

‘Industrie 4.0’ and an Aging Workforce – A Discussion from a Psychological and a Managerial Perspective

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Abstract. The aging workforce is already impacting on companies, particularly those in countries of the industrialized Western world. Furthermore, Western companies are coming under the increasing influence of technological developments, such as ‘Industrie 4.0’, which are in the process of completely changing traditional working environments. In order to maintain their industrial competitiveness, companies need to synchronize these technological developments with their own organizational requirements and in particular with the requirements of an aging workforce. We show how different types of competencies may be categorized in order to enable a successful synchronization. In addition, we take a look at recent developments in the domain of ‘Industrie 4.0’ and derive future research areas for solving the challenges involved.

Keywords: Complexity · Industrie 4.0 · Competence management · Collaboration · Communication · Internet of Things

1 ‘Industrie 4.0’, Internet of Things, and an Aging Workforce: Their Pitfalls for Employees and Employers

The aging of the world’s population is having an impact on all areas of daily life. As a result, the United Nations describe this demographic change as “*one of the most significant social transformations of the twenty-first century*” [1].

To underline this development in numbers: By 2050 every fifth person of the world’s population will be aged 60 years or older. In 2015 only every eighth person belonged to this age group [1]. Especially companies in high-wage countries are affected by the effects of an aging workforce [2, 3].

The main trends which are driving this development are the expansion of life expectancy as well as a decline in birth rates, the latter resulting from better education and birth control [4]. The number of young employees entering the

workforce will fall, and a considerable number of older employees will leave their working lives as a result of the extended age pyramid [2].

Especially companies are struggling with these changes in the age structure of their workforce. Well-trained and highly-skilled employees are the key factor to the success of the German economy [5,6]. With the retirement of these workers, important knowledge for maintaining industrial competitiveness will leave the companies [7]. Therefore, companies increasingly depend on the knowledge, skills, and experience of their older workers. This will force companies to find ways to keep older workers employed for a longer period of time and also to retrain them to meet the challenges of the future through new technological developments. Thus, there is a need to reconsider current workforce training methods and to adapt them to the needs of an older workforce [4]. Although age management seems to be a big topic, Fornalczyk et al. [2] showed that knowledge about age management might be relatively weak among young workers.

Further trends to affect companies are so-called ‘Digitization’ and ‘Automation’. One of the most cited studies on the influence on jobs from these developments is the study by Frey and Osborne concerning the possible loss of jobs due to automation over the next twenty years in the US. As a consequence, 47 % of US workers are in great danger of being replaced by robots [8]. For Germany, Bonin et al. conducted a comparable study based on different types of activities in companies. As a result, only 12 % of tasks are in danger of being automated. Nevertheless, the content of a lot of tasks will change, and many activities will become more complex [9].

Related technologies, e.g., for Digitization and Cyber Physical Systems, will lead to significant economic and social changes and challenges [10]. Furthermore, the trend of an aging workforce is present. In combination this could be a big challenge for companies in the industrialized Western world. Therefore, we should take a closer look at the consequences. In order to describe and summarize these developments, in Germany the term ‘Industrie 4.0’ has become popular [11], so we will use this term hereafter.

2 Changes and Challenges in Organizations Posed by ‘Industrie 4.0’

In this section we describe the main technological trends of ‘Industrie 4.0’ and highlight some changes in the workplace of the future.

2.1 Digitization, Cyber Physical Systems, ‘Industrie 4.0’, and Big Data

Digitization and Cyber Physical Systems are well-known and often cited buzzwords in both academia and industry, as e.g. the related term Big Data [3]. Scientists and practitioners call these technological changes the “fourth industrial revolution” [4–7]. Some other authors claim that this development will change our lives more than any other developments of the past 40 years [8]. But what

do these buzzwords involve? According to Mauro et al. [3], Digitization is the *“process of converting continuous, analog information into discrete, digital and machine-readable format”*. Mayer-Schönberger and Cukier [9] define Digitization as *“making analog information readable by computers, which also makes it easier and cheaper to store and process”*. This development is driven by performance improvements of hardware, e.g., increased computer memory or increased packing density of microprocessors [10]. In this context also the term ‘Datafication’ occurs. Datafication describes the collection of all available data, their transformation into formats in order to quantify them and to generate new helpful information through the analysis of these data [9]. Pattern recognition for logistic systems based on huge data which are analyzed by multivariate statistics or predictive data analytics are examples of these new technical possibilities [12]. This leads to another frequently used term in this context: Big Data. It is a phenomenon related to the actual technological possibilities to generate, transform, analyze, and store big amounts of data. For instance, devices are able to steadily produce user data about behavioral patterns from their users [3].

These new opportunities make the implicit value of the information visible and help to improve decision processes in many areas or help to understand complex relationships. Analytical methods for transforming data into value are, e.g., Machine Learning, Natural Language Processing, and Pattern Recognition [9]. On the other hand concerns about the collection of these data amounts are obvious. One of the main challenges will be to protect the privacy and the personal data of the users. Furthermore, it has to be clarified who will have access to data amounts and who will control the data in order to avoid misconduct [13].

According to Hirsch-Kreinsen and ten Hompel [10], there are two phases of Digitization. In the first phase, the production, communication, and consumption of goods are based on digital processes which are intangible and themselves based on data and information. The second phase is the connection between physical things through Digitization. In the future, physical elements like machines, storages, or materials will be connected throughout the whole value chain. These connected systems are so called Cyber Physical Systems [11]. According to Lee [14], *“Cyber-Physical Systems (CPS) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa”* [14]. At best, Cyber Physical Systems collect data worldwide through sensor systems from other physical systems and actors and respond to them in order to optimize the whole system. Also humans are able to communicate via human-computer interfaces. Figure 1 shows a typical architecture of a Cyber Physical System which includes embedded systems, sensors, and electronic hardware and software. These systems communicate with other systems and humans and are often ‘Systems of Systems’. Together, they build superordinate systems [15].

The focus of this development is the creation of smart and agile factories which use the intelligence of the ‘Internet of Things’ for planning and execution of production [5, 7]. According to Xia et al. [17], Internet of Things *“refers to*

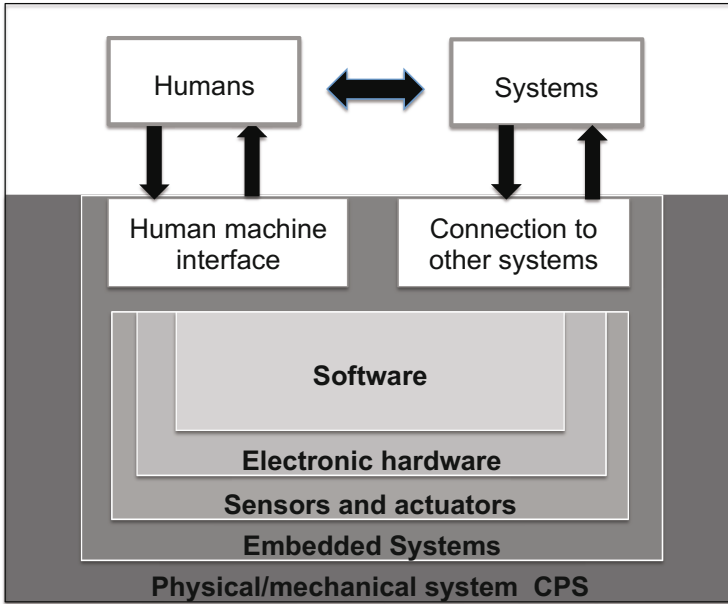


Fig. 1. Architecture of a Cyber Physical System (based on [8,16])

the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence". Schlick et al. [18] summarize the main criteria within production environments which will change in the next years: comprehensive networking, the use of Internet standards for communications, adaptive and agile production systems, smart objects, and a change in the role of the employee. One example of this change will be the opportunity to work from different locations all over the world, which means being independent from any particular location. In this context, it is not necessary to be at the manufacturing site, and it is possible to steer the production processes from outside the factory [19]. Important for the success of Cyber Physical Systems are their design and usage. Specific requirements arise in the fields of safety, usability, or trust in the system [20].

2.2 Changes in the Digital Workplace

To use the full potential of 'Industrie 4.0', organizations have to adapt to the new technological trends. Furthermore, they also have to find the balance between human and technological factors [21]. Dworschak and Zaiser [21] developed two scenarios to describe the extreme for organizing the work and technology within production companies of the future using Cyber Physical Systems (see Table 1). In the automation scenario, the technology guides the employees. Highly skilled employees are just necessary for installing the system, for implementing changes within the system, or for maintenance reasons. For the rest of the time, the system is running the production and the employees have a limited

decision-making power. Within the tool scenario, the employees steer the systems and have a higher degree of freedom in their decision making. As a result, there is a higher need for skilled employees in order to handle the complexity.

Table 1. Scenarios in CPS [21]

Automation scenario	Tool scenario
<ul style="list-style-type: none"> – CPS guide skilled workers – Work is determined by technology – Emergence of a skill gap: Skilled workers cannot develop/build up the know-how for dealing with problems anymore – High-skilled employees are responsible for installation, modification and maintenance of CPS 	<ul style="list-style-type: none"> – Skilled workers guide CPS – CPS supports the decision-making of skilled workers – A successful performance requires the provision of crucial information and suitable approaches of vocational education and training due to an increasing demand for IT, electronic and mechanical knowledge

Kölmel et al. [20] distinguish in this context between a technological and a contextual complexity (see Table 2). Within technological complexity, the employees are confronted with more complex interaction characteristics through Digitization, e.g. systems stability or interfaces [22]. Within contextual complexity, employees are confronted with a change of the task type. For instance, the tasks of the future will have a higher degree of freedom and less structure than before because simple tasks can be automated. As a result, the workforce will experience a change of role. That is, typical tasks will be the supervising of the production and the solving of unexpected problems. In these cases, the employee acts as a problem-solver [27]. Also Autor and Dorn [28] highlight the changes within human tasks in the future workplace. According to them, the content of the tasks will change more and more into collaboration, communication, or creative problem-solving.

Through Digitization, communication in the workplace has already been altered and might be altered even more in the future. Today, plenty of communication channels exist for communication between employees. Besides conventional face-to-face communication, digital communication channels are upcoming (or have already been established), such as email or platform communication [29,30]. In a study by Jäckel and Würfel [31], the majority of employees in an organization (71.5% to 83.8% of the respondents) state that their daily work routine depends strongly on email communication [31]. Moreover, platform communication has developed into an important communication channel for organizational communication within a few years [30]. Nonetheless, there is general agreement in the literature that traditional face-to-face communication is irreplaceable [32]. Face-to-face communication allows employees to clarify uncertainties and to give feedback immediately as well as to transfer non-verbal contents. In conversations, these non-verbal elements play an important role because they can modify or even change completely the verbal message.

Table 2. Technical and contextual complexity of CPS task characteristics from [23]; based on [21, 24–26]

	Technological complexity	Contextual complexity
Increasing challenges of CPS for the workforce	<ul style="list-style-type: none"> – Interaction characteristics of technology (interfaces, coordination, information exchange, systems stability) – System architecture and variety of different systems, agents, architectures, devices, or data-bases 	<ul style="list-style-type: none"> – Broader tasks, roles, or jobs – Open-ended and unstructured tasks (problems) – Less structure – Abstractness – Interpretation and use of information – Collaboration – Information overload

Digital communication channels, such as emails, are not or only to a limited extent able to transfer these important non-verbal elements [33].

Also, collaboration will change in the workplace of the future. One example of the change will be the freedom to work from different locations all over the world and to steer the machines simply via virtual dashboards [19, 34]. Furthermore, teams will use more technological tools for knowledge-sharing and collaborative problem-solving when they work in different offices or manufacturing sites [35]. As a result, they will need different skills for using these collaboration tools. For example, Slack could be used for communication in teams or Google Drive to create text documents in teams on a shared project [34]. Knowledge-sharing technologies could be a powerful tool for solving organizational problems. The use of such technologies is crucial for maintaining industrial competitiveness when knowledge gets lost with retiring employees [36–38]. The control of the physical world by the employees and also the interaction between employees will be changed by the introduction of Cyber Physical Systems [39]. That is, sensors will be able to measure all kinds of movements from the employees and these data can be shared worldwide in real time [15]. In the end, it will be a matter of employee acceptance [40]. Additionally, the need for new collaboration concepts will occur because more and more diverse groups from different cultural and professional backgrounds will be involved in interaction processes [41, 42] in order to solve problems collaboratively [43]. Schuh et al. [44] hypothesize that collaboration and its different dimensions (communication, cooperation, coordination) can be levers for ‘Industrie 4.0’ (see Table 3). Analogously, challenges within collaboration will occur, which will, in this case, be the organizational driver for meeting the requirements of technological developments. For cooperation, also concepts such as open production and open innovation will attract more attention [45]. Highly-skilled and specialized employees will collaborate in new organizational forms to find solutions for complex problems which could not be solved by algorithms or by one discipline alone [42]. As a result, companies have to develop competencies for their workforce with a stronger focus on technological change than before to prepare their employees for the digital age. Especially so-called soft skills, e.g. communication, problem-solving, or self-organization, will become more important [45, 46].

Table 3. Exemplified levers of ‘Industrie 4.0’ in the context of collaboration [33]

	Challenges of Collaboration	Levers of ‘Industrie 4.0’
Communication	Information sharing: Delay between obtaining and interpreting data	High resolution real-time communication for obtaining real-time data directly from the source and exactly when needed
	Sense-making: Inadequate knowledge regarding the global effects of local decisions	Large-scale simulation for assessing the impact of action alternatives in context of the chosen optimization criteria
Coordination	Resource-pooling: Allocation of best- fitting and available resources in production network	Self-forming system-of-systems for the ad-hoc linkage of dispersed resources
	Goal-congruence: Ensuring coherent goals in organizations	End-to-end standardization of reporting for instating consistent objectives throughout all hierarchies
Cooperation	Cross-functional activities: Interdivisional and cross-company cooperation	Virtual representations of physical objects for collaboration without the limitations of the physical world
	Empowerment: Implementing decentralized leadership and decision-making	Automatic control and pre-processing of data for unburdening employees from routine activities in order to put focus on policymaking

3 Characteristics of an Aging Workforce in a Digitized Workplace

Besides the changes in the workplace, also the workforce itself will be changing in the near future. Demographic changes, technology generations [47], and changes in generational values will shape the future work design.

3.1 How Aging Affects the Worker

Aging is a highly individual process, which predominantly strengthens preexisting differences in physical, psychological, and socio-economic backgrounds [48]. This means that inter-individual differences are stronger between older adults than between younger ones [49]. Still, there are systematic processes that do correlate with age. With increasing age, several changes occur in the human body and brain—some of them highly relevant for the working environment.

For example, sensory, senso-motoric, and cognitive capabilities degrade with age. They do so very individually and at different speeds, although some evidence hints at an interrelated degradation process [50,51]. As a result, employees work at different speeds. This means that older employees might be very individually affected by their aging process. Some might still be able to perform complex motoric tasks, while others may only perform well in tasks that require cognitive skills. Matching the task to the working is even more critical for older employees [52,53].

One must note, though, that these skills also still show high plasticity [54], meaning that it is necessary to use and foster the usage of these capabilities even when first signs of degradation occur, in order to prevent further loss.

Social interaction has been shown to prevent the loss of cognitive functions to some extent; Thus, keeping an employee integrated in a social environment such as work is also helpful for retaining capabilities [55].

When looking at job performance and age, no direct correlation can be found [56]. However, older employees statistically tend to be absent more often than younger ones. Older employees do not necessarily get sick more often, but they are often more affected by an illness and also more often struck by illnesses that lead to loss of working capabilities [56].

Older adults often apply compensatory action in order to counteract (e.g. writing things down, planning further ahead [56]) a slowdown in their information processing. This decrease of performance in information processing also shows itself when looking at the learning of new skills. People of higher age have a harder time learning new skills and processing information than younger adults do. Nevertheless, age has no effect on the act of forgetting. Older adults do not forget new knowledge more quickly than younger adults do [56].

3.2 Age as a Resource

One benefit of not forgetting more quickly than younger employees also yields the basis for a strong benefit of older employees. They excel at tasks where knowledge and experience are crucial. The cognitive and affective changes that occur after conducting a task several hundred times (also referred to as ‘expertise’) is beneficial for job performance. Older employees often have more declarative and procedural knowledge about tasks [56], which enhances their capabilities and their sense of security in performing a knowledge-intensive task.

In particular, skills that were ingrained during early adulthood and strengthened on the job [57] tend to show equally high performance in older adults as in younger ones, even when cognitive skills are required that show signs of degradation. It seems to be the case that older adults develop strategies to arrange mental tasks in order differently to optimize the task by using less cognitive load (e.g., looking further ahead, writing things down, pruning options through experience) [56].

When it comes to relatively simple tasks (tasks that require low cognitive load), age is not relevant, as for example primary memory is unaffected by age. Older and younger adults alike remember facts and information equally well [56]

and can apply them to simpler tasks. Furthermore, spontaneous imagination is unaffected by age. This means that tasks that involve creativity can very easily be conducted by older adults.

Overall, older adults show effects of domain specialization [56]. This means that older adults pick and choose where to apply cognitive effort which is more strictly based on experience. This leads to very high performance in areas of specialization and disinterest in other areas. Even when a high information processing speed is required, older adults may outperform younger adults when they can apply more specialized skills. If traversing an option space is necessary for a task (e.g. as in a game of chess), older adults tend to look as equally ahead as younger ones, but prune some options more quickly based on experience. This compensates for the slower information processing speed [56]. When motor-skills are needed, older adults may compensate for lower skill levels by looking further ahead and pre-planning their tasks [56]. This can also lead to higher performance in information-seeking tasks, even when spatial cognition shows signs of degradation [58].

The largest set of skills unaffected by age is the language domain. Older adults are as able to use language [59] as competently as younger ones are.

3.3 Possible Mitigation Strategies

Aging, on its own, is neither a pure benefit nor a pure drawback for individual employees or employers. It is how age and employee demographics are managed that defines organizational performance.

When adding digital media to the equation, the challenge seemingly becomes more simple: Use social media for knowledge exchange from old to young and use age-diverse teams for creativity tasks! However, especially the usage of such technology is different between technology generations [60]. Older users are accustomed to a more formal way of communicating in social media, while younger users tend to carry over their behavior from private social media to work-related settings. These etiquette mismatches may lead to an unfruitful use of digital media and a lack of motivation [61].

To enable successful knowledge transfer in the social media, one must identify benefits and barriers for the individual users and must regard user diversity (incl. age) respectfully [62]. If the individuality of users is disregarded, knowledge sharing might be reduced [63].

Beyond these technological means, it is necessary to adopt processes that ensure successful collaboration in heterogeneous teams. For example, mentoring programs can be used to transfer tacit knowledge from older employees to new hires. This serves a double purpose, as it utilizes capabilities (expertise in older adults and fast learning in younger adults) and ensures protection against crucial knowledge loss. Furthermore, this addresses the motivational differences of the two age groups. Older employees want to share their knowledge and put it to use, while younger employees want to invest in learning and invest in their careers [64].

Overall, it is necessary to value the differences present in the workforce and to match tasks to employees, while allowing growth and knowledge transfer. This can only be achieved by addressing training on the job to match individual preferences, capabilities and task requirements, and necessities.

4 Competence Management

Companies should address these changes in order to maintain competitiveness [6]. To coordinate their resources for training and development, they need tools to analyze the requirements of their technology, their organization, as well as their workforce. For this reason, we discuss competence management as the basis for the management of the aging workforce in the age of ‘Industrie 4.0’. There is no commonly accepted definition of the construct ‘competence’. Erpenbeck and von Rosenstiel [65] argue that competencies of an individual person are “*dispositions for self-organization activities*”. Unlike qualifications, competencies are not measurable with standardized tests. The results of the tests simply show knowledge, but not whether the knowledge could be applied in real-world situations and different contexts. However, competence is also the ability to convert knowledge and qualifications into situation-adequate action [65]. This is similar to the competence definition by Reinhardt and North [66]: “*Competence basically describes a relation between requirements placed on a person/group or self-created requirements and these persons’ skills and potentials to meet these requirements. Competencies are concretized at the moment knowledge is applied and become measurable in the achieved results of the actions.*”¹ It becomes clear that Reinhardt and North highlight, among other things, the application of knowledge and that competencies lead to a measurable use. Besides, there are not just individual competencies of a person. Wilkens et al. [67] underline that competence management should go far beyond pure personnel and educational management and cover the individual and organizational levels of competencies. This is in line with North et al. [68], who argue that individual competencies should be aligned with the technological requirements. Furthermore, competence management should be developed and matched with other organizational requirements, such as e.g. strategic and market decisions, organizational structure, processes, projects, or technologies. This so-called competence adaption can help to coordinate between technologies as organizational requirements and individual competencies [66]. According to Freiling [69], competence is an “*organizational, repeatable, learning-based and therefore non-random ability to sustain the coordinated deployment of assets and resources enabling the firm to reach and defend the state of competitiveness and to achieve the goals*”. So they highlight especially the importance of organizational competencies for the competitiveness of companies [69]. Mills et al. [70] emphasize in the context of organizational competencies the dynamic capabilities of an organization for the adaption of relevant competencies as a main competitive advantage. This concept is linked to resources which are important for change. Individual competencies are often divided into

¹ All direct quotes are translated from German by the authors, where applicable.

professional competencies (technological and, in part, methodological competencies), personal, and soft competencies (in part, methodological, self-management, and social competencies) to describe competencies. In addition, we adopt the approved approach dividing competencies into technical, methodological, social, and self-management competencies (see Fig. 2). Moreover, this classification is often used to develop competence models and frameworks within companies [46, 68, 71, 72].

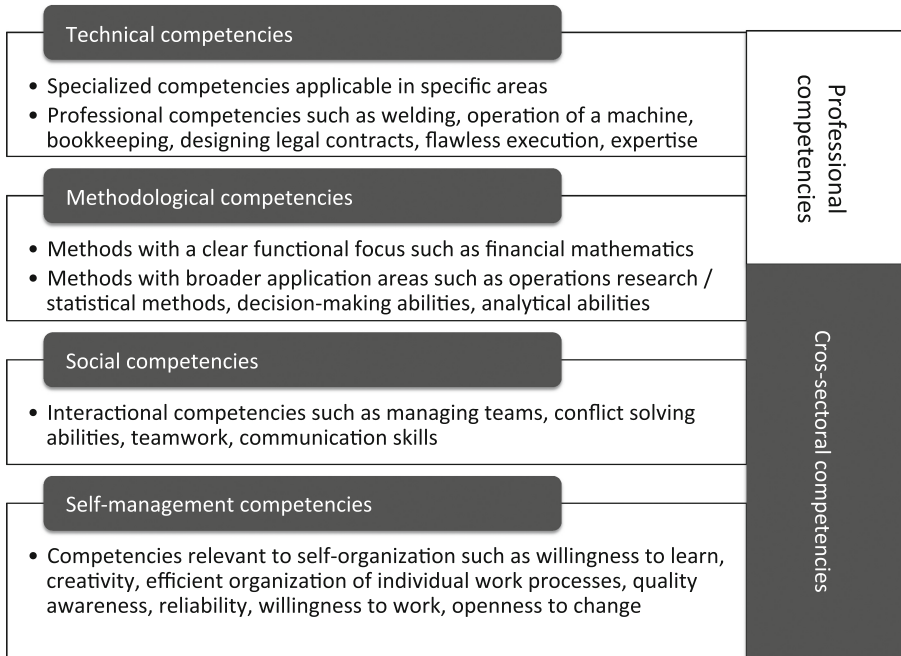


Fig. 2. Competence classification (based and extended) [23, 68, 71–73]

Having developed a competence model to describe the required competencies for the fulfillment of organizational requirements, it is important to use adequate measurement instruments for determining different levels of the respective competence. As a result, a clear classification of the requirements and the status quo of the individual employees should be possible and should constitute the basis for an analysis of the resulting gap. Unfortunately, no commonly accepted model for measuring competencies and their classification exists.

North et al. [68] propose a simple scale with different dimensions for the assessment (knowledge and experience, task complexity, autonomous work and self-management, and capability of reflection) and based on experience (Levels: Connoisseur, Experienced and Advanced, Expert) to describe the different levels of the respective competence. The experienced-based scale could be subdivided into six proficiency level (A1, A2, B1, B2, C1, C2), like the European

Language Portfolio. Letmathe and Schinner [23] proposed an extension to this scale. They divide the task complexity into two fields: technological complexity of the task and contextual complexity of the task. Furthermore, they divide the newly introduced category ‘contextual complexity of the task’ into three already mentioned dimensions which are relevant for ‘Industrie 4.0’: structure of the task, content of the task, and interaction and collaboration. Examples of methods for measuring competencies and classifying employees on these scales are: self-assessments, external assessments, paper-pencil tests, work-samples, or holistic approaches which combine e.g. self-assessments and external assessments in order to capture all dimensions of competencies [74].

5 Description of Further Research Fields for Managing the Aging Workforce and ‘Industrie 4.0’

In an ‘Industrie 4.0’ setting under the influence of quickly fluctuating staff, training routine tasks and building up and retaining of standardized competencies will not be enough. Employees will have to intervene if problems with a higher complexity in uncertain situation occur and, because of this, more different sets of skills will need to be developed and trained to ensure sufficient adaptivity in the workforce within a digitized world. Especially personal and social competencies will receive more attention than before. In this context, communication and communication skills as well as collaboration with experts will become more and more important for solving challenges in future scenarios with high technical challenges for employees resulting from Digitization and an aging workforce. In consequence, we highlight four research areas for supporting the aging workforce in the age of Digitization: coordination-oriented competence control systems, changes in communication and behavior, the path from technology acceptance to transformation acceptance, and teamwork as a lever for collaboration (see Fig. 3).

5.1 Competence Control Systems

Companies have to analyze their current organizational competence portfolio as well as the individual competencies of their aging employees in order to make these transparent for an efficient coordination of their resources. Coordination-oriented competence control systems which help to steer the adaption between technologies as well as organizational requirements and individual competencies are a key instrument for maintaining industrial competitiveness. Furthermore, they can help to keep the employability of the aging workforce despite extensive automation through Cyber Physical Systems and robots. The aim should be to coordinate the human resources of companies at the best place—for the employee as well as for the organization. For this reason, it is necessary to know the experience-based professional competencies as well as the methodological, social, and self-management competencies of the employees. Competence control systems can map the special experiences as well the capabilities of the aging

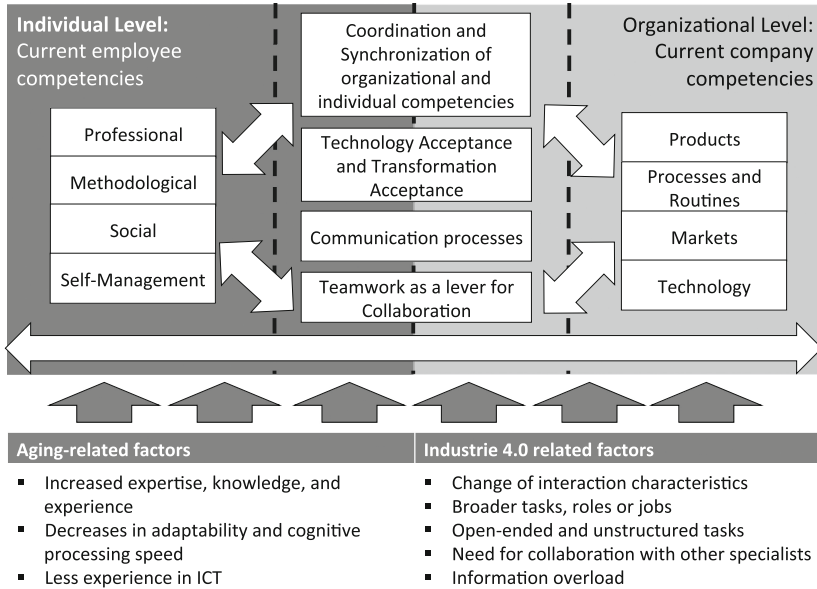


Fig. 3. Ensuring employability of the aging workforce in the age of ‘Industrie 4.0’

workforce in order to use them most effectively for the organization as well to prevent them from engaging in tasks which are too challenging. Companies also should pay attention to the individual characteristics of their employees for the design of effective learning processes [75] in order to build competencies. With the identification of the competence gap between technological as well as organizational requirements it is possible to develop competence-oriented tailored learning programs for synchronizing organizational and individual competencies. Organizational competencies are often induced by the product portfolio, processes, markets, or used technology. For the transfer to competencies on the level of the individual, it is necessary to develop measurement instruments for the description and analysis of organizational and technological requirements as well as individual competencies. These measurement instruments should include measurement scales which also describe the special experiences of the aging workforce as well as the technological requirements which arise through ‘Industrie 4.0’ developments. However, human development through competence management is limited. In this case, communications as well as collaboration with experts and other coworkers can help older employees to solve problems and to remain competitive.

5.2 Teamwork as a Lever for Collaboration

More important than the individual for success is the complete team and team organization requires increased communication. Pentland [76] found that the

style of communication explains about 50% of the variation in a team's successes. Good communication outperformed individual factors such as intelligence, personality, and talent combined. Yet it is not only about the amount of communication, but also the quality of communication. Three qualities influence team performance: energy, engagement, and exploration. Pentland even goes as far as to derive an ideal team-player. The "charismatic connector" democratically invests his time in connecting with everyone on a high energy basis, yet listens more than talks. Besides these quality characteristics, five patterns of good communication were established: (1) Everyone talks and listens in roughly equally much. (2) Members face each other and conduct energetic conversations. (3) Members connect with each other, not just the team leader. (4) Members carry on side conversations within the team. (5) Members break out of the team to explore the outside and bring information back. Making these competencies measurable, and thus teachable, requires sociometric methodology [76,77] and graph-based visualization.

When establishing success in groups, groups as a whole show different properties [78]. Successful groups show indicators of groupthink orientation, which reveals itself as risk-taking behavior, cohesion, and strongly opinionated leaders. Unsuccessful teams on the contrary show signs of vigilance (e.g., internal debate to the point of factionalism).

In times when innovations are being made by small teams within larger company settings, innovators are needed. One personality trait beneficial to entrepreneurial thinking is tolerance for ambiguity [79,80]. Situations in the fast-changing digitized world require from leaders that they adapt quickly to new contexts and that they tolerate that outcomes will not always be either black or white. Sometimes, requirements established carefully can become obsolete during the production process, as change appears quickly in a globalized, digitally interconnected world. But not only the leaders have to deal with a changing world; employees will have to adapt to change as well. When changes of strategy and procedures are conducted, it pays off to integrate the employees into the process [81].

Both the requirements from communication and organizational transformation call for shallower hierarchies, a new form of trust and sense-making between leadership and employees, and a development of competencies required in these new settings. A deeper understanding of these aspects of collaboration is needed.

5.3 Changes in Communication and Behavior

As mentioned above, organizational communication behavior has changed, as more and more digital communication channels are being used nowadays. Nonetheless, in the literature it is argued that conventional face-to-face communication cannot be completely replaced by digital communication channels [32]. During face-to-face communication, also non-verbal elements are transferred, which express the relationship between the conversation partners [82]. If there is a lack of attention to this element, communication might be distracted [33]. Therefore, attention must be paid to how to define and to teach management

competencies in order to overcome this lack of experience with digital communication channels. Additionally, one should not implement upcoming digital communication channels without investigating the (dis-)advantages of their implementation for the organization [83]. More research is needed for evaluating situations where innovative communication channels might be useful for the organization and situations where conventional communication channels should remain unchanged.

Another change in the field of communication incurred by 'Industrie 4.0' is that more and more data are being stored and becoming available for decision support systems. Employees have to decide within a complex environment of, e.g. time stress, interruptions, and digital requirements, which information to select and to employ as a decision basis. Further research should investigate the competencies needed for dealing with huge information amounts in decision-making situations.

5.4 From Technology Acceptance to Transformation Acceptance

When bringing together modern individual competence management and demographically aware human-resource management (see Fig. 3), use of technology-mitigated processes is inevitable. Typically, technology acceptance modeling is used to predict the future success of such systems. Technology acceptance models typically include individual user factors, such as age, gender, prior experience, technical self-efficacy, as well as social factors (e.g., social norms, influence, etc.), and technological factors (e.g., ease of use, usefulness, etc.) [84,85]. And even the influence of cultural effects has been investigated [86,87]. However, emergent effects of change processes in teams and the willingness to adapt under rapidly changing conditions have not been integrated into the models yet. If we see technology as an integrative part of a socio-technical system, not only does the technology need acceptance [88]. To ensure that the efforts in communication, cooperation, collaboration, and coordination are fruitful, it is necessary to understand acceptance of transformation processes from a holistic point of view. For this purpose, it is important to address these questions interdisciplinarily. The utilization of results from these four research areas will ultimately help with successfully managing the challenges posed by 'Industrie 4.0'.

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