ventum
Freedom of movement for children receiving respiratory treatment

Master thesis in Advanced Product Design 2013
Umeå Institute of Design
Simon Fredriksson
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“A respirator greatly restricts your activity and also limits your movement. You may be able to sit up in bed or in a chair, but you usually can’t move around much”

National heart, lung and blood institute (USA) http://www.nhlbi.nih.gov
ABSTRACT

This report is showing the process and result from a project collaboration between Norrlands University hospital and design student Simon Fredriksson.

Respiratory treatment is carried out on patients that for some reason fail to breathe sufficiently to assimilate enough oxygen to survive. The reason for why a person needs respiratory treatment can be many and the length of the treatment varies a lot. It can stretch from a couple of hours during surgery to years in treatment for example Chronic obstructive pulmonary disease (COPD) or Immature lungs.

The project focus have been to look at how to increase the freedom of movement for kids receiving respiratory treatment. Respiratory treatment are complex and involves advanced equipment. It’s demanding both physically and mentally both for patient and involved family and can in some cases carry on for several years. A young child with impaired breathing should still have the freedom of movement and not have to be restricted to the length of a respirator hose and depend on others to be able to move around. Learning how to crawl walk and freely move around should be every childs right. The quote are from the National heart, lung and blood institute in America. My aim is to create a concept that will offer that movement and prove them wrong.

This project is carried out in collaboration with the Neonatal intensive care unit (NICU) at Norrlands University hospital in Umeå.
COLLABORATION

This project is done in collaboration with the neonatal intensive care unit (NICU) at Norrlands University hospital in Umeå. My contact has been Magnus Näslund a trained nurse and a expert in pediatric respiratory care.

A collaboration of this kind makes sure that the project is valid and relevant as well as providing necessary information and insights that would have been impossible to gather with only desktop research. The geographical closeness to the hospital and the amount of support I have been given has been very fruitful and making sure that I have had the best conditions to do a good project.

Besides Magnus expertise I have had the pleasure to get assisted by both doctors and physiotherapists to answer questions and contribute with insights and feedback. I will also give a special thanks to Gunnar Jogensjö. Medicine technician and product specialist in respirators at ResMed, one of the worlds biggest manufacturers of respirators. For support with the technical parts of the project.

This project is funded by Brita-Stina Nordenstedt scholarship
DESIGN OPPORTUNITY

Challenges

Respiratory treatment are needed when a child can't breathe by herself. It's a complex treatment, demanding both physically and mentally for both child and the ones that are close. With multiple caregivers and a variety of complex equipment involved. Respiratory patients are many times suffering form other conditions then just the impaired breathing and can therefor also be physically weaker then the average child.

How the treatment and equipment looks today most products are designed for a stationary tabletop use with patients that have very little or non movement. And almost all products on the market are designed for adults which means that most components are oversized and can cause problems when used on children. My target group with active children in respiratory treatment are not very big but never the less very important.

The main problems with respirators today is that there are the limitations on the length of the air hose (maximum 1.5 meters) to be able to keep up the required pressure and flow of air and the weight (2 kilo for the lightest on the market). This makes it too heavy for the child to move around and to short hoses to get a satisfying range of movement. The hoses itself and connections are also a obvious problem that needs to be solved.

Opportunity

The challenge is to make a respirator that can allow this freedom of movement. How to make it smaller and more portable then todays products and at the same time secure the critical air supply and at the same time increase independence and reduce the dependence of others. The opportunity is to create a concept that have the young target group in mind and fill the gap in todays market.

I'm intending to have a future time frame of 10 years in the project to be able to implement emerging technologies if needed.
WHAT DO I WANT TO DO?

What?
A respiratory system that allows more freedom of movement for the user and increase independence. Focusing on a child’s needs and targeting how to enable play.

Why?
Being able to have an active life and freedom of movement is something that should be every one’s right. Even though you are depending on life supporting equipment. Simplify treatment and therefore increase quality of life for both child and parents.

Who?
The target group is children primarily in the age of 0-6 years that are in need of respiratory treatment.

Where?
The solution is meant to be mobile and work both in a private and in a hospital environment.
GOALS AND WISHES

**Goals**

A respiratory system that allows more freedom of movement for the user and increase independence.

Create a solution adapted for use by children

Simplify usage of respirators for professional and non professional users

Create better air hose management and connections

**Wishes**

Integrate the solution with other devices needed for respiratory treatment

Allow personalizing of the product

Make the respirator work for a larger user group than children
RESEARCH
How do we breathe?

The human respiratory system is made up of organs and tissues that help you breathe. The main parts of this system are the airways, the lungs and linked blood vessels, and the muscles that enable breathing. Your lungs are organs in your chest that allow your body to take in oxygen from the air. They also help remove carbon dioxide from your body in a process called gas exchange. The airways are pipes that carry oxygen-rich air to your lungs and also carry carbon dioxide, out of your lungs.

The airways include

- Nose and linked air passages (called nasal cavities)
- Mouth
- Larynx, or voice box
- Trachea, or windpipe
- Tubes called bronchial tubes or bronchi, and their branches

Air first enters your body through your nose or mouth, which wets and warms the air. (Cold, dry air can irritate your lungs.) The air then travels through your voice box and down your windpipe. The windpipe splits into two bronchial tubes that enter your lungs.

Lungs and Blood Vessels

Your lungs and linked blood vessels deliver oxygen to your body and remove carbon dioxide from your body. Within the lungs, your bronchi branch into thousands of smaller, thinner tubes called bronchioles. These tubes end in bunches of tiny round air sacs called alveoli. Each of these air sacs is covered in a mesh of tiny blood vessels called capillaries. The capillaries connect to a network of arteries and veins that move blood through your body. And through these we can get oxygen in to our blood and ventilate out carbon dioxide.

Muscles Used for Breathing

Multiple muscles are used in the breathing process. Diaphragm intercostal muscles, abdominal muscles and muscles in the neck and collarbone area. The diaphragm is a dome-shaped muscle located below your lungs. It separates the chest cavity from the abdominal cavity and it is the main muscle used for breathing. When you breathe in, or inhale, your diaphragm contracts and moves downward. This increases the space in your chest cavity, into which your lungs expand. As your lungs expand, air is sucked in through your nose or mouth and down to your lungs. At the same time, carbon dioxide moves from the capillaries into the air sacs. When you breathe out, or exhale, your diaphragm relaxes and moves upward into the chest cavity. As the space in the chest cavity gets smaller, air rich in carbon dioxide is forced out of your lungs and windpipe, and then out of your nose or mouth. Breathing out requires no effort from your body unless you have a lung disease or are doing physical activity.

What Controls Your Breathing?

A respiratory control center at the base of your brain controls your breathing. This center sends ongoing signals down your spine and to the muscles involved in breathing. These signals ensure your breathing muscles contract and relax regularly. This allows your breathing to happen automatically, without you being aware of it.
How much do we breathe

An adult person takes around 8-12 breaths per minute in normal conditions. A child's breathing rate is faster and can for a one year old be around 30-40 breaths per minute.

What do we breathe

The air around us contains 78% nitrogen 21% oxygen and 1% of other gases. When we breathe a process called gas exchange happens in the lungs where fresh oxygen gets in to the blood and at the same time transport away the carbon dioxide through exhalation.

After 3-5 minutes without oxygen most people will pass out and the risk for brain damage begins.
After 5 minutes without oxygen most people will die!
WHO NEEDS A RESPIRATOR?

Respiratory treatment are given to patients that fail to breathe sufficiently to assimilate enough oxygen to survive. There can be many reasons of why you will need respiratory treatment.

Sleep apnea is a sleep disorder characterized by abnormal pauses in breathing or instances of abnormally low breathing, during sleep. Sleep apnea is one of the most common reasons for respiratory treatment. Continuous positive airway pressure (CPAP) is the most effective treatment for severe obstructive sleep apnea.

Immature lungs are the most common and most dangerous complication that comes with premature birth. A human lung has something called Alveolus (little cavity in latin) The alveolus needs surfacant to develop fully. A substance that is being introduced at week 32 of the birth cycle. Surfactant prevents the lungs from collapsing, and makes lung inflation easier. Insufficient surfactant leaves respiratory tissue unprotected at birth. Lung tissue may collapse, making breathing difficult. Insufficient lungpower results in low oxygen levels in the blood of premature babies, which in turn leads to Respiratory Distress Syndrome (IRDS).

Respiratory Distress Syndrome (RDS) causes harsh, irregular breathing and difficulties due to the lack of a specific agent (surfactant) in the lungs that helps prevent the lungs from collapsing.

Pneumonia Pneumonia is an infection in the area of the lung involved in the exchange of carbon dioxide and oxygen causing inflammation which reduces the amount of space available for the exchange of air.

Patent Ductus Arteriosus (PDA) This is a cardiac disorder that results in breathing difficulties.

Upper spinal cord injuries Damages to the nerves involved in breathing makes the patient unable to breathe on their own.

Chronic obstructive pulmonary disease (COPD) Narrows the airways and limits airflow which causes shortness of breath (dyspnea). In contrast to asthma, this limitation is poorly reversible and usually gets progressively worse over time. COPD is caused by noxious particles or gas, most commonly from tobacco smoking, which triggers an abnormal inflammatory response in the lung.

In Sweden a total of 2,300 patients have home respiratory treatment.*

The statistics do not disclose how many of those that are children. But approximately 20 new treatments start every year.

COMPLICATIONS

What are the risks of being on a ventilator?

Infections. One of the most serious and common risks of being on a ventilator is pneumonia. The breathing tube that’s put in your airway can allow bacteria to enter your lungs. As a result, you may develop ventilator-associated pneumonia (VAP).

VAP is a major concern for people using ventilators because they’re often already very sick. Pneumonia may make it harder to treat their other disease or condition. VAP is treated with antibiotics. You may need special antibiotics if the VAP is caused by bacteria that are resistant to standard treatment.

The breathing tube also makes it hard for you to cough. Coughing helps clear your airways of lung irritants that can cause infections.

Another risk of being on a ventilator is a sinus infection. This type of infection is more common in people who have endotracheal tubes. (An endotracheal tube is put into your windpipe through your mouth or nose.) Sinus infections are treated with antibiotics.

Pneumothorax. This is a condition in which air leaks out of the lungs and into the space between the lungs and the chest wall. This can cause pain and shortness of breath, and it may cause one or both lungs to collapse.

Lung damage. Pushing air into the lungs with too much pressure can harm the lungs.

Oxygen toxicity. High levels of oxygen can damage the lungs. These problems may occur because of the forced airflow or high levels of oxygen from the ventilator.

Using a ventilator also can put you at risk for blood clots and serious skin infections. These problems tend to occur in people who have certain diseases and/or who are confined to bed or a wheelchair and must remain in one position for long periods.

Another possible problem is damage to the vocal cords from the breathing tube.
HOW DOES A RESPIRATOR WORK

A respirator delivers positive air pressure and consists of a compressible air reservoir or turbine, air and oxygen supplies, a set of valves, tubes and filters, power and circuit boards and a disposable or reusable “patient circuit”. The air reservoir is pneumatically compressed several times a minute to deliver room-air, or in most cases, an air/oxygen mixture to the patient. If a turbine is used, the turbine pushes air through the ventilator, with a flow valve adjusting pressure to meet patient-specific parameters. When overpressure is released, the patient will exhale passively due to the lungs elasticity, the exhaled air being released usually through a one-way valve within the patient circuit called the patient manifold. The oxygen content of the inspired gas can be set from 21 percent (ambient air) to 100 percent (pure oxygen). Pressure and flow characteristics can be set mechanically or electronically. Modern respirators uses two fans or turbines to create the necessary pressure and volume of air that is needed for every breath.

The smaller turbine of the two is constantly spinning and generating Continuous Positive Airway Pressure (CPAP) this raises the atmospheric pressure to avoid lung collapse when exhalation. A rule of thumb for the amount of CPAP pressure is 5 cmH₂O. The larger turbine are the one that provides the preset pressure or volume of air during inhalation. The respirator can be tuned and set to fit a specific patient need when it comes to pressure and amount of air as well as breaths per minute and the length of each breath. There are two ways that a respirator can deliver air to the patient either pressure or volume guided. In pressure guided ventilation a preset pressure are set for the respirator to deliver to the patients lungs in every breath. The machine will keep on delivering air until the desired pressure are meet which is detected by sensors.

In a volume guided setting a fixed air volume are set instead which is tested and approved by the medical personnel. Volume guided ventilation is safer for the pediatric patients when the risk of bursting the patients lungs is removed. The volume pressure are usually measured in centimeter water (cmH₂O) One cmH₂O equals ≈ 98 Pa The volume of air delivered to the patient is called Tidal volume which is the total amount of air displaced in each breath.

“It’s mostly about software, sensors and engine capacity”
Gunnar Jogensjö Product specialist, ResMed Sweden

http://en.wikipedia.org/wiki/Medical_ventilator Received 2013-02-23
TECHNICAL PACKAGE

Exploded view of ResMed Elisée 150.

- Top shell
- Turbine shell
- Turbine foam assembly
- Turbine and heat sink
- Peep micro turbine
- Flow sensors
- Mercignac
- Rotary valve
- Pressurised air assembly
- Left corner cover and expiratory valve
- Right corner cover
- Bottom shell
- Internal battery
WAYS OF TREATMENT

There are different ways of treating respiratory patients. They are separated in invasive and noninvasive treatment. Non invasive treatment with nasal prongs and breathing mask are for shorter treatment periods and for patients that needs respiratory treatment less then 16 hours a day. Endotracheal tube where a hose is feed through the mouth down in to the airway are used mainly for short term treatment for example while performing surgery. For treatment longer than 16 hours a day tracheostomy are used instead. Tracheostomy is when a hole is opened in the throat directly in to the airways bypassing the natural airways and allows the patient to receive the treatment without having something in mouth or nose.
There are two different types of air circuit connected to respiratory treatment. They are called double and single circuits. A single circuit have only one hose coming from the respirator providing positive pressurised air. The exhaled air from the patient are ventilated either through the breathing mask or naturally via mouth or nose. In a single circuit it’s crucial that the air have a way to escape from the system to avoid bursting the patients lungs. When a tracheotomy are used the natural exhalation ways are blocked and the ventilation is done through the second hose in the double circuit system. A double circuit need’s a sealed system instead.
RELATED PRODUCTS

Respiratory treatment are a very complex and demanding treatment where there are not just a respirator involved. There are a couple of other products that are necessary to be able to handle the treatment. Which products that are needed and to what extend are up to the individual patient an their needs. These pages shows example of these kind of products. Because of limited time I will not concentrate to consider or re-design these devices in my concept but I´m aware of their necessity and their function in the treatment cycle.
RESPIRATOR ACCESSORIES

Tracheostomy tube

Nasal prongs

Breathing mask

Endotracheal tube

Pixi mask for children
MARKET RESEARCH

A selection of respirators that are currently on the market. Different specifications and target areas, life and non life support home and hospital environment as well as emergency equipment.

RESMED ELISÉE 150
Weight 4.5 kg
6-hour internal and 6-hour detachable battery
Adult and pediatric patients down to 5 kg body weight

RESMED STELLAR 150
Weight 2.1 kg
2-hour internal and 12-hour with 2 external batteries
Adult and pediatric patients down to 13 kg body weight

NOT SUITABLE FOR LIFE-SUPPORT
PHILIPS RESPIRONICS TRILOGY 100
Weight 5 kg
3-hour internal and 3-hour detachable battery
Adult and pediatric patients down to 5 kg body weight

AIROX LEGENDAIR
Weight 4.5 kg
10-hour internal battery power
Adult and pediatric patients down to 5 kg body weight
**NEWPORT HT70**
Weight 5 kg
10-hour internal battery power
Adult and pediatric patients down to 5 kg body weight

**WEINMANN VENTILOGIC LS**
Weight 6.5 kg
4-hour internal and 4-hour detachable battery
Adult and pediatric patients down to 5 kg body weight

**DRÄGER BABYLOG VN500**
Weight 16 kg (59 kg on trolley)
30 min internal battery optional 100 min external battery
Neonates and pediatric patients

**NOT SUITABLE FOR LIFE-SUPPORT**
**DRÄGER OXYLOG 2000 PLUS**
Weight 5.9 kg
4-hour internal
Non invasive emergency use only
PRODUCT ANALYSIS

A closer look at the ResMed Elisée 150 that is commonly used in Sweden for pediatric respiratory care. Cost around 55 000 sek

Main power and different connection points. O2 inlet in the back. Air filter that needs to be changed once a week. Hard to remove needs a tweezer.

The built in handle is hard to pull out. And it has very little comfort. Power cable has a locking brace to prevent unwanted power cuts.

External battery fitted underneath the product. Hard to change because of bad fasteners, need two hands. In AC mode the external battery is replaced with a power pack. The power packs internal fan is disturbing.

Double patient circuit configuration. Push fitting on the hoses. Filters inside valves to prevent dirt entering the machine. Removable expiration valve to allow for single patient circuit.

All photos: Simon Fredriksson 2013
Heavy to carry, hose management poor

Connection to the trac, more flexibility needed

Poor protection, exposed parts
HOSES AND CONNECTIONS

Research on medical and non-medical air hoses and connections. Different solutions with single and double patient circuits, Limbo hoses that contain inhaled and exhaled air channels in the same hose and different connections. Material used for medical respirator tubing are non-toxic thermoplastics like EVA, POE and PVC.

Non toxic

EVA, POE, PVC

EVA: Ethylene vinyl acetate
POE: Polyolefin elastomers
PVC: Polyvinylchloride

Spiral tubings are made of a high-quality PVC. Advantage of the spiral tubing is the smooth inner surface, for easy run-off of moisture.

Medsiz expandable pediatric limbo hose suitable from 3 kg body weight length, 66 to 183 cm

Spiral tubing with hose insulation

Oxygen hose with nasal prongs

Rotating connectors

http://www.medisize.com/products Received 2013-05-02
http://www.resmed.com Received 2013-04-18

http://www.resmed.com
Non medical hoses and connections for inspiration. Flat, rectangular, spiral, expandable, joined hoses and secure and magnetic connections.
MOVING AIR

Inspirational products on different ways and techniques of moving air which is the fundamental function of a ventilator.

- Rotating
- Pumping
- Spinning
- Pressurize
- Expanding
- Channeling
Freedom of movement for children receiving respiratory treatment

THE USER
MULTIPLE USERS

In this product I see three different users. First you have the active user the patient. In this specific case the patient will have no interaction with the technical parts of the product. On the contrary they should be denied access to these functions to protect themselves and the equipment.

The secondary user is the parents or assistant that are responsible for the home care. These users are not trained medical personnel but they get basic education and need to operate the equipment to the extent that they can perform all the necessary tasks to provide the best care possible in a home environment.

The third user are the professionals. Doctors and nurses that are responsible for setting up the machines and calibrate them for the individual patient. A common scenario is that the machines are pre programmed with one or two user setting. It can be for example night and day settings or settings for when the child is feeling better or worse. These setting should only be available for the third user group and are of no interest for the others. To make the product user friendly for both group two and three it might be an idea to look over how this is done today and see if improvements are needed/wanted.
GROWING TARGET GROUP

I’m targeting children from the age of 0 to 6 years of age. The need for mobility in these age span starting from when the child first starts to crawl and then walk until they are big enough to move around and play more freely. This big target group puts a lot of demand on the final solution. Both level of strength but foremost difference in size are a design challenge that have to be considered and meet.

Average differences for the target group

Weight between 2 - 22 kg

Height between 40 - 120 cm

http://mammasidan.se/ Received 2013-02-16
USER INTERVIEWS

Interviews were conducted with parents of children which have or had respiratory treatment in their homes. The three children all suffer from different disorders that lead to their respiratory treatment but the common denominator for the three is that they were all premature born. The information from the interviews where processed and important quotes where taken out to lead the process forward and identify problem areas.

3 families, 3 kids, one, six and seven years old
Totally 8 years in respirator combined

“The values on the screen gives you comfort, you can see that it works”
“She cried when her respirator had to go on service”
“It’s like an extension of her lungs”
Emma Jonsson 2013

“The hose is in the way all the time, he can’t even lay on his stomach”
“You learn which alarm is which by the sound of it”
Charlotte Svensson 2013

“A wagon that moves easily combined with a harness would be great”
“18 hours per day with assistance was not enough”
Arnica Bäckström 2013
USER OBSERVATION

“All the hoses and cords are the biggest problem”
Charlotte Svensson 2013

Emil 1 year old, born with underdeveloped lungs.
The respirator hose are very bulky and not adapted for use on small kids. In this case the large hose and connections as well as the position in front of Emil prevents him from turning to his stomach and get the necessary training he needs for preparing to crawl. An adapted hose solution and different position could help to solve this problem.

A home visit together with Magnus Näslund, respiratory expert and Veronica Lundberg, physiotherapist where done to observe and understand the daily routines and identify problems.

In a attempt of walking it’s very clear what problems the hose creates.

A try towards being more mobile we put the respirator on Emil’s walking chair. He managed to move around by himself like this. The respirator is still to bulky and the hose management needs to be solved in a good way.
USER OBSERVATION

All the necessary equipment for the respiratory treatment are gathered on a elevating custom made table on wheels. Its very heavy, immobile and restricts the child’s movement in the house. The non-friendly appearance gives a messy and unorganized feeling.
Suction machine used to clear flem and other obstacles from the throat and tracheotomy tube.

Saturation gauge. Measures the oxygen level in the blood in maximum 100 SPO2 and alerts when the preset level is too low. The SPO2 level determines the amount of oxygen that will be added to the treatment.

The oxygen level is controlled through the oxygen regulator.

Feeding pump for nutrition intake through a "button" on the stomach.

Alarms go off regularly, light and sound feedback.
## A DAY IN THEIR LIFE

To get a better overview and be able to understand where the problematic situations occur I have put together a flow chart over how an ordinary day in the users life can look.

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Identified problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>06:00</td>
<td>Morning assistant arrives</td>
<td>Wires from saturation gauge</td>
</tr>
<tr>
<td>06:30</td>
<td>The child wakes up</td>
<td>Trac and hoses are in the way</td>
</tr>
<tr>
<td>07:00</td>
<td>Getting out of bed</td>
<td>WIres from saturation gauge</td>
</tr>
<tr>
<td>07:10</td>
<td>Move to the blanket on living-room floor</td>
<td>Trac and hoses are in the way</td>
</tr>
<tr>
<td>07:15</td>
<td>Eating through a “button” on the stomach</td>
<td>Wires from saturation gauge</td>
</tr>
<tr>
<td>07:30</td>
<td>Playing on the floor</td>
<td>Connection between the tracheostomy tube and hose have no secure connection</td>
</tr>
<tr>
<td>10:15</td>
<td>Eating</td>
<td>Hose management, bulky connections</td>
</tr>
<tr>
<td>10:45</td>
<td>Getting ready to go to town</td>
<td>In the case of when the suction equipment needs to be used the hose needs to come of easily</td>
</tr>
<tr>
<td>12:45</td>
<td>Arriving at destination</td>
<td>Hose management, bulky connections</td>
</tr>
<tr>
<td>13:15</td>
<td>Eating</td>
<td>How to cope with cold temperatures.</td>
</tr>
</tbody>
</table>

Wears bodys that can be unbuttoned and are easy to keep open around the neck. Ordinary T-shirts and sweaters need a wide cut in the neck to fit with the tracheostomy.

Disconnect saturation gauge that are taped to the foot then lower the cart table with all the equipment.

Reading books, playing with soft animals etc. The hoses are constantly in the way in front of the child. The hose keeps coming loose from the trac regularly.

Liquid nutrition are prepared in a syringe. Need to lift shirt or open body to access the “button” Sitting or laying on back when feeding. Irritation in the throat and vomits. Then the hose needs to be removed and the suction machine is used to clear away everything unwanted then the hose are put back in place.

All the necessary equipment has to be loaded in the car. Backup respirator, suction machine, emergency bag, oxygen bottle, primary respirator, baby stroller and nursing bag. A two man job that can take up to an hour. How to secure the respirator and the oxygen bottle in the car are a problem.

Take a decision on how much of the equipment you need to bring with you. How far are you going to be from the car. The outdoor respirator are used with different hoses. A home made hose cover made from fleece are used to block out some of the cold in winter time. -15 degrees Celsius are set as a lowest temperature for going outside, a decision taken by the user. Most respirators are only approved for temperatures down to 0 degrees.

Laying on the back or sitting up, not possible to lay on stomach because of hoses. The hose comes loose from the tracheostomy pipe. Tha alarm sounds, low pressure.

Disconnect saturation gauge that are taped to the foot then lower the cart table with all the equipment.

Wears bodys that can be unbuttoned and are easy to keep open around the neck. Ordinary T-shirts and sweaters need a wide cut in the neck to fit with the tracheostomy.

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Activities

14:00 Morning assistant shift ends
   Checking off the status and how the night has been

14:00 Mid day sleep
   Sleeping are constrained to sleep on the back because of the hoses.

16:15 Eating

16:40 Bathing
   Avoid getting water in to the system. It’s supposed to be a close circuit but the risks are there. Also the obvious problem with electrical appliances and water.

17:30 Playing
   In a play scenario a caretaker have to be present at all times. Both for assisting when the hose comes loose from the trac as well as helping out with the hoses and be ready to clear flem from the throat.

18:00 Turning around
   As a part of a babies development turning round from laying on their back to their stomach are the first step against starting to crawl. The current hose placement makes it impossible for the child to turn around.

19:00 Bed time
   Attaching the saturation gauge to monitor the child’s oxygen level while sleeping.

19:15 Personal time
   Its a full time job to be with and care for the child. The child needs constant attention and support. So getting some personal time and a chance to relax are important.

22:00 Night shift arrives
   Update from the days activities.

22:00-06:30 Check ups
   Constant checkups during the night. The saturation gauge are checked as well as making sure that the hose stays in place. Remote video device are used so the assistant can monitor at a distance on bathroom visits etc.

Identified problems

Hoses are in the way.

The system should be a closed circuit if water for some reason gets in to the hoses it might damage the respirator and cause problems for the child. Electricity and water.

Being able to disconnect the hoses from the trac easily are important as well as it would be good if the connection could be more secure.

Hoses and trac connections are in the way.

Saturation gauge adds more connections.

Remote monitoring of alarms would give security and comfort for the caretaker.
Personalizing products is a growing trend. Being able to choose colors and patterns to have that unique product is offered by more and more companies. Like Nike’s ID program or the personalizing cases and vinyl that is offered by American Skinit.

Skinit and ResMed, a large respiratory equipment manufacturer are already today collaborating with the ResMed Stellar and let you choose between ready made designs or the choice of upload your personal images for a cost of around 40 EUR per set. This relatively low cost make it affordable and makes it possible to change design and expression of your product when its needed. The respirator can grow with the user and its interest.

A positive side effect with the decoration is that the automobile grade vinyl is also offering a protection of the respirator’s surface.

http://www.skinit.com Received 2013-02-06   http://www.nike.com Received 2013-02-06
THE PROBLEMS
PROBLEM AREAS

Alarms, how to solve?
Different alarms are frequently sounding
Can that be avoided, rethink the alarm sounds
Hierarchy in the importance of the sounds
Remote alarms to a handheld device (iPhone etc.)

Placement
Placement in different directions, make it less table top and more mobile as well as implement possibilities for wall mounting.

Mobility and weight
The lack of mobility and the weight of the respirator are the biggest problems to reach freedom of movement for the kids.

Interface and screen
Simplify GUI
Professional and none professional interface
Variable viewing position on the screen

Handling
Improved handle.

Battery
Improve battery time.
Multiple batteries with external charger.
Same type of battery in other machines as well.

Maintenance filter and turbines
The air filter needs to be changed once a mount
Turbines last 15 000 hours (approximately 2 years non stop use)
Rethink how and where the hose should go.

To long, not adapted for a user with a small chin.

Prevent the hose from coming loose all the time, locking

The hose are coming loose very often. A fail proof locking is needed.

Hose connector

Rethink how and where the hose should go.

Hose management

Crucial, one of the biggest issues today. Introduce strain relief.

Nipple

Remove or reposition. Keep the connection as clean and small as possible.

Hoses

Diameter, flexibility material, heating.
CONCLUSION

Respiratory treatment are a very complex and demanding task. There are multi pel devices involved and many different tasks to consider and it’s a life changing event for the families that are affected. It’s a full time task which demands constant attention day and night. After compiling and analyzing the research I decided for a couple of areas that are worth focusing on for the creative phase. These areas are the ones that are most important to fulfill my goals and wishes as well as for creating a good solution to the problems identified.

Mobility  Hose management  Hose connections  Clear interface  Remote alarm function  Personalization

Making the respirator mobile is one of the key problems and the main focus. It can be done in a number of different ways putting it on wheels, carrying it on the back or maybe create a wearable solution like a belt or a garment. New technology, flexible materials and power sources could make it possible.

Hose management are identified as one of the biggest problems with the whole treatment. They are constantly in the way and need to be organized in a good way. Material, flexibility and strain relief will also be considered.

Hose connections needs to be improved. Especially the connection between the tracheostomy tube and the air hose problem occurs. It comes loose very often. It can be to secure though when the air hose are removed frequently to use the suction machine. It also have to be a fail proof lock connection in case of emergency and the hose needs to be removed.

A respirator have multiple options to sound alarms in different situations. The triggers and alarm levels can be set in the interface. Alarms sound frequently during the days, alarms with different importance. Creating a wireless link to display the alarms remotely to a tablet, phone or similar could make the control easier and maybe even combined with a video function for extra security.

A simplified user interface that only displays the necessary information in a clear an graphical way for the everyday user. The parents and the assistant. Advanced settings can only be seen and used by the professionals doctors, nurses who are in charge of setting up the machine.

Personalization might not be the most critical thing in the concept. But considering what these machines mean for the user and the personal affection to the machine that can occur a possibility to make it personal feels important. It can easily be solved with adhesive vinyl that can be personalized.
RESEARCH SUMMARY
IDEATION
EARLY IDEATION

Spontaneous ideas for functions, usage and technical solutions. Small details that are interesting to bring further in the project.
BRAINSTORMING SESSION

A creative session with designers where done to generate new ideas. An introduction to the topic where given and then three topics where treated with following discussion.

Topics:
• Mobility
• Hose management
• Flexible hose connection
BRAINSTORMING SESSION
Rotating connection, front and back use

Hose in the back

“Wastegate” go to single hose

Integrited hose in fabric collar

Flexible hose connection in machine
IDEATION ON PROBLEM AREAS

Spontaneous ideas for functions, usage and technical solutions on the six different areas taken from the research conclusion.

MOBILITY

HOSE MANAGEMENT

HOSE CONNECTIONS
CLEAR INTERFACE

REMOTE ALARM

PERSONALIZATION
CONCEPTS
CONCEPTS

Three concepts where developed and later tested with mock-ups for evaluation on which direction that would fulfill the goals and wishes best.

CONCEPT WHEELS

- Reduce weight
- Hose management
- Hoses to the back
- The vest takes the load
- Indoor and outdoor wheels
- Easy to convert to stationary
- Easy to size adjust
- Fits all sizes of kids

- The vest can be in the way
- Tangle with the tow line
- Respirator gets stuck in obstacles
- How to target older kids (alternative to dragging behind)
CONCEPT BACKPACK

- Flexible
- Short hoses
- No drag line
- Detachable straps, easy to make table top
- The straps can be on a bag instead
- Distributes weight

- Heavy for the smallest
- Risk of damage when falling
- Hard to sit with backrest
- Hard to lay down on back
- Hard to see display

CONCEPT TUBE

- Reduced weight
- Hose management
- Easy to move around
- Good maneuverability
- Fits all ages
- Stable at rest
- Innovative

- The vest
- Risk for tipping over
- No setup display on respirator
MOCK-UPS
Concept wheels are based on the size of ResMed Stellar. A harness and a tow-line is used pull the cart. The weight of the mock-up where 3.5 kg which is well above the targeted weight for my concept. The test was successful and above anticipation. A quick re-design of the hose splitter was also tried out with initial good result.

Due to the medical condition of my intended user I haven't been able to do my mock-up testing on these children. The children I have been using for testing are healthy and most likely physically stronger then the sick ones. I’m fully aware of this and have tried to keep the size and weight as low as possible to increase the chances of it to work on as many users as possible.

*Signe: 9 months old*
Re-designed splitter puts the hoses on the back instead.

The position of the tow-line attachment should be as close to the waist as possible. This simplifies dragging the cart when walking upright.

The tow-line takes away the stress from the hose.

A harness with hose management avoids pulling in the track.
The backpack concept would give great flexibility and freedom for the user, short hoses prevents tangling up in something. The size and weight of the mock-up are close to the smallest available respirator today. The tests revealed that the weight was too great to handle for a small user. A body worn solution might work fine for an older user but excludes the small ones. To make it work for the whole user group the size and weight would have to be reduced significantly which is hard with the internal components.
The weight makes it hard to stand without support. Standing on all four works but takes some effort. The test had to be cancelled pretty fast when it became obvious that the weight was too much for such a small child.
Concept Tube is the most innovative and conceptual of the three. Instead of adding wheels to a respirator it becomes the wheels. The two wheel configuration with a floating center makes it very agile and responsive. Once again a harness is used to attach the tow line and offer possibilities for hose management. The center is weight stabilized so the hose and tow connection will stay in the correct position. The concept also removes the touch screen and interacts with the user with sound and light instead. A updated connection to the trac was also tested.
An updated connection to the trac makes it easy to shift from back to front position of the hoses.

Stable on the side, rotate 360 degrees around center

Strain relief for the hoses on the shoulders

Outdoor test
Testing the concept with children in different sizes and ages are crucial to be able to make a final concept that will work for a broad target group.
Length of tow line needs to be adjusted according to the users height.

Adjustability in the harness or fixed sizes are needed to accommodate different body sizes.

A single hose known as a Limbo hose where tested. This was a hose meant for adults and a little bit to stiff to make it work good. A thinner Limbo hose would be possible and also more suitable for a child.

Caught on a corner are one of the most obvious problems with the concept that need attention to be solved.

Elias: 3 years old
VISIT RESMED

A visit at ResMed’s office in Stockholm where made to show and discuss concepts with respirator professionals. Medicine technician Gunnar Jogensjö answered my questions and explained about functions and possibilities with the respirators and hoses.

Important things to consider when making a respirator:

• Separate air inlet and outlet to avoid bad air circulating back
• Need to have a connection for oxygen
• External power supply, special classification for medical devices
• Possibility for running on 12V
• Position of on/off switch to avoid unintentially turning off
• Air inlet should not be easily blocked
• Air filter easily changed
• Air inlet should handle a maximum flow of 150 L/min
• In pediatric treatment exhaled air must be abled to be measured
• Minimum hose diameter for a child patient is 11mm, smooth inside of the hose minimize turbulence
• A variable hose lenght makes it hard to do hose calibration
• To comply with certain ISO certification for medical devices detailed information of the respirators function such as pressure, volume, alarms and battery indication needs to be available.
• Soundproofing of the turbine is important
Technical service manager Melissa Arana Escobedo and product specialist Gunnar Jogensjö are inspecting one of the concepts.

Technical parts, respirator turbines to use as references. But the future of delivering air in respirators might not be with turbines.

Slimline hose with insulating wrap. The fabric wrap gives a nice feel against the skin and a less medical look.

Split “Limbo” hose with inhale and exhale air in the same hose. Adapted for children it might be interesting for a future concept.
To be able to reduce size, weight and energy consumption in the respirator a change of technology for producing the air flow could be the answer. The turbine in todays respirators are with the battery the biggest components and also the component that uses the most amount of energy.

A demand for a respirator today is that it needs to be able to deliver 150 L/min of air. And it also needs to be able to alternate fast between high and low airflow as well as be able to compensate for sudden pressure drops.

Piezo electric pumps are light contains very few parts and are near to soundless for the human ear. Piezoelectric technology are also very energy efficient which means that together with future battery development battery size could be significantly smaller and lighter then in todays respirators and still keep the same or better battery life.

The idea with a array of pumps makes it possible to reach the demand of change in airflow. A number of the pumps are used to generate the continuous positive air pressure (CPAP) while the remaining pumps activates when triggered by the sensors to generate the breathing pressure. The possibilities to control the flow on or off individually for the pumps would give a quick response and good preconditions to control flow. The idea is also to build in some over capacity in each pump so in the event of some would malfunction there are backup capacity until the respirator can be serviced or exchanged. This gives a sense of security for the user that’s not there in todays products.
FUNCTION

Energy efficient • Low noise • Size • Built in security • Low complexity

Volume calculations are based on a pump chamber of 2cm³ which equals 2 ml. Hertz (Hz) is the duration of one cycle in a repeating event. Example 50 Hz is 50 cycles per second.

Volume needed: 150L/min = 150 000 ml/min
Number of pumps in the concept: 10
10 pumps = 2 ml x 10 = 20 ml of air / cycle

\[
\frac{150 000 \text{ ml}}{10} = 15 000 \text{ ml/min for each pump} \\
\frac{15 000}{60} = 250 \text{ ml/sec} \\
\frac{250 \text{ ml}}{2 \text{ ml}} = 125 \text{ ml/sec} = 125 \text{ Hz}
\]
NEW TECHNOLOGY, NEW POSSIBILITIES

With the new technology in the Piezoelectric micro pumps new opportunities opens up and a second round on a body worn concept where created. Also the decision to take away the display and move all the graphical information to an external device made it possible to reduce both size and weight significantly. Left on the respirator are the key functions confined to only a few buttons and light and sound interaction. Future battery technology can supply increased battery life in a smaller and lighter battery as well as much faster charging times which benefits a body worn concept.
Standing up with the mock-up on her back posed no problems, hose thickness, connections and management needs to be solved in a good way.

An updated smaller backpack version with the new piezo technology, and no screen where tested again on my smallest user Signe to make sure that it would be possible for her to handle in both size and weight.

Mock-up 4
Size 150 x 90 x 30 mm
Weight 0.4 kg
CONCEPT EVALUATION

The concept with highest scores will be concept which will be taken further on in the process. The point scale is from 1-5 and different features multiplies with different value depending on relevance.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
<th>Wheels</th>
<th>Backpack</th>
<th>Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>x 5</td>
<td>2 10</td>
<td>5 25</td>
<td>3 15</td>
</tr>
<tr>
<td>Fitting target group</td>
<td>x 4</td>
<td>4 16</td>
<td>4 16</td>
<td>3 12</td>
</tr>
<tr>
<td>Innovation</td>
<td>x 4</td>
<td>2 8</td>
<td>4 16</td>
<td>4 16</td>
</tr>
<tr>
<td>Stationary use</td>
<td>x3</td>
<td>3 9</td>
<td>4 16</td>
<td>4 12</td>
</tr>
<tr>
<td>Flexibility</td>
<td>x 3</td>
<td>3 9</td>
<td>4 12</td>
<td>4 12</td>
</tr>
<tr>
<td>Hose management</td>
<td>x 3</td>
<td>3 9</td>
<td>2 6</td>
<td>3 9</td>
</tr>
<tr>
<td>Communicative interface</td>
<td>x 2</td>
<td>2 4</td>
<td>2 4</td>
<td>3 6</td>
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<tr>
<td>Personalization</td>
<td>x 1</td>
<td>3 3</td>
<td>3 3</td>
<td>3 3</td>
</tr>
<tr>
<td>Integration with other products</td>
<td>x 1</td>
<td>3 3</td>
<td>3 3</td>
<td>3 3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>71</td>
<td>101</td>
<td>88</td>
</tr>
</tbody>
</table>
Concept Backpack scored the highest points in the evaluation and will be the concept taken to further development.
CONCEPT DIRECTION
TECHNICAL RESEARCH

Research on technical aspects of the concept such as battery weight and capacity and piezopump functionality.

**Battery weight:** A general Li-Ion battery weighs approximately 2 grams/cm$^3$ and 250 wH per kg battery, 1000 charging cycles.

**Lithium sulfur battery (Li-S):** Max capacity 600 wH per kg battery, 1400 charging cycles.

**Piezopump function:** A micro diaphragm pump comprises a valve unit and the pump diaphragm, which, together with the piezoelectric actuator, forms the pump drive. Operation is based on the deformation of a piezo element (disk, plate, etc.) connected to the diaphragm. Applying a voltage deforms the diaphragm (bending effect).

The bending of the diaphragm (metal or silicon) brings about a change in volume of the pump chamber and the medium is transported under the control of the inlet and outlet valves.

The fields of application for piezoelectric pumps are in medical engineering, biotechnology, chemical analysis and process engineering, where reliable dosing of minute amounts of liquids and gases is frequently required.

**Material for product housing:** Flame retardant engineering thermoplastic (ABS)

**Witricity:** Wireless electricity via magnetic fields. Could make batteries very small just as a backup in a home environment.
SIZE EVALUATION

To create a concept that will fit the growing target group measurements where taken on the smallest users in the group. The size where taken from a 10 month old baby who just started to walk. In consideration should be that many respiratory disease children are premature born and might be smaller in size then the average healthy child. A good proportion between width and length should be found that fits the user best.
Multiple size mock-ups to find a good proportion. Even small size variations can make a difference.

How big is a small child's back?

How little can it weigh? A quick test to estimate and validate the weight of the concept.

Hands on with physical mock-ups is the best way for me to evaluate sizes.
Moodboard

- Simplicity
- Color accents
- Clean surfaces
- Soft touch materials
Freedom of movement for children receiving respiratory treatment

Master thesis 2013

Simon Fredriksson

Umeå Institute of Design

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From hand made models, form sketching, milled test models and continuously testing with users lead the form exploration forward to find a satisfying result. Multiple test models were made to be able to evaluate the progress in real life then just on a screen which created a very hands on process.

CNC milled test models to evaluate different shapes and sizes
Constant user testing through the whole process

Evaluating surfaces

Mock-up process
FORM WORK

Refinement in CAD and going in to depth with the small details, even a slight change on a radius or a curve can make a big difference on such a small object. A process constantly shifting back and forth between computer models and testing and evaluation in physical models.
- Both stationary and mobile
- The small details
To be able to offer good mobility the children need to be able to transport the respirator with them. A backpack solution came to be the most suitable solution for this purpose. A design that is easy to take on and off with its velcro secured shoulder straps which at the same time offers good adjustability and protection for the respirator inside. Going for a single hose patient circuit with a passive expiration valve made it possible to create hose management on one of the shoulder straps to guide and prevent from getting stuck with the hose in obstacles.
MODELMAKING

Refinement in CAD and going in to depth with the small details, even a slight change on a radius or a curve can make a big difference on such a small object.
**CMF**

In terms of color material and finish I wanted to create a product that felt not pour medical. Instead something that was in between medical and consumer and add a little bit of bright colors to appeal to a younger user group. The over all impression should be a product that feels serious and you can trust without looking scary or to technical.

- Matte vs Glossy
- Three shades of color
- Mix of medical and consumer
- Trustworthy
ventum

How the future in mobile pediatric respiratory treatment could be
Freedom of movement for children receiving respiratory treatment

Master thesis 2013
Simon Fredriksson
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VIEWS

Weight 400 gram
Double moulded with soft touch material

Injection molded shell of engineering thermoplastics

Collector tank for air and O₂

Piezopump array of 10 pumps, max flow 150l/min

Patient circuit with a retractable hose

Air inlet collector

Magnesium alloy frame

Air inlet

Battery with 12 hour battery life

Induction charging

O₂ connection

Speaker holes
FUNCTIONS

Battery status glowing through a micro perforated surface

Speaker holes

Alarm reset button. In case of no alarm, press and hold for battery check. A white glowing light indicates function.

Automatic child lock, press and hold to unlock.

Mode buttons, day/night setting

Air intake

O₂ inlet
Ventum is induction charged and just placed on the slim charging plate. The charging light is indicating when full charge is reached.

In case of alarm the indication light turns red and an audio warning will sound.

Day/night mode setting. A white glowing light indicates the current mode. The two different modes are programmed by a professional and can’t be changed by the user.
One of the biggest challenges in this project was how to design a product that would work in both stationary and mobile use. Find a good compromise because in the end that’s what needs to be done. I was looking for an expression that felt mobile, a product that is pickable. Something that you just can pick up and be on the go. How the product lift its edge up inviting you to get a good grip. The ticker rounded back with its shape from the round hose in the patient circuit which becomes a natural extension of the product. At the same time when the oxygen hose is connected at the opposite side of the patient circuit connection the respirator becomes the natural connection between the oxygen and air to the patient. The almost book like form factor makes it comfortable to carry in your hand for an older user that don’t need a special carrying solution while the protruding surfaces on the bottom side of the soft touch center provides a good grip.
The concept features a smart hose connection where the patient's personal settings are stored like airflow, pressure and breathing frequency. The benefit of this is that the patient can connect to any machine and instantly start using it with the correct settings. It magnetically snaps which allows for free rotation as well as security of detaching in case of the patient getting stuck in something with the hose. Connecting the hose also starts the respirator and therefore acts like the on/off switch.

A retractable hose is used to facilitate for use on and off the user's body. In a stationary use a longer hose is needed to allow more freedom and also make it easier to put the backpack on and off.
REMOTE ALARM AND MONITORING

In the Ventum concept the main unit is without any screen for graphical feedback this is only communicated through light and sound. The vital data is instead transferred remotely to an external unit such as a standard tablet. Via an app the respirator can be monitored and setup. This is where the non professional user can get values and data that are relevant in a clear way as well as see and respond to the different alarms that can occur. The more basic alarms can be cancelled through the application whilst the more serious alarms demands a cancellation on the respirator to avoid mistakes. A chat function connected to medical personnel can offer quick answers to any questions or worries the user might have. There will also be a connection to the doctor in charge for sending over values and data that are necessary for the medical team to keep track of.
Six glowing dots indicate that induction charging is complete.

Alarm reset through the backpack
Freedom of movement for children receiving respiratory treatment
The backpack is padded for extra protection of the respirator.

A good fit of the backpack and hose management provides good manoeuvrability and provides the freedom that the user deserve.
FINAL MODEL
REFLECTION

For almost six months this project have been the main focus of my everyday life. I have had a vision for how this would be and this being the culmination on my academic carrier I feel almost a void. It’s not until I start to reflect and actually look back on where all this started and what have happened during this journey. Its been high and lows, many late nights and weekends but in the end it’s without a doubt the most worked through project I ever have done and in the end I have a result that I feel content with.

It has been a challenging project with a topic that has a great deal of complexity. With multiple users, mobile and stationary use and a target group that can be tricky to work with because of their young age and lack of ability to give proper feedback. And because of the seriousness in the users medical conditions I haven't been able to do my testing on the actual users. But I have still had the chance to do a lot of physical testing and work with models and mock-ups in a greater extent then in any previous project. Working hands on is something I have been doing throughout my whole design carrier and this is really how I like to work and also should work in the future.

I didn’t reach all my goals on what I hoped to achieve in this project but I see that as a good thing. Because when you reach the stage where you feel “done” and that within the time frame that you are given. Then I think you didn’t set your goals high enough. In design you can always do more but to be a successful designer you must be able to fulfill the most important thing in every project and that is to deliver, and deliver on time. I personally put a great deal of pride in being able to actually do just that. Deliver on time and be able to know when there is enough to be able to make it. It’s not always easy and many times takes some hard work but it’s something that I feel that I have been able to do in this project.
APPENDIX
### TIME PLAN

<table>
<thead>
<tr>
<th>WEEK 4 JAN 21 - 25</th>
<th>WEEK 5 JAN 28 - FEB 1</th>
<th>WEEK 6 FEB 4 - 8</th>
<th>WEEK 7 FEB 11 - 15</th>
<th>WEEK 8 FEB 18 - 22</th>
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<tr>
<td>Project kick-off</td>
<td>Technical research</td>
<td>Meeting with the</td>
<td>Preparing research</td>
<td>Hand in brief Monday</td>
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<td>Research</td>
<td>Existing solutions</td>
<td>respiratory team</td>
<td>presentation</td>
<td>Research presentation</td>
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<td>Requirements</td>
<td>User interviews</td>
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<td>Anders Smith Monday</td>
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<td>Limitations</td>
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<td>Individual feedback</td>
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<td>Anders Smith</td>
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<td>Wednesday</td>
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<td>User visit in Åsele</td>
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<tr>
<td>WEEK 14 APR 1 - 5</td>
<td>WEEK 15 APR 8 - 12</td>
<td>WEEK 16 APR 15 -19</td>
<td>WEEK 17 APR 22 - 26</td>
<td>WEEK 18 APR 29 - MAY 3</td>
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<tr>
<td>Concept refinement</td>
<td>5 weeks left</td>
<td>CAD work ,</td>
<td>Milling and rapid</td>
<td>Deadline report on 3rd</td>
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<tr>
<td>CAD</td>
<td>presentation</td>
<td>prepare for</td>
<td>prototyping</td>
<td>the 3rd</td>
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<td>model</td>
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<td>Anders Smith</td>
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<td>Set the final</td>
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<td>form</td>
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<thead>
<tr>
<th>WEEK 9</th>
<th>FEB 25 - MAR 1</th>
<th>WEEK 10</th>
<th>MAR 4 - 8</th>
<th>WEEK 11</th>
<th>MAR 11 - 15</th>
<th>WEEK 12</th>
<th>MAR 18 - 22</th>
<th>WEEK 13</th>
<th>MAR 25 - 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstorming at the hospital, Wednesday 14:00</td>
<td>Monday Feedback session Anders Smith and Thomas Degn</td>
<td>Mid presentation Anders Smith in Umeå</td>
<td>Concept refinement Mock-ups User testing if possible</td>
<td>Choose direction</td>
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<td>Ideation</td>
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<tr>
<th>WEEK 19</th>
<th>MAY 6 - 10</th>
<th>WEEK 20</th>
<th>MAY 13 - 17</th>
<th>WEEK 21</th>
<th>MAY 20 - 24</th>
<th>WEEK 22</th>
<th>MAY 27 - 31</th>
<th>WEEK 23</th>
<th>JUN 3 - 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making presentation Renderings Video?</td>
<td>Presentation week, final presentations on Thursday and Friday.</td>
<td>Model photo Web exhibition etc.</td>
<td>Rehearsal for the talks UID design talks</td>
<td>Degree party!</td>
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<tr>
<td>Preparation</td>
<td>Presentation</td>
<td>Preparation</td>
<td>Final</td>
<td>Final</td>
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</table>
### DETAILED SCHEDULE SIX WEEKS LEFT

#### WEEK 14 APR 1 - 5

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<tbody>
<tr>
<td>Fix the concept, mockups</td>
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<tr>
<td>Test the mockup</td>
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<tr>
<td>Contact Magnus</td>
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<td>E-Mail Piezo expert</td>
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<td>Milling of concept directions Friday</td>
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#### WEEK 15 APR 8 - 12

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<tbody>
<tr>
<td>5 weeks left presentation on Monday 9:15</td>
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<tr>
<td>Choose directions Set the final form</td>
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<tr>
<td>Detailing</td>
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<tr>
<td>Hose connection</td>
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<tr>
<td>Rapid prototype variants and evaluate</td>
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<tr>
<td>Charging</td>
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<tr>
<td>Humidifier</td>
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<tr>
<td>Backpack</td>
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<tr>
<td>Get backpack done and find a seamstress until Friday</td>
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#### WEEK 16 APR 15 - 19

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<tbody>
<tr>
<td>CAD work, prepare for model</td>
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<tr>
<td>Parts needed, do I have to order stuff?</td>
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<tr>
<td>Rapid prototype as far as its possible</td>
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**Important part to remember**

**Harness / backpack**
easy to take on and off, detachable straps, neoprene case with zipper, water resistant breathable fabrics in the back part, easy to take out of the case. Indoor and outdoor configuration, two respirators two different setups. Good or bad? Contact a seamstress and fix fabric and rapid prototyped details for harness. Milling the kid where do I find a polygon model?

**Hoses**
Limbo hose allows one hose system, adjustable length quick release and strain relief at shoulder
### WEEK 17 APR 22 - 26

- Rapid prototyping beginning of week, assembly and prepare for filming. Filming one day and start cutting. First aid kit for the music?
- Work on report

### WEEK 18 APR 29 - MAY 3

- Edit movie and report work
  - **Deadline report on the 3rd**
- Make presentation
- Renderings
- Buffer time

### WEEK 19 MAY 6 - 10

- Finalize movie
- Making presentation
- Renderings
- Buffer time

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**Respirator**

Silent so no natural feedback, light feedback, warning sounds, remote information on a screen (iPad etc) Easy to change battery and filters. Service piezo pumps. Piezo pump array with built in over capacity, remote SPO2 gauge, separate air inlet and outlet, secure in car on stroller or wheelchair. Remote setup for the experts. Docking to humidifier and power at night and stationary use. 360° hose connection on humidifier. Induction charging, possible with safety demands? Strength of shell how to make it durable.
REFERENCES

Magnus Näslund  Nurse at the Neonatal intensive care unit (NICU) at Norrlands University hospital, Magnus.naslund@vll.se
Gunnar Jogensjö  Product specialist at ResMed Sweden, Gunnar.jogensjo@resmed.se
Emma Jonsson  mother to Johanna 7, former respirator patient, phone interview 2013-02-05
Arnica Bäckström  mother to Dean 6, former respirator patient, personal interview 2013-02-05
http://www.skinit.com Received 2013-02-06
http://www.nike.com Received 2013-02-06
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http://mammasidan.se/ Received 2013-02-16
Charlotte Svensson mother to Emil 1, respirator patient, personal interview 2013-02-20
http://en.wikipedia.org/wiki/Medical_ventilator Received 2013-02-23
http://www.piceramic.com/piezo_applications_more.php?appid=5 Received 2013-03-16
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http://www.witrivity.com/ Received 2013-04-18
www.lakemedelsverket.se Received 2013-04-28
http://www.medisize.com/products Received 2013-05-02