.

It is possible to make a low-tech solution, which will not add a large extra cost or complexity to the product.

It will be possible to adapt the solution into the hygiene stations



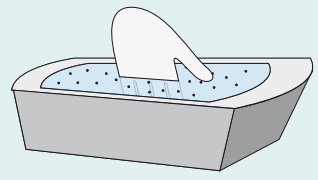
OVER DIMENSIONED NOZZLE

The probability of receiving enough disinfective alcohol is enhanced, but there is still an opportunity of removing the hands before receiving enough. Visitors will not know how far to put in the hands.

It is possible to make a solution where the users cannot operate the dispenser by the hand.

There will be an excessive use of disinfective alcohol, which will be a high expense over time.

The excessive disinfective alcohol will increase the calorific load if not treated carefully.



DISINFECTIVE ALCOHOL MIST CHAMBER

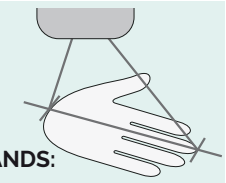
If people do not put their entire hand into the chamber, they will not get enough disinfective alcohol.

The chamber can become a reservoir for microorganisms and cause recontamination if these microorganisms are stirred up into the mist.

A constant disinfective alcohol density in the chamber is important. This can be quite complex to obtain.

The dispenser is difficult to clean properly due to the hollowed out shape.
There is a risk of the HCW inhaling a large amount of disinfective alcohol during their working hours.

MEASURING THE HANDS:



The dispenser will decide the dose of disinfective alcohol needed based on the measured size and the user should be sly in order to avoid the correct dose.

It is possible to make a solution where the users cannot operate the dispenser by the hand.

The product would become quite complex and high-tech to satisfy the task.

If the concept should work properly in the busy working context the technology should be very quick to measure the hand.

CONCLUSION

None of the above concepts meet the criteria satisfyingly. The problem with the different dose sizes is that they cause undesirable complexity to the hand sanitizers. In an attempt to avoid this high product complexity an experiment, upon whether different doses are necessary, is conducted.

3.3 ONE DOSE EXPERIMENT

A rough experiment upon the hands of the group members is conducted to frame a suitable dose size. Here it is experienced that 3 ml is an appropriate dose to keep the hands wet for at least 30 seconds. The experiment was conducted at the Aalborg University City Campus where people with varying hand sizes are filmed while using disinfective alcohol.

From the experiment it is experienced that all experiment participants, with a single exception, have wet hands for at least 30 seconds when receiving 3 ml of disinfective alcohol. Because one participant only has wet hands for 26 seconds it is also learned that the dose can not be smaller than 3 ml.

An explanation to the high variety in the results is that people's perception of dry hands differs. When analysing the videos it is clear that some participants expect to get completely dry hands, which is not the case due to the hand care agent glycerine. Other participants described their hands as dry when they felt like being able to use them again.

Exceeding the 30 seconds might seem like a waste of time for the HCW who can be quite busy. According to the infection hygiene the HCW are already taught to utilize the time to talk to the patients, which both the patients and HCW appreciate.

An unintended finding from the experiment is that all the test users starts rubbing in the disinfective alcohol at the palm, tomb and the back of the hand without any guidance. Most participants also get it between the fingers and those having wet hands for more than 30 seconds are very careful about getting it around the nails and wrist too.

The videos are available in appendix 3.3.

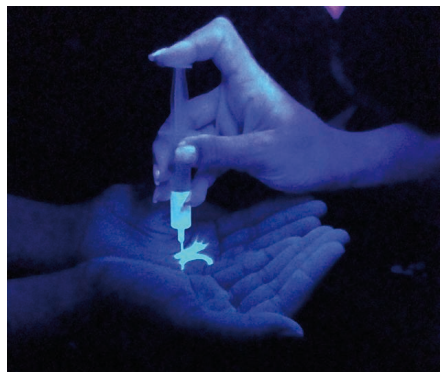
Test subject	Moist
1	70 sec
2	30 sec
3	48 sec
4	46 sec
5	49 sec
6	52 sec
7	73 sec
8	45 sec
9	26 sec
10	34 sec

Moist and not completely dry

3.4 VALIDATION OF 3 ML DOSE

GLITTERBUG

In collaboration with the nurses at the Infection Hygiene Department we have borrowed a hygiene teaching tool called a Glitterbug. The Glitterbug is a large shell with a build-in UV-light that makes it easy to observe how well people distribute hand sanitizer.
To make the hand sanitizer react to UV-light, it has to be mixed with a florescent additive. This additive is invisible in daylight, but shows clearly in the Glitterbug. It would be effective if we could incorporate this feature in our product, but the additive is very hard to wash of afterwards, and stains clothes very easily.



1,5 ML VS 3 ML

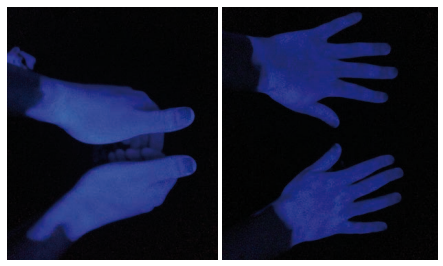
The hand sanitizers currently available at Aalborg University Hospital only provides people with 1,5 ml with each interaction. A brief experiment is conducted to see what the difference is between a 1,5 ml dose and a 3 ml dose.

CONCLUSION

From the experiment it is clear that 1,5ml is not enough to apply disinfective alcohol all over both hands. Neither does the Glitterbug show if the hands are moist for the required 30 seconds. With the 1,5ml dose the hands are dry immediately and the full effect of the disinfective alcohol is not obtained.
Using the current hand sanitizers one must make a double interaction to obtain the 3ml dose of disinfective alcohol. This is counter-intuitive. During their education the HCW learn that they are supposed to pump the hand sanitizers twice, but the visitors do not posses this knowledge and will therefore not use enough disinfective alcohol.

These two pictures show the result of a 1,5 ml dose. The bright areas show where the disinfective alcohol has been applied. The participant has not fluids to reach the entire hand with the 1,5 ml.

Non-disinfected area



These two pictures show the result of a 3 ml dose where it is clear that disinfective alcohol has been applied everywhere, even around the nails.

Findings

- The hand sanitizer must provide 3 ml of disinfective alcohol for each interaction
- A solution showing whether the hands are clean or not is not a possibility

3.5
DELIVERING TO HAND

The delivery method is the most important aspect of the dispenser in terms of the physical user experience. The way the hand sanitizer is delivered does not only dictate the mechanical solutions required to dispense a steady amount of liquid, it also determines how well the sanitizer is spread, and how the user experiences the "feel" of the liquid. Since the physical aspect is so important, we choose to make mockups of as many concepts as possible, to judge the reaction towards them.

REQUIREMENT

There are some general requirements for the way the disinfective alcohol is delivered, which are fulfilled in all of the concepts. These are:

- Must enable interaction without touching the dispensing mechanism.
- Must not force a 30 second pause between each dosage.
- Must be usable while carrying something under one arm.

EXPERIMENT

For some objective opinions upon the concepts a user test is conducted. The participants are asked to evaluate the highly subjective criteria of the feeling of the way the disinfective alcohol is dispensed and if they feel in control during the period of the dispensing.

CRITERIA

The concepts are evaluated upon whether they fulfil the below criteria or not.

Must give a feeling of control.

Must bring a pleasent feeling.

Must be cleanable to the hospital standards.

Must dispense all the liquid in the hands, and hereby limit drip at the floor.

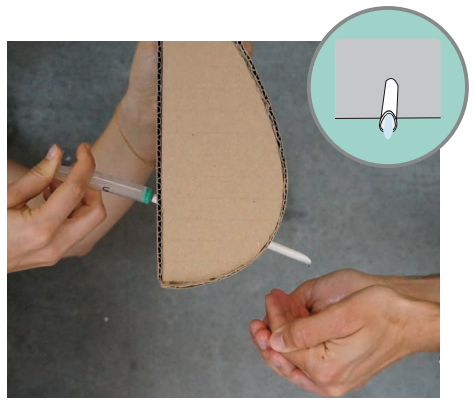
Positive assessment

Negative assessment

CONCEPTS

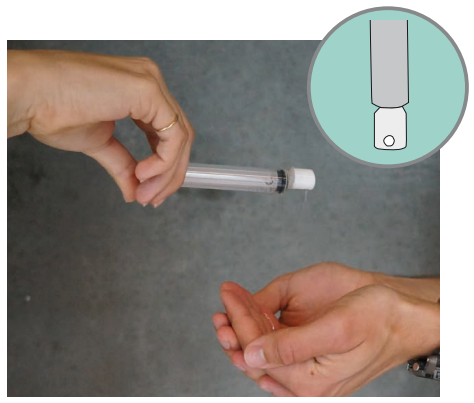
ESPRESSO

This concept is inspired by the pleasant flow of an espresso machine. The goal is to create a soft and slow pour.
The reception is not as expected, and the test subjects especially note that the flow is uneven, and feel uncontrollable and unsatisfying. Furthermore, the viscosity of the liquid is too low to create a smooth, slow flow.



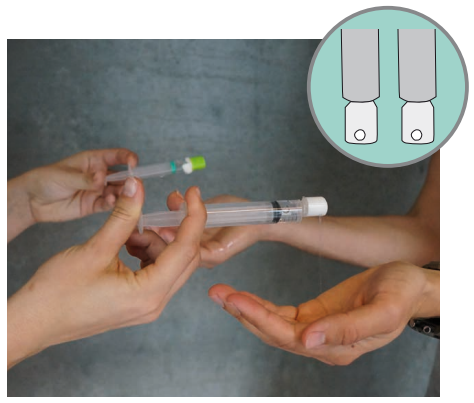
SPRAY

The spray is an attempt to distribute the liquid as much as possible while accommodating all hand sizes. Since the shape of a spray is conical, the user can vary the distance to get full coverage. All four test subjects are very positive with the feeling of the spray. They state that the spray is easy to control and give them a cool soft feeling.
"Very nice, cool, and a good sound. You get a good spread of the liquid"
"Mmm...That is very nice. It is calm, and you feel like you can grab the liquid"



DOUBLE SPRAY

To make sure that the users does not just use a single hand, or even use the other hand to touch the dispenser; a concept with two spray dispensers is developed. The test subjects are very surprised by the concept, and all have trouble understanding what to do at first. They state that it feel harder to control the liquid, and difficult to focus on two points at the same time.
"It feels weird to hold the hands apart"



SYRINGE

The syringe is a thin straight stream, dispensed by a plunger chamber. The size of the stream is very similar to the current hospital dispenser, but the flow is much more consistent. The test subjects also noted this, and they preferred the steady flow. The main downsides are a large amount of splash from the stream, and that the long stream urge the users to remove their hands because they are overwhelmed.

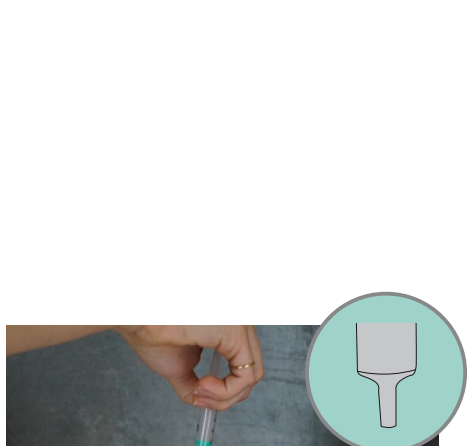
SHOWER

To prevent people from inhaling the mist from the Spray concept, the Shower uses bigger droplets to create a spread out pattern. Since the holes in the dispenser are bigger, the liquid requires very little pressure to dispense, and for that reason, it does not create the same conical patterns as the spray. The test subjects state that it is close to the Spray in terms of overall feeling.

CHAMBER

The chamber is a basic concept of dispensing 3 ml. in one go. The mechanism is a basic turning chamber that fills on the top and dispenses on the bottom. Despite the simple mechanism, none of the test subjects are pleased by the concept. Most preferred to get a steady stream of liquid instead of all at once. The fast pour felt uncontrollable.

> It is like being peed on!



BALL

The ball is another concept that focuses on creating a smooth and mild stream of liquid. The idea is that the liquid covers the ball and creates a soft drop at the bottom because of the shape. The concept is hard to create as a mockup, and that affect the reception of the concept. The stream is uneven, and do not create the desired type of flow. This is also due to the low amount of liquid we are dispensing.

DOME

The dome is derivative of the Ball, and uses a half sphere to dispense a circular pattern of liquid. The liquid flows on the underside of the dome. This concept has similar problems with the low amount of liquid, and do not create the desired flow. This make the test subjects dislike it.

CONCLUSION

The differences between the ways the liquid is dispensed are much larger than expected. The test subjects have very clear and shared opinions on what kind of feeling they like and what they don't like. Especially the spray concept stood out with a very positive reception, and positive comments because it gives a distinct feeling and a nice spread. However, double spray dispensers appears to require too much focus to use comfortably. It is more natural to bring your hands together to apply a liquid.
Another important finding is the importance of the pour and the speed of the flow. It is easier to control a steady stream of liquid instead of an instant pour. The risk of splash increases with the speed of the flow, and should be avoided. The flow itself should also be very consistent since an uneven flow feels unsatisfying, and several test subjects compared it to being peed on.

The Shower concept is also popular among the test subjects, but it is deselected due to the large amount of disinfective required for creating a steady shower-like feeling.

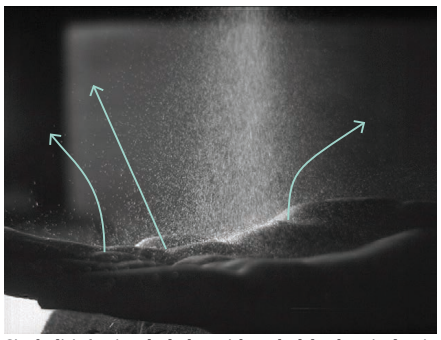
3.6
SPLASH BACK EXPERIMENT

The choice of atomizing the disinfective alcohol is contrary to the recommendations of Statens Serum Institut. They do not recommend applying disinfective alcohol by spray, to avoid people from breathing in the aerosols. [nir]
Based on an assumption, that it is possible to avoid splash back for the spray solution, and hereby avoid people breathing in disinfective alcohol, an experiment is set up.
Aerosols are very small particles that are difficult to capture with an ordinary camera, instead a high-speed camera taking 1000 pictures/second is used.

The distance between hand and spray nozzle is constantly 16 cm, which is the evaluated required size if people should be able to rub in the disinfective alcohol during the dosage there of.

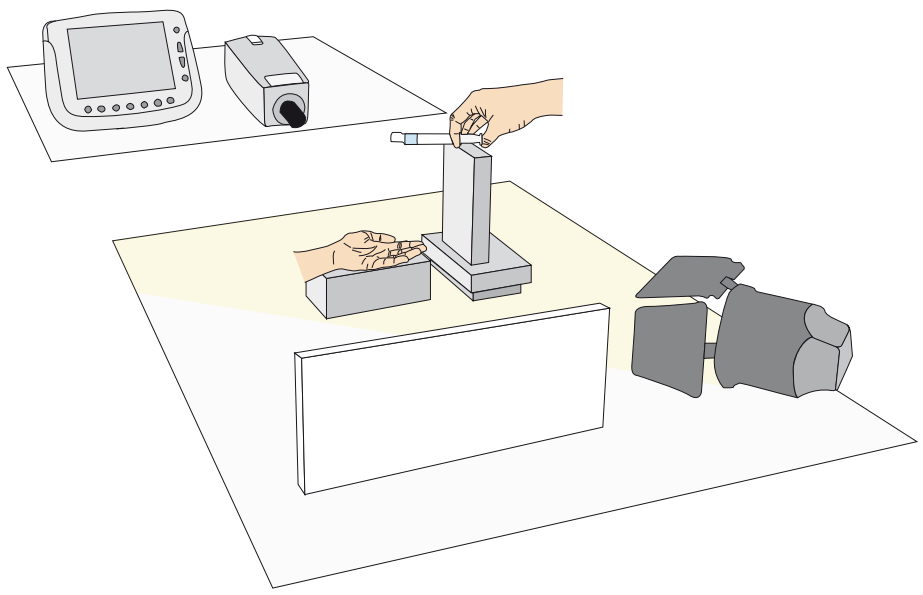
The syringe contains the required 3ml of disinfective alcohol.

For the first experiment the 3ml are sprayed in 3 seconds. This leads to some aerosols splashing hard in many directions and few aerosols splashing back in a vertical direction. It is especially the aerosols with the vertical direction that are important to avoid.



Single disinfective alcohol particles splash back up in the air, without returning within the picture frame, when pumping with a speed of 3 ml/3 sec.

THE EXPERIMENTAL SETUP

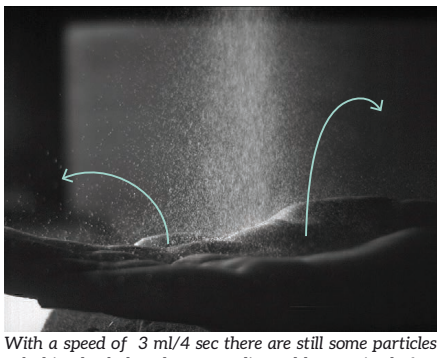


3.7
HCW TESTING CONCEPT

The HCW should use the hand sanitizer several times a day; to them an interaction with the dispenser lasting 4 seconds might sound like a long time. A leading requirement for the hand sanitizer is that it must make the HCW use it more often. If they find 4 seconds of interaction irritating the concept does not work.

The concept is evaluated at the gastroenterological department at Aalborg University Hospital. Here 6 HCW are asked to try the concept and evaluate whether the time of interaction is too long or not. Only 1 out of the HCW thinks that the time of dosage is too long and the concept is hereby considered validated.
In the experiment it is experienced that the HCW do not start rubbing in the disinfective alcohol before they have received the entire dose. It is the intention that the users must start rubbing it in during the 4 seconds of dosage to avoid the large drip at the floor. For the future design process it is necessary to include this finding to obtain the complete effect of the spray concept.

For the next experiment the 3ml are sprayed in 4 seconds. Here some aerosols splash back softly. They are already loosing the ascending direction due to gravity 3-4 cm above the hand. These small splash backs will not cause people to breath in disinfective alcohol aerosols.



With a speed of 3 ml/4 sec there are still some particles splashing back, but they get redirected by gravity before leaving the picture frame.

CONCLUSION

The experiment proves that with a pressure of 3ml/4sec splash back of disinfective alcohol will not be a problem. By showing these videos to decision-makers like the working environment representative, the resistance upon a spray concept can be eliminated.

Videos of the splash back experiments are available in appendix 3.6.

Findings

- The hand sanitizer must encourage the users to start rubbing in the disinfective alcohol during the dosage

3.8 PHYSICAL INTERACTION

During the interviews with the hospital stakeholders opinions upon mechanical- vs. sensor driven interaction differ. According to the infection nurses a sensor driven solution has a distinct preference due to hygienic matters like recontamination and cleaning-friendliness. But it also appears that most of the stakeholders have had bad experiences with sensor driven interactions like e.g. sensor driven faucets.
"We have had troubles with HCW with a large behind who activate the sensor driven faucets unintentionally." Lars Slot Technical Department
These bad experiences might affect the HCW opinion upon sensor driven products in general and an idea generation upon mechanical interactions is therefore conducted. To evaluate the concepts mock-ups are made and tried out.

EVALUATION CRITERIA

3ml — Should deliver 3 ml with one interaction

Must not be physically fatiguing to use several times a day

Must not be a source of contamination

Positive assessment

Negative assessment

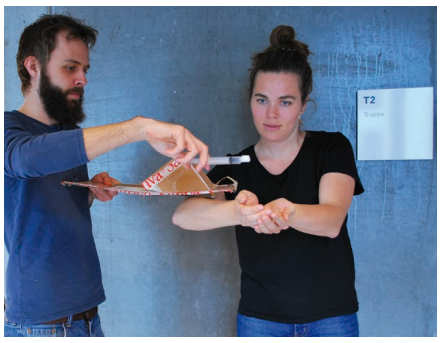
CONCEPTS

KNEE PUSH #1

3ml — The user can choose not to push the plate quite in

The user gets into a challenging position, which is fatiguing for repeating use

Operating the hand sanitizer with the knee will not lead to contamination of the hands

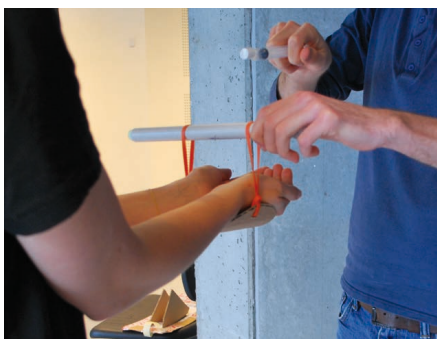


ELBOW PUSH #2

3ml — The user can choose not to push the plate quite in

The user gets into a challenging position, which is fatiguing for repeating use

Operating the hand sanitizer with the elbow will not lead to contamination of the hands



HAND PRESS #3

3ml — The user can choose not to press the plate to the bottom

The interaction does not force the user into an unfamiliar position

Touching the interaction with the hand is a source of recontamination

PEDAL #4

3ml — The user can choose not to press the plate to the bottom

The interaction does not force the user into an unfamiliar position

Operating the hand sanitizer with the foot will not lead to contamination of the hands

SENSOR #5

3ml

The sensor can be predetermined to trigger a 3ml dose

Depending on the placement the interaction will not force the user into an unfamiliar position

Choosing a touch free sensor will prevent contamination of the hands, when used correctly

CONCLUSION

A consistent mechanical solution will not ensure that people receive the required 3ml of disinfective alcohol. To ensure that concept 1-4 delivers the 3ml it must be coupled with an electronic release instead of relying on people pushing the interaction to the bottom.
Imagining that the pedal is combined with an electronic release it fulfils all the criteria just like the sensor concept. To choose between these two concepts they are brought to the gastroenterological department at AUH where the HCW try out the mock-ups.

HCW EVALUATION OF CONCEPTS

For the experiment six HCW try the two models. They all find it difficult to choose between the two concepts when taking point of departure in their experience of the interaction.

Instead all six HCW point out the difficulty in cleaning the floor around a pedal solution, which make them all prefer the sensor solution above the pedal.

From this it is concluded that the hand sanitizer should be sensor driven however it must be highly reliable to avoid irritation and unintended activation of the hand sanitizer.

3.9
PUMP TYPES

THE PERISTALTIC PUMP

The peristaltic pump is the most common pump in similar types of products, like soap dispensers. The peristaltic pump uses a flexible tube to squeeze the liquid forward with the help of a number of rollers. The pump works at slow speeds, and can deliver a precise amount every time, but because of the rollers the pressure is pulsating. Furthermore, the flexible tube can become brittle over time, and needs to be replaced. This replacement can be cumbersome to perform.

PISTON PUMP

The mechanics of a piston pump is identical to the syringe used in the spray mockups. The reciprocating movement of the piston moves the liquid in and out of the main chamber. To get the liquid to move forward, it is necessary to use two valves. Depending on the size of the chamber, this pump can deliver exactly the specified amount every time. The pressure is also consistent when dispensing. The downsides are the need for reciprocating movement and more moving parts due to the need for valves.

LOBE- AND GEAR PUMPS

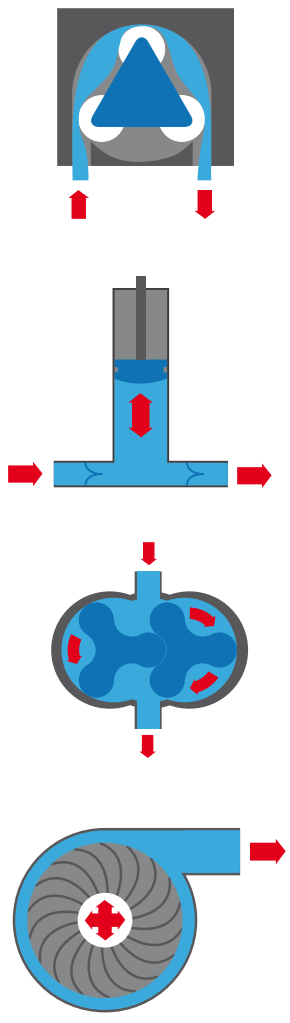
Lobe- and gear pumps uses the displacement of two intersecting wheels to move the liquid around the perimeter of the chamber. These pumps are very precise but create a pulsating pressure and also requires high precision in production to ensure tight tolerances between the gears. The overall construction of gear pumps may be too complicated for this application.

CENTRIFUGAL PUMP

Centrifugal pumps uses centrifugal force to move the liquid from a central entry hole to an exit on the edge of the pump housing. This type of pump is very efficient and creates a very consistent pressure. There is also just a single moving part in the pump. The downside is the inability to provide a low flowrate, which is required in this application.
[pum]

SUM UP

Due to the requirement of consistent pressure and low maintenance, the most suitable pump is the piston pump. This pump delivers a type of flow that is identical to the type of single pulse, consistent pressure that is required.



3.10 CHAMBER

A challenge in correlation to a sensor driven product interaction is the probability of people moving away from the dispenser before the entire dose has been dispensed.
In order to avoid this the users should be able to see the size of the entire dose entitled to them before activating the hand sanitizer. And throughout the dosage it must be visible how much of the dose they are missing.
3ml is a rather large portion and it is the expectation that a large looking portion will enhance people's tendency to put two hands instead of one under the spray nozzle.

CRITERIA

Make 3 ml look like a large portion

Must be compatible with the spray concept

Ready to use immediately after disinfective alcohol dispensation

Positive assessment

Negative assessment

CONCLUSION

The tube shaped chamber fulfils all requirements and it is therefore decided to develop this concept further.

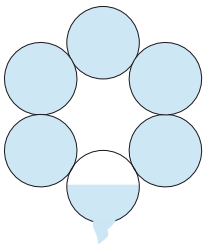
CONCEPT

ROUNDABOUT

The chambers can be narrow, which will make 3ml look like a large portion

The pressure required for the spray concept is difficult to obtain in the transition from the rotating chambers to the spray nozzle

The numerous chambers ensure that the next dose is ready immediately after use

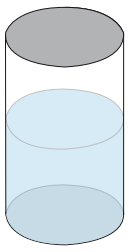


TUBE

It is possible to make the 3ml look improbably large by adjusting the tube radius and hereby enhance the length of it

The tube fulfil the need of a piston pump in connection with the spray nozzle

The tube can be filled quickly and hereby enable several doses immediately after one another



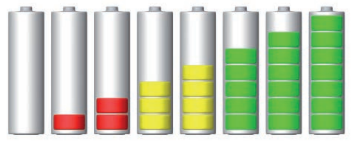
3.11 TUBE CHAMBER

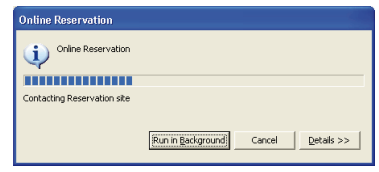
The primary function of the chamber is to communicate the portion size and to give a guidance upon the time left, before the user can remove his hands. To obtain this functionality the user should be able to decode the functionality of the chamber quickly. In our everyday life there are several products upon which we decode the level of e.g. power or detergent.

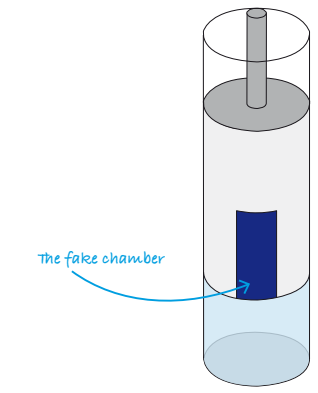
These products all use colour as a level indicator. Looking at the detergents it is easy to understand why, it is effortless to find the detergent level of the orange one whereas one must look more carefully at the transparent detergent to find the level.

According to the disinfection instructions provided by Statens Serum Institut it is not a possibility to colour the disinfective alcohol used at hospitals. [nir] Instead of compromising the communicative functionality by making a chamber with the transparent disinfective alcohol it is decided to make a fake chamber. The chamber does not contain any liquid, but is simply a coloured bar attached to the piston pump.

Since the chamber is attached to the piston pump it must be the same size as the actual chamber containing the disinfective dose. When detailing the internal mechanisms the size of the chamber must be specified, aiming at making it look as large as possible.







3.12 DISINFECTIVE ALCOHOL COMPARTMENT

OBSERVED PROBLEMS

In the market analysis it occurred that most dispensers at the market are accompanied by some expensive refills costing near 50% of the price of the dispenser itself. At these refills the dispensing mechanism is disposable too, which is a reason for the high price. The business case for these dispensers resembles the business case of inexpensive printers accompanied by a returning cost in expensive ink cartridges.
During the observations at AUH spare refills near the dispensers is a recurrent finding. When asked why they are there the answers are that it is to avoid running out of disinfective alcohol at inconvenient moments. When changing the refills to early the HCW places the remains by the sink and uses it without the dispenser, which leads to contamination of the hands.

FOCUS

In the development of the disinfective alcohol compartment the focus is to make a cheap solution with a minimum of disposable material, and to make a solution eliminating the problem of changing the refills before they are empty.

CRITERIA

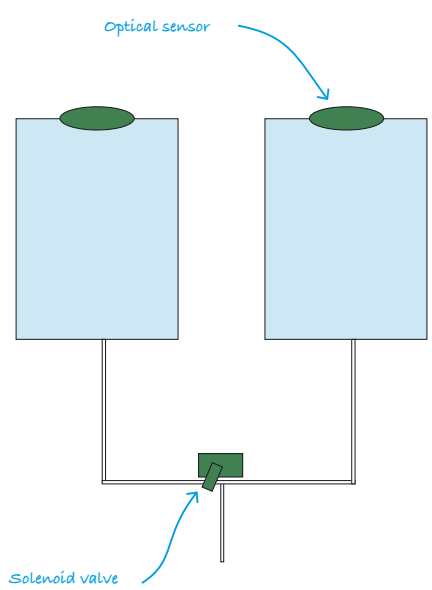
- A durable solution with no risk of leaking
- Empty the compartments completely
- A low cost solution
- Easy to refill

Positive assessment

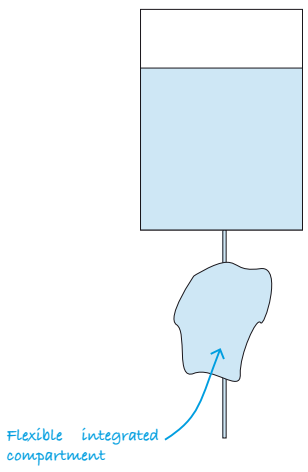
Negative assessment

TWO-COMPARTMENT CONCEPTS

OPTICAL SENSOR COMBINED WITH A SOLENOID VALVE



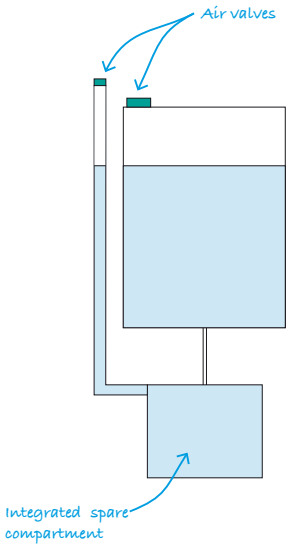
- It is a liquid tight system where the central flip plate is the only moving part
- With accurate optical sensors the flip plate will not flip until the compartment is empty
- The use of sensors and valve heightens the product complexity and hereby the risk of product failure.
- The optical sensor must be accurate to ensure no air in the system



A FLEXIBLE INTEGRATED SPARE COMPARTMENT

- The flexible integrated compartment will wear out over time due to the constant shrinkage and expansion
- The spare compartment ensures that the hand sanitizer will function even with an empty refill
- There is no need of electrical components to make the system work
- The concept can function with a simple drop of the refill upon a needle

3.13



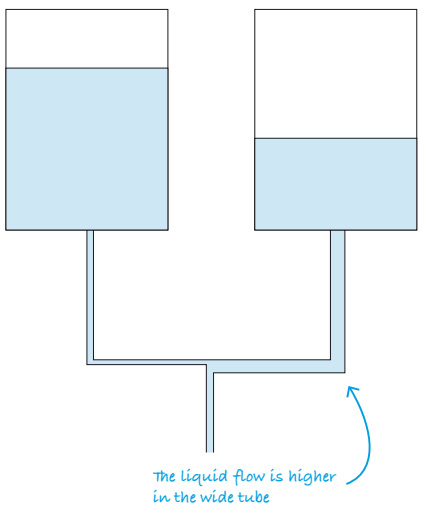
SOLID INTEGRATED SPARE COMPARTMENT WITH PIBE

There are no moving components in this system that will wear out over time, but due to the open structure disinfective alcohol vapour will leak into the hand sanitizer, which creates a risk of fire.

The spare compartment ensures that the hand sanitizer will function even with an empty refill.

There is no need of electrical components to make the system work.

The concept can function with a simple drop of the refill upon a needle.



DIVERSE HOSE DIAMETERS

A durable solution with no risk of leaking. It is a liquid and airtight system with no moving components.

The hoses must be scaled with the purpose of emptying the two compartments asynchronously to ensure to empty both compartments completely before refilling.

There is no need of electrical components to make the system work.

The concept can function with a simple drop of the refill upon a needle.

CONCLUSION

The diverse tube diameter concept solves the problem of not emptying the two refills simultaneously in a simple and inexpensive way. The dimensioning of the tubes must ensure that the refills never get empty simultaneously.

SHELL

Through the user observations of both visitors and HCW the importance of drawing attention to the hand sanitizer occurred. The situations in which it must draw the attention differ for the two user groups. The hand sanitizer must catch the attention of the HCW several times a day, even when they are in the middle of a nursing situation. The visitors should primarily see and use the hand sanitizer before and after visiting their relative.
Besides catching the attention of visitors and HCW the hand sanitizer aesthetics must resemble the aesthetics of a hand hygiene product. In public places like public toilets and restaurants people do not hesitate to use hand hygiene products like e.g. soap- and paper towel dispensers. Concerning the hospital visitors the unconcerned use of the hand sanitizer is one of the goals for this project.
The aesthetics are also briefly inspired by health care products. Examples of such products are available in appendix 3.13. This inspiration is later played down.

WHAT CHARACTERISES A HAND HYGIENE PRODUCT?

To create the look of a hand hygiene product the characteristics of such products are examined.

Colour indicates content properties

- Green is fresh
- Pink is blossom sent
- Orange is soft and gentle treatment
- Blue is natural and ultra hygienic

WHAT WILL STAND OUT IN THE CONTEXT?

To draw attention the hand sanitizer must be aesthetically different from the context. When studying the context the subjects of interest are colours and product idioms. The context is studied at the Gastroenterological Department at AUH.

There are some colours, which are indefensible to use in the hospitals because of their symbolic significance in the context. Due to the severity and pressure of time, which can be present at hospitals they use colour codes to show the level of emergency upon sudden instruments like e.g. the yellow cytostatic buckets and red cord of distress calls.
Hand sanitizers are important in the everyday healthcare situation, but in a situation of emergency where it is a matter of life or death they do not make all the difference in the world. In these situations the hand sanitizer should not resemble a lifesaving product.

The red colour is a well known colour for emergency situation

The blue bed is used by both patients and visitors

The yellow bucket contains toxis waste and is not to be touched by visitors

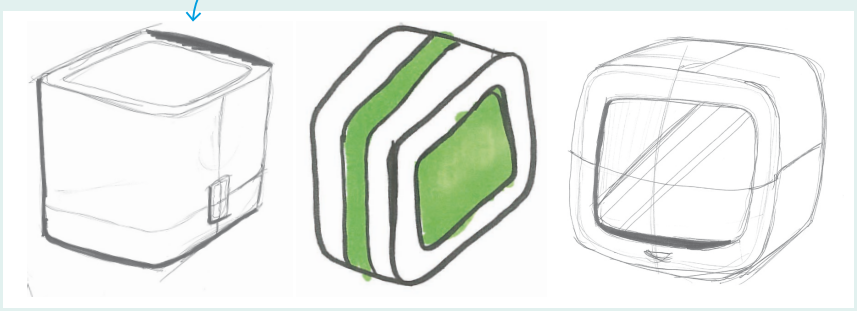
CONCLUSION

To stand out from the context the product idiom must have soft edges to distance itself from the geometric idioms dominating the hospital context. The soft edges also correspond to the requirements from the hygiene semantics, saying that the idiom must be soft and organic.
As explained in the research disinfective alcohol removes 99 % of the microorganisms when used correctly. Due to this high efficiency it will be natural to utilize the blue colour and its association to a high level of hygiene. Furthermore the blue colour does not interfere with any of the emergency products in the context.
Based upon these findings a sketching session upon product aesthetics is conducted.

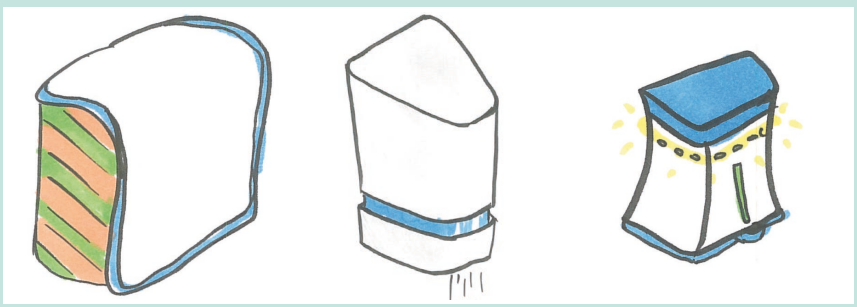
AESTHETICS

The chosen concept for further development

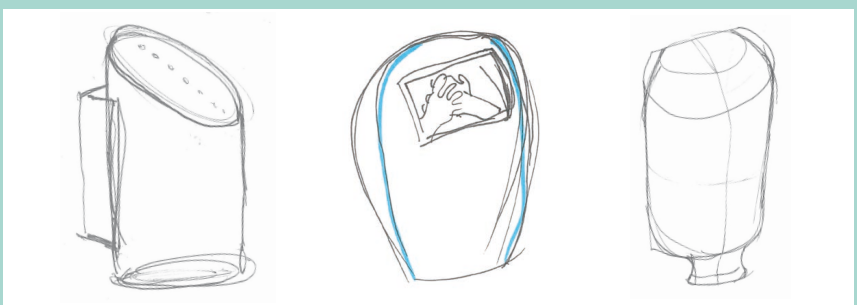
HEALTH CARE INSPIRATION



COLOUR AS A MEAN TO REMIND



SHAPE AS A MEAN TO REMIND



CONCEPT

The concept corresponds to the presented findings, but it still does not catch the intended attention. The product is to calm and static. The purpose of the spray interaction is to make people do circular movements while rubbing in the disinfective alcohol and by this avoid the pool of liquid in the palm of the hand. The aesthetics does not correspond to these movements, which it should. Besides a more dynamic shape there is a need of some stronger means than colour.

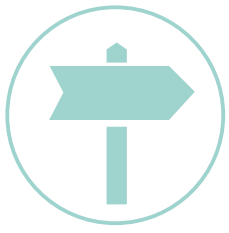
ATTENTION CATCHING MEANS

A brainstorm upon different attention catching means and their possibilities leads to the following.

SOUND
- Intensity
- Annoying sounds
- Pleasing sounds

PLACEMENT
- Interrupt flow

LIGHT
- Pulsating
- Changing colours
- Moving light



NUDGING
- Semiotics
- Colours

SCALE
- Large scale

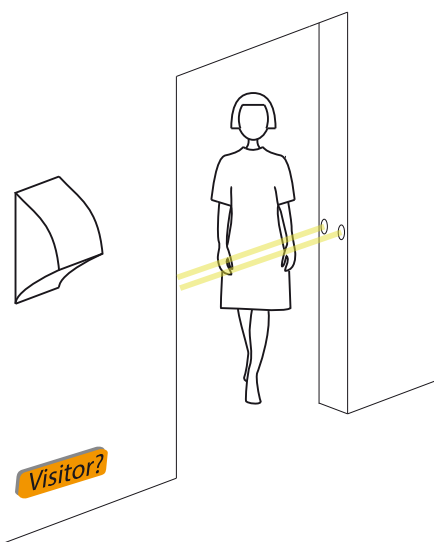
The means to how a product can draw attention shows that it is not just aesthetic aspects, which apply. To broaden the solution space, entirely new product concepts are made to create awareness of the hand sanitizer, instead of just focusing upon the aesthetics as a mean. These concepts are presented at the following pages.

3.15 REMINDER CONCEPTS

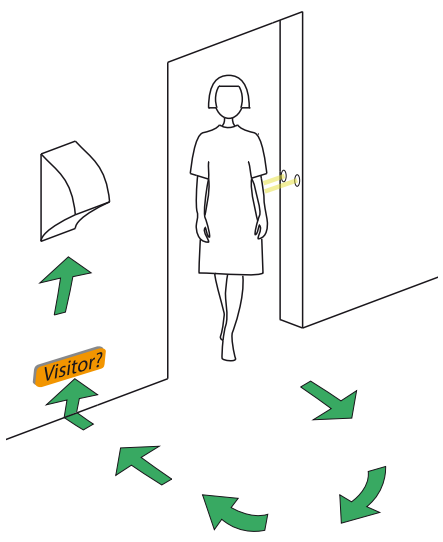
The idea generation upon how to create awareness of the hand sanitizer is focusing upon reminding and forcing people to use disinfectant alcohol through active means changing according to the level of use.
Evaluating the context when it comes to colours and shapes is rather simple as an external observer but deciphering the codes of conduct concerning more extreme awareness creating means like sounds and light is difficult. To understand this code of conduct the HCW at the Neonatal Department at AUH are asked to evaluate the concepts. For the evaluation the HCW are presented to concept illustrations and a model showing the light intensity.

LIGHT CONCEPT

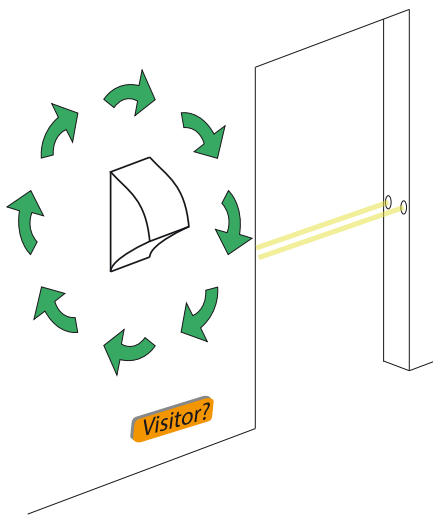
The light concept is aiming at both reminding visitors and HCW to use the hand sanitizer when entering end leaving the ward.



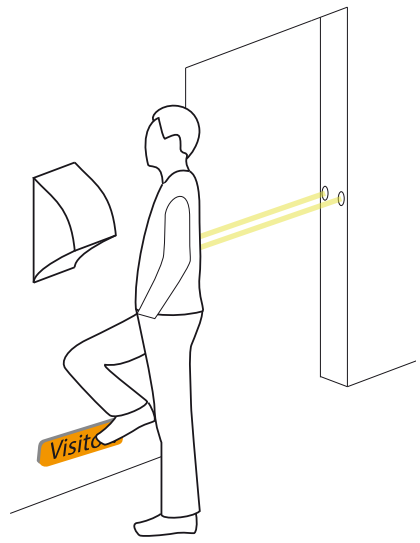
The two beam sensor registers whether people are entering or leaving the ward.



When a person enters the ward luminous arrows lead him to the hand sanitizer.



After a predetermined period of time e.g. 10 minutes luminous arrows will circulate the hand sanitizer to remind the HCW to use it several times throughout the nursing situation and before leaving the ward.



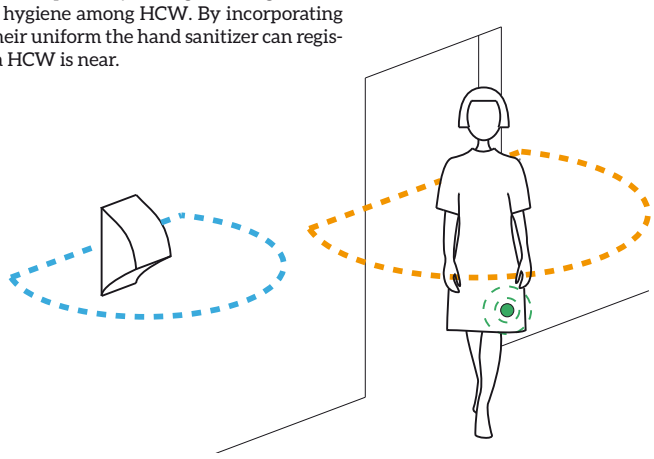
The frequency to which visitors must use disinfective alcohol is lower than the HCW's. To extend the time before circular arrows circulate the hand sanitizer a visitor button is added to the solution.

HCW EVALUATION OF THE CONCEPT

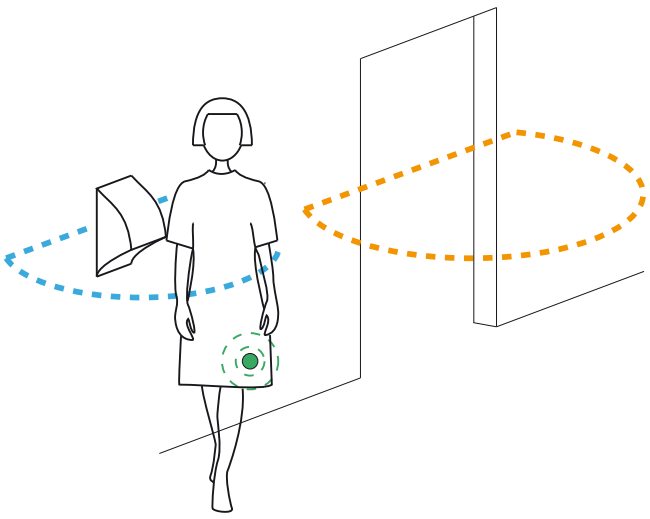
The HCW doubt that the concept works since there are two entrances to a ward at the Neonatal Department while there are also small hand sanitizers by the incubator that both visitors and HCW use. With several HCW at the ward at a time it is not clear who is supposed to use the hand sanitizer. Furthermore the HCW fear that the luminous arrows will create a circus like feeling disturbing the patients and their relatives.

SOUND CONCEPT

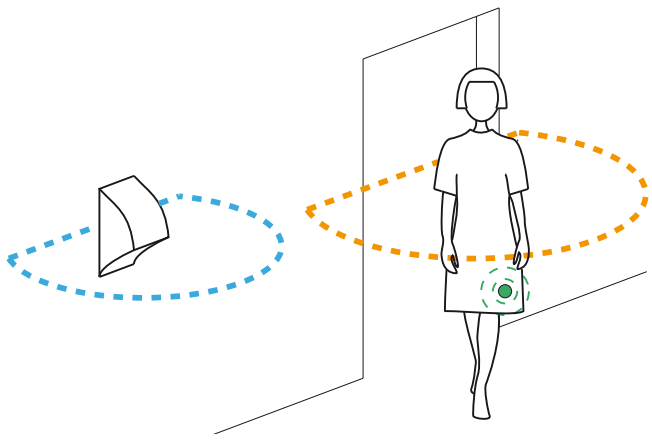
The sound concept is only aiming at raising the level of hand hygiene among HCW. By incorporating a chip in their uniform the hand sanitizer can register when a HCW is near.



When entering the ward the hand sanitizer will make sounds if the HCW has not moved from the orange- into the blue area within 3 seconds.



If the HCW enters the orange area before entering the blue area when leaving the ward the hand sanitizer will make sounds.



The HCW must have been in the blue area shortly before entering the orange area.

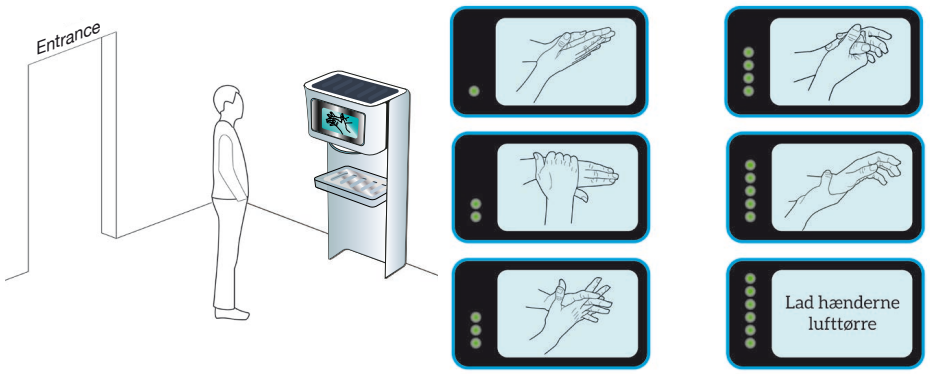
HCW EVALUATION OF THE CONCEPT

When the HCW are presented to the chip in the uniform most of them get associations to the Big Brother TV-show where the participants are under constant surveillance. It might create a bad working environment to have the HCW feel like being under surveillance especially if it becomes a personal chip keeping statistics of their use of disinfective alcohol.

What really worries the HCW about the concept is the use of sound as a reminder. There is very quiet at the hospital to enable the patients to sleep and recover, alarming sounds are used for emergency situation only. The HCW also explain that there are some critical situations where there is no time to use disinfective alcohol and in these situations a continuous sound will be very disturbing.

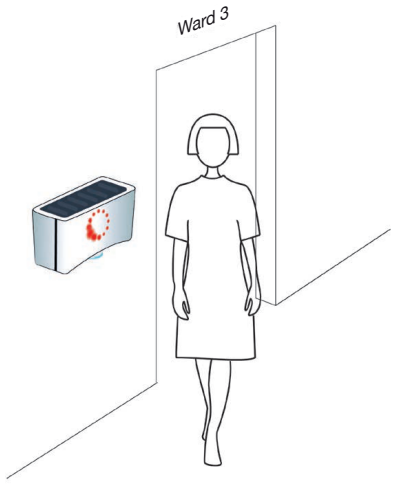
PLATFORM CONCEPT

The platform solution consists of a small wall-mounted- and a larger standing hand sanitizer, with few property variations, which are linked by similar aesthetics.



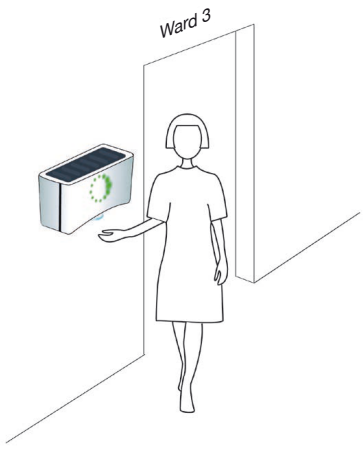
When the visitor enters the hospital he is met by a hand sanitizer, encouraging him to use it through its look and location.

The hand sanitizer in the entrance hall guides the user to use the disinfective alcohol correctly.



Because of the similar aesthetics the visitor can recognise the wall-mounted dispenser as a hand sanitizer and knows that he is allowed to use it.

In the wall-mounted hand sanitizer there is a timer changing the light from green to red when it has not been used for some time. This should remind the HCW to use it more often.



When the HCW uses the hand sanitizer the light changes back to green.

HCW EVALUATION OF THE CONCEPT

The HCW like the idea of introducing the visitors to the hand sanitizer in the entrance hall to put them into a hygiene way of thinking.
There are some worries regarding the flashing red light, but after showing the HCW the intended intensity of the light at the physical model the worry is eliminated. After all they find the light a pleasing way of communicating the need of using disinfective alcohol. The thought behind the colour changes is also that the patients can tell if their HCW is careful of the hand hygiene. The HCW believes in the efficiency of this feature but they do not find it particularly pleasing.
The hygiene responsible nurse at the Neonatal Department Christina Skoda tells that by placing hand sanitizers by all incubators the use of disinfective alcohol has been increased. This adds an additional opportunity to the platform solution in developing a hand sanitizer suitable for the table.

CONCLUSION

The platform solution is the solution best suitable for the hospital context. It does not interfere with the code of conduct at hospitals saying that sounds are for emergency situations only. Concerning the lighting reminder it is concluded that it must not be too bothersome since there is no constant frequency to how often the HCW must use disinfective alcohol and it is very important that the reminder does not annoy the patients who spend a lot of time in the ward.

FURTHER FINDINGS

At the Neonatal Department the number of HCW for each patient is very high. At calm periods they supervise the patients 5-6 times pr hour whereas patients at other departments can lay for hours without supervision. From this experience it becomes clear that the reminder frequency must be adjustable to fulfil its purpose at different departments.
When presenting the atomizing of the disinfective alcohol a HCW becomes very excited and tells that a doctor just recently got disinfective alcohol splashes in her eye due to splash back from the hard beam.

3.16 PROVE OF CONCEPT

At the Neonatal Department the concepts are only evaluated on the basis of some scenario illustrations. To prove whether the concept of changing the colour of the light will remind people to use it more frequently an experiment is put up.
It is not possible to test it upon real HCW, instead a fake nursing situation is put up to test the concept upon our fellow students.

EXPERIMENT

The experiment setup is illustrated at the adjacent figure.
The hand sanitizer model contains an Arduino attached to a proximity sensor and blue and green lights. A source of error in the test is that it is difficult to decipher if blue or green is the warning colour. In the evaluation it is left out of account if the participant reacts to the blue or green colour, the element of interest is if they react to the change of colour or not.

Before using the hand sanitizer the light is one colour. When using the dispenser the colour of the light changes. Through out the experiment the colour changes again to see if the participants notice.

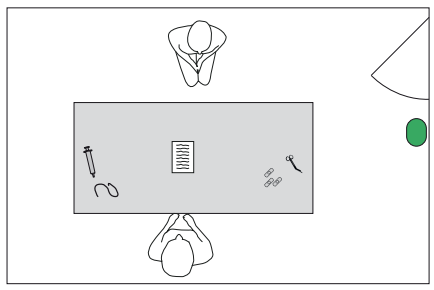
Participant 1 notices that the light upon the hand sanitizer changes and focuses a lot upon the hand sanitizer throughout the rest of the experiment.

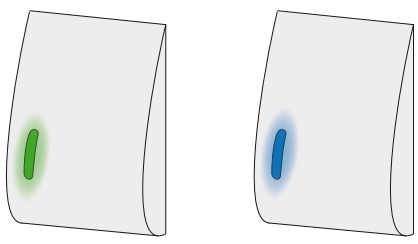
Participant 2 does not register the colour changes upon the hand sanitizer. She relies on her knowledge of when the use of disinfective alcohol is necessary and does not even look at the hand sanitizer throughout the experiment.

Participant 3 is very focussed upon the tasks and does not notice the colour changes upon the hand sanitizer.

CONCLUSION

People do not register colour changes and those noticing become so aware of the hand sanitizer that they forget focusing upon the patient. From the test it is experienced that a change in colours is to weak a signal to remind the HCW to use the hand sanitizer since it takes up to much effort to notice the changes.





3.17 MOVING LIGHT AS A MEAN TO REMIND

From the visit to the Neonatal Department it is learned that the use of sounds oversteps the bounds to how much the reminder may differ from the context. All the while the experiment with the changing colour proved to be too attention demanding in the cases for those even noticing the change.

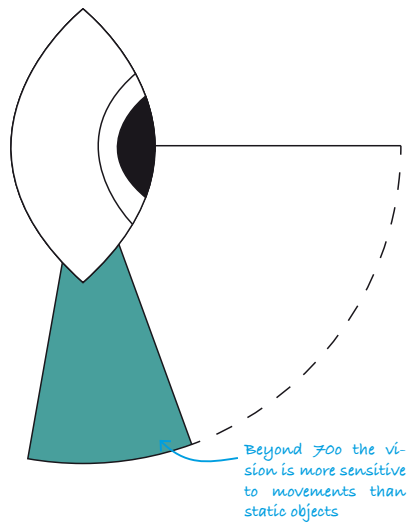
An idea based upon better accessibility in the shape of a table dispenser and an idea utilizing the HCW's need of taking care of people are created. These are deselected. The evaluation is available in appendix 3.17.

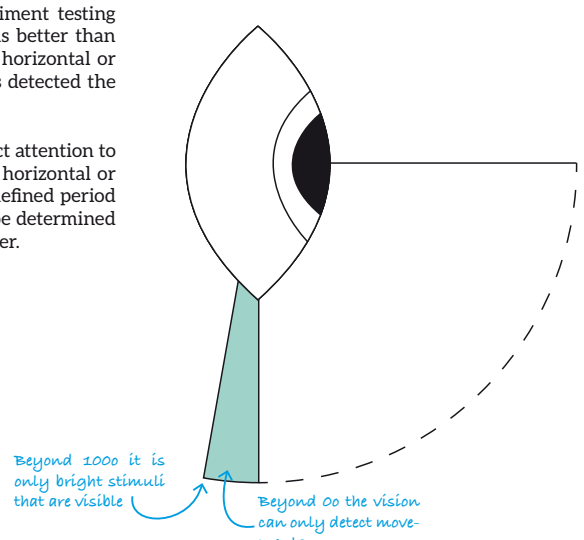
The mean to remind the HCW to use disinfective alcohol more frequently should be detected by the eye and perceived unconsciously.

From the scientific article Vision out of the corner of the eye it is learned that the eye is capable of detecting movements more than 90 degrees from the line of sight. If the moving object is bright it is even detectable more than 100 degrees from the line of sight. [To, M.P.S (2010)]

The article is based upon an experiment testing whether people detect some motions better than others. The result is that a forward horizontal or vertical movement is the one that is detected the best.

These properties are utilized to attract attention to the hand sanitizer by having either horizontal or vertical light turning on after a predefined period of time. The shape of the light will be determined when giving form to the hand sanitizer.





3.18 CONCEPT RE-EVALUATION

The realisation that the concept does not have the desired effect makes us re-evaluate the platform concept and breakdown what the qualities of the concept is. The evaluation is compared to the product mission.

- Placed in the entrance bringing the visitor into a cleaning state of mind

A question of position

- The placement encourages to use
- Screen encourages to use
- The recognisable look of the wall mounted hand sanitizer enables the visitors to see that they may use the product

Obtainable by other means

- Along with the dose of 3ml the instructions upon how to apply it enhances the chance of visitors using the disinfective alcohol correctly
- The visitors learn how to use it by the hospital entrance and can then use the disinfective alcohol without further instruction by the less teaching wall mounted hand sanitizer

- The platform concept is based upon the basic features of a sensor driven physical interaction preventing recontamination and the permanent 3ml dose ensuring moist hands for at least 30 seconds

- A reminder must remind the HCW to use the hand sanitizer more frequently

When looking at the arguments to how the platform concept fulfils the project mission all features can be obtained differently in correlation to the wall mounted hand sanitizer.

The mainstay of the platform principle is the screen attracting people and teaching them how to use disinfective alcohol correctly. The placement of the hand sanitizer in the entrance hall is an important aspect too, but in principle all hand sanitizers can be placed here if applying for an exemption.

A large screen placed above the hand sanitizers, which will be cheaper than incorporating a screen at all dispensers, can easily replace the screen. When removing the screen from the large hand sanitizer the only distinction between the two dispensers is the disinfective alcohol capacity. The initial thought behind the large hand sanitizer was that it should contain enough disinfective alcohol for all persons visiting the hospital per day. This will entail a queue by the dispenser, which is not desirable. Instead it will be a better business case for the hospital to buy several wall-mounted dispensers and place them by the entrance since the price of the large hand sanitizer will be much higher in comparison due to the low number of production.

CONCLUSION

From here the focus of the project will be to develop a single wall-mounted hand sanitizer fulfilling the properties of the platform concept, although the teaching module will be left out of the product development.

3.19 REFILL MATERIALS

The choice of materiel for the refill is based upon the following criteria.

Must be printable
Must be stackable
Must be durable
Must be easy to exchange

Several solutions are evaluated but it is only bag-in-a-box that fulfils all the criteria. The evaluation of other solutions is available in appendix 3.19.

BAG IN A BOX

How the solution fulfils the criteria

Must be printable
It is easy to print upon the cardboard box enabling the refill to communicate its content and other specifications.

Must be stackable
Cardboard boxes can be densely stacked.

Must be durable
Choosing the right kind of cardboard will protect the inside bag. The purpose of the box is to protect the bag during transportation and ease the refill situation compared to a bag solution.

Must be easy to exchange
The stable box will entail an easy refill situation where it is only the inside bag that deforms when emptied.

In the product detailing phase the design of the refill will be further specified.

SECTION SUMUP

Throughout phase 3 the overall concept for the hand sanitizer is determined.
The gathered concept focuses on both reminding people to use the hand sanitizer through moving lights and on making HCW and visitors use disinfective alcohol correctly.
By making a fixed dose of 3 ml the product ensures that users will remain humid hands for the required 30 seconds. The hands free interaction enables people to receive disinfective alcohol without any risk of recontamination of the hands.
The overall technical concepts like the pump and refill system has also been determined. In correlation to the piston pump a fake visual chamber is developed to make sure that people will not remove their hands before the entire dose is dosed.
From this point of the project the aesthetical direction must be re-evaluated and the level of detail must be raised for all components to prove the feasibility and make it ready for delivery.

4.0

PRODUCT DETAILING

The following section is the phase of details and product delivery. In the section the significant parts of the hand sanitizer is specified along with the production and business case.

SUB-COMPONENTS

Cleaning State	Motor	Tube	Shell
Moving Light	Printed Circuit Board	Valves	Bag-in-a-Box
Mounting	Sensor	Connections	Tube Chamber
Piston Pump	Batteries	Atomizer	3 ml Dose

4.1 WORKING WITH ARDUINO

Throughout the project several functional models is used for user experiments. These models are based upon the use of an Arduino. It is especially when testing light flows and sensor interaction that the Arduino is useful.

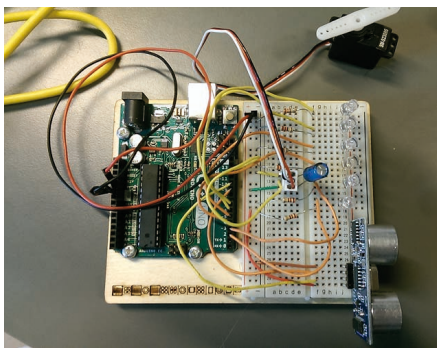
Arduino is an open source electronic platform that makes it easy to make electronic prototypes using standard components. Since the decision is made to use an electric dispensing mechanism, it is important to gain our own experience with the parameters that defines an electronic system.

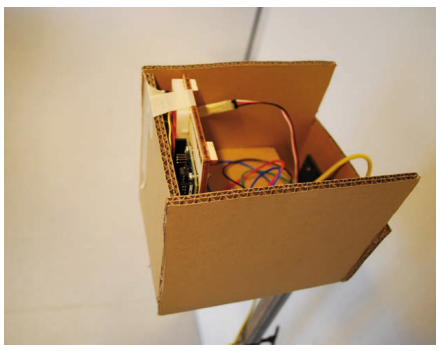
The Arduino is a so-called microcontroller that can be programmed to generate certain responses depending on signals that it gains from a range of different sensors. The sensors used in this project is an ultrasonic distance sensor and different push buttons. The Ultrasonic Sensor is very flexible in its programming which allows us to test the sensitivity and placement in-depth.

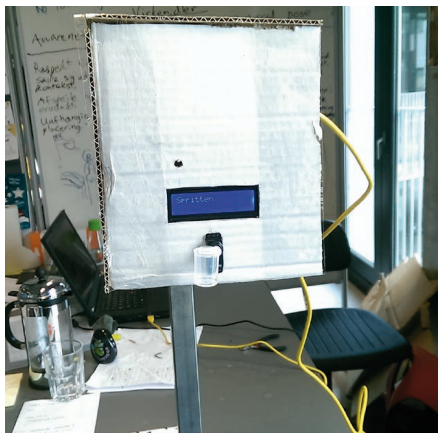
To generate a response a small servo is used to generate movement, and make the prototype dispense a dose of liquid. The speed and duration of the movement can also be programmed as needed.

The programming features also allowed testing of different lighting patterns and responses. By using different colored LED's it is possible to test users' responses to changing colors.

Videos with test models are available in appendix 4.1.







4.2 CHOOSING A MOTOR

SERVO MOTOR

Our initial Arduino experiments uses servomotors because of their power and level of control. In mass production, servomotors become too expensive to use as the main source of movement. Furthermore, the piston pump requires a linear movement, and much space is required to convert the movement of a servomotor into a linear one. For this reason, the servomotor is quickly eliminated.

STEPPER OR DC MOTOR?

The easiest way to drive a piston pump with high force is with a lead screw. This requires a motor in one end to drive the screw, which moves the piston up and down. It is important that the motor can continue to do this exact movement many thousand times without losing precision. A stepper motor is the most precise of the two remaining motors, but is also significantly more expensive and larger than a similar DC motor. A stepper motor remains precise over time because it knows exactly how many revolutions it makes, but that kind of precision is oversized for this product. The piston pump only requires precision in terms endpoints of the piston and that can be solved with a simple DC motor. However, it may be required to "overshoot" the endpoints and have a torque limiter to protect the motor.
Since price is one of the most important factors for success in this mass produced product, the simple DC motor is chosen because the price is significantly lower than the competing solutions.

SERVO MOTOR

\+ High precision
High power

\− Only 180° rotation
High price

STEPPER MOTOR

\+ High Precision
High Durability
High Torque

\− High Price
Requires more advanced controlling
High power use

DC MOTOR

\+ Low price
Simple control

\− High torque requires gearing
Imprecise

4.3 MOTOR SPECIFICATION

The motor drives the piston pump, by driving a nut up and down on a so-called lead screw. In this way, the circular movement of the motor is translated into a linear movement and at the same time increase the force. The total assembly of motor and lead screw is also called a linear actuator.

$$\text{Torque (N/cm)} = \frac{\text{Force (N)} \cdot \text{Pitch (cm)}}{\text{efficiency}}$$

[tho]

To determine the parameters for the motor, one of the key values is how much force the linear actuator will be required to apply on the piston pump. This value will determine how much torque the motor must provide, and the number of treads pr. cm. on the lead screw necessary to deliver the force.

One way to measure this force is to determine how fast the 3 ml. disinfective alcohol should be sprayed, and then measure the force required to reach that time. The simplest way is to use a simple soda bottle filled with water, and use it to press down on the test-syringe. Using increasing amounts of water, the force required to empty the spray in 4 seconds is found to be 1,5 kg or 15 N.

Similarly, the lead of the screw is what determines how much every revolution of the screw moves the nut. Since the stroke of the piston pump is already determined to be 4 cm, and the duration should be 4 seconds, the lead should result in a movement speed of 1 cm/s.

The biggest problem when choosing a motor is to find a motor that is slow enough, since most small DC motors has high speed and low torque. Using a small lead on the lead screw could translate the high RPM into slow linear movement, but there is a physical lower limit for how small the lead can be. So even at the lowest possible lead, a 1000 RPM motor will still move the nut too fast. For this reason, a motor with a build-in gear is chosen to get a motor with slower RPM.
The chosen motor is found on Alibaba.com [ali1] and delivers 274 RPM at 12V.

$$\frac{274 \text{ RPM}}{60\text{sec}} = 4{,}56 \text{ RPS}$$

Since the number of revolutions pr. second is 4,56 it is possible to determine the lead required to reach a speed of 1 cm/s.

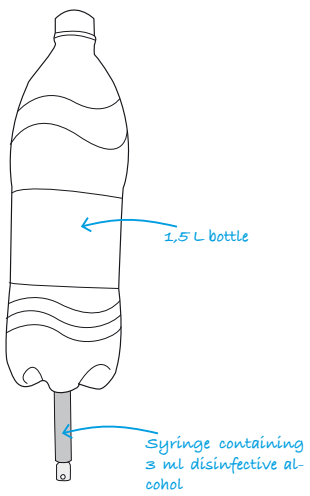
$$4{,}56 \text{ RPS} \cdot \text{Lead} = 1 \text{ cm/s}$$

$$\frac{1\text{cm}}{4{,}46} = 0{,}219 \text{ cm}$$

This gives us the last parameter needed for determining the amount of torque the motor needs to deliver to press down the piston in 4 seconds. The efficiency is set at 0.4 since this is a general guideline for unlubricated lead screws.

$$\text{Torque (N/cm)} = \frac{20 \cdot 0{,}219}{2\ \pi\ 0{,}4} = 1{,}742 \text{ N/cm}$$

The chosen motor delivers 2,8 N/cm at 274 RPM, which confirms that it will be strong enough. It might even be possible to lower the voltage, and still get enough force.



4.4 SENSOR

PASSIVE INFRARED SENSOR

Properties: A passive infrared sensor measures the infrared radiation within its visual field. Humans emit heat, which results in infrared radiation of a sudden wave. It is this infrared radivation the sensor measures. A downside to this type of sensor is that the efficiency relies on people's hand temperature, so people with cold hands will experience worse accuracy. The sensor is passive since it only detects the exogenous radiation and does not emit anything itself.

Price: 7.96$ when buying 100+ units [spa1]

INFRARED SENSOR

Properties: An infrared sensor measures the distance to an object, which enters its field of view. The sensor emits infrared light in a small beam and detects the changes in the returning light. From these data it can calculate the distance to the object. To be able to work in direct sunlight the sensor must be quite sharp. [soc]
The distance to which the sensor reacts can be adjusted to adapt to varying surroundings.
Range: 10-80 cm

Price: 11.16$ when buying 100+ units [spa2]

ULTRASONIC SENSOR:

Properties: The principle of an ultrasonic sensor is the same as an infrared sensor. Instead of emitting infrared light it emits ultrasound. An ultrasonic sensor is sensitive towards sound absorbing materials like e.g. a sponge. Ultrasonic sensors emit a wide beam of sound, which makes it more accurate than the infrared sensor. An ultrasound sensor is available for the Arduino system, and makes it easy to test what distances works best when activating the hand sanitizer.

Range: 0-645 cm

Price: 20.76$ when buying 100+ units [spa3]

EXPERIMENT

With the use of an Arduino with a simple ultrasonic sensor, it is possible to program it to react as closely to a real dispenser as possible. The sensor continuously measures distance, and sends the data back to the Arduino. With the distance-data, it is possible to tell the Arduino what to do, in case of a measured distance that is within the target area for dispensing. By adjusting the target distance, the "sensitivity" of the sensor can easily be changed.
The general experience is that it is relatively simple to adjust the sensor to work flawlessly every time.

EVALUATION

The choice of sensor is an infrared sensor since it is the cheapest one fulfilling the requirements. It should be noted that the prices listed, does not reflect the price of the components in a mass produced product. The prices are chosen because they come from the same supplier, and makes it easier to compare the prices.
When evaluating the sensors the crucial criteria is that it should react instantly. The hand sanitizer should be used by both inexperienced users, who should get an instant feedback that they are operating the dispenser correctly, and busy health care workers who have no time to wait for a slow dispenser.
The PIR sensor is sensitive towards people's hand temperature. A part of the overall product concept is that the hand sanitizers should be possible to place by the entrance to the hospital. This makes the use of PIR sensors inconvenient, since people's hand temperature might be very low when entering the hospital in the winter. Because of the low hand temperature the sensor will not detect them instantly.
When evaluating the infrared- and ultrasonic sensor the accuracy, price and sensor range is what differentiates them. The reason why the ultrasonic sensor is more expensive than the infrared sensor is primarily that it is more precise.
For the hand sanitizer precision is not important, whether people get a reaction when placing the hands 20 cm or 20,5 cm underneath the nozzle is not critical.

4.5 BATTERIES

CAPACITY

The capacity of one-use batteries, are very dependent on the load. At high loads, the total capacity is significantly lower than at low loads. Furthermore, there is a huge difference in performance between the different types of chemistry used, and the general quality of the batteries also has an impact. Therefore the battery manufacturers doesn't commit to writing capacity on their batteries, and it makes it difficult to predict what kind of performance the hospitals should expect when it comes to the battery life of the hand sanitizer.

If they choose to buy cheap Zinc-Carbon batteries, the capacity will only be ~600 mAH at a 200mA drain, but if they choose good Alkaline batteries, the capacity will be ~2300 mAH at 200 mA. [bat]

The motor draws 190 milliamps at load, which lasts for 8 seconds for one dose of liquid. Since batteries are rated by their capacity (milliamps pr. hour) it is simple to estimate the lifetime of the battery.

$$\frac{(8sec/60)}{60} \cdot 190\ mA = 0{,}418\ mAh$$

A worst case scenario would therefore be:

$$\frac{8 \cdot 600mAh}{0{,}418mAh} = 11483\ uses$$

In case of good Alkaline batteries the number of uses would be:

$$\frac{8 \cdot 2300mAh}{0{,}418mAh} = 44019\ uses$$

The difference in lifetime between Zinc-carbon and Alkaline batteries is over 280%, even though the alkaline batteries are only 25% more expensive!

4.6 PRINTED CIRCUIT BOARD

The Printed Circuit Board or PCB is what holds the microchips that controls the electronic functions of the hand sanitizer. The size of the PCB and the choice of components depends on what tasks the product must perform, and the complexity of the code needed to perform these tasks.

The code written for the Arduino during the test of the ultrasonic sensor uses 5.354 Kilobytes of flash storage, and 259 bytes of SRAM storage. Since the finished product will have more features, like dynamic lighting, the code will probably be a little larger. However, it will also be probable that the code could be optimized with the help of an electrical engineer, to save space.

By making sure there is extra space in case of larger code, a target size could be 8 Kb Flash and 1 Kb SRAM.

Atmel is a company that designs a large range of microcontrollers and has design the microcontroller in the Arduino among other thing. By looking at their selection of microcontrollers, they specify that the megaAVR Family is aimed at general purpose and lighting applications. Within this family is a chip called ATmega88PA that meets the storage demands as well as promote very low power usage. [atm]

Active Mode: 0.2mA
Power-down Mode: 0.1µA
Power-save Mode: 0.75µA

With our limited knowledge of electronics, this appears to meet our demands without oversizing. Further optimizing will require the help of specialized engineers.

4.7 MOVING LIGHT

TECHNOLOGY

The choice of light-technology is simple because of the battery driven nature of the dispenser. Only LED technology is competitive when it comes to high output at low voltages, and at a low price.
Other, more flexible solutions, like OLED are still in the early stages of widespread adoption, and are still very expensive to produce.

Similarly, flexible fluorescent tubes can provide the kinds of thin light stripes required, but the lifetime and power consumption is too high.
The biggest challenge with LED lighting is that LEDs are small individual lamps, and therefore cannot produce the thin lines required. One solution could be to use flexible tubes that emits a uniform level of light when illuminated from one end.
This technology solves the thin line challenge, but it is also impossible to create a moving light since the same light illuminates everything. Therefor it will only be possible to create pulsating light.

Taking inspiration from this technology, it would also be possible to use multiple LEDs to illuminate a clear piece of plastic that guides the light to the end of the plastic. This is called Light Piping and is typically used in products where it is not possible to mount the LEDs directly on the interface, or where the LEDs are soldered directly onto a PCB.
Light Pipes are typically limited to straight pipes or single, right-angled bends, to guarantee no loss in brightness. By sacrificing some brightness, it would be possible to guide the light from a row of LEDs on the PCB to the long curved edge on the surface of the hand sanitizer. This will require a custom, injection-molded piece. To ensure that the LEDs does not appear as individual lights, it may be necessary to add a frosting to diffuse the lights.

EXPERIMENT

White LEDs ordered from China are more than bright enough to be seen in broad daylight and cost 10 øre pr. piece. A single LED attached to one end of a piece of clear solid tubing is still bright enough, so the loss of brightness is not detrimental to the function.

CRITERIA

Flexible

Must be able to create a thin, curved line of light.

Variable

Must be able to create a pulsating and moving light

Uniform

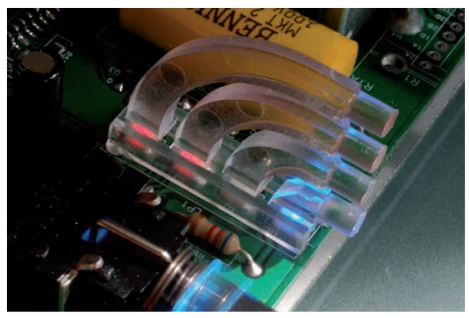
The light must not appear as distinct individual light sources

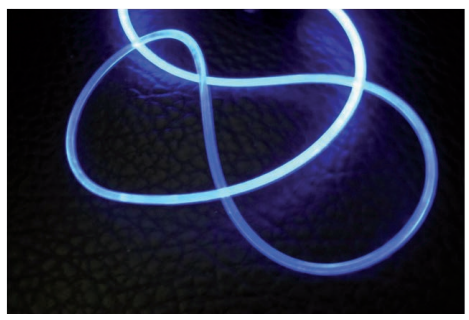
Low power

To preserve battery life, the light must be very low power

High Output

The light must be clearly visible in broad daylight





4.8 DISINFECTIVE ALCOHOL VISCOSITY

Currently there are only two types of hand sanitizer available; liquid sanitizer and gel sanitizer. The main difference between the two is additives is the gel that makes it more viscous and easier to handle in one hand.
So far, the spray solution has only been tested with liquid sanitizer, and there is still a small amount of spill from the solution. It may be possible to make the liquid more viscous, to prevent runoff, and thereby eliminate the last spill.

THE THEORY

"In many respects, viscosity is the most important liquid property. Although in an absolute sense its influence on atomization is no greater than that of surface tension, its importance stems from the fact that it affects not only the drop size distributions in the spray but also the nozzle flow rate and spray pattern." [Lefebre, 1989]

The effect of viscosity on the performance of an atomizer nozzle is quite high. Higher viscosity requires higher pressure of the pump, and the spray cone gets narrower.

THE TEST

The gel used in the test is a store bought consumer gel called Savett Alcogel. The gel is very viscous, and does not move by itself if the bottle is turned upside down. After dispensing 3 ml. of the gel in the hand the initial

Pure gel: The gel holds together well, and does not require the user to cup the hands to prevent runoff. After a few seconds the gel starts to "melt" and adds a thin layer of alcohol on the hand. The gel glides on this layer, and slides around easily. It would be possible to drop the whole blob because it slides around so easily.

Gel in an atomizer – Normal pressure: The gel dispenses in a thin hard beam. The sensation of the beam is not very pleasant. The gel splatters after hitting the hand, and creates drops, but the further application of the gel is comparable to a regular dispensing of gel.
Gel in an atomizer – High pressure: The gel dispenses in a spray that is comparable to the spray of liquid sanitizer. Since the pressure is so high, the time it takes to dispense 3 ml. is much shorter. The spray itself feels thick and weird. The application of the gel is almost identical to liquid sanitizer since the gel has been broken up into tiny droplets, and the "melting" process is instantaneous. The positive aspects of gel is removed by the atomizing process, and is not easier to control than liquid sanitizer.

4.9 PISTON

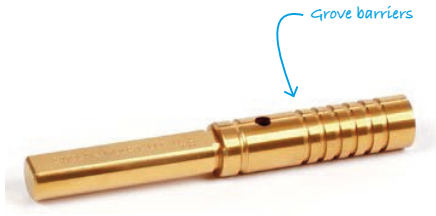
The piston is what pumps the liquid through the system. It also has the extra purpose of showing the user the progress of the dose.

PISTON HEAD

The piston is inspired by the medical syringes used during prototyping, and those syringes uses a piston head made form silicone. This creates an effective seal, but since medical syringes are a single-use item, it is feared that the silicone piston might become brittle over time. Since the goal lifetime is over 35.000 doses for the piston, this might become problematic. The only way to verify this hypothesis is through mechanical testing, and it is outside the scope of the project to carry out these types of tests.
Another way to create a piston head, would be with hard plastic. To create a seal, a thin groove can create a barrier for the liquid. This is also seen in toy steam engines.

MATERIAL

Since it is important that some parts of the chamber is visible, it is necessary to utilize a clear plastic. The plastic must have excellent clarity and must hold up to many thousand doses without becoming clouded from scratching.
The typical plastics used for transparent applications are Polycarbonate, PMMA (acrylic), PVC and PS.
Since the plastics are of the amorphous type these plastics are naturally transparent, and has a good clarity.
PET is also a popular plastic in transparent bottles, but gains its transparency from the blow molding process. [har] ABS and PP are not typically known as clear plastics, but some transparent variants are available.
PMMA is much cheaper than PC but cannot handle exposure to ethanol, which causes instant cracking. This eliminates it from our considerations. [pla1]
According to Plastics International [pla2] PC has the highest Rockwell Hardness. The hardness would make PC a good choice, but the material price is much higher than the other plastics. Instead clear PVC is chosen since it has the highest hardness of the commodity plastics, and in this way is the most resistant to scratches.



SHAPE

The piston itself is a long two-part cylinder which is colored on the bottom and white on the top. This is to simulate a sinking liquid to the user as described in the Chamber-chapter.

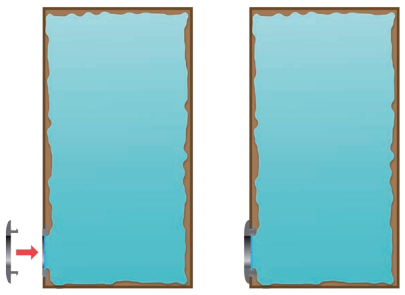
4.10 REFILL

The refills are the biggest components in the hand sanitizer. The amount of refills used pr. year is magnitudes higher than the amount of hand sanitizers. Even though it is only cleaning staff that should perform the refills, the shape and function of the refill has a large impact on the visual identity of the overall product ecosystem.

In an earlier chapter it was decided that a bag-in-box solution is the most ideal because of its stackability and easy printing. The interaction vision for the refill, is to make it as fast and effortless as possible, and should be like plugging in a new ink-cartridge.
This requires the connector in the bag to be quite solid, so the connection can be made without wobbling. The connector should also be covered before use, to make it clear if the refill has been used already.
Another important aspect in terms of the performance of the refill, is how well the bag collapses. If the bag doesn't flatten completely when emptied, there will still be liquid left over that cannot be sucked out. To prevent this, the bag connector is placed in the middle of a flat side of the bag, and not in a corner as typically seen in other bag-in-box applications.

To make sure the bag connector doesn't just push into the box when the refill is inserted, a plastic ring is applied from the outside to lock the connector in place

To create a clear visual link between the hand sanitizer and the refills, some visual elements are repeated on the box. The most recognizable feature is the light lines pointing to the nozzle. These lines are transformed into a solid graphic shape that highlights the bag connector on the refill. This simple element creates a clear relation between the products.



The plastic ring locking the connector in the correct position.

The graphic at the refill is inspired by the lines at the dispenser, which is developed in section 4.16

4.11 VALVES

The function of the piston pump depends on valves to create a one way flow. Similarly, the connections between the refill bags and the dispenser must use valves to prevent drip and spill of liquid if the refills are removed prematurely.

UMBRELLA VALVE

The umbrella valve consists of a molded elastomer in shape of an umbrella. If the flow is pressing on top of the valve, the umbrella flattens out and creates an even stronger seal. If the pressure on the underside of the valve is sufficient, the umbrella will bend upwards and create an opening for the liquid. The umbrella valve is cheap, simple, and durable. The downside is the need for a perforated plate to hold the umbrella itself. This makes assembly a little more complex. It also requires a certain pressure to get the valve to open.

DUCKBILL VALVE

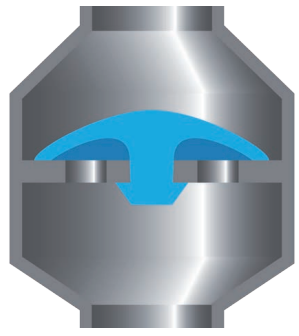
The Duckbill valve is also a molded elastomer with a simple construction. The valve uses its shape to seal itself when the flow is going against the shape. When the flow is going the opposite direction, the valve opens very easily.
Similar to the umbrella valve, the duckbill valve is cheap and simple, but doesn't require extra components, and the size of the valve is so small that it can be fitted directly in the tubes. The required opening pressure is also very low.

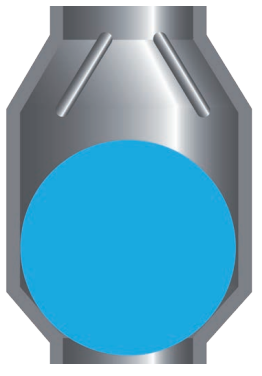
BALL VALVE

The Ball valve uses a ball in a chamber to seal and open the flow.
The ball valve has the same advantages as the other valves, but requires more precision in production, and a dedicated chamber for the ball. It also might be more difficult to replace a broken ball valve.

CONCLUSION

All three valves are able to solve the needs in the hand sanitizer. They are also very similar in cost, so the only real difference is the space needed to make an efficient valve. In this regard, the duckbill valve requires the least amount of space, and is therefore the preferred choice.





4.12 CONNECTIONS

At the current dispenser the moving parts like the pump is attached to the disinfective alcohol refill ensuring that these are exchanged regularly. In our hand sanitizer there is a risk of wearing out the piston pump. This is not exchanged when replacing the disinfective alcohol. Instead it is decided to make the pump replaceable, which may be done when changing the batteries.

There are two types of connections in the hand sanitizer. The connections between the exchangeable piston pump unit and the connections between the refills and the tubes leading into the hand sanitizer. Both connections must ensure a tight seal, and prevent leaks when the different components are removed. Since the whole system operates on the pressure from the piston pump, the connections must be so tight that air cannot enter the system and lessen the performance of the pump.

The connections are defined by the way the components are inserted into the hand sanitizer. Since there is no room for twisting components into place, the connections must work with a simple sliding motion.

The connection between the piston pump unit and the base is also the place where the duckbill valves will be placed. This creates the opportunity to make a connection that at the same time makes it easy to exchange the duckbill valves as they become worn out. This is done by making a connection that must be screwed in and fastens the duckbill valve when doing so.

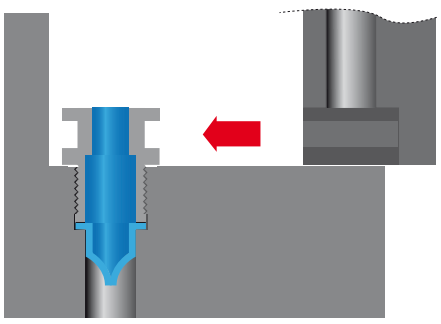
When the piston pump unit is removed there is a chance that there is still a small amount of liquid in the piston itself. Since the duckbill valves are made to create a flow towards the nozzle, they do not prevent leaks. Therefore it is necessary to incorporate a simple solution that closes automatically when the unit is removed. One way to solve this, is to use simple silicone membranes with an x-slit. This makes it necessary to have a male connector that can open the membranes when the parts are connected. Since a male to female connection can only be made head on, it limits the placement of the connection to the back wall of the hand sanitizer.

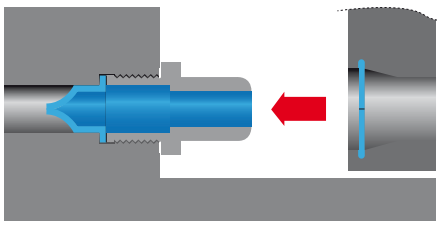
CRITERIA

Small – Since the space in the hand sanitizer is limited, the connections must be as small as possible.

Fast – The exchange of refills must be as fast and easy as the old solution. Therefor it must not require time-consuming fastening such as screwing.

Tight – No disinfective alcohol must drip out if the components are removed at the wrong time.



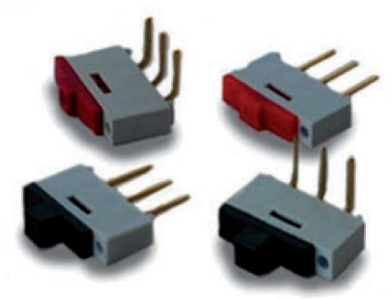


4.13 TUBES

Tubes used in similar products, like automatic soap dispensers and gel dispensers, are typically made from silicone. These tubes are food-safe and does not leak unwanted chemicals into the disinfective alcohol. Connections between tubes are made with ribbed fittings that ensures leak-proof connections. The dimensions of the tubes are determined to be
Inner: 2 mm
Wall: 1 mm,
Outer: 4 mm

4.14 CLEANING STATE

The cleaning staff must clean the hand sanitizer once a day. The cleaning is done by wiping the unit with a universal cleaning agent. When wiping the unit, triggering the sensor is unwanted, and will waste disinfective alcohol if the hand sanitizer starts dispensing during the cleaning. To prevent this, a simple sliding switch is built into the wall fitting. This switch disables the connection to the sensor while the cleaning is done. To prevent regular users to operate the switch, it is placed out of sight.



4.15 MOUNTING

When determining how the hand sanitizer must be mounted the following criteria are set.

Criteria

No visible screws.

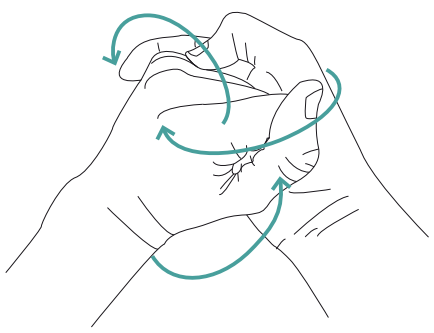
Secure – Must not be removable without tools.

Accessible – The screws must be directly accessible and have space for the use of powertools.

All types of current hand sanitizers are wall mounted with a set of wall screws. To prevent theft or removal of the hand sanitizer, it should not be possible to lift it of the screws and take it with you. Therefore the typical elongated screw holes are not chosen. Instead the mounting must be done through regular holes, and the screws must only be able to be fastened and removed when the hand sanitizer is opened by technical staff or cleaning staff.
To make it easier to mount, the hand sanitizer is split up into a wall fitting-part that must be screwed on the wall. The rest of the hand sanitizer is then slid onto the wall fitting. This makes it a natural cover for the screws. The hand sanitizer is then secured to the wall fitting with a single screw or lock, so visitors or patients are not able to remove it by hand.

4.16 AESTHETICS

From the concept development of the shell page 54 the resulting shape is considered too static and insignificant. It does not resemble the movements the users are supposed to perform.



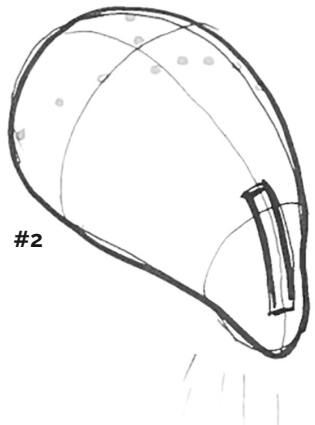
The dynamic hand movements to incorporate in the look of the hand sanitizer.

To adapt these dynamic movements into the dispenser some more organic hand sanitizers are sketched and modelled. Dynamic looking products and products associated with high efficiency are used for inspiration. Appendix 4.16

CONCLUSION

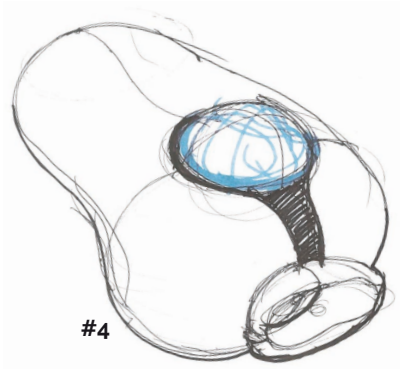
It is difficult to see where to place the hands at idea 1 and 3 whereas the others have a clear direction pointing out the position of the nozzle. When aiming at inexperienced users like the visitors it is highly important to make the interaction with the hand sanitizer easy to understand. From a distance as well as close to the dispenser it must be easy to see where to place the hands for it to activate. The mode of expression from idea 7 is selected for the further aesthetic development since it corresponds to the desired dynamic expression.

#1

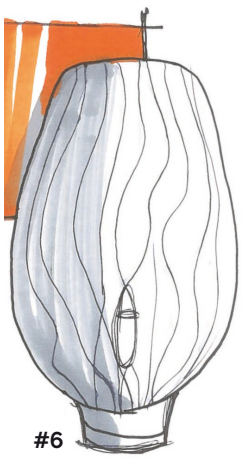


#2

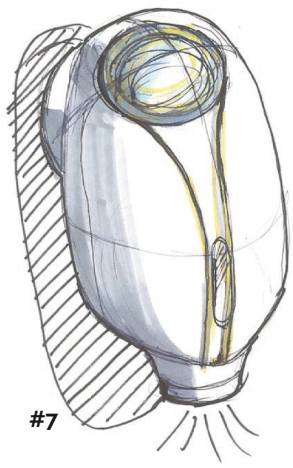
#3



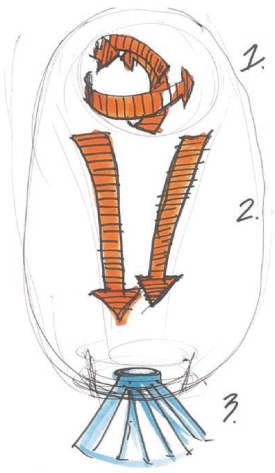
#4



#6



#7



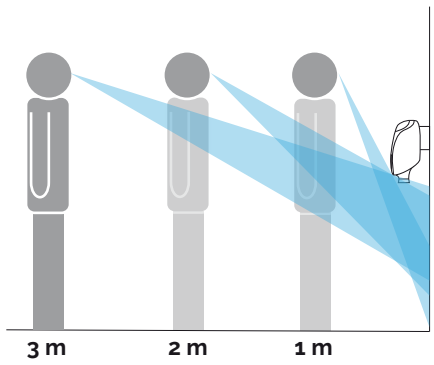
4.17

NOZZLE

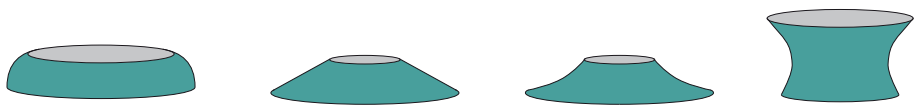
When looking at the nozzle of the concept at page 54 a problem occurs. The nozzle is highly visible from the distance because of the colourful oversized design but due to the vertical front of the hand sanitizer the nozzle totally disappears when you are standing directly by dispenser.

Being able to decode the placement of the nozzle when you are using the hand sanitizer is really important to ensure the disinfective alcohol hit the hands.

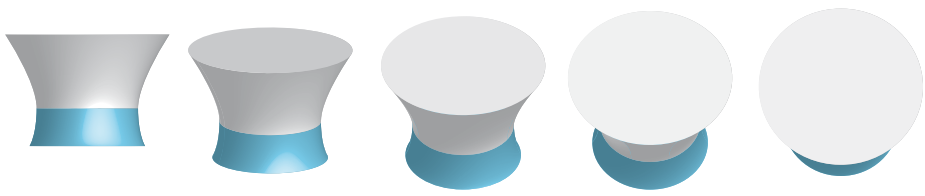
In the development of the shape of the nozzle the focus is to enable the users to see that the disinfective alcohol comes in the shape of a cone instead of the straight beam that they are currently used to. The reason for this focus is to make the users understand that they must use both hands to receive the disinfective alcohol.



SPRAY NOZZLES



For the shape to work the user should be able to detect the spray indicating shape from various distances. When approaching the hand sanitizer the perspective gradually changes from a normal view to a bird's eye view.



The nozzle seen from the distance

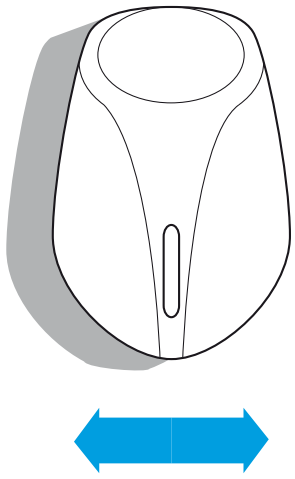
The look of the nozzle when standing directly by the hand sanitizer.

CONCLUSION

The spray indicating shape disappears when approaching the hand sanitizer instead the users should be convinced into using both hands through a different mean like e.g. a wide nozzle.

HAND POSITION

The hand sanitizer should indicate a three-dimensional space where the hands must be positioned to delimit them from accidently touching the hand sanitizer and wall when rubbing in the disinfective alcohol.



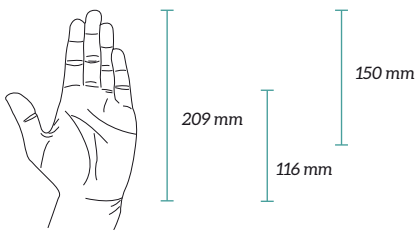
X-AXIS

Looking at the X-axis, the positioning of the hands is indicated by the converging bottom of the hand sanitizer.

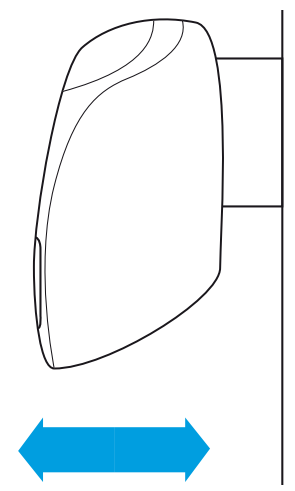
The width of the bottom of the dispenser can be utilized to make people place both hands under the dispenser instead of adding a nozzle to the dynamic shape.

Y-AXIS

The y-axis describes the distance to the wall, for this distance the deciding parameter is the hand size. For the hand size the 95th percentile of non-disabled male hands is used to determine the minimal distance to the wall. This distance is 150 mm.

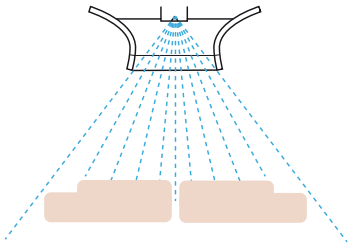


The hand sanitizer must be wall mounted and people generally approach it from the side. Due to this the shape of the side of the hand sanitizer can communicate the placement of the nozzle in proportion to the wall. From here the user can see that the disinfective alcohol will be sprayed below the front of the dispenser.
The tapering shape emphasizes the desired efficient and dynamic look.



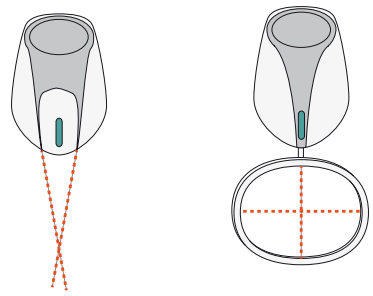
Z-AXIS

To ensure as little disinfective alcohol at the floor as possible it is important to make the users place their hands at a sudden distance to the nozzle. The disinfective alcohol is dosed in a cone entailing a risk that much of it is spilled at the floor if the users place the hands too far from the nozzle.



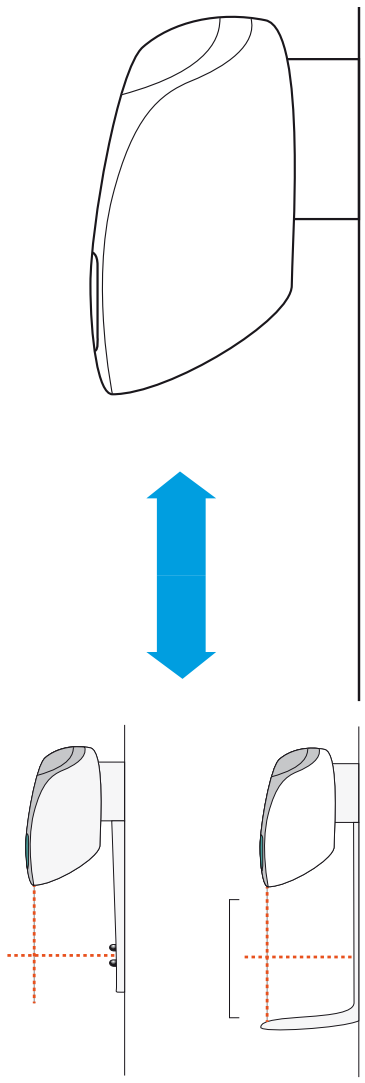
When determining the distance between the sensor and the nozzle it is essential to get a distance between the nozzle and the hands ensuring people will not touch the hand sanitizer when rubbing in the disinfective alcohol.

To be able to point out a position below the dispenser some guidelines must be given. It is a possibility to add some lines at the hand sanitizer projecting a central point below the dispenser or adding an element below the dispenser as a guideline.



#1
Projecting lines

#2
A circle to put hands into



#3
Vertical placement of the sensor

#4
A guiding plate

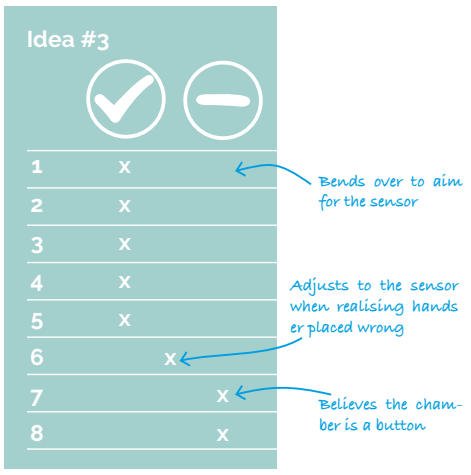
It is considered that people must read too much into idea 1 to place the hands correctly while there is a high risk of recontamination of the hands at idea 2. To choose between idea 3 and 4 a test is conducted.

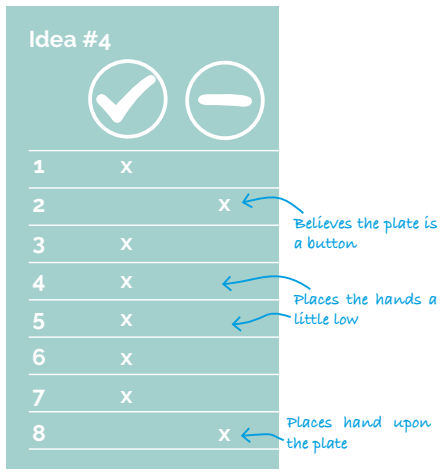
EXPERIMENT

The aim of the experiment is to see if people place their hands where the indicator tells them to.
For the experiment physical models are build and testet. Videos of the experiment is available in appendix 4.17.

Places hands correctly

Places hands incorrectly





OUTCOME

Five out of five participants uses idea 3 correctly when the sensor is placed close to the nozzle. When the sensor is moved further away to provoke people into placing their hands unrealistically far from the nozzle it is only one out of three who ends up using it correctly when noticing the sensor. The two other participants place their hands really close to the nozzle.

Six out of eight uses idea 4 correctly, although two out of the six places their hands quite low, which will become a problem when rubbing in the disinfective alcohol.

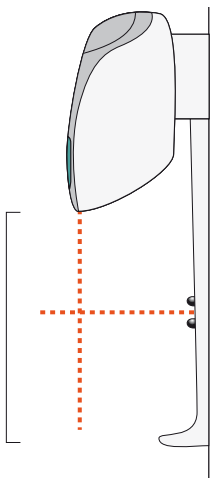
REFINED CONCEPT

As a supplement to the tested ideas a combination of idea 3 and 4 is developed and tested.

The result from the test of idea 5 is that five out of five uses it correctly. An advantage to the small horizontal plate compared to the sensors, is that it is visible when standing by the hand sanitizer and enables the user to adjust the placement of the hands when standing directly by the dispenser.

The sensor is not visible when standing by the dispenser and makes it difficult to predict where to place the hands when standing directly by the dispenser.

Ide #5	✓	−
1	x	
2	x	
3	x	
4	x	
5	x	



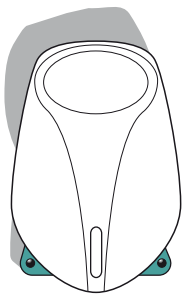
#5 A combinationof idea 3 and 4

Findings

- There must not be anything resembling a button

ALTERNATIVE DESIGN

A visualisation upon placing the sensor on each side of the hand sanitizer is produced, but it is quickly evaluated that it is harder to understand where to position the hands compared to idea 5. The width between the sensors creates a new problem in the determination of where to place the hands on the x-axis.

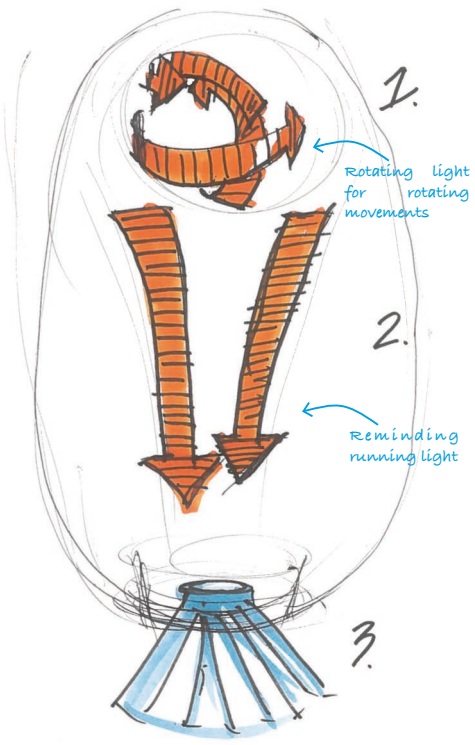


4.18
LIGHT MOVEMENTS

By implementing moving light in the hand sanitizer as a mean to remind the HCW to use it a possibility occurs. Besides utilizing the light to remind it can also be used make people start rubbing in the disinfective alcohol already when it is sprayed at the hands.

The reminding aspect of the moving light follows a predefined frequency where it is turned on for instance when it has not been used for 10 min.
Since the hand sanitizers are primarily positioned at the wards it is important that the light has a pace, which will not irritate the patients.

To make people rub in the disinfective alcohol, already when it is sprayed, a panel with rotating lights is added.



EXPERIMENT

A test is conducted upon whether people react to the rotating light or not and if we can make them react immediately when starting to dosage the disinfective alcohol. For the test a film of rotating light is programmed and then displayed at a computer screen.

Videos from the test are available in appendix 4.18.

The participants do not react as intended. Everyone begin rubbing in the disinfective alcohol in rotating movements as desired, but they do not start immediately. Since the movements are shown at a screen people expect more to happen

The context of the experiment is not true to reality. The rotating light and the spraying mechanism is not physically connected, which entails insecurities in the results. Despite these insecurities it is decided to bring along findings from the experiment.

THE FINDINGS

There must be a change of tempo when activating the dispenser to ensure the users that it is not just a screen saver.
The rotating motions make people do the circular movements already during the dosage.

4.19 PRODUCTION

Because of the overall number of hand sanitizers in a hospital, the only economically viable production method is injection molding of the plastic parts. Injection molding has a very high tooling cost up front, especially in a product with many parts, but it benefits highly from the economy of scale.

To keep the tooling cost down, each individual component is modelled in Solidworks with the goal of using as few side-actions as possible. Each side-action requires more advanced molds, and increases the development cost.
The surface finish of the molds is also a factor that can increase the cost of tooling. To get a high gloss surface on plastics, the surface of the mold must be machined and polished to a very high shine. To cut down on this extra cost, only exterior surfaces are polished. Every component surface that is only visible during maintenance, is finished at a lower grade of polish.
To get uniform surfaces and to prevent sinking of the plastic, the components are also modelled with similar wall thickness. Ribs are used in part requiring extra strength and are modelled with a wall thickness of 75% of the general thickness. A reference part from ProtoMold is used as a general guideline for these thicknesses.

4.20 BUSINESS

MARKET SIZE

Designing for the health care sector is very much unlike designing for a consumer market. The product must show its worth before being implemented at an entire region or even an entire hospital. Four market sizes are illustrated to show the scalability and implementation of the product.
The calculations are conducted to get insights into the cost price opportunities for the different scenarios.

GASTROENTEROLOGICAL DEPARTMENT AUH

Due to the connection to the Gastroenterological Department at AUH this department has been selected as an example of a trial department. By installing the product at an entire department over a longer period of time it will become visible if the product has the desired effect and the HCW get to know the product. At the Gastroenterological Department at AUH they currently have 34 hand sanitizers, which will by the point of departure for the calculations in [app 4.20a]. [app 4.20b]

AALBORG UNIVERSITY HOSPITAL SOUTH

When the product has shown its potential through out the trial period it can be implemented at an entire hospital after undergoing a functional procurement process. For the calculations the number of departments at AUH has been determined to 25 which results in 850 hand sanitizers.

EVERY HOSPITAL IN THE NORTH DENMARK REGION

Due to the collaboration with Ideklinikken the area of interest is the North Denmark Region. At the hospitals in the region there are 1298 beds, which results in 1697 hand sanitizers.

ALL DANISH HOSPITALS

Based upon the total number of beds in Danish public hospitals there is a potential market of at least 19600 hand sanitizers.

For all scenarios the number of hand sanitizers is based upon the number of beds at inpatient wards. This means that e.g. out patient clinic, emergency departments and entrance halls are not included, which means that the market potential is even higher.

4.21 BUSINESS OPPORTUNITIES

According to Birgitte Fjeldgaard from the Procurement Department it is a challenge as a new provider to compete with existing products, within the health care sector, since these products are usually chosen due to low purchase price. However there is an opportunity if a functional procurement is developed.

FUNCTIONAL PROCUREMENT

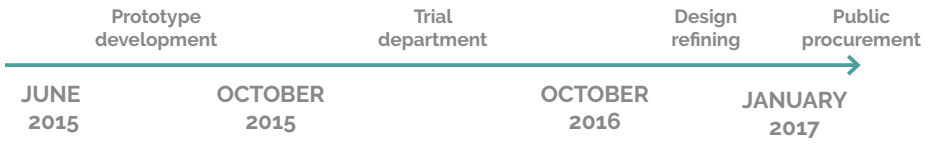
The functional procurement is based upon some specific minimum requirements, which has been proven to have an effect on e.g. the number of HAI. To approach a functional procurement one must be able to prove that the product fulfils the minimum requirements.

THE NEW SUPER HOSPITAL

For new builds the architects also have a saying in the requirements for the interior. This is not considered an opportunity for our product since the focus has been upon improving functionalities and to enhance the use of disinfective alcohol. These factors has also been the focus when designing the look of the hand sanitizer and there has been paid no regards to the architects opinion upon the look of the dispenser.

TRIAL DEPARTMENT

An opportunity to prove the effect of our hand sanitizer is to install it at a trial department for a longer period of time, e.g. for a year, to see the effect it brings. The procurement for hand sanitizers at the Super Hospital is not until 2017, which enables us to produce prototypes to install at a trial department, analyze the results and make improvements of the hand sanitizer before then.



4.22
NET PRESENT VALUE

When determining the effect of implementing the developed hand sanitizer there are two aspects of interest. There is a feel-good aspect focusing upon the decrease in the number of patients acquiring a HAI and an economical aspect focusing upon the profit of implementing the solution.
Implementing the solution creates a profit because of the fewer patients acquiring a HAI.

HAI CAUSED BY BAD HAND HYGIENE

Not all HAI are caused by bad hand hygiene. The estimation upon how many of the HAI that are caused by bad hand hygiene is a guestimate taking its point of departure in the number of routes of infection for each disease. For instance there are four routes of infection causing pneumonia out of these four routes it is only the dropborn route that is not caused by bad hand hygiene. This is the reason why bad hand hygiene is estimated as the reason for 75% of the persons infected by pneumonia.

This estimation gives the result that approximately 46.500 HAI are caused by bad hand hygiene in Denmark per year. This is the number of diseases we can remove if hand hygiene is performed 100% correctly.

RESPONSIBLE OF INFECTION

During the research it was learned that a patient in average is in contact with 9 HCW and 1 visitor each day. The HCW currently use disinfective alcohol 40% of the times they must use it while only 0,52% of the visitors use it during their time at the hospital. This knowledge is incorporated in the calculations.

COST PRICE

When determining the cost price of the hand sanitizer the online tool www.customparts.net is used. The calculation is available in appendix 4.22a.

For a single dispenser the cost price is 459,64 DKK Taking into account both transportation, distribution to stocks, fixed expenses and profit for several links it is decided to take a 400% mark up resulting in a sales price of 1.838 DKK.

CAUSED BY BAD HAND HYGIENE

Urinary tract infection 0%

Pneumonia 75%

Wound infection 75%

Blood poisoning 50%

THE COST ESTIMATION TAKE INTO ACCOUNT I.A.

Materials with defect rate and a 25% mark up

Direct and indirect manpower

Plant force

Machine set-up time for 8 hours

Machine 95% reliability

Tooling price

Manufacturer 10% mark up

THE NPV

For the business case three Net Present Value scenarios are calculated; a worst-case scenario focusing upon a minor improvement in the hand hygiene level, a best-case scenario focusing upon a large improvement and a intermediate scenario. The NPV describes if an investment is any good over a redefined period of time. The NPV in our case are based on a period of 5 years.

The three scenarios create a span within which it will be realistic for the product to end if it is implemented at all public hospitals in The North Denmark Region simultaneously. This is not particularly realistic, but the number of HAI at a single hospital or at a single ward is not available. Since the start-up investment is spread over a higher number of dispensers the NPV will be smaller if the hand sanitizer is only implemented at a single hospital from the start.

For the NPV the visitor percentage is constantly 50% for all three scenarios.

The purpose of an NPV is to see if an investment will entail a profit or not and if it does - when the profit exceeds the initial and running costs.

The market in The North Denmark Region is only approximately 2.000 hand sanitizers, which is not enough to establish a mass production of a product with the complexity of our product. The cost price of the injection moulded parts will be unworkable expensive. Due to this the NPV is based upon a quantity of 10.000 hand sanitizers where the initial cost for The North Denmark Region will be a fifth of the price.

The investment in The North Denmark Region will be 3.600.000 DKK.

The exact calculation is available in appendix 4.22 b.

BEST-CASE SCENARIO

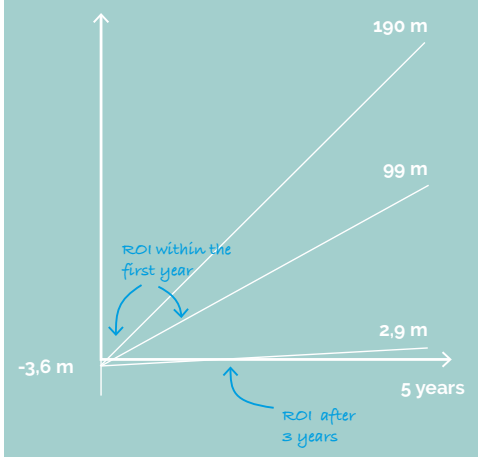
For the best-case scenario the HCW ends up using disinfective alcohol 95%

INTERMEDIATE SCENARIO

For the intermediate scenario the HCW ends up using disinfective alcohol 70%

WORST-CASE SCENARIO

For the worst-case scenario the HCW ends up using disinfective alcohol 41%



5.0

PROJECT SUMMARY

5.1
CONCLUSION

The project pain is the bad level of hand hygiene of HCW and hospital visitors resulting in approximately 100.000 patients acquiring a HAI in Denmark each year, which is the reason for a yearly expense of 1 billion DKK. Throughout the project it is learned that this expense can be lowered drastically even with a small improvement within the level of hand hygiene at hospitals.

From Statens Serum Institut it is learned that the most effective way of killing microorganisms with the least inconvenience is to use disinfective alcohol, which is the reason why the product of this project is the hand sanitizer Cleen.

Looking in to the reasons why HCW and visitors do not use disinfective alcohol as much as they are supposed to shows a pattern. Besides using disinfective alcohol too rarely the HCW also use the hand sanitizers incorrectly, which entails that the effect of killing 99% of microorganisms by using disinfective alcohol fail to happen. To prevent this from happening a large focus has been upon preventing HCW and visitors in using the disinfective alcohol incorrectly. This has resulted in a sensor driven solution providing people with a given 3ml dose ensuring people remain humid hands for at least 30 seconds as required.

Initially the focus was upon enhancing the hospital visitors' use of disinfective alcohol because only 0,52% of them actually use it during their visit. But from the number of visitors compared to the number of HCW being with the patient each day it is obvious that the HCW pose a higher risk of infecting the patients than the visitors do.

The HCW presume that they use disinfective alcohol nearly as frequently as required. This is far from the truth and the basis for this project is therefore that they simply forget to use it. This perception is the reason for implementing a reminding feature in the hand sanitizer. The best suitable reminder is moving light attached to a timer. The light intensity and pace of the movement must be adapted to the context to ensure it is noticed without annoying the patients.
It is the experience that a significant reason why visitors do not use disinfective alcohol is that they do not know that they are supposed to do it and they do not consider that they constitute a risk of infecting the patient. This problem is responded to be suggesting placing Cleen in the hospital entrance hall and making it resemble a hygiene product so visitors know that they can use it without any cause of concern.
The business case of Cleen proves that even small improvements within the level of hand hygiene finances the purchase of new hand sanitizers for all public hospitals in The North Denmark Region already within three years. And this business case is only based upon cost reductions due to a drop in the number of patients getting a HAI, it does not even include the possible drop in sick days among the HCW.

5.2 REFLECTION

STAKEHOLDERS

The interest in the project from all hospital stakeholders and their willingness to help with professional knowledge and user experiments has been a distinct motivating factor throughout the project. The lack of investment in lasting solutions to improve the level of hand hygiene has been particularly thought provoking.

The initial thought behind collaborating with Ideklinikken was to get access to hospital stakeholders who are not a part of our own network. It was a wish to have a department where different concepts could be tested ongoing to evaluate their effects. Unfortunately the process of receiving the contacts dragged on and we decided to utilize our own network within AUH to get access to HCW. This speeded up the process significantly.

BUSINESS

When convincing an institution to invest in a product they must get insights into when the investment is repaid. This is the reason why a NPV is made, but in this case it seems unnecessary since the investment is already repaid within three years for the worst-case scenario where the use of disinfective alcohol only goes up from 40% to 41%.
Instead it could be fruitful to look into the business case from our point of view if considering creating a start-up company around Cleen as a product.
Refill business
An additional business aspect to the development of Cleen is how the refill should be sold. If it must be a part of the company producing the hand sanitizer or if it must be sold through an external supplier like e.g. abenaonline.dk. There is potential for a large yield from the refills since it is a returning income contrary to the sale of the hand sanitizer.

ADDITIONAL DETAILING

For Cleen to be ready for production there are some further detailing to be done.

Moving light
Intensity and pace must be specified

Exchangeable piston pump
Due to a risk of wearing out the piston pump is designed to be exchangeable. This might not be necessary but we have not had an opportunity to test it.

Graphics
The graphic of the refill is a conceptual thought, which needs some processing to incorporate content description and expiration date

Lock
Currently Cleen do not feature a lock. The application for dispensation to place Cleen in the hospital entrance might be eased if a lock is incorporated since the risk of vandalism is decreased.

Optimizing the inner frame
Due to the product complexity of the inner frame this part is very expensive to produce. By simplifying this part the cost price can be lowered.

Shell material
Due to the association to hygiene products the shell is produced in high polished ABS. A high polished surface is exposed to scratches, to which it can become more resistant by making the surface more matt.

Size
Cleen is a double curved shape whereas the refills are boxes. Cleen appears larger than current hand sanitizers at the market. The dispenser could become smaller by modifying it and the refills to decrease the amount of unutilised space.

Throughout the project period the focus has solely been upon the health care sector but that is not the only sector where hand hygiene is of importance. Cleen could also be aiming at restaurants at institutions like kindergartens, schools and larger workplaces.

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5.4
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The illustrations that are not listed below are either photographs or illustrations devloped by the project team.

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p. 72
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p. 73
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Product Report

be careful be

cleen

Anders Klitgaard, Louise Christensen &
Trine Thylkjær Asp

MSc4 ID, Group 7, AAU, May 2015

Introduction

When you are in the hospital, your immune system is often weakened. Poor hygiene can then lead to prolonged hospitalizations and in the worst case; death. Your visitors can unknowingly bring in bacteria and viruses that can turn out to cause infections or make you sicker than you were before. Not only are your friends and family a danger to your fast recovery, but even the nurses that take care of you are not 100% efficient at preforming correct hand hygiene between patients.

Cleen is a modern hand sanitizer for the modern hospital that aims to solve these problems. Using optical sensors and a unique spray-mechanism, the hand sanitizer is completely touch-free. The spray mechanism guarantees a uniform spread of the liquid, and prevents dripping on the floor.
The shape and features of cleen gives it an unprecedented user-friendliness compared to competing dispensers, and makes sure that even first-time users get enough liquid to ensure completely disinfected hands.

Anders Klitgaard

Louise Christensen

Trine Thylkjær Asp

Content

Illustration

p. 4
http://mediad.publicbroadcasting.net/p/wfyi/files/201405/nurse-hands-copy.jpg

Every year 100.000 patients are infected by a HAI at the Danish Public Hospitals. A large part of this is due to the lack of hand hygiene.

cleen

PERFECTLY CLEAN HANDS

Cleen is a modern automatic hand sanitizer made specifically to make it as easy as possible to use correctly. Old hand sanitizers are often hand operated, and creates a hazardous hot-spot for microorganisms. This makes it all-important that the user proceeds to apply the disinfective alcohol in the correct manner. Cleen removes this uncertainty by utilizing optical sensors.

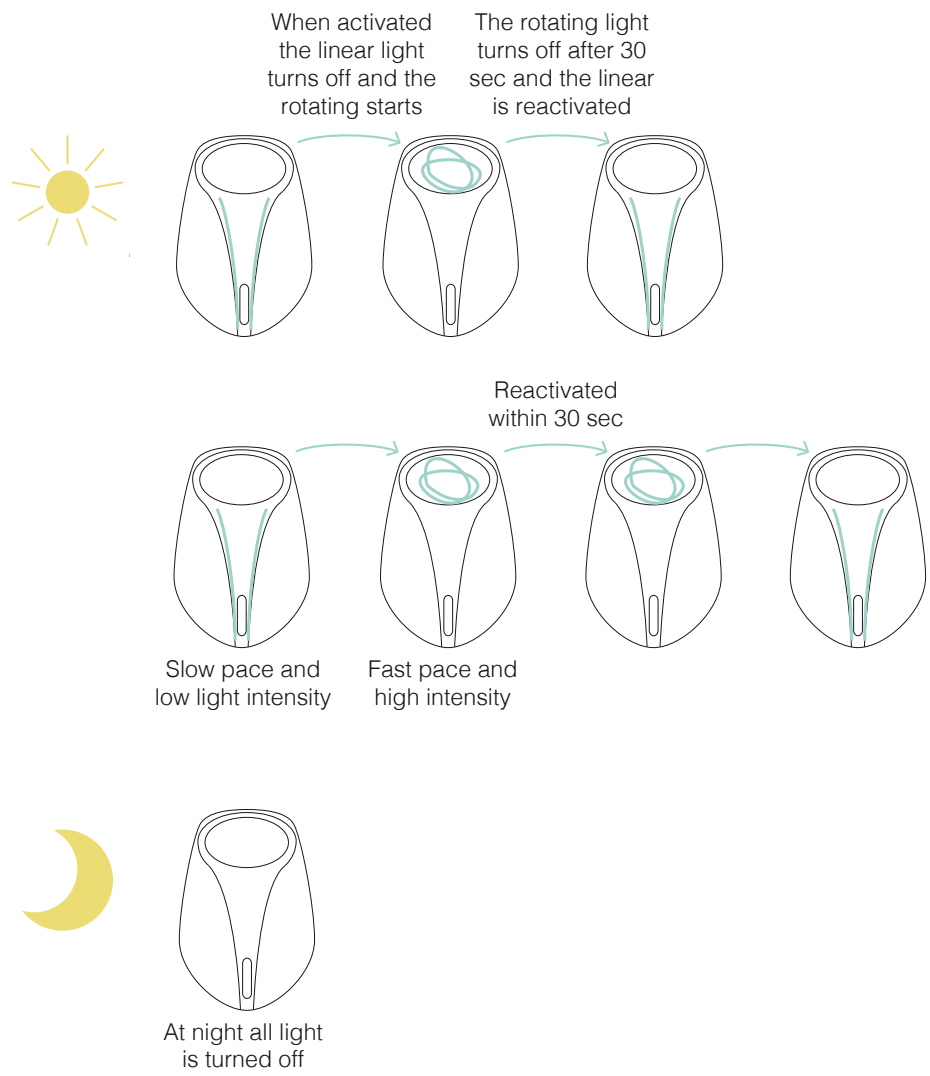
Cleen dispenses 3 ml. disinfective alcohol every time. This is the required amount for a uniform spread of the liquid. By spraying the disinfective alcohol instead of using a regular spout, cleen creates a pleasant cool mist that gives an optimal spread. The spray is ejected over 4 seconds, and enables the user to apply the liquid during the spraying. This eliminates the need for cupping hands, and prevents dripping when applying the large amount of liquid. To illustrate the amount of liquid dispensed, cleen has a distinct chamber that clearly shows how much has been dispensed and how much remains. This shows the user not to remove their hands prematurely.
The most important aspect when getting visitors to sanitize their hands, is to make them aware that the hand sanitizers are not just for nurses and other hospital workers. The product language of old hand sanitizers is so sparse that visitors associate them with something meant for professionals.
Cleen accommodates this problem with an attractive organic design that draws people in with flowing lights, and automatically leads the eyes towards the nozzle.

Cleen is so intuitive that first-time users know how to use it correctly even the first time. Since hospital visits are a rare occurence they will not get many chances to learn a specific procedure. Therefor the user-friendliness of cleen, is essential.

Moving Light

Cleen is provided with vertical moving light as a reminder for the passers by to use it. Furthermore circular light starts when Cleen is used to make people start rubbing in the disinfective alcohol already while it is sprayed. The reminding light is moving in direction of the outlet. The light will change pace depending on whether it is passive and active.

The different stages of light

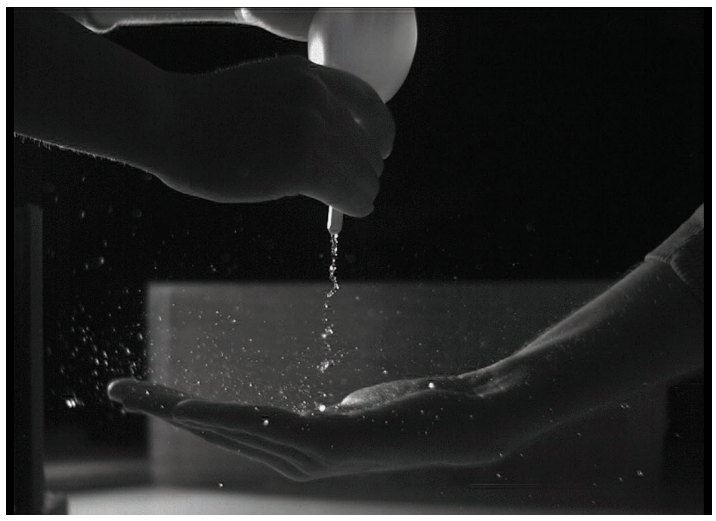


Spray, 3ml, Chamber

To make sure that the hands is 99% free of microorganisms Cleen is using a atomizer to spray out the disinfective alcohol, this also minimize the drip on the floor and helps the user spread the disinfective alcohol properly. Cleen provides the user with a fixed amount of 3 mL disinfective alcohol to ensure that the hands of the user is moist in at least 30 seconds. Cleen is provided with a visible chamber for the user to decode the amount of disinfective alcohol and make sure that they don't remove their hands before they have received the whole dose.

Splash back experiment

From Statens Serum Institut it is experienced that atomizing disinfective alcohol is undesired due to a risk of inhaling it.
An experiment proved this concern to be wrong. As apparent at the pictures below the current hand sanitizers pose a higher risk of swirling disinfective alcohol up in the air.



The currently installed hand sanitizer at AUH

Cleen only creates a minor splash back changed direction before getting near the airways.

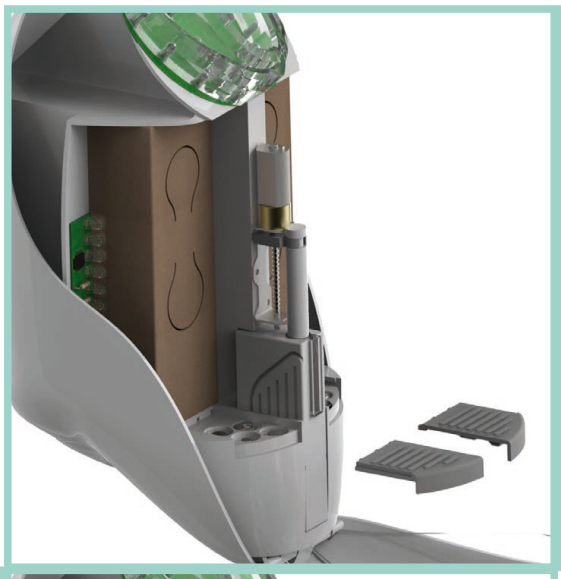
Exchange

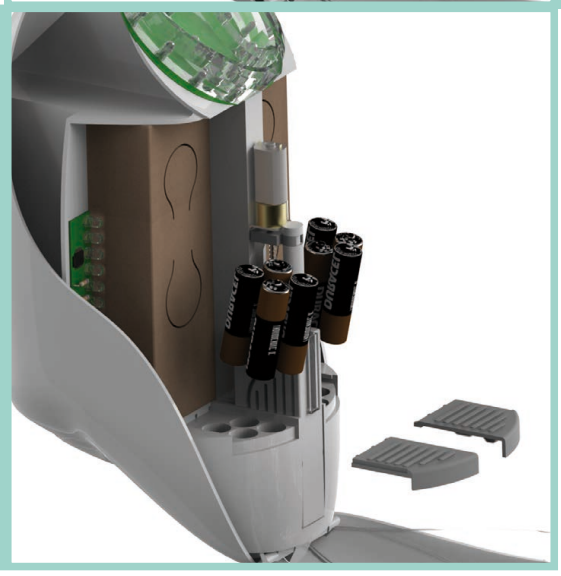
the refill

Opening the front of cleen, provides easy acces to all servicable parts of the product. The most important part is the two 500 ml. refills. By utilizing 2 refills simultaneously, the dispenser can run out of liquid in one refill, and still continue to function until that refill can be exchanged.

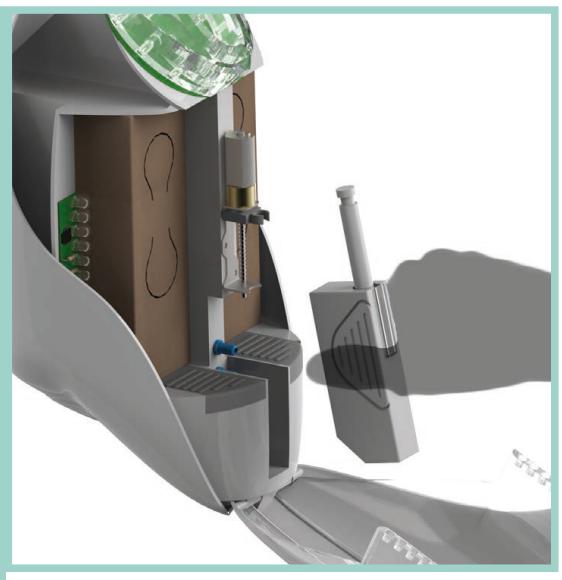
The refills are removed by pulling the box through 2 finger sized holes. Membranes in each box seals the connection and prvents drip. Even if the refills are removed before time.

the batteries





the pistonpump



Once a year, the batteries will need to be exchanged. The access to the batteries is easy and intuitive, and can be done in a minute.

Similarly, the piston pump might reach a point where it doesn't works as good as new. In this case, the exchange is quick and painless and can be done by everone. This means that you don't have to wait for the technical staff to arrive before you can fix the hand sanitizer in your room.

Mounting

To ensure a secure mounting on the wall, the dispenser is mounted with 5 screws. To make mounting as hassle free as possible, the screwholes are placed in a sepearate wall-bracket. This ensures easy acces to the holes, even when using large powertools.

When the wallbracket is fastened, the screws are covered cosmetic shells. This creates a clean and hygenic surface.

Lastly, the dispenser is slid onto the wallbracket and locked in place. Two brass connectors in the lock connects the optical sensors to the dispenser without further work.

Product features

Spray
The spraying of disinfective alcohol is very comfortable and enables the users to spread it equally with a minimum of spil.

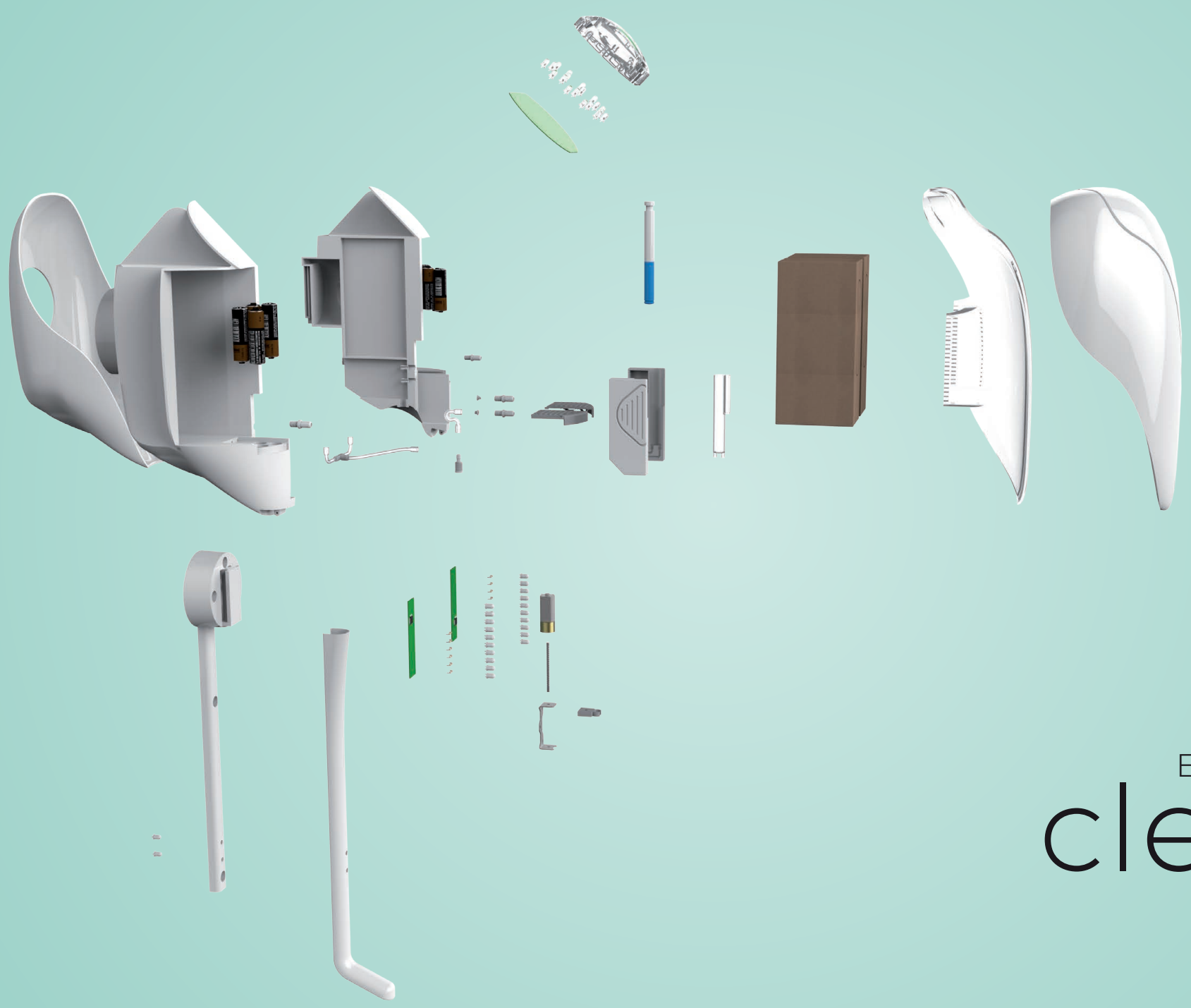
Fixed dose
The fixed dose of 3ml enables the users to kill 99% of the microorganisms at their hands.

Two refill solution
The two refill solution raise the probability of not running out of disinfective alcohol.

Sensor driven
The sensor driven interaction ensures that the hands are not recontaminated during the interaction with Cleen.

Moving light as a reminder
The vertical light is noticed even through the corner of the eye and reminds people to use disinfective alcohol.

Rotating light as instructions
The rotating light illustrates the desired movements of the hands during the time of the dosage.



Exploded view

cleen

cleen SAVES LIVES

Yearly decrease in the number of HAI - in The North Denmark Region

Currently the level of hand hygiene among health care workers is only 40%
By implementing Cleen the level of hand hygiene will be improved resulting in less patients acquiring a HAI.

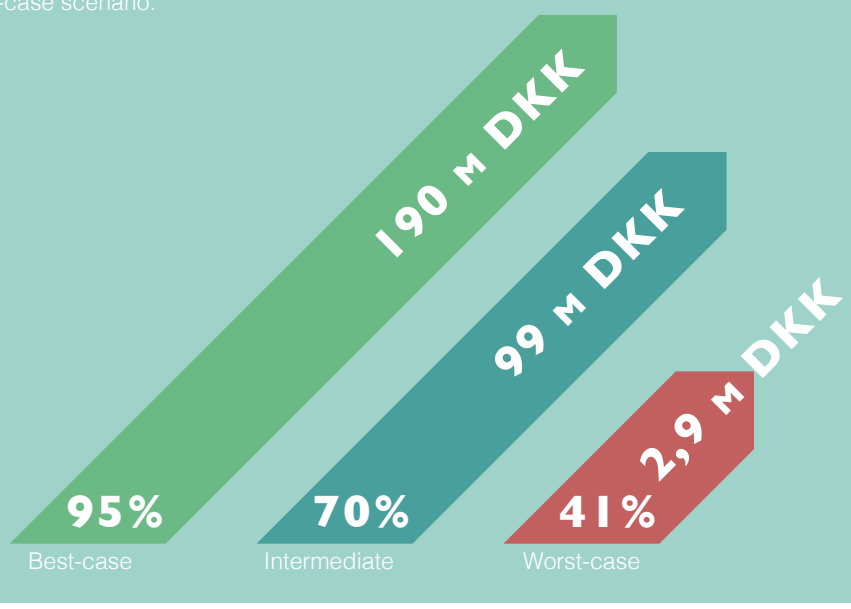
Level of hand hygiene	Yearly decrease in HAI
41%	1050
70%	2800
95%	5100

Business scenarios

For Cleen to prove its efficiency we suggest having a 1 year trial period. In the trial period Cleen will be implemented at a single department and from here the product can be refined. In 2017 Cleen will be ready for the procurement process for the Super Hospital.

Net Present Value

There is a positive NPV for both the best-case-, intermediate- and the worst-case scenario.



Implementation Phase

Teaching Tool

An important part of hand hygiene is an effective spread of the disinfective alcohol. To teach visitors the best practice when applying the liquid, we provide an instructional video that can act as an exciting eye catcher in the entrance hall. Since this is a high-traffic area, we recommend accompaning the video with at least 5 cleen units. This shows the visitors that it isn't just meant for hospital staff, and it teaches them to recognize the hand sanitizers when they proceede into the main parts of the hospital.

cleen