**Proceedings of the Design Society, Volume 5: ICED25**
https://doi.org/10.1017/pds.2025.10148

# Designing user-oriented wearables: integration of a thermoelectric module into a motorcycle protective jacket regarding aspects of functionality, perceived safety, and usability

**Johanna Riedel[1], Martin Luccarelli[1,✉] and Aline Klippel[2]**

*[1] Reutlingen University, Germany, [2] Mahle GmbH, Germany*

✉ martin.luccarelli@reutlingen-university.de

**ABSTRACT:** Among state-of-the-art research, thermoelectric modules using the Peltier effect are used for general personalized climatization. However, none of the personalized climatization approaches found in literature reviewed the usability for the wearer, let alone in the context of motorcycle driving. This work was aimed at integrating Peltier technology into a motorcycling protective item in such a way that it is functional, perceived as safe, and usable for motorcyclists. Multiple integration options observing the requirements for motorcyclist's safety equipment were generated. The functionality and usability of the integration approaches, as well as their impacts on perceived safety of the driver were evaluated. This work could serve as a base for future studies addressing user-oriented methodologies for the validation of technical products in the context of motorcycle protective clothing.

**KEYWORDS:** user centred design, industrial design, new product development, motorcycle clothing, Peltier technology

## 1. Introduction

The thermal comfort of motorcycle riders is restricted by the use of personal protective gear, especially in hot climatic conditions (Taylor, 2015; de Rome et al., 2016; de Rome, 2019). It is further influenced by the wind chill effect, which in cold conditions results in core temperature heat loss (Woods, 1983), and reduced finger dexterity (Daanen, 2009), making it harder for riders to operate the machine functions. Thermal discomfort can provoke unsafe behaviour (Ramsey et al., 1983; Hancock & Vasmatzidis, 2003), induce lack of concentration (Hancock & Vasmatzidis, 2003; Walter & Carraretto, 2016), and influence a human's assessment of orientation, safety, and reaction to emergency situations (Palinkas, 2001). According to Sim et al. (2016), wearable climatization solutions can already be effective if they are palpable on a small part of the body, such as the wrist. In this regard, multiple approaches to improve the thermal comfort of motorcycle riders have been realized in the form of heating or cooling additions to the protective gear, such as cooling vests or heated gloves. Additional research in the field of general personalized climatization has been undertaken using the Peltier technology, a thermoelectric element capable of providing spontaneous hot and cold stimuli in one device. One possible technological constellation is to equip a 5V Peltier element with an additional heat sink, a thermal interface material, and a fan to divert heated or cooled air away from the backside of the element to construct a thermoelectric module. A patent research regarding the topic of integration of Peltier elements into clothing articles in the neck area was performed beforehand and rendered 6 patents, of which none were applicable to the motorcycling context. A preliminary literature research centred around the topic of integration of Peltier elements into motorcycle or other protective clothing was performed using online search engines Google Scholar, Elsevier, IEEE Explore and ResearchGate. The search was performed between October 2023 and March 2024 using the search terms *motorcycle clothing Peltier*, *protective clothing Peltier* and *Peltier clothing*. It was unrestricted to publication date and sorted by relevance. A total of 120 paper titles were screened and after perusal of introduction, conclusions and methods, papers which did not integrate the technology into an actual article of clothing, or which could not be translated into the motorcycling context were eliminated from the review. In the end, seven papers published between 2011 and 2024 were considered for this work. They investigated the integration of Peltier elements into articles of clothing and measured various parameters of the thermal effect with differing constellations of the thermoelectric module. The papers range from ventilation clip-on modules for motorcycle jackets (Eldho et al., 2021), vests with Peltier cells and copper sheets (Sahta et al., 2011), firefighter protective clothing (Vlad et al., 2013), windbreaker jackets (Jahangir et al., 2019), mountaineering jackets (Poikayil et al., 2017), and workwear vests (Darbrowska et al., 2024) with separate Peltier cells, to a jacket with a series of connected Peltier cells (Mitsik & Birdina, 2020). The studies measured temperature (Eldho et al., 2021; Sahta et al., 2011; Vlad et al., 2013; Jahangir et al., 2019; Darbrowska et al., 2024) and humidity (Vlad et al., 2013) differences inside and outside the garment, and found them to be between 1.5 °C (Sahta et al., 2011) and 8 °C (Eldho et al., 2021) lower than the outside temperature. Only three studies (Sahta et al., 2011; Vlad et al., 2013; Dabrowska et al., 2024) tested the thermal effect with humans wearing the vests/jackets, and only the study of Dabrowska et al. (2024) included the wearer's thermal perception using the ISO 7330:2005 international standard ranking for ergonomics of the thermal environment.

On the one hand, the effects of thermal discomfort of motorcycle riders (de Rome, 2019) have shown to negatively influence a rider's behaviour on the road and to endanger his/her safety due to reduced psychomotor skills (Zwolinska, 2013). Complex cognitive tasks related to biomechanical aspects, such as complex motor coordination and sustained attention, are impacted by thermal comfort (Taylor et al., 2016). On the other hand, it has been shown that distractions such as mobile phone usage during riding result in a higher accident rate (Regan et al., 2015). When designing for motorcyclists, it is thus vital to strive for non-distractive and intuitive handling. Biomechanical aspects, such as the energy needed to attach the product in addition to the muscle fatigue caused by riding a motorbike (Velagapudi et al., 2010) and the attention span required to interact with a product featuring a user interface (Van de Sand et al., 2020) must be taken into account. To date, none of the personalized climatization approaches mentioned above reviewed the usability for the wearer in any aspect, let alone in the context of motorcycle driving. In this regard, incorporating qualitative feedback by actual users into product development is of specific relevance to better target the addressed product context. Qualitative feedback stimulated by the description of real-life scenarios and encouragement of natural conversation is crucial to the early processing stage and enables the detection of a user's individual points of interest (Brinkmann, 2020). It further allows the formation of new concepts by establishing deeper and more trustful relationships between interviewer and interviewee (Dearnley 2005). Analysing relationships in general can be performed by clustering conversations into repetitive wordings, recurring phrases and emitted emotions, and this approach can also be used to interpret the relationship between a person and an object (Peterson 2017).

## 1.1. Aim and objectives

In light of the aforementioned considerations, the aim of this work is to integrate a Peltier element into a wearable concept in such a way that it is functional, perceived as safe, and usable in the context of motorcycle protective clothing. We focus our research on the relation of the product to the context, and include functionality as crucial design aspect.

Considering the modular constellation of a 5V Peltier module that measures 30x30x30 mm in total, a thermal effect is only noticeable if in contact with the skin, creating a conflict between the requirement of direct skin contact and direct access to fresh air to ensure the functionality of the thermoelectric module. To realize this integration functionally, i.e. in direct skin contact, so that the wearer is able to feel a thermal effect, while not impeding the safety, the first research question is:

1. *How can the chosen Peltier module be integrated into the motorcycle jacket to provide a palpable thermal effect as well as preserve the safety of the driver?*
   Moreover, evaluating biomechanical aspects of the concept is key to test product usability. As no indications are known about the ease of use of Peltier elements for personal climatization to date, the second research question is:

2. *How can the given technology be integrated into the protective clothing article so that key biomechanical aspects are included in the early product design stage?*

These research questions result in the objectives of a) generating multiple integration options of a Peltier module that consider the requirements for motorcyclist's safety equipment, and b) evaluate the functionality in terms of palpable thermal effect, perceived safety and biomechanical aspects of the integration approaches.

The expected outcome of this work are functional models with a working thermoelectric mechanism, and feedback about their usability in the motorcycling context. As the focus of the functional models is set on the underlying construction principles and their effect on the driver, they do not require market-ready materials or production techniques. The models shall be commented regarding their functionality and usability, but no evaluation of user satisfaction, thermodynamic effect or testing against safety norms shall be performed. This work expects to provide an insight into the importance of incorporating the user into the development process of technical products often solely focussed on functionality. It shall uncover potential usability issues with the integration of technology in a motorcycle context.

## 2. Methods

To fulfil objective a), first, scientific literature research as well as a market review of existing protective clothing was performed. The scientific research used the online research databases IEEE Xplore and Science Direct, the web search engine Google Scholar, and the academic social network Research Gate under the terms of *motorcycle protective clothing* and *safety requirements for motorcycle equipment*, sorted by relevance, with no restriction to publication dates. Two studies, with one referencing a European Norm, were applicable to and included in this paper. The market review was performed online by image and description review of search results for motorcycle protective clothing and motorcycle protective jackets. The image review of 10 different types of protective clothing items was performed to obtain an overview over the structural characteristics of the protective equipment, so that the integrated module would not interfere with the protective functions of the garments. In the second step, an ideation was performed both through individual research and a group work session conducted with six voluntary participants from the automotive industry partner. The participants were of mixed age and gender, had a background in mechanical engineering as well as marketing and business development, and were all but one former or current motorcycle drivers. Each participant prepared one mock-up model with true dimensions but abstract materials such as cardboard, textiles, and foam. The sketches, ideas and mock-ups were evaluated by the authors according to timely realisation, technical feasibility, and estimated safety and usability. Three wearable concepts with the highest scores were subsequently crafted using true technological components and dimensions but abstract materials, such as cardboard, magnets, and soft, non-functional textiles. Further, interim operating panels were attached to the functional models via cable. The functional models served as representative mock-ups for motorcycle jacket sleeves, which resulted as suitable for placement according to research of objective a); cf. 3.1.

To achieve objective b), the functional models were tested for functionality, perceived safety, and biomechanical aspects with eleven male and one female leisure motorcyclist between the ages of 35 and 65. The testing subjects were contacted through an existing network provided by the partner as well as a separate social media search in the Stuttgart region, Germany. To assess the functionality of each model, the users were introduced to the models, assisted with putting them on, and then asked a yes or no question whether they felt a temperature change when turning the device to hot or cold. Further, their spoken words, phrases, and displayed emotions feedbacking the thermal effect with each model were noted down. The subjective feeling of perceived safety of the device was evaluated by verbal feedback and the accompanying forcefulness or emotionality during the feedback. Additionally, a yes/no questionnaire consisting of four questions inspired by a comfort assessment system for wearable devices by Knight and Baber (2005) was pre-formulated and posed. The questions from the initial comfort assessment system were narrowed down to the motorcycling context and included aspects of perceived physical and psychological safety, such as "are you tense or irritated by the device", "does the sample dig into your skin, sit too tight or is it chafing anywhere", "are you scared to damage the device with your movements", and "are you concerned about the device itself or the cables?" The written records of the testers' behaviour, wordings, phrases and emotionality were subsequently classified into repetitive, recurrent and forceful/emotional data according to Owen (1984). The biomechanical aspects of each model were assessed by the users being asked to put on the models themselves, and then dress with provided motorcycle gloves and helmets. Further, a simulation of a motorcycling scenario was performed moving towards, mounting, sitting on, and dismounting an electrical scooter, so that every user could be observed closely and would not be put at risk by the task of testing a new device and driving simultaneously. Both scenarios served to identify any visible struggles or verbally stated disturbances within these movements, such as bending the arm and nestling with glove and helmet closures, or bending over when mounting and dismounting the motorbike. The visual and verbal feedback was noted down using pen and paper. The objectives and respective method steps are visualized in Fig. 1.

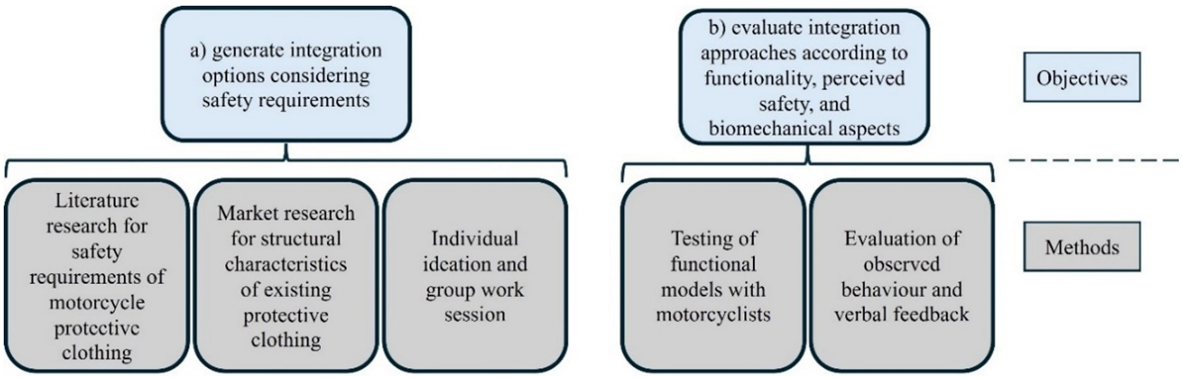


**Figure 1. Objectives and respective methods of this work**

# 3. Results

## 3.1. Thermoelectric module design

Key safety zones of motorcycling armour and current product typology available on the market are of specific interest for the thermoelectric module design, Fig. 2.

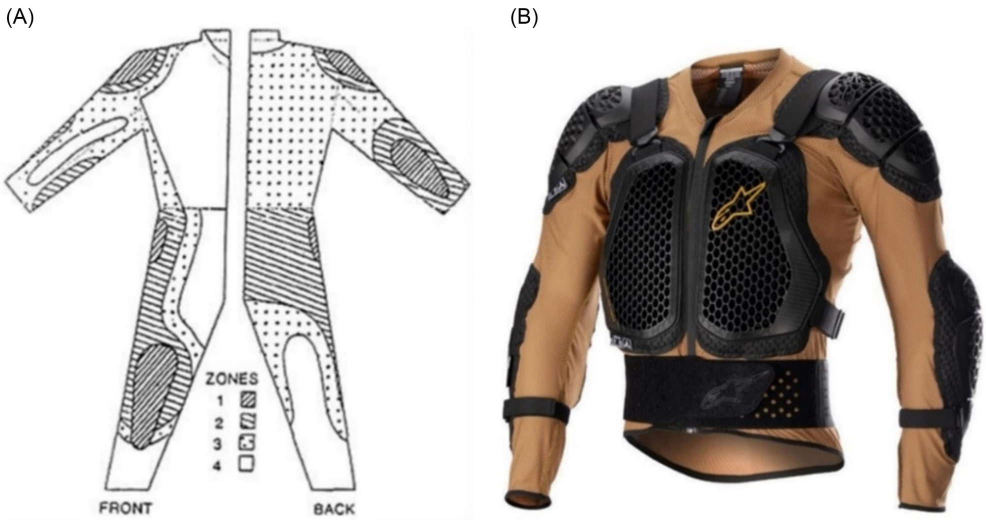


**Figure 2. Safety zones according to Woods (1996) (2A) and an example of current motorcycling armour (Alpinestars 2024) (2B)**

Following the European safety requirements for motorcycle protective clothes, Woods (1996) ranked injury zone from 1, i.e. most likely, to 4, i.e. least likely to be injured during a crash (Fig. 2A). According to this ranking, the inner forearm is located in a low risk for injury zone, explicitly allowing for a less than average protection level. This study was subsequently used to establish the European Standard EN13595:2002, which is nowadays mandatory for personal protective equipment (Meredith et al., 2017). Considering examples of modern motorcycling armour (Fig. 2B), this zone is also accessible for close skin contact and is not covered by protective shields, neither is it exposed to a high degree of chafing. The three functional models, representing the motorcycle jacket sleeves, designed for this location provide three different integration concepts: a permanent integration, a modular approach, and an independent option, Fig. 3.

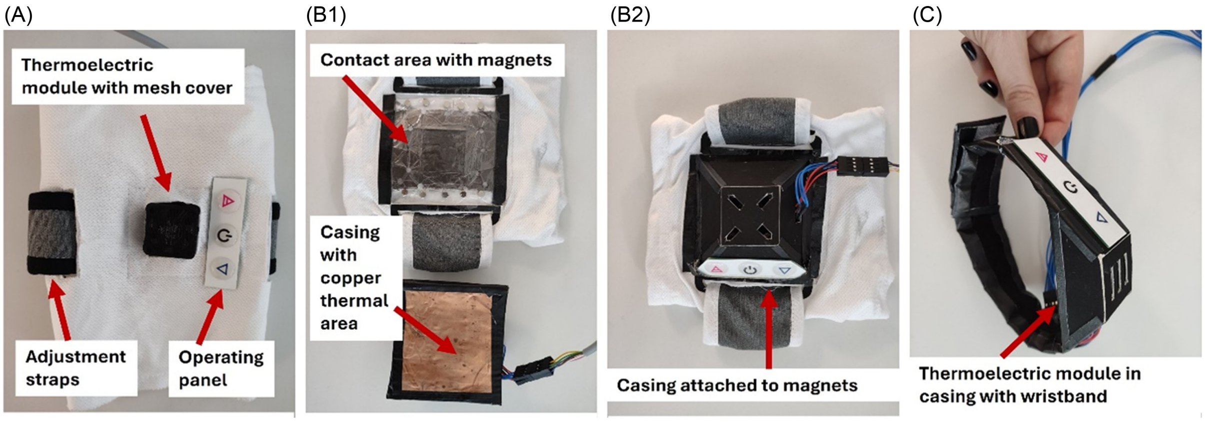


**Figure 3. Functional model variants featuring a permanent integration (3A), a modular approach (3B), and an independent option (3C)**

The permanent integration (Fig. 3A) consists of the thermoelectric module sewn into a modelled jacket sleeve with the use of a thin mesh cover, with no possibility for placement variation and detaching. The mesh fabric is sewn onto a thin fabric layer, enabling the ceramic plate of the Peltier module skin contact with the wearer's forearm via the thin fabric layer. An outer layer covers the technological components and the operating panel and carries additional adjustment straps for individual fitting.

The modular approach (Fig. 3B) contains the thermoelectric module and the operating panel within a cardboard casing closed by an enlarged copper area. The modelled sleeve is equipped with a designated location for attaching the module, containing magnets for the attachment, and a thermo-transfer material as a contact area between copper surface and wearer's forearm. Adjustment straps are added left and right of the module, and the module can be detached from or attached to the contact area (Fig. 3B1 and 3B2, respectively).

The independent option (Fig. 3C) contains the thermoelectric module, the operating panel, and the tightening straps in one device, therefore providing independent positioning on the forearm similar to a wristwatch, and is worn directly on the skin.

The different surfaces and contact areas are implemented to evaluate both the difference in thermal transmission between Peltier on textile, Peltier on copper and thermo-transfer material, and Peltier on copper as well as the subjective feeling of safety with the different options.

## 3.2. Qualitative user test results

### 3.2.1. Functionality

During the first step of the user testing, all twelve users confirm the sensing of a thermal effect in all three samples. Additionally, differences in the thermal comfort between the three differing layering and material constructions of the samples are verbalized by the users. The smaller and less cushioned area of the independent and permanent models is described as "punctual", "stabbing", and "painful" in a total of 40 repetitions by users with a negative emotionality, while the bigger area of the modular option is described as "area-wide", "distributed", and "comfortable" in a total of 41 times by users with a positive emotionality. 20 recurrent phrasings are used to express the discomfort with the smaller area, such as "what irritates me is the punctuality" and 25 phrasings to express comfort with the enlarged area, such as "the bigger area distributes the temperature better; it is not painful". The repetitive wordings (#reps) and examples of recurrent phrasings (#recs), along with their number of various statements referring to the same meaning, are presented in Table 1.

**Table 1. Repetitions and recurrent phrasings regarding thermal effect of functional models**

| Connotations and context | Key words | # reps | Key quote | # recs |
|---|---|---|---|---|
| Negative Thermal distribution of small area | Punctual, | 14 | What irritates me is the punctuality | 20 |
| | Concentrated, stabbing, brutal, painful | 26 | | |
| Positive Thermal distribution of big area | Area-wide | 15 | The bigger area distributes the temperature better, it is not painful | 25 |
| | Area, big area, distributed | 17 | | |
| | Comfortable | 9 | | |

When testing the functionality of the different concepts in combination with motorcycle clothing, different levels of obstruction of the thermoelectric module by protective gloves could be detected, Fig. 4.

(A) (B)

**Figure 4. Wearable concepts with permanent integration (4A) and modular approach (3B) in use**

The permanent integration (4A) can be worn by all users without the glove interfering with the module, given the ample space between module and glove. Similarly, the independent integration option does not interfere with the gloves of the testers since the placement of this module can be chosen freely by each user according to their biometrics. The glove nearly covers the air slits of the modular approach (4B) in some testers due to different arm and glove lengths as well as the increased size of the encapsulation. Additionally, the operating panel is partly covered by the glove. This obstruction may potentially impair the functionality of the fan by hindering air supply.

### 3.2.2. Subjective safety evaluation

None of the functional models is perceived to cause any physical harm during wearing. However, two users mention they are irritated by the modular solution, and two users mention being scared to damage the independent option with their movements. Table 2 summarizes the answers given by the testers for the posed questions and each model.

**Table 2. Subjective safety evaluation**

| Questions | Permanent | | | Modular | | | Independent | | |
|---|---|---|---|---|---|---|---|---|---|
| | yes | no | unsure | yes | no | unsure | yes | no | unsure |
| Are you tense or irritated by the device? | 0 | 12 | 0 | 2 | 9 | 1 | 1 | 11 | 0 |
| Does the sample dig into your skin, sit too tight or is it chafing anywhere? | 0 | 12 | 0 | 0 | 12 | 0 | 0 | 12 | 0 |
| Are you scared to damage the device with your movements? | 1 | 11 | 0 | 1 | 10 | 1 | 3 | 9 | 0 |
| Are you concerned about the device itself or the cables? | 1 | 11 | 0 | 0 | 12 | 0 | 0 | 12 | 0 |

### 3.2.3. Biomechanical evaluation

The height of the functional package is negatively commented with a total of 18 repetitions across all three models. Three users comment negatively on the bigger size of the modular and independent models. However, the pre-determined movements as well as moving around the testing space are performed without issues. All testers voice the inconvenience of attaching the modular and independent solutions, necessitating "fumbling" and "hassling" with the prototypes, and an increased error rate when attaching the samples, e.g. by attaching the module upside down. A high error rate and an added fear of losing the sample is present in the modular and independent solutions, voiced by the users as fear of the module falling off during the ride due to the external attachment construction. This fear is matched in behaviour by repeated checking whether the device was still attached, taking in compromising postures and careful movement while wearing the prototype. Two users specify that the unstable integration makes them fear canting and subsequently losing the module. The permanently integrated sample is described by all 12 users as the most comfortable, such as "this one is disturbing me [the user] even less than the others [samples]". It is also identified as the least fault-prone sample, with no errors when attaching and adjusting. One user notes that he "does not have to worry about this", another that he can "just put on your [his] jacket and go". All users display matching behaviour by undisturbed movement and low levels of attention span while adjusting and taking off the sample. The repetitive wordings and recurrent statements with their given context and connotation are summarized in Table 3.

**Table 3. Repetitive wordings and recurrent statements regarding biomechanical evaluation**

| Connotations and context | Key word & synonyms | #reps | Key quote | #recs |
|---|---|---|---|---|
| Negative Height of thermoelectric module (all solutions) | Height<br>Make-up, loftiness, high | 4<br>14 | - | - |
| Negative Attachment process (modular and independent solution) | Fumbling<br>Hassle, handling, fidgeting, struggle, rubbish | 7<br>6 | This is my least favourite option because of the opening and closing process | 16 |
| Negative Unstable integration (modular and independent solution) | (Fear of) losing, falling | 10 | I would be concerned about losing it, and that would divert my attention from the road | 14 |
| Positive Ease of use (permanent solution) | - | - | This is uncomplicated | 9 |
| Positive Stable integration (permanent solution) | - | - | This is tightly integrated; I don't have to think about it | 8 |

## 4. Discussion

In the following, the impact of the thermal effect caused by the construction varieties on the thermal comfort of the users and further consequences related to it is discussed. Second, the impact of integration type displayed by the concepts on the perceived safety of the driver is considered. Lastly, the impact of the designed variants on biomechanical aspects is discussed and indications for improvement are given.
*Impact of the palpable thermal effect on the thermal comfort:* even with the challenge of needing both access to air and direct skin contact, all three concepts are functional in providing a palpable thermal effect. The differences in arm length-glove ratio as described in chapter 3.2.1 are a potential threat to the function by means of covering the air supply for the fan. Since this issue is not observed in the permanent integration, this integration option could be investigated further regarding ideal placement for a broad spectrum of body types. The difference in make-up of the models greatly influences the thermal comfort of the wearer. As mentioned in 3.2.1, the smaller and less cushioned samples are perceived as irritating, punctual and stabbing, the bigger area with the thermo-transfer material as comfortable. Moreover, the palpable thermal effect of the module and its surrounding materials has a direct impact on the cognitive function of the driver. With the high influence of distraction on a motorcyclist's safety, a stabbing stimulus could potentially result in a thermal discomfort strong enough to divert the driver's attention from the road. In this regard, only the option with the additional enlarged cushioning thermo-transfer material renders both a palpable stimulus and simultaneously a low level of distraction by the temperature.
*Impact of integration type on perceived safety:* considering the results of chapters 3.2.3, the perceived instability of both the modular and independent integration adds feelings of distress and distracts by fear of losing the module. This is mirrored in the results of 3.2.2, where 9 out of 12 users confirm being tense or irritated by the modular device, and 9 out of 12 users note that they are scared to damage the independent option with their movements. These verbal cues are complemented by the visually observed careful behaviours and repeated checking of the non-integrated models in chapter 3.2.3. Although one user states concern about the cables and the device itself, the permanently integrated solution poses the least distraction to the wearer and fulfils the aim of perceived safety in this regard.
*Impact of design variants on user's attention span and force:* during the real-life scenario user testing, multiple indications for improvement of the module design are identified in chapter 3.2.3. A lack of visual cues as to which direction was the correct way to attach the modular and independent models results in a higher attention span needed for attaching the thermoelectric module, and adds insecurity and irritability in the process, displayed by the usage of emotional wordings such as "fidgeting" and "hassle". Especially when wearing the motorcycle gloves during testing and needing to adjust a module, the ease of use decreases with a higher number of attachment steps, while no such issues are present in the permanently integrated solution. In this regard, the obstruction of the glove potentially impairing the functionality of the modular approach mentioned in chapter 3.2.1. may decrease its user-friendliness as well by preventing the user from reaching the buttons without needing to pull down or remove the glove first. As for the sizing of the module, across the different models, the dimensions of the original module (30x30x30 mm) enable an integration that does not disturb the users when performing the standard motorcycling movements. However, even the relatively small size is negatively commented regarding the height and fear of canting (chapter 3.2.3), and the small size of the distribution area is unpopular with all users (chapter 3.2.2).

## 5. Conclusions

This paper aimed to provide a personal climatization to motorcyclists in the form of a thermoelectric module, consisting of a Peltier element, a heat sink, fan, and a thermal interface material. Aspects of functionality, perceived safety, and usability in the context of motorcycle driving were considered when performing the technology integration. A literature and market review, the creation of three functional models, and testing with the target group were carried out. The user testing showed that an integration of the thermoelectric module can be realized functional in the given context. Small changes to the build-up of the module, such as adding and enlarging a layer between Peltier surface and skin, had a great positive influence on the thermal comfort and, connected thereto, the safety of the driver by reducing distraction by thermal stimuli. Additionally, the perceived safety of the driver can be positively influenced by providing a stable integration, and negatively influenced by a flexible integration solution. Regarding biomechanical aspects, users prefer a wearable concept with permanent integration of the module into the article of clothing. Further, testing has shown that the contact surface of the module, transferring the temperature to the wearer, should ideally cover an area bigger than 30x30 mm, but also be as flat as possible or hidden within the protective gear, so that fear of canting and losing during motorcycling activities can be reduced. Currently, the high variety of technical constellations and measuring methods in recent literature indicates that there is no clear knowledge about the most efficient or thermally comfortable technical constellation and make-up. The results of the user testing further highlighted the necessity of additional research in terms of thermal well-being with and technological constellation of the Peltier module, since a punctual thermal stimulus can be perceived as irritating and thus divert the driver's attention from the road. This work stresses the importance of incorporating usability testing for future pursuing of integrating wearable climatization technology in the form of a Peltier element into motorcycle protective clothing. In addition to improvements regarding technological feasibilities, which were examined in multiple scientific papers, the importance of further reviewing safety set-ups of the thermoelectric module and evaluating the thermal comfort of the wearer to ensure a functional and safe product was addressed in this paper. Among its possible applications, the presented work could serve as a base for follow-up studies addressing user-oriented methodologies for the validation of technical products in the context of motorcycle protective clothing.

## References


Alpinestars. (2024). *Motorcycle jackets*. https://www.alpinestars.com/collections/moto-jackets

Brinkmann, Svend. (2020). Unstructured and semistructured interviewing. In P. Levi (Eds.), *The Oxford Handbook of Qualitative Research*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190847388.013.22

Daanen, H. A. M. (2009). Manual Performance Deterioration in the Cold Estimated Using the Wind Chill Equivalent Temperature. *Industrial Health*, 47(3), 262–270. https://doi.org/10.2486/indhealth.47.262

Dabrowska, A., M. Kobus, P. Sowinski, L. Starzak, & B. Pekoslawski. (2024). Integration of Active Clothing with a Personal Cooling System within the NGIoT Architecture for the Improved Comfort of Construction Workers. *Applied Sciences 2024*, 14(2). https://doi.org/10.3390/app14020586

de Rome, L. (2019). Could wearing motorcycle protective clothing compromise rider safety in hot weather? *Accident Analysis & Prevention*, 128, 240–247. https://doi.org/10.1016/j.aap.2019.04.011

de Rome, L, E. A. Taylor, R. J. Croft, J. Brown, M. P. Fitzharris, & N. A. S. Taylor. (2016). Thermal and cardiovascular strain imposed by motorcycle protective clothing under Australian summer conditions. *Ergonomics*, 59(4), 504–513. https://doi.org/10.1080/00140139.2015.1082632

Dearnley, C. (2005). A reflection on the use of semi-structured interviews. *Nurse Researcher*, 13(1), 19–28. https://doi.org/10.7748/nr2005.07.13.1.19.c5997

Eldho, A. S. T., J. T. Paul, J. Kurian, J. Joseph, & P. Brijesh. (2021). Design and analysis of a smart-attachment to jacket and helmet used by two-wheeler riders using Peltier-module. *Materials Today: Proceedings, 42, Part 2*, 862–869. https://doi.org/10.1016/j.matpr.2020.11.718

Hancock, P. A., & I. Vasmatzidis. (2003). Effects of heat stress on cognitive performance: the current state of knowledge. *International Journal of Hyperthermia*, 19(3), 355–372. https://doi.org/10.1080/0265673021000054630

Jahangir, M., M. A. U. Rehman, A. B. Awan, & R. H. Ali. (2019). Design and Testing of Cooling Jacket using Peltier Plate. *2019 International Conference on Applied and Engineering Mathematics (ICAEM)* (pp. 191–196). https://doi.org/10.1109/icaem.2019.8853654

Knight, J. F. & C. Baber. (2005). A Tool to Assess the Comfort of Wearable Computers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 47(1), 77–91. https://doi.org/10.1518/0018720053653875

Mitsik, M. F., & M. V. Byrdina. (2020). Thermoregulation of Smart Clothing based on Peltier Elements. *2020 IEEE East-West Design & Test Symposium (EWDTS)* (pp. 1–5), https://doi.org/10.1109/ewdts50664.2020.9224805

Owen, W. F. (1984). Interpretive themes in relational communication. *Quarterly Journal of Speech*, 70(3). https://doi.org/10.1080/00335638409383697

Palinkas, L. A. (2001). Mental and Cognitive Performance in the Cold. *International Journal of Circumpolar Health*, 60(3), 430–439. https://doi.org/10.1080/22423982.2001.12113048

Peterson, B. L. (2017). Thematic Analysis/Interpretive Thematic Analysis. In J. Matthes, C.S. Davis, & R. F. Potter (Eds.), *The International Encyclopedia of Communication Research Methods* (pp. 1–9). Wiley Sons, Inc. https://doi.org/10.1002/9781118901731.iecrm0249

Poikayil, J. R., J. Francis, D. Saju, A. Suresh, & J. Varghese. (2017). Peltier integrated heating & cooling jacket. *International conference of Electronics, Communication and Aerospace Technology (ICECA)* (pp. 260–263). https://doi.org/10.1109/iceca.2017.8212812

Ramsey, J. D., C. L. Burford, M. Y. Beshir, & R. C. Jensen. (1983). Effects of workplace thermal conditions on safe work behavior. *Journal of Safety Research 14*(3). https://doi.org/10.1016/0022-4375(83)90021-X
Regan, M.A., G. Lintern, R. Hutchinson & C. Turetschek. (2015). Use of Cognitive Work Analysis for exploration of safety management in the operation of motorcycles and scooters. *Accident Analysis & Prevention*, 74. (pp. 279–289). https://doi.org/10.1016/j.aap.2014.07.009
Sahta, I., I. Baltina, & J. Blums. (2011). Development of Microclimate Regulatory Clothes. 9th International Conference on Global Research and Education, Inter-Academia 2010, *Advanced Materials Research*, 222 (pp. 193–196). https://doi.org/10.4028/www.scientific.net/amr.222.193
Sim, S. Y., M. J. Koh, K. M. Joo, S. Noh, S. Park, Y. H. Kim, & K. S. Park. (2016). Estimation of Thermal Sensation Based on Wrist Skin Temperatures. *Sensors (Basel)*, 16(4), 420. https://doi.org/10.3390/s16040420
Taylor, N.A.S. (2015). Overwhelming Physiological Regulation Through Personal Protection. *Journal of Strength and Conditioning Research*, 29, 111–118. https://doi.org/10.1519/jsc.0000000000001030
Taylor, L., S. L. Watkins, H. Marshall, B. J. Dascombe, & J. Foster. (2016). The Impact of Different Environmental Conditions on Cognitive Function: A Focused Review. *Frontiers in Physiology*, 6. https://doi.org/10.3389/fphys.2015.00372
Van de Sand, F., A. K. Frison, P. Zotz, A. Riener & K. Holl. (2020). The role of information processing for product perception. *In User Experience Is Brand Experience: The Psychology Behind Successful Digital Products and Services*. (pp. 17–35). Springer. https://doi.org/10.1007/978-3-030-29868-5_2
Velagapudi, S. P., V. Balasubramanian, R. Babu & V. Mangaraju. (2010). Muscle fatigue due to motorcycle riding. *SAE Technical Paper*, September 2010. https://doi.org/10.4271/2010-32-0100
Vlad, L., S. Mitu, & C. Buhai. (2013). Optimizing the Thermal Physiological Comfort by Introducing Peltier Cells in Simulated Conditions. *Applied Mechanics and Materials*, 371, 792–796. https://doi.org/10.4028/www.scientific.net/amm.371.792
Walter, E. J., & M. Carraretto. (2016). The neurological and cognitive consequences of hyperthermia. *Critical Care*, 20(1), 199–206. https://doi.org/10.1186/s13054-016-1376-4
Woods, R.I. (1983). Cooling of motorcyclists in various clothing during winter in Britain. *Ergonomics*, 26(9). (pp. 847–861). https://doi.org/10.1080/00140138308963413
Woods, R. I. (1996). Specification of motorcyclists' protective clothing designed to reduce road surface impact injuries. In J. S. Johnson & S. Z. Mansdorf, (Eds.), *Performance of Protective Clothing: Fifth Volume* (pp. 3–22). American Society for Testing and Materials. https://doi.org/10.1520/stp14053s
Zwolińska, M. (2013). Thermal subjective sensations of motorcyclists. *Accident Analysis & Prevention*, 50, 1211–1220. https://doi.org/10.1016/j.aap.2012.09.021