

SMART PERSONAL PROTECTIVE EQUIPMENT: INTELLIGENT PROTECTION FOR THE FUTURE

Summary

Smart personal protective equipment (PPE) is becoming more and more common. Such products have been on display at trade fairs and in use for some time. Nevertheless, it is advisable to view the market with a fair degree of scepticism. Although some good products do already exist, smart PPE is a fast-moving area, and all participants are still learning to fully exploit the potential of smart PPE.

What is smart PPE?

PPE, such as safety shoes, ear plugs and protective eyewear, has always been important in protecting the wearer from one or many occupational safety and health (OSH) risks. If an activity carried out by a person — the wearer of the PPE — involves a certain risk that cannot be further reduced by other (collective technical or organisational) means, the use of PPE is essential to enable that person to do their job without or with less risk of injury. PPE must function reliably and provide a high level of protection. This principle of the hierarchy of prevention ⁽²⁾ has been successfully used for a long time ⁽³⁾.

Of course, research and development are carried out in the field of PPE. More and more often, one sees descriptions such as 'intelligent' or 'smart' applied to PPE. The level of protection can be increased by using enhanced materials or electronic components in smart PPE. Enhanced materials have new properties: knee protectors, for instance, are often inflexible and hinder normal movements; however, smart shock-absorbing material can be soft and flexible, allowing normal movement. When protection is needed, in the event of a shock, the smart material's properties change, and the shock-absorbing effect is revealed.

In most cases, the 'smart' part of smart PPE is electronics. In this case, smart PPE combines traditional PPE (e.g. a protective garment) with electronics, such as sensors, detectors, data transfer modules, batteries, cables and other elements.

A well-known example that has already been presented at trade fairs is smart protective garments for firefighters. Various sensors are integrated into the firefighters' garments. They measure body functions such as heart rate, blood pressure and

Smart PPE promises a higher level of protection and more comfort through the use of enhanced materials or electronic components. Sometimes it provides both, and sometimes it provides one of these aspects. What is crucial to understand is that **the combination of traditional PPE with smart elements forms this new type of PPE.** The smart elements increase the protection level, and thus they are an integral part of PPE. Consequently, every time the PPE is tested — be it a conformity assessment or a functionality test — the **smart PPE must be tested as a whole** by the relevant stakeholder, for example the manufacturer, the notified body, the relevant authority or the user.

⁽¹⁾ (Throughout the article the term "users" is understood to include both employers and employees.)

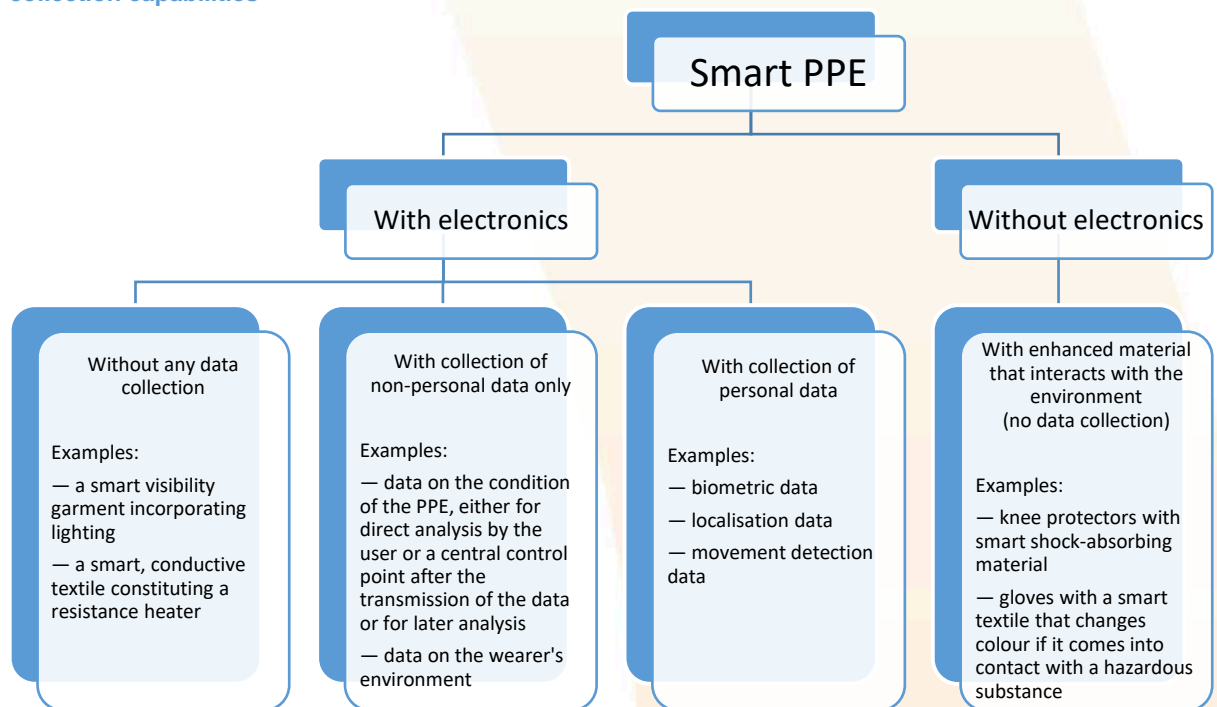
⁽²⁾ https://oshwiki.eu/wiki/Hierarchy_of_prevention_and_control_measures

⁽³⁾ For the use of PPE in the workplace, see Council Directive 89/656/EEC, last amendment on 31.10.2019 (<https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:31989L0656>).

core body temperature. With such data, it is possible to assess the work capabilities of the person in question. This was not possible in the past. Other sensors observing the firefighter's surroundings can detect toxic gases or measure temperature. In addition, information on the condition of the protective equipment after an assignment can be stored. This is very useful for assessing the type of cleaning that is required and whether or not the right level of protection is still assured. All this information can be used to optimise the level of protection provided to firefighters and increase their ability to do their job. Thus, smart PPE protects the wearer at a higher level, sometimes providing more comfort, and it can produce valuable information for care and maintenance. A classification scheme for smart PPE is proposed in Figure 1.

Smart PPE can be characterised by a certain degree of interaction with the environment or reaction to environmental conditions. The current proposal for a definition by the European Committee for Standardization (CEN) — the relevant European standardisation body — is as follows: Smart PPE is 'personal protective equipment that ... exhibits an intended and exploitable response either to changes in its surroundings/environment or to an external signal/input' ⁽⁴⁾.

Figure 1 Proposal for a classification scheme for types of smart PPE, according to composition and data collection capabilities



Challenges for legislation and standardisation

Learning electronics

All of these new developments sound very positive and promising. However, the situation is also very complex. To ensure that smart PPE actually leads to a higher level of protection, all parties involved have some hard work to do on the latest developments in this new sector. Up until now, electric and electronics have not been important in the field of PPE; however,

⁽⁴⁾ See Definition 10.1 in CEN/TC 162/WI 439 of July 2019.

electronics play a major role in recent developments, often representing the ‘smart’ part of smart PPE. As a consequence, manufacturers and conformity assessment bodies under the EU PPE Regulation ⁽⁵⁾ (i.e. notified bodies) are faced with a challenge: they need to ‘learn electronics’. Designing smart PPE is not as simple as assembling a protective jacket with some electronic elements such as sensors, batteries and cables. The entire new product constitutes the PPE and must be tested in accordance with the PPE Regulation, including to ascertain that the product itself does not represent a risk to the user. This is not as easy as combining traditional PPE that conforms with the PPE Regulation on the one hand and certified electronic parts on the other. The combination of both the two forms the PPE as a whole, and it must be tested as a whole. This ensures that no new risks are created by the inclusion of electronics. The relevant PPE tests must be carried out as well as tests relating to electrical safety, and aspects such as surface temperature, battery safety, the impacts of electromagnetic fields (EMF) and electromagnetic compatibility (EMC) must be tested.

The need for standards

The PPE sector benefits from an abundance of standards. Through these standards, the community has ensured a high quality of PPE. This is necessary because of the abovementioned importance of effective and reliable PPE. Not only manufacturers but also users/purchasers and notified bodies appreciate being able to find requirements for specific types of PPE in standards. Users know that PPE that meet the standards is good PPE. Therefore, the professional user orders not just ‘safety shoes’ but ‘safety shoes according to EN ISO 20345’ ⁽⁶⁾. However, the situation in relation to smart PPE is different. There are no standards available yet ⁽⁷⁾. Purchasers cannot follow standards and still have to rely on their own judgement in assessing the quality of smart PPE. If there are any questions, the only way to resolve them is to enter into dialogue directly with the supplier, be it the dealer or the manufacturer, and discuss the performance and capabilities of the new products.

Of course, this gap in the standardisation of smart PPE will be closed. However, this will take some time. In addition, standardisation bodies are starting to recognise that smart PPE products are a completely new type of product. Members of standardisation groups are faced with the same challenge as manufacturers and notified bodies: first, they have to learn about the new technology. One example is the German standardisation project on visibility clothing with active lighting. Since the beginning of 2018, manufacturers, suppliers, notified bodies, users and OSH experts have been working on a technical specification containing health and safety requirements for traditional high-visibility clothing combined with illuminating elements (e.g. light-emitting diodes). Although this product is not strictly smart PPE — there is no interaction with the environment, as the light is switched on by hand — the challenges mentioned above are present all the same. The electrical part of the standard is completely new to textile experts. The publication of this document is expected by the end of 2020.



An example of visibility clothing with active lighting, © UVEX

⁽⁵⁾ Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC.

⁽⁶⁾ EN ISO 20345, ‘Personal protective equipment — safety footwear’.

⁽⁷⁾ However, CEN has published a guide collecting knowledge and recommendations on smart textiles: CEN/TR 16298:2011, ‘Smart textiles — definitions, categorisation, applications and standardization needs’.

Standardisation groups must formulate requirements and testing procedures. Doing this in a new area takes time, as everyone involved needs to be satisfied with the results. However, although the current process is time consuming, the project will act as a kind of pathfinder for future standards on smart PPE.

At European level, there are also some initial standardisation projects in progress ⁽⁸⁾. Drafts of terms and definitions for smart garments and smart PPE are being discussed, as is an initial proposal for a SUCAM ⁽⁹⁾ guideline on smart garments protecting against heat and flame (firefighters' protective clothing falls within the scope of this guideline). The very first draft of a product standard for this kind of smart PPE was presented to the relevant standardisation body in October 2019 ⁽¹⁰⁾.

The hype phase seems to be over

At A+A 2019 — the world's leading trade fair for health and safety at work — only a few out of more than 2,000 exhibitors displayed smart PPE. This may be an indication of the extent of the abovementioned challenges. Some of them were garments with active lighting. One solution integrates a sensor into an active lighting vest that warns the wearer if a mobile machine, equipped with the corresponding sensor, comes too close. The sensor vibrates and generates sound and the lights start flashing. On the machine, similar warning signs appear; it is even possible to use the equipment to control the speed of the machine to avoid collision with the person detected.



An example of collision warning equipment, © Linde Material Handling GmbH

Another smart solution displayed used a sensor that built into underwear to monitor the heart rate of the wearer and communicate with a smartphone. At the current development stage, the system warns the user if the heart rate goes above a customisable threshold, in order to avoid accidents due to excessive stress. The system was developed for workers carrying out maintenance on high-voltage power transmission lines. It is also capable of detecting if the wearer falls and transmitting an immediate emergency call. Another interesting innovation on

⁽⁸⁾ Following standardisation request M/553 as regards advanced garments and ensembles of garments that provide protection against heat and flame, with integrated smart textiles and non-textile elements for enhanced health, safety and survival capabilities.

⁽⁹⁾ SUCAM — selection, use, care and maintenance.

⁽¹⁰⁾ All three documents are being developed as part of CEN/TC 162, 'Protective clothing including hand and arm protection and lifejackets'.

display at the exhibition related to a research project on firefighters' garments for use specifically on vessels. However, only a few new smart PPE products were shown. This may be a sign that the manufacturers have realised that smart PPE is more than just putting textiles and electronics together and that creating smart PPE is not an easy task. It may also be a sign that in the current circumstances it is hard to get such equipment certified by notified bodies. Manufacturers may prefer not to take the risk of investing in the expensive development of smart PPE in case they do not get the necessary certificate at the end. Given this, the current situation can be seen as an obstacle to placing new technology on the European market.

Challenges related to users

Comprehensive information is a must

Users are also required to adapt to the new capabilities of smart PPE. They must be *informed users*; that is, fully informed not only regarding the mode of operation and the functions of the smart PPE but also regarding the limits of the smart elements. Recommendations on operation, use, cleaning and maintenance are required. The manufacturer must provide all this information before sale, so that the future user can select the appropriate PPE. It is self-evident that it must also be supplied on the purchase of the product. As usual, the user should use the smart PPE according to the manufacturer's specifications. For all stakeholders, it would be an advantage if users gave feedback on their experiences and in particular if they gave their suggestions for improvement to the manufacturers. Since the sector is still young, recommendations based on user experiences are very important for the future development and optimisation of smart PPE.

Future users' expectations



An example of a smart firefighter's garment,
© VOCHOC GoodPro

Good PPE is PPE that is used! It follows that smart PPE has to be accepted by the user. Otherwise, the probability that it will not be worn is high, and protection will be removed instead of enhanced. Manufacturers as well as purchasers should have a good understanding of what future users really need and in particular which kinds of smart functions will be accepted.

Let's return to one of the first examples of smart PPE given above: smart firefighters' garments. The 'incident/accident' sites that fire services have to deal with have changed rapidly (e.g. there are more plastics in buildings and cars, more batteries in general and more powerful batteries). This leads to more dangerous conditions for firefighters (e.g. fires that burn faster and hotter, denser smoke, a higher risk of explosion). Better, intelligent protection — smart PPE — could be very effective here. However, first it needs to be clear which smart functions are really useful and — just as importantly — which functions will be accepted by firefighters.

The German Commission for Occupational Health and Safety and Standardisation (KAN) ⁽¹⁾ designed a workshop to collect firefighters' opinions on future smart PPE. Product users drawn from full-time, company and voluntary fire services attended the workshop, as did representatives of the accident insurance institutions through which firefighters are insured,

⁽¹⁾ www.kan.de/en

the research departments of the German Federal Institute for Occupational Safety and Health (BAuA) and the Institute for Occupational Safety and Health of the DGUV ⁽¹²⁾ (IFA).

The overall conclusions of the workshop are presented in the box below.

General conclusions of KAN's smart PPE workshop

First, additional functions must always enhance safety. Gimmicks and the excessive collection of data are two things that must be avoided. The workshop yielded a wealth of specific suggestions.

Data

- 'Less is more' is the motto when it comes to the presentation of data to the wearer. Otherwise, he or she can rapidly become overloaded with information that either distracts from the principal task or is simply ignored.
- Wearers want to trigger the display of certain data themselves.
- An important concern is that the systems should not collect and store the wearer's biometric data continuously or by default.

Functionality

- Users wish to have systems that are flexible and can be adapted to the deployment scenario in question. It should be possible for items of PPE to be fitted with suitable sensors on a case-by-case basis.
- Owing to their experience in burning buildings, the workshop participants challenged the feasibility of a wireless link between sensors on PPE and a central control point. They pointed out that even obtaining a stable wireless voice connection frequently proves difficult during deployments.
- Data on the condition of PPE after an assignment could be very useful: what form of cleaning is required and is the right level of protection still assured?

Acceptance

- All new elements must function reliably at a high level. A facility must be provided for testing them prior to a deployment.
- The equipment must be practical and ergonomic in its operation.
- Its care and maintenance must not entail substantial additional effort.
- Users must be fully informed regarding the mode of operation and the functions of smart PPE, as well as the limits of the smart elements.

Most of the results are of a general nature, and it can be assumed that users of other types of smart PPE would present similar opinions. These results indicate that it would be a great advantage if the user and the manufacturer were in close contact, at least for the selection of more complex smart PPE. The supplier could guide the user in selecting the smart elements, and the user could learn the appropriate use, care and maintenance to ensure protection.

⁽¹²⁾ DGUV — German Social Accident Insurance; see www.dguv.de/en

Challenges posed by the new technology

Smart PPE is supposed to offer a higher level of protection. However, as mentioned above, there are still some hurdles to overcome before the promised benefits can be put into practice. First of all, users in particular must be aware that there is no guarantee of 100 % protection, not even with smart PPE.

Moreover, manufacturers and notified bodies must ensure that smart PPE does not pose new risks to the user. For example, batteries, needed to power electronics and usually worn very close to the body in the case of smart PPE, must not get too hot and must certainly not catch fire or, even worse, explode. Other electrical risks, for example relating to voltage, EMF and EMC, must be minimised. Information needs to be provided on who is not allowed to use smart PPE because of medical implants that may be disturbed by the electrical components. In general, attention must be paid to ensuring that smart and traditional protective elements work well together and do not interfere with each other, in particular by reducing protective properties or creating new risks for the user.

Smart PPE is often associated with data capture, collection and transfer. It is understandable that users emphasise data protection as one of the key requirements for acceptance. Egon L. van den Broek ⁽¹³⁾ explains that users ‘can perceive monitoring technology ... as an invasion of privacy, which is generally experienced to be a stressor. This perception is justified.’ More specifically, Nicola Stacey et al. ⁽¹⁴⁾ state that monitoring of workers ‘can have a negative impact on health and well-being if workers feel that they have to meet challenging performance targets; they have to conform to an expected behaviour that may not come naturally to them; they are unable to interact socially or take breaks when they want to; or their privacy is invaded. ... Constant oversight can cause stress and anxiety.’ This applies in particular ‘when there is no information on/understanding of what data are collected, how they are used and for what purpose’. Consequently, for smart PPE that is capable of data collection to be used successfully, the users must be well informed about what data are collected and what is done with them (with regard to evaluation but also storage). Otherwise, the acceptance of smart PPE among users will be very low. When it comes to handling workers’ data, the General Data Protection Regulation (GDPR) has to be followed. The aim should be to develop designs for smart PPE products, and rules for their use, that minimise data collection.

A major obstacle to placing smart PPE on the market is the lack of methods of testing these products against the PPE Regulation. Manufacturers must test products during the design phase. Notified bodies must carry out tests to certify the products during conformity assessments. Both experience problems because of a lack of appropriate testing methods for smart PPE. Stakeholders need to develop new methods and, where possible, incorporate them into standards. Otherwise, a significant problem will be that manufacturers will not be able to carry out conformity assessment procedures because they will not be able to find any notified body to carry out the required certification. As explained above, it is probable that notified bodies do not currently have the required capabilities.

⁽¹³⁾ See the EU-OSHA discussion paper ‘Monitoring technology: the 21st century’s pursuit of well-being?’ by van den Broek for a detailed discussion on the monitoring of biometric data in particular; the paper includes a chapter on ‘Big Brother as stressor’ (<https://osha.europa.eu/en/publications/monitoring-technology-workplace/>).

⁽¹⁴⁾ See the EU-OSHA report by Stacey et al., *Summary — foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025* (<https://osha.europa.eu/en/publications/summary-foresight-new-and-emerging-occupational-safety-and-health-risks-associated/>).

Another challenge is the end-of-life phase of smart PPE. How can a combination of textiles, plastic, metal and electronics be appropriately and environmentally recycled? Smart PPE will certainly demand specialised recycling methods ⁽¹⁵⁾.

More generally, the smart PPE sector is young. This means that there may be immature products on the market. A degree of wariness about the selection, purchase and use of smart PPE is appropriate. It is therefore very important that all stakeholders exchange their experiences to optimise the products and their application.

Requests and recommendations to stakeholders

The challenges mentioned above are complex but can certainly be addressed. Stakeholders are encouraged to not only focus on their area of work but also keep an eye on the big picture. For such a young sector, it is important that doubts and uncertainties, as well as insights, experiences and suggestions, are exchanged openly and transparently. Through good cooperation, it will be possible for all participants to tap into the potential of smart PPE and to make workplaces healthier and safer.

According to the author, stakeholders should discuss the following suggestions and recommendations.

Policy-making

- Create an appropriate legal framework for notified bodies ⁽¹⁶⁾.

One of the challenges is the certification process. Until now, legislation has required one notified body to take full responsibility for the whole test. It seems that notified bodies in the field of PPE are not able to carry out tests of smart PPE on their own. A change in legislation might overcome this bottleneck. There should be a system in place that makes it possible for two or more notified bodies to work together, each of them taking responsibility for its area of competence regarding the tests carried out. One of them might be the leading body coordinating the work. However, in the end, all the bodies involved would be responsible for the certification. It would need to be ensured that the tests were carried out taking into account the smart PPE as a whole, as explained above.

As changing the legislation might take quite a long time, appropriate guidance from policy-makers might be an interim solution.

This issue is not unique to the PPE sector. Many new, enhanced products in other sectors will also challenge the current system of conformity assessment that is currently focused on one sector or one piece of legislation only.

Notified bodies should receive assistance and perhaps financial support to enable them to develop the new methods of conformity assessment required.

⁽¹⁵⁾ This was one of the results from the PPE forum 'Closing the loop! Promoting circular economy models in personal protective equipment', organised by SBS — Small Business Standards, the European body that advocates for small and medium-sized enterprises in the standardisation process. See <https://www.sbs-sme.eu/event/closing-loop-promoting-circular-economy-models-personal-protective-equipment>

⁽¹⁶⁾ The basic idea of this recommendation was presented in 'Draft guidance conformity assessment and certification of "complex" products (status 06/2014)'. It was produced as a deliverable for the Susta-Smart project (a project funded by the EU seventh framework programme grant agreement no 319055). See <https://www.eu-esf.org/q-a/interesting-articles/4113-susta-smart-guidance-certification-smart-ppe-2014>
In the final report 'Programming Mandate M/509: protective textiles and personal protective clothing and equipment' (delivered in January 2014), the idea was presented in slightly more detail (see point 4.3; <https://www.eu-esf.org/q-a/interesting-articles/4112-programming-mandate-m-509-smart-ppe-final-report>)

- Formulate obligations for manufacturers to enable appropriate and environmental recycling of smart PPE. This would tie in with the EU strategy on the circular economy ⁽¹⁷⁾.
- Request that European standardisation organisations develop appropriate standards in the field of smart PPE.
- Support entities that provide orientation in finding competent partners for development of smart PPE.

Development of smart PPE is a highly interdisciplinary task. Manufacturers/Research institutions need to find suitable partners for development and conformity assessment of smart PPE. Hence, it is suggested to support entities that provide orientation in finding competent partners and that support in the communication between relevant stakeholder groups (e.g. provide funding for the development of an interactive orientation tool for all relevant stakeholder groups and provide funding for a “map of competences” in which stakeholders can find competent partners efficiently).

Research and development

- Develop appropriate testing methods for smart PPE, in particular for combinations of textiles and electronics, that can be used to check all related risks in a proper manner.
- Develop reliable long-distance wireless communication, even in buildings.
- Develop processes for appropriate and environmental recycling of smart PPE.
- Develop safe batteries that can be worn near the human body and do not pose risks to workers such as overheating, explosions or electromagnetic interference.
- Think about the certification/conformity assessment phase from the very beginning of development, involve partners/experts representing all relevant stakeholders to ensure that what you develop is actually put into use - in a safe way.

Standardisation

- Develop appropriate standards for smart PPE, including terms and definitions, product standards and testing methods, as well as guidance documents for users (SUCAM documents).

Notified bodies

- Gain competence in the field of electrics/electronics. This should include the development of relevant testing methods for smart PPE.
- Establish close connections with notified bodies in other sectors to work together on the certification of smart PPE.

Users

- Be informed users!
- Put great value on detailed user information.
- Evaluate the product before purchasing. Are all the functions offered necessary? Do the workers accept them?

⁽¹⁷⁾ <https://ec.europa.eu/environment/circular-economy/>

- Respect workers' rights under the GDPR. Avoid unnecessary collection of personal data.
- Purchasers cannot yet orient themselves using standards. If there are any questions, seek a dialogue with the supplier.
- Follow instructions for operation, use, cleaning and maintenance.
- Train workers before use.
- Document experiences to make the next purchase easier.
- Provide feedback to the manufacturer on experiences in the workplace, as this will lead to further development and improvements.

Manufacturers

- Develop smart PPE that provides added value for the users, namely enhanced protection. This is as crucial for acceptance of smart PPE as a high level of reliability. In addition, smart PPE must be practical in terms of how it is used.
- Provide safe batteries with smart PPE.
- Cooperate with potential users on the development and design of smart PPE as early as possible, for example with regard to the functions needed and the challenges that relate to monitoring personal data.
- Provide transparent and detailed information with smart PPE.
- From the beginning of the development, think of the phase of certification/conformity assessment: is an involvement of a notified body necessary? If so, establish close contact with the notified body designated to carry out conformity assessment early in the development phase and keep in touch with it.

Occupational safety and health experts

- Gain competence in smart PPE.
- Inform users about not only the opportunities that using smart PPE provides (enhanced protection, new methods of protection, collecting data on the condition of the PPE after use) but also the challenges that it brings (the need to ensure that it presents no additional risks, the importance of appropriate use, issues relating to the collection of personal data).
- Be the voice of future users! Work together with manufacturers, notified bodies and standardisation organisations on developing smart PPE and appropriate testing methods and standards for smart PPE.
- Guide and train users on the selection, safe use and appropriate maintenance of smart PPE.

Conclusion

Smart PPE is on the rise and is expected to provide increased protection and new possibilities for using PPE. However, certain changes and actions are needed to achieve this goal. With

research and development and experience of use, supported by appropriate changes in the relevant legislation, smart PPE has great potential to make workplaces safer and healthier in the future.

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This article has been updated on 12/06/2020 to include additional requests and recommendations to stakeholders on the need for interdisciplinary collaboration and the importance of the certification/conformity assessment phase’.

APPENDIX

Examples of possible PPE products using smart materials and/or electronics ⁽¹⁸⁾

Smart knee protectors

Smart shock-absorbing material can be soft and flexible, allowing normal movement such as walking (unlike traditional knee protectors, which are inflexible and hinder normal movement). However, in the event of a shock, the smart material's properties change and the shock-absorbing effect is revealed.

Smart, conductive textiles that constitute a resistance heater

Smart textiles can be conductive and thus have many applications, for example in a smart resistance heater in a garment. The conductive material is connected to an electrical power supply with a constant output voltage and equipped with a temperature sensor to maintain a constant temperature around the heater.

Smart lighting garments

Optical fibres integrated into textiles and connected to a controllable light source can be used as part of smart garments. Equipped with a sensor, these garments will be able to adjust illumination to the amount of light provided by other light sources in the vicinity of the smart garment.

Smart gloves capable of identifying hazardous substances

Chromogenic material take on a different colour depending on an external stimulus (e.g. heat, light, enzymes). This can be used in smart gloves that change colour when they come into contact with hazardous substances.

Smart PPE that communicates with other (potentially hazardous) products

PPE can be equipped with detectors that communicate with corresponding detectors in other products in the vicinity of the wearer. Thus, situations that are to be prevented because they present a risk can be avoided. Such smart PPE can be used to avoid collisions with mobile machinery such as forklift trucks. Another example is smart PPE worn by operators of machinery that ensures that the machine starts working only when the operator is in the designated operator station.

Smart PPE that collects data about its own use

PPE can be equipped with sensors that collect data on use duration or quantity and communicate with a central database. Maintenance cycles can be monitored automatically. For example, the user could be informed when maintenance, a regular inspection or the replacement of the PPE or parts thereof is required.

Sensor-based airbag for protection against critical injuries of cervical/spine column due to a fall

Appropriate airbag and electronic components including assessment logic can be integrated into work wear and fulfil its function in case it is activated by a sensor system which detects a hazardous stimulus. Such a stimulus could be the set of velocity and (angular) acceleration that indicates the fall from a ladder.

⁽¹⁸⁾ Mainly taken from CEN/TR 16298:2011 'Smart textiles — Definitions, categorisation, applications and standardization needs'.