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Review article

Head-worn displays and job content: A systematic literature review

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ABSTRACT

Despite the emergence of head-worn displays at work around forty years ago, few studies have appeared about their impact on job content. To investigate this, a systematic literature review was conducted on these devices and job content, defined as job demands and controls. In total, 3481 studies were identified using five scientific databases. After applying selection criteria, reference searches, citation tracking and an in-depth reading, 28 studies were selected for review. Remarkably, the findings of these studies showed contrasting results. Both increases and decreases in job demands and controls were identified. We distinguished across studies two opposite approaches for the deployment of these devices, i.e. a supportive and a directive approach.

1. Introduction

Although digital technology is rapidly becoming ubiquitous, there is little research on how it is altering the work that people do (Cascio and Montealegre, 2016). Still, it is expected to have a major impact on job content c.q. the quality of working life (Hirsch-Kreinsen, 2016). From the limited amount of literature available, it is apparent that the impact of this umbrella concept on job content varies considerably (Coovert and Thompson, 2013). This observation leads us to investigate changes in job content due to the use of one particular form of digital technology, as reported in the empirical literature. To do so, we focus on the use of head-worn display (HWD).

A HWD is a wearable device that has a small optical display in front of at least one of the wearer's eyes. It either reflects projected immersive augmented reality (AR) data that integrates with the users' surroundings, or it affords digital overlay data that floats in front of the user via the generated projection (Khakurel et al., 2018). In general, it enables individuals to transfer or retrieve digital real-time data (e.g. text-based, symbol-based or animation-based) to colleagues via generated projections (Aromaa et al., 2020; van Lopik et al., 2020; Khakurel et al., 2018). The development of HWDs at work dates back to the late 1980s. From then on, early models proved to be uncomfortable, costly and prone to errors (Caudell and Mizell, 1992; Regenbrecht et al., 2005). In recent years, these shortcomings have been overcome by technological advances in battery efficiency, spread of sensors, cloud computing and miniaturization of powerful computers (Wooldridge, 2015). Although these advances have improved device performance, device usability and affordability, the initially positive expectations of the HWD have not yet been met (Evers et al., 2018). However, certainly now that the measures against the spread of Covid-19 (SARS-CoV-2) put a premium on remote working and physical distancing at work (Barnes, 2020; Hodder, 2020), it is likely that *Amara's Law* will hold for HWDs as well: "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run". If so, the topicality of our subject increases and allows both practitioners, policy makers as well as scholars to anticipate the impact of these devices on their users' job content at work.

In recent years, it has become apparent that the use of HWD is resurfacing (Bottani and Vignali, 2019; del Amo et al., 2018; Palmarini et al., 2018; Tabrizi and Sanguinetti, 2019). We, however, question its impact on the job content, since most research on digital technology at work pays little attention to this matter (Zammuto et al., 2007). Technology is often studied in relation to increased performance, downplaying the role of technology on job content (Orlikowski, 2009). This is striking because socio-technical and macro-ergonomic thinking both emphasize that a successful implementation of any emerging technology is eminently the result of not only technological but also job-related aspects (De Sitter et al., 1997; Kleiner, 2006; Liao et al., 2017). That is why academics insist on a renewed attention at job content under the pretext of a *human-centred design* approach, stating that digital technologies have the potential to improve job content (Hirsch-Kreinsen, 2016; Kaasinen et al., 2020;

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Romero et al., 2016; Waschull et al., 2020).

To study job content we adopted the job demands-control model (JD-C; Karasek, 1979; Parker et al., 2017). This model examines the combined impact of job controls and job demands on burnout risks, focusing particularly on the ability of job controls to buffer job demands. According to the model, jobs should consist of sufficient job controls to execute a series of tasks (i.e. job demands) (Clays et al., 2020). A healthy balance between job controls and job demands will result then in high engagement and low stress, or a favourable job content (Karasek, 1979). A lack of controls combined with high job demands result in reduction of engagement and increased burnout risks (Karasek, 1979). In this study, we focus on job controls and job demands from a socio-technical, macro-ergonomic perspective (De Sitter et al., 1997; Kleiner, 2006). In this sense, job controls are job autonomy, data provision, skill discretion and social support, and job demands are task complexity, physical and cognitive workload, task repetitiveness, predictability, variability and time pressure (see: Table A.1; Van Hootegem et al., 2014).

In Table 1, we summarize our expectations for the use of HWDs and corresponding job controls c.q. job demands, respectively (Aromaa et al., 2016; van Lopik et al., 2020; Khakurel et al., 2018). The use of HWDs substantially increases data provision. In general, this is expected to reduce the need for social support between workers. For the remaining job controls (job autonomy and skill discretion), our expectations are inconclusive. Workers may be closely guided intentionally, reducing their job autonomy and their required skill discretion. In contrast, workers may need to analyse data and consequently decide upon their analyses, increasing both job autonomy and skill discretion. Concerning job demands, physical workload is expected to decrease because work instructions might become remotely accessible. Our assumptions for the other job demands are once more inconclusive: we cannot specify whether work will become more (or less) repetitive, predictable, pressuring, variable, complex and cognitively demanding e.g. cognitive workload can increase because of complex data that needs processing or decrease if instructions are merely guiding workers. In sum, some assumptions are clear, whereas others are inconclusive.

This article contributes to the literature by studying how the use of HWDs affects job content, studied in terms of job controls and job demands. By focusing on this particular aspect of work, we contribute to a clearer understanding of the consequences for jobs wherein HWDs are being used. More specifically, our objective is to provide broadened insight into the pitfalls and advantages for job content, in terms of job controls and job demands, this concerning HWDs applied in practice.

2. Methods

2.1. Search strategy

To address our research topic a systematic review was conducted to collect and summarize all empirical research on the vocational use of HWDs (Petticrew and Roberts, 2008; Shamseer et al., 2015). We selected the studies in four steps. First, two generic and three well-considered work- and/or technology-publishing digital databases (Web of Science, Scopus, Inspec, ScienceDirect and IEEE) were selected and searched. The search was done in March 2019. To capture the full range of relevant studies, the databases were searched without time constraints. These databases were systematically searched by means of Boolean algebra. Three columns of search terms were combined: the first and the second column were synonyms for respectively head-worn displays and job content. The third search column was *work*, to focus specifically on the work environment. In total, 578 Boolean configurations of search terms were composed and examined in the respective databases. A full view of search terms can be found in Appendix (Table A.2). Second, references of the selected studies were scanned in order to identify further relevant literature. Third, we checked the list of articles that cited selected studies via Google Scholar. Fourth, the first author mailed the authors of the selected studies to ask whether they knew other studies concerning the topic of this review.

Table 1
Assumptions about the use of HWDs and job content.

	Dimension of job content	↑	↑/↓	↓
Job controls	Job autonomy		✓	
	Data provision	✓		
	Social support			✓
	Skill discretion		✓	
Job demands	Physical workload			✓
	Repetitiveness		✓	
	Predictability		✓	
	Time pressure		✓	
	Cognitive workload		✓	
	Task variability		✓	
	Task complexity		✓	

Note: "↑", "↓" means that the use of HWDs is clearly expected to respectively "increase", "decrease" the concerning dimension of job content; "↑/↓" means that the impact on job content is inconclusive.

2.2. Selection criteria

Studies were incorporated in the review, if they met the selection criteria below. Studies that did not meet one of the following criteria were excluded:

1. Studies needed to be empirical studies that investigated the impact of HWDs on job content. For this reason, quantitative, qualitative, mixed-methods and case studies were considered.
2. Studies needed to investigate job demands (i.e. task complexity, job variability, job completeness, repetitiveness, time pressure and both physical and cognitive workload) and/or job controls (i.e. job autonomy, data provision, social support and skill discretion).
3. Studies needed to be academic papers. However, since the emerging domain of HWDs has hardly been connected to job content so far, we decided to expand the journal studies with book chapters and conference papers.

2.3. Analysis method

Data analysis was conducted with regard to quality assessment, data extraction and data synthesis. This is in line with the guidelines for systematic reviews (Shamseer et al., 2015).

2.3.1. Quality assessment

After selection the first and the fourth author of this study independently conducted a critical appraisal using QARI, EPHPP and MMAT for respectively qualitative (Table A.3), quantitative (Table A.4) and mixed-method studies (Table A.5) (Hannes et al., 2018; Pace et al., 2012; Thomas et al., 2004). The authors resolved disagreement on selection through discussion (Shamseer et al., 2015). To measure inter-rater reliability, *IBM SPSS Statistics 25* was used. The intraclass correlation coefficients were high, i.e. 0,80 for qualitative; 0,95 for quantitative and 0,82 for mixed-method studies.

2.3.2. Data extraction

The allocation of studies to descriptive categories was performed by means of self-constructed standardized data forms based on earlier literature reviews (see: Delarue et al., 2008; Vermeerbergen et al., 2017). Data were extracted in three steps. First, we reported the reviewed study characteristics. To this end, we reported the date of publication, the country of study, and the document type. Accordingly, we mapped the study design and the methods of data collection used in the selected studies, and we added the study participant information, looking at the number of participants that carried out the study, the gender distribution, their mean age and, if available, the type of user. Second, we reported on the HWDs used in the studies reviewed in terms of the specific hardware, the type of information displayed, the functionality of the device and the HWD-related task. Third, we explored the consequences of using HWDs for job content. To do so, we gathered the extracted job content data and grouped them per dimension.

2.3.3. *Data synthesis*

We found high heterogeneity on the dimensions of job content. The findings were therefore synthesized using the narrative review method (Greenhalgh, 1997). This approach summarizes and integrates the findings of the selected studies for job controls and job demands consecutively (Mulrow, 1994). Quotes were added to increase the findings' credibility (Sandelowski, 1994).

3. Results

3.1. *Findings of reviewed study characteristics*

The database search resulted in 3481 publications. After title and abstract analysis, the first author selected 146 studies. Prior to a first full reading, the selection criteria were applied on these studies to check their eligibility. As a result, 20 studies remained open for review. Afterwards, six articles were included after a reference check. Four more articles were added after a revision of the articles that cited the list of 26 eligible studies. After a second critical in-depth reading, two studies were excluded: one for methodological reasons. The critical appraisal withheld one more study for not meeting the quality standards. The final review included 28 studies. Fig. 1 shows the flow chart of the search strategy.

Table 2 gives an overview of the selected studies. Author(s), country of study, publication date, sector, method, and participant characteristics are displayed sequentially and will be discussed accordingly.

The selected studies conducted research in various countries. So far, most related work has been done in Germany (nine studies), USA (three studies) and Australia (three studies). The publication data show relevant early studies in the period 2005–2013, and a sharp increase in number of published studies per year since 2016. This shows that the HWD as a research topic is slowly gaining momentum (Fig. 2).

Sixteen studies were quantitative, six qualitative and six mixed-methods. In total, eleven of these were experimental studies. Overall, twenty-two studies gathered survey data among samples of users. Interviews were applied in nine studies, whereas observations and focus groups took only place three and two times, respectively.

Table 3 disentangles the HWD characteristics of the specific devices applied in the selected studies. Remarkably, across studies five distinct devices are almost evenly applied for vocational use, i.e. Vuzix-M100 (four studies), Epson Moverio BT-200 (four studies), Microsoft Hololens (five studies), Google Glass (six studies), MicroOptical sv-series (three studies). Because these distinct devices related ambiguously to job controls and job demands (Table A.6), only the descriptive aspects of these devices were presented. More specifically, we distinguished AR HWDs (eighteen studies) and non-AR HWDs (eight studies), monocular (thirteen studies) and binocular immersive see-through HWDs (eight studies). The type of information displayed was in most instances at least partially text-based (eighteen studies), symbol-based (seven studies), or

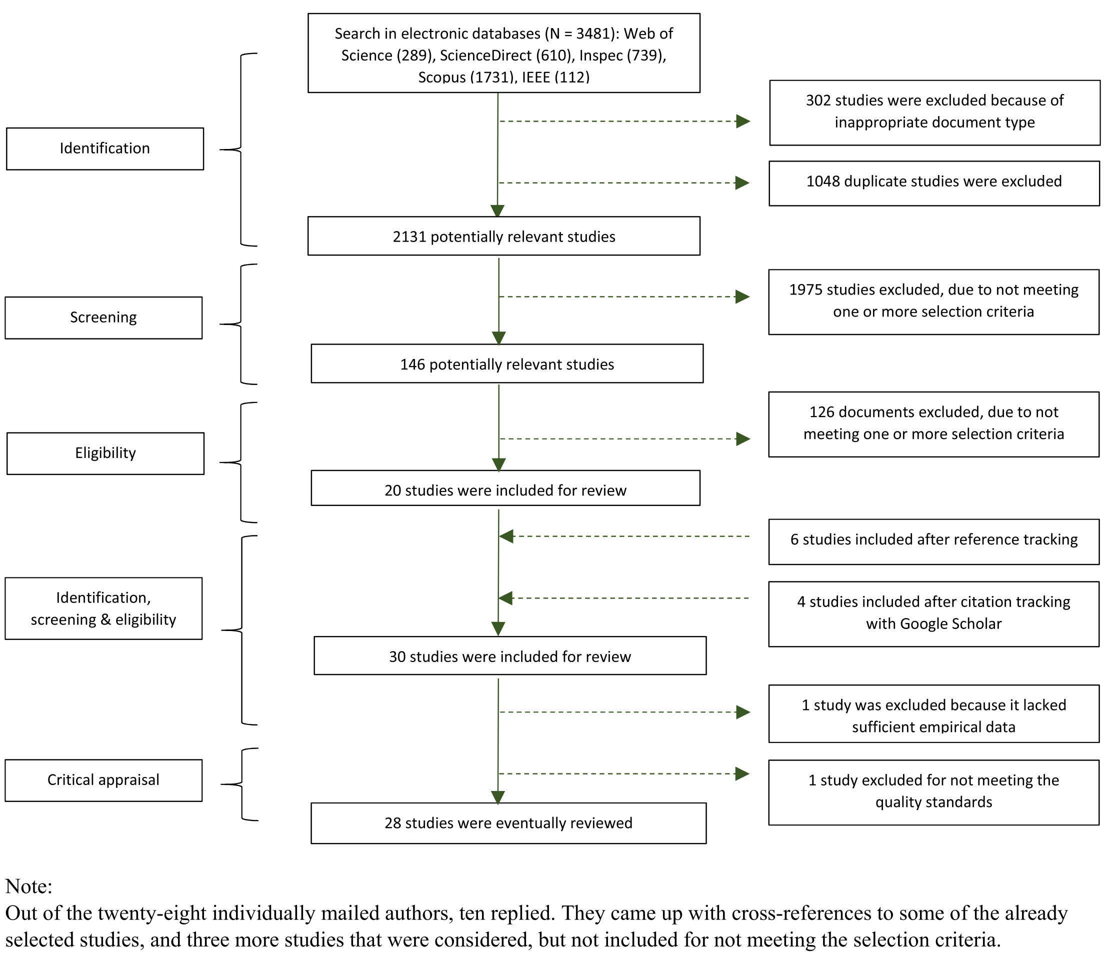

Fig. 1. Flow chart of the search strategy.
Note: Out of the twenty-eight individually mailed authors, ten replied. They came up with cross-references to some of the already selected studies, and three more studies that were considered, but not included for not meeting the selection criteria.

Table 2
Characteristics of the studies reviewed.

GENERAL CHARACTERISTICS			DOCUMENT		STUDY DESIGN				METHOD(S)				PARTICIPANT INFORMATION			
Author(s)	Year of publication	Country of study	Journal article	Conference paper	Quantitative	Qualitative	Mixed-Methods	Experimental	Surveys	Interviews	Observations	Focus groups	Number of participants	Female participants	Participant age (range c.q. mean)	Type of user
Aromaa et al.	2016	Finland		✓		✓				✓			2	0	34–49	*n.s.*
Baumeister et al.	2017	Australia		✓	✓				✓				23	6	20–47	staff & student
Blattgerste et al.	2017	Germany		✓			✓		✓	✓			24	8	20–33	*n.s.*
Borisov et al.	2018	Germany	✓				✓		✓	✓	✓		36			*n.s.*
Brizzi et al.	2018	Italy		✓	✓				✓				22	6	23–40	operators
Cidota et al.	2016	Switzerland		✓	✓				✓				12	4	18–44	participants
Cometti et al.	2018	France	✓		✓				✓							*n.s.*
Danielsson et al.	2018	Sweden		✓			✓		✓		✓		35	16		operators
Drake-Brockman et al.	2016	Australia	✓		✓				✓				40			registrars
Funk et al.	2016	Germany		✓			✓	✓	✓	✓			16	7	20–33	students
Galster et al.	2005	USA		✓	✓			✓	✓				12	8	18–34	participants
Guo et al.	2015	USA	✓		✓			✓	✓				20	8	21–35	operators
Häkkilä et al.	2018	Finland		✓		✓						✓	6		48	operators
Hao & Helo	2017	Finland	✓			✓				✓						domain experts
Kim et al.	2018	USA	✓		✓			✓	✓				16	8	24	students
Klueber et al.	2019	Germany	✓		✓			✓	✓				65	38	19–26	students
Liu et al.	2010	Australia	✓		✓				✓				3	1		anaesthetists
Loch et al.	2016	Germany		✓	✓			✓	✓				17		18–24	students
Mühlematter & Donno	2016	Switzerland		✓	✓			✓	✓				31			*n.s.*
Nakanishi et al.	2010	Japan	✓		✓				✓							*n.s.*
Peruzzini et al.	2020	Italy	✓		✓			✓	✓							participants
Romare et al.	2018	Sweden	✓			✓						✓	36	31	29–64	nurses
Stoltz et al.	2017	UK		✓		✓		✓		✓						participants
Terhoeven et al.	2018	Germany		✓	✓				✓				59	43		*n.s.*
Vinther and Müller	2018	Denmark	✓			✓				✓	✓		4	0	34–61	*n.s.*
Weaver et al.	2010	USA	✓		✓			✓	✓				12	4		students
Werrlich et al.	2018	Germany		✓			✓	✓	✓	✓			30	3		participants
Wille et al.	2014	Germany		✓			✓		✓	✓			20	9	18–67	*n.s.*
TOTAL (Σ)			**13**	**15**	**16**	**6**	**6**	**11**	**22**	**9**	**3**	**2**				

N ote: "*n.s.*" signifies for "not specified".

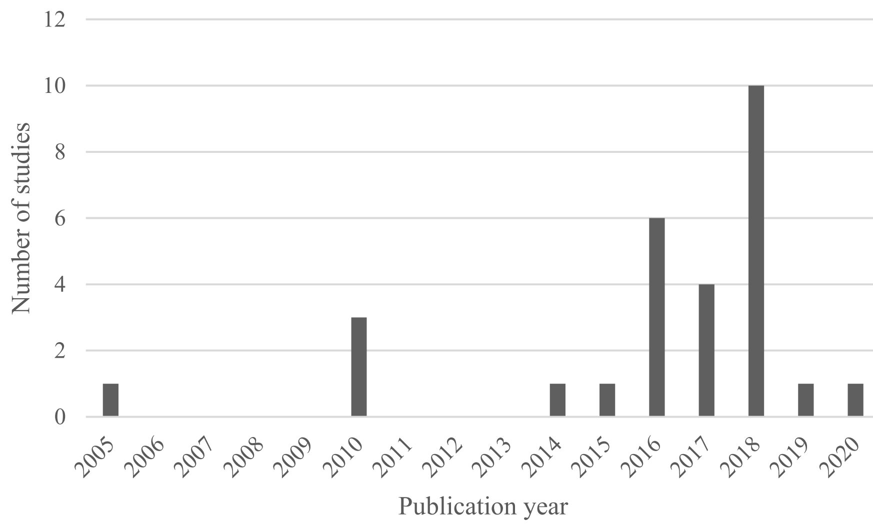

Fig. 2. Publication year and the corresponding number of the relevant studies.

animation-based (eight studies). Concerning functionality, HWDs were applied for instruction (eighteen studies), visualisation (twelve studies), remote access (four studies), or remote support (three studies) to conduct a list of HWD-related tasks. More specifically such tasks concerned assembly (eight studies), maintenance (three studies), patient monitoring (five studies) and order-picking (five studies).

3.2. Findings of reviewed study results

In what follows, we summarize the impact of HWDs on job controls c.q. job demands as investigated in the studies reviewed. A detailed overview of the reviewed study results can be found in Table 4.

3.2.1. HWDs and job controls

Four job controls were investigated: "job autonomy", "data provision", "social support" and "skill discretion". We will discuss them one by one.

Seven studies examined users' autonomy. Workers reported in four studies that they could solve problems autonomously with the provided interface information (Drake-Brockman et al., 2016; Hao and Helo, 2017; Ostendorp et al., 2015; Romare et al., 2018). Although there was room for improvement in linking data provision and the decision-making process (Romare et al., 2018), workers felt more comfortable making decisions because they could now gather information from several sources with the HWD by themselves. Some healthcare workers noted: "*It was particularly helpful that the device allowed workers to monitor operations continuously from a distance*" (Drake-Brockman et al., 2016). In contrast, three other studies reported that the use of HWDs decreased workers' autonomy. Stoltz et al. (2017) found that there was no more need for decision making in manual assembly, stating that: "*Less concentration is required as instructions are easily shown to operators. [Furthermore] the HWD helps to anticipate movements*" (Stoltz et al., 2017). The device initiated the sequence of tasks, and in a sense made the decisions that previously had been taken by workers (Hao and Helo, 2017; Mühlematter and Donno, 2016).

Nineteen studies examined data provision, of which twelve outlined increased data accessibility (Danielsson et al., 2018; Peruzzini et al., 2020). In a healthcare application, for example, the HWD was highly appreciated because of the ability to control patients' parameters remotely. The information was contextually relevant, and workers felt enabled to pick out the parameters they required for investigation (Drake-Brockman et al., 2016; Liu et al., 2010; Romare et al., 2018). Also for other HWD-related tasks, users appreciated the easily accessible data at the workplace (Blattgerste et al., 2017; Cidota et al., 2016; Häkkilä et al., 2018; Wille et al., 2014). Werrlich et al. (2018) particularly specified the usefulness of the device, noting that: "*the user interface […] provides a lot of helpful information*". Four studies presented that data provision can be constraining as well. The HWD sometimes merely imposed its virtual guidance on workers for intuitive tasks. However, Terhoeven et al. (2018) noticed that: "*employees do not assess HWDs as a suitable work assistance in a simple work environment*". Simplified work instructions both frustrated and worried workers (Aromaa et al., 2016; Borisov et al., 2018; Mühlematter and Donno, 2016). Furthermore, Aromaa et al. (2016) noted that it was important that "*the provided information has to be contextually relevant […] The user should be able to trust and understand the information*".

Seven studies researched social support. Contrary to our expectations, four studies positively evaluated social support between colleagues. Accessibility of point-of-view footage facilitated remote collaboration (Hao and Helo, 2017; Romare et al., 2018; Vinther and Müller, 2018). Maintenance technicians that used the HWD were for instance able to virtually assist operators' on-site problem-solving tasks (such as repair and maintenance) in remote locations. In the study of Häkkilä et al. (2018), a worker mentioned the following: "*[the technician] wouldn't have to come to me, [because] he knows I have the basic skills, and I can do [the job] when I get a few hints. If he sees what I see, and I see what he explains or draws, it helps*". However, Danielsson et al. (2018) reported less interaction between operators because of the HWD use. The workers in manual assembly worked more individually. Because of workplace isolation, communication with colleagues decreased (Aromaa et al., 2016; Borisov et al., 2018). Aromaa et al. (2016) addressed that: "*the [HWD] can also change the work in a way that there will be less telephoning and communication between people*". Furthermore, it was important to call into question the connectedness of HWD with already present technologies in the organisation. Werrlich et al. (2018) stated e.g. that a combination of HWD and voice control might distract and disturb other operators and thus hinder work performance. In contrast, the combination of HWD and audio assistance could increase worker collaboration because spoken messages could be added to the data (Romare et al., 2018).

Seven studies related HWD to skills and learning. Five mentioned a skill decrease, because the provision of additional task information reduced the performance gap between an expert and a novice (Brizzi et al., 2018). Maintenance technicians perceived their jobs under threat; "*they might fear new technologies […] since anyone could be capable of doing maintenance*" (Aromaa et al., 2016). Others affirmed that skills may become devaluated and eventually obsolete (Borisov et al., 2018; Stoltz et al., 2017). Terhoeven et al. (2018) added that in their two cases,

Table 3
Characteristics of the studied HWDs, their functionalities, and the related tasks.

	DEVICE							SPECIFICATION		
Author(s)	Vuzix-M100	Epson Moverio BT-200.	Microsoft Hololens	Google Glass.	MicroOptical sv-series.	Other devices	*Not specified*	AR (3D)	Non-AR (2D)	Monocular
Aromaa et al.	✓							✓		✓
Baumeister et al.		✓	✓			✓		✓		
Blattgerste et al.		✓	✓					✓		
Borisov et al.						✓			✓	✓
Brizzi et al.							*n.s.*	✓		
Cidota et al.						✓		✓		
Cometti et al.			✓					✓		
Danielsson et al.							*n.s.*	✓		*n.s.*
Drake-Brockman et al.				✓				✓		✓
Funk et al.		✓						✓		
Galster et al.					✓				✓	✓
Guo et al.				✓	✓				✓	✓
Häkkilä et al.			✓					✓		
Hao & Helo	✓							✓		✓
Kim et al.	✓	✓							✓	✓
Klueber et al.	✓								✓	✓
Liu et al.						✓			✓	
Loch et al.						✓		✓		
Mühlematter & Donno				✓					✓	✓
Nakanishi et al.							*n.s.*	*n.s.*		✓
Peruzzini et al.						✓		✓		✓
Romare et al.							*n.s.*	✓		*n.s.*
Stoltz et al.				✓				✓		✓
Terhoeven et al.							*n.s.*	*n.s.*		*n.s.*
Vinther and Müller				✓					✓	✓
Weaver et al.					✓				✓	
Werrlich et al.			✓					✓		
Wille et al.				✓		7			✓	*n.s.*
TOTAL (Σ)	**4**	**4**	**5**	**6**	**3**	**7**	**5**	**18**	**8**	**13**

Note: (1) The category "Other devices" comprises of all other one-off HWD devices, i.e. in vertical order, Samsung Gear VR, Optinvent, META Space Glasses, Microvision Nomad, Oculus Rift, Tobii Glasses, MAVUS; (2) The HWD-related task for Vinther & Müller (20XX) "cattle monitoring" was categorised as "patient monitoring". The study by Terhoeven et al. (2018) comprises of two HWD-related tasks.

HWDs would shorten learning curves on intuitive tasks, and that learnability would be higher in complex surroundings.

3.2.2. *Impact on job demands*

Although explicitly searched for job variability, job completeness, repetitiveness and time pressure, none of these job demands were researched in the selected studies. That is why job demands were assessed by reviewing "physical workload", "cognitive workload" and "task complexity". We will discuss them one by one.

Ten studies mentioned the impact of the HWD on physical workload and ergonomics, of which seven showed positive results. Study results recognized that HWD enabled workers to work "hands free" or with both hands available (Funk et al., 2016; Peruzzini et al., 2020; Stoltz et al., 2017). Häkkilä et al. (2018) mentioned *"having a hands-free augmented reality view was appreciated, as it would mean less hardware in the hands"*. Workers felt that the device itself was comfortable and unobtrusive to wear (Drake-Brockman et al., 2016). However, three studies showed negative results. HWDs were often bulky or difficult to wear, what lead to discomfort and reduced head mobility (Liu et al., 2010). More recent studies criticized the HWDs' ergonomics, not because merely wearing would make it uncomfortable, but because it might harm eyesight in the long run (Romare et al., 2018; Werrlich et al., 2018). In Romare et al. (2018), *"[…] users thought that the massive input of information would make it too exhausting to wear smart glasses during an entire shift. […] Wearing the HWD in specific situations would be more appealing"*.

Seventeen papers investigated cognitive workload. Six of them showed that participants felt less busy. In healthcare, it seemed now easier to monitor patients (Liu et al., 2010). Furthermore, in the order-picking industry the workload for HWDs was the lowest compared to paper-based picking methods (Guo et al., 2015; Kim et al, 2016, 2019; Weaver et al., 2010; Werrlich et al., 2018). In their study, Werrlich et al. (2018) found that: *"participants that used the HWD stated to have lower mental demands and felt less frustrated compared to participants that did not use the HWD"*. Studies also found that the use of HWDs did not produce additional cognitive workload (Cometti et al., 2018; Loch et al., 2016; Romare et al., 2018). Eleven studies showed, at least partially, increased cognitive workload. In a manual assembly context, three studies reported significantly higher cognitive strain compared to working with tablet instructions (Wille et al., 2014), in-situ instructions (Stoltz et al., 2017) and paper-based instructions (Blattgerste et al., 2017). Wille et al. (2014) showed that: *"although headaches were no longer mentioned, participants still experienced a faster increase in mental fatigue while working with a HWD"*. Other studies indicated that audio instructions and simple user-friendly display might be less exhausting than HWDs (Galster et al., 2005; Klueber et al., 2019).

Ten studies researched the relation between HWDs and task complexity. In total, six publications showed positive results. HWD users were less prone to interruptions and distractions, and work seemed easier to interpret with HWD (Liu et al., 2010; Nakanishi et al., 2010; Werrlich et al., 2018). Liu et al. (2010) noticed that: *"workers could detect events more easily and were continuously able to monitor the operations without turning around"*. Three other studies showed both positive and negative points. Blattgerste et al. (2017) for instance stated that the HWD information was easy to interpret for most of the participants, yet not for all. Another study found that, although the device was not perceived as distracting in general, sometimes the device was experienced as harassing (Drake-Brockman et al., 2016). Four study results showed that the HWD increased task complexity. The HWD after all required you to keep paying attention to both information displayed on the HWD and workplace. In addition, four studies showed that workers were sometimes disproportionally focused on the HWD instructions. The demand to focus on both information displayed on the HWD and work

SPECIFICATION	INFORMATION			FUNCTIONALITY				HWD-RELATED TASK				
Binocular	Text-based	Symbol-based	Animation-based	Instructions	Visualisation	Remote access	Remote support	Assembly	Maintenance	Patient monitoring	Order-picking	Other tasks
	✓	✓		✓					✓			
✓			✓	✓								✓
		✓	✓	✓				✓				
	✓				✓							✓
✓		✓		✓				✓				
✓		✓		✓								✓
✓	✓			✓							✓	
n.s.	✓			✓	✓			✓				
	✓				✓	✓	✓			✓		
✓			✓	✓				✓				
	✓			✓								✓
	✓			✓								✓
✓		✓			✓				✓			
	✓			✓	✓		✓					✓
			✓		✓						✓	
	✓					✓				✓		
✓	✓				✓	✓				✓		
✓			✓		✓			✓				
	✓			✓								✓
	✓			✓								✓
	✓			✓	✓			✓				
n.s.	✓		✓			✓	✓			✓		
	✓	✓		✓							✓	
n.s.	✓			✓				✓			✓	
	✓				✓					✓		
			✓	✓	✓						✓	
✓		✓	✓		✓				✓			
n.s.	✓			✓				✓				
8	**18**	**7**	**8**	**18**	**12**	**4**	**3**	**8**	**3**	**5**	**5**	**8**

environment could distract and thus raise complexity (Funk et al., 2016; Mühlematter and Donno, 2016; Vinther and Müller, 2018). In some cases *"the device caused minor distractions"* (Drake-Brockman et al., 2016)". In three other studies, HWDs were functioning together with other devices (Aromaa et al., 2016). Similar inputs via different devices made it consequently difficult, because the inputs were regarded as separate instructions (Borisov et al., 2018). "*Communication through both auditory and visual modalities results in a single instruction being perceived as two separate instructions, causing an unintended reaction* (Nakanishi et al., 2010)".

4. Discussion

In this study we investigated how the use of HWDs affected job content. We did this by investigating both job controls as well as job demands. For the latter we looked at physical workload, cognitive workload, and task complexity. For the former we looked at job autonomy, data provision, social support, and skill discretion. Remarkably, our results were not unidirectional. Instead, HWDs affected the various job controls and job demands under study in contrasting ways. Some studies reported strengthened job controls with regard to remote social support and increased job autonomy. Combined with rising task complexity, jobs in these studies met more challenging tasks. In contrast, other studies reported decreases in job controls, e.g. a loss of decision making authority, decreased social support or increased digital monitoring. Combined with a continuous sequence of HWD-initiated instructions, jobs in these studies had to cope with more exhaustive tasks. The use of HWDs clearly transformed job content, yet in contrasting ways across the studies reviewed.

4.1. *Explaining conflicting results: supportive and directive approach*

To interpret these apparently conflicting results, we draw attention to the embeddedness of the HWD, i.e. the employment of the HWD in its concrete work setting and in the organisation context. Previous studies in the fields of organisation studies and macro-ergonomics have repeatedly demonstrated that researching the embeddedness of (digital) technologies in organisations is of utmost importance for understanding the impact of it on job content (Benders, 1995; Blauner, 1964; Braverman, 1974; Castells, 1996; Dempsey et al., 2010; Hirsch-Kreinsen, 2016; Zuboff, 1988).

Still, the embeddedness of HWDs was hardly considered in the studies reviewed. To the contrary, the starting point of most of the studies reviewed was the (mal)functioning of the device itself and its direct impact on distinct performance outcomes (Table A.7). Nevertheless, most of the studies reviewed did share some information on the particular HWD-related task, information that may serve as a stepping stone for the embeddedness of the HWD in its concrete work setting. Looking for explanation, we related distinct HWD-related tasks to job controls and job demands (Table A.8). Despite the small amount of papers per HWD-related task and their incomplete job content analysis, we gained three preliminary insights. One: across HWD-related tasks, only patient monitoring was one-sidedly positively related to job autonomy. Two: information on social support was remarkably lacking, irrespective of the HWD-related task. However, previous studies on technology and work repeatedly pointed at the importance of social support. Three: the direction for job demands in general seemed to vary ambiguously within and across HWD-related tasks. In general, both changes in job controls and job demands occurred, but the changes across HWD-related tasks were ambiguous. Future research should clarify this ambiguity across tasks in-depth.

Table 4
Association of HWDs and job controls c.q. job demands.

	JOB CONTROLS												JOB DEMANDS								
	Job autonomy			Data provision			Social support			Skill discretion			Physical workload			Cognitive workload			Task complexity		
Author(s)	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓
Aromaa et al. (2016)						✓		✓				✓								✓	
Baumeister et al. (2017)																	✓				
Blattgerste et al. (2017)				✓													✓			✓	
Borisov et al. (2018)						✓			✓			✓			✓						
Brizzi et al. (2018)					✓							✓									
Cidota et al. (2016)	✓			✓												✓					
Cometti et al. (2018)													✓					✓			
Danielsson et al. (2018)				✓																	
Drake-Brockman et al., 2016	✓				✓						✓		✓							✓	
Funk et al. (2016)				✓									✓					✓			✓
Galster et al. (2005)																		✓			
Guo et al. (2015)				✓												✓					
Häkkilä et al. (2018)				✓			✓						✓								
Hao & Helo (2017)		✓			✓		✓														
Kim et al., (2019)															✓	✓					
Klueber et al. (2019)																		✓			
Liu et al. (2010)	✓			✓											✓	✓			✓		
Loch et al. (2016)																	✓				
Mühlematter & Donno (2016)			✓			✓							✓					✓			✓
Nakanishi et al. (2010)																	✓		✓		
Peruzzini et al. (2020)				✓									✓								
Romare et al., 2018	✓			✓			✓										✓				
Stoltz et al. (2017)			✓									✓	✓								✓
Terhoeven et al. (2018)				✓		✓				✓		✓									
Vinther and Müller (2018)					✓		✓														✓
Weaver et al. (2010)				✓												✓					
Werrlich et al. (2018)				✓					✓		✓					✓			✓		
Wille et al. (2014)																		✓			
TOTAL (Σ)	4	1	2	12	4	4	4	1	2	1	2	5	7	0	3	6	5	6	3	3	4

Note: (1) "↑" signifies head-worn displays positively influence the job control c.q. job demand, specified in the top row, according to the study indicated in the left column; "↓" signifies that head-worn displays negatively influence the specified job control c.q. job demand; "↑/↓" signifies head-worn displays correlate ambiguously with this job demand; (2) Since *job variability*, *work pressure*, *repetitiveness* and *time pressure* were not reported, these columns were not added to the table; (3) The study by Terhoeven et al. (2018) comprises of two cases with distinct results.

A more explicit interpretation of these conflicting results may be that the studies reviewed mostly lacked insight on the organisation context. The organisation context is indeed known to, at least partially, constitute job content, irrespective of digital technologies. We noticed that if the specific work setting and the organisation context were mentioned more thoroughly, two contrasting, yet clearer approaches emerged. The first approach became particularly clear in two articles that showed how the use of HWDs related to decentralized work (Drake-Brockman et al., 2016; Häkkilä et al., 2018). Here, regularly information updates intentionally facilitated the connection between shop floor and back-office workers. Remarkably, the workers in these studies felt they already possessed job autonomy with regard to their tasks as of before the implementation of the HWD. More so, workers felt their job autonomy had increased now that they could gather information remotely via the HWDs. The second approach became clear in three studies. These studies showed how real-time connection intentionally led to more organisational control (Hao and Helo, 2017; Stoltz et al., 2017; Mühlematter and Donno, 2016). Worker activities were collected centrally for continuous monitoring, e.g. managers and technicians could access distributed footage to diagnose and solve issues quickly. To a significant extent, the HWD prescribed all work tasks, and made the decisions previously made by a human.

Thus, the embeddedness of the HWD results in two contrasting approaches, i.e. a supportive approach and a directive counterpart. We hypothesize that the former approach is applied in task environments where work is hard to standardize and jobs tend to be complex. In those cases, employees require substantial support so that they can make decisions independently. The directive approach on the other hand, intentionally narrows down job controls by standardizing the work, so that jobs consist of a series of simple, closely manageable tasks. The supportive approach purveys high job controls to cope with the high job demands, whereas the directive approach intentionally constrains favourable job controls. This distinction nuances the positively biased expectations of changes regarding job content around digital technologies. Following the renewed attention for the concept *human-centred design*, one would indeed argue that the changes with regard to job controls and job demands would relate to the supportive approach. However, we found that HWDs at work may also steer workers to follow a series of highly controllable tasks. Ironically, jobs with such directive design may also be seen to be human-centred, but focus on eliminating human interventions.

Up until now, few studies on digital technologies (e.g. HWDs) have taken into account their embeddedness in the organisation context. Future studies should account for these distinct approaches and how they affect job content before and after the technology implementation. Another suggestion would be to investigate the implications of digital technology design on job content. It should be questioned to what extent the design of one particular digital technology and its surrounding organisation context may have a combined impact on job content. Scholars who study the impact of digital technologies on job content should consider the lineages between two untapped research avenues. One is to integrate the organisation context when focusing on the task-level human-computer interaction. Another is to integrate the technological characteristics and the design context of digital technologies to enrich the understanding of job content. Future studies should be stimulated to no longer study the design and the use of digital technologies separately (Bailey and Barley, 2020).

4.2. Methodological recommendations

Based on the different methods that were applied in the studies reviewed (Table 2), we outline three future research avenues. First, future studies should depart from the experimental short-term lab environments and focus on in-depth cases which digital technologies are being designed for, and used in. It is indeed only when digital technologies are studied when practiced by workers during their daily work activities that the embeddedness within a particular organisation context may surface. Secondly, the reviewed studies contained mostly single case studies. We recommend cross-organisational studies to qualitatively compare the embedded use of HWDs, the HWD-related tasks, but also the particular material characteristics of the rapidly evolving HWDs. Finally, one digital technology (HWD or other) may have distinct functionalities (Table 3). Today, there is a remaining lack of research on distinct functionalities of digital technologies and how they relate to job content (Kallinikos et al., 2013; Leonardi, 2012).

4.3. Practical implications

More research in real work environments on this topic has to be executed to instruct policy makers, employee representatives and managers concretely on the implementation of HWDs. Due to Covid-19 (SARS-CoV-2), HWDs gained renewed managerial attention because of the potential to assist workers remotely, so as to ensure physical distancing. However, managers that are about to implement the HWD should do it cautiously. They should consider the impact of HWD use on job content, because only favourable job content, and therefore high quality of working life, is required to sustain performance on the long run. From this perspective, organisations should aim to implement HWDs supportively. If, however, the use is directive, measures should be taken to avoid counter-productive consequences.

5. Conclusion

Various organisations have started to implement head-worn displays (HWDs) at work. However, few studies have researched the impact on HWD users' job content. This article is the first to conduct a systematic review on how the use of HWDs affects job content. The studies reviewed show that HWDs have a clear impact on job controls and job demands. In general and related to the elements of job demands, the use of HWDs increases both cognitive workload and data provision, while it decreases physical workload. Concerning job controls, the impact on task complexity, job autonomy, social support and skill discretion varies. To explain this variation, we discuss that the embedded use of HWDs in the organisation context can go both ways: (1) either the HWD is supportive and thus intentionally used to improve job autonomy and social support or (2) the HWD is directive and consciously designed to maximize manageability and controllability. Organisations should make an informed decision on their approach, as the use of HWDs can affect job content in various ways.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX

Table A.1Definitions of job content dimensions.

		Definition	Author(s)
Job controls	Job autonomy	The degree to which a job provides control possibilities.	Van Hootegem et al. (2014)
	Social support	The degree to which a job provides opportunities for advice and assistance from peers/supervisors.	Morgeson and Humphrey (2006)
	Skill discretion	The range of skills that are usable on the job.	Karasek (1979)
	Data provision	The degree to which there is sufficient feedback on the results of the work, and whether there is sufficient information about the purpose of the work and its tasks.	Van Hootegem et al. (2014)
Job demands	Completeness	The degree to which a job is complete, meaning that the job includes preparatory, supportive and executive tasks.	Van Hootegem et al. (2014)
	Variability	The degree to which changes in the environment influence the relation between tasks and their outcome.	Van Hootegem et al. (2014)
	Physical workload	The degree to which workers are exhausted because of physical responses, such as i.e. muscular work, climate and vibration. Changes may occur in a short-term period, such as changes over the day, as well as in long-term periods, such as increase/decrease in muscle strength.	De Sitter et al. (1997)
	Cognitive workload	The degree to which a worker is responsible for monitoring its inputs, methods and outputs. This relates to analysing, problem-solving and production responsibility.	Van Hootegem et al. (2014)
	Time pressure	The degree to which there is a high number of requirements within a limited time space.	Van Hootegem et al. (2014)

Table A.2List of searching terms.

15	Head worn display	34	Job controls c.q. job demands	1	Work*
1	Smart glasses	1	Feedback	1	Work*
2	Head mounted display	2	Contact possibility		
3	Head worn display	3	Social support		
4	Head up display	4	Supervisory support		
5	Head mounted device	5	Problem solving		
6	Head worn device	6	Information access		
7	Head up device	7	Job demand*		
8	AR glasses	8	Variety		
9	Augmented Reality glasses	9	Variability		
10	Head attached	10	Complexity		
11	Head-mounted display	11	Time pressure		
12	Head-worn display	12	Repetitive*		
13	Head-up display	13	Routine		
14	Head-mounted device	14	Predictability		
15	Head-worn device	15	Specialisation		
		16	Task significance		
		17	Emotional demand*		
		18	Task identity		
		19	Emotional experience		
		20	Short-cycled		
		21	Work pressure		
		22	Job content		
		23	Job characteristic*		
		24	Job control*		
		25	Job resource*		
		26	Job autonomy		
		27	Decision authority		
		28	Work environment		
		29	Organi*ation		
		30	Centrali*ation		
		31	Decentrali*ation		
		32	Empowerment		
		33	Workplace		
		34	Quality of working life		

Table A.3Quality check of qualitative studies reviewed.

Studies reviewed	CRITICAL APPRAISAL CRITERIA										Conclusion
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Danielsson et al. (2018)	Unclear	Yes	Yes	No	Yes	Unclear	Yes	No	Yes	Yes	Reviewer 1: Inclusion
	Unclear	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Reviewer 2: Inclusion
Häkkilä et al. (2018)	Unclear	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Reviewer 1: Inclusion
	Unclear	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Reviewer 2: Inclusion
Hao & Helo (2017)	Unclear	Yes	Yes	No	Yes	Unclear	Unclear	No	No	Yes	Reviewer 1: Inclusion
	Unclear	Yes	Yes	No	Yes	Unclear	Yes	No	No	Yes	Reviewer 2: Inclusion
Ostendorp et al. (2015)	Unclear	Yes	Yes	No	No	No	No	No	No	No	Reviewer 1: Exclusion
	Unclear	No	No	No	No	No	No	No	No	No	Reviewer 2: Exclusion
Romare et al. (2018)	Unclear	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Reviewer 1: Inclusion
	Unclear	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Reviewer 2: Inclusion
Stoltz et al. (2017)	Unclear	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Reviewer 1: Inclusion
	Unclear	Yes	Yes	No	Yes	No	No	No	No	Yes	Reviewer 2: Inclusion
Vinther and Müller (2018)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Reviewer 1: Inclusion
	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Unclear	Yes	Reviewer 2: Inclusion

Note: The critical appraisal criteria are the following.
(1)There is congruity between the stated philosophical perspective and the research methodology.
(2)There is congruity between the research methodology and the research question or objectives.
(3)There is congruity between the research methodology and the methods used to collect data.
(4)There is congruity between the research methodology and the representation and analysis of data.
(5)There is congruity between the research methodology and the interpretation of results.
(6)There is a statement locating the researcher culturally or theoretically.
(7)The influence of the researcher on the research, and vice versa, is addressed.
(8)Participants, and their voices, are adequately represented.
(9)The research is ethical according to current criteria or, for recent studies, there is evidence of ethical approval by an appropriate body.
(10)Conclusions drawn in the research report do appear to flow from the analysis, or interpretation, of the data.

Table A.4Quality check of quantitative studies reviewed.

Studies reviewed	CRITICAL APPRAISAL CRITERIA					Conclusion
	Selection bias	Study design	Confounders	Blinding	Data collection method	
Baumeister et al. (2017)	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Brizzi et al. (2018)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Exclusion
	Moderate	Moderate	Moderate	Moderate	Moderate	Reviewer 2: Inclusion
Cidota et al. (2016)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 2: Inclusion
Cometti et al. (2018)	Moderate	Moderate	Moderate	Moderate	Strong	Reviewer 1: Inclusion
	Moderate	Moderate	Moderate	Moderate	Strong	Reviewer 2: Inclusion
Drake-Brockman et al. (2016)	Weak	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Galster et al. (2005)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Exclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Guo et al. (2015)	Moderate	Moderate	Weak	Moderate	Moderate	Reviewer 1: Inclusion
	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Klueber et al. (2019)	Weak	Strong	Moderate	Moderate	Strong	Reviewer 1: Inclusion
	Weak	Strong	Moderate	Moderate	Strong	Reviewer 2: Inclusion
Kim et al. (2019)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Liu et al. (2010)	Moderate	Moderate	Moderate	Moderate	Moderate	Reviewer 1: Inclusion
	Moderate	Moderate	Moderate	Moderate	Moderate	Reviewer 2: Inclusion
Loch et al. (2016)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Mühlematter & Donno (2016)	Moderate	Moderate	Weak	Moderate	Weak	Reviewer 1: Inclusion
	Moderate	Moderate	Weak	Moderate	Weak	Reviewer 2: Inclusion
Nakanishi et al. (2010)	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 2: Inclusion
Peruzzini et al. (2020)	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Terhoeven et al. (2018)	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Moderate	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion
Weaver et al. (2010)	Weak	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Moderate	Reviewer 2: Inclusion
Wille et al. (2014)	Weak	Moderate	Weak	Moderate	Strong	Reviewer 1: Inclusion
	Weak	Moderate	Weak	Moderate	Strong	Reviewer 2: Inclusion

Table A.5Quality check based on Mixed Methods Appraisal Tool (MMAT) of mixed-methods studies reviewed

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
Aromaa et al. (2016)	No	Yes	Yes	?	?	No	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Reviewer 1: Inclusion
	Yes	Yes	?	?	?	No	Yes	Yes	?	Yes	Yes	Yes	No	No	Yes	Reviewer 2: Inclusion
Blattgerste et al. (2017)	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No	No	No	Reviewer 1: Inclusion
	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No	No	Yes	Reviewer 2: Inclusion
Borisov et al. (2018)	Yes	Yes	?	?	?	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Reviewer 1: Inclusion
	Yes	Yes	?	?	?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Reviewer 2: Inclusion
Funk et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Reviewer 1: Inclusion
	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Reviewer 2: Inclusion
Werrlich et al. (2018)	Yes	Yes	Yes	Yes	Yes	?	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Reviewer 1: Inclusion
	Yes	Yes	Yes	Yes	Yes	?	Yes	Yes	?	Yes	No	No	No	No	Yes	Reviewer 2: Inclusion

Note: The critical appraisal criteria are the following.
(1)Is the qualitative approach appropriate to answer the research question?.
(2)Are the qualitative data collection methods adequate to address the research question?.
(3)Are the findings adequately derived from the data?.
(4)Is the interpretation of results sufficiently substantiated by data?.
(5)Is there coherence between qualitative data sources, collection, analysis and interpretation?.
(6)Is the sampling strategy relevant to address the research question?.
(7)Is the sample representative of the target population?.
(8)Are the measurements appropriate?.
(9)Is the risk of nonresponse bias low?.
(10)Is the statistical analysis appropriate to answer the research question?.
(11)Is there an adequate rationale for using a mixed methods design to address the research question?.
(12)Are the different components of the study effectively integrated to answer the research question?.
(13)Are the outputs of the integration of qualitative and quantitative components adequately interpreted?.
(14)Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?.
(15)Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?.

Table A.6HWD device and job content

		Job autonomy			Data provision			Social support			Skill discretion			Physical workload			Cognitive workload			Task complexity		
Author(s)		↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓
Aromaa	Vuzix M-100					✓			✓				✓								✓	
Hao & Helo	Vuzix M-100		✓			✓		✓														
Kim	Vuzix M-100															✓	✓					
Klueber	Vuzix M-100																		✓			
TOTAL (Σ)	**Vuzix M-100**		1			2		1	1				1			1	1		1		1	
Baumeister	Epson Moverio																	✓				
Blattgerste	Epson Moverio				✓													✓			✓	
Funk	Epson Moverio				✓									✓					✓			
Kim	Epson Moverio															✓	✓					
TOTAL (Σ)	**Epson Moverio**				2			1	1					1		1	1	2	1		2	
Baumeister	Microsoft Hololens																	✓				
Blattgerste	Microsoft Hololens				✓													✓			✓	
Cometti	Microsoft Hololens													✓					✓			
Häkkilä	Microsoft Hololens				✓			✓						✓								
Werrlich	Microsoft Hololens				✓					✓		✓					✓			✓		
TOTAL (Σ)	**Microsoft Hololens**				3			1		1		1		2			1	2	1	1	1	
Drake-Brock …	Google Glass	✓				✓								✓							✓	
Guo	Google Glass				✓												✓					
Mühlematter …	Google Glass			✓			✓							✓					✓			✓
Stoltz	Google Glass			✓									✓	✓								✓
Vinther	Google Glass					✓		✓														✓
Wille	Google Glass															✓						
TOTAL (Σ)	**Google Glass**	1		2	1	2	1	1					1	3		1	1		1		1	3
Galster	MicroOptical																		✓			
Guo	MicroOptical				✓												✓					
Weaver	MicroOptical				✓												✓					
TOTAL (Σ)	**MicroOptical**				2												2		1			

Note: (1) "↑" signifies head-worn displays positively influence with this outcome, specified in the top row, according to the study indicated in the left column; "↓" signifies that head-worn displays negatively influence with this outcome; "↑/↓" signifies the devices correlate ambiguously with the outcome.

Table A.7Related outcomes

	Engagement			Performance			Technology acceptance			Ergonomics			Time efficiency			Accuracy			Enthusiasm		
Author(s)	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓
Aromaa et al. (2016)							✓								✓	✓					
Baumeister et al. (2017)																					
Blattgerste et al. (2017)													✓			✓			✓		
Borisov et al. (2018)		✓				✓			✓			✓									
Brizzi et al. (2018)													✓			✓					
Cidota et al. (2016)	✓																				
Cometti et al. (2018)																					
Danielsson et al. (2018)													✓			✓			✓		
Drake-Brockman et al. (2016)							✓			✓											
Funk et al. (2016)										✓					✓			✓			
Galster et al. (2005)																✓					
Guo et al. (2015)	✓												✓			✓					
Häkkilä et al. (2018)										✓											
Hao & Helo (2017)	✓																				
Liu et al. (2010)				✓									✓			✓					
Klueber et al. (2019)																✓					
Liu et al. (2010)				✓								✓		✓							
Loch et al. (2016)				✓										✓		✓					
Mühlematter & Donno (2016)								✓		✓					✓	✓					
Nakanishi et al. (2010)								✓					✓								
Peruzzini et al. (2020)	✓						✓			✓											
Romare et al. (2018)												✓				✓					
Stoltz et al. (2017)							✓			✓					✓			✓	✓		
Terhoeven et al. (2018)								✓									✓				
Vinther and Müller (2018)															✓						
Weaver et al. (2010)													✓			✓			✓		
Werrlich et al. (2018)															✓	✓			✓		
Wille et al. (2014)		✓			✓								✓						✓		
TOTAL (Σ)	4	2	0	3	1	1	4	3	1	6	0	3	8	2	6	13	1	2	7	0	0

Note: (1) "↑" signifies head-worn displays positively influence with this outcome, specified in the top row, according to the study indicated in the left column; "↓" signifies that head-worn displays negatively influence with this outcome; "↑/↓" signifies the devices correlate ambiguously with the outcome.

Table A.8HWD-related task and job content

		Job autonomy			Data provision			Social support			Skill discretion			Physical workload			Cognitive workload			Task complexity		
Author(s)		↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓	↑	↑/↓	↓
Blattgerste	Assembly				✓														✓		✓	
Brizzi	Assembly					✓							✓									
Danielsson	Assembly				✓																	
Funk	Assembly				✓									✓					✓			
Loch	Assembly																	✓				
Peruzzini	Assembly				✓									✓								
Terhoeven	Assembly										✓											
Wille	Assembly															✓						
TOTAL (Σ)	**Assembly**				**4**	**1**					**1**		**1**	**2**		**1**		**1**	**2**		**1**	
Aromaa	Maintenance						✓		✓				✓								✓	
Hao	Maintenance		✓			✓		✓														
Werrlich	Maintenance				✓					✓		✓					✓			✓		
TOTAL (Σ)	**Maintenance**		**1**		**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**				**1**			**1**	**1**	
Vinther	Monitoring					✓		✓														✓
Drake-Brockman	Monitoring	✓				✓								✓							✓	
Klueber	Monitoring															✓						
Liu	Monitoring	✓			✓											✓	✓			✓		
Romare	Monitoring	✓			✓			✓										✓				
TOTAL (Σ)	**Monitoring**	**3**			**2**	**2**		**2**						**1**		**2**	**1**	**1**		**1**	**1**	**1**
Cometti	Order-picking													✓					✓			
Guo	Order-picking				✓												✓					
Kim	Order-picking															✓	✓					
Stoltz	Order-picking			✓									✓	✓								✓
Weaver	Order-picking				✓												✓					
Terhoeven	Order-picking												✓									
TOTAL (Σ)	**Order-picking**			**1**	**2**								**2**	**2**		**1**	**3**		**1**			**1**

Note: (1) "↑" signifies head-worn displays positively influence this outcome, specified in the top row, according to the study indicated in the left column; "↓" signifies that head-worn displays negatively influence with this outcome; "↑/↓" signifies the devices correlate ambiguously with the outcome.

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