DP2 Soft things, Industrial Design, TU/e

HeadFirst

Foldable headprotection integrated in a jacket

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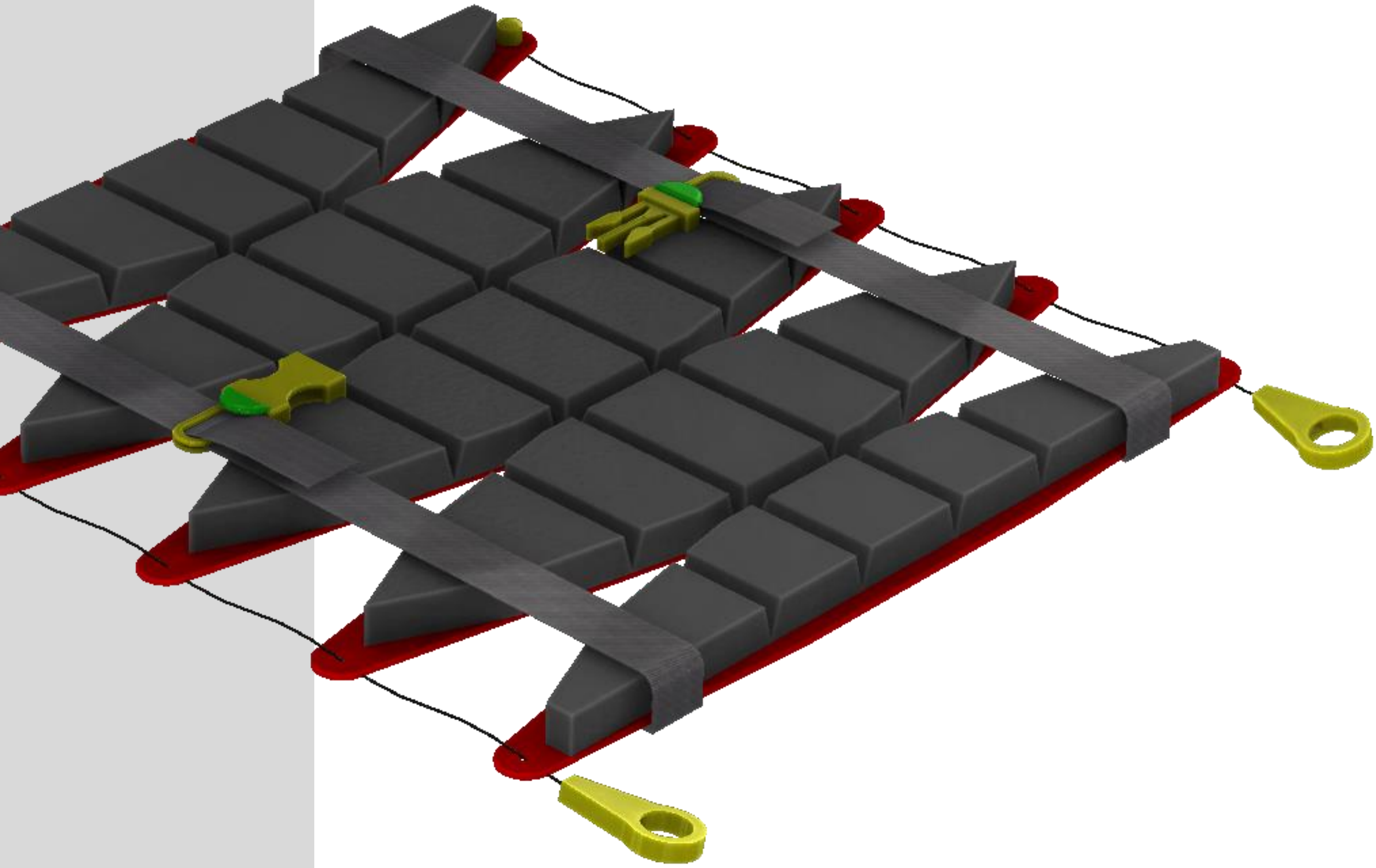

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2 IDEATION

2.1 IDEA

Nowadays, helmets are not always worn. People may not like the look of wearing a helmet or they do not like having to deal with carrying them around when not using it. The idea is to put a helmet in a jacket. The jacket needs to be comfortable when the helmet is worn as well as when the helmet is put inside of it. The jacket needs to provide protection against cold and small harm. There can be looked at different users as small children, skaters and elderly.

2.2 USERS

2.2.1 Questionnaire 1

(Questionnaire can be found in the appendix 7.1.1)
Children seem to really trust themselves, they are assured that they won't fall when playing. That is also why they do not wear any protection while cycling. They do not think other children that do wear a helmet, because they have to cycle a long way or because of epilepsy, are strange looking. For them that is okay, this shows that wearing a helmet can be accepted.
Parents seem to need a wakeup call, they tell that other children are not wearing any protection so they don't give their own children any. Also the carrying of your child's helmet when reaching destination is a thing that is disappointing about a helmet. When they are asked about the idea of a helmet within a jacket, they all think it is a good idea and would use it.

2.2.2 Personas

 *Figure 1*	Isa is 10 years old. Her hobbies are drawing, hockey and playing with friends. She is in group 6. She has an older brother that is in group 7 of the same school. Together they go to school by bike every morning. She don't like to wear a helmet. She thinks it doesn't look cool and she trusts herself that she won't fall.

 *Figure 2*	Monique is 44 and the mother of 3 children (6, 8, 10). She works 3 days a week. Her children do not wear protection when they are cycling. This is because she hates carrying the helmet around and she thinks her children will forget them at school.

2.2.3 Stakeholders

Children: User
Parents: Buyer, makes decision to buy
In the case of the helmet jacket it will be unlikely that the children are going to ask the parents for this product. In the interviews it shows that children are willing to wear it but they still rather not. It are the parents that need to be convinced of the product. That is why it is important to also look at the wishes of the parents. The most important requirement for the parents is safety and that the helmet is integrated so that they don't have to walk around with the helmet.

2.3 Research

2.3.1 Bike accidents children

Consument en Veiligheid is a Dutch organisation that combines research to accidents, injuries, victims, behaviour and experience of the target group with development and implementation of prevention campaigns[1]. Drs. Buuron is the coordinator of children and youth at this organization. She names that 4, 5, 12, 13 and 14 year olds are often involved in bike accidents. The youngest are learning how to ride a bike, the older children often user their bikes more regular. The youngest children are easiest to focus on when looking at stimulating to wear a helmet. Most accidents are one sided falls. For this kind of accidents a helmet could be very useful to prevent injuries. Prof. Dr. Goslings, head of medical TraumaNet AMC, states that every year there are approximately 26.000 children and youth that are being treated by the emergency department after a bike accident. A helmet is an effective, simple and cheap tool. Also Drs. Bakker, a rehabilitation physician is an advocate for bike helmets. Children are still developing, little brain injury can have big consequences.

If children wear a helmet during a bicycle-accident, the risk of head injury is reduced by 63% and the risk of loss of consciousness by 86%.[2]

2.3.2 Design helmets

Most helmets consist of two layers, an hard outer layer and a foam inner layer. The outer layer is meant to spread the energy of the impact to a broader area, also the outer layer is there to keep the foam in place and to prevent neck injuries. The friction between a helmet and the ground is smaller than the friction between a head and the ground. Without wearing a helmet the friction might cause the neck to get jerked, the helmet prevents this by letting the head skip across the street. The inner layer should be able to absorb impacts and limit the linear acceleration [3] [4]. The material should be able to crack, chip or compress. The material has to absorb the energy of the impact, this will result in damage on the helmet but reduces damage on the head. When a material goes back to the original shape the energy passes inward to the head.[5]

The shape change of the foam is also the reason why after a fall the helmet is not safe to use anymore. At the place of impact the material is deformed resulting in a weakness.

The kinetic energy is converted intomechanical energy that breaks the helmet. The foam increases the stopping time of the head. This increase will reduce the deceleration of the head. The formula $a = \Delta v / t$ shows this relation. With Newton's second law, $F = ma$, it is visible that when the deceleration is reduced also the force will be reduced.

2.3.3 Regulation

European manufacturers have to meet the standards of EN 1078 in order to meet the essential safety requirements of the European Personal Protective Equipment Directive.[6] [7]EN 1078 specifies requirements and tests methods for bicycle helmets. Besides that, it covers helmet construction.

Before testing, the helmet needs to subject to pre-treatment, ranging from being put in different temperatures from -20 ^{o}C to 50 ^{o}C to artificial aging by strong lights, simulating weeks of sunlight[8].

The impact must be tested by fall tests, on a flat anvil with an impact at 6,3 m/s, a kerbstone and a hemisphere, both with an impact at 5 m/s. The resultant deceleration must not exceed 250g.[9]

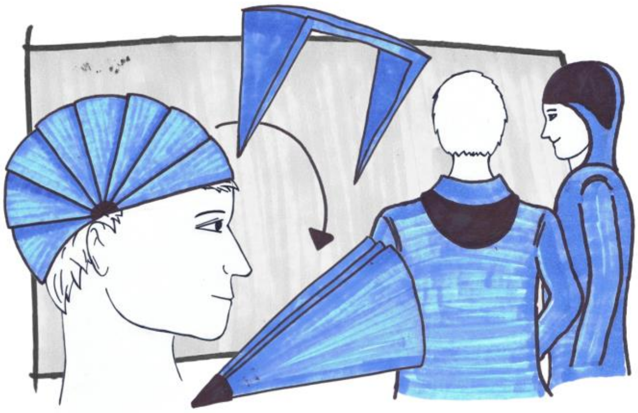
Also a Roll-Off test needs to be done. The helmet is positioned face-downward and a weight is attached to the rear edge of the helmet. After that, the helmet is positioned face-forward and again a weight is attached, this time to the front edge. In both cases the helmet may be shifted, but should not roll of the head.[10]

For children helmets there is an extra regulation, EN 1080[11]. This regulation states that the retention system must be able to self-release under a force between 90 and 160 Newton[12]. This rule was made after deaths of children caused by strangulation when wearing a helmet, this could occur when a playing child gets trapped. The chin strap must be more than 15 mm wide and should be able to be adjusted for good fit. Some or all visible parts of the retention system should be green.

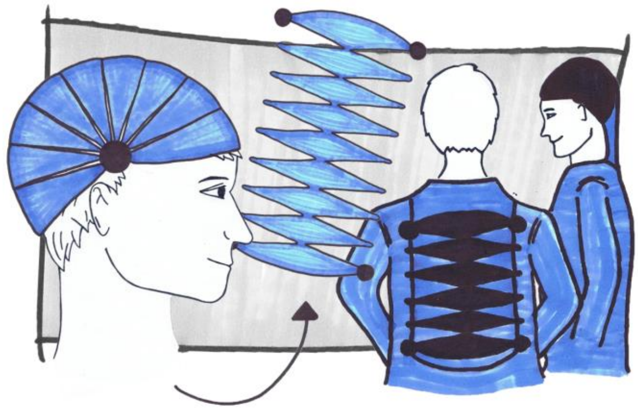
3 CONCEPTUALIZATION

3.1 DESIGN HELMET

3.1.1 Shape helmet



The helmet consist of separate pieces connected in the middle. The pieces can be folded into each other when not wearing the helmet. When wearing the helmet the wearer need to put on the hoodie, this will fold out the helmet.



The helmet will be one piece of a flexible but hard material. When the helmet is not worn it will be flat. To fold the helmet into the right shape the corners at the side need to be folded together and clicked into place between the spheres at the outer ends.

QOC analysis	armadillo helmet	folding helmet
Strength of helmet X2	3 (x2=6)	2 (x2=6)
easy to fold	2	0
Comfortability	-2	-2
Safety when small X2	-1 (x2=-2)	2 (x2=4)
Feasibility	-2	-1
total	2	7

While safety is most important these factors weight double.

The armadillo helmet is more likely to be stronger. While the separate pieces can be made of a hard material, the folding helmet needs to be of a flexible material to be able to go from flat to a helmet shape. Also the Armadillo helmet will be easier to fold in and out of shape while it only needs to be folded open or in. In case of the folding helmet the separate pieces at the side need to be connected to the outer circles. In both cases the jacket will be less comfortable than a normal jacket. The armadillo helmet will not limit movements but it is a hard bowl shape at the back of the neck which can bounce around when running and can be annoying. The folding helmet can limit movement. The hard bowl shape of the armadillo helmet can also be dangerous. A hard object at the back of the neck can then cause harm.

3.1.2 Shape

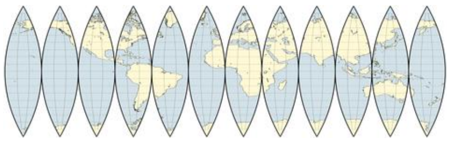
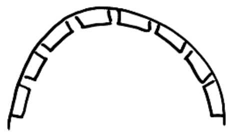


Figure 3

The helmet has a shape that can be compared to a half sphere. In card making sinusoidal maps are used to make a projection of the spherical earth on a plane13. When folding this plane it creates a sphere.

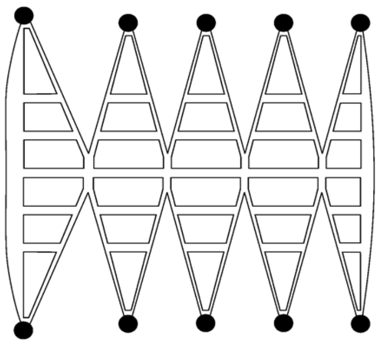
The sinusoidal shape can be used as inspiration for the shape of the helmet. .While the helmet has to cover most of the surface of the head there need to be ventilation holes in the helmet as well. To do this the curved lines can be replaced by straight lines.

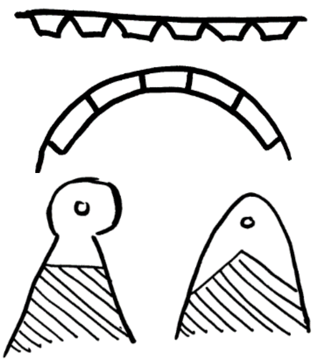
Also in the helmet there should be more room in the middle to connected the different segments. When these are not connected properly this could make the helmet not as sturdy as it should be.



Having multiple small pieces of foam makes it possible to keep the foam parts as flat as possible and still getting the right shape when bend. By keeping space in between the foam parts, space for bending is created.

Shape 1:

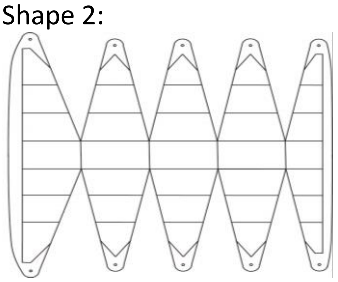




The foam parts needs to contain a big, solid surface in the middle to make the force be spread to as much foam as possible. The space between the pieces of foam prevents the force from spreading, to solve this the foam pieces need to touch each other. This can be done by angling the sides of the foam.

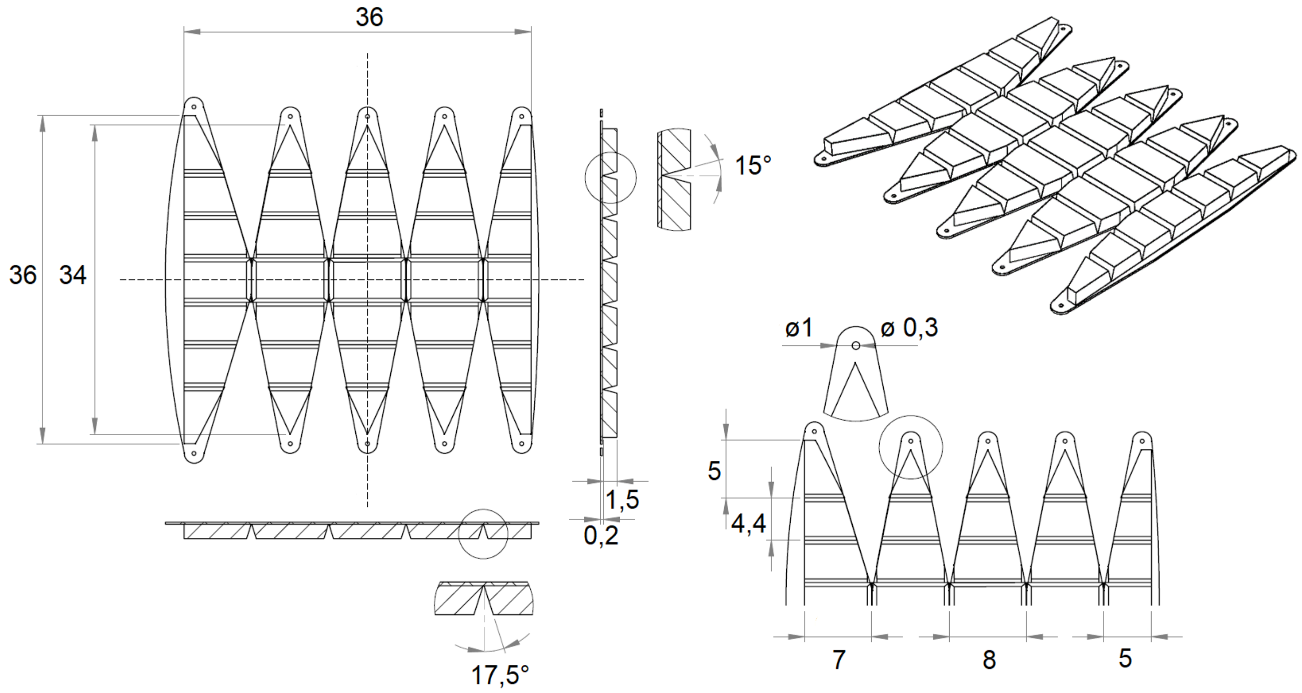
Another problem with shape 1 is that the connection circles make the helmet wider than necessary. This makes the fitting of the jacket more uncomfortable when it is placed in the backpocket. The space is needed to be able to slice segments over each other to connect them. This can be solved by making the last piece of foam a triangle.

Shape 2:



3.1.3 Measurements

The measurement are in cm, how the measurements are calculated can be found in the appendix 7.3.2.

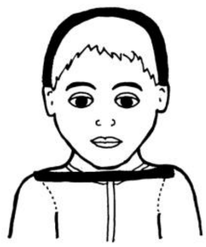


3.2 JACKET

3.2.1 Questionnaire

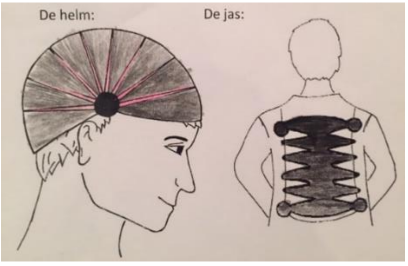
Some measurements had to be done to make sure whether the head protection idea was possible for children. Therefore the length from ear to ear, which is the width of the helmet, and the width of the area on the back of a child, between the shoulders was measured.

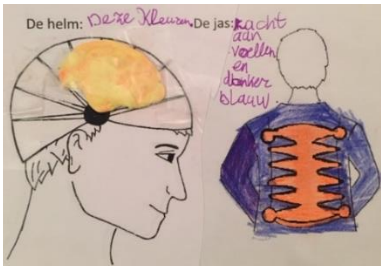
If the length from ear to ear would turn out wider than the width of the back of the child, the idea would not be possible, as the helmet would not fit in a jacket and be uncomfortable to wear.
All of the measurements are around 30 cm for both the head and the back and according to this the idea seems possible to continue with. (Full table can be found in appendix 7.3.3)

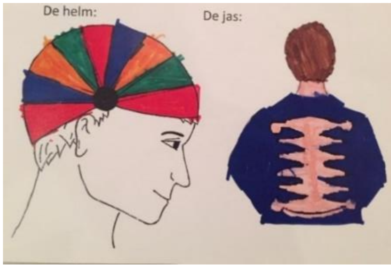


To get to know more about what children want according to looks a questionnaire was made, which can be found (including results) in the appendix 7.3.3.

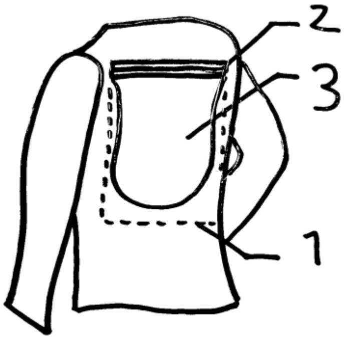
As a conclusion from the questionnaire, most of the children said they never wear a helmet or only when skiing. A thing that immediately stood out of the drawing parts were two questionnaires of girls, both 11 years old. One of the girls is outstanding, she wanted bright colors and the other girl is very shy and has a low self-esteem. This was seen within their design, the outstanding girl worked with bright colors and the shy girl with black and a modest use of pink. The two designs (two most left pictures) brought the idea of making a plane version and a more childish version of the design. Most kids use a lot of bright colors (most right pictures) and they think mountain biking, roller coasters and the police are cool. Because all contain speed and force, a superhero theme may be a good design for the more childish design.







3.2.2 Design jacket



On the inside of the jacket there is a bag (1) , in which the helmet can fit when it is not folded. By making an opening (2) in the jacket between the shoulder blades, which is connected to the bag, the user is able to pull the helmet out of the bag, and onto its head.
The hoodie (3) had to be able to go over the helmet and should be easy to put on and off, also when the helmet is in the bag. Because of this the hoodie would not be attached to the top of the jacket but under the pocket. While the hoodie would be connected to the back and not to the sides of the neckline (which can be seen in normal hoodies), the hoodie might also be able to twist more easily. This can limit the obstruction which a normal hoodie cause, while the hoodie turns with the head.

The jacket is designed to give it a superhero feel. Giving a cool feeling to wearing the jacket and helmet. Several, possible designs of the jacket are shown below.

3.3 Materials

At first it was difficult to find the right materials, as there are so many different materials available. After doing a lot of research, a couple of materials were found that could probably work, but it was hard to decide which one was best to use. Therefore the decision was made to discuss it with an expert, F. Delbressine. He advised to use the materials that are normally used in helmets, as they are already researched and have the best properties. These materials are discussed below.

The helmet exists of two different layers: a hard shell and a foam layer.

3.3.1 Hard shell

The most important properties of the material for the outer shell are:

- It should be bendable, as it has to be folded into the right shape without being deformed.
- It should have a high impact strength, because it needs to spread the energy of the impact.
- It should be easy to manufacture

At first it was decided to make the hard shell out of ABS plastic (Acrylonitrile butadiene styrene). The reason for this is that is one of the most used materials for the outer shells in other helmets, due to its good properties. It has a great impact strength and it is not affected by everyday temperature changes[14] [15].

Unfortunately after doing research, it was found that ABS is hard manufacture. Due to the size of the prototype, the only possibility is to lasercut. ABS has a relatively low melting point (105 degrees Celsius)[16] and therefore the edges will not be smooth if lasercutted.

Finally it was decided to use PETG, which is a modified version of PET-plastic. It has almost similar properties to ABS. ABS has a slightly higher impact strength[17] [18], but since the hard shell only has the function to spread the energy of the impact, this is considered to be still reasonable. Another important difference is that PETG is a bit more flexible than ABS[1920], which is positive for this design, as it has to be bendable.

On top of that, PETG can be lasercutted very well, also in Vertigo, which makes it an easy to manufacture material. The melting point of PETG (around 255 degrees Celsius[21]) is higher than the melting point of ABS. The result of this is that laser cutting PETG will give a clearer cut.

3.3.2 Foam layer

The most important properties of the material for the foam layer are:

- It should be able to absorb energy.
- It should be easy to manufacture

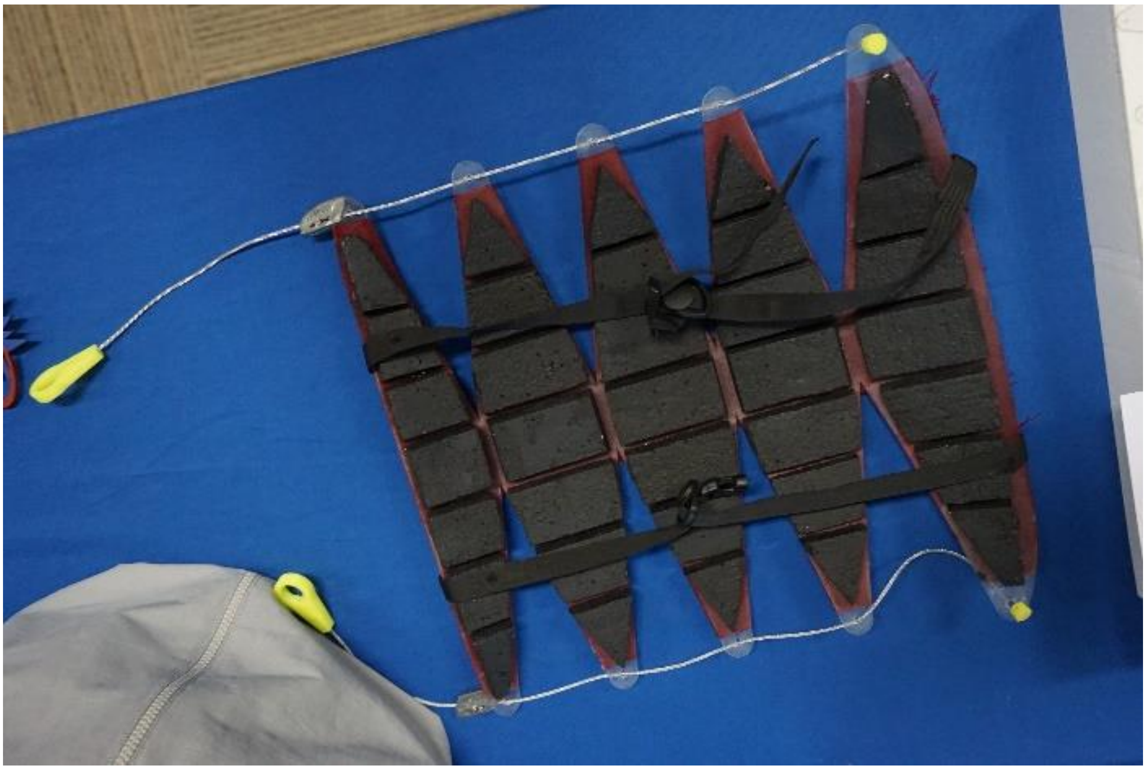
Soft foam is only there for comfort. The impact in a crash is so big, that the soft foam would immediately bottom out[22]. A great solution for this is crushable foam. A crushable foam exists of really small beads, closed-cells. In a crash the cell walls will be crushed. This slows the head down, which decreases the deceleration and the force on the head, but it also means that the helmet has to be replaced after a crash.

EPS is a crushable foam that is often used in helmets. It is very lightweight (it is approximately 95% air) and durable[23], which makes it very appropriate to use in a helmet for children. Most important, it is really good at energy absorbing, due to the closed-cell structure. The material is also easy to manufacture. A way of shaping the material is by using a hot wire. This melts the foam and gives a clean cut.

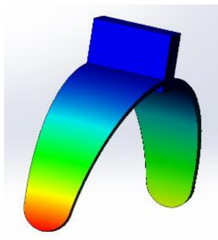
4 REALIZATION

4.1 HELMET

1. The shape of the helmet was drawn using illustrator.
2. The base plate was cut out of some PETG using a laser cutter.
3. Fabric was heat pressed onto one side of the PETG plate.
4. At every end of each segment, a hole with a diameter of 3mm was drilled.
5. The foam (EPS) was cut into different shapes by using a hot wire. By changing the angle of the wire the sides could be angled.
6. The foam was painted black for aesthetic, it also was meant to prevent beads from coming lose by forming a thin layer around them.
7. When completely dry, the foam was glued onto the side of the PETG plate on the side without fabric.
8. The neckband is then attached to the helmet, it’s attached to the first and last segment, about 3 cm from the end on each side, with the clips facing upwards on the foam side.
9. The steel cable is reeled through the ends of the segments, after which the cable lock, the wire end stop and the wire end pull are attached.



4.2 CLOSING MECHANISM

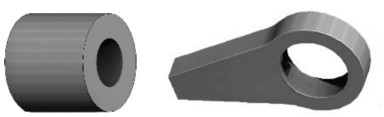


Since there will be a lot of impact on the helmet when the user is in an accident. The helmet needs to be held together by something that can withstand a lot of force. The simulations shows a segment with pressure on top (blue block). The colours represent displacement. The segment is not able to move down while there is a head, the displacement is big in the ends of the segment, they want to move out. The closing mechanism needs to prevent this and keep them all in place.

It was decided to use a steel cable with a diameter of 2mm. This cable goes though the holes at the end of each plate. One end of the cable is connected to the wire end pull, the other is connected to a wire end stop. When the user pulls the wire end pull, the cable will shorten, which results into the helmet folding in.

However, the cable was able to move back, since there was nothing that locked it in its position, which is the reason we used the B-lock cable lock. This thing is able to lock a cable in a certain position making it unable to go back to its original position and therefore “locking” the cable. One can find online that when this lock is used in combination with a 2mm cable it will be able to handle forces up to 50kg. The cable only locks movement in one direction, this means the lock doesn’t need to be pressed when closing the helmet. The lock only needs to be opened to open up the helmet.

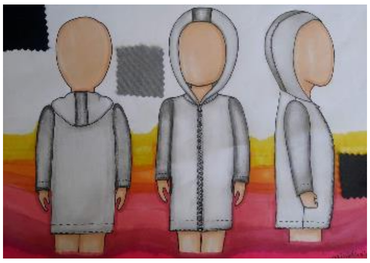
The end of the wire needs to be shielded to prevent possible injuries of the end of the wires, for example when getting in the eye. Also the ends make sure the wires stay in the helmet and don’t slide through. These parts are 3D printed.



4.3 Jacket

4.3.1 Summa

During this part of the project, SUMMA student assisted us, their skills on this area are more developed and therefore this cooperation could really benefit the project.
Unfortunately, some of the instructions given to the SUMMA student were unclear, which resulted into them delivering a different jacket than what was expected. There where miscommunications because a different way of thinking. What seems logical for us might be illogical for them and the other way around. Using more drawings instead of explanations would made the ideas clearer.



4.3.2 Alterations

To make the jacket fit for a helmet some alterations had to be done. In the original jacket it was not possible to get the helmet out of the pocket with the jacket on, the jacket had to be taken off first. Originally the idea was that the jacket could stay on. making it easier to use. So the pocket for the helmet had to be changed so that the opening of the pocket would be at the back of the jacket instead of on the inside. To achieve this, the old pocket was removed and a bound pocket was made. The black lines in the figure form the opening and are on the back of jacket, this was made with bright yellow fabric. The light grey lines form the pocket itself that is on the inside of the jacket. For the pocket itself the lining was used, as this is a very smooth fabric that makes it easier to 'glide' the helmet in. The second adjustment that has been made was to remove the hoodie. Now that the opening of the pocket was placed on the back, the hoodie was covering the opening, making it harder to reach for the helmet. Therefore it was quickly decided that the hoody had to be removed. After it was removed, the same yellow fabric was used to neatly finish off the collar.

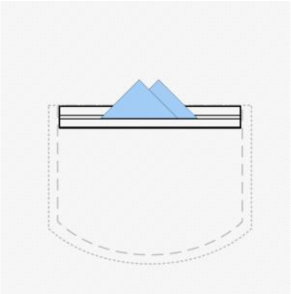


Figure 4

5 Validation

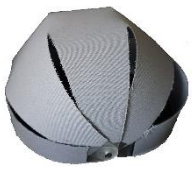
5.1 Tests

5.1.1 Material

The tests are mostly done on PETG this is the material used for the outer shell of the helmet and it is a different material than what is normally used for a helmet. EPS is frequently used in helmets. Therefore the assumption can be made that the material has the right properties to pass the official safety tests.

Nr.	Name	Execution	Wanted result
1	Scratch test	Scratch on the outside of the helmet with a nail, does the material stay intact, are there scratch marks, does material come loose?	The outer shell of the helmet must stay intact, some scratch marks are allowed

<table>
<tr><td colspan="4">Result:

When scratching with a nail not much force was needed to cause scratch marks. When a bit of pressure was used material came loose. When adding fabric the material seemed more durable a better resistant to scratches.</td></tr>
<tr><td>2</td><td>Bending test</td><td>Form the helmet in its non-flat shape. Keep the helmet in this shape for a week. Does the helmet become flat again by itself?</td><td>The material goes back to its initial flat shape</td></tr>
<tr><td colspan="4">Result:
 
Even after a week the material goes back to its initial flat shape. There is nothing odd to feel on the material and there are no visible consequences of the material being bent.</td></tr>
<tr><td>3</td><td>Rain test</td><td>A small prototype of Pet-G is placed outside in the rain for a whole day.</td><td>There are no changes in the material properties.</td></tr>
<tr><td colspan="4">Result:
After a whole day in the rain and letting in lay in the water for a while there are not changes in material properties.</td></tr>
<tr><td>4</td><td>Heat test</td><td>The helmet is put under a heat pressed to see the reaction of the material when heated.</td><td>The material should not deform and change in properties when the temperature is lower than 50</td></tr>
<tr><td colspan="4">Result:
As said on the material, it needs to be heated to more than 70°C for some time, to possible see some deformations.
After heat pressing, for 10 seconds with a temperature of 150°C, the PETG is easy to deform. After cooling down there is no visible and feelable difference from before. When deforming the material while it cools down the material stays in this shape but is still flexible.</td></tr>
</table>

5.1.2 Safety

Safety is very important when designing a helmet. There are also requirements of tests that need to be done and which need to be passed before being able to sell the product as a helmet. When not all tests can be executed properly or when not all tests can be passed the product should be called head protection.

Nr.	Name	Required by	Execution	Wanted result
1	Drop test	EN 1078	Drop helmet in head form from on a flat anvil, a curb stone and a hemisphere. The head form falls guided using a rail. In the center of the head form is an accelerometer to measure the impact. The head needs to hit the flat anvil with a speed of 6,3 m/s, the curbstone and hemisphere need to be hit with a speed of 5,0 m/s.	Deceleration must not exceed 250g.

Result:
This tests couldn't be done while we didn't have the proper tools, like an accelerometer that could measure up to 1000g. Therefor the test had to be done differently.
The replacement test is calculations done in combination with testing. The deformation of the foam is found by doing tests, this value is used in calculations.

A 4,5 kg weight is dropped on the foam with a width of 1,5 cm, to measure how much the foam deforms. The weight needs to hit the foam with a speed of 6,3 m/s. The height of which the weight needs to be dropped to reach this speed can be calculated.

$$a = \frac{\Delta v}{\Delta t} \rightarrow \Delta t = \frac{\Delta v}{a} \qquad \Delta t = \frac{6{,}3}{9.81} = 0{,}64\ s$$

$$s = v_{gem} \cdot t \qquad s = (\frac{1}{2} \cdot 6{,}3) \cdot 0{,}64 = 2\ m$$

Foam piece	1	2	3	4
Permanent deformation	0,6 cm	0,7 cm	broke in half	0,7 cm
Average deformation	0,67 cm			

$$a_{head}(in\ g) = \frac{\frac{6{,}3^2}{2 * 0{,}0067}}{9{,}81} = 287g$$

Some tests where planned but not done, these can be found in the appendix (7.5.1).

5.1.3 User

One can find summaries of different methods within the appendix 7.2.5. With different parts of this methods a user test is set up. What follows is a short summary of what parts of which method is used for the user tests of the HeadFirst!.

The think-aloud method will be used within the user test, the children are asked to talk aloud when doing something. The second method, storify, shows to ask the same question in the beginning and on the end to see the difference. The co-constructing stories is about telling a story and asking for an opinion about that story and not about showing a prototype. Children like to use their hands and play, with the co-constructing stories they are only having a conversation, this can be a little bit difficult and they could get bored.
In the appendix, 7.5.2, a starting evaluation can be found, this shows the choices for the setting of the user test. The eventual user test that has been done and the results of it can be found below. The test was done with 5 children (two boys, three girls) from group 6 of the elementary school this means they are all aged around 10.

Nr.	Test Name	Execution	Wanted result
1	Start question	Ask children what they think of wearing a helmet.	Wearing a helmet is not cool.

Result:
All the children did not wear a helmet themselves, only when mountain biking or skiing. None of the kids thinks it is strange to wear a helmet. They do think it looks more weird when a girl wears a helmet than when a boy wears a helmet but that is because girls usually have long hair.

<table>
<tr><td>2</td><td>Jacket on</td><td>Children put on the jacket.
How does the jacket fit with the HeadFirst! in it? And how does it fit without the head first?
Ask them to move with their arms and run around with the jacket on.</td><td>Children do think that the jacket fits comfortable with and without the helmet.</td></tr>
<tr><td colspan="4">Result:
The jacket without a helmet in it is a bit long but fits comfortable. When the helmet is in the jacket the jacket does not fit properly it obstructs the children of moving their arms.</td></tr>
<tr><td>3</td><td>First try</td><td>Without any explanation the children have to put the jacket on and place the head protection on their head.</td><td>The children intuitively know what they should do. It does not have to work but they have to be on the right track.</td></tr>
<tr><td colspan="4">Result:
Since the headpiece is not attached to the jacket, the headpiece was given without a jacket. First, they clicked in the closing piece for the chin because they recognized that part, after that they needed explanation of what to do next. They intuitively said that you had to pull the wires but were not confident enough to try.</td></tr>
<tr><td>4</td><td>Second try.</td><td>The children get an explanation on how they should put the head protection of the jacket on and the try to do it.</td><td>It does not have to go fast but it has to be done in the right way without any help.</td></tr>
<tr><td colspan="4">Result:
After an explanation it was very easy to close the headpieces by pulling the wires, all the children were able to do that without any difficulties.</td></tr>
<tr><td>5</td><td>Trying until it goes smooth.</td><td>We ask the children again to put on the head protection again until they can do it smoothly within a certain amount of time.</td><td>Within 3 extra times of practice the children should be able to put on their protection within 15 seconds.</td></tr>
<tr><td colspan="4">Result:
With the second try everything went smooth already only the placing on the head stayed difficult. Intuitively children wanted to place the head piece wrong on their head. Because of the stress on the sides of the helmets the shape of the helmets become oval and your head should push this in the right form. The children intuitively thought about the shape of their head and felt like they should turn the helmet with a quarter. After an explanation they all did it right.</td></tr>
<tr><td>6</td><td>What do you think?</td><td>The children are asked what they think of the helmet. Would they wear this in public?</td><td>They answer that they would wear it and not be ashamed for it when they are with friends.</td></tr>
<tr><td colspan="4">Result:
The headpiece is cool. You can place it in a jacket and take it everywhere with you, all the children prefer this helm above a regular one.</td></tr>
</table>

5.2 Conclusion

According to the tests that have been done, it can be concluded that the product does not meet the criteria of a helmet. The result of the drop test was that the average deformation is 0,67 centimeters, this results in an acceleration of 284g, which is higher than the criteria of 250g. This value is also determined in a test different from the original tests, the different test can result in deviant results. Also other required tests could not be done and therefore there was not confirmation whether the product would pass these tests or not. Therefore the product cannot be called a *helmet*, but should be called *head protection*. The outcome of 287 does show that the product provide protection. The deceleration when wearing the product will be significantly lower than when the product is not worn. Also the materials seem to be well chosen. The PETG is a different material compared to most regular helmets, which are made of ABS. Still PETG passed several tests. It is flexible enough to go in and out of shape, it is strong enough to survive the impact and rain and heat do no change the properties. Making it able to survive the outside conditions.

All the children thought the helmet was very cool and preferred this one over the standard helmet. The pulling of the wires to get the flat piece to form the shape to put on was intuitively done.
A thing that was already known but came out of the user test very strongly was that the helmet needs a lot of things fixed. The jacket for example, when the helmet is inside of the pocket it is very tight and obstructs a child to move its arms properly. This can be explained by the alterations made to the jacket, which connected the bag to parts of the sleeves. To solve this problem there should be looked to the design of the jacket, together with a clothing designer, they have more experience in how to make clothes comfortable.
Also the locks are too difficult to open, children do not have enough strength to shift the pins of the locks. The solution for this would be an extra piece attached to the shifting piece of the locks. It is should be easier for children to pull a piece of fabric than to move the small piece of metal which is now hurting their fingers when trying.

6 PERSONAL REFLECTIONS

6.1 LUCA VAN BREDA

Before I started this project I made some goals for myself. I wanted to learn more about materials and how to use them in a design. I particularly wanted to focus on material research. Besides that, I wanted to learn how to 3D-print and how to use the machines in the wearable-senses lab. In short, the competencies I wanted to improve are *technology and* Realization¸ *math, data and computing* and *business and entrepreneurship.*

During this project I was mainly responsible for the material research. Besides that, I did research in the earlier stages of the project about tests and laws for helmets and possible target groups. I worked on the prototypes for the midterm and final demo day (cutting foam, laser cutting the hard shell, sewing the jacket), did calculations as a form of testing and I made a business plan.

By doing a lot of material research for this project I learned a lot about material properties and how to use them to select a material. As our focus was on head protection, I learned which properties are an important factor for this, like the elastic modulus and the compressive strength. We looked at this together with F. Delbressine and he explained the physical part behind this, which was a good learning opportunity.
We also discussed some calculations that we could use as a form of testing. The results from these calculations were that there were huge forces on the helmet and especially on the lock-system. We found this out quite late and this led to some design solution that I was not very happy about, which probably could have been improved if we had more time. Therefore I learned how important it is to start testing and calculating sooner. By adding physics and learning about materials I improved the *math, data and computing* and the *technology and realization competency*.
The material research and calculations helped me to see how a project can be made more scientific. I missed this a bit in the project at first, which made me feel like I was designing a product without actually learning something in-depth or theoretical to challenge myself. In a future project I will focus on this more, to create more learning opportunities.

Another important learning point for me was alternating the jackets. Firstly, when the jackets turned out to be not useful for the demo day, I learned how difficult it is to share your idea. I assumed that the Summa students understood what we expected from them, but this turned out to be not true. Next time when I work with a third party, I will communicate my ideas better, by for example making clear drawings. Besides that, I would contact them more often during the process, so that any problem or miscommunication can be solved earlier. This realization helps me to improve my *professional skills*.
Secondly, I learned how to work under the pressure of a time-limit. I am a perfectionist and I focus a lot on details. This can lead to spending too much time on a task. I only had a couple of days to work on the jacket, which forced me to let go of some of the control.
Finally, by working on the jacket I had the opportunity to practice more with the machines in the wearable senses lab, which was one my goals. I learned some more completed (sewing)skills, for example how to make a bound pocket. By practicing this I improved the t*echnology and realization and the creativity and aesthetics* competency. I think I can use this overall knowledge of how to work with the machine in future projects, because I would like to work with fabrics again in the future.

One of my goals was to improve my business and entrepreneurship competency and I wanted to achieve this by making a business model. I had never done this before and I found it quite difficult. In the end I feel like making one business plan is not enough to really improve this competency. Therefore I want do this again in my next project and read a book about it (The business model generation, by A. Osterwalder, Y. Pigneur)

Group work

The start of the project was a bit difficult. Each of us had different interests, which led to some conflicting ideas and directions, but the overall atmosphere in the group was good. There were no major problems in the group work or during meetings. However one thing that I found hard to deal with was the big difference in motivation within the group. On one hand some people were not very motivated, which sometimes let to some tension in the group as some tasks were not finished on time. On the other hand some people were really motivated, so sometimes tasks were already done before I even had the time to start. I feel like I was a bit in the middle of this.

I think my role in the project was a mix between the realisator and the researcher. These are both roles in the design process that I enjoy and want to focus on.

Overall, I am quite happy with the outcome of the project and my own learning process. I focused on my goals and achieved most of them. Although some a little bit different than I first had in mind, but I think that is unavoidable when your work within a group. However I would have liked to experiment more with different prototypes, instead of discussing solutions. I like to work with a hands-on approach and I missed that a little bit during this project. Therefore I would like to pay more attention to this in my next projects, by experimenting more with prototyping.

6.2 Lieke de Mare

In the beginning of this year I wanted to learn more about electronics and my goal was to do the electronics and programming for the project. While the group went in a different way we had a design with no electronics. Because of this I focused on my other goals, learning more about realization and making professional visuals.

During the design project I did some research (target group, how helmets work, requirements, user test methods), I designed the shape of the helmet and the foam (drawings, calculations), made the 3D models, 3d printed, made the tests plan for the safety and material tests and I executed some of these tests. I also was the main pitcher during the demo days and during the weekly meetings.

I started working with Solidworks and learned how to make parts and assemblies. The 3D models where 3D printed, many do-overs where necessary for me to start understanding how to use the machine. You can't just simply print. There are many different setting that need to be adapted before starting the print and while printing. As Troy said 'You should work with the 3D printer as if it were a sewing machine' meaning you can't start it and walk away, you should guide the print. In the end I was able to successfully print parts for the prototype.

The 3D models were also used for visuals. By changing the materials, the colours and the lights a realistic image of the design could be made. In Solidworks I also learned how to make drawings of the design where measurements, details and sections could be shown. The shape was too complicated for me to make good sketched by hand. Solidworks helped to still make good visuals.

I also tried to work with simulations to see how materials react to different pressures. This could be used to see how much EPS deforms under a certain pressure. I was able to find out how this simulation works by testing with blocks of different materials, but while EPS is not in the material database I was not able to see the results I needed. By making a simple try version of a retention system I was able to try other simulation functions. My goal in doing this was not to design the retention system, while I realised I didn't have the time, but learn more about the use of simulations. The results also ended up not useful for the report (but they are in the appendix 7.6). Still it was useful while I now understand several of the simulation functions.

Another thing I learned during this project was that there are very strict requirements and tests. But also that many company's simply avoid requirements by added little messages where they say the helmet is not suited for kids, even though the helmet has a childish design. The messages show that they acknowledge that they don't pass the requirements for children helmets.

The required tests were not doable for us while they required equipment we didn't have access to. Also while helmets are not made to withstand impact more than ones many helmets needed to me made for proper testing. The time is costed to make all the foam pieces made this very hard. This is way we needed to think of other methods. Like not using a full helmet put testing pieces and working with a combination of testing and calculations. Luca and I looked at this calculations with help from Delbrissine. Doing this was a nice repetition of physics which I hadn't used in half a year. Delbrissine also helped us realising that force in the locking mechanism would be very big. I had realised that the mechanism needed to be strong a would require a lock but didn't realise the actual force. In combinations with late testing of how to close the helmet we ended up in a problem. The closing and locking mechanism should be easy to use but also very strong. I'm not happy with our end solution for this problem. So this is something I regret not starting sooner with and would be the first thing I would try to make better when we would continue working with this project. When we had more time I would also have looked to the retention system.

Working together was hard in the beginning. We all had different interests and goals which made it hard to come to a project we all thought was interesting. This had costs sometime in the beginning of the project. During the project there were still some problems in the group while I had the idea some were not very motivated. I became a bit of the organiser of the group. I for example tried to keep everything up to date. What was hard that for some people tasks were really necessary, they had to be given a tasks because otherwise they didn't know what to do. While I'm bad a speaking out against group members there were sometimes frustrations I was not expressing, like when I had the feeling some members where not doing their tasks. We did end up having a conversation about this and this went very well. I have to learn to speak out, this keeps me from getting frustrated and gives them a fair chance to responded and if they agree to change.

Goals in short:

- While I didn't use electronics and programming in this project I want to use it in the next project and I will try to do some small project in my free time. Before the end of next quartile I have used programming.
- Next time I will speak about possible problems in the group and not stay silent which makes me frustrated and which is also not fair against other group members.
- I will continue working with Solidworks to not forget how it works and possible use the simulation tools in other projects.

6.3 Milan de Meij

I learned a lot during this project. At the start I had some problems getting into the flow, one of the reasons was that we as a group were just some sort of scraped together something. We all had different interests and therefore it was a little bit awkward and not very efficient at the start. During the first couple of weeks, it was expected that we delivered something tangible every time we had a project meeting. We switched our focus a lot of times during these weeks, which made it feel like we didn't really knew what we were doing, taking some motivation away. We switched ideas a lot of time. Eventually we settled on an idea that we all had motivation to work on, and from there on we started to make more progression.

Before starting the project, I already had some small thoughts on which areas I wanted to evolve, mainly realization and aesthetics. These areas interested me the most, and I hoped that I could use this project to work on these areas. During the project, I was mainly busy with the conceptualization and thinking about how we could solve different things. One example of this is that I had to work out how we could pull the different end of the segments together, and hold them in place. Lieke took a very big role in this, since she was very interested in 3D printing, which we used a lot. Also, with making 3D models, she made it much easier to make the final prototype, since the dimensions that we had to use were already decided this way. It also made it very clear since whenever you use a 3D model you can already see what it has to look like in the end.

I hope that I can grow on this area even more, by doing what Lieke did next time. I should have probably taken a bigger leader role during these things, since I wanted to grow on this area. But since Lieke already took this role, I didn't feel like doing so, because to be completely honest, it was also very nice, since this left fewer work for me, but also my other teammates. Lieke took a leader role in general, which is very good I think. We did have some discussions however, since she mentioned that she thought I didn't do enough and/or wasn't active enough. One thing that I didn't like about that whole situation is that she never spoke to me directly about it, I had to find out about that though another teammate. We had a good talk about it later, and I felt like she was not angry or anything with me, but that she did feel like I should be more active. After that talk, I feel like I was more active. Another thing I realized is that I am generally more active whenever we were meeting together. During these meetings I produced more work, and I almost always did whatever was asked of me.

As mentioned, even though we had some minor issues that were solved quickly, the atmosphere in the group was great in general. After the first couple of weeks of starting up, we start working on it more seriously I think the general results we produced are good. Something I would change if we had more time, is making the prototype even better, not changing a lot of things, but I believe a few very small changes would make it look even better and work way better as well.

For my next project, I hope I can work on the area of realization even more. Things like 3D printing and laser cutting really impressed me during this project, now that I've seen what you can accomplish whilst using these techniques. I had signed up for Crafting Everyday Soft Things again, as my second choice this time, so if I happen to get a project on this area again, I will definitely use these techniques. Other than that, I am fairly happy looking back at the project. I really learned a lot during the demo day as well, mainly on how to properly present your ideas, since this year's demo day was way more professional then last year's one.

6.4 Lynn Visser

This project showed me a whole new side within the industrial design studies, working with soft things was a totally new experience for me. I learned a lot about all the new techniques that are possible. New machines about the heat press, the lock machine and the embroidery machines were introduced to me. The embroidery machine is something I would still like to learn a lot more about in the future. I taught myself how to make 3D models within fusion 360, it was fun to learn and I am proud, I am not a professional but know the basics. Due to some assistance difficulties during my first time using the 3D printer at the wearable senses lab I was not encouraged to continue my learning process within 3D-printing. This is a shame, I hope to continue my learning process in the future when I feel more comfortable about it.

Within this project the user tests were given to me as a task. I read a lot of studies about different kinds of ways to do a user test and learned a lot about in which situation what kind of user test fits best. I really liked doing stuff with and for the kids for example dressing up as a doctor with Halloween measuring the heads of children that came for a trick or treat. This was a dynamic process which was fun and easy for me. The bigger user test that I did, was the final one with the prototype. This was a lot more difficult. My very first time doing user test was with elderly people, they are slow and they listen carefully. Children are easily distracted and not patient at all. Especially this user test was hard since it was a group of children. It was a chaos and hard to filter all the good information out of it. Despite that I wrote a whole test plan in advance it was very hard to follow that plan. For the next time I would like to give the arranging of the test plan a better look. Go take a look at the venue where you will do the user test. By doing this I will know better what is possible to do in this way I will be better prepared for the things that might happen and come with a good solution for any difficulties. Another thing that I learned during my studies within different types of user tests is that it is important to hide the camera since it can make the user feel nervous and therefore change their answers. During the user tests I tried not to focus on the camera but this was difficult. Next time I will set up the camera before I start the test in this way I do not have to put any focus on it and the user is less influenced by it.

The ambiance in the group was a nice one, everyone worked hard, had an eager to learn and liked the process. One of our teammates really pushed us to start with writing the report early in the process. Without her I would have never thought about doing this but she learned us that this was a great thing to do. Our report is very extended and shows really everything that we have done. Even the small things that would have been forgotten if we just started in the last phase are mentioned. This way of writing down your process and start with the report in an early phase of the process is a thing that I would definitely take with me for next projects.

Also a goal that I would like to accomplish for next projects is to be able to make my own visuals. I was very impressed by Lieke who did some of the visuals with drawing and I want to be able to do that as well since you can make everything so much more clear. For the demoday I tried to make my own visual by using Photoshop to give a drawn boy a certain type of jacket. This worked out quite well but I want to become better and better. With the course exploratory sketching, that I will follow next semester, I hope that I will be able to draw my idea in a clear way. Want I want to add my visuals to a report I should look into a program to draw on a big mousepad and get the drawing on my computer. I will find this program by asking my fellow students and do some research online.

A last goal for the future is working with more electronics than we have done now. I am not very good at working with electronics and last project one of my goals was to help within the electronic part of my next project to improve myself. To get better with this I hope that there will be more opportunities to learn more about this within my industrial design learning program.

7 APPENDIX

7.1 IDEATION

7.1.1 Interview

Child	Fleur	Stijn	Rik
How old are you?	10	8	9
In what grade are you?	group 7	group 4	group 4
Do you wear protection when do activities like riding your bike or skateboarding?	No. Only wearing wrist protection when skating.	I only wear a helmet when mountain biking	Not when I'm just cycling
Why do / don't you wear protection?	Because I do not think it looks cool	I trust myself that I don't fall	I don't need it, I'm pro in cycling
Do other children you know wear protection? What do you think of that?	Yes, a boy in my class wear a helmet but he has epilepsy	Yes, he lives far away from school, I think it's okay	Yes, I think it's not that weird
Would you wear a 'cool' version?	I don't know, when it doesn't rain wearing a hood would look strange	Maybe I would	Yes

Parents	Annet
How old are your children?	7 and 10
Do they wear any protection?	No they don't wear any protection
Why do / don't they wear protection?	I don't see it with other children. I trust that it will be okay. I also never wore protection myself.
Would it for you make any difference when your children are cycling within busy traffic?	Yes, I would definitely oblige my children to wear a helmet when they had to cycle within busy traffic every day.
What do you think about integrating a helmet in clothes?	When you can make it fit into clothing is a nice solution because now you always have to carry the helmet the whole day with you.

7.1.2 Others users

7.1.2.1 E-bikers

There is a rise in e-bike usage, in the Netherlands the users are mostly elderly. Elderly choose an e-bike while this makes them able to still bike, even while they don't have the energy and force to use a normal bike. But the e-bike also gets more popular for younger people, for home to school and home to work traffic. Even though e-bikes can go up to 25 kilometers an hour, there is not a law that enforces wearing a helmet.

Figure 5

Sien is 75 years old, because of her e-bike she still is very mobile. She isn't able to use a normal bike anymore. The speed of the e-bike can be nice because she can get to places fast, but it also a bit scare while because of her age she is afraid she can't react fast enough is something happens. A helmet makes her feel saver. But she only wears one when she visits her grandchildren. When going to the supermarket she doesn't put it on while she has nowhere to put it when she is in the store.

Figure 6

Sanders is 28 years old. He lives 18 kilometers away from his work and uses the e-bike to commute. He doesn't wear a helmet. On a normal bike he never used it this hasn't changed when he went from normal bike to e-bike.

7.1.2.2 Skaters

Skaters often perform stunts, these can be dangerous. Skaters themselves mention that they don't like the image of a helmet, it looks uncool. When doing new stunts they do wear it while practising new stunts often involves falling the first few times. The helmets are bulky and ugly.

Figure 7

Dennis is 19 years old, he skates as a hobby twice a week. He doesn't wear protection, only when practicing new stunts. When doing the regular stuff het wear no protection at all while he thinks it look stupid.

7.2 EXTRA RESEARCH

7.2.1 Fit of helmet

Children have a bigger chance of suffering a head injury, when their helmet is significantly wider than their head. 58% of children under the age of 10 compared to 37% of the children over the age of ten had a difference in width of 1,25 cm or bigger. From this information we can conclude that helmets for younger children (under 10 years) have a poor fit compared to the helmets for older children (over 10 years)[24]. Cyclists whose helmet has a poor fit have double the risk of suffering a head injury than cyclists whose helmet fits properly. Helmets often fit older children better than young children.

7.2.2 Brain injuries in accidents

The coup and contre-coup theory, proposed by Margagni in 1766, states that when a head is truck the brains first moves to towards the place of impact, producing coup injury. Than the brain bounces back to strike the skull at the opposite side, producing contre-coup injury[25]. To reduce damage the linear acceleration has to be reduced[26].

A new theory of Holbourn looked at angular rotation being the principal factor of brain injury[27] [28]. The behaviour of the skull and brain would be determined by the properties of the skull and brain and by Newton's laws of motion. Some properties of the brain being: uniform density (about the same as water), extreme incompressibility and low rigidity. Holborn stated that the forces of linear and angular acceleration would create strains in the brain. Only shear-strains would be important in damaging the brain, angular rotation would cause bigger strains and would therefore have a bigger impact on the brain than linear rotation.

Observations of injuries have shown that the injuries of the brains or rarely opposite of each other. They mainly occur in the frontal and temporal lobes and in the sylvian fissure. Looking at the shape of the brains and the internal surface of the skull this observations are consistent with the theory of Holbourn[29].

Still the designs of helmets are often based on limiting linear acceleration while for these a simple solution can be found and while still many people are convinced of these theory.

7.2.3 Folding helmet

When doing some more research into this type of helmet, it was discovered that a similar helmet had already been made before. This helmet was discovered while working on the project, therefore, it was decided to still continue working on this idea.

Some changes to the found design had to be made to call this project something new. Additional focus was laid on implementing this helmet into a jacket to stimulate people wearing helmets.

When working on the project there wasn't looked at this design. It was only used as inspiration and confirmed that the idea was possible.

Figure 8

7.2.4 calculations impact

Mass human head m_{head}: 4,5 kg [30 31 32]
Average speed bike v_{bike}: 12 km/h [33] ≈ 3,3 m/s
Height head on bike h_{head}: 1,5 m

Approximate speed at which the head hits the ground:

$$m * g * h_{head} = \frac{1}{2} * m * {v_{down}}^2$$

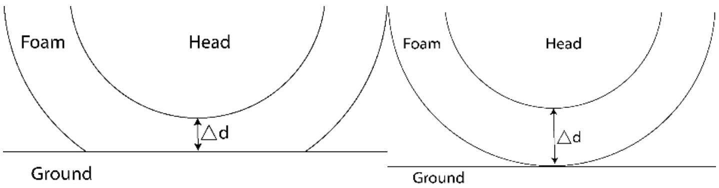
$$g * h_{head} = \frac{1}{2} * {v_{down}}^2$$

$v_{down}{}^2 = 2 * g * h_d$
$v_{down} = \sqrt{2 * g * h_{head}}$
$v_{down} \approx \sqrt{2 * 9{,}81 * 1{,}35} \approx 5{,}15\ m/s$

v_{down} and v_{bike} are both a vector, so they can be added.
By using Pythagoras v_{head} can be calculated
$v_{head}{}^2 = v_{down}{}^2 + v_{bike}{}^2$
$v_{head} = \sqrt{v_{down}{}^2 + v_{bike}{}^2}$
$v_{head} \approx \sqrt{5{,}15^2 + 3{,}3^2} \approx 6{,}1\ m/s$

We can now calculate the force, for this we need the momentum of the head and the time it takes to come to stop:
$F_{head} = \frac{\Delta p_{head}}{\Delta t}$
$\Delta p_{head} = m_{head} * v_{head}$
$\Delta t = \frac{\Delta d}{v_{head\ gem}}$

To calculate Δt , we need to know Δd . When the helmet hits the ground, the foam inside the helmet gets crushed. D1 shows the thickness of the foam right before the helmet hits the ground, d2 right after. Δd is the difference between d1 and d2. D1 is 1,5 cm and d2 is unknown. We estimate that the difference between d1 and d2 will be 1 cm.



$$\Delta t = \frac{\Delta d}{v_{head\ gem}} = \frac{\Delta d}{\frac{1}{2} * v_{head}} \approx \frac{0{,}01}{\frac{1}{2} * 6{,}1} \approx 0{,}0033\ s$$
$$\Delta p_{head} = m_{head} * v_{head} \approx 4{,}5 * 6{,}1 \approx 27{,}5\ kgm/s$$

$$F_{head} = \frac{\Delta p_{head}}{\Delta t} \approx \frac{27{,}5}{0{,}0033\ s} \approx 8{,}4\ kN$$

Finally, we want to calculate how big the acceleration of the head is during the crash while wearing the helmet:
$F_{head} = m_{head} * a_{head}$
$a_{head} = \frac{F_{head}}{m_{head}} \approx \frac{8{,}4*10^3}{4{,}5} \approx 1{,}9 * 10^3\ m/s^2$, which is 190g ($\frac{1{,}9*10^3}{9{,}81} = 190g$)

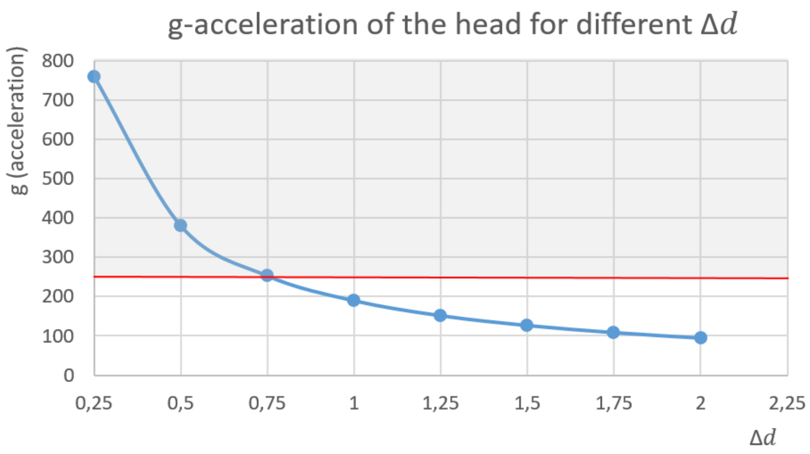
All formula put together:

$$a_{head} = \frac{\frac{\frac{m_{head} * v_{head}}{\Delta d}}{\frac{1}{2}\sqrt{v_{down}{}^2 + v_{bike}{}^2}}}{m_{head}} \rightarrow a_{head}(in\ g) = \frac{\frac{(\frac{1}{2}\sqrt{2 * g * h_{head} + v_{bike}{}^2}) * v_{head}}{\Delta d}}{g}$$

Straight fall:

$$a_{head} = \frac{\frac{m_{head} * v_{head}}{\frac{\Delta d}{\frac{1}{2} v_{down}}}}{m_{head}} \rightarrow a_{head}(in\ g) = \frac{\frac{{v_{impact}}^2}{2\Delta d}}{g}$$

To make this calculation we had to make some assumptions, like the velocity of the bike. The figure below shows the calculated acceleration for each Δd. The red line represents the criteria of 250g.



It is important to keep in mind that Δd means how much foam is crushed, not how thick the initial layer of foam is. To find the value of Δd tests are done.

7.2.5 Methods of user tests

When designing a new product a designer has to do user tests to gather information about what the user wants. Most of the time user tests are qualitative. Problems that come with this are that a user test is subjective, context-dependent and dynamic. Another problem that appears while doing user test is that it it hard to get information about the emotional, contextual and temporal aspects of an experience. Since the HeadFirst! project needs to be tested by user, these problem appear and therefore a testplan should be written before starting. The following research methods try to bridge those problems and are used to create the testplan for this design case.

7.2.5.1 Think-aloud Methods in Qualitative research[34]

Think-aloud research is a method in which participants speak aloud any words in their mind as they complete a task. This kind of research can be effectively interpreted through a qualitative lens. Where participants should be treated as quasi-researchers and their efforts rewarded with reciprocity. During the research is collected with recording material but to keep everything as natural as possible those devices should not be emphasized.

The goal of the research is to give the researcher insight into the processes of working memory but there are several difficulties of which researcher need to be aware. To understand the relationship of thought and words one looks back at Vygotsky's (1962) Thought and Language. This theory shows that the "inner speech" is almost inaccessible to experiments. It is not easy to understand someone else's think aloud process since the inner speech is not meant to be communicative to anyone but the thinker.

Although translation of the inner thoughts into a language is necessary before others could understand them much of the thought is not "stored" verbally. Therefore researchers need to be aware that even thinking aloud, trying to make the inner speech external, cannot reveal deeper thought processes in their true complexity. There are many thought processes which are not verbalized in working memory just because they are automatic or because their "intermediate" processing passes through so quickly that there is not time to verbalize it.

Researchers who want to use think-aloud techniques to reflect natural thought processes have to design their methodologies with great care to avoid over-influencing their participants.
Akyel and Kamisli (1996) recommend that think-aloud tasks require “cognitively demanding language use” so that participants cannot rely on automaticity to perform the task. A task that can be broken into shorter units so that it can be worked on one unit at a time is also recommended because it would prevent overload of working memory. (As Ericsson and Simon (1980) stressed, think-aloud data from working memory will always be incomplete and exclude a number of thought processes which are not held in working memory long enough to be expressed verbally since they are automatically done. To check whether the think processes of the participant is understood well the researcher could end its research with a questionnaire.

7.2.5.2 Storify in qualitative research[35]

Storify guides and assists designers in the concept generation stage by providing assistance in sorting and organizing the elements of and experience similar to the elements of a story such as characters, setting, plot and theme, communicating and discussing strategies on how to guide a user towards an intended experience. The similarity between the key properties of a story and an experience are that they are both made up of: people, places and objects. Because of those three elements they are created over time. Most importantly, stories and experiences evoke and influence the emotions of their experientors.
Storify contains of three layers as a conceptual design process:
Backstage, where a designer collects and interprets information that will help within the design process.

- User experience briefing, discovering the needs and expectations of the user from this an user experience brief is made which can be used as starting point for the process.
- Insploration, with the brief in mind designers start to look around with a new project specific filter of attention while collecting useful materials for the conceptualization process. There are no boundaries for information, recorded speech or videos could be added as well.

Stage: developing user experiences and product concepts.

- Breakdown, all the useful material that is gathered (by several designers for one project) during the insploration, is arranged by a designer within the groups: People, Places and Objects and after that all the groups from all the designers are placed in the overall groups: Characters, Settings and Props that are needed for the specific context that they have in mind.
- Theme-up, there is decided what the core quality and value of experience that tot should be achieved by a design.
- Establishing shot, a establishing shot is made out of the big useful material groups (characters, settings and props). This can be the first frame of a storyboard clarifying the experience. This can help designers to build a context that inspires them within the process. This is done with using five helpful aspects:
    - Physical context, about when and the location of the experience.
    - Emotional context, characters’ feelings at the moment of experience.
    - Sensory context, experienced through the five senses.
    - Historical context, saying something that creates the feeling of being in another time in history, most of the time with a problem that needed to be solved.
    - Memory context, personal connections like a flashback they remember parts of the context.
- Key framing, sorting out all the useful and divide information into three key frames and two in between frames to create a full experience. Designers start with the key frames (first, middle and last frame) and connect those with the in between frames. All the frames could have multiple alternatives to flexibly discuss various experiences.
- Dramatization, one set of frames is chosen, than the designers give the key frames fitting emotions. This enables the design team to reflect on the quality of their user experience design.

Review: the generated concepts are evaluated by designers, users and other stakeholders. The concepts can be shown in three different ways: A written synopsis, a comics page or a film strip.

- Evaluation and reflection, bridge the gap between the designer and the intended user. This is done by a structured observation protocol, pre-session and post-session questionnaires with users based on available methods of the user experience.

7.2.5.3 Co-constructing stories: in qualitative research[36]

Can be described as a design technique that enables a designer to get in-depth user feedback and suggestion during a formative concept evaluation.
In short, the method goes with the assumption that users are better prepared to judge whether novel design concepts. One session of the method takes 45 minutes and consists of two phases: the sensation phase and the elaboration phace.

- Sensation phase: The designer starts telling a fictional story to the user. In this story the context of interest is introduced and setting the stage for a dialogue. After the story, the user is asked whether he/she recognizes this story and why or why not. As a result of the dialogue where the designer asks non-directive questions, relevant past experiences of the user are brought up. This enriches the designer's understanding of the current content of use.
- Elaboration phase: The designer, again, tells a fictional story which introduces the concept. When the story is over the designer asks about the positive and negative aspects of the concept, this by only asking what the user liked and disliked about the story. Then, the designer asks the user how the story would be if the main character was the user himself.

In this way the user is forced to sketch the situations he envisions. Again with non-directive questions the designer encourages the user to complement the original concept story about with content representing anticipated future experiences based on his needs, dreams and aspirations.

7.3 CONCEPTUALIZATION

7.3.1 Requirements

In case of helmet all requirements need to be met.
In case of head protection requirements 7, 10 and 12 don't need to be met, but coming as close as possible to the criteria of requirements 10 and 12 is preferable.

Functional
Requirement: 1
Description: The helmet needs to provide protection
Rationale: When a child falls from his/her bike, a helmet needs to reduce injuries
Fit criterion: The injuries need to be substantially lower to the head when a child falls when wearing the helmet than when not wearing the helmet.

Requirement: 2
Description: The helmet needs to be able to made smaller when not using it
Rationale: When a child wears the jacket without having the helmet on there should be a big helmet hanging on their back
Fit criterion: The helmets measurements need to be able to reduce by 50%

Requirement: 3
Description: The vision of the child should not be limited by the jacket and helmet
Rationale: Limited vision is dangerous in traffic
Fit criterion: The vision is not limited when wearing the helmet

Look & feel
Requirement: 4
Description: The jacket needs to be comfortable when the helmet is not worn
Rationale: When the jacket doesn't feel comfortable people don't want to wear it
Fit criterion: 99% of the questioned children need to find the jacket comfortable

Requirement: 5
Description: The jacket needs to be comfortable when the helmet is worn
Rationale: When the jacket doesn't feel comfortable people don't want to wear it
Fit criterion: 99% of the questioned children need to find the jacket and helmet at least as comfortable as when wearing a regular jacket and regular helmet

Requirement: 6.1
Description: The jacket needs to look cool
Rationale: Children don't think helmets look cool but when a cool option is made, making them feel like they wear a superhero suit, they might like it
Fit criterion: 60% of the children think the jacket is cool and from the others half think the jacket is not uncool or
Requirement: 6.2
Description: When the helmet is not in use, the jacket shouldn't look very different from a normal jacket
Rationale: Children don't like it when everybody can see they have a helmet jacket
Fit criterion: 70% of questioned people don't see what the jacket makes different (not being told about the product)

Requirement: 7
Description: Some or all visible parts of the retention system should be green.
Rationale: This is stated in regulation EN 1080 for children helmets
Fit criterion: At least one part of the retention system is green

Requirement: 8
Description: The helmet shouldn't overheat the head
Rationale: When a helm is worn the head is covered, this could result in overheating the head which is dangerous and can cause problems like fainting.
Fit criterion: A child should be able to wear the helmet for one hour at a temperature of 30 ^{o}C without having symptoms of overheating.

Ease of use
Requirement: 9
Description: A child older than 5 needs to be able to put the helmet correctly in place and remove the helmet themselves within 20 seconds
Rationale: Children also need to be able to use the product when there is no one who can help them with it
Fit criterion: 90% of the questioned 5+ year old need to be able to put on and off the helmet, within 20 seconds for each part of the process, by himself after using 5 times

Performance
Requirement: 10
Description: The helmet should pass drop tests
Rationale: To be able to call the product a helmet regulation EN 1078 needs to be met, the drop tests are in the regulation
Fit criterion: The helmet should be dropped on a head form on a flat anvil, a curb stone and a hemisphere. The impact should not exceed 250g.

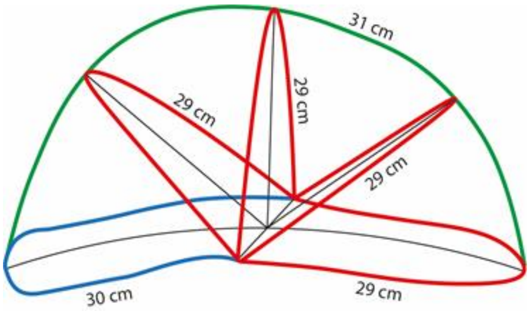
Requirement: 11
Description: The helmet should pass a roll-off test
Rationale: To be able to call the product a helmet regulation EN 1078 needs to be met, the roll-off tests are in the regulation
Fit criterion: When a weight is attached to the rear age of a faced down helmet and when a weight is attached to the front edge of a face forward helmet the helmet may shift but not roll off

Requirement: 12
Description: The retention system should release after certain force
Rationale: Regulation EN 1080 needs to be met, the release of the retention system prevents strangulation
Fit criterion: The retention system should release under a force between 90 and 160 newton

Requirement: 12
Description: The helmet needs to prevent neck injuries by sliding
Rationale: When a helmet doesn't slide on the ground but rolls the neck of the wearer can get jammed causing injuries
Fit criterion: When the helmet, in a head form, is tossed horizontally, the helmet should slide and not roll.

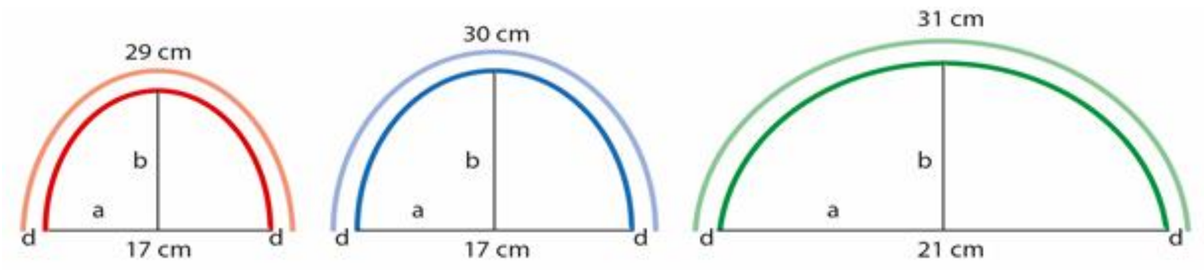
7.3.2 Calculations measurements helmet

7.3.2.1 Measurements children helmet



Measurements of a children's helmet size S/M, measurements are from the inside

7.3.2.2 Calculations



Parts of helmet imagined as half ellipses to approach the measurements of the outside of the helmet, when looked at different thicknesses

$$Perimeter\ ellipse\ inside\ (p_i) \approx \pi\sqrt{2(a^2 + b^2)}$$

$$Perimeter\ ellipse\ outside\ (p_0) \approx \pi\sqrt{2((a+d)^2 + (b+d)^2)}$$

$$Perimeter\ half\ ellipse\ outside\ (p_{0\ half}) \approx \frac{\pi\sqrt{2((a+d)^2 + (b+d)^2)}}{2}$$

Inside:

$$29 \cdot 2 \approx \pi \sqrt{2((\frac{17}{2})^2 + b^2)}$$

$$b \approx 10$$

Outside:

$$p_{o\ half} \approx \frac{\pi\sqrt{2((\frac{17}{2} + d)^2 + (10 + d)^2)}}{2}$$

$d = 0{,}5$	$p_{o\ half} \approx 31$
$d = 1{,}0$	$p_{o\ half} \approx 32$
$d = 1{,}5$	$p_{o\ half} \approx 34$
$d = 2{,}0$	$p_{o\ half} \approx 35$
$d = 2{,}5$	$p_{o\ half} \approx 37$

In cm

Inside:

$$30 \cdot 2 \approx \pi \sqrt{2((\frac{17}{2})^2 + b^2)}$$

$$b \approx 11$$

Outside:

$$p_{o\ half} \approx \frac{\pi\sqrt{2((\frac{17}{2} + d)^2 + (11 + d)^2)}}{2}$$

$d = 0{,}5$	$p_{o\ half} \approx 33$
$d = 1{,}0$	$p_{o\ half} \approx 34$
$d = 1{,}5$	$p_{o\ half} \approx 36$
$d = 2{,}0$	$p_{o\ half} \approx 37$
$d = 2{,}5$	$p_{o\ half} \approx 39$

In cm

Inside:

$$31 \cdot 2 \approx \pi \sqrt{2((\frac{21}{2})^2 + b^2)}$$

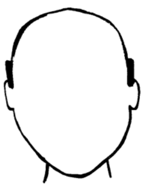
$$b \approx 9{,}2$$

Outside:

$$p_{o\ half} \approx \frac{\pi\sqrt{2((\frac{21}{2} + d)^2 + (9{,}2 + d)^2)}}{2}$$

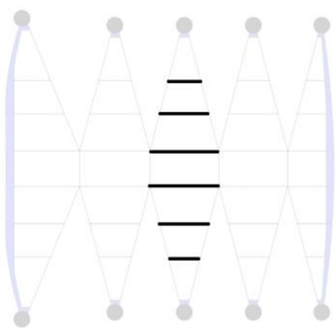
$d = 0{,}5$	$p_{o\ half} \approx 33$
$d = 1{,}0$	$p_{o\ half} \approx 34$
$d = 1{,}5$	$p_{o\ half} \approx 36$
$d = 2{,}0$	$p_{o\ half} \approx 37$
$d = 2{,}5$	$p_{o\ half} \approx 39$

In cm



Change in angle: 180^o

Amount of angles sides:



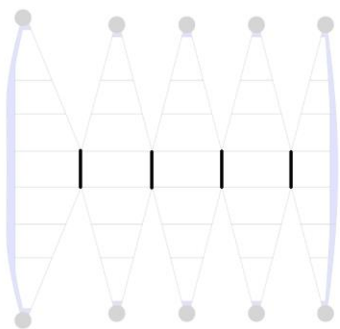
$6 \cdot 2 = 12$

Angle:

$180 : 12 = 15^o$

Change in angle: 140^o

Amount of angles sides:



$4 \cdot 2 = 8$

Angle:

$140 : 8 = 17{,}5^o$

7.3.3 Results questionnaire

The results of the measurements:

Gender	Length from ear to ear (cm)	Width between the shoulders (cm)	Class (Dutch school-system)
Girl	30	30	8
Girl	30	30	8
Boy	31	30	8
Boy	29	29	8
Boy	30	30	8
Girl	30	30	7
Girl	30	30	7
Girl	29	27	7
Boy	30	25	5

The design process is a collaborative participation, children are involved in the process and their opinion has an influence on the outcome of every step within the process. With this kind of process a questionnaire was made to make a decision for the appearance of the jacket. When making a questionnaire one has to think about what kind of questionnaire should be chosen, what fits the target group the most and with what kind of questions is the central question answered the most optimal. The central question of the questionnaire reads: 'What do children that go to elementary school think is cool?'

Because the answers of the children is about what they like, with a lot of open questions this questionnaire is a qualitative one. This can also be seen within the question with a blanc design of the helmet which children could decorate themselves. For children it might be hard to express themselves with words it is a lot easier for them to just show what they think is cool. After this drawing part there are question about what they drew and where their inspiration came from just to make it more clear for us.
To make filling in the questionnaire attractive to children again this process was adapted to their interests. With in mind that they watch a lot of YouTube videos a video was made that came with the questionnaire. A QR code can be found on this page which leads to the video.
(Link of the video: https://www.youtube.com/watch?v=_k7HX_HW6H0&t=30s)

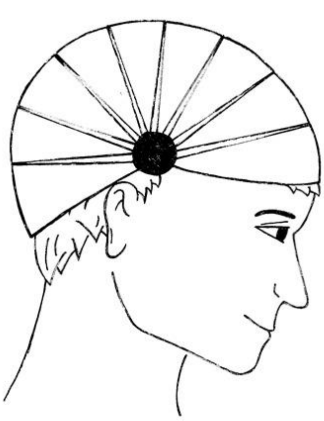
Within this video Lynn, the girl next door as the children from her street know her, introduced herself and told the children what she wanted. To make the whole process complete there was a box with stars, bows, glitter and other things that would make children curious. They could hand in their questionnaire by putting it in 'Lynn's Box'.
A table with the results of the questionnaires that were handed in can be found below.

7.3.3.1 Questionnaire

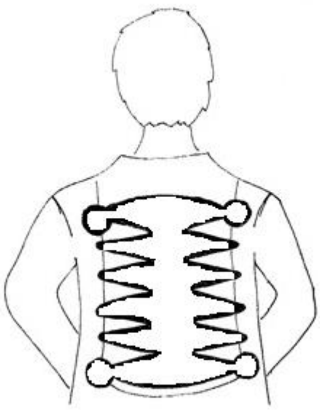
Ik ben een:
□Jongen □Meisje
Ik ben … jaar oud
Ik zit in groep … van basisschool ……………………
Mijn lievelingskleur is …………………
Dit vind ik stoer:………………………………
Draag jij wel eens een helm? ……………………………
Ontwerp je eigen jas en (onzichtbare) helm!
(Deze moet je zelf willen dragen!)

I am a:
□Boy □Girl
I am … years old
I'm in group … of preschool ……………………
My favorite colour is …………………
I think this is cool:………………………………
Do you sometimes wear a helmet? …………………………
Design your own jacket and (invisible) helmet!
(You should want to wear them yourselfs!)

De helm:



De jas:

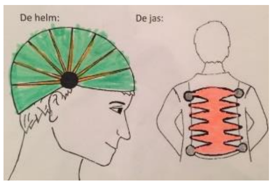
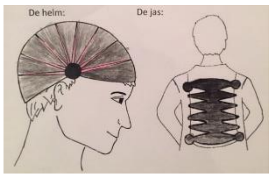


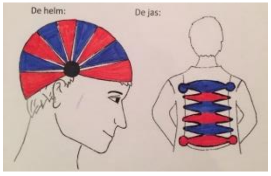
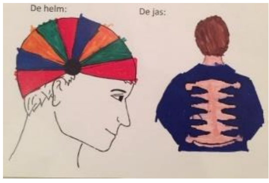
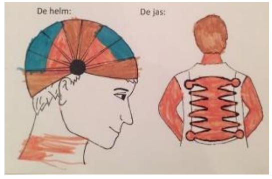
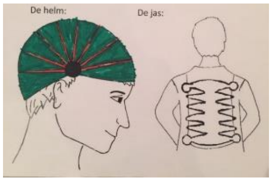
The helmet: *The jacket:*

Dit heb ik getekend:
……………………………………………………………………………………………
Waar heb je je inspiratie vandaan gehaald?
……………………………………………………………………………………………

This is what I draw:
Where did you get your inspiration from?

7.3.3.2 Table of results

Gender	Age	Group	favourite colour	Cool	Wears helmet?	Design
Boy	8	5	Green	Mountain-bikes	No	
Girl	10	7	Light Blue	Sneakers	No	

Boy	11	8	blue	Roller-coaster	when skiing	
Girl	5	2	Pink	Sports	Yes	
Boy	8	5	Red	The police	Yes, when cycling	
Boy	9	6	Blue	A lion	When skiing	
Girl	11	8	Bright colours	When a lot of people wear this design	No	

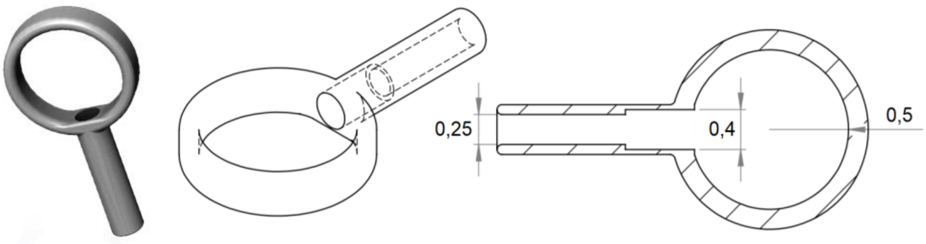
7.4 Realisation

7.4.1 3D printing of cable ends

7.4.1.1 Pulling part

The end of the wire can be sharp and dangerous while it could be close to the eyes of children. Also pulling the wire can be hard. By making a pulling part the end is shielded and pulling is made easier while a finger can be put through the hole to pull.

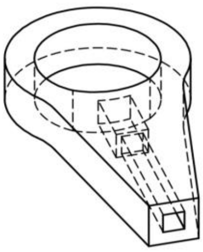
Shape 1:

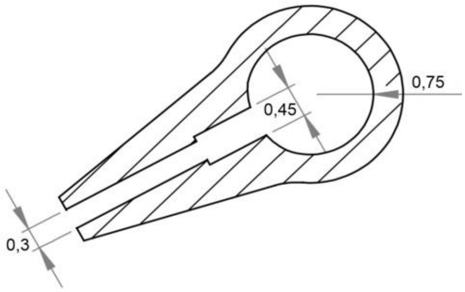


Printer: Ultimaker 2 extended
Nozzle Size: 0,4 mm
Layer height: 0,2 mm
Filament colour: Blue

The piece is very small. The details can't be done by the 3D printer and the cylinders are closed due to support material.

Shape 2: Support material is removed, the shape is less detailed and bigger.





Printer: Ultimaker 2 extended
Nozzle Size: 0,4 mm
Layer height: 0,2 mm
Filament colour: Blue

One side looks great, the other side is full of holes caused by faulty material flow.

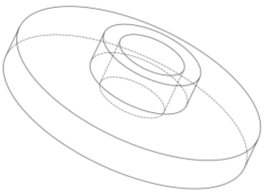
Printer: Ultimaker 2
Nozzle Size: 0,8 mm
Layer height: 0,2 mm
Filament colour: Yellow

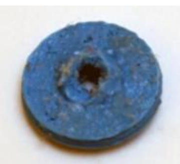
By using another printer with a bigger nozzle size the part turn out much better.

7.4.1.2 Stop part

The little cylinder goes through the last layer of the helmet. The bigger cylinder is in the back and prevents the wire from sliding through.

Shape 1:





Printer: Ultimaker 2 extended

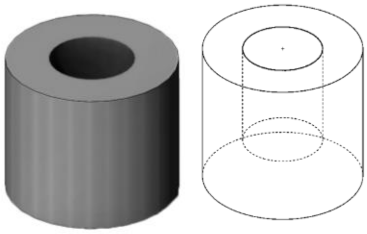
Nozzle Size: 0,4 mm

Layer height: 0,2 mm

Filament colour: Blue

The material flow wasn't constant and hole wasn't big enough to attach the wire sturdy. A thin part isn't necessary while there is enough room because of the thickness of the foam.

Shape 2: The little cylinder is removed while the printer wasn't able to print this small detail. The bigger cylinder is stretched out to make it possible for the wire to be attached more sturdy.

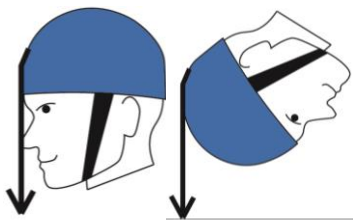


	Printer: Ultimaker 2 extended Nozzle Size: 0,4 mm Layer height: 0,2 mm Filament colour: Blue	The material flow wasn't constant and hole wasn't big enough to attach the wire sturdy. A thin part isn't necessary while there is enough room because of the thickness of the foam.
	Printer: Ultimaker 2 Nozzle Size: 0,8 mm Layer height: 0,2 mm Filament colour: Yellow	The material flow should be adapted regularly, especially with small objects. In the beginning the flow should be lowered from the regular setting to 95%, afterwards the flow should be increased to 137%. Like Troy says 'You should work with the 3D printer as if it were a sewing machine'.
	Printer: Ultimaker 2 Nozzle Size: 0,8 mm Layer height: 0,2 mm Filament colour: Yellow	When regulation the material flow the parts comes out fine.

7.4.2 Design of the jacket

7.5 VALIDATION

7.5.1 safety tests

<table>
<tr><th>Nr.</th><th>Test Name</th><th>Required by</th><th>Execution</th><th>Wanted result</th></tr>
<tr><td>2</td><td>Roll off test</td><td>EN 1078</td><td>A 4 kg weight is attached to the rear edge of a faced down helmet, this weight is is dropped from 2m. The test is repeated with the weight attached to the front edge of a face forward helmet.
</td><td>The helmet may shift but not roll off.</td></tr>
<tr><td colspan="5">Result:
This test couldn’t be done because of lack of time. The test could break the helmet which was still needed for the user tests. Because the user tests had more priority this tests wasn’t done.</td></tr>
<tr><td>3</td><td>Retention system test</td><td>EN 1080</td><td>A bucket is attached to the chip strap of the helmet. The weight must be increased till the retention system releases.</td><td>The needed force must be between 90 and 160 newton. Using
$F_z = mg$the minimum weight and maximum weight can be calculated. $m_{min} = \frac{90}{9,81} \approx 9,2\ kg$ and $m_{max} = \frac{160}{9,81} \approx 16,3\ kg$</td></tr>
<tr><td colspan="5">Result:
Because of lack of time there was no time to make the retention system. There is looked at a design and forces using Solidworks. But there was no useful outcome when looking at needed forces.</td></tr>
</table>

7.5.2 User test

What do we want to know? Research question: Will children use the helmet?
Who are the users that will be tested? The target group: children from 8 to 12 years old How much? 5 children for a user test one of them continues with a dairy test How will be made sure that the compete? Candy and make it feel like they are doing something really important, make them feel important because they like that. Important Since children are really influenced by other children it is important to test everything with all children at the same time. In this way they are in an environment that they will be in when they would really be in when using the head protection.
Data collection, what has to be answered? What do the children think of the jacket? Do they have any things to add? Extra How do the children use the jacket without any information? How many times will it cost before they can easily put it on their head? How many time does it take to put the head part of the jacket on?
Setting A playground At home At a school, on their outside area?

Nr.	Name	Execution	Wanted result
8	Dairy test	One of the interviewed kids takes the jacket with him/her and wears it for two days, especially when they cycle to school. What do they think of it now? Would they still buy it?	The child thinks it is a nice jacket and feel safe when they wear it.
Result: This test is not finished because of a lack of time. Before the children could test the helmet, it needed to be save, nothing should come lose. Especially when the child uses the helmet alone without a group member would could see problems and prevent possibly dangerous situations.			

7.6 RETENTION SYSTEM

The retention system must be able to self-release under a force between 90 and 160 Newton. This force is divided over the two sides of the chin strap. While the straps are pushing against the side of the head and while the direction of the force can be different the force on both sides will not be precisely half of the force pushing down. While the range where the retention system must fail is 70 newton the definition can be neglected, the force at both sides will be estimated to be between 45 and 80 Newton.

The design of the retention system is based on the standard locking system, which can be seen in a lot of helmet. But in the retention system the holes are not open making it not able to open the lock. The lock will only be released if there is enough pressure to reshape the inner part to make if come out of the outer part.

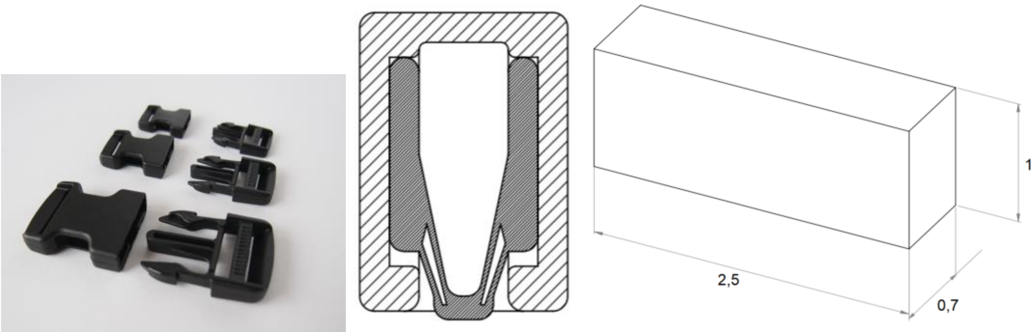
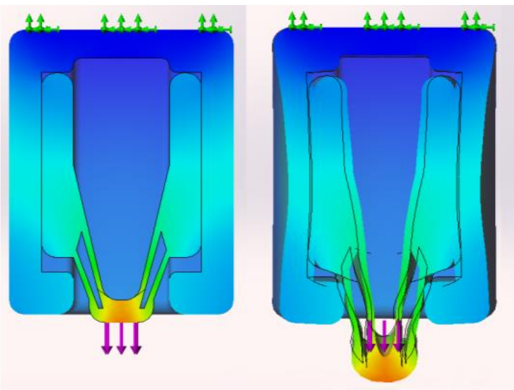
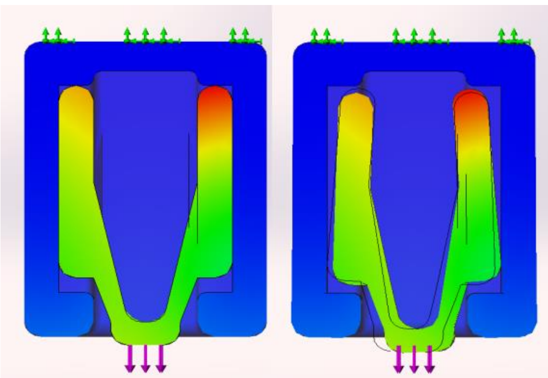


Figure 9

The needed forse is tested in Solidworks using simulation. The material used is pom, this material is also used in other snap locks 37. The two parts are made separately and placed together. The upper side of the outer part is fixed (green arrows), meaning this side is not able to move. A force of 60 Newton is added to the bottom side of the inner part (pink arrows).

	On the left the results are visible. On the right the deformed retention system is visible. It is visible that both parts are deformed, this can be explained by a fault in the simulation. Both parts are touching at the sides, this connections were fixed, meaning they are stuck to each other. To solve this problem the connections need to be set to no penetration, meaning they can touch each other but not intersect.
	The visible result show that the inner part deforms while the outer parts keeps it shape. There is still a fault in the simulation. The inner parts stays in its initial position and doesn't move down. This problem wasn't solved by doing a motion study. Also doing a simulation on only the inner parts was tried to see how the material deforms. But without the limitations of the outer part the deformation was not realistic.

7.7 BUSINESS PLAN

7.7.1 Canvas business plan[38]

Key Partners

- Helmet suppliers, they have a lot of knowledge about (selling) helmets. Besides that, they already have a customer base.

Key Activities

Improving product:
- Every six months a new design will be created to keep up with trends.

Customer service:
- A refund when the product malfunctions

Key Resources

- Employees
- Storage
- Distribution (transport)
- ADvertisement

Value Propositions

This product differs from other head protection and helmets because it is easy to transport. It is stored in the jacket, so no need to hold it when it's not used.

Besides that, it is also very hard to forget, as it is implemented in the jacket and therefore you always have t with you.

The above makes the product very user-friendly and minimizes the struggles that come with wearing normal head protection.

Customer Relationships

Personal assistence:
A sales representative will be in contact with the customers while they are purchasing the product. This customer service is also available after the purchase has been made,

Channels

The product will be sold in bikeshops and other outdoor-related shops (physical shops and online).

Customer Segments

Children of the age 7 up till 12 who ride a bicycle are the user of the product.

It is expected that their parents will be buying the product for them, which makes the them the customers.

Cost Structure

Costs per product:

Materials: €16,75
Marketing costs: €0,40 Transport and packaging: €0,40
Manufacturing: €12,1
Total costs: €29,65

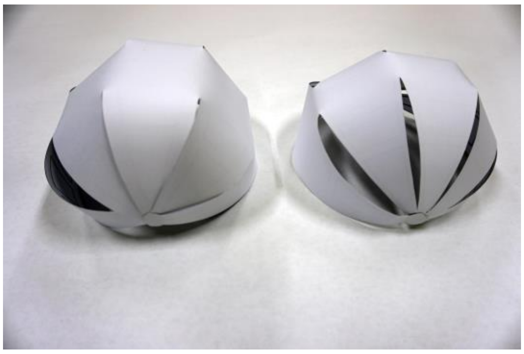
Revenue Streams

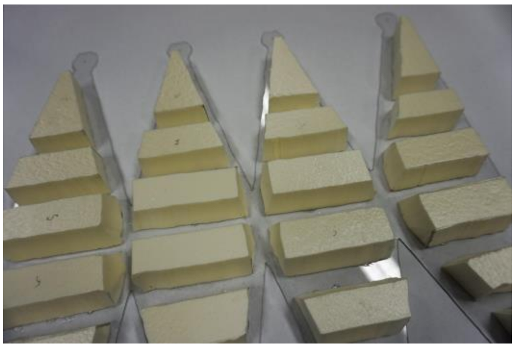
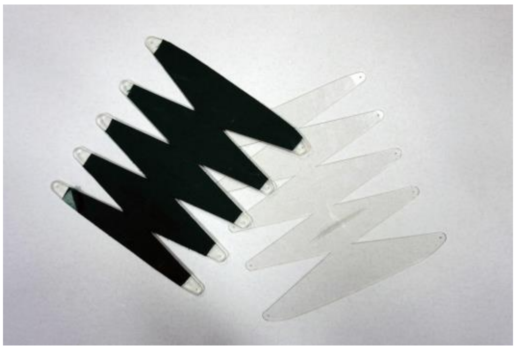
Totals costs per product: €29,65
Retail price: €75
profit per product: 45,35

7.7.2 Name and logo

The name of the design is HeadFirst! This name is chosen because it is one combination of words that says two things. When you fall with your head pointing to the ground and therefore will touch the ground as a first part of your body this is called a headfirst. Another thing that it says is 'think about your head first, a fall on the head can do so much damage and a therefore a helmet should be worn. The logo of the helmet is made to look like a superhero logo with the colors and the spikes, this to keep up with the overall theme.

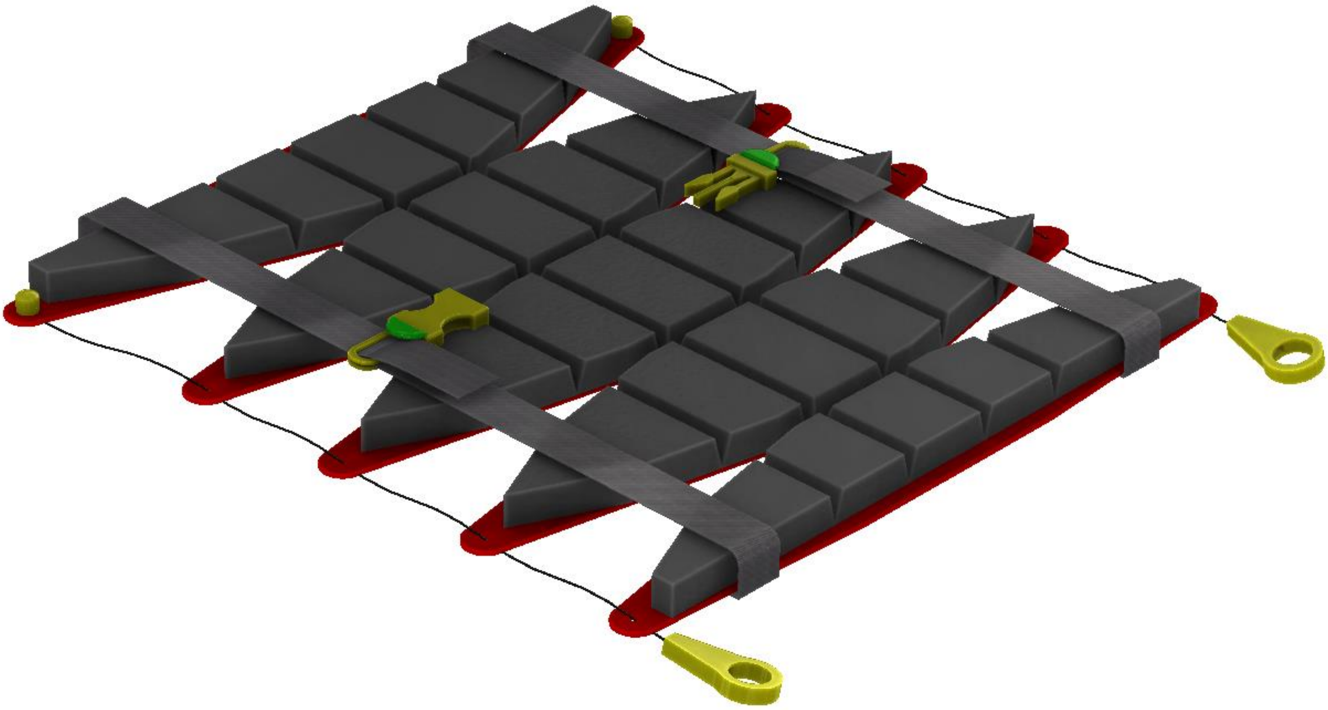
7.8 PROTOTYPES

	Paper prototypes to test the shape of the helmet. The left paper prototype has rounded sides, the right has straight sides. On the left the different segments of the helmet touch each other. On the right there is room in between. This room is good for ventilation.

 	Jacket for midterm demo day. This prototype is made out of cardboard and attached to a hoodie. The helmet needed to be flipped to put in on the head. This was very difficult to do on your own. Also the helmet would be very visible while the inside of the helmet would be on the outside. Another downside if this would be that the foam would be very vulnerable. When leaning against a wall the force will be spread end won't be big enough to damage the foam. But when there is force on a single piece of foam, like when something hits it, the foam could reshape resulting in helmet which is not safe to use anymore.
	Prototype with Pet-G and foam to test the shape with more realistic materials. When bend there is room between the foam pieces, this would result the energy not being able to spread to a bigger surface.
	Smaller pieces of Pet-G laser cutted in the shape of the helmet. With this smaller pieces tests could be done like soaking the material in water, bending in and out of shape, scratching, and heatpressing.

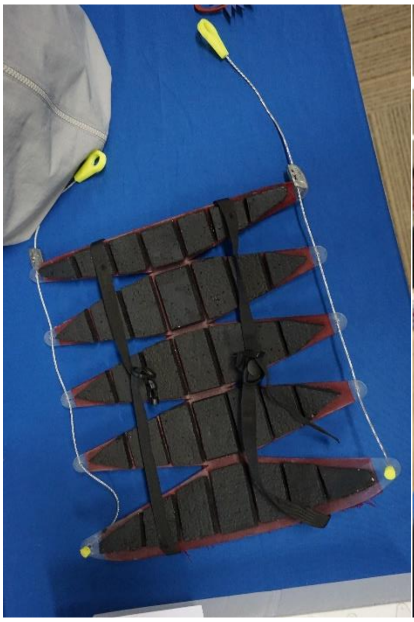
7.9 Extra visuals

7.9.1 helmet



7.9.2 jacket

7.9.3 Demo day



7.9.4 User tests

8 REFERENCES

Programs

Solidworks:
3D models, drawings and simulations.

Cura:
3D printing

Illustrator:
Drawings, lasercut

Pictures

Figure 1:
Girl, retrieved from https://static.pexels.com/photos/45861/child-girl-blond-long-hair-45861.jpeg

Figure 2:
Woman, retrieved from https://pixabay.com/p-1138435/?no_redirect

Figure 3:
Projection earth, retrieved from http://www.progonos.com/furuti/MapProj/Normal/ProjInt/projInt.html

Figure 4:
Bound pocket, retrieved from https://commons.wikimedia.org/wiki/File:Bound_pocket.png

Figure 5:
Old woman, retrieved from https://pixabay.com/nl/andrea-taylor-oude-vrouwen-portret-743885/

Figure 6:
Man, retrieved from https://www.pexels.com/photo/adult-blur-business-close-up-428341/

Figure 7:
Skater, retrieved from https://pixabay.com/nl/skater-park-schaatsen-levensstijl-821502/

Figure 8:
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Figure 9:
Snaplock, retrieved from http://www.plasticprop.com/

Experts

dr.ir. F.L.M. (Frank) Delbressine
Physics and materials

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