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Trend Analysis by Risk Observation: How the German Statutory Accident Insurance Prepares for the Future in Occupational Safety and Health

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ABSTRACT

Background: The risk observatory (RO) of the German Social Accident Insurance (DGUV) provides strategic support to the German Social Accident Insurance Institutions (GSAIL) in proactive prevention. It does so by identifying future challenges and opportunities for occupational safety and health (OSH) resulting from new trends and developments that affect employees as well as children in elementary education, pupils, and students.

Methods: The core of the RO is an online survey that relies on a pool of new trends and developments identified via internet and literature research. 865 prevention experts of the GSAIL and the DGUV participated in the survey. They rated trends and developments regarding their sector-specific risks and opportunities for OSH in the 5 years to come.

Results: Sector-specific and over-all results show that besides well-known OSH risks such as musculo-skeletal stress and noise, developments relevant for OSH come to the fore that do not have their origin in work itself, but are strongly influenced by political, social, economic, environmental, or technical developments that accident insurance can only peripherally influence. Shortage of skilled staff was identified as a threat to OSH in almost all sectors.

Conclusions: Prevention must find ways to address repercussions of such OSH risks. Cooperation and political awareness are therefore gaining in importance. Also, implementing a prevention culture in society and strengthening individuals' health and safety literacy, e.g., by target-group-specific communication and sensitization, as well as early safety and health education, help to counteract those OSH risks.

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1. Introduction

Being prepared for future challenges and opportunities gives a competitive edge in decision-making and enables rapid responses – also in occupational safety and health (OSH). In a working world that is becoming increasingly complex and subject to ever shorter innovation cycles, it is important to set priorities and invest in the particularly relevant OSH topics. Economic crises such as the one caused by the Covid-19 pandemic increase financial pressure also in

OSH and make priority-setting indispensable. In Germany, OSH is based on a dual system which encompasses state authorities at state and federal level and the German Social Accident Insurance Institutions (GSAIL). While the state authorities have the task of monitoring the implementation of state legislation across all economic sectors, the GSAIL's focus is on specific sectors in terms of prevention, medical and vocational rehabilitation, and compensation in connection with occupational accidents and diseases including commuting accidents and accidents in educational institutions. The GSAIL's labor

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inspectors assess workplaces adherent to enterprises and organizations of the specific sector they insure and provide sector-adapted OSH consultancy and support. The GSAIL currently insure nearly 64.2 million people. The GSAIL's and their umbrella organization's (the German Social Accident Insurance (DGUV)), legal mandate calls for all appropriate means to be employed to prevent occupational accidents and diseases and work-related health risks, as well as investigating their causes [1]. Anticipating the repercussions for OSH of new and emerging technological, political, economic, environmental, or social trends and developments at work, in kindergartens, schools, or universities is one way of fulfilling the legal mandate and is essential for developing appropriate preventive measures at an early stage. To enlarge their efforts in proactive prevention, the GSAIL entrusted the Institute for OSH of the DGUV with the setup of an OSH risk observatory (RO) in 2011.

The RO scrutinizes new and emerging developments in the different economic sectors, identifies the most important developments for each sector, and analyzes them with respect to their inherent OSH risks and opportunities. This enables the sector-oriented GSAIL to respond to priority sector-specific prevention needs. The RO also supports the GSAIL in identifying areas of common interest having the potential for cooperation and common activities, thus avoiding double work and investments.

To gain insight into which developments, trends, or innovations affect which sectors to which extent, the RO relies on the GSAIL's labor inspectors' sector-specific expertise and experience and is, as the GSAIL are, organized on a sector-specific basis.

Compared with other approaches of anticipatory research in OSH, the sector-specificity is a special feature of the RO and is consistent with the sector-specificity of the German system of statutory accident insurance. To our knowledge, the RO is the only OSH risk observatory in Germany and the only that provides sector-specific predictions for such a wide range of sectors.

In line with this, the article highlights the most important issues for accident insurance in specific economic sectors, clusters of sectors, and in Germany as a whole. The priority issues are the results of an online survey among prevention experts of the GSAIL, mostly their labor inspectors, and subsequent in-depth research (see Section 2). Furthermore, the article points to challenges for prevention due to increasingly complex combinations of social, political, economic, technological, or environmental developments often leading to strain that can only be tackled when GSAIL join forces with other stakeholders, e.g., in politics. Thus, the results of the RO also help the GSAIL to connect with other stakeholders in science, economy, society, and politics, to raise awareness for OSH issues in these communities, and to stipulate common actions, where necessary. Finally, and most importantly, this article provides insight into the process the RO and the GSAIL have implemented to improve proactive prevention and to develop ideas for preventive measures, which, we hope, is of interest to others being active in the field of anticipatory OSH research.

2. Methods

2.1. Survey rationale and participants

The RO relies on global trends and subordinate developments. It assumes that the impacts for OSH of each development may vary sector-wise, thus leading to sector-specific needs in the prevention

of occupational accidents, occupational diseases, or other health impairments. Considering the sector-specific OSH needs arising from a development allows the derivation of tailor-made, highly effective prevention measures (see Fig. 1). For instance, in the energy sector, the expansion of renewable energy sources leads to the deconstruction of nuclear power plants and a need for advice how to safely deal with contaminated dust. However, in the heating, ventilation, and air-conditioning trade, it fosters e.g., the installation of solar panels on roofs leading to a rising demand for training in electrical engineering and in how to work safely on roofs.

Due to their sector-specific knowledge and experience gathered in numerous inspections of workplaces and during consultancy the GSAIL's prevention experts, mostly GSAIL labor inspectors, seem best suited to provide information on the importance of new developments for OSH in the specific sector they inspect and to participate in the RO online survey. 949 prevention experts were nominated for participation by the managers of the GSAIL. 865 took part. Thus, the response rate was 91.5 %.

2.2. Five-year-cycle and clusters

The RO conducts its online survey in a 5-year-cycle. The first cycle started in 2012 and ended in 2016; the second started in 2017 and ended in 2021. The online surveys in both survey rounds were conducted in 3 clusters to which the GSAIL were assigned, as were their participating experts. In the second survey round, prevention experts responded to the questionnaire in spring 2017, 2018, or 2019. Table 1 shows the clustering of the GSAIL in the second survey round and the participants' response rates per cluster.

2.3. Trends, developments, and 5-year-prospect

The RO's temporal focus is the near future. Thus, in the online survey, developments are evaluated by their significance for OSH in the 5 years to come.

The pool of trends and developments in the second survey round relied on the pool of the first survey round as a considerable number of developments was still relevant for the near future in 2017. All 63 items of the first survey round can be found in [2] as well as the sources from which they were derived in 2011. However, 20 of these 63 developments were omitted as the developments were either considered as outcomes of another development ($n = 6$), as outdated ($n = 4$), or as irrelevant with respect to OSH according to the labor inspectors' assessment in the first survey round ($n = 6$). Four developments were merged with others. Six of the remaining 43 developments were renamed.

Likewise, 30 developments were newly added in the second survey round. Three were notified to the DGUV trend search (items numbers 17, 18, and 51, see Table 2), which is a reporting system for new trends in the DGUV and one (item number 52) was reported to the RO team by a member of the German Road Safety Council. A further 11 were identified from the literature: 3 (items numbers 26, 27, and 28) from a publication of the Council of the European Union [3], 2 (items numbers 6 and 8) from the weekly paper "VDI Nachrichten" [4,5], 1 (item number 68) from 2 popular scientific books [6,7] and 5 (items numbers 7, 15, 16, 69, and 70) from different gray literature [8–12]. Two (items numbers 30 and 72) stemmed from free text answers in the first survey round. Further 7 developments (items numbers 9, 11, 32, 34, 35, 36, and



Fig. 1. From a global trend to a prevention measure.

Table 1
Clustering of the GSAll in the second survey round (2017–2021) and response rates

Cluster, year of conduction of online survey, names of accident insurance institutions	Number of reported contacts	Number of actual respondents	Response rate (%)
Cluster 1, 2017 GSAll for the public sector in: Baden-Württemberg, Bavaria, Berlin, Brandenburg, the Free Hanseatic City of Bremen, Schleswig-Holstein and Hamburg, Hesse, Mecklenburg-West Pomerania, North Rhine- Westphalia, Rhineland- Palatinate, the Saarland, Saxony, Saxony-Anhalt, Thuringia, and Lower Saxony. GSAll for local authorities in Bavaria, the Hanover region, the Oldenburg region, and the Brunswick region. GSAll for the fire services in: the Hanseatic regions of Hamburg, Mecklenburg- West Pomerania and Schleswig Holstein, Saxony- Anhalt and Thuringia, Lower Saxony, and Brandenburg. GSAll for the Federal Government and for the railway services, and GSAll for the health and welfare services	282	255	90.4
Cluster 2, 2018 GSAll for the trade and logistics industry, GSAll for the administrative sector, and GSAll for commercial transport, postal logistics and telecommunication	211	194	91.9
Cluster 3, 2019 GSAll for the raw materials and chemical industry, GSAll for the energy, textile, electrical and media products sectors, GSAll for the woodworking and metalworking industries, GSAll for the foodstuffs and catering industry, and GSAll for the building trade	455	416	91.4
All	945	865	91.5

73) were identified from discussions with prevention experts. Six developments (items numbers 5, 10, 29, 31, 33, and 71) came out of the political and/or societal discussion at the time the item pool was established. "Digitalization" was added as a new global trend and the global trend "unhealthy lifestyle" was replaced by "societal change."

Table 2 shows all 73 developments included in the second survey round.

2.4. Sectors

The prevention managers of all GSAll named 47 sectors that they wished to be covered by RO analyses: public sectors (e.g., schools, kindergartens, public administration, clinics), sectors related to services (e.g., commerce, logistics, goods transport), to manufacturing

(e.g., chemical industry, meat processing, wood processing), and to construction (e.g., surface construction, underground work).

2.5. Sector-specific questionnaires

For each sector, a sector-specific questionnaire was prepared by consensus of the RO team and a prevention expert for the respective sector that contained approximately 40 developments relevant for OSH in this sector out of the 73 developments.

This publication presents results for 7 sectors. Of those, 2 ("public administration" and "electrotechnical industry") were adopted unchanged from the original 47 sectors. To represent a larger part of the study population, we however merged 12 of the remaining 45 sectors into 5 bigger and distinct sectors: Thus, "education" is an aggregation of the sectors "schools" and "kindergartens," "health and social care" combines "hospitals and clinics" and "nursing homes and outpatient care," and "commerce" encompasses "commerce" and "goods logistics." "Road transport" aggregates "passenger transport on roads" and "goods transport on roads" and the "construction sector" consists of "surface construction," "underground work," "carpentry and roofing," and "demolition works." Table 2 shows the assigned developments for the 7 sectors on which we report in this article.

2.6. Online survey and statistical analyses

The RO conducted a 2-stage online survey in each cluster. In the first stage, the prevention experts were asked to differentiate each of the approximately 40 developments included in the sector-specific questionnaire on a 9-point continuum starting with 1 = not at all significant and ending with 9 = very significant (5 = neither/nor). For each development they had to answer the same question: "In the prospect of the coming 5 years, how significant will this development be for the OSH of the employees in the sector that you inspect?" "Not applicable" was a response option but answering was compulsory. For each development included in the sector-specific questionnaire, the mean value (M) and standard deviation (SD) were calculated. For each sector, the developments were ranked based on the M and SD . Moreover, 95% confidence intervals were calculated for each M to evaluate whether the developments exhibit a statistically significant differentiation (for more detailed explications see Ref. [2]). The TOP developments of each sector were identified based on the calculation of statistically significant differentiation of (groups of) developments supplemented by a rule that limits the number of TOP developments to at least 4 and at most 18 per sector. In the second stage, the prevention experts were asked for prevention ideas as free text answers for each of the TOP developments in their sector.

2.7. Advanced analyses and sector overviews

The TOP developments of a sector and the associated prevention ideas were starting points for an in-depth internet and literature search with the aim of creating a sector overview. It contains a background section that informs, for example, about political framework conditions, innovations, the number of people employed in the sector, the economic situation, and the organization of business (large vs. small and medium-sized enterprises) and highlights risks and opportunities for OSH within the sector, provides focus areas for prevention, and ideas for concrete preventive measures. All sector overviews can be found in German on the DGUV's website (webcode d1181777). Moreover, some of them are published in sector-specific journals to specifically inform and sensitize the managers and employees in enterprises and organizations of the respective sectors (e.g., Ref. [13–15]).

Table 2 Global trends, associated developments, and affiliation of developments to sector-specific questionnaires

Item number	Global trend	Associated developments	Public administration	Education	Health and social services	Commerce	Road transport	Construction	Electro-technical industry
1	New technologies	Use of technologies to generate renewable energy and to reduce carbon emissions					X		X
2		Use of biotechnologies (e.g., genetic engineering, plasma-medicine)			X				
3		Complexity of human-machine interfaces			X	X	X	X	X
4		Use of technologies to reuse raw materials			X	X	X		X
5		Fracking for the extraction of mineral oil and natural gas							
6		Novel lighting systems (e.g., LEDs, OLEDs)	X	X	X	X	X	X	X
7		3-D-printing and printed electronics			X	X	X	X	X
8		Transdermal plaster and micro needles			X				
9		Autonomous vehicles (including drones and intra-plant logistics)			X	X	X	X	X
10		Changes to and extension of the electrical power grid							
11		Body-worn carrying aid (e.g., exoskeletons)			X	X		X	
12	Digitalization	Use of information technologies (IT) and networked automation, also at mobile work	X	X	X	X	X	X	X
13		Collaborative robots and artificial intelligence			X	X	X	X	X
14		Centralization and density of monitoring activities (e.g., in control rooms)			X	X	X	X	X
15		Wearables (e.g., to record health-relevant data)	X	X	X	X	X	X	X
16		Augmented reality (e.g., Google glasses)			X	X	X	X	X
17		Cyberattacks on digital systems	X	X	X	X	X	X	X
18		Brain-computer-interfaces (digital ergonomics)			X	X	X	X	X
19	Exposure to health-hazardous substances/products	Exposure to nanomaterials			X			X	X
20		Exposure to epoxy resins						X	
21		Exposure to synthetic mineral fibers						X	X
22		Exposure to diesel engine emissions			X	X	X	X	X
23		Exposure to mold spores			X	X	X	X	X
24		Resistance to medicines							
25		Resistance to disinfectants/sterilizing agents	X	X	X	X	X	X	X
26		Endocrine disruptors							
27		Carcinogenic and mutagenic substances						X	X
28		Substances toxic to reproduction							
29		Biocides and pesticides							
30		Smells	X	X	X	X	X	X	X
31		Hazard generated by carbon monoxide							
32		Change of materials and/or their type of storage (e.g., lithium-ion batteries instead of paper)			X	X			
33		Lithium							X
34		Hardly soluble dusts						X	X
35		Explosive substances (e.g., organic peroxides)			X	X	X	X	X
36		Sensitizing substances (e.g., enzymes, isocyanates)			X	X	X	X	X
37	Exposure to physical effects	Prolonged and/or one-sided musculoskeletal stress	X	X	X	X	X	X	X
38		Ultraviolet (UV) radiation		X				X	X
39		Electrical and electromagnetic fields						X	X
40		Thermal exposure (cold, heat)			X	X	X	X	X
41		Stress due to poor visibility and poor lighting			X	X	X	X	X
42		Noise	X	X	X	X	X	X	X
43		Vibration			X	X	X	X	X

44	Globalization	Job insecurity and increasingly insecure contracts of employment	X	X	X	X	X	X	X	X	X	X	X
45		Work intensity, longer working hours and extension of responsibility (e.g. due to staff cuts)	X	X	X	X	X	X	X	X	X	X	X
46		Pressure to succeed in schools and during training	X	X	X	X	X	X	X	X	X	X	X
47		Flexibilization of work (e.g., worktime models, alternating workplaces)	X	X	X	X	X	X	X	X	X	X	X
48		Demand for mobility/increasing traffic density	X	X	X	X	X	X	X	X	X	X	X
49		Need for intercultural and language skills	X	X	X	X	X	X	X	X	X	X	X
50		Migration of pathogens	X	X	X	X	X	X	X	X	X	X	X
51		<i>International OSH-relevant harmonization efforts (standardization, CEIA, TTIP)</i>	X	X	X	X	X	X	X	X	X	X	X
52		<i>Longer and/or heavier transport vehicles</i>	X	X	X	X	X	X	X	X	X	X	X
53	Transition to a service economy	Physical inactivity during insured activity	X	X	X	X	X	X	X	X	X	X	X
54		Demand for emotional (psychological) skills during insured activity	X	X	X	X	X	X	X	X	X	X	X
55		Physical violence during insured activity	X	X	X	X	X	X	X	X	X	X	X
56		Psychological violence (e.g., (cyber)-bullying) during insured activity	X	X	X	X	X	X	X	X	X	X	X
57	Demographic change	Demographic change and unbalanced age structure	X	X	X	X	X	X	X	X	X	X	X
58		Increasing proportion of female employees	X	X	X	X	X	X	X	X	X	X	X
59		Inclusion of people with disabilities	X	X	X	X	X	X	X	X	X	X	X
60		Shortage of skilled staff	X	X	X	X	X	X	X	X	X	X	X
61	Number and/or severity of disasters	Natural disasters and extreme weather conditions	X	X	X	X	X	X	X	X	X	X	X
62		Industrial accidents	X	X	X	X	X	X	X	X	X	X	X
63		Traffic disasters	X	X	X	X	X	X	X	X	X	X	X
64		Terrorist attacks, robberies, and mass shootings	X	X	X	X	X	X	X	X	X	X	X
65	Societal change	Lack of physical activity during leisure hours	X	X	X	X	X	X	X	X	X	X	X
66		Unhealthy diet	X	X	X	X	X	X	X	X	X	X	X
67		Consumption of legal and illegal addictive substances	X	X	X	X	X	X	X	X	X	X	X
68		<i>Personality or behavioral disorders (e.g., narcissism) generated by education, media, or markets</i>	X	X	X	X	X	X	X	X	X	X	X
69		<i>Deterioration of wage, social and value standards</i>	X	X	X	X	X	X	X	X	X	X	X
70		<i>Necessity for life-long and interdisciplinary learning</i>	X	X	X	X	X	X	X	X	X	X	X
71		<i>Share of kids under the age of three in kindergartens and children's day care</i>	X	X	X	X	X	X	X	X	X	X	X
72		<i>Lack of societal and/or financial recognition</i>	X	X	X	X	X	X	X	X	X	X	X
73		<i>Need for renovation/redevelopment</i>	X	X	X	X	X	X	X	X	X	X	X

Italic type indicates the 30 newly added developments in the second survey round.

Table 3
TOP developments in different sectors

Items and statistical parameters	Public administration (n = 23)	Education (n = 60)	Health and social services (n = 37)	Commerce (n = 50)	Road transport (n = 22)	Construction (n = 74)	Electrotechnical industry (n = 35)
Item	Work intensity	Noise	Musculo-skeletal stress	Musculo-skeletal stress	Autonomous vehicles	Shortage of skilled staff	Complexity of human-machine-interfaces
M; SD	7,955; 1,090	8,541; 0,954	8,544; 0,909	7,480; 1,074	8,409; 1,008	8,405; 0,935	7,571; 1,170
95% CI	[7,471, 8,438]	[8,104, 8,596]	[8,251, 8,830]	[7,175, 7,785]	[7,962, 8,856]	[8,189, 8,622]	[7,169, 7,973]
n	22	60	37	50	22	74	35
Item	Musculo-skeletal stress	Kids under the age of three	Work intensity	Work intensity	Demographic change	UV radiation	Autonomous vehicles
M; SD	7,783; 1,445	8,207; 1,236	8,444; 0,909	7,420; 1,012	7,714; 1,056	8,338; 1,101	7,543; 1,990
95% CI	[7,158, 8,407]	[7,737, 8,677]	[8,137, 8,752]	[7,132, 7,708]	[7,234, 8,195]	[8,083, 8,593]	[6,859, 8,227]
n	23	29	36	50	21	74	35
Item	Demographic change	Intercultural and language skills	Shortage of skilled staff	Intercultural and language skills	Musculo-skeletal stress	Demographic change	Collaborative robots
M; SD	7,696; 1,550	8,100; 0,986	8,444; 0,969	7,220; 1,375	7,591; 1,790	8,000; 1,170	and artificial intelligence
95% CI	[7,025, 8,366]	[7,845, 8,355]	[8,772]	[6,829, 7,611]	[6,797, 8,385]	[7,729, 8,271]	7,441; 1,637
n	23	60	36	50	22	74	[6,870 – 8,012]
Item	Cyberattacks	Inclusion of people with disabilities	Demographic change	Job insecurity	IT use and networked automation	Noise	Work intensity
M; SD	7,478; 1,855	8,083; 1,078	8,429; 1,065	7,220; 1,447	7,455; 1,057	7,946; 1,169	7,429; 1,220
95% CI	[6,676, 8,281]	[7,805, 8,362]	[8,063, 8,794]	[6,809, 7,631]	[6,986, 7,923]	[7,675, 8,217]	[7,010, 7,848]
n	23	60	35	50	22	74	35
Item	Shortage of skilled staff	Emotional demands during insured activity	Resistance to medicine	Resistance to medicine	Emotional skills during insured activity	Musculo-skeletal stress	Shortage of skilled staff
M; SD	7,409; 1,368	7,900; 1,053	8,028; 1,082	8,028; 1,082	7,417; 1,311	7,919; 1,120	7,343; 1,714
95% CI	[6,802, 8,016]	[7,628, 8,172]	[7,662, 8,394]	[7,662, 8,394]	[6,583, 8,250]	[7,660, 8,178]	[6,754, 7,932]
n	22	60	36	36	12	74	35
Item	IT use and networked automation	Shortage of skilled staff	Emotional demands during insured activity	Emotional demands during insured activity	Shortage of skilled staff	Thermal exposure	IT use and networked automation
M; SD	7,391; 1,234	7,800; 1,549	7,865; 1,251	7,865; 1,251	7,409; 1,368	7,689; 1,313	7,303; 1,447
95% CI	[6,858, 7,925]	[7,400, 8,200]	[7,448, 8,282]	[7,448, 8,282]	[6,802, 8,016]	[7,385, 7,993]	[6,790, 7,816]
n	23	60	37	37	22	74	33
Item	Physical inactivity during insured activity	Need for renovation/re-development	Intercultural and language skills	Intercultural and language skills	Physical inactivity during insured activity	Intercultural and language skills	Mobility/traffic density
M; SD	7,391; 1,270	7,525; 1,331	7,833; 1,521	7,833; 1,521	7,364; 1,255	7,689; 1,613	7,171; 1,543
95% CI	[6,842, 7,940]	[7,179, 7,872]	[7,319, 8,348]	[7,319, 8,348]	[6,807, 7,920]	[7,316, 8,063]	[6,641, 7,702]
n	23	59	36	36	22	74	35
Item	Emotional demands during insured activity	Life-long learning	Resistance to disinfectants	Resistance to disinfectants	Physical violence	Synthetic mineral fibers	
M; SD	7,182; 1,259	7,267; 1,765	7,811; 1,076	7,811; 1,076	7,333; 1,155	7,676; 1,589	
95% CI	[6,624, 7,740]	[6,811, 7,723]	[7,452, 8,170]	[7,452, 8,170]	[6,600, 8,067]	[7,308, 8,044]	
n	22	60	37	37	12	74	
Item	Need for renovation/re-development	Work intensity	Physical violence	Physical violence	Complexity of human-machine-interfaces	Carcinogenic and mutagenic substances	
M; SD	7,130; 1,217	7,237; 1,466	7,676; 1,258	7,676; 1,258	7,318; 1,585	7,542; 1,565	
95% CI	[6,604, 7,657]	[6,855, 7,619]	[7,259, 8,092]	[7,259, 8,092]	[6,615, 8,021]	[7,174, 7,909]	
n	23	59	37	37	22	72	

Item	Physical violence	Demographic change	Flexibilization of work	Diesel engine emissions
M; SD	7,045; 1,588	7,119; 1,588	7,306; 1,348	7,419; 1,843
95% CI	[6,341, 7,750]	[6,705, 7,532]	[6,849, 7,762]	[6,992, 7,846]
n	22	59	36	74
Item	Mobility/traffic density	Pressure to succeed in schools/training	Migration of pathogens	Vibration
M; SD	7,043; 1,918	7,089; 1,730	7,182; 1,704	7,405; 1,433
95% CI	[6,214, 7,873]	[6,626, 7,553]	[6,578, 7,786]	[7,073, 7,737]
n	23	56	33	74
Item	Flexibilization of work	Lack of recognition	Psychological violence	Work intensity
M; SD	7,000; 1,732	7,068; 1,731	7,162; 1,344	7,397; 1,392
95% CI	[6,251, 7,749]	[6,617, 7,519]	[6,714, 7,610]	[7,073, 7,722]
n	23	59	37	73
Item	Lack of recognition	Personality or behavioral disorders	Lack of recognition	
M; SD	6,957; 1,461	7,018; 1,531	7,139; 1,693	
95% CI	[6,325, 7,588]	[6,608, 7,428]	[6,566, 7,712]	
n	23	56	36	
Item	Life-long learning	Musculo-skeletal stress	Life-long learning	
M; SD	6,957; 1,894	7,017; 1,935	7,059; 1,632	
95% CI	[6,137, 7,776]	[6,517, 7,517]	[6,489, 7,628]	
n	23	60	34	
Item	Psychological violence	Psychological violence	Sensitizing substances	
M; SD	6,909; 1,849	6,900; 1,928	6,912; 1,712	
95% CI	[6,089, 7,729]	[6,402, 7,398]	[6,314, 7,509]	
n	22	60	34	

The name of a development written in bold indicates that this development is significantly less important than the (group of) development(s) listed above. Subsequent developments not written in bold are just as important as the preceding development in bold.

Note: IT = information technologies; UV = ultraviolet.

3. Results

3.1. TOP developments in specific sectors

The RO identified TOP developments for 42 of the 47 sectors. For 3 of the 47 sectors less than 10 prevention experts answered the questionnaire. Thus, a statistical analysis was not considered reasonable. A further 2 sectors turned out to be too heterogeneous in terms of type and quantity of professional activities so that we refrained from statistical analysis. [Table 3](#) shows the TOP developments with respect to prevention priorities in OSH for the 5 years to come in the 7 selected sectors. The name of a development written in bold indicates that this development is significantly less important than the (group of) development(s) listed above. Subsequent developments not written in bold are just as important as the preceding development in bold.

“Shortage of skilled staff” and “musculoskeletal stress” occur in 6 of the 7 sectors among the TOP developments; “demographic change” and “work intensity” in 5, and “intercultural and language skills” in 4 of them. Despite these overlaps, there are clear differences in the sectors. The TOP developments in [Table 3](#) reflect the situation in the 7 sectors, which will be described in the following.

Public administration:

In public administration “work intensity,” “musculoskeletal stress,” “demographic change,” and “cyberattacks” score highest. Work intensity is a consequence of a shrinking labor force due to low birth rates and the baby-boomer generation soon being retired. It is also the result of downsizing since the early 1990s where lean management, cost and activity accounting, efficient IT-solutions and outsourcing were means to modernize the public administration [16]. It manifests in increased mental strain and musculoskeletal stress for those remaining. Musculoskeletal stress in public administration often relates to physical inactivity e.g., through the omission of breaks. By 2030 a shortage of more than 800,000 employees is expected in public administration [17]. Meanwhile demands are increasing due to e.g., e-government, late opening hours, privacy protection, multitasking, and customer expectations regarding short processing times. In addition, the occurrence of cyberattacks is increasing and cyber resilience in public administration needs improvement in terms of safer systems including sensibilization of employees regarding malware [18]. Besides digitalization, an increasingly demanding and aggressive clientele will have a significant impact on OSH in public administration and requires conflict resolution and de-escalation skills [19].

Education:

In education, noise was found to be the biggest stressor together with tasks linked to a higher number of kids under the age of three. Another stressor is shortage of skilled staff that particularly impinges on the task of inclusion—not only of children with disabilities or unusual behavior patterns, but also of children with poor German language skills and different cultural backgrounds. In recent years, kindergartens and schools have taken in many children from Syria who have fled the war, and they are currently taking in many children from Ukraine. This has already and will further increase the need for intercultural and special education competences. In the case of nursery-school teachers, the increasing demands and higher physical strain due to lifting and carrying of toddlers go along with mediocre remuneration and effort-reward imbalance [20]. In consequence of years of cost-saving, schools are and will be particularly affected by the need for renovation and

redevelopment, which may offer opportunities to implement noise protection measures in construction projects.

Health and social services:

Musculoskeletal stress' along with “work intensity,” “shortage of skilled staff,” and “demographic change” scored highest. The shortage of nursing staff is aggravated by COVID-19 and will further increase due to the combination of growing work demands and low wages. It leads to immense work intensity and musculoskeletal stress for those doing the job. Another threat for OSH in clinics and care facilities are resistances to medicines and disinfectants/sterilizing agents. The development “migration of pathogens” was ranked among the TOP developments and its importance became apparent with the COVID-19 pandemic. Due to work intensity and a more demanding and partly aggressive clientele, emotional skills and health literacy are of growing importance in health and social services to manage critical situations and protect one’s own mental and physical health [21]. Particularly in the field of care, policy-makers should develop concepts to combat the shortage of skilled workers, and thus make it possible to organize work in a way that is appreciative and age-appropriate.

Commerce:

In commerce, “musculoskeletal stress” is on top, followed by “work intensity,” “intercultural and language skills,” and “job insecurity.” This sector is characterized by a booming, international online commerce and a growing number of logistics orders. Intercultural and language skills are significant, especially in logistics and wholesale, due to global supply chains. However, it currently remains uncertain whether experiences made during the COVID-19 pandemic and increased efforts for sustainability will lead to relocalization. Job insecurity goes along with declining collective bargaining coverage and downsizing in stationary retail. Musculoskeletal stress is particularly increasing for employees of parcel services due to higher work intensity [22], which also calls for ergonomics and age-appropriate work designs.

Road transport:

Here, the most important development is “autonomous vehicles.” New traffic concepts in passenger road transport envisage on-demand and autonomous vehicles to realize the shift away from an individual motor-operated traffic [23]. It is yet unclear what kind of impacts the implementation of these plans will have for employees in driving services. However, today’s predominant concern for OSH, especially in goods road transport, is the shortage of professional drivers that amounts presently to 60,000 to 80,000 with an upward trend [24], leading to frequent exceeding of driving times. Musculoskeletal stress due to physical inactivity while driving is an important common OSH risk to professional drivers [25].

Construction:

“Shortage of skilled staff” and “UV radiation” are the most important developments for OSH in this sector. Well-known OSH risks such as exposure to UV radiation, musculoskeletal stress, thermal exposure, noise, or vibration are still prevalent and call for constant sensitization of employers and employees for protective measures. These exposures combined with low to medium wages are reason enough for most young people in Germany to seek employment outside the construction sector. With the baby-boomer generation soon being retired, the biggest challenge is

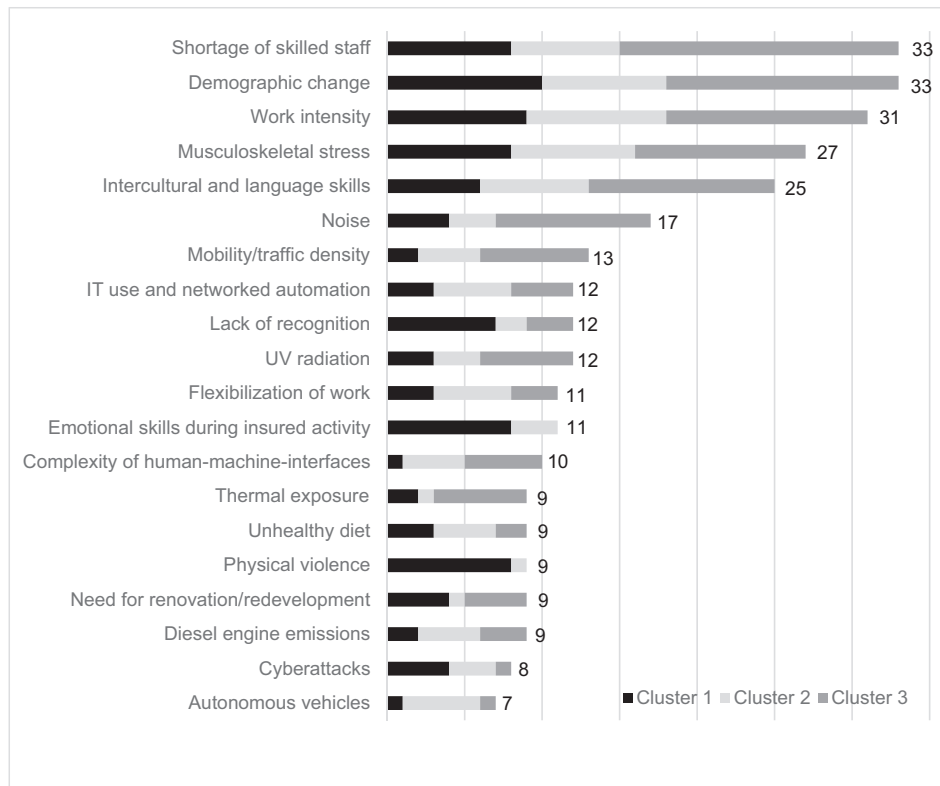


Fig. 2. The 20 most important developments over the 42 sectors analyzed in the RO.

shortage of skilled staff. The huge proportion of 99.9 % small and medium-sized enterprises (SMEs) in the German construction sector [26] aggravates the problem: the fewer people working in a company, the lower its resilience to staff shortages. To balance the lack of domestic junior staff, the employment of foreign and migrant workers is high in construction and requires elaborated intercultural and language skills to implement health and safety measures. Moreover, if unskilled or inexperienced workers take over tasks, they are easily overtaxed and have a high risk of accidents.

Electrotechnical industry:

In this innovative industry that enables among others industry 4.0, automation, the use of real-time data, cobots, artificial intelligence, or drones, a group of 7 developments is most important (see Table 3). Highly qualified staff is needed but not sufficiently available. Not only, but also because of this, life-long learning is on the agenda. Competencies in electrical engineering should possibly be complemented with skills in computer science. To follow the rapid pace of innovation and the handling of increasingly complex tasks can make employees feel anxious about potential non-fulfillment. Digitalization, technological innovation, and shortage of skilled staff are drivers of work intensity.

The above-mentioned sector overviews on the DGUV's website provide detailed insights into the sector-specific impacts for OSH and preventive measures.

3.2. TOP developments for accident insurance in Germany as a whole

Statistical analyses of the total sample are not possible due to the use of sector-specific questionnaires. However, it was possible to count how often a development turned up as a TOP development

in the 42 sectors analyzed in the RO. Thus, a rough assessment of the most important developments for accident insurance in Germany as a whole was possible. Fig. 2 shows the results of the count and presents the TOP 20 over all 42 sectors.

“Shortage of skilled staff” and “demographic change” were both counted 33 times, “work intensity” 31, “musculoskeletal stress” 27, and “intercultural and language skills” 25 times. In at least 60 % of all 42 sectors, these “TOP 5” ranked among the TOP developments. One explanation is the high interconnectedness of these developments: A shrinking workforce due to low birth rates and retirement of the baby-boomer generation, increases work intensity and musculoskeletal stress for those remaining. In turn, global migration, recruitment of foreign workers or inclusion of people with poor language skills due to a migration background in the labor market go along with extensive demands for intercultural and language skills but reduce work intensity and musculoskeletal stress among those already doing the job. Because of their importance for numerous sectors and their interaction, all 5 developments qualify for exchange, cooperation, and common prevention activities of the GSAll.

Surprisingly, well-known developments such as “noise,” “UV radiation,” “thermal exposure,” or “diesel engine emissions” still rank among the TOP 20 over all 42 sectors. An explanation for this can be that existing prevention measures might not sufficiently reach the target groups (e.g., the use of auxiliary means to address musculoskeletal problems). Besides, new aspects of well-known developments emerge (e.g., noise-induced health impairments due to ultra- or infrasound). Also, new occupational diseases (e.g., skin cancer due to occupational exposure to UV radiation, which was added to the German list of occupational diseases in 2015) can require additional prevention activities.

Fig. 2 also shows differences in priority prevention needs. In cluster 1 which includes the sectors of the accident insurance institutions of the public sector “lack of societal and/or financial

recognition,” “emotional demands,” and “physical violence during the insured activity” play a larger role than in the other clusters. In the sectors of cluster 2 “autonomous vehicles” are much more important for OSH than in the sectors of cluster 1 or 3. In cluster 3 the developments “shortage of skilled staff,” “thermal exposure,” and “noise” are more important than in the sectors of the clusters 1 and 2.

4. Discussion

4.1. General conclusion

The result section reveals that developments relevant for OSH are frequently interconnected. Tackling the repercussions of interconnected developments needs a holistic prevention approach including interdisciplinary and multi-dimensional prevention measures that combine technical, organizational, and individual approaches and consider the respective target groups.

The results also demonstrate that the developments do not all have their origin in work itself but are often strongly influenced by political, social, economic, environmental, or technical conditions that the GSAIL can only peripherally influence. In these cases, prevention approaches can benefit from cooperation with appropriate partners. The general need for cooperation has already been recognized by politics and the ground has long been prepared for cooperation. So, e.g., the Act to Strengthen Health Promotion and Prevention entered into force in 2015 [27]. It requires cooperation within the German social security system and resulted in concrete cooperations, e.g., of the GSAIL for the building trade and five Guild health insurance funds [28] or the state framework agreement between the health insurance funds and social insurance institutions active in Mecklenburg–West–Pomerania [29]. Moreover, since 2007 the Joint German Occupational Safety and Health Strategy strengthens cooperation between the GSAIL and state and federal OSH authorities, currently focusing on enforcement of a holistic OSH risk assessment. Sector-specific cooperation could be realized e.g., through common OSH campaigns of the specific GSAIL and guilds. More and systematic cooperation can probably make an important contribution to OSH and to the future viability of the German economy or some particularly affected sectors. Specifically, the RO findings suggest that cooperation regarding the TOP 5 could be beneficial to OSH in a wide range of sectors. Addressing “shortage of skilled staff” seems particularly effective given that it is strongly intertwined with demographics, work intensity, musculoskeletal stress, and intercultural and language skills. Additional issues for joint action could also be: “Lack of societal and/or financial recognition,” “emotional demands,” and “physical violence during the insured activity” in cluster 1; “autonomous vehicles” in cluster 2, and “noise,” and “thermal exposure” in cluster 3.

The GSAIL support employees and companies through prevention measures e.g., OSH consultancy, information, and sector-adapted qualification offers. Using the example of shortage of skilled staff being the predominant issue for almost all sectors we elaborate in the next paragraphs how RO results provide a starting point for further reflection and deduction of preventive measures. One starting point is the following question: Which solutions will politics and economic institutions find to fill the increasing staff gaps and to integrate potentially available people (e.g., females, unskilled or migrant workers, long-term unemployed, people with disability) in the labor market? That in turn leads to 3 major questions for the statutory accident insurance:

1. How can the accident insurance contribute to closing the staff gap? Here, as mentioned above, sector-related and cross-

sectoral cooperation and qualification are of utmost importance. Moreover, OSH itself plays an essential role as safe and healthy working conditions enhance the attractiveness of a sector for people searching employment. Also providing consultancy that is precisely tailored to SMEs (e.g., on age(ing)-appropriate work organization) helps to counteract staff shortfalls as SMEs are the least resilient to it—a preventive approach that more and more GSAIL rate as effective and adopt [30].

2. Which will be the effects on OSH that emanate from measures (e.g., remote work and flexibilization of working hours) put forward to attract potentially available people and which prevention measures are most needed under these circumstances? As to remote work, the accident insurance in Germany reacted quickly by conceiving e.g., seminars on ergonomics and time management in remote work, a check list for safe and healthy remote work that consider sector-specific features, and practical guidance to combat “zoom fatigue”.
3. Does the vocational integration of specific groups (e.g., unskilled workers, migrant workers) require adaptation of preventive measures and a specific way of addressing them when aiming at implementing a culture of prevention?

The importance of addressing a target group effectively is also emphasized by the finding that well-known developments such as musculoskeletal stress and noise are still of great importance for OSH. Successful prevention must find appropriate information pathways and consider that e.g., young employees or employees with poor language skills might favor videos or social media over brochures and detailed instructions.

Besides the stronger adaptation of preventive measures to target-groups, the integration of health and safety aspects in curricula from elementary education onwards might also help to establish and reinforce a prevention culture in society. In line with that, the DGUV has recently compiled sets of experiments suitable for children in kindergartens and addressing different OSH-related subjects and provides training for nursery-school teachers. In a context where remote work and individual responsibility become more important, the individual’s health and safety literacy is of even greater significance for OSH than ever before. Thus, OSH communication and consultancy must more than ever go beyond the organizational level and must also address the individual to anchor health and safety literacy in society. Social media play an important role in broad-based communication. GSAIL started to extend their information offer to these media several years ago and are expanding it continuously in a targeted manner.

As shown above, the RO analyses provide prevention priorities for the specific sectors of the GSAIL and for the statutory accident insurance in Germany as a whole. Knowing prevention priorities is a prerequisite to derive measures that respond to actual sector-specific and cross-sectoral prevention needs and to open up new perspectives for joint efforts both within and outside the accident insurance scheme. The systematic approach of the RO is unique in statutory accident insurance and a valuable tool to prepare for future challenges in OSH and maintain safe and healthy workplaces.

4.2. Methodological shortcomings of the RO and outlook

During the RO analyses, we have realized limitations regarding the future prospect of the results. The RO aims at providing information on the relevance of new and emerging developments with respect to OSH in the 5 years to come. However, we often got status-quo descriptions of (interactions of) already existing developments with potential to persist or gain in relevance in the 5 years to come. Two main reasons could explain this fact: First, the

online survey might be deficient in inherently novel and up-to-date developments. Second, the GSAIL's prevention experts focused on presently relevant developments and had difficulties in imagining the future of their companies' sectors. This might have been the case as the GSAIL's labor inspectors are very much involved in day-to-day-business and wish to solve current problems more than to anticipate new ones. Therefore, in the third survey round, the included developments will have a more future-like character. Furthermore, the survey will exclusively focus on effects for OSH that require totally new prevention approaches and not just adaptations of existing ones. Moreover, our sample will basically encompass scientific experts from different research institutions, scientific societies, and universities being familiar with new developments and innovations and will be extended by prevention experts of the GSAIL, the DGUV, the state and federal OSH authorities, companies/institutions, or employer or trade unions to involve people bringing in different perspectives. Furthermore, we are planning to complement the online-survey and the in-depth literature and Internet research with expert interviews regarding TOP developments and thus to expand our understanding of the associated repercussions for OSH.

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Conflicts of interest

No potential conflict of interest was reported by the authors.

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