InForm

Improving motorcycling safety through embodied hazards in motorcycle grips

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Abstract

It is a well-known fact that riding a motorcycle is more dangerous than driving a car. A crash is more detrimental for motorcyclists due to their vulnerability. One of the most important causes for a crash is because motorcyclists are easily overlooked. Products for increasing visibility, such as reflective jackets, do help somewhat, but their effectiveness relies on the attention of other drivers. Additionally, products to inform road users (including motorcyclists) heavily rely on visual and auditory attention. This report describes the design process of InForm, a set of motorcycle grips that help the rider navigate traffic safer by providing blind spot warnings, collision detection and intersection support, through tactile, peripheral feedback. InForm aims to improve the rider's environmental awareness. This should decrease the reaction time and risk of missing potentially hazardous details. Consequently, creating a safer ride, with fewer traffic accidents resulting from poor visibility.

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Introduction

Many contemporary interfaces rely on visual elements and require visual, focused attention of the user. Such visual attention cannot be divided over multiple activities simultaneously [2]. Strikingly, driving through traffic requires a high visual workload. 95% of the information is communicated through vision [9]. Increasing attention demanding activities could result in a cognitive failure where the driver simply misses clearly visible objects [9]. This poses a design challenge for activities that require constant focused attention, including driving in traffic. Sub-activities, such as following a navigation device or changing the radio channel should distract as little as possible from the main activity through well designed interfaces. These interfaces should communicate information and support interaction without risking cognitive failure. This automatically disregards auditory and visual feedback modalities [9].

A valuable target group is motorcyclists, for they are vulnerable road users. Studies show that, per travelled distance, motorcyclists are 20 - 40 times more likely to die in a crash compared to passenger car occupants [22,25]. In the Netherlands, this accounts for 52 and 44 fatal accidents in 2019 and 2020 respectively [7].

Intelligent Transportation Systems (ITSs) are concerned with safety enhancing technology for a variety of modes of transport. However, despite the high potential benefits, ITS development for motorcyclists is limited [1,4,25]. One reason for this is the incompatibility of ITSs for motorcycles because they are balance vehicles [1,4]. Literature and user studies illustrate that one of the most important hazards of motorcycling results from (lack of) visibility [18,22], which could partly be attributed to visual information overload [9]. Products for increasing visibility, such as reflective jackets, do help somewhat, but their effectiveness still relies on the attention of other drivers.

Combining the visual and auditory information overload with vulnerability of motorcyclists poses the following design challenge: how to design an interface that communicates information to improve the safety of motorcyclists, without risking cognitive failure? To be suitable for motorcycles, some additional intricacies apply. For example, interaction possibilities and space for an interface are more limited compared to cars.

This project focuses on communicating surrounding traffic to the motorcyclist, thereby improving their situational awareness and reaction time, which benefits the safety of powered two-wheelers (PTWs) [25]. By doing so, the motorcyclist keeps in control over their safety, without relying on the attention of other road users. This enables motorcyclists to navigate safely and timely out of potentially dangerous situations.

Communicating surroundings is achieved by the design of InForm (fig 1). InForm is a set of motorcycle grips that help the rider navigate traffic safer by providing blind spot detection (BSD), collision detection and intersection support, through tactile shape change. In contrast to contemporary blind spot warning lights, tactile feedback does not require visual, nor focused attention, but rather adds a layer of peripheral information on top of the rider's vision [2]. In other words, InForm creates an immersive experience by embodying surrounding traffic, while supporting motorcycling as the context-of-use.

InForm increases the rider's environmental awareness and decreases reaction time, and the risk of missing potentially hazardous details, by continuously embodying their surroundings in the periphery of attention, thus creating a safer ride.

Fig 1. InForm motorcycle grip.

Related work

This section discusses some areas of related work regarding traffic safety and some alternative feedback modalities. Firstly, common reasons for motorcycle accidents are mentioned, including an overview of intelligent transportation systems (ITSs). These relate to safety enhancement technologies for transportation in general. This is followed by the major causes for poor motorcycle visibility. Next, some benchmarking is done on blind spot detection products for motorcycles. Lastly, tactile feedback is discussed as alternative feedback modality compared to common visual feedback.

Causes of motorcycle accidents

Due to the vulnerability and high fatality rates for crashes upon motorcyclists, numerous studies have tried to map out the most important causes for fatalities. This information is essential when attempting to improve motorcycle safety [4]. Common causes for fatal crashes include improper use of helmets, truck involvement, alcohol and drugs effects, running off-road, and loss of control [4,18,22,23]. Loss of control due to stability issues or braking power were found to be relevant in almost all motorcycle crash types, which is why these are prioritized in the development for motorcycle ITSs [4,23].

ITSs are concerned with technologies that include ABS, lane assist, blind spot detection, collision warning, traction control, etc. However, motorcycles have been largely overlooked in the development of ITS technologies [1,4,25]. A partial reason for this is the incompatibility of some ITSs for PTWs (powered two-wheelers), such as automatic braking systems or airbags. These require modifications to be suitable for motorcycles [1,4], for example, airbag vests compared to integrated airbags in a car's interior. What's more, motorcyclists could benefit from motorcycle-specific technology, including balance assist, adaptive lights, and collision detection [1,4,25]. Collision detection (which is part of environmental awareness) could improve reaction time, where a 0.5 second improvement can prevent about 60% of the rear-end collisions, and 1 second can prevent about 90% [1,9].

Most of the aforementioned causes and innovations do however merely explain why a crash may be fatal, they do not explain why the crashes occurred in the first place. Notably, 75% of motorcycle crashes involve other vehicles [1,4]. According to the National Highway Traffic Safety Administration, most of these crashes are due to poor visibility of the motorcyclist [22]. Other drivers simply did not see them.

Poor visibility of motorcyclists

Poor visibility of motorcycles causes additional risks for accidents. The vulnerability of motorcyclists makes this a serious problem. Literature shows that the poor visibility can be attributed to three main causes.

Saccades

People see way less then we might think. Most of the image we see is filled in by our brain and only a small point is actually in focus. While scanning around, our brain creates a complete picture of all the small bits of information it received from rapid eye movements, called saccades. Since motorcycles make up a relatively small part of our vision, they tend to be missed by our eyes, especially if they are going fast. [3,15].

Selective attention

Selective attention causes inattentional blindness (fig 2), which occurs when people fail to consciously perceive a

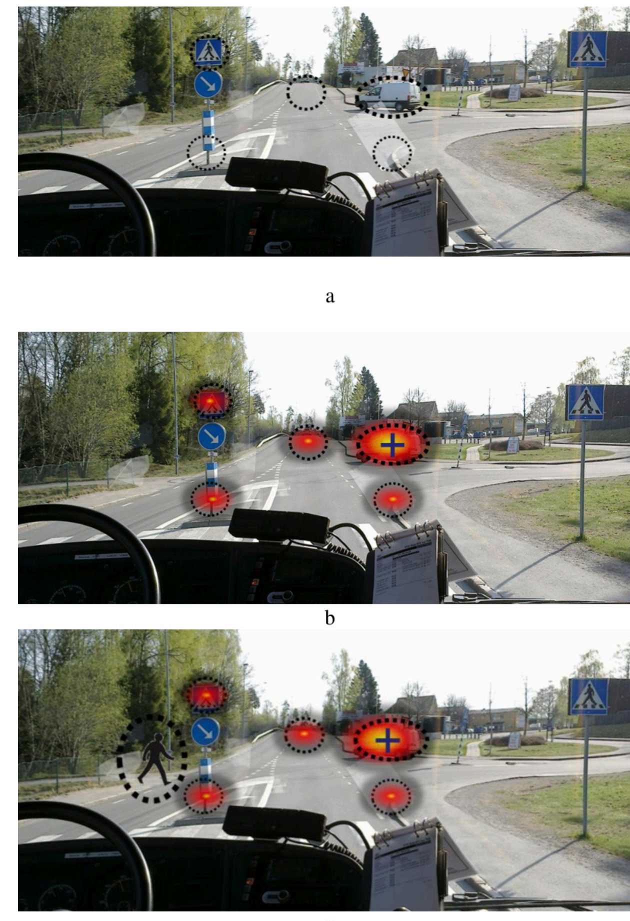


Fig 2. *"Conceptualization of inattention in terms of mismatches between the driver's actual resource allocation (heat maps) and that demanded by activities critical for safe driving (dashed rings). The attentional activation level is represented by the intensity of the heat map while the activation demanded is represented by the line width of the rings. The "+" represents the current gaze direction"* [12].

task-irrelevant object [6]. Car drivers, who search for hazards before crossing intersections are prone to ignoring a motorcycle, simply because it is not perceived as a danger to them [12]. In other words, the motorcycle is task-irrelevant while scanning an intersection and is suppressed from processing in the brain [8].

Contrast

People perceive motion and high contrast better. And since motorcycles are relatively small and usually black, together with the commonality for motorcyclist to wear black clothing, they will be much harder to see than larger and brighter coloured vehicles. Especially in low light situations, or when the sun blinds the person driving towards you [15].

Blind spot detection systems

There are a numerous blind spot detection (BSD) and collision detection systems for motorcycles on the market. Including: Senzar BSD [26], Bosch advanced rider assistance systems [5], Vigorplus [30], ThirdEYE [17], KiWAV BSD [19] and Ride Vision [24]. This confirms that the technology for identifying environmental hazards already exists. The most common product is a blind spot warning light in or near the mirror (fig 3), similar to those implemented in modern cars (fig 4). Popular sensors seem to be radar or cameras, located at the front and rear of the bike. Some of these systems also employ front and rear collision detection.

Haptic Steering wheel feedback

Driving through traffic requires a high visual workload and increasing attention demanding tasks could result in a cognitive failure where the driver simply misses clearly visible objects [9]. The designs discussed here apply haptics to the steering wheel of a car, as alternative feedback modality for communicating a variety of information.

The first design is a smart steering wheel cover [16]. The steering wheel changes colour and vibrates when the driver is driving too aggressively and wastes fuel. The second design employs a vibrating steering wheel cover to communicate blind spots, GPS navigation, parking assist, lane departure and forward collision by vibrating on different locations and intensities around the steering wheel [14] (fig 5). Third, a study was performed on the efficacy of blind spot warning systems (BSWS) and collision avoidance through a haptic steering wheel and seat belt. The steering wheel vibrates on the half (left or right) that requires attention, which was more effective than a vibrating seat belt [9]. The study showed that the haptic steering wheel did improve the collision prevention rate and avoidance distance, although more research to warning timing and vibration intensity is necessary to optimize performance.

Fig 3. Motorcycle blind spot warning light on a mirror

Fig 4. Blind spot warning light in car mirror.

Fig 5. Haptic steering wheel cover.

Knowledge gap & design opportunities

Motorcycles are vulnerable road users, yet they are being left out of safety enhancing innovations. Automated adjustments are increasingly being incorporated in car design, including adaptive cruise control, emergency braking, and autonomous parking [1]. Such automation is not suitable for PTWs, as they are balance vehicles. However, this does not mean there are no other ways to enhance the safety of PTWs. A benefit of motorcycles is their manoeuvrability and speed. These can be used in conjunction with informing technology in order to remedy the visibility hazards.

The BSD interaction with the user clearly did not receive a lot of attention. They all use warning lights, which have considerable issues. The way of providing situational feedback relies on abstract visual cues. Feedback could be missed, especially in bright sunlight, and it lacks information about the seriousness of the hazard. Even worse, it requires a trade-off between attention on the road or feedback lights, it cannot be parallel, thus it disrupts the motorcycling activity.

The haptic steering wheel designs show a promising alternative to solve the issue of visual information overload, but they are all designed for cars. The feedback is mapped to a circular steering wheel and needs to be translated to a straight handlebar/grips. The mapping between the feedback and intended action of the steering wheel is also much stronger than for motorcycle handlebars, since turning a motorcycle happens mainly through body position, not by turning the handlebars. Secondly, the use of vibration is not suitable for motorcycles, due to vibration of the engine and wind. Although, the application of tactile, rather than audio visual feedback, does seem to improve the reaction time, which is an essential aspect of collision avoidance. In addition, up to five different states were possible to differentiate according to [14], although the study did not elaborately report the results.

Design process

This section describes the activities of each phase of the iterative design process. The overall process exists out of three sub-iterations that include an ideation, prototyping and testing phase. The process started with an exploratory and empathizing phase to scope the design space of the project (See fig 6.).

Process overview

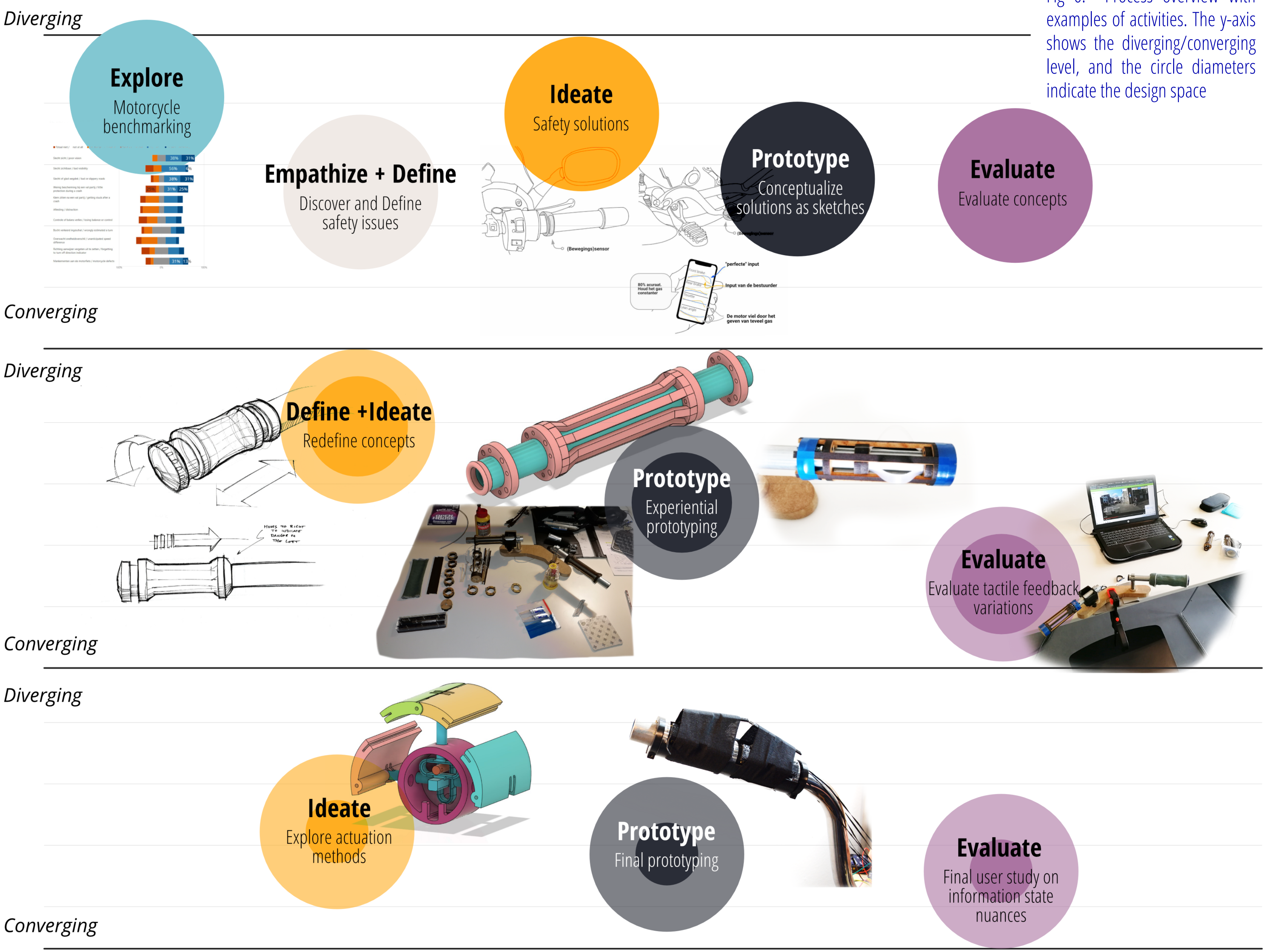


Fig 6. Process overview with examples of activities. The y-axis shows the diverging/converging level, and the circle diameters indicate the design space

Motorcycle benchmarking – exploring the design space

The project initiated with a general exploration of the design space related to motorcycling. In the process, many products were compared, to find which area seemed most appropriate to design for (see appendix A). Personal (first person) experiences from being a beginner motorcyclist pushed the design space in the direction of safety. Interestingly, most products on the market could be attributed with an aspect of improving safety. Some direct (such as advanced brake lights), and some indirect (such as navigation to help identifying intersections in time). Ultimately, a selection of common safety issues was extracted from the motorcycle accessories and systems (see identified safety issues list).

Modern safety related products seem to mainly focus on automating processes, in order to improve safety. This is also shown in the developments of ITSs, including emergency braking and automatic turn signal cancellers [1,4,28]. On the other hand, products that offer controls often consist of abstract buttons and elaborate menus [25] (fig 7). These are rather difficult to find without looking and while wearing gloves, not to mention the (visual) distraction they cause. Here is room for improvement. This already shows some interaction design opportunities.

Fig 7. Sena intercom system that uses button combinations to access functions.

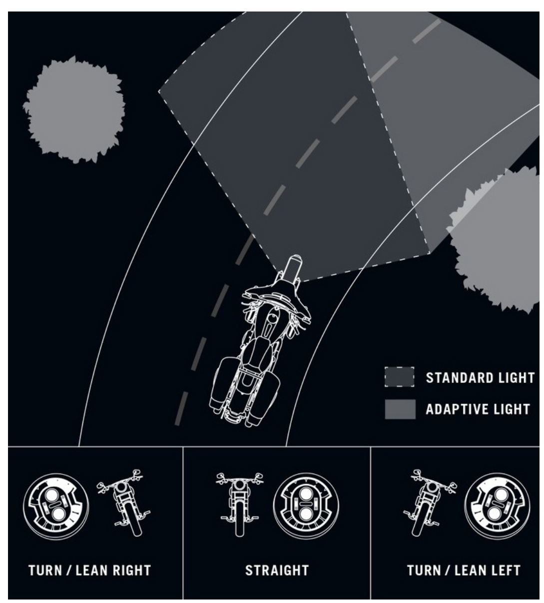


Fig 8. Daymaker adaptive headlamp.

Identified safety issues

- **Distraction / confusion**
  navigating, interacting (fig 7),
- **Wrongly anticipating corner radius**
- **Forgetting to turn off indicator**
- **Unexpected speed difference**
  engine braking
- **Poor visibility**
- **Poor vision (fig 8)**
- **Poor road conditions**
  holes, gravel, oil, water, lighting, blockades, sharp corners
- **Losing control**
  powerful motorcycle, one-handed control due to interacting (fig 7)
- **Insecure or unpredictable behaviour**
  re-starters, beginners
- **Getting stuck after a crash**
- **Poor protective gear**

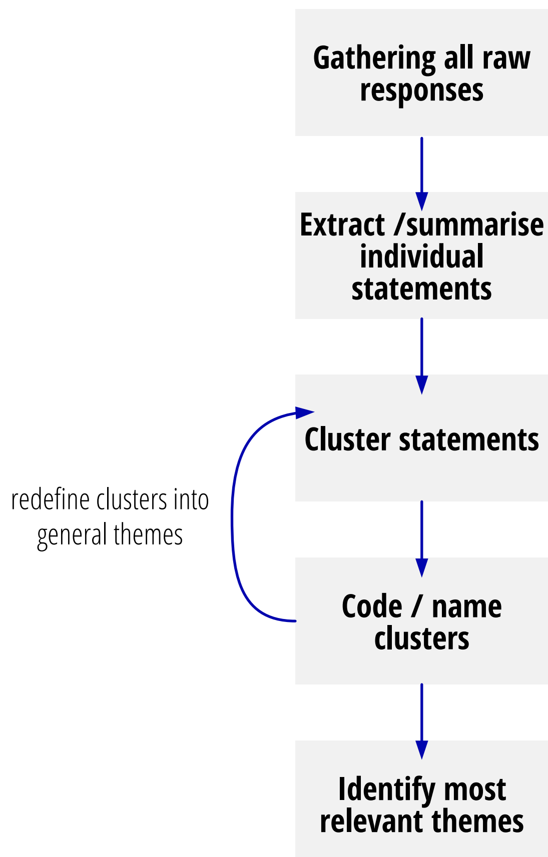


Fig 9. Inductive thematic analysis process

Discover & Define safety issues

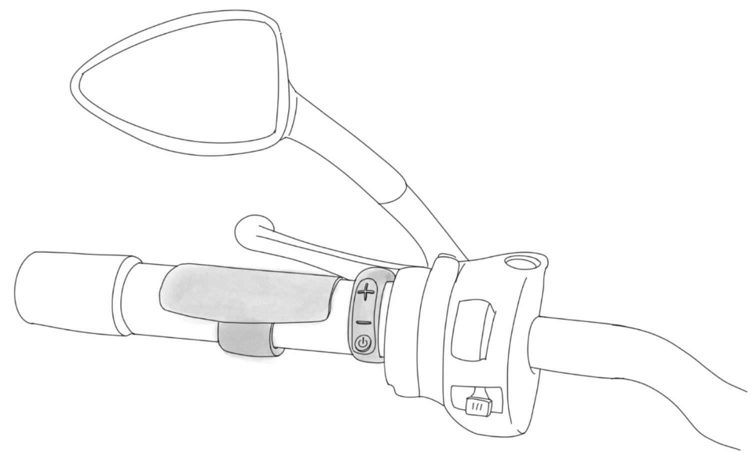
Now that the scope is narrowed to improving motorcycling safety, the next step is to find the which safety issues are most essential. A broad (second person) survey was conducted to gain insights into personal experiences of motorcyclists regarding motorcycle safety issues, which were then cross validated with a (third person) literature study and the identified safety issues from benchmarking.

Personal experiences survey

Through a set of closed and open questions (see appendix B), relevant themes related to motorcycling were found. 17 responses were analysed using inductive thematic analysis (fig 9). According to this study, vision and visibility were most relevant regarding safety. Other recurring themes include motorcycle maintenance, protective gear, and road conditions (see appendix B for more elaborate results). The safety issues regarding poor motorcycle visibility are confirmed by literature (see related work section). Hence improving visibility became the project's goal.

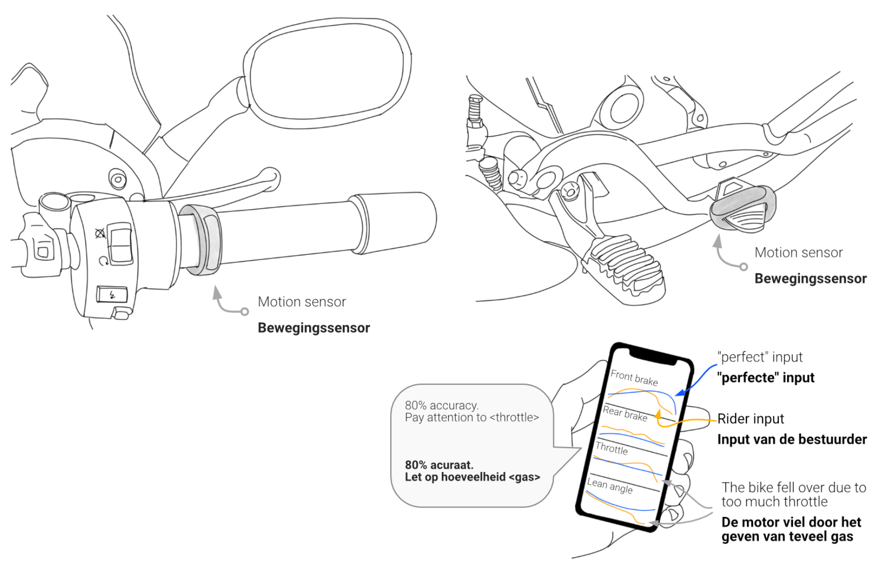
Ideating & Conceptualizing safety solutions

The initial benchmarking showed many opportunities for valuable motorcycling innovations. In addition, at this point in the process, the survey data served as a source of inspiration rather than an obligation. Therefore, besides only focusing on visibility, five concepts spanning over a wider range were drawn up and validated. This time, the validation served the purpose of identifying essential attributes of each concept and confirming safety issues. Each concept, as described next, relates to one or more safety issues (fig 10) (see appendix C).



Heated grips (add-on)

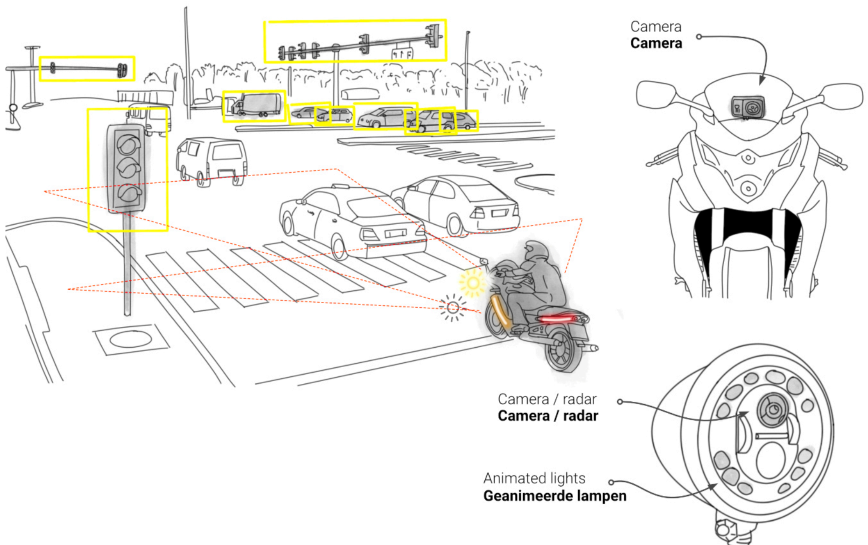
Heated grips add-on with intensity control. Add-on feature allows to easily turn all sorts of grips into heated grips, also for older bikes.



Driving Review

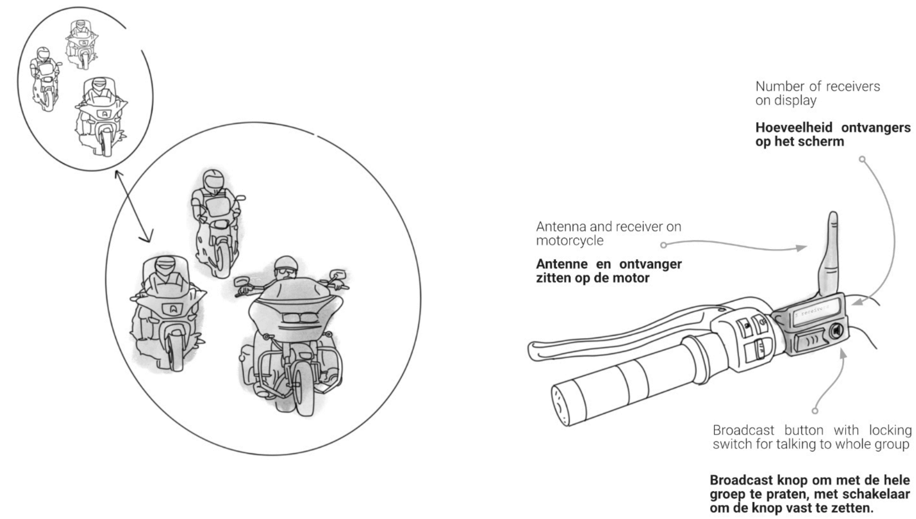
The app (or some other product) produces a "score" based on usage of controls, specifically meant for beginners and re-starters. It indicates which controls are most important that negatively (and positively) influence the score. This allows for self-reflection and more specific training insights for the instructor.

Fig 10. Five concepts related to safety improvements used for user evaluation (continued on next page).



Intersection visibility

A camera or radar recognises intersections and side-of-vehicles. Near intersections, additional lights start to animate to attract attention to the motorcycle and improve visibility.

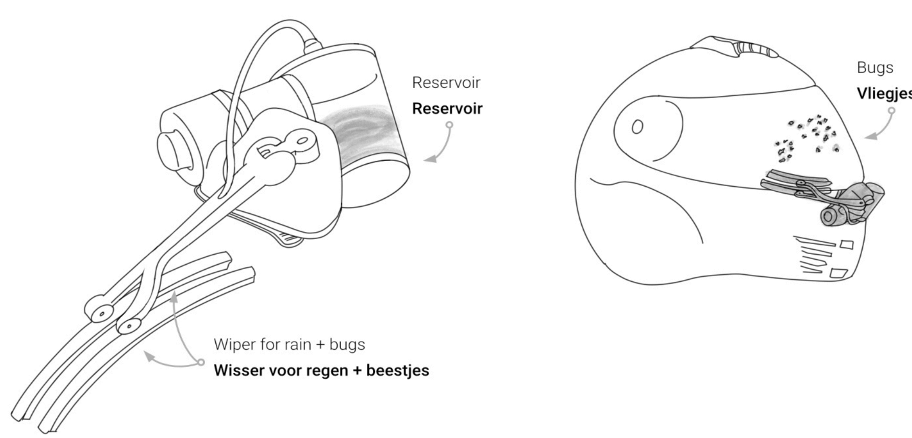


Dynamic group communication

Proximity based communication. Automatically talk with riders close to you for more dynamic group rides without overflowing the amount of conversation on the same channel.

Visor Cleaner

Visor wiper for a helmet with an additional reservoir filled with cleaning fluid to directly clean bugs from the visor.



Concept Evaluation – Identifying essential safety attributes

The aforementioned concepts are evaluated in a more extensive survey. This survey received 65 responses. Each concept was evaluated in terms of general opinion, pitfalls, usefulness, and relation to improving safety. Results were analysed using grounded theory method [10,11], described in detail in appendix D.

Visual and auditory distraction was the most mentioned critique. Which resonates with literature about visual and auditory information overload in traffic. Obviously, this needs to be prevented, pushing the project towards tangible and embodied interaction. Other important aspects were to improve visibility, not impact the handling of the motorcycle, and preferred built-in features rather than add-on “gadgets”. Noteworthy is the expectation to blindly rely on the intersection visibility concept, and contradictory become less careful.

Fig 11. BMW handlebar controls offer extensive control options during riding, at the expense of (visual) attention to traffic.

Redefining concepts - tactile (embodied) blind spot warnings

Expert evaluation

The concepts and preliminary results were also discussed with an interaction design expert from Bureau Moeilijke Dingen, a design studio in Eindhoven. From this discussion, an interesting new direction emerged, namely, communicating visibility to the motorcyclist, instead of improving the visibility for other road users. By doing so, the reliance on other driver’s attention and potential blind trust in the system are eliminated.

Tactile feedback

The handlebar grips were of special interest because they are in constant contact with the hands, making them well suited for providing non-visual and non-auditory feedback. Naturally, this opened up the opportunity to use tactile feedback. In addition, the grips could function as input device to support interaction. Originally this idea included moving some of the controls (indicators, horn, lights, etc.) to the grips. Adaptivity would have to dissipate some of the complexity found on modern motorcycle controls (fig 11). The underlying safety issue here is loss of control, which occurs when looking for the correct button. However, this idea was let go to prevent mixing multiple design goals, and communicating visibility seemed more relevant regarding safety.

At this point, the question remains: how to communicate visibility? Both in terms of feedback and the information it represents. Since motorcyclists are easily overlooked [9,18,22], and cut off as a result, communicating surrounding traffic seemed most appropriate because they form potential hazards. This is similar to what blind spot warning systems communicate. The major difference, and therefore value, is the feedback type. Tactile, in contrast to visual feedback, can be perceived continuously and in parallel with the visual information of the motorcyclist [2].

Prototyping tactile situational embodiment

Exploratory prototyping informed insights on two dimensions: interaction modality (radical vs. incremental) and information rate (pro-active/ continuous vs. reactive). Each dimension was explored with a couple of sketches and low-fi prototypes. These low-fi prototypes were then detailed for validation by means of Experience prototyping [20]. The goal of the prototypes is to find what combination of each dimension yields the most intuitive and effective feedback about blind spot visibility.

Three types of tactile feedback were prototyped, namely motion, shape change, and force feedback (fig 11). Originally, rotation was included as a fourth feedback type, but this was abandoned due to the close mapping and impact it could have on the throttle. Literature on alternative (tactile) feedback modalities for communicating blind spot and collision warnings only use vibrations, which are not suitable for application on a motorcycle due to engine and wind vibrations.

In addition to blind spot warnings, the motion and shape change feedback include collision detection and intersection support.

Fig 11. Three types of tactile feedback to communicate surrounding traffic. Top to bottom: force, motion and shape change.

Force feedback (fig 12 - 13)

Force feedback was implemented in the indicator switch. This enables the feedback type to be reactive/passive, as it responds to an initial input. This implementation allows testing both the information rate (reactive) and modality (force). When the direction of the indicator requires additional attention, a force relative to the seriousness of the hazard will push back on the switch. The force is applied using tension-springs at various locations to ensure consistent feedback.

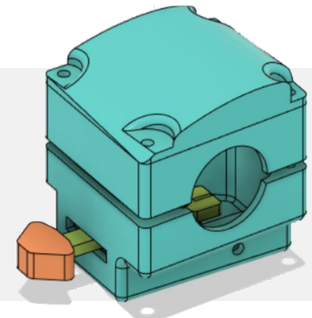


Fig 12. CAD model of force feedback switch.

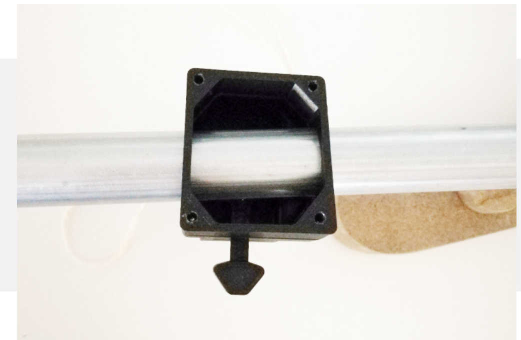


Fig 13. 3D printed model of force feedback switch.

Motion feedback (fig 14 - 16)

Motion feedback was implemented in the grips. Feedback in the grips can be pro-active as it is provided continuously and autonomously. They move left or right on the handlebars to guide the rider away from potential hazards. Actuation of the motion was achieved by pulling on thin threads attached to both sides of the grips.

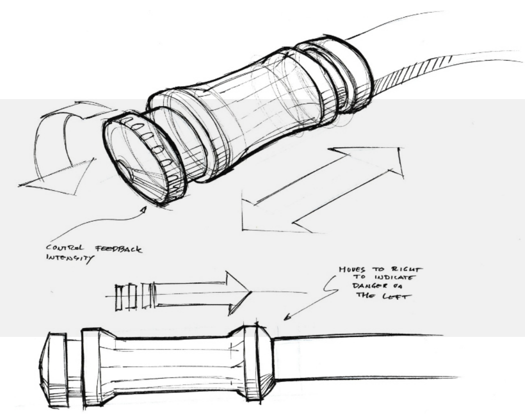


Fig 14. Motion feedback sketch.

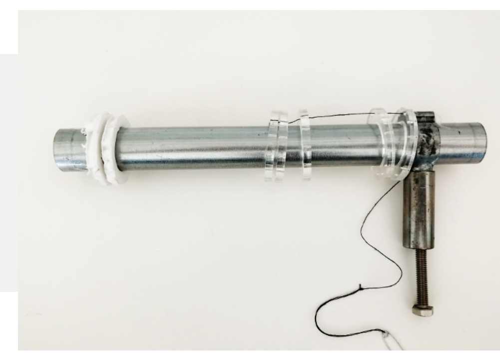


Fig 15. Motion feedback prototype. Motion achieved through sliding rings, actuated by strings.

Shape change (fig 17 - 21)

Finally, a form of shape change was implemented in the grips. The outsides of the grips grow in diameter to communicate obstacles, i.e., closing in traffic. Shape change was achieved by pulling a slider that pushes out flexible plastic strip. This feedback is also pro-active.

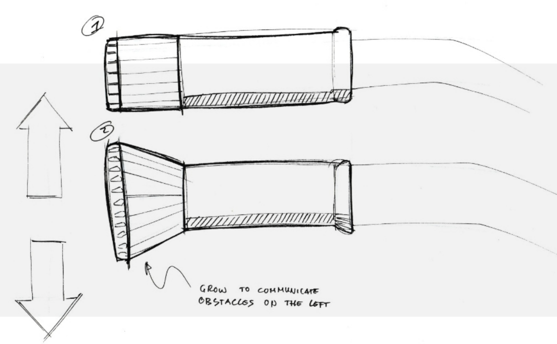


Fig 17. Shape change sketch.

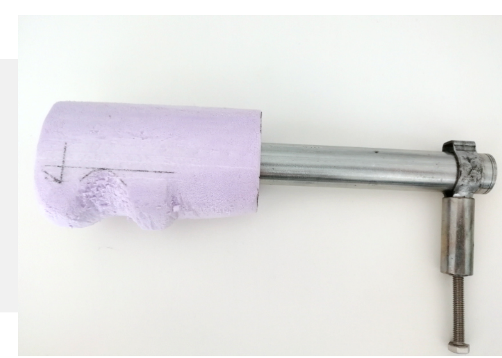


Fig 18. Shape change feedback prototype. Shape change was explored through a rotating shape.

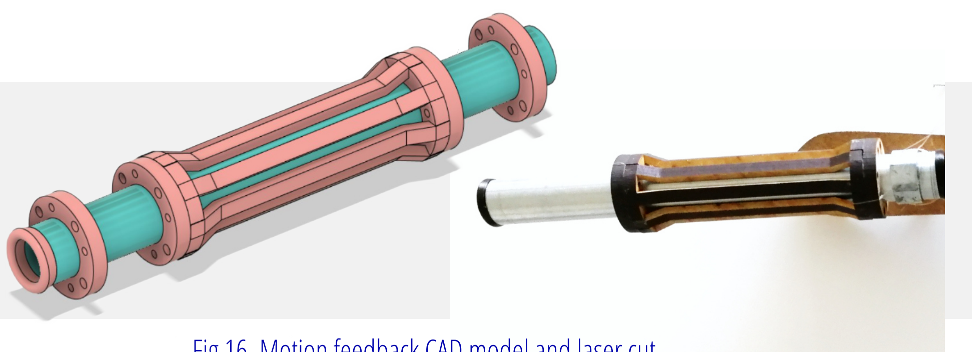


Fig 16. Motion feedback CAD model and laser cut prototype.

Fig 19. Shape change feedback prototype with foam.

Fig 20. Shape change feedback prototype with akyprop, a stronger flexible material.

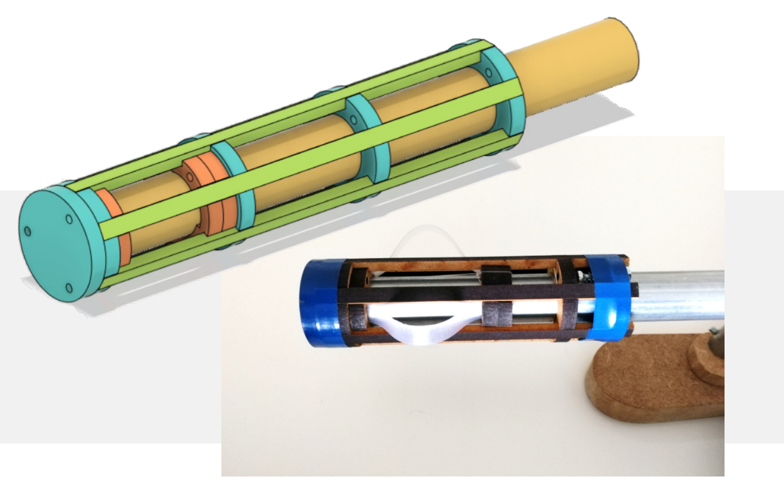


Fig 21. CAD model and laser cut prototype of shape change prototype.

Evaluation of tactile situational embodiment

Method

For the test, a first-person motorcycling video was used together with the prototypes (fig 22). To gain the insights, a concurrent think aloud protocol was followed, by which participants are asked to verbalize their experiences in that moment [20]. After the scenarios were completed, a short follow-up interview took place to learn about the participants' actions and experiences in more depth. Results were analysed using deductive thematic analysis, with the themes being intuitiveness, effectiveness, and additional features. Comments of participants were summarized and categorized according to these themes.

Results

The shape changing feedback was intuitively linked to guiding attention left or right, and often interpreted to warn about obstacles (or a shrinking space cushion). Motion feedback and force feedback for these tests were much less clear (both intuitively and effectively). The motion feedback felt most aggressive and even imperative, and potentially impacted the handling of the motorcycle. Also, the force feedback was often not clearly noticed. Especially without comparing to the "non-force" direction.

The shape changing grips are more nuanced in giving feedback, focused on informing the rider, whereas the motion feedback is much more guiding towards a specific action. This makes shape change also useful for intersections and communicating the distinction between someone in your blind spot and you in someone else's blind spot. See appendix E for more detailed results.

A combination of shape change and motion seems to hold most potential, where shape change provides environmental information continuously, and motion feedback triggers an action when absolutely required (e.g., near impact, merging issue). Since the motion feedback will be relatively rare, it will therefore not be habituated or overlooked. Continuous feedback is expected to become part of the motorcycling experience, and inform the rider in their periphery of attention, so they are aware of their environment without explicitly noticing the shape change. This could make an appropriate response faster to execute [9] and thereby significantly lowering rear-end collision risks [1]. These findings informed the final phase for the design of InForm: Informing through form (shape).

Fig 22. Experiment setup. A laptop to show first person motorcycle videos to simulate a context. The handlebar and grips prototype clamped to the desk to simulate tactile feedback.

Requirements

From the literature studies, testing and benchmarking, a set of requirements are established. Their relevancy is explained next to each requirement. These requirements function as a set of success criteria for the final design. They include both functional and non-functional requirements.

Requirement	Relevancy
1. Improve situational awareness	*Improving safety (main goal) by alerting motorcyclist of potential danger and lowering reaction time [30].*
2. Don't cause distraction during riding	*Causing distraction creates more danger, while the feedback design aims to lower (visual) distraction. Additionally, distraction was the main criticism of motorcyclists in an early concept evaluation study.*
3. Don't take over control	*Motorcycles are balance vehicles; automated actuation could be dangerous [19].*
4. Solution must not impede handling of the motorcycle	*Motorcyclists expressed their concerns about the risk of affecting the motorcycle handling in an experiment about different feedback types. Losing control is a significant reason for motorcycle accidents [20,19].*
5. Water and shock proof	*The grips are used outside and are subjected to the weather and constant vibration of the engine.*
6. Digestible feedback rate	*Too much feedback could result in an information overload, risking the feedback to be annoying or even distracting. This concern was also highlighted in the feedback type experiments.*
7. Clearly perceivable and distinguishable feedback while riding (wind, rain, vibrations)	*Unnoticeable feedback won't improve situational awareness. The feedback needs to be noticeable in all weather conditions since the visibility aggravates in poor weather conditions.*

Final design: InForm

The aforementioned phases led to design of InForm. InForm is a set of motorcycle grips that help a motorcyclist navigate traffic safer by providing blind spot warning, collision detection and intersection support through shape change (fig 23). Informing the user about their surrounding allows for quicker response times and better awareness of potential hazards, which is especially relevant for motorcyclist, as they are easily overlooked. The feedback is nuanced to differentiate between hazards in front, beside, and behind the user. In addition, they inform about closing-in traffic (fig 24 - 26).

Shape change does not require visual attention of the user, making the modality appropriate for application in traffic. Alternative tactile modalities were less effective or appropriate, in that they influence handling of the motorcycle or were not intuitive enough.

Fig 23. InForm changing shape at the center-inside location

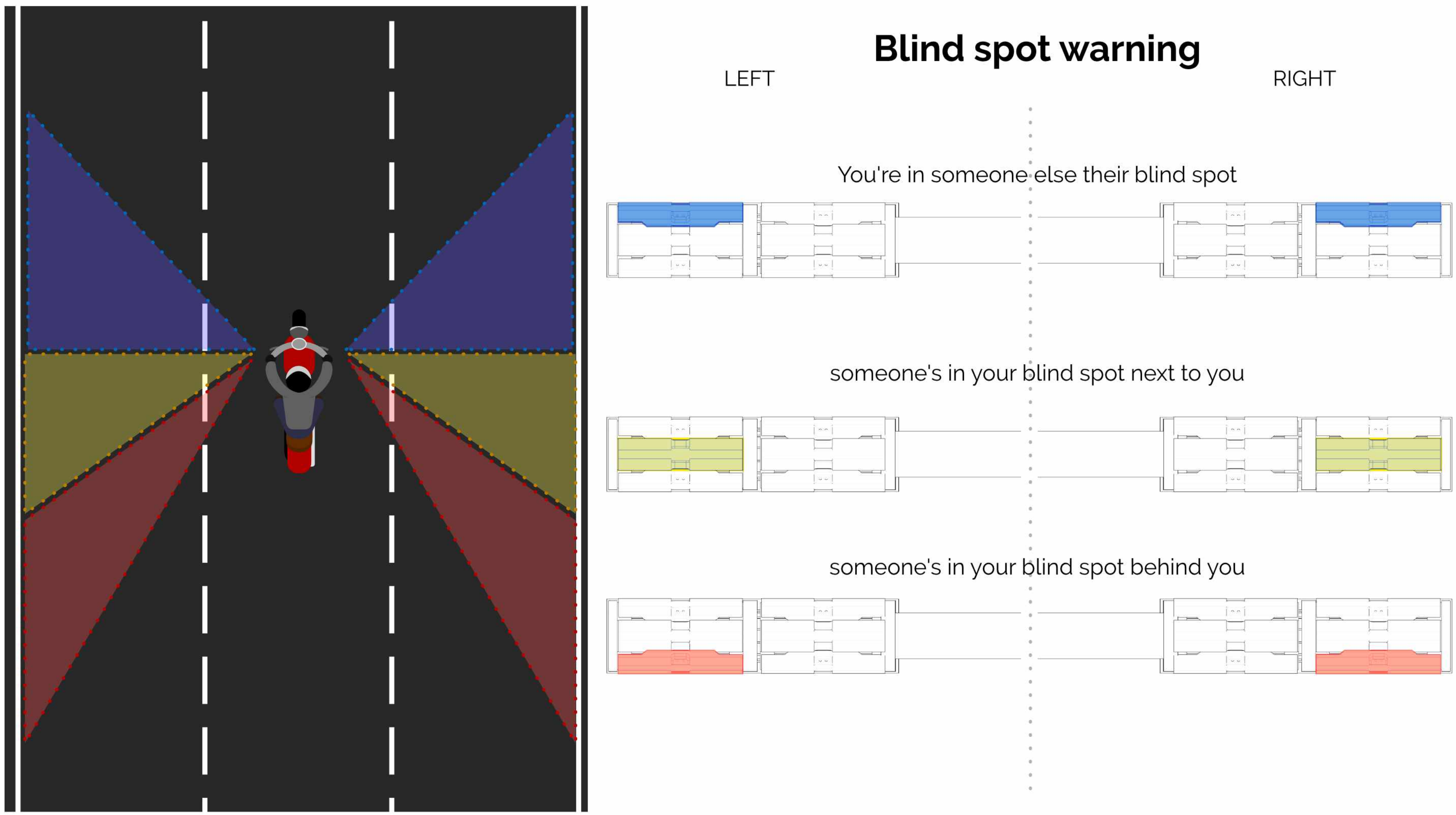
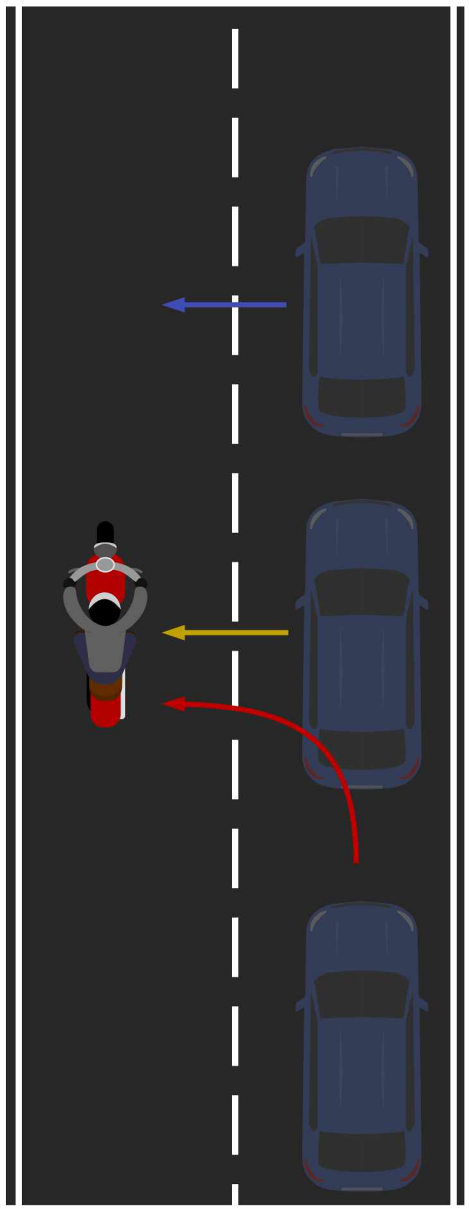


Fig 24. Blind spot warning is embodied at the outsides of the grips, relative to the location of the vehicle in the blind spot.



Collision detection

double actuation for closing in traffic,
depending on their relative location

Fig 25. Collision warnings are provided through both outside and inside panels, relative to the location of the colliding hazard.

Intersection support

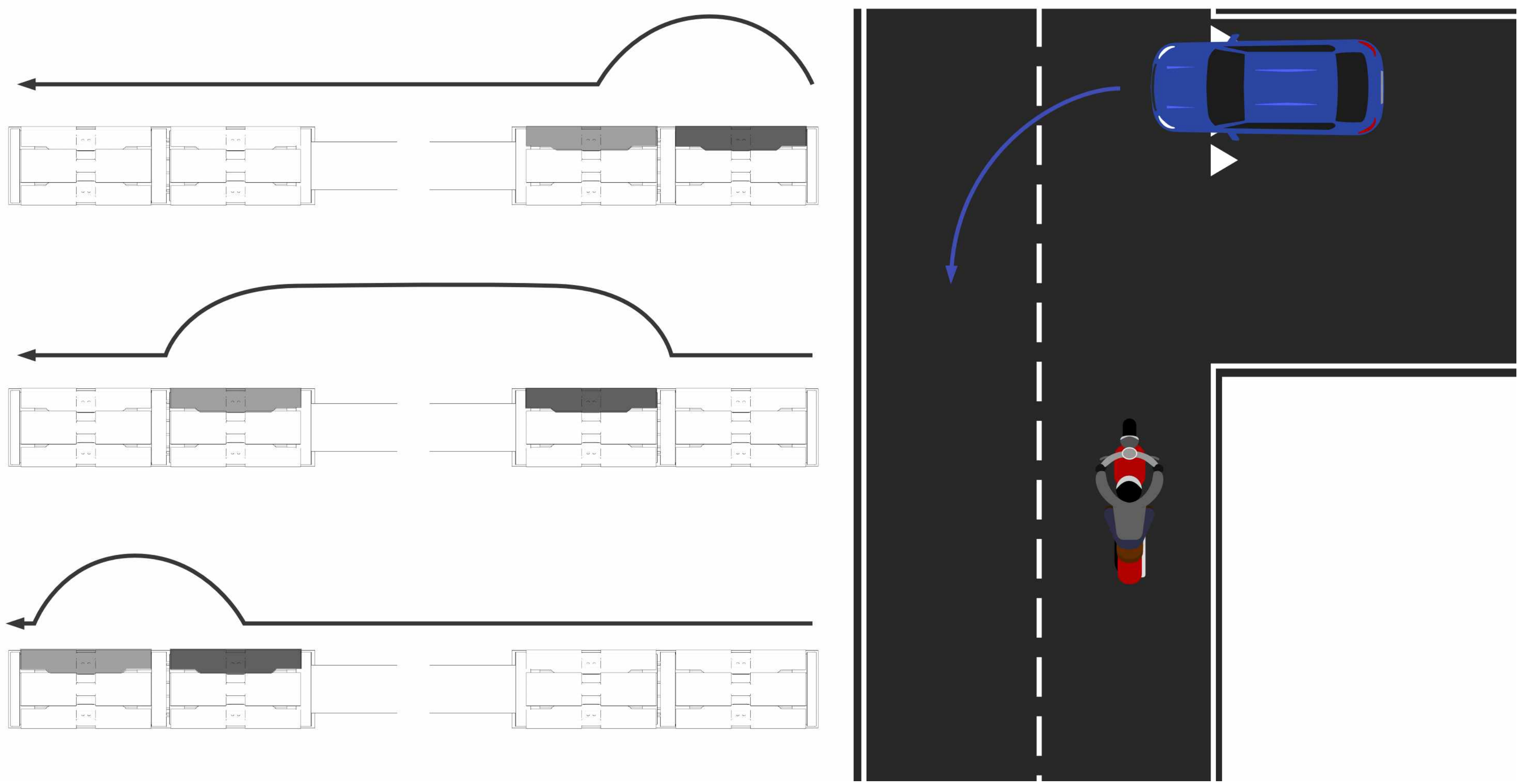


Fig 26. Intersection support is embodied through a shape "wave" through the front of the grips that point towards the hazardous vehicle.

Exploration of actuation

A variety of methods could be used to achieve shape change. The final iteration explored two approaches: Mechanical and pneumatic shape change. Each of these includes a variety of actuation methods (fig 27). The nuanced feedback is achieved through actuation of six individually controllable panels. Two in front, two on top, and two at the rear of the grips (fig 28).

The pneumatic actuation was tested using two balloons constrained by a cardboard tube (fig 29). This approximated a plunger pump type of actuation (fig 30). Some experimentation with different sizes and locations of the balloons resulted in the conclusion that pneumatics feels too friendly and playful, due to its soft and bouncy characteristics. This does not fit the message that is being communicated. Therefore, mechanical actuation was used for the final prototype.

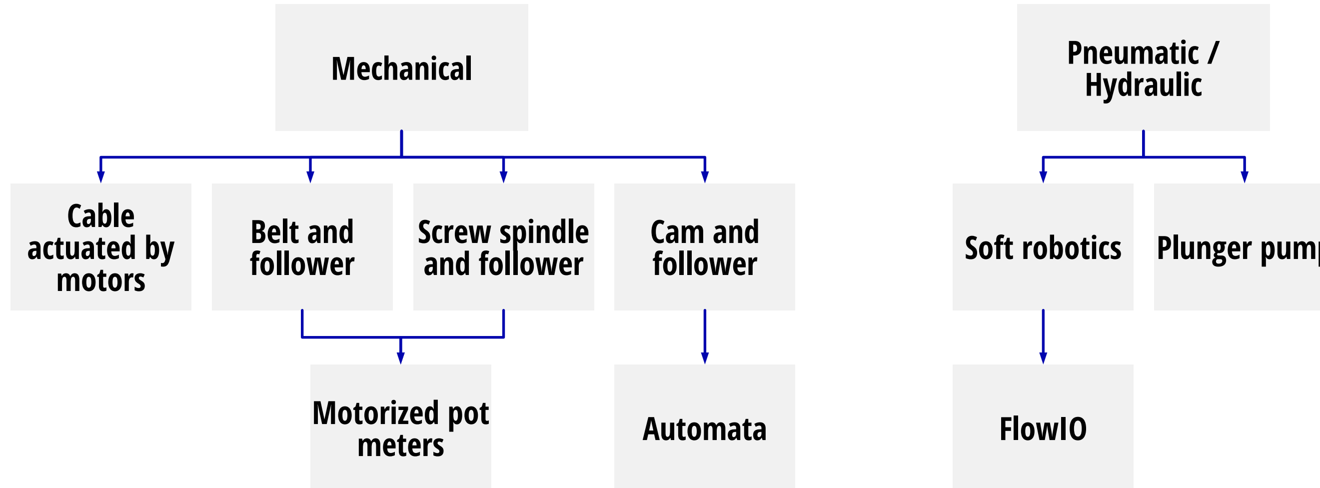


Fig 27. Overview of explored actuation methods

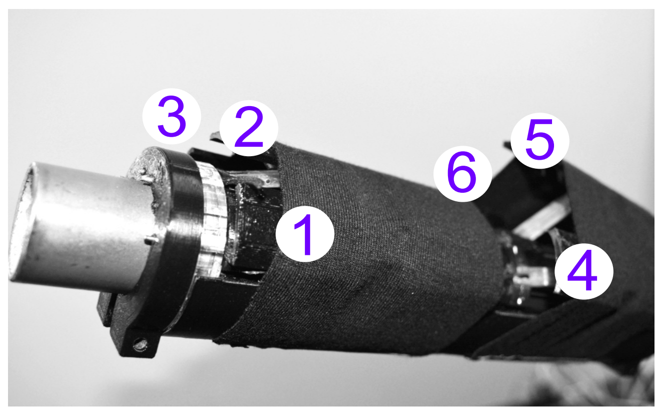


Fig 28. Six individually movable panels to control the shape change.

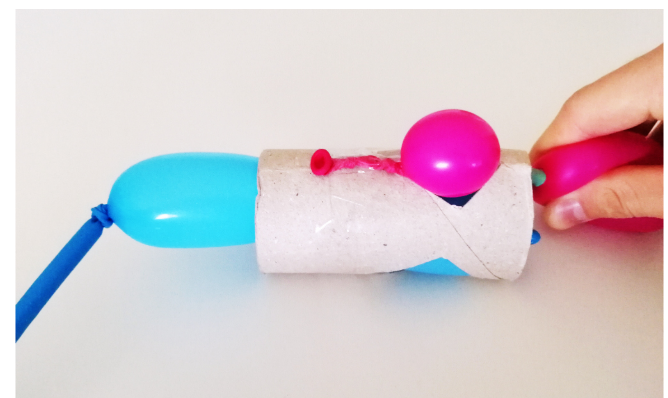


Fig 29. Pneumatic experience lo-fi prototype.

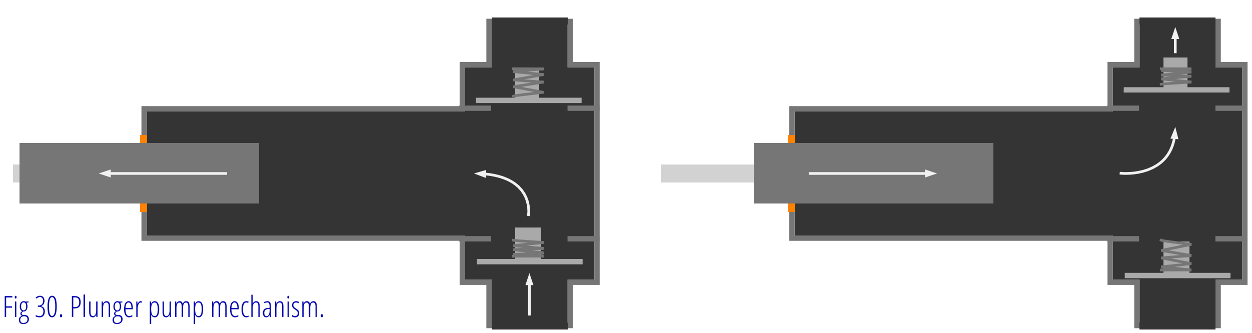


Fig 30. Plunger pump mechanism.

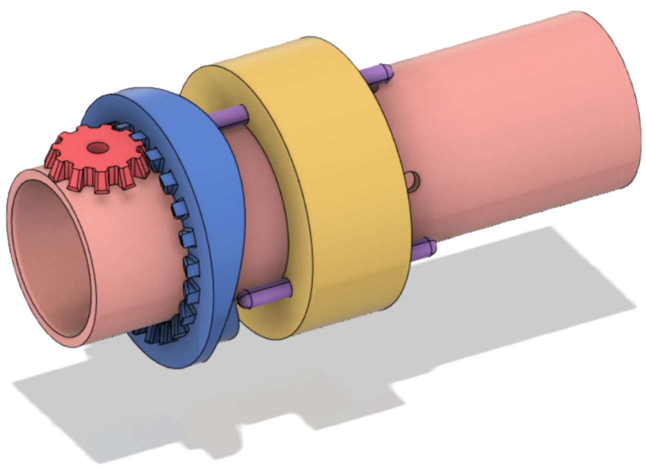


Fig 31. Push rods on cam mechanism CAD model

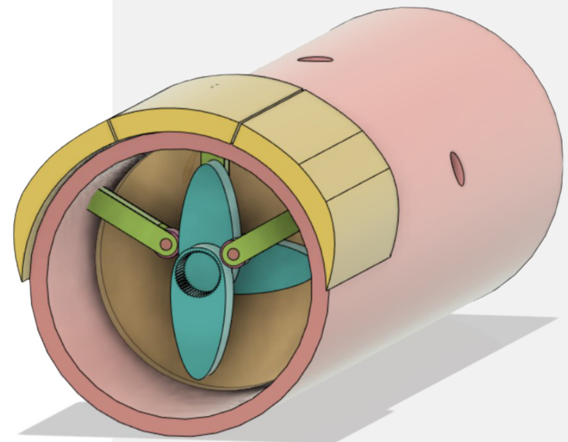


Fig 32. Cam and follower mechanism CAD model.

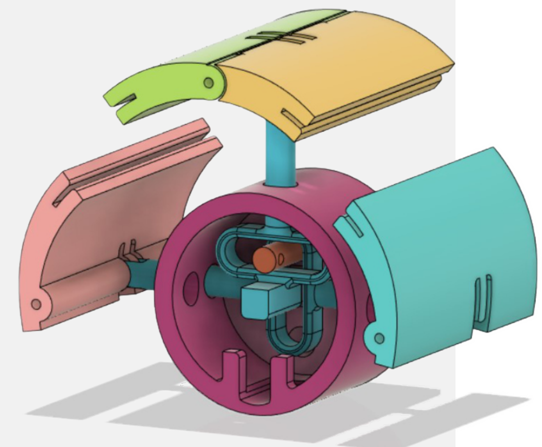


Fig 33. Follower in rail CAD model

Prototyping nuances

Multiple of the aforementioned methods were modelled using Fusion360 CAD software, inspired by literature and rotary to linear motion [13,21,27,29] (fig 31 - 33). A major concern, illustrated by the prior shape change prototype, was the actuation strength. This became a more challenging issue now that there were more individual panels. Ultimately, a similar approach to the slider mechanism was used (fig 34).

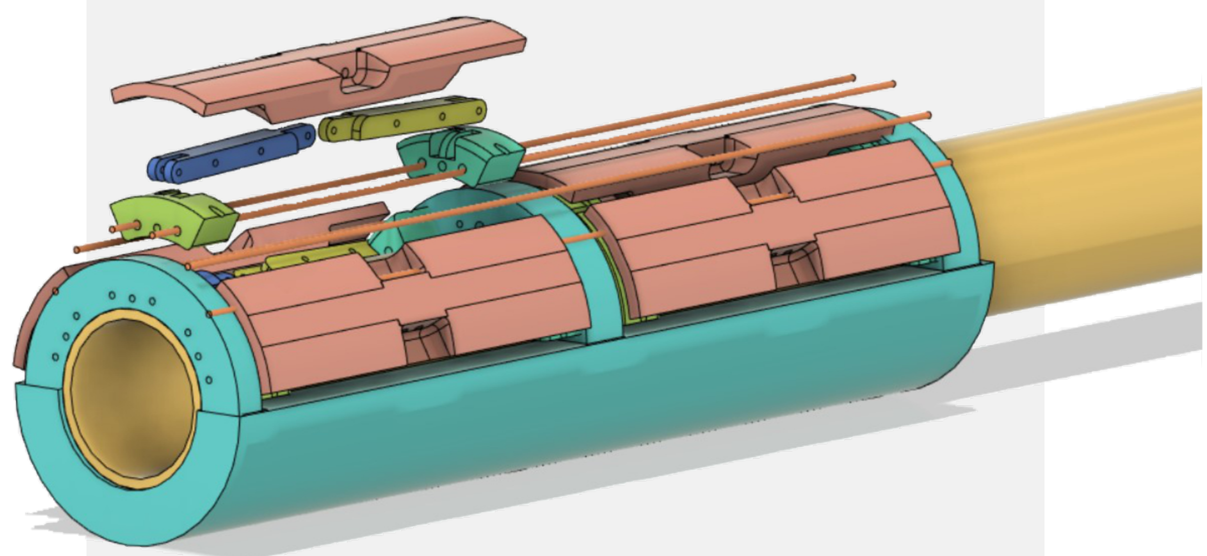


Fig 34. Final prototype CAD model. Slider mechanism.

Six separate sliders (3D printed PLA), each on two rails (brass rods), would move towards each other to push up a set of arms (Laser cut Vivak). These arms are attached to the six panels (3D printed PLA) that create the final shape (fig 35). To push the panels back down and hold them straight, an elastic fabric enclosed the complete grip (fig 36 and 37). The strength and manufacturing techniques required a trade-off with the styling and size of the grips. For example, the fabric should actually be some sort of grippy rubber, and the grips should be smaller in both diameter and length. Also, a major challenge surfaced when trying to implement the actuation into the grips or handlebar. This challenge was postponed since it did not really contribute to the questions this prototype meant to answer.

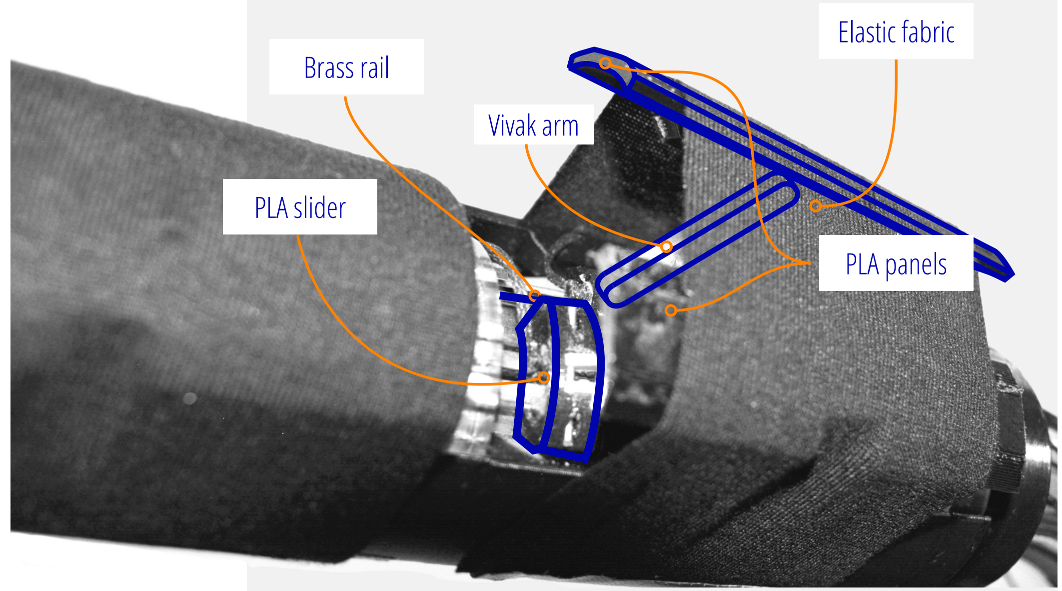


Fig 35. Annotated components of the final prototype.

Fig 36. Final prototype with fabric covering the whole grip.

Fig 37. Fabric functions as a spring to push the panels back down.

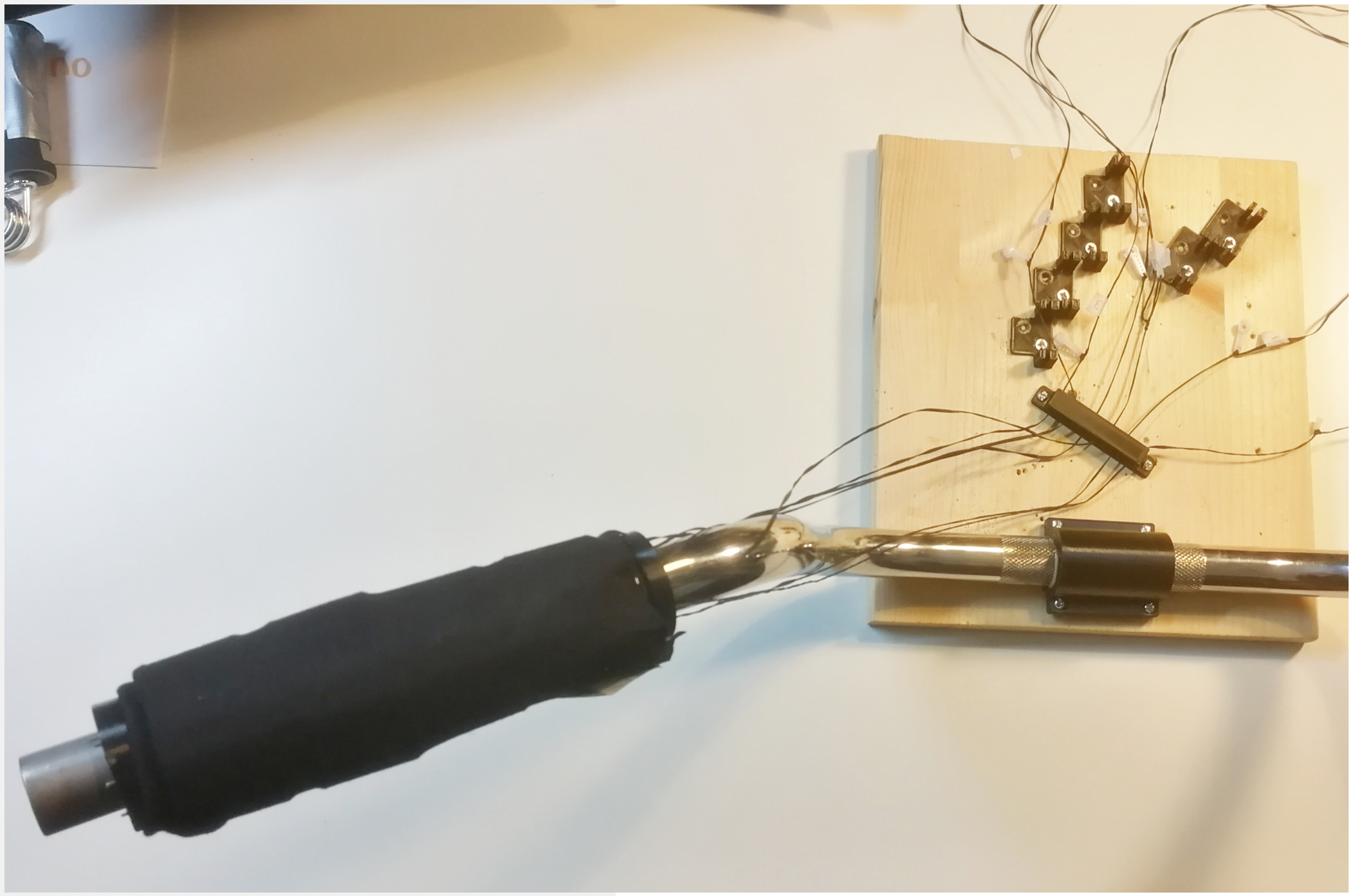


Fig 38. Final experiment setup (without servo motors in place).

The sliders moved by pulling on attached strings with six servo motors (fig 38). The actuation could also be done using only two servo motors (one for each “ring”), but this approach allowed for easier exploration possibilities regarding the timing of each panel relative to each other. The final timing came down to the panels lagging half a phase (1 * PI) behind on the adjacent leading panel. This means, when a car approaches your blind spot, the rear panel moves up first, followed by the center panel at the moment the rear panel reaches the top, etc. This created a natural “flow” through the panels when a car passes, yet a clearly identifiable distinction between rear, side, and front.

Final user study on information state nuances

The final prototype enriched the communicated information, which should make it easier to interpret the varying types of feedback. A prior experiment about feedback types highlighted some additional concerns that require validation. They include:

- When (not) to provide feedback?
    - How to communicate a feedback "pause" (if applicable)?
- How to differentiate between blind spot warnings and sideway collision detection?
- Which and how many shape states can be perceived intuitively?
- And finally, how to achieve shape change?

The latter question has already been discussed, but it requires more attention for implementation in a real-world context. The first question cannot be answered yet, because it is context dependent and requires longitudinal testing to validate whether the feedback will shift to the periphery of attention.

Therefore, to complete the design of InForm from a conceptual perspective, an additional experiment was conducted to evaluate the number of identifiable and recognizable information states by means of shape change.

Method

For the experiment, three types of transitions were tested.

- From default to a single state,
- from default to single state and quickly back to default ("tapping"), and
- only the state without transition.

Each transition was prompted 5 times per transition and per (set of) panel(s). The experiment was conducted with three people, amongst whom one was a self-reflection. The final experiment was not conducted in depth, due to limitations in time and availability of participants (due to a lockdown). Therefore, it's purpose is to give a preliminary indication of the refinements, that will require more in-depth validation in the future.

Results

The results are summarized in a confusion matrix. Each transition is indicated as a separate row (fig 39).

The transitioning states were all recognized with a near 100% accuracy, except for the front panels sometimes. These were confused with the center panels, due to their small variation in perceived location on the hand palm. They were expected to push on the fingertips instead.

When the panels reach beyond the inside the hand palm, it feels like the feedback points towards the other side of the grip (i.e., the right grip seems to point to the left side of the motorcycle, which is not what is communicated). Therefore, the panels should remain within the surface of the hand palm. The non-transition state was more difficult to accurately notice as it took longer to recognize. However, the general location was accurately pointed out (i.e., rear, center, or front).

The inside rear location of the panels is difficult to differentiate from the inside center, without a reference (either inside center or outside rear panel). The individual panels could be felt, which made recognizing their locations easier since you know where your hand is relative to the grip. With some experience of the tactile feeling, recognizing the panels became easier, indicating a small learning curve.

Conclusion

The overall location and meaning were perceived well. Even when the intensity was kept minimal ("tapping" panels). The panels should be sized down in length, to fit within the hand palm, and the front panels should be moved down, touching the fingertips in order to be able to accurately communicate the direction of surrounding traffic and thereby potential hazards. However, in this experiment, the attention demanding environment of traffic was not considered, nor were the vibrations of the motorcycle or weather interfering with the perception of the feedback.

	Input inside front	inside center	inside rear	outside front	outside center	outside rear
Perceived inside front	15 (default to state) 15 (state “tapping”) 15 (state only)	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0
inside center	0 0 0	15 14 15	2 1 0	0 0 0	0 0 0	0 0 0
inside rear	0 0 0	0 0 0	13 14 15	0 0 0	0 0 0	0 0 0
outside front	0 0 0	0 0 0	0 0 0	15 15 15	0 0 0	0 0 0
outside center	0 0 0	0 0 0	0 0 0	0 0 0	15 15 12	3 2 0
outside rear	0 0 0	0 0 0	0 0 0	0 0 0	0 0 3	12 13 15

Fig 39. Confusion matrix of final experiment results .

Discussion

Improving safety through tactile experience

InForm, as it is now, shows great potential, but this potential still needs extensive testing and refinement to fit the real-world context of motorcycling and implementation of sensing technology. Currently, the project is mostly restricted to the design of the interactive experience. This experience entailed embodying surrounding traffic to improve the situational awareness of the user. Safety is improved by providing better awareness of potential hazards which therefore enables motorcyclists to anticipate better and react quicker.

User involvement

The design of InForm is heavily inspired by experienced and beginner motorcyclists. Through exploratory and validating surveys and experiments, both the concept and implementation were regularly tested to guarantee a valuable improvement for motorcycling safety. Within the motorcycle community, there are many differing opinions on safety, styling, behaviour, etc. This complicated selecting a valuable initial topic, and it will therefore probably result in InForm not being universally accepted among motorcyclists. Nevertheless, user studies did show a promising value for embodied feedback and situational awareness to improve safety. Multiple participants asked whether the design would actually be sold anytime. This positive response motivated the continuation of the project to reach a higher fidelity product.

Limitations

Limitations of the project are that the improvement on situational awareness has not yet been tested, nor has the influence of contextual factors or distraction while riding been addressed (see requirements). In addition, the final experiment requires more in-depth testing to validate the meaningfulness and recognizability of all the information states. Not all technical requirements are determined or met yet, as they belong to a higher fidelity implementation (such as water and shock proof). Finally, the styling needs more attention for ensuring acceptance by the motorcycle community. The lack of styling is due to the focus on tactile experience and because the technical implementation will likely affect the material and form choices.

Conclusion

Motorcyclists are easily overlooked due to a variety of reasons [3,6,8,15,22,24]. This creates dangerous situations, aggravated by the vulnerability of motorcyclists. Efforts to improve safety range from active (crash prevention) to passive (injury prevention) safety measures [25]. However, the development of such safety systems is lagging behind for PTWs [1,4,25]. In addition to the poor visibility, interfaces in traffic require a high visual and auditory workload [9]. This renders these feedback modalities unsuitable for application in traffic. There is a need for an alternative interaction style that improves motorcycle visibility without relying on the attention of other road users or risking cognitive failure of the user. InForm indirectly addresses the visibility by providing meaningful situational information through tactile feedback, on which the user can act accordingly. Thereby, it improves situational awareness and reaction time. Ultimately, this contributes to a safer ride [9,18], with fewer traffic accidents resulting from poor visibility. As a concept, InForm has proven its value. However, to be implemented as a final product, there are some areas that still require testing and refinement, including testing in context, refining nuanced (directional) feedback, validating the effect on reaction time, situational awareness and improved safety, and the appearance of the grips.

Acknowledgements

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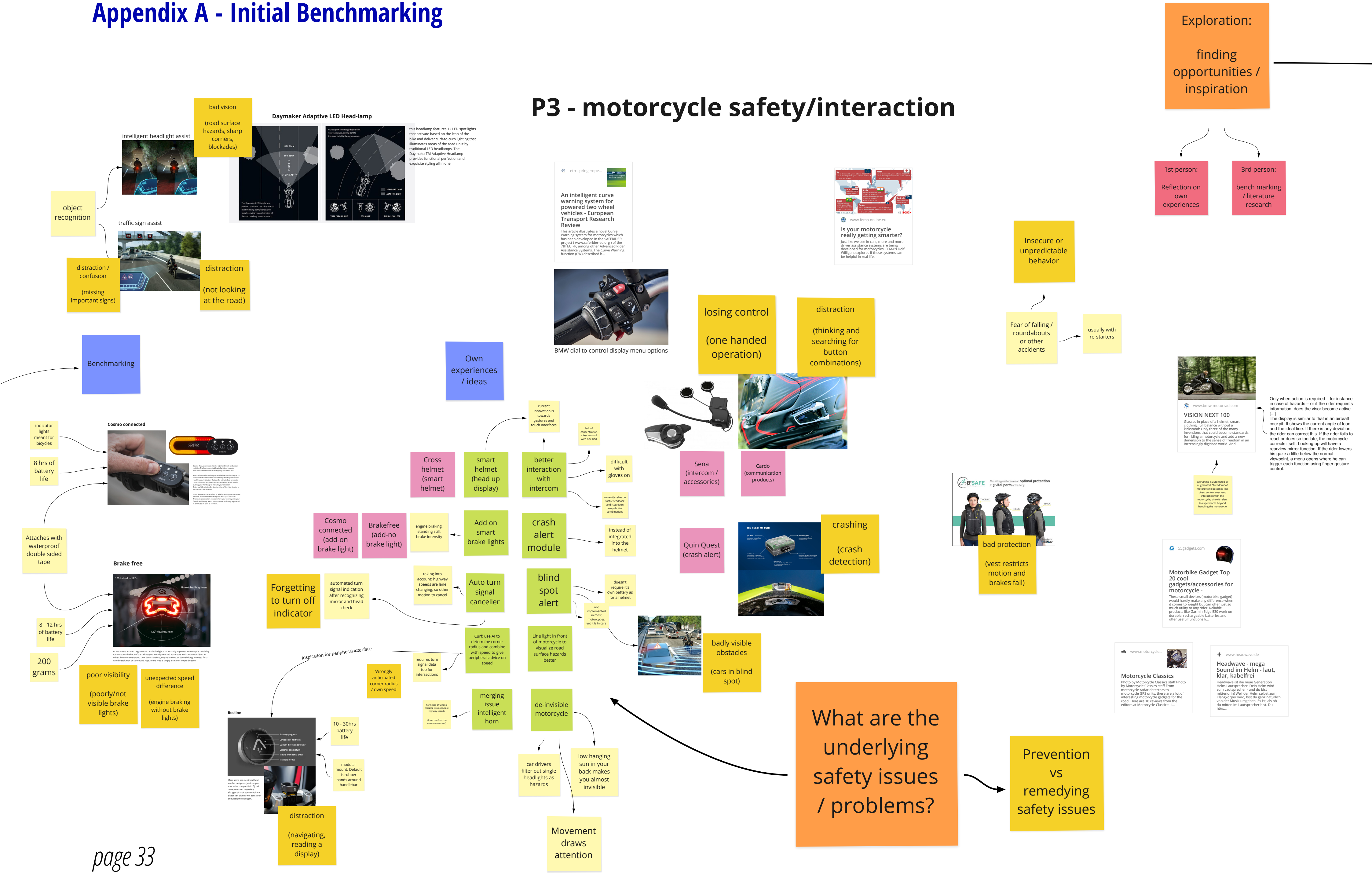
Appendix

Appendix A - Initial Benchmarking



Appendix B - Personal experiences survey setup and results

Questions

- What is you age?
- How many years of motorcycling experience do you have?
- How would you rate your own skill level regarding motorcycling?

  beginner - [] - novice - [] - professional

- What type of motorcycle(s) do you drive?
  - standard
  - naked
  - cruiser / chopper
  - dirt bike
  - adventure
  - dual sport (adventure sport)
  - super sport
  - tourer
  - sports touring
- What category does your motorcycle belong to?
  - A1 (< 11 kW (15PK) and < 125cc), A2 (11 - 35 kW (15 - 48PK)), A3 (> 35 kW (> 48PK))
- Where do you think improvements can be made regarding motorcycling? That includes improvements for comfort, safety, navigation, luggage, touring, maintenance, etc., etc.
- What are your experiences with risks/hazards during motorcycling?
- How relevant do you rate the following hazards for your safety during motorcycling?

	Totaal niet / not at all	Een beetje / somewhat	Neutraal / neutral	Erg / very	Extreem / extremely
Slecht zicht / poor vision					
Slecht zichtbaar / bad visibility					
Slecht of glad wegdek / bad or slippery roads					
Weinig bescherming bij een val partij / little protection during a crash					
Klem zitten na een val partij / getting stuck after a crash					
Afleiding / distraction					
Controle of balans verlies / losing balance or control					
Bocht verkeerd ingeschat / wrongly estimated a turn					
Overwacht snelheidsverschil / unanticipated speed difference					
Richting aanwijzer vergeten uit te zetten / forgetting to turn off direction indicator					
Mankementen aan de motorfiets / motorcycle defects					

- Why have you distributed the above-mentioned hazards that way?
- What do you do to resolve or remedy these safety issues?
- What products that could help to remedy potential risks/hazards do you use?
- What products DO you know that could help to remedy potential risks/hazards, which you DO NOT use? Why don't you use those?

- What are important factors/properties to you regarding motorcycle safety accessories or products?
- (optional) Here, you could add additional comments if you like:

Results

The survey received 17 responses of motorcyclists with varying experience and ages. Two people withdrew from the survey, yielding 15 usable respondents. 81% consider themselves novices or advanced riders. The mean years of experience is 32.5, with a standard deviation of 15.8 year, i.e. the experience is quite broad. Ages are between 36 and 55+ years. 14/15 ride a full power (>35kW) motorcycle. There is no dominant type of bike amongst the respondents.

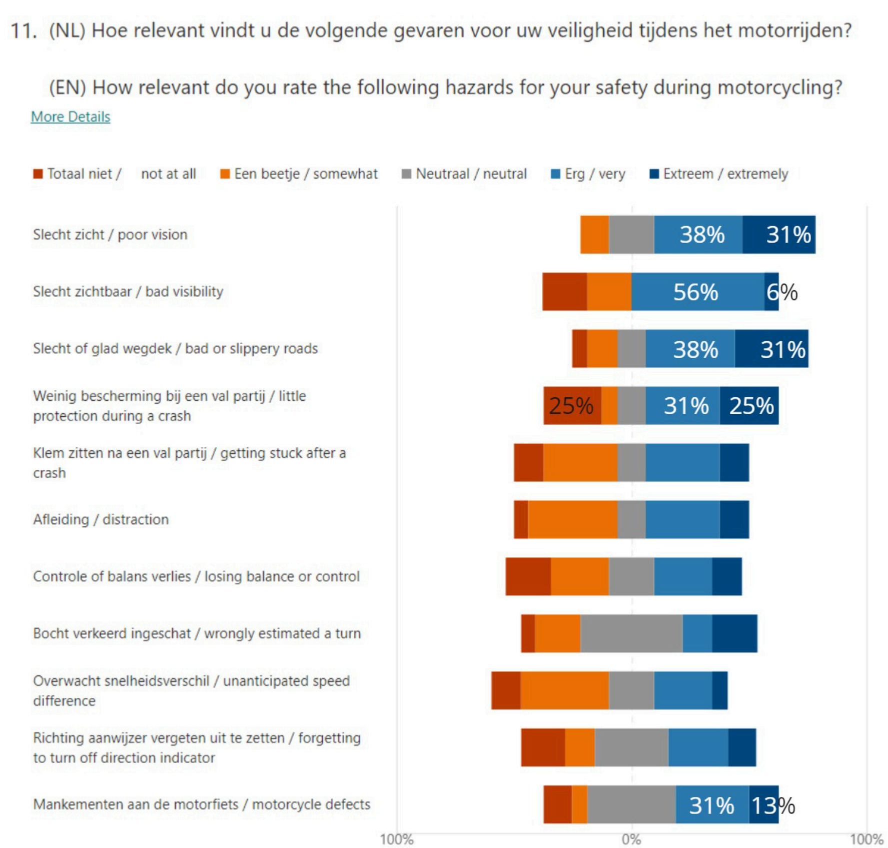


Fig B1. Results overview of Likert scale question.

Recurring themes were:

- maintenance of the motorcycle (mentioned by 14 participants),
- protective gear* mentioned by (11 participants),
- visibility (for other drivers) (mentioned by 8 participants),
- vision (for the driver), -and
- road conditions.

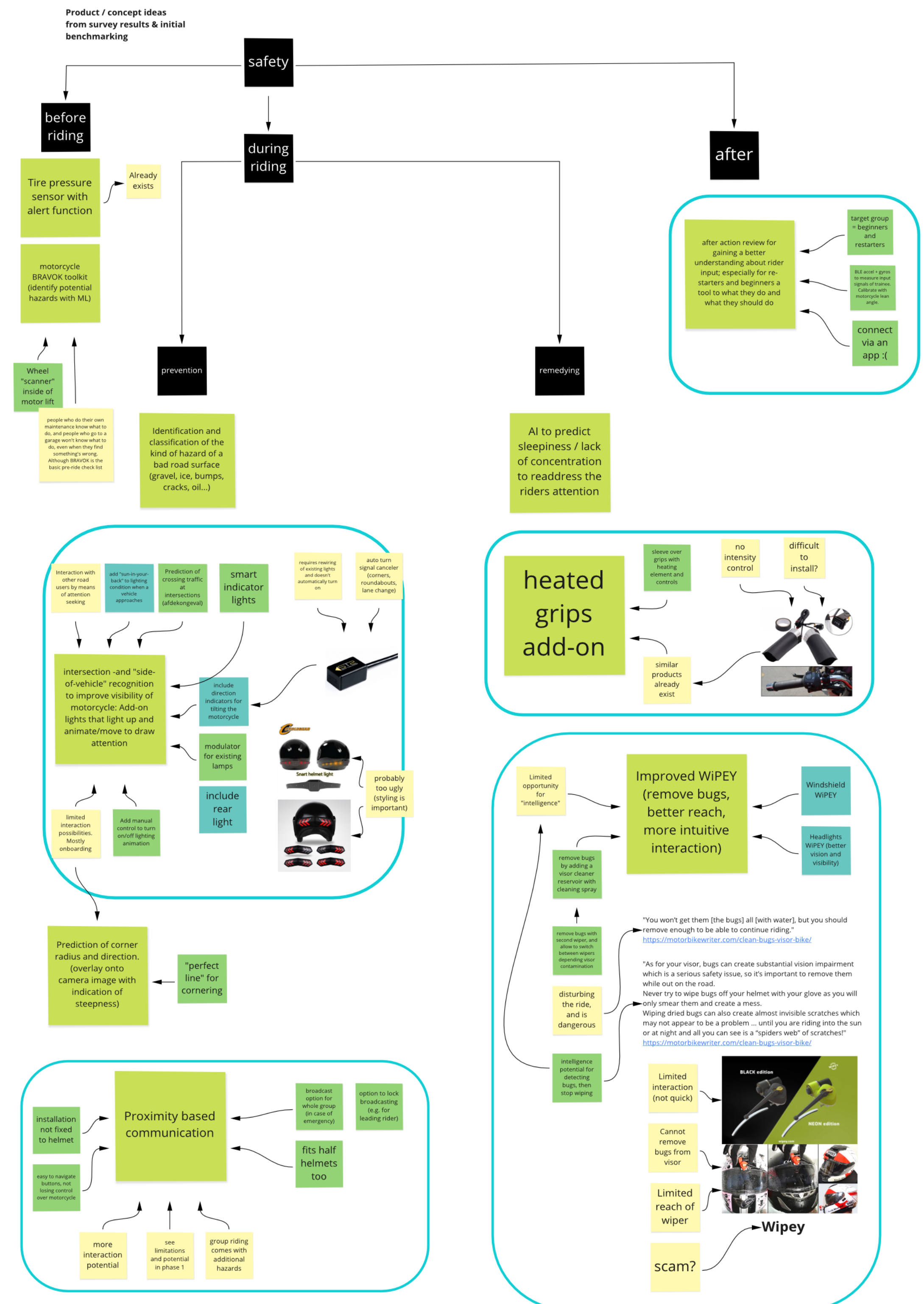
Road conditions aren't included in many written responses (although related answers can be found, such as good tires for better grip or vision to identify hazards). However, it does score the highest relevancy, together with vision, on the Likert scale.

Noteworthy is the division of the protective gear category of the Likert scale. Some riders find it 'very' to 'extremely relevant' for ensuring safety, while it also has the highest score for 'not at all important'. Additionally, protective gear is a very common risk management product, despite the questionable added safety from a user experience point of view. This indicates quite some varying opinions regarding protective gear.

Maintenance of the motorcycle on the other hand is mentioned in almost every question, in one or another context. The same goes for visibility of the motorcyclist, which both also score quite high relevancy on the Likert scale.

Lastly, a recurring theme (code) is distraction and anticipation of other (car) drivers, as well as maintenance and protective and visible gear. Although, the visibility of the gear (e.g. bright yellow colors) is a fragile aspect for ensuring protection (probably due to styling).

Appendix C - Brainstorm on safety concepts



Appendix D - Evaluating safety concepts

Results

See fig C1.

Analysis grounded theory method

The analysis is based on grounded theory method from [10,11]. First the whole dataset was exported as CSV and read through, then comments were categorized into positive, negative and neutral. Next was to seek patterns (using codes) in the reasons for (dis)liking or observing the concepts to find important aspects for each (or multiple) concepts [initial open coding]. These codes are then linked to find and refine themes that depict the most important elements [intermediate axial coding]. Themes are rated by counting the comments that belong to each theme, and then redefined or combined from small (low rated) themes once more [intermediate axial coding]. The number of mentions also gives an indication of the importance of each theme (i.e. aspect) to some extent. Lastly, the found themes are divided into general and concept-specific aspects. The "theory" that's found here relates to the selection and importance of safety aspects [modified* advanced selective coding].

Fig C1. Results of evaluating safety concepts .

Results of concept evaluation

Identified themes

- Build-in features preferred over "gadgets"
- Don't cause (visual /auditory) distraction
- Don't affect handling of the bike
- Visibility is key

preferred and most useful safety feature (questions from survey) is improving visibility, though not necessarily by means of the described concepts

Themes per concept

numbers are number of participants who mentioned the theme. n=65

{concept specific} {general aspects}

Heated grips

Built-in grips is better or already present on motorcycle 17

Outside of the hands become cold(er) too due to wind (use wind covers) 10

Risk of slipping off, less control or changing feel of the grip 7

Only suited for "cold weather/ all season riders" 7

Cover whole grip / larger area for more equal heat distribution over whole hand 7

Thicker or heated gloves for cold weather are preferred (less adjustable though) 6

Useful for multiple motorcycles/ seasons due to quick (de)installation 6

Installation / Routing of the cables should be easy and clean 6

Vulnerable to theft 3

The heating elements change the look of the grips (they should look good or maintain the existing looks) 2

Improves safety due to better concentration, faster reaction, better feeling of the controls and ensure more comfort

47/61 think heated grips improve safety

Driving review

Beginner/ restarter target group was specifically mentioned in concept description

Differing opinions, from enthusiastic to extremely negative

not for private use, but valuable for lessons/ beginners /supervision of instructor 18

Personal skill improvement / insights / fuel consumption optimization 14

app/score could cause distraction or cause the rider to push the limits, therefore less safety 6

Experienced riders as target group for skill fine tuning (e.g. racing) 6

The actual experience is more valuable than the graphs 7

Adjustable for different motorcycles. Every motorcycle rides differently 5

The app should include external factors such as road conditions and traffic 5

Sensors should not affect handling of the controls (e.g. built-in) 2

don't use app *during* riding 2

connect to the CPU of the motor to get (more) data

(works only with new types of motors) 2

good for understanding actions and their consequences (simulate bad vs good actions)

safety is mostly attributed to insights or feedback to control the motorcycle

26/61 think the driving review will improve safety

Intersection visibility

Edge case: driving behind work traffic carrying traffic signs. Will the model classify this as an intersection?

additional ideas: brake light attention when standing still; blind spot mirror for motorcycles

confusion or distraction of other drivers, or reliance from motorcyclists themselves, which compromises safety 23

effectiveness (over time) / accuracy is questioned 7

Participants rather trust in /rely on their own skills 7

too complex, keep it simple 6

Animating lights could be forbidden 5

some participants thought the concept included a display, thus causes distraction 4

built-in on new motorcycles yes, otherwise not interesting 4

No "Christmas" lights 4

The user (motor cyclist) should stay in control over the system 2

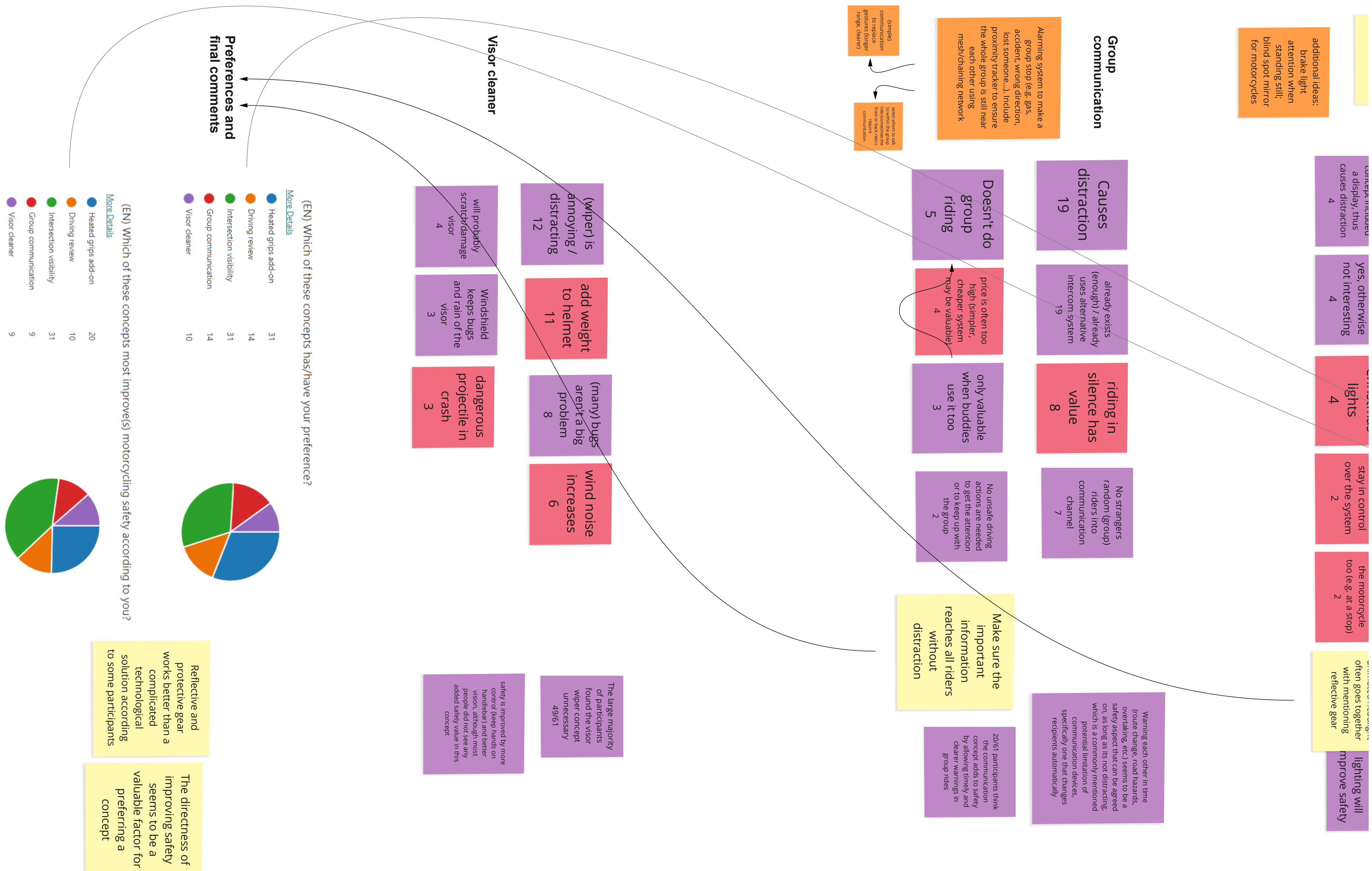
Attract attention from the rear of the motorcycle too (e.g. at a stop) 2

Improving visibility by mean of animated headlight often goes together with mentioning reflective gear

improving visibility was described as the goal of the concept

Better visibility is seen as the value for safety (24/61), though many participants question the resulting lack of attention from the motorcyclist

37/61 think the intersection lighting will improve safety


additional ideas: brake light attention when standing still; blind spot mirror for motorcycles
a display, thus causes distraction 4
yes, otherwise not interesting 4
lights 4
stay in control over the system 2
the motorcycle too (e.g. at a stop) 2
often goes together with mentioning reflective gear
lighting will improve safety
Group communication
Alarming system to make a group stop (e.g. gas, accident, wrong direction, lost someone...). Include proximity tracker to ensure the whole group is still near each other using mesh/chaining network
Causes distraction 19
already exists (enough) / already uses alternative intercom system 19
riding in silence has value 8
No strangers random (group) riders into communication channel 7
Warning each other in time (route change, road hazards, overtaking, etc.) seems to be a safety aspect that can be agreed on, as long as its not distracting, which is a commonly mentioned potential limitation of communication devices, specifically one that changes recipients automatically
Doesn't do group riding 5
price is often too high (simpler, cheaper system may be valuable) 4
only valuable when buddies use it too 3
No unsafe driving actions are needed to get the attention or to keep up with the group 2
Make sure the important information reaches all riders without distraction
20/61 participants think the communication concept adds to safety by allowing timely and clearer warnings in group rides
Visor cleaner
(wiper) is annoying / distracting 12
add weight to helmet 11
(many) bugs aren't a big problem 8
wind noise increases 6
The large majority of participants found the visor wiper concept unnecessary 49/61
will probably scratch/damage visor 4
Windshield keeps bugs and rain of the visor 3
dangerous projectile in crash 3
safety is improved by more control (keep hands on handlebar) and better vision, although most people did not see any added safety value in this concept
Preferences and final comments
(EN) Which of these concepts has/have your preference?
More Details
Heated grips add-on 31
Driving review 14
Intersection visibility 31
Group communication 14
Visor cleaner 10
(EN) Which of these concepts most improve(s) motorcycling safety according to you?
More Details
Heated grips add-on 20
Driving review 10
Intersection visibility 31
Group communication 9
Visor cleaner 9
Reflective and protective gear works better than a complicated technological solution according to some participants
The directness of improving safety seems to be a valuable factor for preferring a concept

Appendix E – Detailed results of tactile feedback experiment

Motion feedback

The motion feedback feels most aggressive and imperative. It almost forces the rider to go in a certain direction, rather than informing about hazards or escape paths (which were the most mentioned meanings of the feedback according to participants). This results in the experience that the system tries to take over control or as if it is driving for you. Especially in turns, moving the handlebars could affect the motorcycle handling negatively. This experience does not match with the general mindset of (hobby) motorcycling and therefore risks not being accepted by the users [25].

Moreover, it could be dangerous is the system actually takes over control, since a false sensor reading could always happen, with unexpected or simply a dangerous autonomous response as a result.

In addition to the undesired experience, participants had varying ideas by the meaning of the feedback. An essential difference is where some participants assumed the feedback was informing or guiding (e.g., "There's a possible escape path on your left"), in contrast to a high alert action trigger (e.g., "Swerve left now to avoid a collision!"). This mismatch could cause serious problems on the road when interpreted incorrectly.

Force feedback

The force feedback implemented in the turn indicator switch triggered an additional (shoulder) check before taking a turn. However, the actual meaning of the feedback was not clear and varied from warning about obstacles to forbidden access to roads.

Also, the force (feedback) was often not clearly noticed. Especially individually, without comparing to the "non-force" direction. The reasons could be the difference in force and the short interaction time. Although the spring tension was already at such a strength that it actually takes some effort to push into it. Increasing the force even more would impede using the blinker, which causes issues of its own.

Shape change feedback

The shape changing feedback was intuitively linked to guiding attention left or right, and often interpreted to warn about obstacles.

It also allowed for informing on a continuous scale rather than binary, depending on the amount of danger or attention required. This nuance solves the interpretation issue of the motion feedback that links to the magnitude of the hazard at hand. The shape change did not seem to trigger a specific action, but guided attention to the left or right of the environment.

A downside of the shape changing feedback is the possibility of missing the information when not holding the grips (some riders drive with one hand).

Information rate

During the tests there were concerns that continuous feedback will probably cause information overload, and ultimately an "immunity" to the feedback. The information needs to be communicated only when it is digestible or when immediate action is required to prevent an accident. Having some degree of continuity and regularity will on the one hand make the feedback become part of the driving experience, making an appropriate response faster to execute since it's partially muscle memory.

Possible solutions are to turn off the feedback (while indicating it's off) at low speeds or when too many triggers are sensed (e.g. when driving past a busy lane at a stop light, with the exception of lane-changers).

Reflection

Rick van Schie

Project: InForm

Semester: M2.1

Date: 13 Jan 2022

Vision and Identity development

The role of testing for making decisions

When beginning a project, I used to start with research activities, including user research. This matched my view on “desirability”. However, I changed my perspective about desirability. Validation now plays a more critical role than initial research. I get inspired by my own experiences, which guide to a design challenge/goal. The solution to this problem can be validated with a prototype.

Especially in the early phases of this project, I struggled with finding the answers I was looking for. Doing background research aggravated the feeling that I had to make the right decision right away, which let to postponing decisions all together. Hence, I adopted the notion that users don't know what they want (desire) until they experience it. Later in the process, I learned to make more decisions based on “gut feeling” and design intuition. The test results therefore functioned as inspiration and validation rather than requirements. I also realized that working towards a milestone such as demo day helps to define the project. A project of a whole year, without demo day, would likely be more abstract for longer.

Fit with context-of-use

Making prototypes sooner helped making (important) decisions (fig 1). The experienceable prototypes proved more useful than sketches and 3D models, which I often relied on in prior projects, because experienceable prototypes allowed to illustrate the (mis)match with the context-of-use. A (mis)fit with context is a good reason not to fully comply with my vision. For this project that refers to a rather limited interaction, because adding more interaction possibilities creates additional potential distractions during riding. Also, AI (currently) has had a small role, and was only implemented conceptually because the project’s focus was on the tactile experience. I intent to include AI more in the following phases of the project, as it covers a significant part of my designer identity and vision.

Implementation of my vision

This project contributes to my FMP by developing an individual design process, with focus on meaningful interaction for an application area where interaction is highly constrained. The project made me realize that meaningful interaction is extremely valuable for activities that require focused attention to begin with; where there's no place for distraction. My vision is applied in this project by designing an interaction that becomes “part of the motorcycling experience". The value of such a meaningful experience here is the prevention of distraction and awareness of the surroundings in traffic, therefore making the activity safer.

Framing FMP

Initially, I intended to execute a separate FMP, since I have difficulties defining a design challenge. I found myself most comfortable in the early stages of the design process, right after the design brief. Here, there’s still room for exploration and innovation, but the overall direction has been defined. Without the design brief, I find it quite hard to decide on the most valuable direction. The reason I decided to take my M2.1 project further is because I got to pursue a different opportunity I would not want to pass on, namely, designing a high-fidelity product that comes closer to being market ready. I think this will provide new valuable learning points, since I have not yet reached this stage of a design process during my education to become a designer. Additionally, finishing my masters with a more complete design will also proof valuable for starting my career.

Fig 1. Lo-fi pneumatic experience prototype.

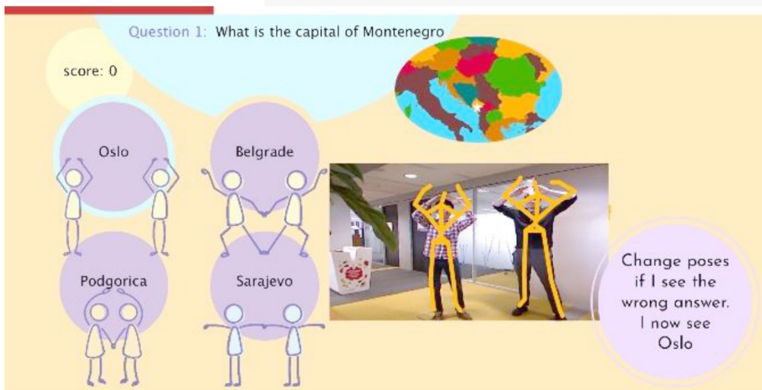


Fig 2. Quiz interface (in Processing) using a Kinect to classify poses.

Fig 3. User test setup for validating tactile experiences.

PDP Goals

1) Implement a working learning algorithm on a micro controller

During the course Embodying Intelligent Behaviour in a Social Context, I learned to train and implement my own pose-classification algorithm in Python using SciKitLearn (fig 2). In addition, we used a Kinect to gather three-dimensional data for training the model. These learning points broadened my skills for designing and prototyping intelligent products with advanced sensors. We did not yet implement the algorithm onto a micro controller or SoC (such as a Raspberry Pi), because it did not fit the learning goals of the course. However, SciKitLearn does provide possibilities to do so if required.

2) Expand my silicone casting manufacturing skills by designing a custom mould and cast silicone for my design project & 3) Design and deploy a custom PCB for my design project

These goals were not achieved during the current phases of the project. As mentioned in the goal descriptions, these were anticipated activities, which are still relevant, though they fit better in the remaining phases of the project. The look and feel, in terms of materials (goal 2), received little attention, and the design was not yet ready for the level of detailing that would make casting silicone worthwhile. This also goes for PCB design, which will only be relevant for long lasting testing or implementation in a high-fidelity prototype due to the smaller size and reliability of the electronics.

4) Create a more confident planning and scoping of the design project

One of the first activities while starting this project was creating an overall planning, including a couple of testing moments. I intentionally started with exploring the design space, starting from my own experience, which I quickly cross validated with literature and user studies. However, I ran into trouble when making decisions (as explained above). I do think that my planning lasted, although I found it rather difficult to anticipate the outcome fidelity (as is illustrated by not achieving goals 2 and 3). I felt more focused throughout the process due to the general structure of my planning and I am more confident in initiating a project. This is why I plan to experience the detailing and finalizing phases of a design process by continuing this project for my FMP.

5) Taking a truly user centred perspective

I am pretty confident that this goal was achieved. Throughout the project I regularly validated and explored my concepts with real users by using open-ended surveys, detailed concept descriptions, and experienceable prototypes (fig 3). However, I realized that "desire" got a different meaning. I found that testing after creation works better than before, for me. It is less constraining, while still including the desire of the users.