Introduction
The received design brief, "Design brief for a product that allows multiple tasks to be performed when walking in the rain," outlines the need for a product that allows the user to remain dry, and perform multiple tasks whilst walking in the rain. The following report will outline the process through which this product was designed. Firstly, the design brief will be reframed where necessary to enable an analysis of the possible engineering solutions to the problem. This will be followed by descriptions of three candidate conceptual design solutions. Finally, these solutions will be assessed to select the one which best addresses the reframed objectives and criteria.

Design Brief Reframing
The received product brief gives a clear picture of the design problem. It proficiently explains the need for rain gear that does not occupy one’s hands, and outlines the deficiencies of products currently in use. However, some deficiencies were present in the brief, which led to reframing before various engineering solutions could be assessed.

Evaluating Stakeholders
One of the deficiencies of the received design brief was that the stakeholders were not prioritized and the primary and secondary stakeholders were not distinguished. Additionally, the reasons as to why these particular groups were stakeholders was not given. Below is a table of prioritized stakeholders, along with their reason for being a stakeholder.

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users (primary)</td>
<td>· All criteria above should be met in order to provide the users with maximum convenience, efficiency and safety</td>
</tr>
<tr>
<td>Fellow pedestrians around product users</td>
<td>· If the product is too large or too wide or has sharp edges, etc. it affects the safety of people walking around the user. Consequently, the impact of the product on other walking pedestrians should be minimal.</td>
</tr>
<tr>
<td>(secondary)</td>
<td></td>
</tr>
<tr>
<td>Designer and Manufacturer</td>
<td>· Raw materials used for production should be easily obtained and have minimal cost</td>
</tr>
<tr>
<td></td>
<td>· The product should not require complicated manufacturing process</td>
</tr>
<tr>
<td>Environment</td>
<td>· Raw materials used on producing the product should be environmental-friendly, at least to the extent of being non-toxic to humans and other wildlife</td>
</tr>
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</table>

Reframing of Objectives
Firstly, objectives to try and make the product minimize environmental impact and manufacturing costs, along with the criteria that measured manufacturing cost and the raw materials' environmental impact, were removed due to the team's limited ability to analyze such features. Additionally, an objective in the brief stated that the product should have a "minimal impact on the physical appearance of the user." This objective was removed because of its inherent subjectivity. Having "minimal impact on physical appearance" was not properly defined. For example, it could be argued
that a transparent semi-circular bubble does not impact physical appearance because the transparent nature of the outfit means that what the user is wearing underneath is still visible and, therefore, not impacted. However, to some users, the idea of wearing a semi-circular bubble could be considered as ridiculous and having a huge impact on their physical appearance, regardless of whether or not the rainwear is transparent. After removing the objectives mentioned above, the reframed objectives are presented below.

The product is being designed for the following features:

1. Multitasking – the product should allow the user to perform multiple tasks
2. Portability – the product should be easy to store and carry after use
3. Durability – the product should protect the user and his/her belonging from rain and wind without collapsing
4. Safety – the product should be safe to the users and to the people around the users

Based off of these reframed objectives, the criteria were also reframed.

Reframed Criteria:

1. Time required by a normal user to implement the product [lower time required is better, metric: seconds]
2. The weight of the product [lower weight is better, metric: kg]
3. Volume of product in storage state [lower volume is better, metric: m³]
4. The force resisted by the product before failure/damage due to wind and/or rain [larger magnitude of force resisted is better, metric: N]
5. The surface area of the water and wind resisting structure/material of the product [larger surface area is better, metric: m²]

Constraints presented by the original design brief

1. The product should provide at least the same properties of the current umbrella and raincoats in terms of protection from the rain.
2. The product should not weigh more than 2kg
3. The product should have no sharp edges or blades
4. The product must accommodate at least one person
5. The product should allow a minimum of two basic tasks to be performed in a dry environment while walking in the rain
6. The product should not cost more than $25 dollars to manufacture
7. The product should not impact the line of vision of the user

Different ways of approaching the problem

Three different approaches to the problem were identified. They are outlined below.

1. First, the group could view the multitasking in the rain problem from the perspective that the main problem is that the user’s hands are occupied. So, existing umbrellas, etc are viewed as proficient at protecting users from the rain. They just occupy at least one hand, limiting the ability of the user to multitask. Consequently, the approach to this problem would be to design a product that supports an existing umbrella in some way that adequately protects you from the rain while freeing up the user’s hands so that he or she can multitask.
2. Another approach would be to view the problem from the perspective of raingear. The fundamental problem with raingear is that although it adequately protects the user and leaves both hands free, the raingear only protects the user’s body. Whatever the user holds in his or her hands gets wet, limiting the user’s ability to multitask. The approach to this problem would be to design raingear that the user wears that could protect a certain area around the user, allowing him or her to do multiple tasks in that area.
3. A final approach would be to design some form of rain protection that itself multitasks, meaning that it functions as more than just rain protection and increases the number of things that the user can do.
Concept 1

This concept was developed in mind for the user to have the maximum freedom during his or her walk in the rain, by creating a mini circular space with radius of 60 cm (approx. forearm's length), providing 360° protection.

In order to maintain the overall shape of the product, the top portion that acts as the spread of the umbrella should be made of rigid structures (a plate or a web resembling the usual umbrella). The wind- and water-resisting component (veil) is to be made of transparent material to give user vision, with an attribute to counteract the adhesive properties of rain that might obstruct the line of vision while in usage; to solve that, a layer of FEP (Fluorinated ethylene propylene) should coat the outer parts of the veil. Also the rigid horizontal members on the veil are to be separated such that the members itself do not cross into the line of vision. (see Fig 2)

To support portability, the veil is to have a zipper on its rigid horizontal members that will allow the partitions of the veil to be stored in smaller volume (see Fig 3); and therefore the veil should be of a material not prone to crumpling and fold marks.

All of the rigid members and the plate/web are to be moulded to the specified shape, particularly important since the horizontal members need to be folded for storage.

Fig. 1 - The general appearance and dimensions of

Fig. 2 - Specifics of the veil

Time:

With the design so far outlined, the implementation would require about 60 seconds:

- Opening the apparatus from storage state (15~20 s)
- Securing headgear (10~15 s)
- Unfolding the veils (20~30 s)

(Based on experiment with similar apparatus)

1 Michael Griggs
Weight:

Approximated value of weight²:

- Acrylic members (thickness 1.5mm): $2 \times (1.18 \text{kg/m}^3) \times (V) = 1.84 \times 10^{-1} \text{ kg}$
- Acrylic plate (thickness 1.5 mm): $(1.18 \text{kg/m}^3) \times (V) = 6.11 \times 10^{-1} \text{ kg}$
- Veil (thickness 1mm): $(0.95 \text{ kg/m}^3) \times (V) = 5.75 \times 10^{-1} \text{ kg}$

Total approximated weight: $1.4 \text{ kg}$

Sturdiness:

The average wind force that would be exerted on the product was approximated, with assumptions in variables³⁴, using

$$F = \frac{1}{2} \rho C v^2 A,$$

where $\rho$ is the air density (assumed $1.2 \times 10^{-3}$ kg/m³), $C$ is the drag coefficient (1.5 bluff), $v$ is the average wind speed (gust) ($10 \text{ m/s}$) [3], and $A$ is the tributary area (remo decide for yourself if we even need this or just simply say:

…was approximated to be $8.4 \times 10^{-2} \text{ N}$.)

Since the area of this product is the largest one of the proposed solutions, it will be subjected to the highest wind force. All work will be done by the neck and will cause severe strain on the neck if worn for a long time.

To compensate for the uncomfortable set-up of the apparatus, the headgear that secures the connection between the user and the veil should made of comfort foams, namely corresponding to the likeness of a bicycle helmet.

Protection against Water and Wind:

This criterion will be simply measured approximately with the given dimensions using surface area:

$$SA = SA_{\text{plate}} + SA_{\text{veil}} = \frac{1}{3} (4\pi r^2) + h^2 \pi r = (1.27 \text{ m}^2) + (6.05 \text{ m}^2) = 7.32 \text{ m}^2$$

Safety:

Although not explicitly said in the brief, safety is always the underlying criterion for any product for use. Approximately 50000 people fall yearly in Australia due to slipping on snow or ice on sidewalks because of the decreased coefficient of friction.
indicating rain will contribute to the likeliness of a fall. Having relatively small space to maneuver your hands in usage of this product could interfere with prevention of a serious injury. If the product were to give the user more space, it could be obstructing other pedestrians (see Fig. 3). From experiment, we concluded that the 50 cm radius would provide enough space for the user to break his or her fall from slipping while in use of the product.

Another consideration on choosing the radius was the height of the product. The radius was to be approx. 55 cm since it should not restrict leg’s range of motion (40~45°) (see Fig. 4)

**Concept 2**

The following candidate solution was drafted by using the concept of protecting the user only from above much like an umbrella, but without the need to occupy his or her hands. As demonstrated with the previous concept, covering the entire body can significantly increase the force exerted on the user by the wind and rain. Therefore, a plastic "hood" is used to protect the user’s proximity from the rain. Within the protected area under this hood, the user is free to perform basic tasks like eating food or using a mobile phone without getting wet.

The received design brief requires that the user’s hands be free while being protected from the elements by the product. To achieve this, the plastic hood is attached to a backpack. Note that the backpack is not retrofitted. Since the backpack and hood are worn by the user using shoulder straps, the hands are not occupied. Instead of using a more complicated mechanism to fold and stow the hood inside the backpack, the hood can be stowed outside as a backpack "cover." This is achieved by using a revolute joint and knuckle joint to enable the articulation required for this operation. To ensure the plastic hood stays in position while being used for protection, a rigid tubular frame must be implemented inside the backpack. This will increase the rigidity of the product, which will improve the metrics as measured in criterion 4. To improve the portability of the product, a mechanism to remove the plastic hood from the backpack can be implemented. This will allow the user to simply use the backpack when it is not raining.

To achieve a higher durability when presented with strong winds (criterion 4), the plastic hood can be made from a single piece of acrylic (polymethlamethacrylate) manufactured using injection moulding. This material is recommended because it is transparent, thereby allowing the product user to have unobstructed vision. Acrylic also typically has a yield strength of 65.5MPa. It was realised that droplets of water often congregate on plastics due to adhesive forces, potentially causing an obstruction of vision for the user. A layer of FEP (Fluorinated ethylene propylene) should be used to coat the acrylic hood’s outer surface to prevent water accumulating on it. FEP is applied here since its water absorption percentage is around 30 times lower than that of acrylic. Alternatively, an abrasion resistant coating of Lexan can be used in place of the hydrophobic one. However, acrylic is the material used to contribute to the hood’s structural rigidity since it has a higher yield stress than FEP and is cheaper than Lexan.

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5 Johanna Ruotsalainen  
6 Melissa Sabo  
7 Mechanical joints  
8 Altuglas  
9 Polymer Plastics Company  
10 Dupont
Using the dimensions of an average human\textsuperscript{7}, the following diagram displays the recommended dimensions for concept 2.

Concept 2 has certain advantages over a traditional umbrella, which can be treated as the current exemplar “solution.” Concept 2 is more durable (criterion 4) since the acrylic hood is to be made out of a single piece instead of the thin metal ribs used on traditional umbrellas that are prone to breakage in high winds\textsuperscript{8}. Even though concept 2 fares worse than the umbrella in criteria 1-3, it is very important to note that the concept allows the user to have his or her hands completely unoccupied (constraint 5). A traditional umbrella and concept 2 have a similar level of rain protection (assessed in criterion 5). However, note that unlike an umbrella, the direction of the acrylic hood cannot be adjusted to compensate for situations where the rain does not fall orthogonal to the ground due to winds. In conclusion, concept 2 is less compact and lightweight and easy to implement than an umbrella. However, concept 2 has is more durable, and keeps the user’s hands completely free.

**Concept 3:**

**Basics:**

The original candidate consisted of a four-point standard harness\textsuperscript{9} with a metal plate extending from the centre of the harness, with an umbrella protruding from the top of the plate. The harness is secured to the user using a buckle and tongue\textsuperscript{10}. The revised version of the candidate consists of a four-point standard harness with metal tubes attached to the backside of the harness, one on each side, which in turn are attached to tubes with a slit, that allow the umbrella tube to be "snapped" in (see figure 7).

**Evaluation based on Objectives:**

Both iterations of the umbrella harness meets a satisfies objectives, namely protecting the user from the rain and wind by providing cover, and allowing the user to perform multiple tasks by removing the need to manually hold an umbrella in addition to being safe to those around the user.

\textsuperscript{7} Michael Griggs
\textsuperscript{8} Info.com
\textsuperscript{9} Nicky Grist
\textsuperscript{10} Securon
Evaluation based on Constraints:

Upon assessment, the original concept was found to have met a portion of the constraints - specifically that it provides properties similar to that of an umbrella, it has no sharp edges or blades, it accommodates one person, and the product does not impact the line of vision of the user. The revised concept met the same constraints as the original, in addition to allowing the user to have both hands free while still being dry.

Evaluation Based On Criteria:

When evaluated against the criteria, we realized that the first iteration of the umbrella harness takes a long time to implement, relative to the implementation of an umbrella or raincoat. We were unable to find information that explicitly states the time that it takes to open an umbrella versus the time that it takes to put on a harness, however intuitively we sensed that putting on a harness, especially one that is on your back, takes a larger amount of time than simply pressing a button and opening an umbrella. This is why the revised version of the umbrella harness includes a strap that is similar to that of a backpack (see figure 2). The strap eliminates the need to fiddle with straps that lie behind the back of the user, thus decreasing the time needed to implement the product and increasing the ease of implementation. Also, by eliminating the rigid plate and replacing it with metal tubes the product becomes lighter through the removal of material and more compact when stored, as now the harness can be folded and the umbrella can be removed, decreasing the storage volume.
Final design concept selection

Weighted matrix and pair wise comparison:

A weighted matrix is used to select the two most effective design solutions. The criteria weightings were decided based on the relative importance allocated to them by team members. Finally, the two highest scoring concepts from the weighted matrix are directly compared against the criteria to select the optimal solution for the received design brief problem.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria weighting</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Time)</td>
<td>0.20</td>
<td>4</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>2 (Product weight)</td>
<td>0.05</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>3 (Storage state volume)</td>
<td>0.25</td>
<td>2</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>4 (Force resisted by the product before failure)</td>
<td>0.15</td>
<td>8</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>5 (Surface area)</td>
<td>0.30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>1.0</td>
<td>5.8</td>
<td>7.1</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Pair wise comparison:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Time)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2 (Product weight)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3 (Storage state volume)</td>
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</tr>
<tr>
<td>5 (Surface area)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Concepts 2 and 3 were selected for the pair wise comparison. Concept 1 lost points mainly because of its relatively large storage state volume and large time to implement on a user. In the pair wise comparison, concepts 2 and 3 were judged to be similar in the first 4 criteria. However, concept 3 was judged to be superior in criterion 5 since it has an adjustability and tilting feature for the attached umbrella that will be difficult to implement in concept 2. On the whole, the team judges that concept 3 will be the most optimal solution to the design problem. It is the simplest and lightest solution proposed that keeps the user’s hands free while keeping him or her dry.
Preferred candidate: Candidate 3 (Umbrella Harness)

The Basics:

Our final design (fig. 10) consists of a back member made of a malleable material (perhaps plastic or rubber), two straps similar to those of a backpack, a central strap, a head member made of the same material as the back member, two "bolts", and three metal tubes.

The Back Member:

The back member has a width of 40 cm, because the umbrella harness is meant to allow the user to still wear a backpack while using the product. According to J. Michael Griggs’ "Resources for producing theatre in the Loeb drama centre", the average width of a person's shoulders is about 45 cm. Thus, a width of 35 cm allows the user to wear the product, while at the same time not feeling like they are wearing two backpacks. The member is meant to be made out of a malleable material in order to allow for the natural bending and curvature associated with the product being worn against the body in a tight manner. The back member is 40 cm wide and 35 cm long. These dimensions were chosen again using Griggs’ resource as a reference; since the average length of a person's torso is 28 inches (about 71 cm) the length of the member was chosen so that it would reach about half way down the user's back and conform to the natural curvature of the spine when subjected to an inwards force.

The Head Member:

The head member is made up of the same material as the back member and has a metal tube attached to its top face. The head member extends 15 cm above the shoulders and contains the tubes that will support the weight of the umbrella.

The Tubes:

The tubes are one millimetre in thickness and diameter of 1 centimetre. These tubes are connected to the main tube located in the head member and are attached to a joint, which allows the tube to rotate on the plane perpendicular to the user's body.
The distance of these tubes from the shoulder of the user is adjusted by pulling, thus extending the tube in a manner similar to extending the antenna of a radio. An umbrella, when used, will be inserted into one of the two secondary tubes and tightened using the "bolt", freeing the hands of the user. In order to maximize the umbrella's protection from the rain, the joint allows the umbrella to rotate as previously mentioned. To rotate the umbrella either backwards or forwards, all the user must do is adjust the length of the main tube, such that when the umbrella rotates, its tube and handle sit under his or arm pit.

Main Features:

1. The Rotating Joint: The joint allows the user to adjust the coverage of the umbrella depending on the direction of the rain, thus increasing the ability of the product to protect the user from the rain.

2. The Extending Tube: The main purpose of the rotating joint is to allow the user to adjust the position of the umbrella however, if the tube was of fixed length, some users will not be able to make use of the joint because the handle of the umbrella would push against their bodies. By allowing the adjustment of the length of the tube, users of different sizes can use the joint feature, as it allows the handle to be placed in a common area - below the armpit and between the arm and the torso. Thus, this feature allows the product to be used by a wider range of people.

3. The Head Member: The main purpose of the head member is to allow the user to wear a backpack while still using the harness. The head member raises the main tube past the shoulders and is sloped to allow room for the straps of a backpack. The reason why the main tube is raised over the shoulders is that if the tube were at shoulder level, it would dig into the back of the user while a backpack is worn, making the user uncomfortable.

Conclusion:

Some attempts have already been made to solve the problem of keeping your hands available while walking in the rain (see figures 11 and 12 above), however we feel that our solution is unique and independent from the pre-existing solutions. Both of the previous solutions a) are not compatible with different umbrellas and b) do not allow for the adjustment of the position of the umbrella. While deciding on the final solution, we realized that we were not coming up with an original solution but rather building on a pre-existing solution (the umbrella itself), which follows the concept of TRIZ which in essence states that the majority of designs are not original but merely build off of a pre-existing design or solution.
References:


