The 'new' older worker

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J. Sharit. The 'new' older worker. Gerontechnology 2020;19(2):102-114; https://doi.org/10.4017/gt.2020.19.2.003.00 **Background** The expectation is that in the future there will be a greater number of older workers and that more of them will want to extend their work lives, whether due to financial need or because of the value they place on being engaged in the workforce. **Research aim** For many reasons, there is a strong possibility that older individuals may be viewed as less desirable for employment. The goal of this paper is to demonstrate ways in which older people can prove valuable in current and future job roles. **Methods** Four topics will be examined from the standpoint of their implications for the employability of older workers: the use of exoskeletons for aiding the work activities of older workers; the growing importance of teams in organizations; the importance of experienced older workers as repositories of institutional knowledge; and the role of older workers within the context of growing automation in the workplace. **Results** Challenges remain in determining the usability of exoskeletons for older adults within the context of work operations. While concerns exist employing older people in teams or collaborative arrangements with automation, the unique attributes of older workers may also make them valuable assets in these roles. Older workers are essential to organizations for documenting and transferring critical organizational knowledge. **Conclusions** The skills, abilities, and preferences within growing cohorts of older workers should be capable of being accommodated within organizations, thereby supporting older worker, organizational, and societal goals.

Keywords: Older workers, ageism myths, exoskeletons, institutional knowledge, teamwork, automation

Introduction

The topic of older workers is multifaceted and being continuously shaped by the confluence of economic, political, social, cultural, and technological considerations. The Center for Research and Education on Aging and Technology Enhancement (CREATE; www.create-center.org) (Czaja, Sharit, Charness, Fisk, & Rogers, 2001), in its commitment to addressing issues encompassing this topic, has sponsored two specialized conferences on aging and work, first in 2008 and again in 2018, which served as forerunners, respectively, to two edited books (Czaja & Sharit, 2009; Czaja, Sharit, & James, 2019).

In the relatively close span of time between these two conferences one trend has remained clear: in the future, we should expect not only a greater number of older workers but also that a greater percentage of them will want to work longer. This circumstance is partly due to the aging of the population—the number of Americans aged 65 and older is projected to nearly double from 52 million in 2018 to 95 million by 2060, and the 65-and-older age group's share of the total population will rise from 16 percent to 23 percent (Population Reference Bureau, 2019). Correspondingly, by 2024 the growth rate of workers aged 65-74 and 75+ is expected to be about 55% and 86%, respectively, far greater than the 5% growth rate for the overall labor force (Toossi & Torpey, 2017). Other industrialized nations are seeing similar trends; in Japan and South Korea, the workforce is aging even faster (Jong-Wha, 2018). *Figure 1*, which is based on a 2015 Gallup survey, shows that 37% of nonretired Americans expect to retire after age 65, up from 31% in 2009 and nearly three times the 14% who indicated this intention in 1995. Although 32% expect to retire before age 65, which is the first time this figure has topped 30% since 2009, it is still down considerably from 49% in 1995.

Why people want to work longer

There are many reasons why workers today desire to work or earn income into their 70s and even 80s. The corporate shift from defined-benefit retirement plans, which guaranteed a steady income following retirement, to defined-contribution plans, which shifts the responsibility of saving on workers, has left many older people unable to leave work for financial reasons (Purtill, 2018). Many people in the U.S. cannot get by with Social Security alone (Cahill & Quinn, 2019), especially for those who claim their benefits before they turn 70. A much more volatile econom-

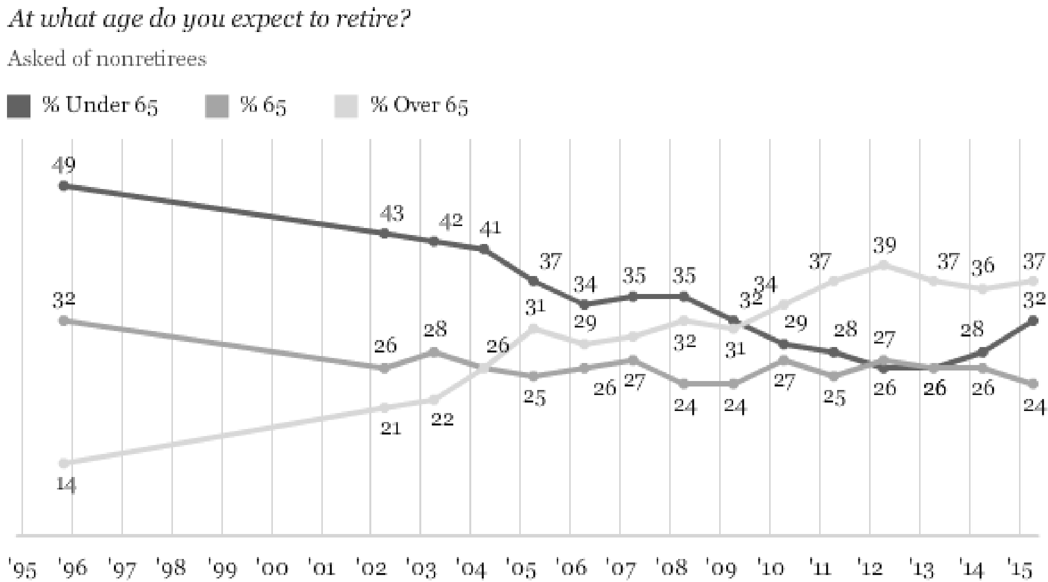

Figure 1. Expectations regarding when people believe they will retire. (Source: Rifkin, 2015)

ic climate, due in part to the dynamics of a global economy, can further contribute to apprehension regarding leaving the workforce. For many women who deferred work opportunities or careers to raise children, they may only just be beginning to make an impact in their profession in their later fifties. Another factor is the increased life expectancy across the industrialized world, which may translate into the belief that one has more years of healthy life than ever before (Purtill, 2018). Somewhat ironically, longer life expectancies have also given rise to the need for more involvement by middle-aged and older workers in some form of caregiving (Schulz, 2019), and thus the possible need for maintaining income later in their lives to sustain other family members.

People may also want to work longer or be reluctant to completely abandon their jobs because of the value they place on the intellectual and social stimulation that their jobs provide them or, in the same vein, the psychological importance of feeling relevant (Kanfer & Fletcher, 2019). As noted by Fasbender, Wang, Voltmer, and Deller (2015), the motivation to remain engaged in work may be important to older workers irrespective of their financial situations as it provides a sense of efficacy and identity. The desire for and importance of socialization (Henderson, 2019) and engagement in productive work activities for preserving mental as well as physical health has also been emphasized in various media and has contributed to making older workers more wary of abrupt transitions from work to retirement and interested in at least seeking various types of bridge arrangements. That may mean part-time work, to allow for more free time with family or friends, less time at a job that's become more physically taxing, flexibility to accommodate other lifestyle changes or even contractual or freelance work. Various forms of technology have also lessened the burden of commuting, which for many older workers may have contributed to leaving the workforce.

For the many older individuals who want to continue working, whether in their current fields or in new ones, the opportunities for employment will depend, as always, on the economic climate, although in some cases the education and skill levels of these individuals will be a factor, implying that job-training programs for seniors will be needed and should be made available (Heidkamp & Van Horn, 2019). According to a recent report (Brandon, 2019), these future jobs include college instructors, administrative assistant roles, managerial positions, nurses and home health aides, real estate agents, sales jobs, driver jobs (at least in the near future), providing child care, financial managers and accountant services, writing jobs, and engineering-related positions. Even in the industrial work sector, where the conventional stereotype is that as workers age they become increasingly incapable of carrying out the requisite manual work activities, there are various light industrial jobs whose energy expenditure and musculoskeletal demands are commensurate with the abilities of many older adults, and furthermore, offer the opportunity to exercise the kinds of cognitive skills that are embraced by and are well within the capabilities of older workers (Sharit, 2019). These jobs include automotive assembly, consumer electronic manufacturing, and food production, and many of these types of jobs are likely to remain in high demand.

Organizational and societal perspectives

Extending the work lives of their employees or hiring older workers may also benefit organizations. Research from the Milken Institute's Center for the Future of Aging and the Stanford Center on Longevity (Carstensen & Irving, 2016) found that older employees took fewer sick days, showed stronger problem-solving skills, and were more likely to be highly satisfied at work than their younger colleagues. Also, there is evidence that age diversity within teams is positively related to performance when teams are engaged in complex decision-making tasks (SHRM Foundation, 2019). The current emphasis in many organizations on autonomy and self-regulating workgroups (e.g., teams)—cornerstones of socio-technical system design principles (Sharit, 2019)—is also consistent with the characterization of many older workers as having greater institutional knowledge and experience and better mediation and communication skills, which make them more likely to be stabilizing influences in various tasks. Organizations are also placing greater value on older workers' institutional knowledge and expertise, which is becoming a scarcer resource in today's employment climate where younger workers choose to remain with organizations for much shorter periods and instead seek freelance or more variable work experiences. This knowledge also positions older workers to serve as mentors to younger employees (Hanson & Lesser, 2009).

From a societal standpoint, having more older workers also reduces the strain on publicly financed retirement and health benefit programs and compensates for the fact that there are relatively fewer younger adults who work and pay taxes. As older adults continue to work and remain as taxpayers they are more likely to continue to be engaged in the economy as consumers, which benefits everyone. The benefits to the economy of having healthier, productive people in older cohorts were noted by Irving (2018), who indicated that by 2020 the spending power of those aged 60 and older is expected to be $15 trillion annually.

One consideration that may make older workers less attractive to employers is that employers may prefer 'digital natives'—younger workers who have grown up with technology and will be able to use new systems with ease—as opposed to 'digital immigrants', who usually comprise older workers who came of age before the internet (Beier, Torres, & Beal, 2019), and who are assumed to be slow to adapt to technology, reluctant to learn, and costly to train. It can be argued, however, that as older adults are becoming more educated, healthier, and active, and generally receptive to using new technologies (as corroborated by many CREATE studies), this tendency among employers is proving less valid (Czaja, 2019). Adopting e-learning and other technology-based worker training approaches that are tailored for older adults (Czaja & Sharit, 2012), with some reliance as well on younger colleagues for supporting training (Hanson & Lesser, 2009), can also mitigate many of these concerns.

Most importantly, to promote the employability of older workers it is necessary to create and maintain a culture that dispels (ageism) myths (Froidevaux, Alterman, & Wang, 2019), specifically, that older workers are technophobic, uninterested in learning, unable to learn new skills, unreliable, worse performers than younger workers, and more prone to absenteeism and turnover. Several companies seem committed to countering these myths and, in recognizing the unique contributions of these workers, have gone to considerable lengths to accommodate them. Some classic case studies include BMW (Champion, 2009), who retooled their production facility by installing ergonomic seating and softer floors, enlarging the type on the computers, and supplying more supportive work boots—changes which were accompanied by increased productivity and decreased absenteeism. Another example is Alexandria Industries in Minnesota (DePass, 2017), where manufacturers have installed ergonomic seats in trucks and redesigned assembly lines to avoid repetitive motion injuries.

Overview of the paper

In this paper, consistent with the underlying theme of CREATE, the focus will be on a subset of aging and work issues that are linked to technology, and which can have important implications for future tasks and the employability of older workers. First, the potential role of exoskeletons for aiding the manual work activities of older workers will be examined. Next, the growing importance of teams in organizations and the value to organizations of having older workers on these teams will be discussed. The importance of experienced older workers as repositories of institutional knowledge and their roles in disseminating and preserving this knowledge within organizations will then be reviewed. Finally, the role of older workers within the context of growing automation in the workplace will be considered. Ultimately, the objective is to better understand how the skills, abilities, and preferences of older workers can be reconciled with the current and future objectives and practices of organizations to ensure the successful attainment of older worker, organizational, and societal goals.

Exoskeletons

Despite the large variability among older adults in physical capabilities, physical decline is a hallmark of aging. Significant declines with aging can

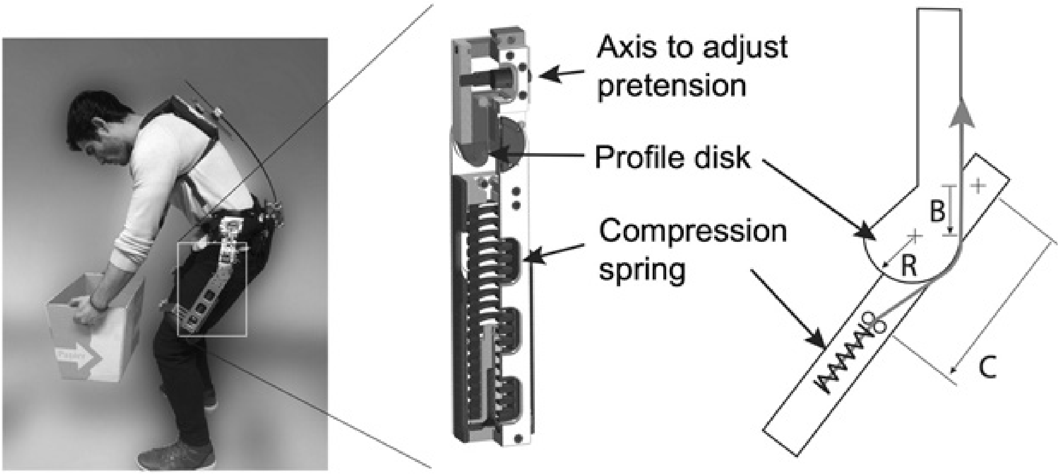

Figure 2. Picture of the spring-based, passive hip actuator on the SPEXOR exoskeleton prototype (Source: Näf et al., 2018; written informed consent was obtained from the participant by Naf et al. to publish this picture). The right side illustrates the coil spring, which is compressed during hip flexion. (Source: Toxiri et al., 2019.)

occur in the capacity for energy expenditure, the capability for generating muscular forces needed for dynamic lifting and carrying tasks, sustaining static loads, flexibility in movement (which can be critical for avoiding injury), joint mobility, and more generally, in resilience to activities that demand fatigue-inducing postures or repetitive motions (Kramarow, Lentzer, Rooks, Weeks, & Saydah, 1999; Kroemer, 2007, 2009).

Exoskeletons are wearable devices which are capable of offering people additional support and strength through the generation of forces and torques on one or more of their joints to assist them in the execution of physical activities. Thus, they can potentially benefit older workers who want to (or must) perform manual work activities at moderate to heavy intensities, especially those activities that cannot easily be automated. However, to understand the potential benefit of exoskeletons for older workers it is essential that these devices be examined more carefully; as noted by Toxiri et al. (2019), while exoskeletons may reduce the physical workload on workers, they may be impractical or infeasible in some circumstances.

Figure 3. Picture of the parallel-elastic actuator on the Robo-Mate active trunk. The spring is implemented with a bungee cord and acts in parallel to a gear motor, hidden by the black cover in this picture. (Source: Toxiri, Calanca, Ortiz, Fiorini, & Caldwell, 2018.)

Generally, an exoskeleton generates assistive forces or torques employing either passive components (e.g., compact rotational springs or elastic bands), which can store or dissipate energy provided by the user (*Figure 2*), or powered actuators, (e.g., electric motors), which can introduce additional energy from external sources (e.g., batteries) on-demand (*Figure 3*). Another distinction between existing exoskeletons is the direction of the assistive forces (e.g., of forces contributing to back extension or hip extension), which are either parallel or perpendicular to the body segments. In assisting with low-back extension, a force parallel to the spine also contributes to unwanted compression on the intervertebral discs in the lower back, whereas a perpendicular force does not have this drawback (Abdoli-E, Stevenson, Reid, & Bryant, 2007). The occurrence of parallel forces is characteristic of soft exoskeletons, also known as exosuits, which do not have rigid structures. Instead, they consist of garments worn on body segments (adjacent to the joint that is assisted) that are used to pull two body segments together, typically via a cable or (elastic) straps or bands that are situated close to the user's body (Lamers, Yang, & Zelik, 2017).

In contrast, rigid exoskeletons are constructed with rigid frames that connect actuators to garments worn by the user and tend to use space lateral to the user's body. These rigid frames run in parallel with body segments and apply forces perpendicular to these segments (e.g., the trunk and thighs). Most rigid exoskeletons support back extension by pulling the upper torso backwards via backpack-like shoulder straps. Exoskeletons can also be constructed that combine soft and rigid components, and thus may be able to exploit the advantages of each of these types of exoskeletons. For example, carbon fiber rods can be used which act both as force generators as well as structures to transfer forces between the user's pelvis and torso (Toxiri et al, 2019).

Despite the advantages related to spinal loading associated with rigid components in exoskeletons, the coupling of these devices with human joints can produce kinematic incompatibility arising from misalignment between the artificial (exoskeleton) and corresponding anatomical joints, and subsequently forces that can contribute to discomfort. Designs of articulated components that minimize these effects are thus critical. Another issue with exoskeletons comprised of rigid structures is that the assistive forces exerted on the torso and legs can result in a reaction force on the user's pelvis, lower back, or abdomen (Lamers et al., 2017).

Active exoskeletons also require some type of control strategy that can adapt the device's assistive action into user intent. Examples of control strategies include using measurements from the device or the environment; information such as electromyography that is captured from the user; or a control interface that requires explicit input from the user (Chen, Grazi, Lanotte, Vitiello, & Crea, 2018; Toxiri et al., 2019), all of which carry their own set of problems. Fully passive exoskeletons have no means of autonomous adaptation to user intent during operation, although some may have manual switches or regulators to enable adjustment of their characteristics.

Toxiri et al. (2019) suggest using passive exoskeletons for tasks requiring light to moderate assistance, such as holding stooped postures or handling light loads, and active exoskeletons to assist with demanding and dynamic tasks, such as handling heavier loads. Although soft back-support exoskeletons are currently not as common as rigid ones, they offer the advantage of possibly being more lightweight and capable of being worn underneath working clothes, and by offering less hindrance to a movement they may be more acceptable to older workers. However, such exoskeletons, as emphasized earlier, also provide lesser reductions of biomechanical joint loading.

Challenges for Older Workers in Using Exoskeletons

Despite the various opportunities for application of exoskeletons, for example, in industry, rehabilitation, the military, and in supporting older adults in activities of daily living (Shore, Power, De Eyton, & O'Sullivan, 2018), user perspectives of exoskeleton technology have been minimal. In fact, Hill et al. (2017) noted that there is no 'literary' evidence of user involvement in the development or design of exoskeletons. It is thus not surprising, especially given the numerous design considerations associated with exoskeletons, that usability studies (e.g., Power, Hartigan, Ortiz, & O'Sullivan, 2019) and development of standards and regulations to support the use of exoskeletons in the workplace (Lowe, Billotte, & Peterson, 2019) are only just beginning to emerge. Assessing exoskeleton usability, however, may be especially challenging for older users as there is a need to pay particular attention to issues such as minimizing the risk of falls (when wearing an exoskeleton), comfort in use, and ease of putting on and taking off the device (Wolff, Parker, Borisoff, Mortenson, & Mattie, 2014).

In this regard, both soft (passive) and rigid (active) exoskeletons may be problematic for older workers. While soft exoskeletons can contribute to unwanted compression to what already may be fragile intervertebral discs, rigid exoskeletons can contribute to discomfort due to misalignment between artificial and corresponding anatomical joints. Moreover, the actuators (e.g., motors or springs) of both active and passive exoskeletons tend to be relatively large, which can increase their lateral footprint and possibly more adversely restrict the older user's ability to maneuver the workplace environment effectively. With active exoskeletons, increasing their power generally makes their mass heavier and their control more challenging, which may be a serious constraint for many older users in terms of comfort, safety, and efficiency, and thus a factor in their acceptance of these devices.

Minimizing unnecessary constraints and discomfort is likely to be especially important for older exoskeleton users, suggesting the need for designs that do not hinder movement in different planes or induce feelings of restriction. Thus, careful consideration needs to be given to design details which ensure: attachments (e.g., braces) which connect exoskeleton elements to corresponding human limbs distribute forces in a manner that minimizes discomfort (e.g., pressure on the chest and thighs); materials do not promote excessive heat production during sustained use; the exoskeleton can be put on and removed quickly, easily, and autonomously; manual adjustments to accommodate users of different body dimensions can be made easily; control strategies implemented through sensor information can distinguish between different activities as a basis for the exoskeleton's provision of assistance; the sensors are not obtrusive but rather integrated into the exoskeleton; and the user's perception of the instantiation of control strategies is smooth and intuitive and does not induce excessive cognitive load.

Examples of the use of exoskeletons for work operations

To date, several experimental and less formal field studies involving the use of exoskeletons in work settings have been initiated. For example, Ford is investing in the (non-powered) EksoVest, a passive exoskeleton that supports factory employees' upper bodies to ease strain when lifting and performing overhead tasks, which some Ford employees, including older employees, perform up to 4,600 times per day (Chow 2017; Hard, 2017). The EksoVest is currently being tested in two U.S. factories as part of a pilot program, with plans to expand the program to European and South American sites. Lowe's, which is the second-largest chain of home improvement stores in the U.S., is exploring the use of an exoskeleton that combines soft and rigid components in a pilot program at one of its stores (Murphy, 2017). This exoskeleton is intended to help workers offset some of the strain on their muscles and joints as they pick up and move heavy and awkward items (e.g., bags of cement or paint buckets). Another example of the usefulness of exoskeletons for work operations comes from a Japanese hauling company (Tatsumi Shokai Logistics). This company has invested in an exoskeleton that assists many of their older employees in their frequent loading, unloading, carrying, and bending tasks (Financial Tribune, 2016), thereby enabling them to keep working as efficiently as they can for as long as possible. However, much work remains ahead before principles and guidelines can be established that are directed at making exoskeleton designs compatible with older workers' needs, preferences, and work operations, as well as for educating organizations on issues that may need to be considered for the realization of these devices for their older workers.

Teamwork and older workers

Organizations rely on teams of workers to solve difficult problems or carry out challenging projects (Smyer & Pitt-Catsouphes, 2009), and this tendency is likely to become even more pronounced with the availability of powerful technologies for facilitating communication and the pooling of team members' knowledge bases. Assuming that older adults are generally more mature and possess better mediation and communication skills than younger adults, and are also in a better position to leverage domain expertise to exploit the collaborative benefits of teamwork, it would appear that the aging of the workforce could turn out to be a boon for many organizations that rely on teams. However, there are various aspects to teamwork that could argue both for and against its suitability for older workers. For example, increasingly prevalent teamwork applications such as Slack (that centralize chat, group, and private discussion channels, and allow controlled information sharing) require technological literacy. This could not only influence the selection of workers who will comprise a team, but also the attitudes of younger team members who may believe that their older counterparts are not adequately skilled.

Technology skills supporting teamwork activities may become even more vital in virtual teams, which consist of individuals who work across time, space, and organizational boundaries with links dependent on communication technology. Workers comprising virtual teams demand personal flexibility and tend to be more productive due to less commuting and travel time, factors which may be appealing to older workers. However, virtual team members also demand increasing technological sophistication (Ferrazi, 2014), especially in the face of growing inter-organizational cooperation. They must also be adaptive and resilient to a changing variety of tasks and responsibilities, and because virtual teams will be expected to be able to repeatedly change membership without losing productivity there will be less time available for team members to learn how to work together. The ability to adapt to such changes, however, is not an attribute most managers typically associate with older workers (Sharit, Czaja, Hernandez, & Nair, 2009);

According to Hedge, Borman, & Lammlein (2006) even conventional teamwork demands may be stressful to older workers, with age-related cognitive processing declines (Park et al., 2002) a possible factor contributing to this situation. In a scheme developed by Kozlowski and Ilgen (2006), team processes were classified into three major categories: cognitive, affective/motivational, and behavioral. Using this scheme, Smyer and Pitt-Catsouphes (2009) highlighted key themes to illustrate how age might affect team functioning. Of note here is the cognitive category, which considers a team member's team mental models and transactive memory. Team mental models refer to representations of knowledge that are common to the team members, whereas transactive memory refers to knowledge regarding how information is distributed among the team members (i.e., knowledge of who knows what). Taken together, these cognitive structures enable team members to organize and acquire information necessary to anticipate and execute actions, but may be adversely impacted by normal age-related declines in cognitive processing and thereby place older workers at a disadvantage, especially in team leadership roles.

A more recent perspective on teamwork and older workers was considered by Paoletti, Gilberto, Beier, & Salas (2019), who cite evidence that teams with a higher average age report better production quality, fewer sick occasions, and lower team burnout (Gellert & Kuipers, 2008), as well as evidence which indicated no relationship between team age diversity and performance outcomes (Joshi & Roh, 2009). They also call attention to the construct 'need for cognition', defined as the extent to which the team enjoys being thoughtful versus taking cognitive short-cuts, which could be critical for team performance, and refer to evidence that high need for cognition benefits team performance in age-diverse teams whereas low need for cognition has the opposite effect. These effects may be mediated partly through team communication: teams with a higher need for cognition tend to communicate more (Kearney, Gebert, & Voelpel, 2009). Together with evidence that older workers are perceived by managers as having better oral (and written) communication skills than younger workers (Sharit et al., 2009), these findings suggest that including older individuals on teams could prove beneficial to organizations by promoting a culture of thinking through and discussing problems and tasks, rather than one that welcomes swifter processing of information.

Age-diverse teams, however, may harbor underlying concerns by the younger team members regarding older team members' commitment to team success and their ability to make positive contributions to team performance. For example, a common negative aging stereotype is that learning ability declines with aging, a perceived shortcoming that Paoletti et al. (2019) note is regarded within an organizational context as a deficiency in the ability for older workers to develop new skills. However, as pointed out by Charness (2019), the knowledge that generally increases as we age and effective training and well-designed technology tools can counter these concerns. Nonetheless, it may be worthwhile for organizations that rely on age-diverse teams to more formally consider ways to prepare older workers for the dynamics and unique challenges that they may confront as members of such teams.

Perhaps most importantly, older workers are more likely to have accumulated significant work experiences that uniquely shape their job-related knowledge and skills and have a greater understanding about what constitutes successful work behaviors, which they can use to improve team functioning. Thus, they can draw from their existing knowledge (e.g., of successful organizational strategies) and utilize existing mental models to position themselves in ways that lead to improved team coordination and reduced team stress, and thereby greater team success. Indeed, it is the unique organizational knowledge, including technical and strategic knowledge, and experience of older workers that make them invaluable assets to many organizations, especially in climates of shorter tenures among younger workers, and opens the door for the possibility of exploiting new work opportunities for older workers as discussed in the next section.

Documenting and transferring institutional knowledge from older workers

The unique institutional knowledge and expertise possessed by many experienced older workers are essential for enabling organizations to remain productive (Beier et al., 2019). It is thus no surprise that the immense value of older workers' expertise has management professionals concerned about the 'lost knowledge' that would result from the mass-exodus of retirement-aged employees (Hirsch, 2017; Smyer & Pitt-Catsouphes, 2009). The Society of Human Resource Management (SHRM) has urged HR professionals and managers to commit resources to retain seasoned employees to avert having a significant amount of technical job knowledge leaving with retirees, and for more emphasis to be placed on strategies that facilitate knowledge transfer from older, experienced employees to younger, less experienced employees (Beier et al., 2019; Paullin, 2014). This should also benefit older workers as it provides a unique opportunity for them to remain productively engaged—that is, to have a sense of purpose at work (Calvo et al., 2009) by 'mattering' to the organization.

There are several types of knowledge that an employee may possess within an organization (Froidevaux et al., 2019; Peterson & Spiker, 2005) which can become lost when that employee leaves the organization. These include explicit knowledge, which is the knowledge that is easily expressed such as a simple rule governing operations or transactions; tacit knowledge, which is the knowledge that is known by the individual but may be difficult to express, for example, knowledge underlying highly learned procedural skills such as controlling an industrial process; intellectual knowledge, which is knowledge encompassing more refined facts and concepts about various kinds of subject matter; and social knowledge, which is knowledge about interpersonal relationships and access to social networks, for example, knowledge about dealing with difficult people or handling difficult situations.

Mentoring

Perhaps the most fundamental and familiar approach to implementing a knowledge transfer process is through mentoring of younger employees (Hanson & Lesser, 2009; Froidevaux et al., 2019). SHRM considers mentoring an efficient way to transfer tacit organizational knowledge between employees and cites practices embraced by NASA who uses a phased retirement plan (Miller, 2017) that is coupled with on-the-job mentoring and information exchange between the outgoing employee and their protégés (Hirsch, 2017). Moreover, in a study by Taneva, Arnold, and Nicolson (2016), the opportunity to mentor and transfer knowledge was considered by older workers as the desired form of organizational support, presumably by enabling them to perceive value and meaningfulness in their work. This type of knowledge transfer by older workers, perhaps as mediated through technologies and strategies discussed in the ensuing sections, can also be part of a reciprocal cycle whereby younger workers, in turn, provide technical knowledge and support (in a relaxed informal environment) that can help their older counterparts attain work-related goals (Hanson & Lesser, 2009). The intergenerational exchanges of information underlying mentoring-based knowledge transfer can also serve to promote lesser prejudice among younger employees toward working with older workers; this, in turn, could prompt a positive cycle of knowledge transfer and thus a continuation of the knowledge-transfer process (Froidevaux et al., 2019).

It should be noted, however, that only those positions within an organization that have the potential to impact organizational performance should be considered for this (or any) knowledge transfer process. Moreover, the decision of where the knowledge transfer is most needed within an organization will likely depend on various factors including the knowledge level of the individual, the degree to which work operations are anticipated to become automated, and whether a suitable successor is available.

Task and cognitive task analysis to support knowledge transfer

Task analysis (TA) is a method for providing a breakdown of the physical and cognitive activities by an individual or team that are necessary for meeting task or operational goals (Hollnagel, 2006), and thus can be used to inform less knowledgeable employees about aspects of the job that may be difficult to capture and communicate in other knowledge transfer processes (e.g., mentoring). For example, using TA the skilled or experienced employee may be able to point out where, when, and why the worker may be receiving information that is not sufficiently salient, clear, complete, and interpretable; at which work steps the system operation would allow errors from previous task steps to be corrected or recovered; what knowledge is needed to perform the requisite operations in various situations; or if there are ergonomic issues which could interfere with the successful execution of tasks.

In a type of TA method referred to as hierarchical task analysis (HTA), operational goals are examined in terms of their subordinate goals and their accompanying plans; these plans, in turn, define the sequence of steps needed to accomplish each of those goals (Shepherd, 2000). When used in conjunction with a modified hazard analysis and quality improvement technique known as failure modes and effects analysis, HTA is capable of more concisely identifying the challenges associated with the various task elements (Fisk, Rogers, Charness, Czaja, & Sharit, 2009; Sharit, Hernandez, Nair, Kuhn, & Czaja, 2011).

Cognitive task analysis (CTA), a variant of TA, was developed for obtaining more insight into the knowledge and thought processes (and thus tacit knowledge) that underlie observable task performance. An example of a CTA method is ACTA (Applied Cognitive Task Analysis) developed by Militello and Hutton (1998). ACTA relies on subject-matter experts (SMEs) and consists of three complementary techniques: the task diagram (the SME highlights the difficult cognitive aspects of the task); the knowledge audit (the SME describes how domain knowledge or skill is used in actual experiences); and the simulation interview (a challenging scenario is presented to the SME who, in response to probes of events within the scenario, provides situation assessments, actions, critical cues, and potential errors). In using a method such as ACTA as a knowledge transfer tool within an organization, experienced older workers can assume the role of SMEs.

TA and CTA can be intensive to perform as these methods may rely on the complementary application of various data collection methods (e.g., videos, audiotapes, verbal protocols or 'think aloud' techniques, and simulation exercises). However, they can expose the kinds of tacit knowledge details that more conventional approaches to knowledge transfer are incapable of identifying and thus serve as vehicles for explicit documentation of deeper institutional knowledge and expertise.

Knowledge engineering

Knowledge engineering refers to a set of methods usually directed at obtaining explicit and intellectual knowledge from one or more experts, as well as representing and validating that knowledge, to build artificial (software) systems, notably expert systems (ESs), that emulate the reasoning and behavior of human experts in a given field of expertise (Kendal & Creen, 2007; Lehto, Boose, Sharit, & Salvendy, 1992). ESs can span different degrees of complexity, from tasks based on relatively straightforward chaining of rules to those based on more complex knowledge structures that may allow for deeper reasoning. They can also provide answers in a consulting type of role, for example, in aiding workers' fault diagnosis activities. Toward this end, experienced older workers can serve important roles in organizations not only as possessors of the necessary knowledge base needed for programmers to construct ESs, but also to verify the results of these programs.

Another knowledge-based system that can be used for capturing institutional knowledge has been referred to as case-based reasoning (Kolodner, 1993). In this approach, new problems are solved based on computer storage of information associated with similar past problems or 'cases' which are 'matched' to the new problems. Using their accumulated knowledge and experience, older workers can serve important roles in helping programmers within organizations develop case-based systems through their understanding of the relevant information associated with past problems, and their ability to recognize the similarities in patterns between newer and older problem contexts.

Simulation of work processes

Simulations allow capturing the deeper contexts—including relevant perceptual and cognitive elements—associated with work scenarios, and consequently are the reason why they are the basis for training workers to perform an array of complex operations across a wide variety of circumstances. Simulations of operational scenarios can be instantiated in many ways: high-fidelity simulators can be built to mimic real-world physical and cognitive operational environments (e.g., flight or nuclear power plant simulators); simpler computer-graphic driven simulations can be used to train workers to control various industrial processes; and video-based demonstrations of interactions between people, such as healthcare or financial workers, can be used to illustrate proper communication or interpersonal behaviors (i.e., social knowledge).

Older workers can make use of their experiences and knowledge when collaborating with technology-skilled employees within their organization to build or verify these types of simulations. Furthermore, because these simulations embody important knowledge, institutional knowledge and expertise can be captured, preserved, and even used as a basis for training. For example, in hospital settings, older healthcare workers can help shape the development of videos designed to simulate various activities, such as handoffs between medical providers across shifts. In this case, the simulations can focus on the implications of insufficient or inappropriate querying of the provider who is being relieved, the implications of interruptions occurring during this process, and other scenarios that can have important patient safety implications. In the domain of financial services, various concerns raised by clients along with appropriate responses, both to the client's problem and behaviors, can be simulated. Ultimately, these simulations can become a core element of an organization's institutional knowledge, and because they provide a visual reconstruction of scenarios of different degrees of breadth and depth, they are much more efficient and instructive than traditional knowledge transfer processes, such as procedure manuals (Froidevaux et al., 2019), for future employees to learn from.

Older worker collaboration with automation

Technologies such as advanced sensors, robotic devices, and artificial (machine) intelligence provide the potential for many work activities to be automated. Although the proportion of occupations that can be fully automated currently is relatively small, it has been estimated that about 60% of all occupations have at least 30% of their activities that are technically automatable, and in two decades 50% of all of today's work activities may be able to be automated (Beier et al., 2019; Manyika, 2017).

While predictions regarding the extent and pace of advances in artificial intelligence, as well as the impact of such advances on the work sector, are subject to some degree of speculation, in the upcoming decades technological innovations will likely redefine many jobs performed by people. Organizations will need to adapt by allocating functions to their workers and intelligent machines in ways that exploit the unique capabilities of people and automation and that also maximize their joint information processing, decision making, and control behaviors (Hollnagel & Woods, 2005; Sharit, 1997). These kinds of partnerships imply the possible need for new collaborative communication protocols to ensure that people and intelligent machines are aware of and understand each other's intentions and actions. In cases where people and automation are not explicitly working jointly but the worker is primarily responsible for monitoring the automation, requisite knowledge regarding when and how to intervene and possibly assume control from automation may be needed.

An argument against employing older workers in such collaborative arrangements is that these work roles imply large demands on cognitive abilities known to exhibit age-related declines (Park et al., 2002). Specifically, these cognitive abilities would be needed to support information-processing activities directed at tracking the system's operations and status; monitoring what the automation is doing and planning to do; building and 'running' mental models to explain the behaviors of these intelligent agents; and coordinating one's assessments with those of intelligent machine partners.

However, there is also the possibility of benefits associated with integrating older workers with automation. The proliferation of automation in many jobs may increase the potential for generating more meaningful work by replacing routine or repetitive tasks, which could allow workers to focus on those tasks which utilize creative and affective processes (Manyika, 2017). For example, in industrial process control operations experienced older workers may be able to place more emphasis on situational awareness to anticipate future problems, and on ways to improve system processes, often by working jointly with intelligent systems to augment their knowledge and experience-based capabilities (Sharit, 2019). Another important consideration is that for familiar work activities, and particularly those for which the older worker has an extensive knowledge base, declines in cognitive abilities may be compensated by job-related or domain knowledge that the older worker has available.

Warr (1994, 2000) has suggested that for different types of jobs, age and experience could interact in unique ways that could explain or predict why one generally does not find negative age-performance relationships. Whereas placing older workers in jobs that require very rapid processing of continuously changing information is likely to result in age-related performance declines, in the absence of severe or even moderate time pressure, and where the knowledge-based judgment or skilled activities are required, these negative relationships should not be apparent (Warr, 1994).

Generally, as more procedural or predictable tasks become handled by smart machines, humans will become more responsible for tasks that require perceptual/attention skills in monitoring work processes; diagnostic/inferential skills for interpreting intelligent machine-based information; judgement and decision-making skills for handling exceptions and anomalies; and communication skills for coordination in distributed decision environments (Sharit, 2019). These activities entail the skills and abilities that knowledgeable and experienced older workers should possess. Experienced older workers who are part of the transition of work process changes moving in the direction of automation may even be more advantageous to the organization than younger, more technically savvy workers as the older worker may have a better understanding of what the automation needs to accomplish and better instincts regarding the reliability and effectiveness of the automation.

Conclusions

The aging of the population is fueling the increasing percentage of older workers comprising the workforce, and economic, societal, and other forces are dictating changes in attitudes that are driving a larger percentage of these older workers to extend their work lives. At the same time, organizations are placing greater emphasis on teamwork, preserving institutional knowledge, and artificial intelligence systems, which are contributing to changes in the very nature of human work and organizational enterprises. As a consequence, many older workers may have to redefine themselves. While older workers will likely always face some degree of opposition from employers who embrace stereotypical myths which, in the context of the workplace, translate into workers who are less physically capable, motivated, productive, healthy, trainable, adaptable to workplace changes, willing to collaborate with younger team members, and skilled with technology, as argued in this paper the changes gradually unfolding in workplaces and organizations may also open the door to new opportunities for many of these workers. Not only may they be able to exploit technology that enables them to perform demanding physical activities later into their work lives, but their experience, knowledge, and dispositions may make them valuable assets in organizations as critical players on intergenerational teams, possessors and conveyers of explicit, tacit, intellectual, and social institutional knowledge that, through various technologies, can be captured and transferred, and even have advantages under certain conditions when working jointly with automation. Time will tell if and how these 'new' older worker roles become established in organizations and the extent to which stereotypical myths that might be embraced by employers serve to oppose the transition of older workers into these new roles.

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