© *Academy of Management Annals*
2021, Vol. 15, No. 2, 406–454.
https://doi.org/10.5465/annals.2019.0057

CAN HIGH-QUALITY JOBS HELP WORKERS LEARN NEW TRICKS? A MULTIDISCIPLINARY REVIEW OF WORK DESIGN FOR COGNITION

SHARON K. PARKER
Curtin University

M.K. WARD
Curtin University

GWENITH G. FISHER
Colorado State University

Understanding whether and how work design affects human cognition is important because: (a) cognition is necessary for job performance, (b) digital technologies increase the need for cognition, and (c) it is vital to maintain cognitive functioning in the mature workforce. We synthesize research from work design, human factors, learning, occupational health, and lifespan perspectives. Defining cognition in terms of both knowledge and cognitive processes or fluid abilities, we show that five types of work characteristics (job complexity, job autonomy, relational work design, job feedback, and psychosocial demands) affect employees' cognition via multiple pathways. In the short-to-medium term, we identify three cognitively enriching pathways (opportunity for use of cognition, accelerated knowledge acquisition, motivated exploratory learning) and two cognitively harmful pathways (strain-impaired cognition, depleted cognitive capacity). We also identify three longer-term pathways (cognitive preservation, accumulated knowledge, and ill-health impairment). Based on the emerging evidence for the role of work design in promoting cognition, we propose an integrative model suggesting that the short-to-medium term processes between work design and cognition accumulate to affect longer-term cognitive outcomes, such as the prevention of cognitive decline as one ages. We also identify further directions for research and methodological improvements.

"You can teach an old dog new tricks, and this old dog wants to learn."

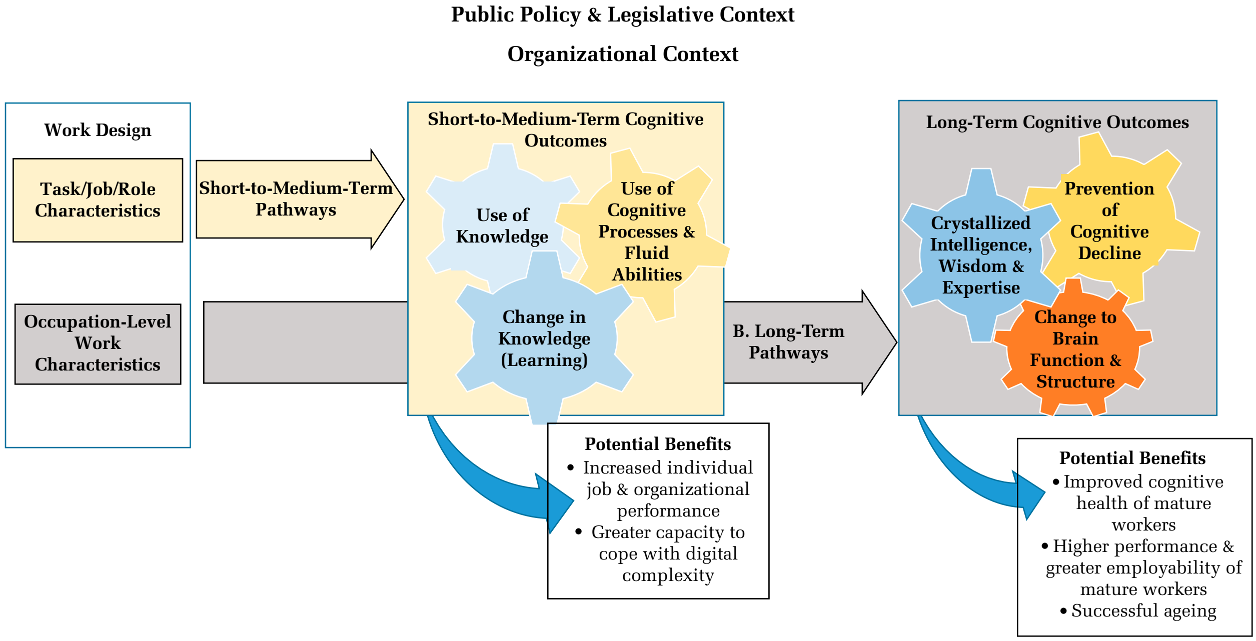
—Thomas P. "Tip" O'Neill, Jr.

Using ratings from experts, Miner (2003) identified work design theories as among the most scientifically valid and practically useful theories in the field of management. Drawing on the classic "job characteristic model" (Hackman & Oldham, 1976), there is a strong theoretical underpinning as to what constitutes well-designed work. There is also clear evidence that psychologically well-designed work—for example, work that offers job autonomy and variety—enhances employee motivation, performance, health, and well-being (for a review of over 5,000 articles, see Parker, Morgeson, & Johns, 2017). Yet, we believe that there is untapped potential for work design to promote cognition: good work design might be a crucial part of an enriching work environment that helps "old dogs learn new tricks" and preserves cognitive functioning as workers age.

Our aim in this review is to investigate the link between work design and cognition. We bring together diverse perspectives from multiple disciplines, using work design theory as the integrating theory. We thus go beyond existing reviews on the effect of work and cognition that have been "within discipline" (e.g., Fisher, Chaffee, Tetrick, Davalos, & Potter,

The first and second author's contribution to this research was supported by Australian Research Council grant FL160100033. The third author's contribution was supported by the Mountain and Plains Education and Research Center (T42OH009229), funded by the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, USA. The content is the sole responsibility of the authors and does not necessarily represent the official views of the Centers for Disease Control and Prevention or the U.S. Department ofHealth and Human Services.

FIGURE 1
Overview of Work–Design Cognition Links in the Short to Medium Term, and in the Long Term, and Their Potential Benefits



2017; Nexø, Meng, & Borg, 2016; Parker, 2017; Wielenga-Meijer, Taris, Kompier, & Wigboldus, 2010). Combining perspectives allows the identification of missing aspects in each theoretical field, and hence develops a more comprehensive picture. Our guiding framework for the review is shown in Figure 1. As depicted, we are concerned with how work design can affect cognition via two distinct yet connected temporal processes: (a) a short- to medium-term process, and (b) a long-term process.

In a "short- to medium-term process" (Figure 1, yellow shading), well-designed tasks, jobs, or roles give workers the opportunity to use their knowledge and cognitive processes or fluid abilities, and also facilitate change in knowledge (e.g., learning, the development of expertise). As summarized in Figure 1, such short- to medium-term cognitive processes are crucial in organizations for two main reasons. First, cognition is a key input to individual-level performance, which in aggregate affects organizational performance. Thus, cognition is one of the most important "capacity" drivers of effective individual work performance (Carpini, Parker, & Griffin, 2017). Across many different types of jobs, core task performance is predicted by job knowledge (Schmitt, Cortina, Ingerick, & Wiechmann, 2003) as well as cognitive processes (Hunter, 1986; Schmidt & Hunter, 2004). These cognitive variables also predict "adaptive performance," or coping with and responding well to change (Jundt, Shoss, & Huang, 2015), and "proactive performance," such as initiating new work methods (Frese & Fay, 2001). The link between cognition and work performance has been elucidated in a meta-analysis that found that those who engage in informal learning at work have on average 32% higher performance than those who do not (Cerasoli, Alliger, Donsbach, Mathieu, Tannenbaum, & Orvis, 2018). At the organizational level, performance is derived from members collectively learning how to respond to dynamic changes to the environment, which requires "continuously enhancing and upgrading the capabilities of individuals so as to enable them to create new value" (Bartlett & Ghoshal, 1998: 33).

Second, when work design promotes short- to medium-term cognitive outcomes, a further benefit is that this helps to build a workforce able to deal with increasingly complex work as a result of technological change. The past two decades have seen a rapid increase in the proportion of knowledge work occupations and this trend is expected to continue (Holford, 2019; Jacobs, 2017). The rapid pace of digitalization, such as the increasing use of artificial intelligence, means that individuals will need to be able to quickly adapt by learning new skills and new roles (Dellot & Wallace-Stephens, 2017).

Many new roles will be more cognitively demanding as manual and routine tasks are automated (Frey & Osborne, 2017). Thus, the changing world of work means that questions about how to foster cognition and accelerate learning will increase in relevance into the future (Parker & Grote, 2019), as indeed has been shown by large-scale government programs focused on this aim, such as the UK's Foresight project on "mental capital" (U.K. Government Office for Science, 2008).

There is also emerging evidence for a "longer-term cognitive process" (gray shading in Figure 1). As we shall see, over longer time periods, occupational work characteristics can help to prevent a decline in cognitive processes and fluid abilities, with some evidence of underpinning changes in brain neurology. This process is important, given the global trend toward people working until older ages due to increased longevity and changes in economic policies about later pensions to sustain economic growth (Fisher, Chaffee, & Sonnega, 2016). Having workers stay in the workforce longer means attending to the question of how to maintain the cognitive performance of mature workers (Fisher et al., 2016), especially given that some cognitive functions decline with age. Enhancing cognitive health among mature workers has benefits for not only for the retention, employability, and performance of mature workers, but also for these individuals' successful aging more broadly.

Our guiding framework (Figure 1) indicates that work design and these processes sit within an organizational context, and are shaped by elements within that context (such as leadership styles, organizational structure, culture, and strategy). Likewise, organizations—and, in turn, work design—are embedded within a wider public policy and legislative environment that affect employment law and retirement timing. Importantly, one implication of this nesting of work design within wider contexts is that work design can be changed—not only through processes like job crafting and local work redesign, but also through altering the organizational or public policy or legislative context. We return to this point later, when we discuss the practical implications of the present research.

In this article, we describe the key concepts in this review (cognition and work design), as well as our deliberately broad approach for capturing the diverse literature on this topic. We then review the findings, synthesized across the diverse perspectives in the literature. Finally, we propose an integrating model, identify key insights, and propose future research directions.

KEY CONCEPTS AND REVIEW APPROACH

We sought to identify all papers that consider or investigate the link between work design and cognition, with both of these elements considered broadly, as we elaborate next.

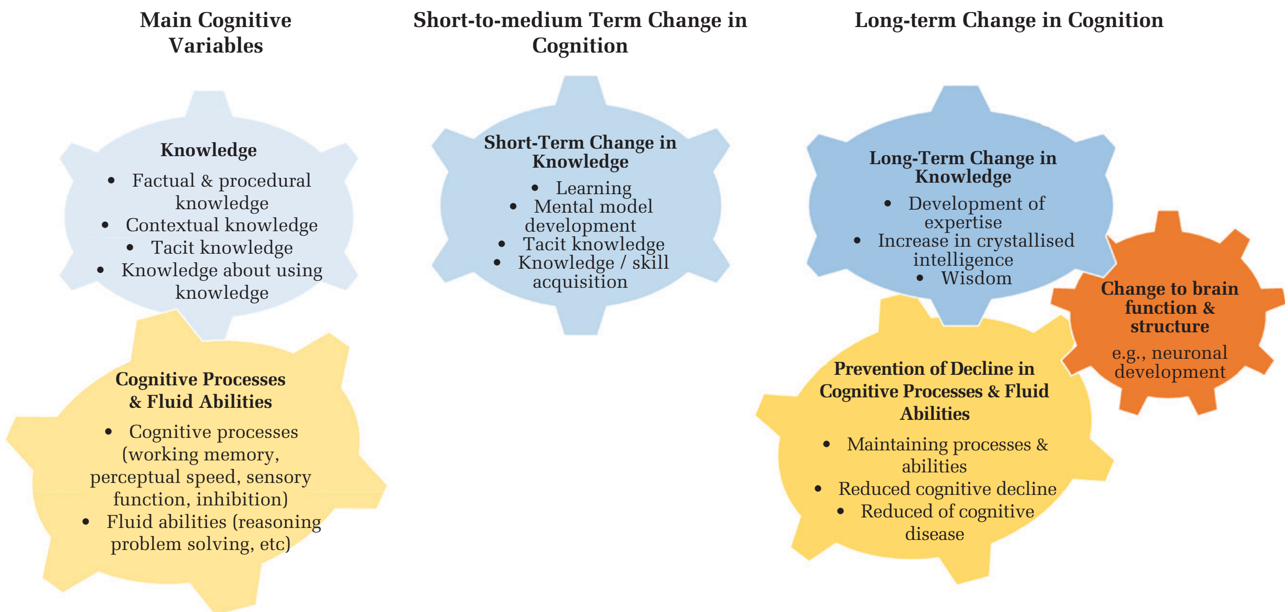
Cognition

In cognitive psychology (Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010), there are two key categories of cognitive variables: "knowledge" (mental representations) and "cognitive processes and fluid abilities" (mental operations that transform and manipulate representations). This distinction between knowledge and cognitive processes or fluid abilities underpins the distinction between crystallized and fluid intelligence (Horn & Cattell, 1967), and between cognitive pragmatics and cognitive mechanics (Baltes, 1987). Figure 2 shows our focus on these elements of cognition, as well as on change in these aspects of cognition.

More specifically, "knowledge" includes aspects such as declarative or factual knowledge (knowing *that*), procedural knowledge (knowing *how*), and tacit knowledge (non-codified, informally obtained knowledge). These forms of knowledge can change in short time frames as people learn new concepts and develop new skills. Knowledge typically also increases over the life span based on experience and accumulated expertise, with some people developing wisdom (e.g., the capacity to make sound judgments). As an example of knowledge in the workplace, a salesperson can apply their knowledge of a product's features to sell products to clients. With repeated opportunity, the salesperson will learn more about the product and the clients, developing expertise and more nuanced mental models. Over many years, their accumulated knowledge makes them an unusually effective and wise judge of challenging clients and complex product issues.

In contrast, "cognitive processes and fluid abilities" are capabilities that allow us to solve problems and engage in other such mental operations. Four key cognitive processes (Park, 2000) are perceptual speed, working memory, inhibitory function, and sensory function. "Perceptual speed" is relevant for all cognitive tasks, not just timed tasks, because it affects how we acquire and process information (Salthouse, 1996); however, processing speed is especially important for complex tasks (Park, 2000). "Working memory" is "the amount of online cognitive resources available at any given moment to process information" (Park, 2000: 10). "Inhibition"

FIGURE 2
Overview of Cognitive Variables of Interest in This Article



Note: We also depict changes in brain structure and function to show where they fit, although not a direct focus in this review.

refers to how well individuals filter out irrelevant information that can distract from attending to relevant information. "Sensory function" includes visual and auditory acuity, which affects cognitive functioning (Lindenberger & Baltes, 1994). Such processes underpin fluid cognitive abilities (Horn & Cattell, 1967), such as one's ability to solve novel problems, to make spatial judgments, and to engage in reasoning. Cognitive processes and fluid abilities tend to be invariant across context and stable over time, except for a decline as people age. Thus, in performing their work, the salesperson referred to above will use various cognitive processes, such as working memory, and fluid abilities, such as reasoning. Although the salesperson's opportunity to apply these cognitive processes will vary over time, their underlying abilities will tend to stay stable, with perhaps gradual decline in some abilities as they age. Neurologically, such changes can be reflected in changes to brain structure (e.g., gray-matter volumes) and function (e.g., cortex activation patterns) (Lövdén et al., 2010).

Work Design

"Work design" is about the nature of people's tasks, activities, relationships, and responsibilities at work, and how these are structured and organized (Parker, 2014). In the case of the salesperson, the work might involve highly routine tasks with a tight script for talking to clients, or it might involve complex tasks with high autonomy over what the person says to clients. These jobs vary in their work design, which, in turn, is likely to affect the salesperson's job satisfaction, job strain, performance, and—our focus here—their knowledge and cognitive processes or abilities.

Early interest in work design was captured by the classic job characteristics model (Hackman & Oldham, 1976), which posited that five key work characteristics (job autonomy, task variety, task identity, task significance, and job feedback) generate internal motivational states (experienced responsibility, a sense of meaning, and the knowledge of one's results) that in turn lead to greater employee job satisfaction, performance, and attendance. A related early theory is the demand–control model (Karasek, 1979), which proposed that each of low job autonomy and high demands cause psychological strain, yet high demands are acceptable for strain if autonomy is also high. In such an active job, employees can use their autonomy to manage the ensuing demands, thereby reducing their negative effects on strain and health.

Beyond these traditional theories, there have been expansions in the work characteristics considered to be important. These extensions include ensuring the core motivational work characteristics in the job characteristics model capture all of the key aspects of work design (e.g., Morgeson & Campion, 2002; Parker & Wall, 1998) and, similarly, extending "control" in the demand–control model to cover a broader set of "resources" (the job demands–resources model [Demerouti, Bakker, Nachreiner, & Schaufeli, 2001]). Job demands have also been argued to include both challenge demands and hindrance demands (Crawford, LePine, & Rich, 2010). A relational work design perspective focuses on the social aspects of work, such as social support and interdependence (Grant, 2007; Grant & Parker, 2009). Work design studies also sometimes consider physical work characteristics (e.g., noise levels), although these aspects are out of the scope of the current review.

Work design theory has also expanded to consider outcomes beyond motivation and strain or health. Especially relevant here, researchers have advanced a learning and development approach, arguing that key work characteristics foster knowledge acquisition and learning (Frese & Zapf, 1994; Parker, 2014; Taris & Feij, 2004; Wall, Jackson, & Davids, 1992). Although several earlier theories inform this perspective, most relevant is Karasek and Theorell's (1990) "active learning hypothesis," which proposed that active jobs (high in autonomy and demands) enable and motivate learning, mastery, and skill development. In a systematic review of this research, Wielenga-Meijer et al. (2010) concluded there to be overall positive effects of work design on learning, and Parker (2017) summarized this evidence in a "work design growth model."

Here, we extend and develop this work design–cognition perspective, which comes from particular disciplines (especially those of applied or organizational psychology, organizational behavior, management, and occupational health); it focuses on a particular level (the job level), and it focuses on a particular time frame (usually months or a few years). However, there is a larger literature to consider. At one extreme, some studies focus on momentary neurological and cognitive effects of task attributes; at the other extreme, lifespan studies link work to cognition over very long periods and operationalize work design at the level of an occupation. Synthesizing across these and other perspectives offers a more complete picture of how work design affects cognition.

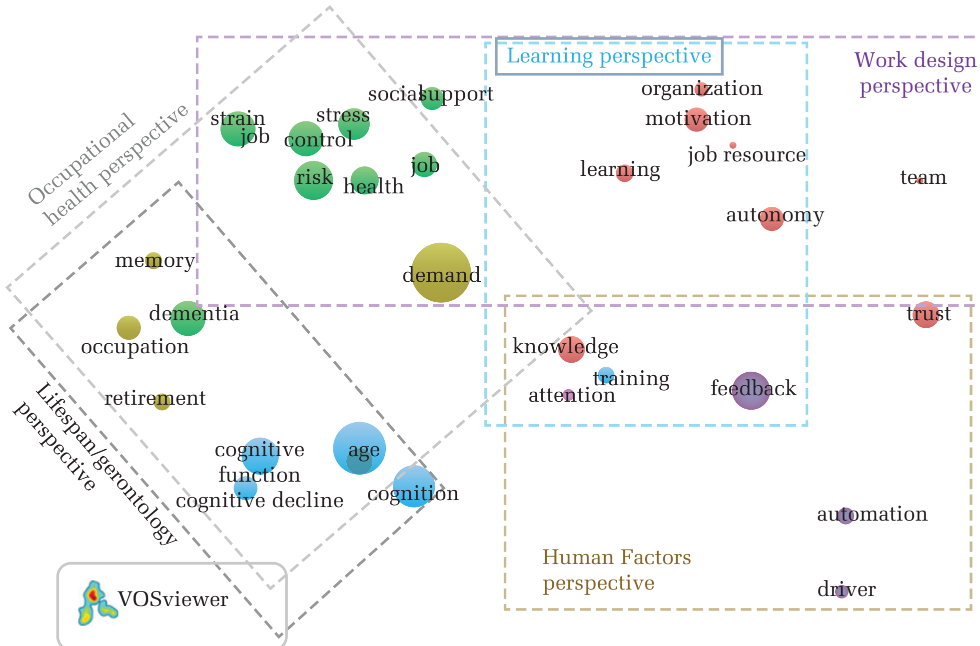
Review Approach and Perspectives That Link Work Design with Cognition

To capture these multiple and diverse perspectives on work design and cognition, we adopted a broad approach to our review. After some initial backward referencing from published reviews to get a sense of the literatures, we conducted a systematic review using Web of Science and articles in top-ranked journals across multiple disciplines (neuroscience, public health, aging, experimental psychology, gerontology, management, and more) to find publications that included both key work design variables and cognition, with both concepts defined broadly (see Appendix A for more details of this process, as well as search terms). We identified approximately 180 articles from this process. We then subjected the articles that we obtained to a scientific bibliometric mapping process (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011; Ding & Yang, 2020), with the goal being to visually depict the diverse literatures on the topic of work design and cognition (rather than to conduct an in-depth analysis of the detailed topic clusters). We used the *VOSviewer* software (van Eck & Waltman, 2010) to analyze and visually depict the data (Figure 3). The program calculates the co-occurrence of scientific terms in abstracts, and the strength of association between terms is used as input for the map. The map visualizes the strengths of associations between terms such that relatedness among terms is indicated by position and relative distance (van Eck & Waltman, 2010, 2014; see Appendix A for more details). Clusters were identified using the VOSviewer program; terms that are more similar to each other (and different from the terms of another cluster) are grouped together into a common color (see van Eck & Waltman, 2010, 2014, for a more detailed explanation of VOSviewer parameters). We briefly summarize the diverse perspectives, and provide example studies, in Appendix S1 (online supplementary resource).

Three main clusters emerged from the VOSviewer analysis, and, after discussion, we then indicated the five perspectives included in this interdisciplinary review onto the scientific map. This overlay shows the level of overlap among the five perspectives. The first perspective is a "work design perspective," which we discussed above. As shown in Figure 3 (red–green cluster, purple square), this perspective focuses particularly on job resources such as job autonomy, and the effects on outcomes like motivation and learning, as well as topics such as team work.

The work design perspective is spatially close to a "learning perspective" (Figure 3, mostly red cluster, aqua square, with terms such as "feedback," "learning," "knowledge," and "training"), which reflects the fact that learning studies come from similar disciplines. Example topics in this perspective

FIGURE 3
Findings from a VOSviewer Analysis and How the Identified Topics Map onto Diverse Perspectives in the Literature



include leadership development (DeRue & Wellman, 2009); effect of feedback on learning and performance (Kluger & DeNisi, 1996); informal learning (Cerasoli et al., 2018); training motivation (Colquitt, LePine, & Noe, 2000), knowledge sharing (Wang & Noe, 2010); team or organizational learning (Kozlowski, Chao, & Jensen, 2010); and learning engagement (Noe, Tews, & Michel, 2017). Some learning theories focus on learning as a way to narrow discrepancies between goals and performance, such as goal setting theory (Locke & Latham, 1990), social cognitive theory (Bandura, 1989), and expectancy theory (Vroom, 1964). Other theories focus on how intrinsic motivation fosters one's desire to learn (Colarelli, Dean, & Konstans, 1987), as well as learning-oriented behaviors such persistence in the face of setbacks (Debowski, Wood, & Bandura, 2001). Usually, in these studies, work design is one of many contextual antecedents rather than being the focus. The indicators of cognition tend to be knowledge or change in knowledge. This is a large literature, so we discuss this perspective mostly with reference to reviews and meta-analyses.

The "human factors perspective" is next closest to the work design perspective (gold square, mostly red cluster, terms such as "feedback," "automation," and "driver"), and includes disciplines like human factors, cognitive ergonomics, and neuro-ergonomics. These studies mostly focus at the task level, examining questions such as the effect of task load, autonomy, or feedback on complex task performance, learning, and situational awareness (e.g., Young, Lenne, Beanland, Salmon, & Stanton, 2015). Depletion is the primary assumed mechanism. For example, drawing on theories of attention and resources, such as Wickens's (2004) multiple resources theory, Hockey's (1997) cognitive-energetical framework, and Sweller's (1988) cognitive load theory, it is assumed that high levels of mental work load consume attentional resources, and therefore impair learning and performance. Study designs in this perspective are mostly experimental simulations of complex systems. Some studies focus on learning mechanisms, such as the idea that, when work is designed for automation in a way that the person is "left out of the loop" (cannot exercise autonomy over the system), this impairs their situational awareness (Stanton et al., 2006). Such research is influenced by sociotechnical systems theory (Cherns, 1976)—a popular work design theory concerned with jointly optimizing the social and technical aspects of work. Attention and information processing theories, such as

Endsley's (1995) model of situational awareness, also guide this literature.

The fourth perspective relevant to work design and cognition is the "lifespan or aging perspective" (dark gray square, blue cluster, topics such as "retirement," "cognitive function," and "dementia"). These longitudinal or cohort studies come from disciplines such as sociology, epidemiology, gerontology, and developmental psychology. Research in the lifespan or aging perspective is often concerned with understanding the role of work design as an environmental factor that might affect cognitive functioning and aging over the lifespan. Thus, this research has very long time spans, such as 10 to 20 years, and usually considers work at an occupational level. Most often, lifespan and aging studies focus on occupational-level complexity or autonomy as the key work variable (Finkel, Andel, Gatz, & Pedersen, 2009; Fisher, Stachowski, Infurna, Faul, Grosch, & Tetrick, 2014), although some studies have considered other characteristics (Andel, Finkel, & Pedersen, 2015; Grzywacz, Segel-Karpas, & Lachman, 2016; Oltmanns et al., 2017). In terms of cognition, the focus is usually on cognitive processes or abilities assessed using tests or using neurocognitive measures of brain structure and function (e.g., brain imaging [Stuss & Knight, 2013]). The predominant theory focuses on cognitive preservation ("use it or lose it" or closely related processes) or, sometimes, a psychological strain or health mechanism.

A fifth approach, somewhat overlapping with the lifespan approach, is the "occupational health perspective" (gray square, blue and green cluster, terms such as "health," "strain" and "risk"). Disciplines are quite close to a lifespan perspective, and topics include healthy work design, occupational safety, aging, psychosocial or physical exposures, and worker health and well-being. Cognition and brain health have received attention as key outcomes of work in this literature because cognition is necessary for everyday functioning (Clouston et al., 2013), and because cognition can be affected by unhealthy work in later life (Fisher et al., 2017; Grzywacz et al., 2016). Theoretically, this perspective draws on the demand–control model of strain (described above) as well as more dynamic theories of stress as a process that unfolds over time (Ganster & Rosen, 2013) and the "allostatic load model" (McEwen, 1998) that explains physiological stress processes (Ganster & Rosen, 2013: 1086). For example, the stressor–strain model indicates that work stressors can lead to strain outcomes such as poor mental health and, in turn, decreased cognitive functioning (Beehr, Jex, Stacy, & Murray, 2000). Most of the key studies in occupational health are longitudinal—and, occasionally, prospective cohort—studies that investigate how work relates to cognition over long periods.

Finally, although it does not show up on the VOSviewer map, studies from a "neurological perspective" are also relevant. These studies do not empirically consider work design (hence their invisibility in Figure 3), but they are relevant because they link stimuli in the environment with cognition-related brain structure and function. For example, some neurologically oriented studies focus on environmental conditions that lead to changes to neural circuits—called neuroplasticity—which in turn affects cognitive functioning (Keller & Just, 2016) and may lead to longer-term cognitive outcomes (Burzynska, Jiao, & Ganster, 2018). A classic study in this line of research by Rosenzweig, Krech, Bennett, and Diamond (1962) demonstrated that enriching the environment in rat cages changed the rats' brain chemistry and brain weight. Subsequent research, often using animal models, has shown the importance of cognitive, social, and physical stimulation for environments to be considered enriched, with a key property being the maintenance of novelty, such as by regularly changing toys (e.g., Simpson & Kelly, 2011). We give examples of studies from this perspective where they help explain potential mechanisms linking work design and cognition.

In summary, the traditional work design literature has expanded to consider how the nature and structure of people's work shapes their use of knowledge and learning. However, our review shows that there is a wider evidence base from different disciplines, with shorter and longer time scales, and with work considered at lower and higher levels of analysis. Next, we synthesize this research conducted to address the question as to whether and how work design affects cognition, focusing first on short- to medium-term cognitive processes and second on long-term cognitive processes.

WHETHER AND HOW WORK DESIGN AFFECT SHORT- TO MEDIUM-TERM COGNITION

In our review, we identified five categories of psychological work characteristics (work design) for which there is reasonable evidence of a link to cognition. The first two are core to the traditional job characteristics model: job autonomy and feedback. "Job autonomy," which we use interchangeably with the term "job control," refers to the degree of decision-making at work, such as one's influence over general decisions (decision-making autonomy), the opportunity to choose timing of work tasks (timing autonomy or control), and being able to choose one's work methods (method autonomy or control). "Feedback" refers to information about the effectiveness of one's work behaviors (Ilgen, Fisher, & Taylor, 1979). Feedback can come from the job (as focused on in the job characteristics model), or from formally structured systems, such as performance appraisal systems, from others in the environment, such as peers and supervisors, from electronic systems, and from self-driven efforts to obtain feedback (feedback seeking).

The remaining three categories of work characteristics—job complexity, relational aspects of work, and psychosocial demands—extend beyond the traditional job characteristics model. "Job complexity" refers to the extent to which a job puts mental demands on a worker that require aptitude, skill, training, thought, and creativity, and independent judgment (Schaubroeck, Ganster, & Kemmerer, 1994). Some studies (e.g., Fisher et al., 2014) refer to mental demands rather than job complexity, and terms such as cognitive demands, intellectually stimulating work, or challenge demands also capture this aspect. "Relational aspects of work" concern the social context within which tasks are executed, such as the degree of social contact, support, task interdependence, and interaction outside the organization. Finally, "psychosocial demands," key to the demand–control model of strain (Karasek, 1979), such as work load and emotional demands, include those social and organizational "aspects of a job that require sustained physical or mental effort and are therefore associated with certain physiological or psychological costs" (Demerouti et al., 2001: 501).

We identified multiple work design–cognition pathways by which these aspects of work design affect cognition (see Table 1). In the following sections, we focus on the ways in which cognition is affected in the short to medium term, including three cognitively enriching pathways ("opportunity for use of cognition," "accelerated knowledge acquisition," "motivated exploratory learning") and two cognitively harmful pathways ("strain-impaired cognition," "depleted cognitive capacity"). We unpack each mechanism, and review the evidence for the most important work characteristics within each.

Opportunity for Use of Cognition

A simple and direct path linking work design and cognition concerns the application of one's knowledge, and the use of one's cognitive processes and fluid abilities. Aspects of work design can create more, or fewer, opportunities for individuals to use their existing knowledge, and to apply their cognitive processes or fluid abilities. For example, if a salesperson has high job complexity in which they have to repeatedly sort out challenging contractual issues, they not only have the opportunity to apply knowledge of contracting, but they also engage in problem-solving, which relies on cognitive processes like working memory and uses cognitive abilities such as reasoning. Likewise, if a salesperson has no autonomy to address customer complaints, and instead needs to refer problems to their supervisor, this reduces the salesperson's chance to apply their product knowledge, as well as to engage in problem-solving that draws on their expertise.

In fact, this "opportunity for use of cognition" pathway has rarely been empirically investigated as a unique and separate path, although it is implied in tests of other pathways. For example, if work design accelerates knowledge acquisition, then that implies more opportunity for use of cognition. This pathway is also part of the longer-term cognitive preservation pathway that focuses on how "using" cognition prevents "losing" cognition. We can think of this pathway as similar to the effect on one's muscles of engaging in a physical workout. That is, a physical workout uses one's muscles, with attributes of the workout (e.g., ease of access; type of activity, like walk versus swim; length of time engaged in the activity) influencing which muscles are used and to what extent. Likewise, work allows one to use knowledge and apply one's cognitive processes or abilities, with the design of the work (e.g., complexity, autonomy) shaping which knowledge, cognitive processes, and cognitive abilities are used, and to what extent.

Accelerated Knowledge Acquisition

Some physical workouts are highly oriented toward skill acquisition. For example, consider a tennis drills session in which the player engages in dynamic tennis play and receives feedback from the play itself, as well as from the coach. Such a workout does much more than use one's muscles: it accelerates the tennis player's acquisition of skill by virtue of the player's active engagement. Likewise, we assert that work can do more than "use" one's knowledge and cognitive processes or abilities. That is—when designed in ways that enhance individuals' active engagement—work can accelerate workers'

TABLE 1
Major Pathways Linking Work Design and Cognition Identified in the Review

Pathway	Description	Physical Analogy	Example	Relevant Work Characteristics
Short- to Medium-Term Cognitive Processes				
Opportunity for use of cognition	Work affects people's opportunity to apply knowledge and to use their cognitive abilities, with work design influencing the extent and type of cognition used.	A physical workout uses one's muscles, with attributes of the workout (e.g., the type of activity, such as walk versus swim; length of time engaged in) influencing which muscles are used and to what extent.	If a salesperson has to sort out complex contractual issues, they use their knowledge of contracting, and engage in problem-solving, which in turn relies on cognitive processes like working memory and uses cognitive abilities such as reasoning.	Rarely empirically examined, although theoretically assumed in the preservation pathway. Especially linked to job complexity.
Accelerated knowledge acquisition	Work, when designed in ways that enhance individuals' active problem-solving, accelerate workers' knowledge acquisition, facilitating deeper and broader forms of learning.	Some physical workouts are highly oriented toward skill acquisition, such as a tennis drills session in which the player engages in dynamic tennis play and receives feedback from the play itself, as well as from the coach. This active engagement accelerates the tennis player's acquisition of skill.	Because a salesperson has the autonomy to solve problems for clients, and then get direct and immediate feedback on their approach, they very quickly acquire knowledge about what solutions are best, increasing their speed of learning.	Evidence is strongest for job autonomy alone, and combinations of autonomy, demands or complexity, and feedback.
Motivated exploratory learning	Work designs that are intrinsically motivating stimulate workers to learn and engage in learning-oriented behaviors that enhance their use of cognitive abilities, and lead them to use and acquire new knowledge.	An internally motivated person who engages in a tennis drills session will fully exploit the active learning opportunities created in the session (e.g., experimenting with strategies, persisting if a tactic doesn't immediately work, asking for feedback), and will therefore learn more.	Because a salesperson has an intrinsically motivating job with complex problems to solve, they are open to learning new skills, and willing to explore new ways of solving the problems—behaviors that boost their knowledge and mean they use increasingly complex cognitive abilities.	Evidence is strongest for job autonomy, relational aspects of work design (such as social support), and feedback from the job itself or holistic feedback assessments. Some evidence of positive effects of challenge demands in conjunction with autonomy.
Strain-impaired cognition	Work stressors increase psychological strain, which invokes physiological stress responses that impair learning and cognition.	If engaging in a workout, such as tennis drills, causes physical strain or injury, then the benefits of the workout on muscle development and skill acquisition will be impaired and even negative.	A salesperson is exposed to regular high work pressure, which increases cortisol in their body, which impairs their attention and interferes with learning.	Clear evidence that a lack of job autonomy, feedback, or relational work design characteristics and excess psychological job demands can lead to strain; also evidence that strain impairs learning. Few

TABLE 1
(Continued)

Pathway	Description	Physical Analogy	Example	Relevant Work Characteristics
				studies have examined how work design affects learning via strain.
Depleted cognitive capacity	Excessive cognitive demands of tasks exceed one's mental capacity, leading to depletion, and thereby impairing learning.	A new training program is so physically convoluted or overwhelming that it means one cannot fully execute the program, which inhibits the chance for muscle development or skill acquisition.	A salesperson attempts to learn a new IT system at the same time as monitoring a large number of complex incoming queries, which makes it difficult for that person to learn the new skill.	Complex tasks can exceed people's memory capacity and impair learning. Sustained vigilance tasks also deplete cognition due to excess attention and self-regulation requirements.
Long-Term Cognitive Processes				
Cognitive preservation	Work designs that allow for workers' greater use of cognition can help to maintain cognitive abilities and prevent decline as a result of aging.	By using one's muscles repeatedly and over time, one prevents the deterioration in muscle strength that can otherwise occur with aging.	Because a salesperson has regularly engaged in complex tasks and used brain in their career, that salesperson has preserved functioning so their cognitive decline is reduced at age 60.	Job autonomy, job complexity, and social complexity appear to protect against long-term cognitive decline, with the evidence most consistent for job autonomy.
Accumulated knowledge	Over time, by promoting and accelerating learning, work design can lead to the development of long-term crystallized intelligence, wisdom, and expertise.	Long-term development of skill creates muscle memory that enables ease of skill use later on in life.	A salesperson working for many years in an enriched job acquires deep expertise that, in turn, results in the allocation of more enriched work, promoting greater knowledge and wisdom, in a positive spiral. At age 65, the salesperson mentors juniors in how to manage complex projects.	Currently, no evidence for this pathway, but long-term exposure to work characteristics that promote learning should foster this process.
Chronic ill-health impairment	Work that is chronically stressful can impair physiological systems, and even cause cardiovascular disease, which increases cognitive decline as one ages.	Continued engagement in workouts that cause damage can create long-term injuries that then affect muscular and physical health in the long term.	A salesperson is exposed to chronic levels of low control and high demands, contributing to a heart attack in middle age, which causes loss of cognitive function.	Some initial evidence that stressful work characteristics (e.g., low autonomy–high demands) can affect vascular systems and contribute to cognitive decline.

knowledge acquisition, facilitating deeper and broader forms of learning. For example, because a salesperson has the autonomy to solve problems for clients, and then to get direct and immediate feedback on their approach, they very quickly acquire knowledge about what solutions are best, increasing their speed of learning.

Job autonomy, feedback, and combinations of autonomy, demands, feedback, and complexity have had the most attention in relation to this path.

Job autonomy. In the human factors literature, job autonomy is often considered important for enhancing knowledge acquisition because it allows for more active interaction with the work tasks, especially the opportunity to dynamically engage with problems that emerge. For example, in regard to automation, Endsley (2018) presented strong evidence from a review that higher levels of automation (which implies lower human autonomy over the system) reduce people's situational awareness because the lack of active interaction means that people become passive processors of information. Lower situational awareness, in turn, reduces people's ability to recover when automation fails. Endsley (2017: 8) referred to the automation conundrum in which "the more automation is added to a system, the more reliable and robust that automation is, the less likely that human operators overseeing the automation will be aware of critical information and able to take over manual control when needed." Endsley (2017) proposed the HASO (human-autonomy system oversight) model, which advocates the need for humans to retain autonomy over automated systems so that they maintain a sufficient level of situational awareness to be able to take over effectively when required. A meta-analysis of 18 experiments by Onnasch, Wickens, Li, and Manzey (2014) supported this conclusion, demonstrating that, although higher automation (in which the machine autonomously decides or implements actions) positively predicts routine performance when the machine is functioning well, as shown in nine studies, higher automation also means poorer recovery from system failure. The authors advocated that, "if return-to-manual performance issues are of serious concern, human operators should be kept involved at least to some extent in decision and action selection as well as action implementation" (Onnasch et al., 2014: 486). Others studies have reached similar conclusions (e.g., Onnasch & Hösterey, 2019).

Research from the work design perspective also points to the role of job autonomy in enabling the development of knowledge. Parker and Axtell (2001) showed that job autonomy, and the wider scope of action that autonomy generates, led to greater self-reported understanding about other departments, customers, and the wider organization (which they referred to as "integrated understanding"), which was in turn associated with employees being more able to adopt the perspective of their internal suppliers. At the team level, Aoki (1986) discussed how more Japanese-oriented forms of work design that have broader jobs, job rotation, more autonomy, and greater engagement of operators in problem-solving are more likely than traditional specialized American job structures to facilitate collective "learning by doing," such as via joint problem-solving, and are more likely to facilitate knowledge sharing across team members to solve emergent challenges, thereby broadening people's knowledge. Others have similarly argued that self-managing teams with team-level autonomy are especially likely to learn because of these teams' greater opportunity for engagement in active decision-making, as well as the high level of ownership and heedful relating that can occur. For instance, in their analysis of four studies of self-managing teams, Druskat and Pescosolido (2002) showed that learning was a dominant feature at the beginning of these autonomous teams, and helped to account for their effectiveness, although learning opportunities faded over time as formal training and knowledge sharing opportunities reduced, and as the work system became more routine. In a study of 115 teams in five multinational corporations, team autonomy (but not team feedback) predicted team learning, which in turn predicted team performance (Zellmer-Bruhn & Gibson, 2006).

Some empirical studies have focused on how work design can accelerate knowledge acquisition by allowing people to engage their cognitive abilities one at a time, and in a manner that most suits them, thereby enabling more effective use of those abilities (e.g., de Lange, Taris, Jansen, Kompier, Houtman, & Bongers, 2010). As a specific example, Elfering, Grebner, and de Tribolet-Hardy (2013) reasoned that high timing control (such as control over work hours and the timing of one's tasks) enables people to allocate their tasks according to their cognitive resources, such as to have breaks when they are fatigued or to do more difficult tasks when resources are highest, which should allow better cognitive performance. Consistent with this reasoning, these authors found that timing control was associated with lower levels of self-reported cognitive failure (e.g., reports of memory failures), albeit not with accidents or near accidents. Similarly, Lawrie, Tuckey, and Dollard (2018) theorized that autonomy gives individuals the opportunity to organize their work more efficiently to allow attentional focus (mindfulness), whereas non-autonomous work is associated with automatized responding. Over two weeks, daily job control (as well as also lower levels of daily psychological demands) predicted mindfulness, and in turn self-reported learning, especially within workplaces that strongly valued employees' psychological health. Scholars have likewise argued that low control jobs with high levels of standardization foster the development of routines that, although helpful for efficiency, impair creativity and adaptivity as a result of functional fixedness. In support of such a process, Niessen and Volmer (2010) found that individuals with low autonomy did not transition well to high autonomy situations, with impaired performance in the new situation, suggesting reduced adaptivity and learning.

Feedback. Human factors scholars often consider feedback to be a key input from the environment for promoting situational awareness at the individual, team, or system level (for a review, see Stanton, Salmon, Walker, Salas, & Hancock, 2017). For example, a lack of feedback has been implicated in an operator's inability to resume control after automation failure because of people being "out of the loop" and not getting access to the knowledge they need (Endsley & Kiris, 1995). One way to keep people in the loop is to provide employees with continuous feedback about the state of the system (Norman, 1990). Such feedback has been shown to support performance and skill maintenance in aviation (Sarter, Woods, & Billings, 1997).

However, the effects of feedback on knowledge acquisition are inconsistent overall. In the context of automated driving, for example, results of simulation studies are mixed. Cohen-Lazry, Borowsky, and Oron-Gilad (2017) showed that verbal feedback to autonomous drivers about the vehicle and its environment increased drivers' attentiveness, but not their ability to recover from an emergency situation, and a study that simulated robot use in battlefields (Chen & Barnes, 2012) showed no difference in situational awareness according to the degree of feedback. In contrast, Seppelt and Lee (2019) showed the superiority of continuous feedback in visual displays relative to discrete warnings in fostering drivers' situational awareness and performance. Another study showed that Amazon Mechanical Turk workers' trust in automation and their performance is enhanced with feedback, especially when the reliability of the system is unknown (Mishler, Chen, Sabic, Hu, Li, & Proctor, 2017).

Although there are many reasons for these mixed effects (we explain motivational ones later), scholars from the learning perspective have discussed how feedback can sometimes backfire because it becomes a crutch, focusing attention to the goal of getting positive feedback and shortcutting one's actual learning (Kluger & DeNisi, 1996). Several studies support this idea, showing that detailed feedback can promote better performance in an initial task, yet reduce transfer of training to a later task because the feedback provides too much guidance and inhibits information processing (Goodman, Wood, & Chen, 2011). Similarly, in the domain of error training, highly detailed feedback has been shown to reduce exploration and learning (Keith & Frese, 2008). Some authors recommend feedback from the task itself, rather than from an external agent, because the former supports learning through discovery (Frese & Zapf, 1994; Kluger & DeNisi, 1996). This latter perspective is consistent with the research discussed next, which suggests that knowledge acquisition is best enhanced with combinations of feedback from the task plus other aspects of work design.

Combinations of job complexity, challenge demands, job autonomy, and job feedback. Most of the work design studies that focus on accelerated knowledge acquisition mechanisms consider some combination of job complexity or challenge demands, autonomy, and feedback. Theoretically, the expanded demand–control model of strain (Karasek & Theorell, 1990; Taris & Kompier, 2005) proposed that an "active job"—which has both high demands and high control—promotes learning. High demands stimulate the need for employees to explore effective work strategies to achieve their goals, and, on the other hand, high job control allows exploration of, and experimentation with, these different strategies. Thus, together, demands and autonomy facilitate the acquisition of knowledge. In a similar vein, Frese and Zapf (1994) summarized German action theory (Hacker, 1985) to argue that job autonomy, job complexity, and feedback together promote learning. Collectively, these work design attributes mean that individuals engage in a "complete" action sequence involving goal setting, plan development, decision-making, monitoring, and feedback, which then supports learning as to what plans are effective, and enables a process of deep "intellectual penetration" (Frese & Zapf, 1994: 297).

More specifically, from the German action theory perspective, well-designed work involves the use of conscious forms of action regulation, or "decision necessities." In other words, work has some degree of complexity. When work is complex, over time, problem-solving and meta-cognitive strategies get used more and more, and, with repeated use, these strategies become routinized and automated, freeing up further resources for learning and yet deeper intellectual penetration of the task. Importantly, regarding "complex," these authors' argument is not that work should be "complicated," but that work should involve a high level of action regulation. In other words, in contrast to a notion that work promotes learning because it requires a high use of working memory, the argument is that work that involves the consideration of multiple diverse goals, plans, feedbacks, and the linkages among these elements will enhance knowledge acquisition. Whereas complicatedness can cause fatigue and overload, complex decision necessities supports the acquisition of deep expertise. But it is not just about complexity—autonomy is an important part of this puzzle too. Frese and Zapf (1994) argued that, if job autonomy or control (which they referred to as "decision possibilities") are lacking, then job complexity ("decision necessities") can be experienced as overwhelming. When job autonomy is absent, the action sequence is incomplete, which impairs cognitive processes and the associated learning. Thus, autonomy is important—not because of motivation, but because "people who have control can do better because they can choose adequate strategies to deal with a situation" (Frese & Zapf, 1994: 319). In essence, autonomy promotes flexible responses to complex situations, and workers can then learn which responses work most effectively.

Building on arguments from German action theory, and similar to the arguments about autonomy and automation (above), work design scholars have argued that autonomy—usually in combination with feedback—changes the way people interact with their work tasks, thereby accelerating learning. In particular, Wall and colleagues (e.g., Wall & Jackson, 1995) have argued that autonomy means workers can control variances at the source (such as by fixing a minor machine fault themselves, instead of having to call out a specialist), which then means the worker gets immediate feedback about the impact of their actions. This means the worker can learn about cause and effect from the task itself, which enhances the complexity of their mental models. Moreover, although not explicitly stated by Wall and colleagues, the fact that there are variances to control in the situation implies that some degree of job complexity or challenge demands are necessary for fostering this mental model development.

Consistent with the idea that autonomy facilitates "deep" learning, a series of studies led by Wall have shown that machine operators given greater autonomy learn to anticipate and then prevent faults (Jackson & Wall, 1991; Wall, Corbett, Martin, Clegg, & Jackson, 1990; Wall et al., 1992). Using a novel methodology in which they analyzed the pattern of machine breakdowns, the researchers were able to rule out an alternative explanation, the "quick response mechanism" (in which operators respond more quickly than calling out specialists), because they showed an initial decrease in downtime of 20% that was due to quick responses was followed by a large and delayed decrease of 70% of downtime, which the authors assumed was due to employees learning to prevent problems. Likewise, in studies that support the idea that autonomy combined with feedback can aid learning through discovery, Leach and colleagues investigated the effects of a combined empowerment or feedback initiative. In an initial study, Leach, Jackson, and Wall (2001) reported that the organization had introduced an empowerment initiative that was only partially successful in improving fault rectification. These authors observed that a lack of knowledge about some faults was limiting the scope for operators to engage in rectification (i.e., to make use of their autonomy). Hence, a feedback process was carefully designed (participatively, with operators, engineers, and others) to provide specific feedback that was directed to faults only of relevance, that incorporated an opportunity to learn, and that was non-threatening to the self. After the intervention, time series analysis of data on engineer call outs and machine utilization data showed clear positive effects of the intervention, as well as evidence of improvement over time, suggesting learning. Motivation was not affected, but operators reported an increase in knowledge sharing and lower perceived likelihood of making expensive mistakes. In a follow-up study of the same intervention, Leach et al. (2003) showed that job knowledge about faults increased as a result of the intervention, especially for novices, which the authors attributed to the combination of autonomy and feedback fostering a deeper form of learning. In essence, job autonomy allows one to explore different learning strategies in the face of complexity and challenging demands, while feedback provides information about the effectiveness of these strategies. This idea of job aspects working together to promote learning is consistent with socio-technical systems theory, which advocates that change in one part of the system (e.g., autonomy) needs to be accompanied by change in other parts of the system (Cherns, 1987; Clegg, 2000; Trist & Bamforth, 1951).

Summary. There is strong evidence that autonomy, feedback, and job complexity (or challenging demands) operate in a synergistic way to accelerate workers' knowledge acquisition, with theory and research across human factors and work design perspectives showing these work characteristics together accelerate learning. There is also some evidence for autonomy alone, such as that autonomy enables the acquisition of broader knowledge and the promotion of mindful and flexible modes of operating. However, there is little clear evidence for complexity alone, and mixed evidence for feedback by itself, with the latter perhaps reflecting the fact that feedback systems can be poorly designed and that feedback might best support learning if it comes directly from the task.

Motivated Exploratory Learning

To continue the metaphor introduced above, compare a person who loves tennis engaging in a tennis drills session with a person engaging in a tennis drills session under sufferance (perhaps coerced by a parent). The person who loves tennis will be motivated to exploit the active learning opportunities created in the session. For example, they will be willing to experiment with different strategies, carefully observing the consequences of various shots, persisting if a tactic doesn't immediately work, and asking for and listening to feedback—all of which are likely to increase the quality of the workout and the skills acquired. In a similar vein, depending on their work design, people vary in their motivation at work, which shapes their willingness to exploit any learning opportunities offered by the work or to create new learning opportunities. Those high in motivation as a result of well-designed work will be likely to explore and try things when completing their tasks, and indeed to take on ever-more challenging tasks, and hence will enhance the extent to which they employ cognitive processes, use their cognitive abilities, and use and acquire new knowledge.

This pathway draws on theorizing from the classic job characteristics model (Hackman & Oldham, 1976) that well-designed work fosters internalized motivation. But the present pathway goes further to suggest that motivation then stimulates workers' desire to learn or engage in learning-oriented behaviors. Also relevant to this path is Kanfer and Ackerman's (1989) motivation-based theory of skill acquisition, which proposes that learning is facilitated by challenging situations paired with motivation. For example, because a salesperson has an intrinsically motivating job with complex problems to solve, they are open to learning new skills, and willing to explore new ways of solving problems—behaviors that boost their knowledge and mean they use increasingly complex cognitive abilities. All five categories of work characteristics have been implicated in this motivated exploratory learning pathway, as we discuss next.

Job autonomy. Autonomy might be an especially important work characteristic for promoting learning via motivation because autonomy promotes a strong sense of responsibility for the work (Hackman & Oldham, 1976), as well as a broader and more flexible sense of ownership (Parker, Wall, & Jackson, 1997)—both of which are likely to motivate a desire to learn so as to more effectively meet one's goals. Similarly, scholars have argued that trainees learn best when they autonomously try to gain knowledge and skills (Kozlowski et al., 2010). There are several empirical examples in the literature. For example, Holman and Wall (2002) showed that job control was related to both cognitive work-based learning strategies (such as working out which aspects of the job are important) and behavioral work-based learning (such as asking for more information from others when needed), which in turn predicted idea generation. In a cross-sectional study, Parker and Sprigg (1999) showed that job autonomy predicted perceived mastery and, for proactive individuals, role breadth self-efficacy (the belief in one's capability to engage in a broader arrange of tasks beyond technical ones)—outcomes that the authors framed as "learning oriented." In a longitudinal study, de Lange et al. (2010) found—especially for middle-aged workers—reciprocal links between work and learning. Thus, job control (and also job demands, but not social support) predicted motivation to learn and active problem-solving three years later, and active problem-solving behavior predicted later work characteristics, in a positive spiral.

Showing further support for a motivation process, in an experimental puzzle task, Wielenga-Meijer et al. (2010) manipulated autonomy during practice trials, and then examined individuals' performance on a subsequent "transfer" task. Their findings showed that, although autonomy did not help participants to repeat previously learned behavior in the same task (indeed, full autonomy was worse), those with moderate and full autonomy performed better in the transfer task than those with low autonomy, because they were motivated to learn and they engaged in more exploration. Using the same manipulation, in a later study, Wielenga-Meijer, Taris, Wigboldus, and Kompier (2012) found that cognitively demanding interactions reduced learning in the low and full autonomy conditions, but did not impair learning in the moderate autonomy condition, suggesting that moderate autonomy helps people to learn from high cognitive demands. Foss, Minbaeva, Pedersen, and Reinholt (2009) showed, in a cross-sectional study, that job autonomy promoted intrinsic motivation, which in turn generated knowledge sharing (feedback and task identify also fostered knowledge sharing via other motivational processes); and, in a meta-analysis, Cerasoli et al. (2018) showed the importance of job autonomy (also resources, demands, and support) as an antecedent of informal learning. Likewise, several studies (e.g., Kyndt, Raes, Dochy, & Janssens, 2013) have shown that "choice independence" at work (similar to job autonomy or control [Kirby, Knapper, Evans, Carty, & Gadula, 2003]) or autonomy-supportive work contexts (Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004) predict a "deep learning" approach in which the person has a strong intrinsic interest in learning and hence uses an array of integrative learning strategies, and negatively predicts a "surface-disorganized" learning approach in which the motive is mostly extrinsic and surface techniques like rote learning are used. These studies, however, tend to be cross-sectional and reliant on self-reported measures of learning. Bergman et al. (2012), in a large population-based sample, used a longitudinal study with a three-year time lag to show that those with high autonomy were more likely to report using general problem-solving strategies.

Feedback. Traditional learning theory links feedback to learning via motivation. Thus, Thorndike's (1913) law of effect assumes that positive feedback reinforces, or motivates, the correct behavior, whereas negative feedback punishes and demotivates the incorrect behavior. Subsequent theories are more complex, but have a similar focus on how feedback motivates discrepancy-reduction behaviors related to feedback. For example, control theory (Carver & Scheier, 1981) and goal-setting theory (Locke & Latham, 1990) assume that behavior is goal directed, and that feedback motivates people to assess their behavior in relation to their goals and then to put in effort to reduce discrepancies between the goal and the feedback.

However, these theoretical perspectives are too simple, and do not account for the mixed effects of feedback in empirical studies (e.g., Balcazar, Hopkins, & Suarez, 1985; Wielenga-Meijer et al., 2010), the relatively small and varying effects of feedback interventions (Ivers et al., 2014), or the moderating role of factors such as the credibility of the source and the timing of the feedback (Lechermeier & Fassnacht, 2018). More nuanced theorizing suggests that feedback can be a double-edged sword for learning, in part because it isn't always motivating. Thus, Kluger and DeNisi (1996) argued that, when feedback promotes attention to the task itself, it enables learning, but often feedback is evaluative about the self, and then is demotivating.

Specifically, these authors proposed that feedback affects three hierarchical processes: task-learning processes, task-motivation processes, and meta-task processes involving the self. Attention is normally at the mid-hierarchical level; that is, the task-motivation processes that involve eliminating feedback-goal discrepancies. But feedback can also direct attention down the hierarchy (e.g., if the feedback sign is negative and additional effort is not resolving the discrepancy), which prompts the individual to engage in learning strategies to meet the goal. Feedback can also direct attention up toward the self, causing negative affect and focusing attention on the self rather than the task. For example, feedback involving praise can impair performance because it focuses individuals' attention on their higher-order self-goals. This theorizing was supported in Kluger and DeNisi's (1996) meta-analysis, which showed that, although there was an average positive effect of feedback interventions on performance, more than one third of applications resulted in decreased performance, consistent with the three processes. For instance, highlighting the downside of evaluative feedback for learning, Foss et al. (2009) showed that, when feedback is assessed formally, such as having a performance evaluation, it predicts extrinsic motivation, which in turn reduces knowledge sharing.

Such findings have led DeNisi and Kluger (2000) to recommend (among other endorsements) a focus on the task and task performance only, not on the person or any part of the person's self-concept. It is interesting to observe how this recommendation dovetails with a focus on feedback from the job itself. Feedback from the job (i.e., getting clear and direct information about one's performance from carrying out the work activities per se) has been the traditional focus of job design theory (Hackman & Oldham, 1976). As this feedback is not mediated through supervisors, feedback from the job itself is less likely to implicate self-focused processes such as evaluation, and therefore should be more supportive of learning. Consistent with this reasoning, in their meta-analysis, Kluger and DeNisi (1996) found that computer-generated feedback was preferable to having supervisors deliver feedback, which they attributed in part to the lack of implication of the self (note, though, that contemporary versions of computer-generated feedback can be more negative due to their emphasis on control).

It is clear from the above discussion that the effects of feedback on motivation—and, hence, performance and learning—are complex. It might be surprising, therefore, to note that a meta-analysis of work design studies by Humphrey et al. (2007) showed that feedback from the job positively predicted job satisfaction, growth satisfaction, internal work motivation, and subjective performance, and it did so not only via knowledge of results, but also via the motivational states of experienced meaningfulness and experienced responsibility. Feedback from others also predicted various motivation outcomes. The highly consistent impact of feedback on motivation in this literature can be explained by its holistic focus, relative to the feedback research in the learning literature. In other words, in the work design literature, less attention is given to fine-grained aspects of feedback (positive vs. negative, etc.), and instead the focus is on an employees' overall judgment that they get information about how they are doing in their job. In a similar vein, scholars (e.g., Steelman, Levy, & Snell, 2004) introduced the notion of a "supportive feedback environment" to capture multiple aspects of feedback covered in the more detailed goal-setting research (e.g., source credibility, feedback quality, feedback delivery). These authors showed that a supervisor-oriented version and a coworker-oriented version of supportive feedback environment each positively predicted employees' motivation to use the feedback. Gabriel, Frantz, Levy, and Hilliard (2014) found that, especially for those with a strong feedback orientation, a positive supervisor feedback environment predicted employees' sense of meaning, competence, and self-determination. Overall, when feedback is operationalized as a more holistic judgment or as a comprehensive concept that covers evidence-based supportive elements, it seems that people find it motivating, which should in turn foster greater learning.

Job complexity. According to Humphrey, Nahrgang, and Morgeson (2007), knowledge characteristics of work, such as job complexity, are intrinsically motivating because they allow individuals to demonstrate and reinforce their sense of competence on the job. In their meta-analysis of work design and outcomes, Humphrey and colleagues found that information processing and job complexity were both positively related to job satisfaction, and job complexity also predicted job involvement. Based on these findings, we expect that individuals in complex jobs will be more motivated to learn, and more likely to engage in positive learning strategies. There are, however, few studies that have directly examined links among job complexity, motivation, and learning.

Relational work design. Some scholars have argued that relational aspects of work design affect cognition by creating a social context that motivates employees to learn. Thus, Jiang, Jackson, and Colakoglu (2016) drew on Kanfer and Ackerman's (1989) motivation-based theory of skill acquisition to predict that team task characteristics would result in relational forms of learning. Cross-sectional results showed that team task interdependence and routineness interacted to predict "personal skill development" (defined as new skills and abilities that enable better working relationships). Specifically, when team task interdependence was high and routineness low (indicating high job complexity), skill development was higher, whereas team task interdependence had a negative effect on learning when tasks were high in routineness (low complexity). Putting aside the cross-sectional limitations of this study, it suggests that the aspects of jobs that make them complex (e.g., social plus cognitive aspects) might positively interact—a notion that most studies have not considered.

Studies from a learning perspective also show positive links between relational aspects of work and knowledge acquisition. For example, Cerasoli et al. (2018) argued that social support motivates people to engage in informal learning because the latter is a discretionary behavior that others can reinforce and encourage. Their meta-analysis identified eight studies that linked support from peers or managers and informal learning behaviors, with the latter behaviors being shown to predict knowledge and skill acquisition. Supportive managers also motivate greater engagement in formal learning activities, as well as activities such as career planning (e.g., Birdi, Allan, & Warr, 1997), and supportive peers or managers can motivate greater transfer of training to the workplace (Facteau, Dobbins, Russell, Ladd, & Kudisch, 1995). In another meta-analysis, Colquitt et al. (2000) showed that supervisor support and peer support predicted motivation to learn, as well as transfer of training, with motivation to learn being positively related to declarative knowledge and skill acquisition. Studies also show that successful teams develop shared mental models, or shared knowledge about the environment and expected behavior, which aids team performance (e.g., Cannon-Bowers, Salas, & Converse, 1993). Not only is learning about the task and the environment enhanced through teamwork, but also people's learning about "how to work in a team" is developed (Wilson, Goodman, & Cronin, 2007). In contrast to the above evidence linking relational work design to cognition, in their longitudinal study, de Lange et al. (2010) showed that supervisor support at baseline predicted *less* active problem-solving three years later for middle-aged workers, with no relationships between these variables for young or old participants.

Psychosocial demands. The findings linking demands, motivation, and learning are mixed. In their review, Wielenga-Meijer and colleagues (2010) identified 18 studies linking job demands with learning and found reasonable support for a positive associations between job demands and motivation, and between job demands and learning, with a handful of experimental studies showing positive links among job demands (operationalized as "goal difficulty"), motivation, and learning. They explained their findings as being consistent with Karasek's (1998), such that it is the "*combination* [emphasis in original] of high demands and high autonomy that facilitates learning, meaning that whether demands will be overwhelming depends on the level of control offered by the job" (Wielenga-Meijer et al., 2010: 357). However, another explanation for positive learning effects of demands is that the review mostly focused on demands such as goal difficulty, which is a type of "challenge" demand. The challenge stressor–hindrance stressor framework (LePine, Podsakoff, & LePine, 2005) proposes that job demands that are appraised as challenges (i.e., they require effort but also are likely to result in development or rewards) are positively related to motivation and performance (LePine et al., 2005)—and, we might assume, learning. Overall, even though most of the studies were experimental, it does indeed seem "challenge" sorts of demands motivate learning, although usually in conjunction with autonomy. Another caveat may be stability. In two field studies, Rosen et al. (2020) identified that the positive association between challenge stressors and performance existed only when challenge stressors are stable (predictable), with unpredictable challenge stressors being associated with attentiveness and anxiety, and lowered performance, suggesting they might also interfere with learning.

From the perspective of the challenge stressor–hindrance framework, we would expect job demands appraised as hindrances (which involve excessive or undesirable constraints) to reduce the motivation for learning. Providing some support, in health care, Latif et al. (2019) observed that organizational constraints limited the opportunity to transfer learning from an educational program to improving service equity and outcomes for patients. Likewise, in an initial meta-analysis, Pindek and Spector (2016a) found organizational constraints related to higher frustration, intention to quit, lower job satisfaction, and lower commitment, suggesting a negative impact on motivation. However, in another analysis, Pindek and Spector (2016b) reported weak meta-analytic relationships between hindrance demands—organizational constraints—and performance, which they explained as being due to mixed perceptions of this demand as both a hindrance and a challenge. The latter finding is consistent with general critiques of the challenge–hindrance stressor model that question the simplistic conclusions of this model (e.g., Mazzola & Disselhorst, 2019). Overall, there is some very weak evidence that hindrance demands might impinge on motivated learning, but perhaps the most striking finding is the lack of studies examining this link.

Summary. The clearest finding is that job autonomy and relational aspects of work design such as social support tend to enhance intrinsic motivation, the motivation to learn, and hence workers' engagement in exploratory and other learning-oriented behaviors. The motivated learning effects of job complexity have rarely been studied, although are often assumed. Regarding feedback, the evidence is most strong for feedback from the job itself, and for holistic judgments of having information available about how one is doing. The effects of demands on motivated learning are mixed: some evidence shows that challenge demands like goal difficulty promote motivated learning, especially in conjunction with autonomy, but there is little clear evidence that hindrance demands impair motivated learning. More attention has been given to the role of such demands for strain, as we discuss next.

Strain-Impaired Cognition

If engaging in a workout, such as tennis drills, causes physical strain or injury, then the potential benefits of the workout on muscle development and skill acquisition will be impaired, and, in fact, the workout might be negative for these outcomes. Likewise, if engaging in work causes severe psychological strain, then one's use of knowledge and cognitive ability, as well as one's knowledge acquisition, are also likely to be impaired. As documented in occupational health and work design perspectives, work can include objective or perceived "stressors" (e.g., hindrance demands such as role conflict) that can trigger a stress response, involving psychological, psychosomatic, and physiological effects that then affect cognition. These stressors can be acute (e.g., an immediate threat, such as a new impending deadline) or chronic (ongoing, such as continuously heavy workload, shift work, or dealing with a supervisor with poor leadership skills). In the short term (we discuss longer-term effects later), the stress response includes the more rapid secretion of cortisol and other glucocorticoids that increase the amount of sugar, or glucose, in the bloodstream. Although the surge of glucocorticoids can increase energy and improve short-term immediate recall, research shows it can also impair longer-term retrieval and executive functioning, and reduce attentional resources (Kuhlmann, Piel, & Wolf, 2005; Shields, Sazma, McCullough, & Yonelinas, 2017; Sliwinski, Smyth, Hofer, & Stawski, 2006). A meta-analysis of 133 studies by Shields and colleagues concluded a complex association between acute stress and cognition: stressors that occur prior to encoding or during retrieval generally impair memory, whereas stressors that occur post-encoding can improve memory, unless the stressor occurs in a context that differs from the original encoding process (Shields et al., 2017). Difficulty with encoding information means increased difficulty with learning.

There are many aspects of job design that may contribute to the stress process, including a lack of job autonomy, relational work design, psychological demands, and feedback.

Autonomy. Work design scholars have theorized that a lack of job autonomy causes psychological strain because it is an aversive state in which people do not meet their needs for autonomy, and because individuals do not have the control to adequately manage demands. Meta-analyses support the effect of low autonomy on psychological strain (Humphrey et al., 2007; Spector, 1986). Likewise, occupational health studies have linked lower job control to various indicators of allostatic load (e.g., Andel et al., 2015; Li, Zhang, Sun, Ke, Dong, & Wang, 2007; Sun, Wang, Zhang, & Li, 2007). However, only a handful of studies have gone further to link autonomy and its effects on strain with learning or cognition more broadly. In three samples of call center employees, including one assessed longitudinally, Holman and Wall (2002) showed that low job autonomy predicted higher levels of depression, which, in turn, resulted in lower skill use (as well as the reciprocal relationship). Similarly, for a group of young workers new to their jobs, Taris and Feij (2004) found that learning (self-reported engagement in learning activities) was highest in high demand, high control jobs, and lowest in low control, low demand jobs, providing cross-sectional support for the demand–control hypothesis. Longitudinally, over three time periods each separated by one year, learning significantly increased from Time 1 to Time 3 for the low demand and high control group only. Consistent with the idea that strain impairs learning, there were also lagged effects of Time 1 and Time 2 experiencing strain on Time 2 and Time 3 self-reported learning.

Relational work design. Although the role of social support for reducing strain is well established in the broader literature (e.g., LaRocco, House, & French, 1980), few studies have investigated how relational work characteristics might affect cognition through strain processes. In one exception, Porath, Foulk, and Erez (2015) investigated workplace incivility, one type of work-related interpersonal stressor, and found that incivility reduces attentional resources and thus interferes with working memory, cognitive processing, and cognitive abilities such as problem-solving and creativity.

Feedback. Providing feedback can, theoretically, reduce stress and strain because employees know better what is expected of them. Humphrey et al. (2007) presented meta-analytic evidence of this process: feedback from the job (assessed as an overall judgment of having information about one's performance) was associated with lower role ambiguity, role conflict, anxiety, absenteeism, and stress; and feedback from others also predicted lower stress and burnout. However, feedback can invoke negative emotions when it implicates the self, suggesting the potential for increasing strain. In addition, feedback processes are also often part of broader performance management systems that aim to do much more than provide information to employees. For example, electronic performance monitoring can be intended to provide employees with feedback to aid their learning and development, but it also can have the purpose of comparing employees, rewarding different levels of performance, and surveilling or controlling employees (Ravid, Tomczak, White, & Behrend, 2020). This means that feedback systems are sometimes invasive and lacking in transparency, with such factors explaining why electronic monitoring systems often cause psychological strain (Aiello & Kolb, 1995). Scholars advocate designing these systems with a purpose of development, with transparency, and with a focus on work-related behaviors (Tomczak, Lanzo, & Aguinis, 2018). Although there are few empirical studies, we might expect that feedback systems that are poorly designed act as psychosocial demands, as we discuss next.

Psychosocial demands. Excessive psychological work demands (e.g., long work hours, work role overload, role conflict, work–nonwork conflict), sometimes referred to as "hindrance stressors," are typically related to strain (Ice, Ang, Greenberg, & Burgard, 2020; LePine et al., 2005; Virtanen et al., 2009). Consequently, such demands could reduce learning via a stress response, which, as explained above, can interfere with effective cognitive processing and cognitive abilities (e.g., memory, fluid reasoning). For example, Sliwinski et al. (2006) examined between- and within-person changes in relation to daily stressful experiences, and found that reaction time was slower on days with lots of stressful experiences compared to low-stress days. They concluded that cognitive interference resulting from the stress process competes for cognitive attentional resources. Hyun, Sliwinski, and Smyth (2019) studied the relation between stress *anticipated* for the next day and cognition later on that day and found that, for individuals of all ages, stress anticipation reported upon waking, but not on the previous night, was associated with poorer working memory later that day. Virtanen and colleagues (2009) found that British civil servants in the Whitehall II study who worked longer hours performed worse five years later in both vocabulary and reasoning tests, thus pointing to important differences in both crystallized and fluid abilities. These findings add to a growing body of research indicating that cognition suffers in relation to demands, in part because of the cognitive burden of these demands.

Boström, Hörnsten, Lundman, Stenlund, and Isaksson (2013) surveyed Swedish diabetes nurse specialists and found role conflict exhibited a strong correlation with higher demands such as workload, irregular work, overtime, and rapid pace of work; and a similarly strong correlation with learning demands, including managing various work tasks, training practical skills, and acquiring new knowledge. In Pindek and Spector's (2016a) meta-analysis reported above, organizational constraints positively related to behavioral (counterproductive work behaviors), physical (somatic symptoms), and psychological (emotions and job satisfaction) strains—although learning was not examined. Military nurses who must simultaneously fulfill two roles, as they perform military duties and provide health care, experience role conflict, and consequently experience moral distress when they face situations with conflicting obligatory courses of action (van Rensburg & Zagenhagen, 2017). Three studies have found neither nurse educators nor students appear to have learned the skills needed to fulfill both roles (Caka & Lekalakala-Mokgele, 2013; Caka, Van Rooyen, & Jordan, 2015; van Rensburg & Zagenhagen, 2017) that could reflect the excess demands of carrying out both roles. Finally, in the domain of education, Chan and Sfard (2020) found that role conflict undermined the effectiveness of learning mathematics in peer interactions in 7th grade dyads.

Summary. Based on research in occupational health and work design, past research has demonstrated that some aspects of work design (e.g., a lack of job autonomy, a lack of feedback, relational work design characteristics, psychological job demands) can function as psychological stressors that lead to strain. In the short term, such stressors invoke physiological changes based on cortisol and allostatic load, which in turn is associated with less attention and worse cognitive functioning in the form of decrements in cognitive abilities. Overall, however, there is a need for more studies that specifically examine how work design affects learning via enhanced strain.

Depleted Cognitive Capacity

Imagine that your physical trainer has developed for you a new program that you embark on, but find to be so physically convoluted or overwhelming that you cannot actually execute the program. In such a situation, benefits for your muscle development or skill acquisition are likely to be inhibited. Mentally, one can observe a similar process occurring when excessive cognitive demands of work exceed one's mental capacity, leading to depletion, and thereby impairing learning. The dominant theory relevant to this pathway comes from the human factors perspective. Cognitive load theory (Sweller, 1988) espouses that human working memory and attention are limited. From this perspective, when intrinsic cognitive load is very high, with a task that has many informational elements that interact in multiple ways and a learner that lacks expertise, memory capacity can be exceeded and hence learning and performance impaired. This theory is frequently applied in research that seeks to best understand how to teach people complex tasks. For example, when tasks are complex, cognitive load that is defined as "extraneous" (i.e., load that is not necessary for learning, such as poor instructions) can especially detract from learning (for more details on types of cognitive load, see Wickens, 2014).

The main work characteristics that have been considered with respect to this pathway include job feedback, complexity, and psychosocial demands.

Feedback. Many of the human factors studies that seek to understand how people learn focus on the role of feedback. These studies show that the role of feedback is different for complex tasks relative to simple tasks, and also that what might facilitate performance in the training task is not the same as what facilitates performance in a transfer task (i.e., learning). For example, whereas frequent and complete feedback results in better performance on the initial task, it creates worse performance on the transfer task (for a review, see van Merriënboer, Kester, & Paas, 2006). Moreover, while infrequent feedback supports transfer if the task is simple, evidence shows that additional strategies are needed for complex tasks (such as unpacking the task, and making it simpler in the beginning). Studies have also compared delayed versus instant feedback, with some suggestion that delayed feedback is preferable for complex tasks. As with the literature on motivational aspects of feedback, the level of nuance of these studies with regard to different types of feedback, interactions with complexity, and also learner experience have not been applied to how feedback helps people to learn from their day-to-day work tasks.

One of the very few work studies that considers feedback in relation to a load and depletion perspective, at least conceptually, is that by DeRue and Wellman (2009). These authors showed that, when job feedback is high, "developmental challenge" at work predicts leadership development, whereas, when feedback is low, there is no positive effect of challenging work activities on leaders' skill development. The authors attributed this finding to the uncertainty-reducing effects of feedback, which the authors suggested makes the demands less intense and frees up employees' cognitive resources for learning and skill development. Although the findings of this study might seem contrary to those of the human factors studies, the feedback focused on here is general in nature, likely to be dispersed relatively infrequently (certainly not continuously), and likely to involve delays (it is quite rare for feedback from others to be immediate).

Complexity. The human factors and ergonomics literature is replete with studies that have examined the effect of task complexity on mental workload, showing that complex tasks are harder to learn in the short term than simpler ones (Sweller, 1988). These studies focus on cognition during short time frames (e.g., seconds to minutes or hours). Many studies investigate task complexity in driving and other situations in which mental workload is the focal dependent variable, whereas other studies focus on mental workload as a mediator in relation to performance (e.g., Galy, Paxion, & Berthelon, 2018). For example, Haji, Rojas, Childs, de Ribaupierre, and Dubrowski (2015) conducted an experiment in a surgery simulation, and showed that mental effort ratings were higher, and task performance was lower, in the more complex condition. As another example, drawing on cognitive load theory, in a cross-sectional study, Lin (2010) showed that task complexity was associated with greater role conflict, which in turn predicted lower self-rated learning effectiveness. Trust, however, was associated with lower role conflict, suggesting positive social factors might offset the effects of complexity. More generally, most of this literature has moved beyond investigating whether high complexity of a task makes it more difficult to learn (which seems clear) to understand what can be done to support learning when tasks are more complex (van Merriënboer et al., 2006).

Some studies show how task complexity affects neurological functioning. For example, in a study of a "go–no-go" task (a computerized task used to assess inhibitory control), electroencephalography and behavioral data showed that task complexity imposes higher working memory demands that, in turn, impacted negatively on executive functioning—specifically, inhibitory control—measured in the brain (Chmielewski, Mückschel, Stock, & Beste, 2015. As another example, Keller and Just (2016) showed how a complex task resulted in changes in the hippocampus, leading them to conclude that high complexity impairs learning.

Psychosocial demands. The type of demand that has had most attention from a cognitive load perspective is a high level of vigilance—that is, the need to maintain attention for long periods of time. A common finding in neuroscience and human factors studies is that sustained vigilance results in cognitive resource reduction that, in turn, increases mental fatigue on a task (e.g., Lim, Wu, Wang, Detre, Dinges, & Rao, 2010). Ironically, vigilance demands can be greatest for monotonous and intellectually unchallenging tasks, in part because very high levels of self-regulation are required to keep the person focused on the task. In a systematic review of experimental studies that investigated neural mechanisms related to vigilance and attention, Langner and Eickhoff (2013) found that high vigilance demands involve a complex interaction of brain regions, suggesting multiple cognitive processes at play.

Summary. There is a general consensus that mental load increases when dealing with complex tasks, which can exceed people's memory capacity and impair short-term performance and, possibly, learning. However, we cannot be sure about this implication for work design since most studies of complexity and depletion focus on a single task, usually simulating a training situation, and as such have a short timespan (e.g., minutes), as well as a focus on immediate performance. As we consider later, in the Discussion section, it is possible that there are different findings over time, and at a higher level of analysis. Moreover, literature from cognitive load theory provides guidance as to how to help people learn at very high levels of complexity (e.g., through simple to complex sequencing), and it could be that some of these ideas might be applied to work design. Research is clear that tasks (especially monotonous ones) requiring sustained attention can be depleting, not only because of the attention required but also the self-regulation to stay on task. As we discuss later, this finding is increasingly relevant to the topic of work design and cognition given rising levels of automation.

WHETHER AND HOW WORK DESIGN AFFECTS LONG-TERM COGNITION

In the review, we identified evidence that work design can potentially affect cognition in the longer term. Most evidence focuses on a longer-term positive pathway in which cognitive abilities are maintained over a lifespan, or the degree of decline in abilities is slowed ("cognitive preservation"). Cognitive preservation, sometimes referred to as "use it or lose it," is assumed to arise from the repeated "use" of one's cognitive abilities—that is, the cumulative effects of the opportunity for cognition pathway we described above. A further theoretically plausible longer-term positive pathway also potentially arising from the repeated occurrence of this pathway over time is an "accumulated expertise or wisdom" pathway, which we indicate in the model and discuss here briefly, even though there is currently little evidence for this process (we return to this point in the Discussion). A further long-term pathway ("ill-health impairment") is the negative effect of ill health, especially cardiovascular ill health, on longer-term cognitive functioning—a pathway that is likely to be an accumulation over time of the strain-impaired cognition pathway discussed above.

Cognitive Preservation

As discussed above, work characteristics can affect workers' opportunity, motivation, and capacity to use and develop their knowledge, and to use their cognitive processes or abilities. Here, we consider the intriguing idea that, over time, work designs that allow for workers' greater use of cognition can help to maintain cognitive abilities and prevent decline as a result of aging, likely as a result of changing brain structure or function. With respect to the physical analogy, by using one's muscles repeatedly and over time, one prevents the deterioration in muscle strength that can otherwise occur with aging.

Three interrelated theories have been offered to explain the mechanism by which work design affects cognition over the longer term. First, according to the "use it or lose it" hypothesis (Hultsch, Hertzog, Small, & Dixon, 1999; Salthouse, 1991, 2006), an individual's level of cognitive functioning is determined by the mechanism of "differential preservation" (which compares to the mechanism of "preserved differentiation")[1] in which an individual's functioning is presumed to depend on their current mental activity. In other words, individuals who are consistently mentally active ("use it") will "preserve" their cognitive function (i.e., fail to "lose it") more so than those who are not consistently mentally active. Second, the cognitive reserve hypothesis proposes that being engaged in mentally stimulating environments is associated with increased neuronal development, which in turn leads to the development of a cognitive reserve (Stern, 2012). Third, Schooler's (1984) theory of environmental influences purports that, if a person's environment has variable environmental stimuli, this requires individuals to make more complex decisions, which in turn affects their intellectual functioning (Schooler, Mulatu, & Oates, 1999). But, if high levels of cognitive functioning are not needed, intellectual abilities will not be maintained and cognitive functioning will decrease, consistent with the cognitive reserve hypothesis.

Three work design variables seem to shape cognition via use it or lose it processes: (a) job autonomy, (b) job complexity, and (c) relational work design. These work design variables have also been conceptualized as psychological work demands and resources, as explained below.

Job autonomy. Studies have theorized that exercising job autonomy involves the active use of cognitive processing and abilities, which, over time, builds up cognitive reserve and leads to preserved differentiation. In a systematic review of longitudinal studies investigating the effect of work on cognition and dementia, Then et al. (2014) identified four studies focused on job autonomy, from which they inferred positive evidence. First, Seidler, Nienhaus, Bernhardt, Kauppinen, Elo, and Frölich (2004) showed that more control at work (as well as higher challenge

[1] Preserved differentiation suggests that individuals who have had higher levels of cognitive functioning previously in their lives are those who maintain beneficial levels of mental activity as they age.

and high social demands) was associated with a smaller risk of dementia. Second, Andel et al. (2012) used twins to show a link between high job control (and high social support) and a lower risk of dementia. Third, in a cohort study, Wang, Wahlberg, Karp, Winblad, and Fratiglioni (2012) reported a link between low job control (as well as high job strain) and higher dementia risk; and, fourth, in a Swedish population study, Andel, Crowe, Kåreholt, Wastesson, and Parker (2011) identified a positive link between job control and cognition. Nexø et al. (2016)'s later review identified three further studies of relevance: Andel et al. (2011), which found that low job control predicted poorer cognitive functioning over 32 years; Elovainio et al. (2009), which showed that job control predicted subsequent phonemic fluency; and Yu, Ryan, Schaie, Willis, and Kolanowski (2009), which demonstrated that job control predicted verbal memory and inductive reasoning, and improved these functions over 14 years. On the basis of these studies, Nexø et al. (2016) concluded that there is "moderate evidence" that job control improves cognition.

Following these reviews, several studies have since provided further evidence. For example, Andel, Infurna, Hahn Rickenbach, Crowe, Marchiondo, and Fisher (2015) used the Health and Retirement Study to track the effects of the level of job control and psychological job demands in one's job held for at least ten years prior on episodic memory up to and beyond the time of retirement. Although low job control was not associated with any change in episodic memory during the period leading up to retirement, it was correlated with poorer episodic memory at the time people retired, and there was a faster rate of decline in memory following retirement for those with low job control; job demands were unrelated to episodic memory. Unfortunately, it is not possible to rule out selection effects (i.e., that cognition affects occupational choice) within this design. Similar issues apply to Sabbath, Andel, Zins, Goldberg, and Berr (2016), who drew on 2,149 participants from the French GAZEL cohort study who had retired, and found that low job control assessed four years before retirement predicted lower cognitive scores (e.g., executive function) following retirement, after adjusting for controls.

Dong, Eaton, Spira, Agnew, Surkan, and Mojtabai (2018) found that those with low job control had greater decreases in cognition and memory 11 years later, controlling for baseline scores, with the largest decreases being for individuals with high demands combined with low job control. Hülür, Ram, Willis, Schaie, and Gerstorf (2019) provided a rare example of a longitudinal lifespan approach based on perceptions of work characteristics rather than occupational proxies to assess work design. Using data from the Seattle Longitudinal Study (like Yu et al., 2009, summarized above), as expected, they found that later-born cohorts (1939–1966) performed better on cognitive tasks and had less age-related decline in word fluency than earlier-born cohorts (1901–1938); later-born cohorts also had more enriched work designs, as shown by high "worker control" (defined as a lack of prescriptive rules about work processes) and high "work innovation" (defined as work involving variety, change, and new approaches, and therefore is similar to job complexity). Using latent growth curve modeling, Hülür et al. (2019) further found that average levels of worker control, work autonomy (independent decision-making), and work innovation (like job complexity) predicted greater cognitive performance, with work control and work autonomy also predicting a less steep age-related decline in various cognitive measures (mostly, inductive reasoning). This study strengthens existing evidence linking job autonomy and cognition, although it is still possible that more cognitively able individuals self-selected into, or crafted, more autonomous work over time. Pan, Xu, Mangialasche, Dekhtyar, Fratiglioni, and Wang (2019) used a Swedish cohort study to consider exposure, or the length of time of having job autonomy. They followed up more than 2,000 dementia-free 60-year-olds for nine years and found that those with high job control and high demands (i.e., an "active job") in the longest-held job had lower cognitive decline, compared to other combinations of demand and control. Also, a longer duration in an active job was associated with slower cognitive decline, providing further evidence of the theorized complexity mechanism.

Job complexity. Studies have shown that being engaged in more complex jobs is positively related to cognition. But such studies simply establish a link between these variables, and it is likely that people with higher cognitive abilities choose more cognitively complex jobs (i.e., the reverse causal pathway to our focus in the present study). Job complexity can also be conceptualized as a mental work demand (Fisher et al., 2014); the more complex the job, the more cognitively demanding the job will be, requiring the use of cognitive processing and cognitive abilities. Thus, the strongest evidence for a "use it or lose it" process triggered by work design comes from showing a link between work design and a later *change* in cognition. Several studies provide such evidence. For example, Bosma, van Boxtel, Ponds, Houx, and Jolles (2003) found that workers in less complex jobs showed more rapid declines in processing speed, memory, and general cognitive status three years later. In addition, their results indicated that those with lower levels of education might be more likely to reduce cognitive decline with an increase in mentally stimulating work. As another example, Marquié, Duarte, Bessières, Dalm, Gentil, and Ruidavets (2010) used the VISAT longitudinal study of over 3,000 workers, and showed that cognitive stimulation both at work and outside of work predicted cognitive efficiency (e.g., processing speed) and more favorable changes in cognition over 10 years. Likewise, Potter Helms, and Plassman (2008) found that, among World War II veterans, work in more mentally demanding jobs was associated with higher levels of cognitive functioning in later life, when controlling for age, education, and general intelligence in early adulthood. Potter et al. (2008) also reported that individuals with lower intelligence earlier on seemed to benefit more from doing work that was characterized as intellectually demanding, compared to those with higher ability levels. Fisher et al. (2014) analyzed episodic memory scores (from an immediate and delayed recall task) collected in the U.S. Health and Retirement Study over an 18-year period and found that workers in more mentally demanding (complex) jobs (measured at the occupational level) had higher levels of cognitive functioning and declined less compared to those in less complex jobs. Pool, Weuve, Wilson, Bültmann, Evans, and Mendes de Leon (2016) also investigated occupational-level complexity among participants in the Chicago Health and Aging Project using the same measure of mental demands as Fisher et al. (2014) and found similar results: higher occupational complexity is associated with better cognitive functioning and less decline in later life.

However, there are also some findings that appear contrary or mixed. One study found more rapid cognitive decline for people in complex work (Singh-Manoux, Marmot, Glymour, Sabia, Kivimäki, & Dugravot, 2011), and two studies have identified no effect of complexity on cognitive change (Gow, Avlund, & Mortensen, 2014; Lane, Windsor, Andel, & Luszcz, 2017). To help resolve these inconsistencies, a recent study by Hyun, Katz, Lipton, and Sliwinski (2021) shed light on rates of cognitive decline using data from the Einstein Aging Study. Although their results supported prior research showing that job complexity demonstrated a protective effect on cognitive decline, individuals in more complex jobs exhibited faster rates of cognitive decline in cognitive processing speed and executive functioning after retirement. This finding is consistent with the "use it or lose it" notion; individuals in complex occupations build up higher levels of cognitive reserve and therefore have slower rates of cognitive decline in earlier stages of aging, but, when the brain reaches a point of advanced aging, then the decline is steeper. Steeper cognitive decline after retirement is consistent with the idea that the environment has changed, and therefore the protective effects of work no longer apply. One implication from this finding is that it might be cognitively beneficial for individuals in complex jobs to stay in their work longer in order to "keep the beneficial effect of mental stimulation accumulated throughout life" (Hyun et al., 2021: 678).

Studies examining neurological changes also support the use it or lose it hypothesis. For example, Oltmanns and colleagues (2017) reported results of a workplace intervention that introduced work task changes (i.e., novelty) among automotive manufacturing workers in Germany. Workers who experienced more work task changes (which we assume is associated with job complexity) over a 17-year period demonstrated better cognitive processing speed and working memory, as well as more gray matter volume in brain regions associated with learning and age-related cognitive decline. Likewise, in a study using MRI data based on 151 retired participants (aged 70 years or older) from the Sydney Memory and Aging Study, Suo et al. (2012) found that management experience in midlife was the dominant contribution to increased gray volume matter in the hippocampus. For a smaller subset of people, within their longitudinal neuroimaging data, there was much less atrophy in the hippocampal structure over the period for those with high levels of supervisory experience in midlife. Although supervising others involves work characteristics in addition to job complexity (e.g., higher job autonomy, relational work design), this study is intriguing in suggesting similar findings to those found within the lifespan or aging perspectives.

Relational work design. Drawing on similar logic to the studies described above, it has also been assumed in some literatures that many interactions with people at work, or lots of social contact, creates a form of "social complexity," which then affects cognition through differential preservation. In an early twin study, Andel et al. (2005) showed psychological demands in the form of complexity of work with people (involving, e.g., organizing tasks, supervising, and negotiation) was associated with a lower risk of Alzheimer's disease. Likewise, using data from a Scottish cohort study, Smart, Gow, and Deary (2014) showed that jobs with high complexity based on high social or interpersonal demands in one's main lifetime occupation predicted cognitive ability after controlling for cognitive ability at 11 years of age, and was more important than complexity with data and things. In a similar study with a stronger design (cognition assessed over six time points, and survey data assessed four times), and using twins from the Swedish Adoption/Twin Study of Aging, Finkel et al. (2009) found that the complexity of people from one's main occupation resulted in increases in verbal ability and buffered against declines in spatial ability, up until retirement, after controlling for education (complexity with data or things was again not significant in this model). Providing further evidence of differential preservation, following retirement, high complexity based on social or interpersonal demands related to a steeper decline in spatial abilities, consistent with the idea that complexity based on social job demands is a protective form of mental exercise. In other studies, Seidler et al. (2004) showed that high social demands were associated with a lower risk of dementia, and Andel et al. (2011), in a two-wave study, showed that low complexity based on social demands predicted higher cognitive impairment, and more so than low complexity based on other aspects of jobs.

Most lifespan studies, however, have neglected to consider what happens outside of work when investigating the link between work and cognition. An exception is Andel, Silverstein, and Kåreholt (2015). Using longitudinal data from two Swedish studies, and with a broad range of controls, their study showed that complexity of work with people (and data) related to better late-life cognition, as did social leisure activity. The authors also found a compensatory mechanism such that, when complexity of work with people was high, cognitive leisure activity was no longer significantly related to late-life cognition, and, at moderate levels of complexity with people, social leisure activity showed no relationship to late-life cognition. The authors argued that these results show that engaging in complex environments in midlife—be it through leisure of work—"grows" cognitive reserves for later life. However, this study did not examine change in cognition.

Summary. Taken together, job complexity, job autonomy, and social complexity can all be conceptualized as specific types of mental work demands (Fisher et al., 2014) that "use" greater levels of cognitive processes and use of cognitive abilities to mentally process information, make decisions, solve problems, and interact with others. Overall, there is fairly strong evidence supporting the use it or lose it pathway, with several studies indicating that job complexity, job autonomy, and social complexity protect against long-term cognitive decline, with the evidence most consistent for job autonomy. Some challenges of this literature, however, include a handful of contradictory studies, a failure to actually test the "use it or lose it" mechanism, and the use of occupational-level proxies to assess work design. With regard to the latter issue, as an example, "complexity with people" is coded by matching a person's occupation to the United States Department of Labor's online *Dictionary of Occupational Titles* (https://occupationalinfo.org), and then using the tasks from the occupation to infer the work design. This is a highly indirect way of assessing complexity, and such a measure likely conflates very different work characteristics, such as the degree of mental stimulation and social contact.

Accumulated Knowledge

Previously, we discussed how work design can accelerate the acquisition of deeper and broader knowledge. Extrapolated over time, we would expect that, via this accumulation process, work design will foster learning, which, over time, can lead to the development of expertise. A related term used in the cognitive aging literature is "crystallized intelligence," which is defined as knowledge or acculturation, and is a type of cognitive functioning that remains stable or increases with age (Horn & Cattell, 1967). "Wisdom" is conceptually similar and refers to the application of knowledge, often using judgment acquired through experience (Grossmann, 2017; Staudinger & Glück, 2011). No studies have linked work design to these sorts of accumulated knowledge outcome at this stage.

Although the cognitive aging literature has identified consistent age-related declines in fluid cognitive abilities, such as memory and reasoning, Ng and Feldman's (2008) meta-analysis examining the association between age and job performance found that job performance does not decline with age. One explanation for this result is the accumulation of knowledge and expertise over time, such that declines in memory and processing speed can be offset by increasing knowledge and experience. Another explanation corresponds to cognitive load theory (Sweller, 1988), in which the attentional resources and memory capacity needed to complete a task are reduced when the task is familiar. A physical example of this accumulated knowledge phenomenon is the development of long-term muscle memory, which develops based on increasing neuronal connections in the motor cortex as well as strengthening muscle fibers (Bachtiar et al., 2018). Muscle memory can improve athletic performance, such as physical agility or specialized skills (e.g., perfecting a golf swing).

Chronic Ill-Health Impairment

Earlier, we discussed how work stressors such as hindrance demands can cause a stress response, which interferes with learning. In the longer term, consistent with the allostatic load model of stress (Ganster & Rosen, 2013; McEwen & Stellar, 1993), exposure to chronic stressors (e.g., stressful life events) is associated with a higher prevalence of cognitive decline (e.g., memory impairment, dementia) among older adults (e.g., Peavy et al., 2009; Seeman, McEwen, Rowe, & Singer, 2001). Cortisol might be a key explanatory mechanism, with studies showing increased cortisol predicting reduced cognitive functioning (Lupien, Lecours, Lussier, Schwartz, Nair, & Meaney, 1994). In addition, the occupational health literature has found consistent support for a positive association between low autonomy–high demands jobs and cardiovascular disease (e.g., the Whitehall studies [Kuper & Marmot, 2003; Marmot, Rose, Shipley, & Hamilton, 1978]). This link may result from increased cortisol levels that weaken immune system functioning (Segerstrom & Miller, 2004), or other factors associated with chronic stress (e.g., obesity, poor sleep) that are known risk factors for cardiovascular disease. In turn, poor cardiovascular system functioning hampers attention and cognitive processing—and learning.

Nevertheless, despite the above theory and evidence suggesting that it is plausible to expect a link between work design and cognitive impairment over time via health processes, few studies have examined this link. Andel et al. (2012) provided some evidence, from an analysis of a population-based study of dementia in Swedish twins, that work characteristics (extrapolated from occupational data) relate to the risk of dementia. The authors found that lower job autonomy, in combination with lower social support and higher job demands, predicted a greater risk of any dementia, especially vascular dementia, as well as Alzheimer's disease, with the vascular dementia results suggesting to the authors the possibility of a strain–health mechanism in which chronic stress causes dysregulation of body systems such as the cardiovascular system (or allostasis). Interestingly, low autonomy alone predicted dementia risk for women. Although the specific mechanisms are not assessed, a handful of studies have linked psychosocial demands to declines in cognitive functioning over moderate to long time periods. For example, in the study described above, as well as showing a decline in vocabulary (crystallized intelligence), Virtanen and colleagues (2009) showed that people who worked longer hours performed worse five years later on reasoning tests, thus pointing to a change in fluid abilities. Ice et al. (2020) investigated work hours and work–family histories among women in 14 countries studied in the Survey of Health, Ageing, and Retirement in Europe and reported that partnered women who worked part-time performed best on tests of cognitive functioning, and partnered mothers who were unpaid caregivers performed lower on cognitive measures compared to full-time working mothers. The authors inferred that partnered women working part-time experience less stress, although the retrospective nature of the study has obvious limitations.

INTEGRATION AND IMPLICATIONS

In this section, we bring together the core findings from our review and identify key implications.

Implications for Work Design Research and Theory

Traditional work design theory, such as that articulated through the job characteristics model, has focused on the motivating potential of work, with the associated implications for outcomes like performance and turnover. Other theories have considered the stress and strain implications of excess demands and protective job resources. But what has been relatively neglected to date is the idea that work design can be a powerful force for enhancing or impairing cognition. Altogether, although the perspectives and time scales are diverse, we conclude from our review that *job autonomy, job feedback, relational work aspects, job complexity, and psychosocial demands can affect workers' cognition in the short to medium term, as well as in the long term, through multiple pathways*.

More specifically, research from the work design, human factors, and learning perspectives fields shows that work design can enhance or harm cognition in the short to medium term via multiple pathways. To date, the strongest evidence is for the *accelerated knowledge acquisition* and *motivated exploratory learning* pathways. The former emerges especially from a synergistic combination of autonomy, complexity (or demands), and feedback, although some evidence suggests for autonomy alone, and the latter arises especially from autonomy and relational characteristics such as social support. Feedback can also motivate learning, especially when it is quite general in form and comes from the job itself. Evidence is also strong at the task level (less so at the job level) that *depleted cognitive capacity* and hence reduced learning arises from excessive task complexity and highly monotonous vigilance tasks because of the high load on working memory and attention, respectively. In support of the *strain-impaired cognition* pathway, many studies show that low levels of autonomy, poorly designed feedback, and hindrance demands cause strain, and much evidence shows strain impairs learning, although only a handful of studies examine the links from work design to learning to strain. Finally, although few studies have explicitly focused on this process as a unique path, it is logical that well-designed work shapes workers' *opportunity for cognitive use*.

This short- to medium-term work design–cognition literature is important because it shows that work design is a powerful way to foster learning within a job, with consequences for individual job performance and, in aggregate, organizational performance, as well as consequences for individuals' skill development. Returning to the salesperson example, if a salesperson has job autonomy, this allows more complex decision-making that uses cognitive abilities (opportunities for cognitive use) as well as more opportunity to deal with variances at the source and hence to develop complex mental models about the work system (accelerated knowledge acquisition), greater ownership and hence a desire to learn to solve complex problems (motivated exploratory learning), and a greater capacity to mitigate stressful demands, thereby reducing both strain (strain-impaired cognition) as well as depletion (depleted cognitive capacity). All of these processes mean the salesperson is likely to not only use their cognition, but also develop and learn deeper and broader knowledge about the sales process and their clients, and thereby be more effective in their job.

Our review went beyond the short to medium term to consider the longer-term cognitive outcomes of work design. Deriving from different disciplinary perspectives including occupational health and lifespan gerontology, reasonably strong evidence has emerged to link occupational-level work design to long-term cognitive ability outcomes, such as the prevention of cognitive decline or lowered risk of Alzheimer's disease. This longitudinal research base, in which studies examine change in cognition, suggests that having autonomy and complexity in one's occupation can, over multiple years, protect against decline in cognitive abilities. Although the mechanisms are rarely assessed in this research, there is strong theory and evidence in other fields that these protective effects of work design occur via a "use it or lose it" process of *cognitive preservation*. For these occupational-level work characteristics, there is even some evidence of "dose" effects, such that longer-term exposures have stronger effects on preserving cognitive functioning. The fact that several studies show a decline in cognition after retirement for people in complex and autonomous jobs adds to the evidence base. Additionally, there is a small amount of evidence that work design features such as low autonomy and excessive demands can impair longer-term cognitive functioning through a *chronic ill-health pathway*. No studies that we are aware of have examined how long-term exposure to particular work designs result in *accumulated knowledge*, and in turn crystallized intelligence, deep expertise, and wisdom, despite the plausibility of this path.

The long-term research suggesting that work design can accumulate over time to affect the cognitive functioning of workers has multiple important organizational, societal, and economic implications. A salesperson who works for many years in a complex and autonomous job is more likely to maintain their cognitive functioning right up until retirement, whereas a salesperson working long-term in a tightly prescribed job with routine tasks is more likely to experience a decline in cognitive processes like working memory over time. As we discussed at the outset, maintaining cognitive functioning of employees is set to become more important for society and the economy because of the growing aging population. Staying in work longer increases the need to take steps to maintain mature workers' cognitive functioning, and our review suggests that work design is one vehicle by which this need might be better achieved.

Focusing on cognition as an outcome of work design will expand work design theory in new ways. For example, the idea that complex work promotes learning suggests more attention to work characteristics that generate a discrepancy between one's current level of knowledge or ability and that required in the task or job. A focus on "discrepancy" goes against traditional theories often drawn on in work design research, such as person environment–fit theory, which considers a misfit between the demands of a job and someone's abilities as a negative motivational state to be avoided. In fact, some misfit—such as work that stretches one knowledge, skills, and abilities—is what our brains need in the longer term to stay cognitively healthy. As Lövdén et al. (2010: 662) discussed, a "prolonged mismatch" between environmental demands and functional capacity is what drives brain plasticity. Of course, our review also shows that excess misfit will be problematic insofar as it is also important that workers manage the demands of their jobs, minimizing exposures to stressors or coping with unavoidable stressors in a way that limits strain. Lövdén et al. (2010: 662) reached a similar conclusion, arguing that "mismatches must be located between these two extremes (e.g., a too-easy and a too-difficult task) to trigger and direct plastic changes." The key point is that work can be deliberately designed to "use" and develop one's cognitive abilities, and to support the use and development of one's knowledge.

Practice and Policy Implications

Crucially, in most contexts, work can be redesigned. There is a long history of organizational interventions such as job enrichment, empowerment, and self-managing teams that increase variety and autonomy within work (Cordery, Mueller, & Smith, 1991; Kirkman & Rosen, 1999; Knight & Parker, 2021). These are mostly considered from the perspective of motivation and performance, but our review highlights their wider value for using employee knowledge and cognitive abilities, for fostering learning, and for cognitive health. Leader behavior can also affect work design, as do organizational cultures and technologies, which provides further avenues for intervention. For example, managers should aim to design and structure work in a way that can minimize job stressors, boredom, and fatigue, and to provide instrumental and social support to employees, when possible, to help alleviate or buffer potential stressors. Avoiding overprescribed work procedures and excessively standardized protocols, such as is increasingly prevalent in knowledge work (e.g., teachers being required to follow highly prescribed lesson plans), is one example of how organizational practices need to be altered to foster greater job autonomy and its associated cognitive benefits.

Earlier, we depicted how work design is also embedded within a broader public policy and legislative context, beyond the organization (see Figure 1). Change at this broader level might well be needed to bring about improved work designs that foster cognition over longer time spans. Large-scale population studies tend to show that well-designed work is lacking for many workers. For example, the sixth European Working Conditions survey (Eurofound, 2016) of over 44,000 workers showed that one out of five workers holds a "poor-quality" job (e.g., with low skill use, autonomy, and poor conditions), and a further 13% hold an "under-pressure" job (e.g., with excess demands) (see Parker, Van den Broeck, & Holman, 2017, for further such data). Likewise, levels of over-qualification, in which people's skills, experience, and education exceed the job requirements, are rife. For example, one U.S. study estimated that 34% of college graduates, and 44% of new college graduates, work in a job in which college education is not required (Federal Reserve Bank of New York, 2017), while other studies show that particular groups are vulnerable to over-qualification, such as migrants and minority groups (Nielsen, 2011). Such large-scale studies suggest that evidence-based knowledge about what constitutes work design is not being acted upon, with potential spillover consequences for the long-term cognitive functioning of large numbers of people.

National-level policies on aspects that affect the quality of work design, such as precarious employment, health and safety, and even automation and digitalization, should be considered from the perspective of the cognitive well-being of society. Take the case of automation and digitalization. On the one hand, there are projections for greater job complexity as a result of more routine tasks being carried out with the help of algorithms, robots, or other forms of digitalization (e.g., Brynjolfsson & McAfee, 2014)—a trend that implies both the greater need for fostering cognition in the workplace (Cohen & Levinthal, 1990) as well as the greater potential opportunity for work to promote cognitive development. On the other hand, digitalization has the potential to increase computer-based control in the workplace, which can hamper autonomy and reduce opportunities for learning (Parker & Grote, 2019). Evidence shows that applications of automation in manufacturing sometimes mean that workers become passive monitors who lose knowledge and skills, making it harder for them to recover operations should the automation break down. Even in professional contexts like surgery, learning can be hampered with new technologies. Beane (2018), for instance, showed that robots in surgery can reduce the opportunities for trainees to engage in challenging tasks, thereby impairing their learning. This research highlights the need to ensure positive work designs that support learning when implementing digital technologies. From a policy perspective, this means expanding consideration of the ethical implications of digital technologies beyond the current emphasis (e.g., biased algorithm-based decision-making) to include how these technologies affect work design. It also means going beyond the predominant focus on how many jobs will be replaced by technology to also considering the quality of the remaining jobs (Parker & Grote, 2019).

Individual Implications

Individuals likely understand the value of attending formal training for their development, but they may have less awareness of the importance for their learning and cognitive health of well-designed work. Likewise, individuals often understand the need to choose an "occupation" that is going to be intellectually stimulating, but they are less likely to recognize that—irrespective of occupational choice—the quality of jobs *within* their occupation will shape their lifelong learning. Thus, individuals should be encouraged to proactively achieve better work designs for themselves. Job crafting is one important "bottom-up" mechanism by which workers can mold their jobs to create better work designs (e.g., Tims, Bakker, & Derks, 2012), and this review especially highlights the importance of deliberately negotiating more job autonomy, building networks to increase social support, taking on more complex projects, and seeking feedback—all of which have positive cognitive consequences. O'Mahony and Bechky's (2006) research showed that some contract workers intentionally engage in "stretchwork" (work that includes some tasks that exceed existing competencies) to build skills over their career. Other self-initiated career strategies such as seeking promotions, or moving to new jobs or occupations, will help to foster cognitive outcomes if these moves result in better work designs. As noted above, such strategies will need to be balanced alongside recognizing limits and being aware of stressors that contribute to strain, depletion of cognitive resources, and poor health, which then lead to impaired cognitive functioning.

Nevertheless, evidence also shows some individuals are less likely to engage in crafting and other such proactive strategies to achieve better work designs. For example, people high in approach temperament, promotion focus, proactive personality, extraversion, conscientiousness, openness, and future-oriented thinking are more likely to engage in approach forms of crafting (see Zhang & Parker, 2019, for a summary) and to gravitate toward jobs with a richer task content (Brenninkmeijer, Vink, Dorenbosch, Beudeker, & Rink, 2018). Individuals lacking or low in approach or promotion focus might need additional support to craft their work. Socioeconomic status and age are also relevant factors to consider (Strenze, 2007). For example, Truxillo, Cadiz, Rineer, Zaniboni, and Fraccaroli (2012) argued, based on socioemotional selectivity theory, that younger workers will give knowledge-related goals higher priority because they perceive time as being more open ended, whereas older workers will give emotional goals a higher priority. Such a strategy might not be in the best interests of mature workers. At the same time, older people are less likely to craft their jobs (Ng & Feldman, 2008), even though this activity might in fact be more important for mature workers, some of whom face cognitive decline.

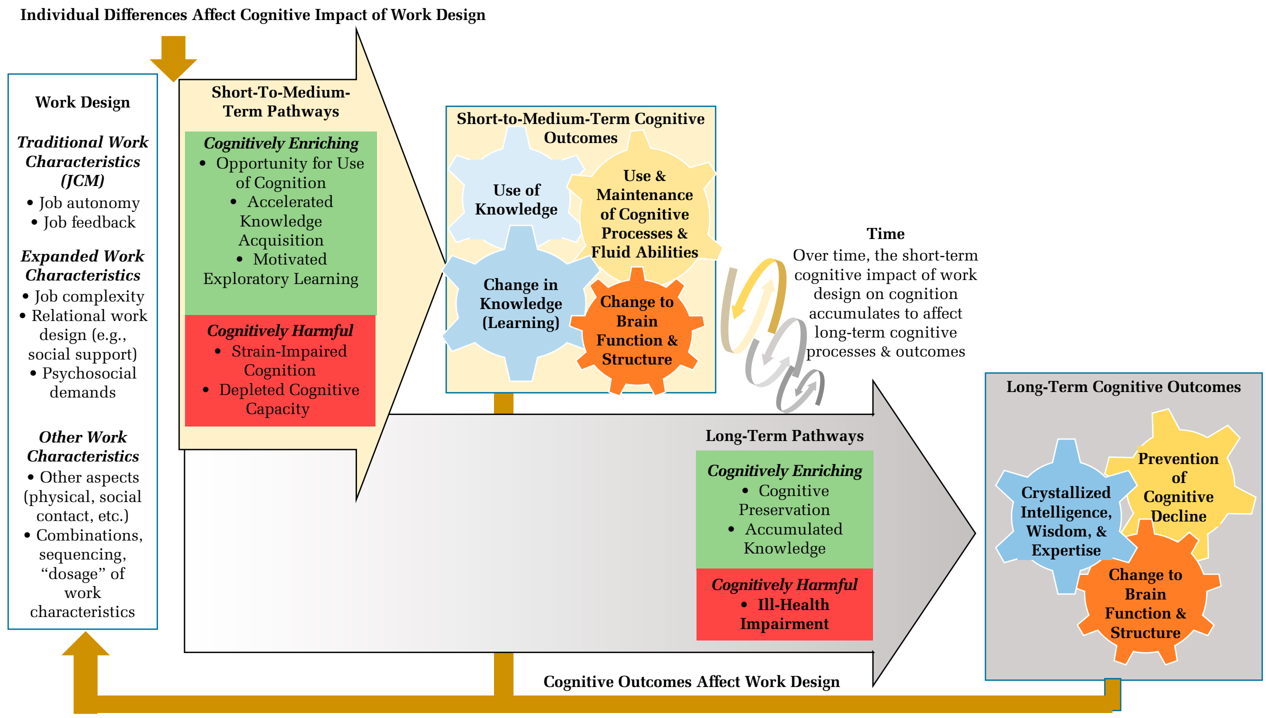
FUTURE DIRECTIONS

In Figure 4, we propose an integrative model to bring together the work design and cognition literatures that have been disconnected not just temporally, but also in terms of attention to distinct mechanisms, different types of cognition, and even different work design variables. Synthesizing these elements has identified important future directions, as we elaborate next (Table 2).

Connecting and Expanding the Pathways Linking Work Design and Cognition

We have identified multiple pathways, yet know little about whether and how these pathways interrelate. On the one hand, there are likely to be positive synergies, such as when work design motivates learning behaviors (*motivated exploratory learning*), with the ensuing behaviors, such as exploring alternative solutions, then *accelerating knowledge acquisition* and expanding the *opportunity for cognitive use*. On the other hand, there could well be tensions. For example, high levels of demands and autonomy can result in cognitively enhancing processes such

FIGURE 4
Integrative Model of Work Design and Cognition over Different Time Frames



Note: JCM = job characteristic model.

as motivated exploratory learning, but high demands are also likely to create some strain, and even cognitive depletion, so these processes could both be activated by enriched work, albeit potentially with different relative impacts. Questions to consider include, for example: "How do work–design cognitive pathways interrelate and interact, and do they have similar or different effects?"

More specifically, in Figure 4, we depict how short- to medium-term links between work design and cognition can accumulate over time to create longer-term outcomes. But little research has theorized, let alone tested, such temporal interactions. For example, conceptually, research linking work design to change in long-term cognitive abilities has mostly assumed (but not tested) a cognitive preservation process in which particular work characteristics such as complexity use more cognitive abilities which prevents their loss over time. But, as our model shows, work characteristics affect people's more immediate use of cognition in multiple ways (accelerates learning, motivated exploration, etc.), and these additional pathways are also likely to have cumulative effects over time, aggregating over a career to increase people's use of cognitive ability and hence preventing decline. We recommend developing and testing theory about the underpinning pathways linking work design and long-term cognitive ability to address the following questions: "Do short- to medium-term cognitive effects of work design on knowledge accumulate over time to affect cognitive abilities?" and "If so, exactly how does work design prevent a decline in cognitive abilities (i.e., through which pathways)?"

As our review demonstrated, most short- to medium-term studies linking work design and cognition have focused on knowledge or change in knowledge as the cognitive outcome. No studies that we are aware of have examined how work design affects either the use of cognitive processes or abilities or any change in cognitive processes or abilities. Instead, cognitive abilities tend to be antecedents to work design choices, or, occasionally, moderators of work design effects. Yet, it would be interesting to explore, for example, whether the move to self-managing teams (say) is associated with greater use of working memory or engagement in reasoning (i.e., enhanced use of cognitive

TABLE 2
Future Directions and Methodological Improvements

	Future Directions
Connecting and expanding the pathways	• How do work–design cognitive pathways interrelate and interact, and do they have similar or different effects?
	• Do short- to medium-term cognitive effects of work design on knowledge accumulate over time to affect cognitive abilities? If so, exactly how does work design prevent a decline cognitive abilities (i.e., through which pathways)?
	• Does work design have any impact on the use of, or maintenance of, cognitive abilities in the short to medium term?
	• Are there long-term effects on work design on crystallized intelligence, such as the development of wisdom, or accelerating the likelihood of an individual becoming a deep expert?
	• Are brain functions or structures affected by work design in the short and long term, and, if so, which structures and functions are affected and how do they relate to changes in cognitive processing and abilities?
Dynamics and timing of cognitive processes	• How long do protective effects of well-designed work last?
	• What are the dynamic effects of work design and cognition, such as the recursive effects of cognition on work design and the possibility of amplifying spirals?
Work design antecedents	• How *much* exposure to well-designed work is needed to engender long-term cognitive benefits, and how continuous does this exposure need to be?
	• What sequencing of work designs is most important?
	• Beyond complexity, autonomy, and stressful demands, what other work characteristics positively impact on workers' long-term cognition?
	• What are the cognitive effects of profiles of work characteristics?
Broader questions	• How do psychosocial aspects of work design interact with physical aspects of work and other factors outside of work?
	• Who benefits cognitively most and least from well-designed work, and are additional supports needed for some individuals?
	• How should work be designed to accommodate cognition?
	Methodological Suggestions
Measurement	• Use direct measures of work design rather than occupational proxies
	• Assess mechanisms directly and comprehensively
	• Use specific measures to assess specific cognitive abilities
	• Complement studies on cognition by using neurological techniques
Research design	• Measure work design, mechanisms, and cognition multiple times over the lifespan so that issues of exposure, timing, and causality can be unraveled
	• Design studies to disentangle level effects

abilities), as well as whether—as a result of this greater use—there is better preservation of cognitive ability over a five-year period, compared to similar workers whose jobs are deskilled. In other words, we recommend asking: "Does work design have any impact on the use of, or maintenance of, cognitive abilities in the short to medium term?"

The main focus of long-term studies linking work and cognition has been on changes in cognitive abilities—notably, the prevention of decline. However, we suggest in our integrative model that work design might not only change cognitive abilities, but also result in knowledge acquisition in the long term—that is, greater crystallized intelligence and wisdom. Indeed, it is well understood in the aging literature that mature workers possess crystallized intelligence and wisdom, but this is assumed to derive from their "work experience." What we propose here is that enriched work designs—high in autonomy, feedback, complexity, and support—can enhance workers' "work experiences," and thereby—in the longer term—accelerate and maintain mature workers' development of wisdom and deep expertise. Frese and Zapf (1994) discussed how exceptional performers in work can anticipate work situations better, and plan and achieve deep intellectual penetration of the task, resulting in an ability to perform fewer work activities yet be more effective. Perhaps quality work design helps to foster such advanced expertise? Such knowledge accumulation might also be important from a compensatory perspective. The notion of successful aging captures the idea that engaging in lifelong learning can help people to compensate for declining cognitive capabilities (Baltes, 1987).

Imagine our salesperson working for many years in an enriched job, which then fosters the development of complex mental models about the products, situational awareness about the company, and wisdom about handling difficult clients. Such accumulated knowledge will enable the salespersons' outstanding job performance, rapid promotion, further allocation of complex responsibilities, and so on, in a positive spiral over a career, rendering the salesperson a deep expert in the longer term, and allowing them to compensate for any deficit in cognitive abilities. This potential longer-term value of work design for knowledge accumulation has been neglected. We thus recommend asking: "Are there long-term effects on work design on crystallized intelligence, such as the development of wisdom, or accelerating the likelihood of an individual becoming a deep expert?"

In a similar vein, with rare exceptions (Oltmanns et al., 2017), studies have not considered the neurological effects of work design. We think it would be possible and worthwhile to explore, using experiments and simulations, the effects on brain function of engaging in enriched, autonomous work versus simplified work, in the same way that studies have examined the neural mechanisms underpinning the effects of various types of leadership (e.g., Molenberghs, Prochilo, Steffens, Zacher, & Haslam, 2017). For example, evidence shows that an increased use of working memory processes can result in changes to the density of dopamine receptors (Lövdén et al., 2010). We expect to see considerable new knowledge about the effects of job design on cognition over the next 10 to 20 years deriving from the application of the neurocognitive and neuroanatomy approaches. We recommend asking: "Are brain functions and/or structures affected by work design in the short and long term, and, if so, which structures and functions are affected and how do they relate to changes in cognitive processing and abilities?"

Dynamics and Timing of Cognitive Processes

Once we begin to connect short- to medium-term and long-term cognitive processes, important questions about the timing and dynamics of change arise. For example: "How long do protective effects of well-designed work last?" If one has spent 20 years in well-designed work, but opts for a low-quality and precarious position just before retirement, are cognitive benefits of the earlier work maintained? As depicted in the integrative model, we also need to consider recursive relationships among work characteristics and cognition. In other words, we focused here on how work design affects cognition, but, of course, cognition also affects work design. From a lifespan perspective, there is evidence of that an individuals' initial cognitive functioning predicts their aging success, presumably in part from the work designs they opt into or craft; and, from a career perspective, there is evidence of the gravitational hypothesis (McCormick, Jeanneret, & Mecham, 1972), in which individuals gravitate toward jobs and occupations that fit their mental ability. This means that positive spirals might occur in which individuals with higher cognitive abilities select into, or craft, better work designs that, in turn, are likely to maintain those cognitive abilities.

Indeed, it might be that, over time, as the cyclical relationships repeat among these variables, effects on cognitive functioning amplify. Such a process would be similar to what de Lange, Taris, Kompier, Houtman, and Bongers (2005) referred to as an "upward selection mechanism," in which cognitively effective workers are more likely to be promoted to stimulating work, or to be allocated more challenging tasks, and a "drift" mechanism, in which cognitively less effective workers tend to end up in poorer-quality work. Theoretically, such time-based mechanisms are consistent with similar arguments that have been made in relation to work and personality change. For example, the corresponsive principle (Roberts, Caspi, & Moffitt, 2003) proposes that life experiences will strengthen individual characteristics that bring people to such life experiences in the first place (Frese, Garst, & Fay, 2007). Research from other work design domains support such spirals. For example, using a four-wave study, Frese et al. (2007) showed that work characteristics affected personal initiative via control orientation, and control orientation and personal initiative affected later work characteristics, in a positive spiral. Altogether, therefore, we need to ask questions such as: "What are the dynamic effects of work design and cognition, such as the recursive effects of cognition on work design and the possibility of amplifying spirals?"

Work Design Antecedents of Cognition

Our review shows that work design affects cognition, but there is more to do to unpack about the "work design" part of this equation. One important set of questions is as follows: "How *much* exposure to well-designed work is needed to engender long-term cognitive benefits?" and "How continuous does this exposure need to be?" Thus, there is emerging evidence about the "dose" of well-designed work, but this research is in its infancy. We know little about the impact of multiple jobs over a career. Lifespan effects of work design on cognition are largely based on the concept of "lifelong" jobs or occupations. Yet, the idea of staying in one job or one occupation for the entirety of a career is increasingly outdated. This gives rise to questions such as "What combinations of work design across a career are likely to be cognitively beneficial?" and "What impact will more frequent and varied career changes have?" High switching means more uncertainty and reduced ability to make longer-term plans, which might reduce people's sense of control. For people working in multiple jobs at one point in time, perhaps they will need to balance their various jobs based on the work design of each, and check that they are getting key work design ingredients from their portfolio rather than a single job? Such questions have yet to be explored.

A further question is as follows: "What sequencing of work designs across a work life is most important?" That is, when is it most important for work designs to help people preserve their cognitive functioning? Is it best to maximize the opportunity for cognitive development when one is younger, by designing the most challenging work, or, in fact, does it mean that, during this time, since cognitive mechanics are at their peak anyway, challenging work makes less difference? Answers to such questions have important implications for choices about work design. For example, cognitive speed (important for higher-order cognitive processes) is higher at younger ages (Hartshorne & Germine, 2015), which might lead to a recommendation that managers should give the most intellectually challenging work to younger employees. But perhaps it is more important to have complex work designs at the end of one's career, to maximize the cognitive reserve available for retirement?

There is also more to learn about *which aspects of psychosocial work design are important, and for which pathways*? Lifespan and occupational health studies focus mostly on job (and people) complexity and job autonomy, and, to some extent, psychosocial demands. To the extent that relational aspects are considered, most attention is given to people complexity, rather than the amount of social contact people have at work or even their level of social support they receive. There is a great deal of evidence from the aging literature showing the strain-reducing effects of support (see Sherman, Cheng, Fingerman, & Schnyer, 2016), and the work design literature shows that support is motivating (Parker, Van den Broeck, & Holman, 2017), so support at work might play a stronger role in mitigating against cognitive decline than hitherto assumed. Likewise, there are many work design aspects that have had almost no attention in relation to cognition, either in the short or long term. For example, role clarity might increase the likelihood that a worker can retain cognitive benefits from a complex environment; and task significance (the perception of doing something worthwhile) or contact with beneficiaries (e.g., connecting with end users of the work) might provide a strong motivation to learn to do one's job better, thereby fostering more learning over a lifespan. Lifespan theories of aging would predict that older workers might especially respond positively to task significance because they are more focused on meaning in their work (Kanfer & Ackerman, 2004).

The existing research has also mostly glossed the surface in terms of the effects of demands, with human factors research being more nuanced in the types of demands it considers (e.g., visual, auditory, psychosocial, physical). As work changes, new or amended work characteristics will also emerge. For example, there might be wider, yet weaker, sets of network ties, more often mediated through electronic systems rather than in-person interactions. Could this lead to more superficial conversations, sharing, and hence less learning from each other? As previously discussed, the potential for invasive monitoring through digital devices is also now much greater, which might impair cognition because of the heightened stress and intensity these systems can cause. In sum, we recommend investigating the question: "Beyond complexity, autonomy, and stressful demands, what work characteristics positively impact on workers' long-term and short- to medium-term cognition?"

There has also been some attention to the combination of demands and control, but, overall, there is much more scope to consider combinations of work characteristics (Parker, 2014). For example, a complex job without social contact and support might increase stress, which narrows attention and restricts learning, implying the value of examining complexity and support together. Likewise, a challenging and stimulating job, which this review suggests might positively affect cognition, might well be associated with much greater amounts of time spent sitting, with this review suggesting that sedentary work might impair cognition, resulting in a net null effect. We recommend asking: "What are the cognitive effects of profiles of work characteristics?"

Broader Questions

Our focus in this review has been on the psychosocial aspects of work design, but we need to consider the following question: "How do psychosocial aspects of work design interact with physical aspects of work, and other factors outside of work?" For instance, one study we reviewed found that leisure might compensate for social complexity at work, suggesting that cognitive stimulation is important in one domain or other, but not necessarily both. This result is important, especially in light of prior research by Potter and colleagues (2008), who found an interaction between earlier-life cognitive ability, cognitive job complexity, and cognitive functioning such that workers with lower levels of cognitive abilities in earlier life seemed to benefit more from cognitively complex work. Nevertheless, there is much scope to examine further how aspects of work might interact with factors outside of work. For example, physical activity outside of work might be especially important when individuals engage in mentally stimulating work that means they are rather sedentary at work. On the other hand, physical activity outside of work might have a negligible effect for people with high physical work demands. Another outside work aspect that has had little attention in relation to work design is sleep. For example, the effects of work demands on cognition might actually be mediated through disruptive sleep patterns. Alternatively, achieving reasonable sleep might be an important complement to stimulating work. Such interactions between work and nonwork or sleep have not been considered. At the least, future research should control for such activities.

Our model depicts a potential role for individual differences as a moderator of the link between work design and cognition (see the brown arrow in Figure 4). It is well recognized in the neurological studies on environmental enrichment that "enrichment" for humans arises not only from environmental complexity, but also from one's inclination to participate in the environment and the frequency of such participation (Sale, Berardi, & Maffei, 2014). The idea that environment and individual factors interact to affect outcomes is also consistent with work design research showing that individuals react differently to work characteristics depending on their personality (Parker, 2014), and is also consistent with studies that examine leader development over time (DeRue & Wellman, 2009). With the exception of some studies showing that less educated or lower cognitive ability individuals might benefit most from enriched work, the predominant perspective in long-term lifespan studies is that work factors such as occupational complexity have main effects on cognition. Hence, we ask: "Who benefits cognitively most or least from well-designed work, and are extra supports needed for some?"

It is important to acknowledge that our focus in this article has been on how work design affects cognition, rather than how cognition shapes work design, and especially the idea that work can be designed to accommodate people's level of cognitive ability as well as changes in cognition. For example, evidence suggests cognitive processing involving social intelligence peaks later in life (at around 45–50 years old; Hartshorne & Germine, 2015). Perhaps managers could leverage this enhanced cognitive ability to recognize emotions in faces, and increase relational aspects of work design for older workers? In terms of accommodating changes in cognition through work design, according to Craik and Byrd (1982), environmental supports can be developed to assist older adults by decreasing cognitive processing requirements. Such changes can allow mature workers to be effective in their work. Finally, some highly innovative work redesign interventions deliberately create inclusive work designs that offer new roles for intellectually disabled individuals (Zijlstra, van Ruitenbeek, Mulders, & van Lierop, 2017).

METHODOLOGICAL IMPROVEMENTS

Here, we identify improvements that will strengthen the evidence base going forward.

Measurement

Empirically, the effects of work design on long-term cognition might have been underestimated. Focusing on occupation-level attributes in the lifespan approach likely understates the role of work design in influencing cognition. While there are undoubtedly occupation-level influences levels on work characteristics, work design is affected by many factors beyond occupation, such as national-level factors (e.g., institutional regimes), the design of the organization in which the job is conducted, the behavior of one's leader, and the job incumbent's own actions within the job (e.g., crafting; Parker, Andrei, & Van den Broeck, 2019). Indeed, occupations have a relatively small influence on psychosocial work characteristics. Dierdorff and Morgeson (2013) showed the percentage of variance in work design due to occupation was low for most psychosocial work characteristics, such as job complexity (5.1%), job autonomy (13.6%), task variety (1.9%), social support (2.3%), and feedback from others (4.8%), with feedback from the job (17.2%) being somewhat of an exception, and physical work characteristics being quite well captured by occupational data (32.8%). In addition, when work design is measured indirectly, such as by matching a person's occupation to the *Dictionary of Occupational Titles* or Occupational Information Network (O*NET) database (https://www.onetonline.org) and then using the tasks for the occupation to *infer* the work design, this approach is imprecise. For example, the "taking instructions" task in the *Dictionary* is coded as low social complexity, when in fact this task might also be low in autonomy. Therefore, when the influence of work on cognition is modeled using occupational proxies, work design is only loosely captured, likely underestimating the effect of work on long-term change in cognitive functioning and creating uncertainty as to which characteristics matter. We recommend the following approach: *Use direct measures of work design rather than occupational proxies.*

As previously discussed, cohort studies with nonexperimental designs comprise the bulk of studies that investigate change in cognitive functioning as one ages, but explanatory mechanisms have almost never been assessed. In part, this is because most of these studies have been designed with other purposes in mind. As new studies are designed, we recommend *directly assessing the full range of possible mechanisms* that might link work design and cognitive abilities. In terms of assessing cognitive processes or abilities, we advocate *using specific measures to assess particular domains of cognitive ability*, rather than collapsing aspects into a single score as has often been done. Specific cognitive abilities exhibit different trajectories of change (Horn & Cattell, 1967; Park, 2000), and pooling functions into one score might attenuate or mask significant effects of work design. Another issue with using an overall cognitive score is that work design might differentially impact specific cognitive functions. For example, a job with high complexity buffers cognitive aging, yet sedentary time does the reverse (Lane et al., 2017). In addition, future research would benefit from *complementing measures of cognition with neurocognitive assessments*.

Research Design and Levels of Analysis

To further advance the literature, we recommend *direct assessments of work design and cognition multiple times over one's career*, so that it is possible to examine issues such as the degree of "exposure" required for a work characteristic to have an impact. For example, as recommended by Parker, Andrei, and Li (2014), using multi-wave panels with evenly and unevenly spaced waves allows the chance to examine or control for time-variant effects (via evenly-spaced time lags) while examining how work design affects outcomes (via unevenly spaced time lags). Across-time change in work characteristics can also be considered (e.g., Landsbergis & Theorell, 2000) and reverse causal or reciprocal processes should be routinely tested. Particularly useful for understanding causality might be the opportunity to examine the effect of change in work characteristics on change in cognition, ruling out beta and gamma changes in perceived work characteristics as rival explanations (Golembiewski, Billingsley, & Yeager, 1976). This might mean conducting research during important transitions, such as when a person moves to a new job, or when a person's job is automated.

In this domain of research, it is also crucial to *consider levels of analysis issues*. As we showed in the review, complexity at the task and job level can have opposite effects. For example, while cognitive load at the within-person task level can be negative with respect to learning a specific task (e.g., because of the greater drain on working memory), cognitive load in the form of complex work within a job can be positive for motivation and learning. It is important to avoid the "fallacy of the wrong level" (Klein, Dansereau, & Hall, 1994) by designing studies to disentangle effects at different level.

CONCLUSION

Our review and analysis of the psychosocial work design and cognition literature identified five perspectives: (a) work design, (b) learning, (c) human factors, (d) lifespan or aging, and (e) occupational health. Based on these distinct perspectives, we described cognitively-enriching and cognitively-harmful mechanisms by which work characteristics can lead to short- to medium-term use and maintenance of cognitive abilities, as well as changes in knowledge, followed by the prevention of cognitive decline for working adults over their lifespan, longer-term acquisition of knowledge or crystallized intelligence, and possible changes in brain structure and function. The empirical evidence regarding the ways in which our work can shape our short- to medium- and longer-term cognition is growing, suggesting it is important to design work in ways that will foster cognitive enrichment through autonomy, feedback, learning, and motivation, and minimize cognitively harmful effects (e.g., work-related stress, lack of feedback). The benefits of well-designed work and positive cognitive outcomes apply to workers, organizations, and society as a whole.

REFERENCES

Aiello, J. R., & Kolb, K. J. 1995. Electronic performance monitoring and social context: Impact on productivity and stress. ***Journal of Applied Psychology***, 80: 339–353.

Andel, R., Crowe, M., Hahn, E. A., Mortimer, J. A., Pedersen, N. L., Fratiglioni, L., Johansson, B., & Gatz, M. 2012. Work-related stress may increase the risk of vascular dementia. ***Journal of the American Geriatrics Society***, 60: 60–67.

Andel, R., Crowe, M., Kåreholt, I., Wastesson, J., & Parker, M. G. 2011. Indicators of job strain at midlife and cognitive functioning in advanced old age. ***Journals of Gerontology: Series B***, 66B: 287–291.

Andel, R., Crowe, M., Pedersen, N. L., Mortimer, J., Crimmins, E., Johansson, B., & Gatz, M. 2005. Complexity of work and risk of Alzheimer's disease: A population-based study of Swedish twins. ***Journals of Gerontology: Series B***, 60: 251–258.

Andel, R., Finkel, D., & Pedersen, N. L. 2015. Effects of preretirement work complexity and postretirement leisure activity on cognitive aging. ***Journals of Gerontology: Series B***, 71: 849–856.

Andel, R., Infurna, F. J., Hahn Rickenbach, E. A., Crowe, M., Marchiondo, L., & Fisher, G. G. 2015. Job strain and trajectories of change in episodic memory before and after retirement: Results from the Health and Retirement Study. ***Journal of Epidemiology and Community Health***, 69: 442–446.

Andel, R., Silverstein, M., & Kåreholt, I. 2015. The role of midlife occupational complexity and leisure activity in late-life cognition. ***Journals of Gerontology: Series B***, 70: 314–321.

Aoki, M. 1986. Horizontal vs. vertical information structure of the firm. ***American Economic Review***, 76: 971–983.

Bachtiar, V., Johnstone, A., Berrington, A., Lemke, C., Johansen-Berg, H., Emir, U., & Stagg, C. J. 2018. Modulating regional motor cortical excitability with noninvasive brain stimulation results in neurochemical changes in bilateral motor cortices. ***Journal of Neuroscience***, 38: 7327–7336.

Balcazar, F., Hopkins, B. L., & Suarez, Y. 1985. A critical, objective review of performance feedback. ***Journal of Organizational Behavior Management***, 7: 65–89.

Baltes, P. B. 1987. Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. ***Developmental Psychology***, 23: 611–626.

Bandura, A. 1989. Human agency in social cognitive theory. ***American Psychologist***, 44: 1175–1184.

Bartlett, C. A., & Ghoshal, S. 1998. Beyond strategic planning to organization learning: Lifeblood of the individualized corporation. ***Strategy and Leadership***, 26: 34–39.

Beane, M. 2018. Shadow learning: Building robotic surgical skill when approved means fail. ***Administrative Science Quarterly***, 64: 87–123.

Beehr, T. A., Jex, S. M., Stacy, B. A., & Murray, M. A. 2000. Work stressors and coworker support as predictors of individual strain and job performance. ***Journal of Organizational Behavior***, 21: 391–405.

Bergman, P. N., Ahlberg, G., Johansson, G., Stoetzer, U., Åborg, C., Hallsten, L., & Lundberg, I. 2012. Do job demands and job control affect problem-solving? ***Work and Stress***, 42: 195–203.

Birdi, K., Allan, C., & Warr, P. 1997. Correlates and perceived outcomes of 4 types of employee development activity. ***Journal of Applied Psychology***, 82: 845–857.

Bosma, H., van Boxtel, M. P. J., Ponds, R. W. H. M., Houx, P. J. H., & Jolles, J. 2003. Education and age-related cognitive decline: The contribution of mental workload. ***Educational Gerontology***, 29: 165–173.

Boström, E., Hörnsten, Å., Lundman, B., Stenlund, H., & Isaksson, U. 2013. Role clarity and role conflict among Swedish diabetes specialist nurses. ***Primary Care Diabetes***, 7: 207–212.

Brenninkmeijer, V., Vink, M., Dorenbosch, L. W., Beudeker, D. A., & Rink, F. 2018. Regulatory fit at work: Gravitational effects and associations with employee well-being. ***European Journal of Work and Organizational Psychology***, 27: 809–821.

Brynjolfsson, E., & McAfee, A. 2014. ***The second machine age: Work, progress, and prosperity in a time of brilliant technologies***. New York, NY: WW Norton & Company.

Burzynska, A. Z., Jiao, Y., & Ganster, D. C. 2018. Adult-life occupational exposures: Enriched environment or a stressor for the aging brain? ***Work, Aging and Retirement***, 5: 3–23.

Caka, E. M., & Lekalakala-Mokgele, S. 2013. The South African military nursing college pupil enrolled nurses' experiences of the clinical learning environment. ***Health SA Gesondheid***, 18: 1–11.

Caka, E. M., Van Rooyen, R. M., & Jordan, P. 2015. Dual transitions in nursing: A military perspective. ***Africa Journal of Nursing and Midwifery***, 17(Suppl. 1): 191–208.

Cannon-Bowers, J. A., Salas, E., & Converse, S. 1993. Shared mental models in expert team decision making. In J. N. Castellan, Jr., (Ed.), ***Individual and group decision making: Current issues***: 221–246. Hillsdale, NJ: Lawrence Erlbaum Associates.

Carpini, J. A., Parker, S. K., & Griffin, M. A. 2017. A look back and a leap forward: A review and synthesis of the individual work performance literature. ***Academy of Management Annals***, 11: 825–885.

Carver, C. S., & Scheier, M. F. 1981. The self-attention-induced feedback loop and social facilitation. ***Journal of Experimental Social Psychology***, 17: 545–568.

Cerasoli, C. P., Alliger, G. M., Donsbach, J. S., Mathieu, J. E., Tannenbaum, S. I., & Orvis, K. A. 2018. Antecedents and outcomes of informal learning behaviors: A meta-analysis. ***Journal of Business and Psychology***, 33: 203–230.

Chan, M. C. E., & Sfard, A. 2020. On learning that could have happened: The same tale in two cities. ***Journal of Mathematical Behavior***, 60: 100815.

Chen, J. Y. C., & Barnes, M. J. 2012. Supervisory control of multiple robots in dynamic tasking environments. ***Ergonomics***, 55: 1043–1058.

Cherns, A. 1976. The principles of sociotechnical design. ***Human Relations***, 29: 783–792.

Cherns, A. 1987. Principles of sociotechnical design revisited. ***Human Relations***, 40: 153–161.

Chmielewski, W. X., Mückschel, M., Stock, A.-K., & Beste, C. 2015. The impact of mental workload on inhibitory control subprocesses. ***NeuroImage***, 112: 96–104.

Clegg, C. 2000. Sociotechnical principles for system design. ***Applied Ergonomics***, 31: 463–477.

Clouston, S. A. P., Brewster, P., Kuh, D., Richards, M., Cooper, R., Hardy, R., Rubin, M. S., & Hofer, S. M. 2013. The dynamic relationship between physical function and cognition in longitudinal aging cohorts. ***Epidemiologic Reviews***, 35: 33–50.

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. 2011. Science mapping software tools: Review, analysis, and cooperative study among tools. ***Journal of the American Society for Information Science and Technology***, 62: 1382–1402.

Cohen, W. M., & Levinthal, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly***, 35: 128–152.

Cohen-Lazry, G., Borowsky, A., & Oron-Gilad, T. 2017. The effects of continuous driving-related feedback on drivers' response to automation failures. ***Proceedings of the Human Factors and Ergonomics Society Annual Meeting***, 61: 1980–1984.

Colarelli, S. M., Dean, R. A., & Konstans, C. 1987. Comparative effects of personal and situational influences on job outcomes of new professionals. ***Journal of Applied Psychology***, 72: 558–566.

Colquitt, J. A., LePine, J. A., & Noe, R. A. 2000. Toward an integrative theory of training motivation: A meta-analytic path analysis of 20 years of research. ***Journal of Applied Psychology***, 85: 678–707.

Cordery, J. L., Mueller, W. S., & Smith, L. M. 1991. Attitudinal and behavioral effects of autonomous group working: A longitudinal field study. ***Academy of Management Journal***, 34: 464–476.

Craik, F. I. M., & Byrd, M. 1982. Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik (Ed.), ***Aging and cognitive processes***: 191–211. New York, NY: Plenum Press.

Crawford, E. R., LePine, J. A., & Rich, B. L. 2010. Linking job demands and resources to employee engagement and burnout: A theoretical extension and meta-analytic test. ***Journal of Applied Psychology***, 95: 834–848.

de Lange, A. H., Taris, T. W., Jansen, P., Kompier, M. A. J., Houtman, I. L. D., & Bongers, P. M. 2010. On the relationships among work characteristics and learning-related behavior: Does age matter? ***Journal of Organizational Behavior***, 31: 925–950.

de Lange, A. H., Taris, T. W., Kompier, M. A. J., Houtman, I. L. D., & Bongers, P. M. 2005. Different mechanisms to explain the reversed effects of mental health on work characteristics. ***Scandinavian Journal of Work, Environment & Health***, 31: 3–14.

Debowski, S., Wood, R. E., & Bandura, A. 2001. Impact of guided exploration and enactive exploration on self-regulatory mechanisms and information acquisition through electronic search. ***Journal of Applied Psychology***, 86: 1129–1141.

Dellot, B., & Wallace-Stephens, F. 2017, September 18. ***The age of automation: Artificial intelligence, robotics and the future of low-skilled work***. Retrieved from https://www.thersa.org/globalassets/pdfs/reports/rsa_the-age-of-automation-report.pdf

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. 2001. The job demands–resources model of burnout. ***Journal of Applied Psychology***, 86: 499–512.

DeNisi, A. S., & Kluger, A. N. 2000. Feedback effectiveness: Can 360-degree appraisals be improved? ***Academy of Management Perspectives***, 14: 129–139.

DeRue, D. S., & Wellman, N. 2009. Developing leaders via experience: The role of developmental challenge, learning orientation, and feedback availability. ***Journal of Applied Psychology***, 94: 859–875.

Dierdorff, E. C., & Morgeson, F. P. 2013. Getting what the occupation gives: Exploring multilevel links between work design and occupational values. ***Personnel Psychology***, 66: 687–721.

Ding, X., & Yang, Z. 2020. Knowledge mapping of platform research: A visual analysis using VOSviewer and CiteSpace. ***Electronic Commerce Research***. Published online. doi: 10.1007/s10660-020-09410-7

Dong, L., Eaton, W. W., Spira, A. P., Agnew, J., Surkan, P. J., & Mojtabai, R. 2018. Job strain and cognitive change: The Baltimore Epidemiologic Catchment Area follow-up study. ***Occupational and Environmental Medicine***, 75: 856–862.

Druskat, V. U., & Pescosolido, A. T. 2002. The content of effective teamwork mental models in self-managing teams: Ownership, learning and heedful interrelating. ***Human Relations***, 55: 283–314.

Elfering, A., Grebner, S., & de Tribolet-Hardy, F. 2013. The long arm of time pressure at work: Cognitive failure and commuting near-accidents. ***European Journal of Work and Organizational Psychology***, 22: 737–749.

Elovainio, M., Ferrie, J. E., Singh-Manoux, A., Gimeno, D., De Vogli, R., Shipley, M. J., Vahtera, J., Brunner, E. J., & Kivimäki, M. 2009. Cumulative exposure to high-strain and active jobs as predictors of cognitive function: The Whitehall II study. ***Occupational and Environmental Medicine***, 66: 32–37.

Endsley, M. R. 1995. Towards a theory of situation awareness in dynamic systems. ***Human Factors***, 37: 32–64.

Endsley, M. R. 2017. Autonomous driving systems: A preliminary naturalistic study of the Tesla Model S. ***Journal of Cognitive Engineering and Decision Making***, 11: 225–238.

Endsley, M. R. 2018. Level of automation forms a key aspect of autonomy design. ***Journal of Cognitive Engineering and Decision Making***, 12: 29–34.

Endsley, M. R., & Kiris, E. O. 1995. The out-of-the-loop performance problem and level of control in automation. ***Human Factors***, 37: 381–394.

Eurofound. 2016, November 17. ***Sixth European working conditions survey – Overview report***. Retrieved from https://www.eurofound.europa.eu/publications/report/2016/working-conditions/sixth-european-working-conditions-survey-overview-report

Facteau, J. D., Dobbins, G. H., Russell, J. E. A., Ladd, R. T., & Kudisch, J. D. 1995. The influence of general perceptions of the training environment on pretraining motivation and perceived training transfer. ***Journal of Management***, 21: 1–25.

Federal Reserve Bank of New York. 2017. The labor market for recent college graduates [Data set]. Retrieved from https://www.newyorkfed.org/research/college-labor-market/college-labor-market_underemployment_rates.html

Finkel, D., Andel, R., Gatz, M., & Pedersen, N. L. 2009. The role of occupational complexity in trajectories of cognitive aging before and after retirement. ***Psychology and Aging***, 24: 563–573.

Fisher, G. G., Chaffee, D. S., & Sonnega, A. 2016. Retirement timing: A review and recommendations for future research. ***Work, Aging and Retirement***, 2: 230–261.

Fisher, G. G., Chaffee, D. S., Tetrick, L. E., Davalos, D. B., & Potter, G. G. 2017. Cognitive functioning, aging, and work: A review and recommendations for research and practice. ***Journal of Occupational Health Psychology***, 22: 314–336.

Fisher, G. G., Stachowski, A., Infurna, F. J., Faul, J. D., Grosch, J., & Tetrick, L. E. 2014. Mental work demands, retirement, and longitudinal trajectories of cognitive functioning. ***Journal of Occupational Health Psychology***, 19: 231–242.

Foss, N. J., Minbaeva, D. B., Pedersen, T., & Reinholt, M. 2009. Encouraging knowledge sharing among employees: How job design matters. ***Human Resource Management***, 48: 871–893.

Frese, M. 1982. Occupational socialization and psychological development: An underemphasized research perspective in industrial psychology. ***Journal of Occupational Psychology***, 55: 209–224.

Frese, M., & Fay, D. 2001. Personal initiative: An active performance concept for work in the 21st century. ***Research in Organizational Behavior***, 23: 133–187.

Frese, M., Garst, H., & Fay, D. 2007. Making things happen: Reciprocal relationships between work characteristics and personal initiative in a four-wave longitudinal structural equation model. ***Journal of Applied Psychology***, 92: 1084–1102.

Frese, M., & Zapf, D. 1994. Action as the core of work psychology: A German approach. In H. C. Triandis, M. D. Dunnette, & L. M. Hough (Eds.), ***Handbook of industrial and organizational psychology***, vol. 4 (2nd ed.): 271–340. Palo Alto, CA: Consulting Psychologists Press.

Frey, C. B., & Osborne, M. A. 2017. The future of employment: How susceptible are jobs to computerisation? ***Technological Forecasting and Social Change***, 114: 254–280.

Gabriel, A. S., Frantz, N. B., Levy, P. E., & Hilliard, A. W. 2014. The supervisor feedback environment is empowering, but not all the time: Feedback orientation as a critical moderator. ***Journal of Occupational and Organizational Psychology***, 87: 487–506.

Galy, E., Paxion, J., & Berthelon, C. 2018. Measuring mental workload with the NASA-TLX needs to examine each dimension rather than relying on the global score: An example with driving. ***Ergonomics***, 61: 517–527.

Ganster, D. C., & Rosen, C. C. 2013. Work stress and employee health: A multidisciplinary review. ***Journal of Management***, 39: 1085–1122.

Golembiewski, R. T., Billingsley, K., & Yeager, S. 1976. Measuring change and persistence in human affairs: Types of change generated by OD designs. ***Journal of Applied Behavioral Science***, 12: 133–157.

Goodman, J. S., Wood, R. E., & Chen, Z. 2011. Feedback specificity, information processing, and transfer of training. ***Organizational Behavior and Human Decision Processes***, 115: 253–267.

Gow, A. J., Avlund, K., & Mortensen, E. L. 2014. Occupational characteristics and cognitive aging in the Glostrup 1914 cohort. ***Journals of Gerontology: Series B***, 69: 228–236.

Grant, A. M. 2007. Relational job design and the motivation to make a prosocial difference. ***Academy of Management Review***, 32: 393–417.

Grant, A. M., & Parker, S. K. 2009. Redesigning work design theories: The rise of relational and proactive perspectives. ***Academy of Management Annals***, 3: 317–375.

Grossmann, I. 2017. Wisdom in context. ***Perspectives on Psychological Science***, 12: 233–257.

Grzywacz, J. G., Segel-Karpas, D., & Lachman, M. E. 2016. Workplace exposures and cognitive function during adulthood: Evidence from National Survey of Midlife Development and the O* NET. ***Journal of Occupational and Environmental Medicine***, 58: 535–541.

Hacker, W. 1985. Activity: A fruitful concept in industrial psychology. In M. Frese & J. Sabini (Eds.), ***Goal-directed behavior: The concept of action in psychology*** (pp. 262–283). Hillsdale, NJ: Erlbaum.

Hackman, J. R., & Oldham, G. R. 1976. Motivation through the design of work: Test of a theory. ***Organizational Behavior and Human Performance***, 16: 250–279.

Haji, F. A., Rojas, D., Childs, R., de Ribaupierre, S., & Dubrowski, A. 2015. Measuring cognitive load: Performance, mental effort and simulation task complexity. ***Medical Education***, 49: 815–827.

Hartshorne, J. K., & Germine, L. T. 2015. When does cognitive functioning peak? The asynchronous rise and fall of different cognitive abilities across the life span. ***Psychological Science***, 26: 433–443.

Hockey, G. R. J. 1997. Compensatory control in the regulation of human performance under stress and high workload: A cognitive–energetical framework. ***Biological Psychology***, 45: 73–93.

Holford, W. D. 2019. The future of human creative knowledge work within the digital economy. ***Futures***, 105: 143–154.

Holman, D. J., & Wall, T. D. 2002. Work characteristics, learning-related outcomes, and strain: A test of competing direct effects, mediated, and moderated models. ***Journal of Occupational Health Psychology***, 7: 283–301.

Horn, J. L., & Cattell, R. B. 1967. Age differences in fluid and crystallized intelligence. ***Acta Psychologica***, 26: 107–129.

Hout, M. C., & Goldinger, S. D. 2011. Multiple-target search increases workload but enhances incidental learning: A computational modelling approach to a memory paradox. ***Visual Cognition***, 19: 1315–1318.

Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. 1999. Use it or lose it: Engaged lifestyle as a buffer of cognitive decline in aging? ***Psychology and Aging***, 14: 245–263.

Hülür, G., Ram, N., Willis, S. L., Schaie, K. W., & Gerstorf, D. 2019. Cohort differences in cognitive aging: The role of perceived work environment. ***Psychology and Aging***, 34: 1040–1054.

Humphrey, S. E., Nahrgang, J. D., & Morgeson, F. P. 2007. Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. ***Journal of Applied Psychology***, 92: 1332–1356.

Hunter, J. E. 1986. Cognitive ability, cognitive aptitudes, job knowledge, and job performance. ***Journal of Vocational Behavior***, 29: 340–362.

Hyun, J., Katz, M. J., Lipton, R. B., & Sliwinski, M. J. 2021. Mentally challenging occupations are associated with more rapid cognitive decline at later stages of cognitive aging. ***Journals of Gerontology: Series B***, 76: 671–680.

Hyun, J., Sliwinski, M. J., & Smyth, J. M. 2019. Waking up on the wrong side of the bed: The effects of stress anticipation on working memory in daily life. ***Journals of Gerontology: Series B***, 74: 38–46.

Ice, E., Ang, S., Greenberg, K., & Burgard, S. 2020. Women's work–family histories and cognitive performance in later life. ***American Journal of Epidemiology***, 189: 922–930.

Ilgen, D. R., Fisher, C. D., & Taylor, M. S. 1979. Consequences of individual feedback on behavior in organizations. ***Journal of Applied Psychology***, 64: 349–371.

Ivers, N. M., Grimshaw, J. M., Jamtvedt, G., Flottorp, S., O'Brien, M. A., French, S. D., Young, J., & Odgaard-Jensen, J. 2014. Growing literature, stagnant science? Systematic review, meta-regression and cumulative analysis of audit and feedback interventions in health care. ***Journal of General Internal Medicine***, 29: 1534–1541.

Jackson, P. R., & Wall, T. D. 1991. How does operator control enhance performance of advanced manufacturing technology? ***Ergonomics***, 34: 1301–1311.

Jacobs, R. L. 2017. Knowledge work and human resource development. ***Human Resource Development Review***, 16: 176–202.

Jiang, Y., Jackson, S. E., & Colakoglu, S. 2016. An empirical examination of personal learning within the context of teams. ***Journal of Organizational Behavior***, 37: 654–672.

Jundt, D. K., Shoss, M. K., & Huang, J. L. 2015. Individual adaptive performance in organizations: A review. ***Journal of Organizational Behavior***, 36(Suppl. 1): S53–S71.

Kanfer, R., & Ackerman, P. L. 1989. Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition. ***Journal of Applied Psychology***, 74: 657–690.

Kanfer, R., & Ackerman, P. L. 2004. Aging, adult development, and work motivation. ***Academy of Management Review***, 29: 440–458.

Karasek, R. A. 1979. Job demands, job decision latitude, and mental strain: Implications for job redesign. ***Administrative Science Quarterly***, 24: 285–308.

Karasek, R. A. 1998. Demand/control model: A social-emotional and psychological approach to stress risk and active behavior development. In J. M. Stellman (Ed.), ***ILO encyclopedia of occupational health and safety*** (4th ed.): 34.6–34.14. Geneva, Switzerland: International Labour Office.

Karasek, R. A., & Theorell, T. 1990. ***Healthy work: Stress, productivity, and the reconstruction of working life***. New York, NY: Basic Books.

Keith, N., & Frese, M. 2008. Effectiveness of error management training: A meta-analysis. ***Journal of Applied Psychology***, 93: 59–69.

Keller, T. A., & Just, M. A. 2016. Structural and functional neuroplasticity in human learning of spatial routes. ***NeuroImage***, 125: 256–266.

Kirby, J. R., Knapper, C. K., Evans, C. J., Carty, A. E., & Gadula, C. 2003. Approaches to learning at work and workplace climate. ***International Journal of Training and Development***, 7: 31–52.

Kirkman, B. L., & Rosen, B. 1999. Beyond self-management: Antecedents and consequences of team empowerment. ***Academy of Management Journal***, 42: 58–74.

Klein, K. J., Dansereau, F., & Hall, R. J. 1994. Levels issues in theory development, data collection, and analysis. ***Academy of Management Review***, 19: 195–229.

Kluger, A. N., & DeNisi, A. 1996. The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. ***Psychological Bulletin***, 119: 254–284.

Knight, C., & Parker, S. K. 2021. How work design interventions affect performance: An evidence-based model from a systematic review. ***Human Relations***, 74: 69–104.

Kohn, M. L., & Schooler, C. 1978. The reciprocal effects of the substantive complexity of work and intellectual flexibility: A longitudinal assessment. ***American Journal of Sociology***, 84: 24–52.

Kozlowski, S. W. J., Chao, G. T., & Jensen, J. M. 2010. Building an infrastructure for organizational learning: A multilevel approach. In S. W. J. Kozlowski & E. Salas (Eds.), ***Learning, training, and development in organizations***: 363–403. New York, NY: Routledge.

Kuhlmann, S., Piel, M., & Wolf, O. T. 2005. Impaired memory retrieval after psychosocial stress in healthy young men. ***Journal of Neuroscience***, 25: 2977–2982.

Kuper, H., & Marmot, M. 2003. Job strain, job demands, decision latitude, and risk of coronary heart disease within the Whitehall II study. ***Journal of Epidemiology and Community Health***, 57: 147–153.

Kyndt, E., Raes, E., Dochy, F., & Janssens, E. 2013. Approaches to learning at work: Investigating work motivation, perceived workload, and choice independence. ***Journal of Career Development***, 40: 271–291.

Landsbergis, P. A., & Theorell, T. 2000. Self-report questionnaires. In P. L. Schnall, K. Belkic, P. A. Landsbergis, & D. Baker (Eds.), ***The workplace and cardiovascular disease***, vol. 15: 163–171. Philadelphia, PA: Hanley & Belfus.

Lane, A. P., Windsor, T. D., Andel, R., & Luszcz, M. A. 2017. Is occupational complexity associated with cognitive performance or decline? Results from the Australian Longitudinal Study of Ageing. ***Gerontology***, 63: 550–559.

Langner, R., & Eickhoff, S. B. 2013. Sustaining attention to simple tasks: A meta-analytic review of the neural mechanisms of vigilant attention. ***Psychological Bulletin***, 139: 870–900.

LaRocco, J. M., House, J. S., & French, Jr., J. R. P. 1980. Social support, occupational stress, and health. ***Journal of Health and Social Behavior***, 21: 202–218.

Latif, A., Waring, J., Pollock, K., Solomon, J., Gulzar, N., Choudhary, S., & Anderson, C. 2019. Towards equity: A qualitative exploration of the implementation and impact of a digital educational intervention for pharmacy professionals in England. ***International Journal for Equity in Health***, 18: 1–11.

Lawrie, E. J., Tuckey, M. R., & Dollard, M. F. 2018. Job design for mindful work: The boosting effect of psychosocial safety climate. ***Journal of Occupational Health Psychology***, 23: 483–495.

Leach, D. J., Jackson, P., & Wall, T. 2001. Realizing the potential of empowerment: The impact of a feedback intervention on the performance of complex technology. ***Ergonomics***, 44: 870–886.

Leach, D. J., Wall, T. D., & Jackson, P. R. 2003. The effect of empowerment on job knowledge: An empirical test involving operators of complex technology. ***Journal of Occupational and Organizational Psychology***, 76: 27–52.

Lechermeier, J., & Fassnacht, M. 2018. How do performance feedback characteristics influence recipients' reactions? A state-of-the-art review on feedback source, timing, and valence effects. ***Management Review Quarterly***, 68: 145–193.

LePine, J. A., Podsakoff, N. P., & LePine, M. A. 2005. A meta-analytic test of the challenge stressor–hindrance stressor framework: An explanation for inconsistent relationships among stressors and performance. ***Academy of Management Journal***, 48: 764–775.

Li, W., Zhang, J.-Q., Sun, J., Ke, J.-H., Dong, Z.-Y., & Wang, S. 2007. Job stress related to glyco-lipid allostatic load, adiponectin and visfatin. ***Stress and Health***, 23: 257–266.

Lim, J., Wu, W.-C., Wang, J., Detre, J. A., Dinges, D. F., & Rao, H. 2010. Imaging brain fatigue from sustained mental workload: An ASL perfusion study of the time-on-task effect. ***NeuroImage***, 49: 3426–3435.

Lin, C.-P. 2010. Understanding negative impacts of perceived cognitive load on job learning effectiveness: A social capital solution. ***Human Factors***, 52: 627–642.

Lindenberger, U., & Baltes, P. B. 1994. Sensory functioning and intelligence in old age: A strong connection. ***Psychology and Aging***, 9: 339–355.

Locke, E. A., & Latham, G. P. 1990. ***A theory of goal setting & task performance***. Englewood Cliffs, NJ: Prentice Hall.

Locke, E. A., & Latham, G. P. 2015. Breaking the rules: A historical overview of goal-setting theory. In A. J. Elliot (Ed.), ***Advances in motivation science***, vol. 2: 99–126. Waltham, MA: Academic Press.

Lövdén, M., Bäckman, L., Lindenberger, U., Schaefer, S., & Schmiedek, F. 2010. A theoretical framework for the study of adult cognitive plasticity. ***Psychological Bulletin***, 136: 659–676.

Marmot, M. G., Rose, G., Shipley, M., & Hamilton, P. J. 1978. Employment grade and coronary heart disease in British civil servants. ***Journal of Epidemiology and Community Health***, 32: 244–249.

Marquié, J. C., Duarte, L. R., Bessières, P., Dalm, C., Gentil, C., & Ruidavets, J. B. 2010. Higher mental stimulation at work is associated with improved cognitive functioning in both young and older workers. ***Ergonomics***, 53: 1287–1301.

Mazzola, J. J., & Disselhorst, R. 2019. Should we be "challenging" employees?: A critical review and meta-analysis of the challenge–hindrance model of stress. ***Journal of Organizational Behavior***, 40: 949–961.

McCormick, E. J., Jeanneret, P. R., & Mecham, R. C. 1972. A study of job characteristics and job dimensions as based on the Position Analysis Questionnaire (PAQ). ***Journal of Applied Psychology***, 56: 347–368.

McEwen, B. S. 1998. Stress, adaptation, and disease: Allostasis and allostatic load. ***Annals of the New York Academy of Sciences***, 840: 33–44.

McEwen, B. S., & Stellar, E. 1993. Stress and the individual: Mechanisms leading to disease. ***Archives of Internal Medicine***, 153: 2093–2101.

McKendrick, R., Ayaz, H., Olmstead, R., & Parasuraman, R. 2014. Enhancing dual-task performance with verbal and spatial working memory training: Continuous monitoring of cerebral hemodynamics with NIRS. ***NeuroImage***, 85: 1014–1026.

Miner, J. B. 2003. The rated importance, scientific validity, and practical usefulness of organizational behavior theories: A quantitative review. ***Academy of Management Learning & Education***, 2: 250–268.

Mishler, S., Chen, J., Sabic, E., Hu, B., Li, N., & Proctor, R. W. 2017. Description–experience gap: The role of feedback and description in human trust in automation. ***Proceedings of the Human Factors and Ergonomics Society Annual Meeting***, 61: 313–313.

Molenberghs, P., Prochilo, G., Steffens, N. K., Zacher, H., & Haslam, S. A. 2017. The neuroscience of inspirational leadership: The importance of collective-oriented language and shared group membership. ***Journal of Management***, 43: 2168–2194.

Morgeson, F. P., & Campion, M. A. 2002. Minimizing tradeoffs when redesigning work: Evidence from a longitudinal quasi-experiment. ***Personnel Psychology***, 55: 589–612.

Nexø, M. A., Meng, A., & Borg, V. 2016. Can psychosocial work conditions protect against age-related cognitive decline? Results from a systematic review. ***Occupational and Environmental Medicine***, 73: 487–496.

Nexo, M. A., Watt, T., Pedersen, J., Bonnema, S. J., Hegedüs, L., Rasmussen, A. K., Feldt-Rasmussen, U., & Bjorner, J. B. 2014. Increased risk of long-term sickness absence, lower rate of return to work, and higher risk of unemployment and disability pensioning for thyroid patients: A Danish register-based cohort study. ***Journal of Clinical Endocrinology and Metabolism***, 99: 3184–3192.

Ng, T. W., & Feldman, D. C. 2008. The relationship of age to ten dimensions of job performance. ***Journal of Applied Psychology***, 93: 392–423.

Nielsen, C. P. 2011. Immigrant overeducation: Evidence from Denmark. ***Journal of Population Economics***, 24: 499–520.

Niessen, C., & Volmer, J. 2010. Adaptation to increased work autonomy: The role of task reflection. ***European Journal of Work and Organizational Psychology***, 19: 442–460.

Noe, R. A., Tews, M. J., & Michel, J. W. 2017. Managers' informal learning: A trait activation theory perspective. ***International Journal of Training and Development***, 21: 1–17.

Norman, D. A. 1990. The "problem" with automation: Inappropriate feedback and interaction, not "over-automation." ***Philosophical Transactions of the Royal Society of London: Series B, Biological Sciences***, 327: 585–593.

O'Mahony, S., & Bechky, B. A. 2006. Stretchwork: Managing the career progression paradox in external labor markets. ***Academy of Management Journal***, 49: 918–941.

Oltmanns, J., Godde, B., Winneke, A. H., Richter, G., Niemann, C., Voelcker-Rehage, C., Schömann, K., & Staudinger, U. M. 2017. Don't lose your brain at work: The role of recurrent novelty at work in cognitive and brain aging. ***Frontiers in Psychology***, 8. Published online. doi: 10.3389/fpsyg.2017.00117

Onnasch, L., & Hösterey, S. 2019. Stages of decision automation: Impact on operators' role, awareness and monitoring. ***Proceedings of the Human Factors and Ergonomics Society Annual Meeting***, 63: 282–286.

Onnasch, L., Wickens, C. D., Li, H., & Manzey, D. 2014. Human performance consequences of stages and levels of automation: An integrated meta-analysis. ***Human Factors***, 56: 476–488.

Pan, K. Y., Xu, W., Mangialasche, F., Dekhtyar, S., Fratiglioni, L., & Wang, H. X. 2019. Working life psychosocial conditions in relation to late-life cognitive decline: A population-based cohort study. ***Journal of Alzheimer's Disease***, 67: 315–325.

Park, D. C. 2000. The basic mechanism accounting for age-related decline in cognitive function. In D. C. Park & N. Schwarz (Eds.), ***Cognitive aging: A primer***: 3–22. New York, NY: Psychology Press.

Parker, S. K. 2014. Beyond motivation: Job and work design for development, health, ambidexterity, and more. ***Annual Review of Psychology***, 65: 661–691.

Parker, S. K. 2017. Work design growth model: How work characteristics promote learning and development. In G. E. Ellingson & R. A. Noe (Eds.), ***Autonomous learning in the workplace***: 159–183. New York, NY: Routledge.

Parker, S. K., Andrei, D. M., & Li, W.-D. 2014. An overdue overhaul: Revamping work design theory from a time perspective. In A. Shipp & Y. Fried (Eds.), ***Time and work: How time impacts individuals***: 191–228. New York, NY: Psychology Press.

Parker, S. K., Andrei, D. M., & Van den Broeck, A. 2019. Poor work design begets poor work design: Capacity and willingness antecedents of individual work design behavior. ***Journal of Applied Psychology***, 104: 907–928.

Parker, S. K., & Axtell, C. M. 2001. Seeing another viewpoint: Antecedents and outcomes of employee perspective taking. ***Academy of Management Journal***, 44: 1085–1100.

Parker, S. K., & Grote, G. 2019. Automation, algorithms, and beyond: Why work design matters more than ever in a digital world. ***Applied Psychology***. Published online ahead of print. doi: 10.1111/apps.12241

Parker, S. K., Morgeson, F. P., & Johns, G. 2017. One hundred years of work design research: Looking back and looking forward. ***Journal of Applied Psychology***, 102: 403–420.

Parker, S. K., & Sprigg, C. A. 1999. Minimizing strain and maximizing learning: The role of job demands, job control, and proactive personality. ***Journal of Applied Psychology***, 84: 925–939.

Parker, S. K., Van den Broeck, A., & Holman, D. 2017. Work design influences: A synthesis of multilevel factors that affect the design of jobs. ***Academy of Management Annals***, 11: 267–308.

Parker, S. K., & Wall, T. D. 1998. ***Job and work design: Organizing work to promote well-being and effectiveness***. Thousand Oaks, CA: SAGE.

Parker, S. K., Wall, T. D., & Jackson, P. R. 1997. "That's not my job": Developing flexible employee work orientations. ***Academy of Management Journal***, 40: 899–929.

Peavy, G. M., Salmon, D. P., Jacobson, M. W., Hervey, A., Gamst, A. C., Wolfson, T., Patterson, T. L., Goldman, S., Mills, P. J., Khandrika, S., & Galasko, D. 2009. Effects of chronic stress on memory decline in cognitively normal and mildly impaired older adults. ***American Journal of Psychiatry***, 166: 1384–1391.

Pindek, S., & Spector, P. E. 2016a. Explaining the surprisingly weak relationship between organizational constraints and job performance. ***Human Performance***, 29: 191–208.

Pindek, S., & Spector, P. E. 2016b. Organizational constraints: A meta-analysis of a major stressor. ***Work and Stress***, 30: 7–25.

Pool, L. R., Weuve, J., Wilson, R. S., Bültmann, U., Evans, D. A., & Mendes de Leon, C. F. 2016. Occupational cognitive requirements and late-life cognitive aging. ***Neurology***, 86: 1386–1392.

Porath, C. L., Foulk, T., & Erez, A. 2015. How incivility hijacks performance: It robs cognitive resources, increases dysfunctional behavior, and infects team dynamics and functioning. ***Organizational Dynamics***, 44: 258–265.

Potter, G. G., Helms, M. J., & Plassman, B. L. 2008. Associations of job demands and intelligence with cognitive performance among men in late life. ***Neurology***, 70: 1803–1808.

Rand, K. M., Creem-Regehr, S. H., & Thompson, W. B. 2015. Spatial learning while navigating with severely degraded viewing: The role of attention and mobility monitoring. ***Journal of Experimental Psychology: Human Perception and Performance***, 41: 649–664.

Ravid, D. M., Tomczak, D. L., White, J. C., & Behrend, T. S. 2020. EPM 20/20: A review, framework, and research agenda for electronic performance monitoring. ***Journal of Management***, 46: 100–126.

Roberts, B. W., Caspi, A., & Moffitt, T. E. 2003. Work experiences and personality development in young adulthood. ***Journal of Personality and Social Psychology***, 84: 582–593.

Rosen, C. C., Dimotakis, N., Cole, M. S., Taylor, S. G., Simon, L. S., Smith, T. A., & Reina, C. S. 2020. When challenges hinder: An investigation of when and how challenge stressors impact employee outcomes. ***Journal of Applied Psychology***, 105: 1181–1206.

Rosenzweig, M. R., Krech, D., Bennett, E. L., & Diamond, M. C. 1962. Effects of environmental complexity and training on brain chemistry and anatomy: A replication and extension. ***Journal of Comparative and Physiological Psychology***, 55: 429–437.

Sabbath, E. L., Andel, R., Zins, M., Goldberg, M., & Berr, C. 2016. Domains of cognitive function in early old age: Which ones are predicted by pre-retirement psychosocial work characteristics? ***Occupational and Environmental Medicine***, 73: 640–647.

Sale, A., Berardi, N., & Maffei, L. 2014. Environment and brain plasticity: Towards an endogenous pharmacotherapy. ***Physiological Reviews***, 94: 189–234.

Salthouse, T. A. 1991. Theoretical perspectives on cognitive aging. In C. L. Armstrong & L. Morrow (Eds.), ***Aging***: 297–313. New York, NY: Springer.

Salthouse, T. A. 1996. The processing-speed theory of adult age differences in cognition. ***Psychological Review***, 103: 403–428.

Salthouse, T. A. 2006. Mental exercise and mental aging: Evaluating the validity of the "use it or lose it" hypothesis. ***Perspectives on Psychological Science***, 1: 68–87.

Sarter, N. B., Woods, D. D., & Billings, C. E. 1997. Automation surprises. In G. Salvendy (Ed.), ***Handbook of human factors & ergonomics*** (2nd ed.): 1926–1943. New York, NY: Wiley.

Schaubroeck, J., Ganster, D. C., & Kemmerer, B. E. 1994. Job complexity, "type A" behavior, and cardiovascular disorder: A prospective study. ***Academy of Management Journal***, 37: 426–439.

Schmidt, F. L., & Hunter, J. 2004. General mental ability in the world of work: Occupational attainment and job performance. ***Journal of Personality and Social Psychology***, 86: 162–173.

Schmitt, N., Cortina, J. M., Ingerick, M. J., & Wiechmann, D. 2003. Personnel selection and employee performance. In I. B. Weiner (Ed.), ***Handbook of psychology***: 77–105. Hoboken, NJ: John Wiley & Sons.

Schooler, C. 1984. Psychological effects of complex environments during the life span: A review and theory. ***Intelligence***, 8: 259–281.

Schooler, C., Mulatu, M. S., & Oates, G. 1999. The continuing effects of substantively complex work on the intellectual functioning of older workers. ***Psychology and Aging***, 14: 483–506.

Seeman, T. E., McEwen, B. S., Rowe, J. W., & Singer, B. H. 2001. Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. ***Proceedings of the National Academy of Sciences of the United States of America***, 98: 4770–4775.

Segerstrom, S. C., & Miller, G. E. 2004. Psychological stress and the human immune system: A meta-analytic study of 30 years of inquiry. ***Psychological Bulletin***, 130: 601–630.

Seidler, A., Nienhaus, A., Bernhardt, T., Kauppinen, T., Elo, A. L., & Frölich, L. 2004. Psychosocial work factors and dementia. ***Occupational and Environmental Medicine***, 61: 962–971.

Seppelt, B. D., & Lee, J. D. 2019. Keeping the driver in the loop: Dynamic feedback to support appropriate use of imperfect vehicle control automation. ***International Journal of Human-Computer Studies***, 125: 66–80.

Sherman, S. M., Cheng, Y.-P., Fingerman, K. L., & Schnyer, D. M. 2016. Social support, stress and the aging brain. ***Social Cognitive and Affective Neuroscience***, 11: 1050–1058.

Shields, G. S., Sazma, M. A., McCullough, A. M., & Yonelinas, A. P. 2017. The effects of acute stress on episodic memory: A meta-analysis and integrative review. ***Psychological Bulletin***, 143: 636–675.

Simpson, J., & Kelly, J. P. 2011. The impact of environmental enrichment in laboratory rats: Behavioural and neurochemical aspects. ***Behavioural Brain Research***, 222: 246–264.

Singh-Manoux, A., Marmot, M. G., Glymour, M., Sabia, S., Kivimäki, M., & Dugravot, A. 2011. Does cognitive reserve shape cognitive decline? ***Annals of Neurology***, 70: 296–304.

Sliwinski, M. J., Smyth, J. M., Hofer, S. M., & Stawski, R. S. 2006. Intraindividual coupling of daily stress and cognition. ***Psychology and Aging***, 21: 545–557.

Smart, E. L., Gow, A. J., & Deary, I. J. 2014. Occupational complexity and lifetime cognitive abilities. ***Neurology***, 83: 2285–2291.

Spector, P. E. 1986. Perceived control by employees: A meta-analysis of studies concerning autonomy and participation at work. ***Human Relations***, 39: 1005–1016.

Stanton, N. A., Salmon, P. M., Walker, G. H., Salas, E., & Hancock, P. A. 2017. State-of-science: Situation awareness in individuals, teams and systems. ***Ergonomics***, 60: 449–466.

Stanton, N. A., Stewart, R., Harris, D., Houghton, R. J., Baber, C., McMaster, R., Salmon, P., Hoyle, G., Walker, G., Young, M. S., Dymott, R., & Green, D. 2006. Distributed situation awareness in dynamic systems: Theoretical development and application of an ergonomics methodology. ***Ergonomics***, 49: 1288–1311.

Staudinger, U. M. 2020. The positive plasticity of adult development: Potential for the 21st century. ***American Psychologist***, 75: 540–553.

Staudinger, U. M., & Glück, J. 2011. Psychological wisdom research: Commonalities and differences in a growing field. ***Annual Review of Psychology***, 62: 215–241.

Steelman, L. A., Levy, P. E., & Snell, A. F. 2004. The feedback environment scale: Construct definition, measurement, and validation. ***Educational and Psychological Measurement***, 64: 165–184.

Stern, Y. 2012. Cognitive reserve in ageing and Alzheimer's disease. ***Lancet Neurology***, 11: 1006–1012.

Strenze, T. 2007. Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. ***Intelligence***, 35: 401–426.

Stuss, D. T., & Knight, R. T. (Eds.) 2013. ***Principles of frontal lobe function***. New York, NY: Oxford University Press.

Sun, J., Wang, S., Zhang, J.-Q., & Li, W. 2007. Assessing the cumulative effects of stress: The association between job stress and allostatic load in a large sample of Chinese employees. ***Work and Stress***, 21: 333–347.

Suo, C., León, I., Brodaty, H., Trollor, J., Wen, W., Sachdev, P., & Valenzuela, M. J. 2012. Supervisory experience at work is linked to low rate of hippocampal atrophy in late life. ***NeuroImage***, 63: 1542–1551.

Sweller, J. 1988. Cognitive load during problem solving: Effects on learning. ***Cognitive Science***, 12: 257–285.

Taris, T. W., & Feij, J. A. 2004. Learning and strain among newcomers: A three-wave study on the effects of job demands and job control. ***Journal of Psychology***, 138: 543–563.

Taris, T. W., & Kompier, M. A. J. 2005. Job demands, job control, strain and learning behavior: Review and research agenda. In G. A. Alexander-Stamatios & C. L. Cooper (Eds.), ***Research companion to organizational health psychology***: 132–150. Northampton, MA: Edward Elgar Publishing.

Then, F. S., Luck, T., Luppa, M., Thinschmidt, M., Deckert, S., Nieuwenhuijsen, K., Seidler, A., & Riedel-Heller, S. G. 2014. Systematic review of the effect of the psychosocial working environment on cognition and dementia. ***Occupational and Environmental Medicine***, 71: 358–365.

Thorndike, E. L. 1913. ***Educational psychology***, vol. 2. New York, NY: Teachers College, Columbia University.

Tims, M., Bakker, A. B., & Derks, D. 2012. Development and validation of the job crafting scale. ***Journal of Vocational Behavior***, 80: 173–186.

Tomczak, D. L., Lanzo, L. A., & Aguinis, H. 2018. Evidence-based recommendations for employee performance monitoring. ***Business Horizons***, 61: 251–259.

Trist, E. L., & Bamforth, K. W. 1951. Some social and psychological consequences of the Longwall Method of coal-getting: An examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. ***Human Relations***, 4: 3–38.

Truxillo, D. M., Cadiz, D. M., Rineer, J. R., Zaniboni, S., & Fraccaroli, F. 2012. A lifespan perspective on job design: Fitting the job and the worker to promote job satisfaction, engagement, and performance. ***Organizational Psychology Review***, 2: 340–360.

U.K. Government Office for Science. 2008. Mental capital and wellbeing [Foresight project]. Retrieved from https://www.gov.uk/government/collections/mental-capital-and-wellbeing

van Eck, N. J., & Waltman, L. 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. ***Scientometrics***, 84: 523–538.

van Eck, N. J., & Waltman, L. 2014. Visualizing bibliometric networks. In Y. Ding (Ed.), ***Measuring scholarly impact***: 285–320. Sydney, Australia: Springer International Publishing.

van Merriënboer, J. J. G., Kester, L., & Paas, F. 2006. Teaching complex rather than simple tasks: Balancing intrinsic and germane load to enhance transfer of learning. ***Applied Cognitive Psychology***, 20: 343–352.

van Rensburg, G., & Zagenhagen, K. 2017. Serving two masters: Professional role conflict in a military teaching and learning environment. ***Journal of Military and Veterans' Health***, 25: 30–35.

Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M., & Deci, E. L. 2004. Motivating learning, performance, and persistence: The synergistic effects of intrinsic goal contents and autonomy-supportive contexts. ***Journal of Personality and Social Psychology***, 87: 246–260.

Virtanen, M., Jokela, M., Vahtera, J., Kivimaki, M., Singh-Manoux, A., Ferrie, J. E., Gimeno, D., Mamot, M. G., & Kivimäki, M. 2009. Long working hours and cognitive function: The Whitehall II study. ***American Journal of Epidemiology***, 169: 596–605.

Vroom, V. H. 1964. ***Work and motivation***. New York, NY: Wiley.

Wall, T. D., Corbett, J. M., Martin, R., Clegg, C. W., & Jackson, P. R. 1990. Advanced manufacturing technology, work design, and performance: A change study. ***Journal of Applied Psychology***, 75: 691–697.

Wall, T. D., & Jackson, P. R. 1995. New manufacturing initiatives and shopfloor job design. In A. Howard (Ed.), ***The changing nature of work***: 139–174. San Francisco, CA: Jossey-Bass.

Wall, T. D., Jackson, P. R., & Davids, K. 1992. Operator work design and robotics system performance: A serendipitous field study. ***Journal of Applied Psychology***, 77: 353–362.

Wang, S., & Noe, R. A. 2010. Knowledge sharing: A review and directions for future research. ***Human Resource Management Review***, 20: 115–131.

Wang, H.-X., Wahlberg, M., Karp, A., Winblad, B., & Fratiglioni, L. 2012. Psychosocial stress at work is associated with increased dementia risk in late life. ***Alzheimer's & Dementia***, 8: 114–120.

Wickens, C. D. 2004. Multiple resource time sharing models. In N. A. Stanton, A. Hedge, K. Brookhuis, E. Salas, & H. W. Hendrick (Eds.), ***Handbook of human factors and ergonomics methods***: 427–434. Boca Raton, FL: CRC Press.

Wickens, C. D. 2014. Effort in human factors performance and decision making. ***Human Factors***, 56: 1329–1336.

Wielenga-Meijer, E. G. A., Taris, T. W., Kompier, M. A. J., & Wigboldus, D. H. J. 2010. From task characteristics to learning: A systematic review. ***Scandinavian Journal of Psychology***, 51: 363–375.

Wielenga-Meijer, E. G. A., Taris, T. W., Wigboldus, D. H. J., & Kompier, M. A. J. 2012. Don't bother me: Learning as a function of task autonomy and cognitive demands. ***Human Resource Development International***, 15: 5–23.

Wilson, J. M., Goodman, P. S., & Cronin, M. A. 2007. Group learning. ***Academy of Management Review***, 32: 1041–1059.

Young, K. L., Lenne, M. G., Beanland, V. C., Salmon, P. M., & Stanton, N. A. 2015. Where do novice and experienced drivers direct their attention on approach to urban rail level crossings? ***Accident; Analysis and Prevention***, 77: 1–11.

Yu, F., Ryan, L. H., Schaie, K. W., Willis, S. L., & Kolanowski, A. 2009. Factors associated with cognition in adults: The Seattle Longitudinal Study. ***Research in Nursing & Health***, 32: 540–550.

Zellmer-Bruhn, M., & Gibson, C. 2006. Multinational organization context: Implications for team learning and performance. ***Academy of Management Journal***, 49: 501–518.

Zhang, F., & Parker, S. K. 2019. Reorienting job crafting research: A hierarchical structure of job crafting concepts and integrative review. ***Journal of Organizational Behavior***, 40: 126–146.

Zijlstra, F., van Ruitenbeek, G., Mulders, H., & van Lierop, B. 2017. Designing work for inclusiveness. In A. Arenas, D. Di Marco, L. Munduate, & M. Euwema (Eds.), ***Shaping inclusive workplaces through social dialogue***: 121–137. Cham, Switzerland: Springer.

Sharon K. Parker (s.parker@curtin.edu.au) is a John Curtin Distinguished Professor at Curtin University, an Australian Research Council Laureate Fellow, director of the Centre for Transformative Work Design, and a Chief Investigator for the Centre of Excellence in Population Ageing Research. Research interests include work design, proactivity, mental health, and job performance.

M. K. Ward (mk.ward@curtin.edu.au) is a research fellow in the Centre for Transformative Work Design at Curtin University's Future of Work Institute. She received a PhD and MS in industrial and organizational psychology from North Carolina State University. Her research interests include work design in entrepreneurship, and designing work to enhance cognition.

Gwenith G. Fisher (gwen.fisher@colostate.edu) is an associate professor in the Department of Psychology at Colorado State University, adjunct associate professor in the Colorado School of Public Health, and affiliate investigator with the Centre of Excellence in Population Ageing Research. Her research examines factors related to worker health and well-being, including cognitive functioning.

APPENDIX A
APPROACH TO REVIEW AND SCIENTIFIC MAPPING

The review process was extensive, entailing multiple steps to ensure we captured relevant articles from a range of relevant disciplines. There was an initial review, a review conducted within Web of Science, and backward referencing. VOSviewer was then used to map the literature.

Procedure for Initial Literature Review

First, we backward referenced Fisher et al.'s (2017) review article, as well as other review articles, and searched for more recent articles that may not have been included in their review. Thus, in Google Scholar, we searched for articles published after 2016 that included the terms "work design" OR "job design" OR "work complexity" AND cognition. Sorted by relevance, the second author reviewed the first 30 pages of 3,270 search results. There were 64 articles to screen for inclusion or exclusion.

Procedure for Web of Science Systematic Review

Search terms used in Web of Science were created based on terms used in research literature in work design, cognition, and neuroscience. For work design, we included search terms relevant to the job characteristics model, job demands–control model, job demands–resources, sociotechnical systems theory or autonomous work groups, and role theory (Parker, Morgeson, & Johns, 2017). We also used terms that we observed to be more commonly used in other fields, but which are closely aligned with work design concepts (e.g., "occupational complexity" is often used in lifespan research, and "task complexity" is often used in human factors research). We initially restricted all of our searches to articles published within the last 10 years (2009–2019). This was an appropriate cutoff to retrieve relevant and timely publications based in part on the observation that empirical work in organizational neuroscience began to be published around 2009. There were too many work design search terms to include in a single search. We created two groups of terms that were searched, and then combined with the "OR" Boolean operator. Work design search terms returned 47,719 search results. Cognition (1,950,761 results) and neuroscience (352,211 results) search terms were grouped and then combined using the "OR" operator, returning 2,174,221 results. Next, to find articles that included any of the work design search terms and any of the cognition or neuroscience search terms, we combined work design and cognition or neuroscience groups of search terms using the "AND" operator. This resulted in 9,994 articles that had any of the work design search terms *and* any of the cognition or neuroscience terms in the title, abstract, or keywords.

To retrieve quality publications in relevant disciplines, we identified top-ranked journals according to SCImago's 2017 H index values in the following subject areas: neuroscience, neuroscience miscellaneous, developmental neuroscience, behavioral neuroscience, cognitive neuroscience, cellular and molecular neuroscience, applied psychology, developmental and educational psychology, psychology miscellaneous, neuropsychology and physiological psychology, social psychology, public health, environmental and occupational health, occupational therapy, ergonomics, aging, computer vision and pattern recognition, experimental and cognitive psychology, occupational health, and gerontology. We focused on publications since 2009 to capture more recent work, knowing these later publications would cite key earlier studies. To do this, we generated lists of sources in each of those fields of study, creating four separate searches in Web of Science for all articles published between 2009 and 2019 in any of the journals listed. Then, we used the "AND" operator to restrict search results of articles that had both work design terms *and* cognition or neuroscience terms to only articles published in top organizational behavior (375), cognition (115), neuroscience (95), and gerontology or occupational health (91) journals. Then, we combined results from each of those four searches using the "OR" operator to give a full list of 619 search results wherein we manually reviewed the abstracts for inclusion or exclusion from the current paper.

Our initial review combined with the systematic review revealed over 650 articles. After excluding irrelevant papers, we identified approximately 80 empirical studies that examined the link between work design and cognition, and seven review or conceptual articles. Finally, to check our search process was comprehensive, we used backward reference searching from previous reviews and pivotal papers. In this broader review, we included papers that were published earlier than 2009. We obtained over 100 further articles via this process.

List of Search Terms Used in WOS Systematic Review

Work design search terms.
(TS=("Skill Variety") OR TS=("Task variety") OR TS=("Problem-solving demands") OR TS=("Information processing demands") OR TS=("work speciali$ation") OR TS=("job speciali$ation") OR TS=("work complexity") OR TS=("job complexity") OR TS=("work feedback") OR TS=("job feedback") OR TS=("Feedback from job*") OR TS=("Task Identity") OR TS=("Role Clarity") OR TS=("role ambiguity") OR TS=("Feedback from other*") OR TS=("work * ambiguity") OR TS=("performance * ambiguity") OR TS=("schedul* ambiguity") OR TS=("job autonomy") OR TS=("autonomy in the job") OR TS=("work autonomy") OR TS=("autonomy in work") OR TS=("job control") OR TS=("control * job") OR TS=("work control") OR TS=("control at work") OR TS=("control in work") OR TS=("work-scheduling autonomy") OR TS=("autonomy * Work-scheduling") OR TS=("decision-making autonomy") OR TS=("autonomy * decision-making") OR TS=("work method* autonomy") OR TS=("autonomy * work methods*") OR TS=("work social support") OR TS=("work * social support") OR TS=("social support * work") OR TS=("social support * job") OR TS=("job social support") OR TS=("job * social support") OR TS=("Task significance") OR TS=("work significance") OR TS=("perceived social worth") OR TS=("manager* support") OR TS=("colleague support") OR TS=("coworker support") OR TS=("work* interdependence") OR TS=("job* interdependence"))

Work Design Search Terms.* (continued*)
(TS=("interaction out* organi$ation") OR TS=("contact with beneficiar*") OR TS=("beneficiar* contact") OR TS=("work *role conflict") OR TS=("job *role conflict") OR TS=("work *time pressure") OR TS=("job *time pressure") OR TS=("task *time pressure") OR TS=("monitor* demand*") OR TS=("emotion* demand*") OR TS=("role conflict* work") OR TS=("work* role conflict") OR TS=("job role conflict") OR TS=("role conflict* job") OR TS=("work*load") OR TS=("job demand*") OR TS=("work demand*") OR TS=("cost responsibilit*") OR TS=("work-to-family conflict*") OR TS=("work home conflict*") OR TS=("emotional labo*") OR TS=("cognitive work demand*") OR TS=("cognitive job demand*") OR TS=("physical demand*") OR TS=("work design-*") OR TS=("job design*") OR TS=("job characteristic*") OR TS=("work characteristic*") OR TS=("task characteristic*") OR TS=("job redesign*") OR TS=("work redesign*") OR TS=("team redesig*") OR TS=("job enlargement*") OR TS=("work enlargement*") OR TS=("job enrich*") OR TS=("work enrich*") OR TS=("job reorgani$ation*") OR TS=("job rotat*") OR TS=("work rotat*") OR TS=("team empower*") OR TS=("work empower*") OR TS=("participative redesign") OR TS=("participative work redesign") OR TS=("participative work design") OR TS=("autonomous work team*") OR TS=("autonomous work group*") OR TS=("self-manag* team*") OR TS=("self-manag* group*"))

Cognitive Search Terms.
TS=("memory") OR TS=("attention") OR TS=("executive function*") OR TS=("higher order problem-solving") OR TS=("language") OR TS=("visual processing") OR TS=("visual perception") OR TS=("learning") OR TS=("social processing ") OR TS=("emotional processing") OR TS=("cognition") OR TS=("cognitive") OR TS=("self-regulation") OR TS=("systems supporting regulation") OR TS=("learning") OR TS=("speed of complex cognitive processes ") OR TS=("cogniti* processing speed") OR TS=("cognitive speed") OR TS=("mental model") OR TS=("situational awareness") OR TS=("intelligence") OR TS=("neural structures") OR TS=("synap* density") OR TS=("dementia") OR TS=("Alzheimer*")

Neuroscience Search Terms.
TS=("hippocamp*") OR TS=("fronto-temporal systems*") OR TS=("prefrontal cortex") OR TS=("frontostriatal network*") OR TS=("frontostriatal circuit*") OR TS=("temporal lobe") OR TS=("temporal cortex") OR TS=("prefrontal cortex") OR TS=("*frontal lobe") OR TS=("parietal lobe") OR TS=("parietal cortex") OR TS=("occipital") OR TS=("*plasticity") OR TS=("limbic system") OR TS=("inferior prefrontal") OR TS=("dorsal and ventral lateral prefrontal cortext") OR TS=("posterior medial prefrontal cortex") OR TS=("amygdala") OR TS=("ventral striatum") OR TS=("dorsal premotor regions") OR TS=("temporal-parietal junction") OR TS=("dorsal medial prefrontal cortex") OR TS=("precuneus") OR TS=("*plasticity") OR TS=("right dorsolateral prefrontal cortex") OR TS=("default mode

network") OR TS=("right superior parietal lobe") OR TS=("myelination") OR TS=("gr$y matter") OR TS=("white matter") OR TS=("inferior temporal cortex") OR TS=("perirhinal cortex") OR TS=("parahippocampal cortex") OR TS=("entorhinal cortex") OR TS=("lateral entorhinal area") OR TS=("medial entorhinal")

List or Journal Outlets Used to Restrict Search Results

Organizational Behavior Journal Outlets. SO=(Academy of Management Annals OR Academy of Management Executive OR Academy of Management Journal OR Academy of Management Perspectives OR Academy of Management Review OR Administrative Science Quarterly OR Applied Psychology Health "AND" Well Being OR Applied Psychology An International Review OR Asia Pacific Journal of Management OR British Journal of Management OR California Management Review OR Decision Sciences OR European Journal of Work "AND" Organizational Psychology OR European Review of Applied Psychology OR Group "AND" Organization Management OR Harvard Business Review OR Human Performance OR Human Relations OR Human Resource Management OR Human Resource Management Journal OR Human Resource Management Review OR International Journal of Management Reviews OR Journal of Applied Psychology OR Journal of Behavioural Decision Making OR Journal of Business "AND" Psychology OR Journal of Career Assessment OR Journal of Career Development OR Journal of Experimental Psychology Applied OR Journal of International Business Studies OR Journal of Management OR Journal of Management Studies OR Journal of Managerial Psychology OR Journal of Occupational "AND" Organizational Psychology OR Journal of Occupational Health Psychology OR Journal of Organizational Behaviour OR Journal of Organizational Behaviour Management OR Journal of Vocational Behaviour OR Leadership Quarterly OR Management "AND" Organization Review OR Management Science OR Motivation "AND" Emotion OR International Journal of Management Science OR Organization OR Organization Science OR Organization Studies OR Organizational Behaviour "AND" Human OR Decision Processes OR Organizational Dynamics OR Organizational Research Methods OR Personnel Psychology OR Psychological Bulletin OR Research in Organizational Behaviour OR Sloan Management Review OR Work "AND" Stress OR Entrepreneurship Theory "AND" Practice OR Journal Of Business Venturing OR Small Business Economics OR Strategic Entrepreneurship Journal OR Annual Review Of Organizational Psychology "AND" Organizational Behaviour OR Organizational Behaviour "AND" Human Decision Processes)

Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2009-2019

Cognition Outlets. SO=(Trends in Cognitive Sciences OR Neuropsychologia OR Cognition OR Behaviour Research "AND" Therapy OR Psychophysiology OR Physiology "AND" Behaviour OR Journal of Experimental Psychology Learning Memory "AND" Cognition OR Journal of Experimental Psychology General OR Journal of Experimental Psychology Human Perception "AND" Performance OR Psychonomic Bulletin "AND" Review OR Journal of Memory "AND" Language OR Behaviour Research Methods OR Brain "AND" Cognition OR Memory "AND" Cognition OR Cognition "AND" Emotion OR Brain "AND" Language OR Cognitive Psychology OR Neurobiology of Learning "AND" Memory OR Attention Perception Psychophysics OR Journal of Experimental Child Psychology OR Evolution "AND" Human Behaviour OR Cognitive Science OR Cortex OR Consciousness "AND" Cognition OR Acta Psychologica OR Cognitive Therapy "AND" Research OR Applied Cognitive Psychology OR Cognitive Neuropsychology OR Perception OR Social Cognitive "AND" Affective Neuroscience OR Intelligence OR Developmental Review OR Journal of Experimental Psychology Applied OR Visual Cognition OR Cognitive Development OR Language Cognition "AND" Neuroscience OR Motivation "AND" Emotion OR Multivariate Behavioural Research)

Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2009-2019

Neuroscience Outlets. SO=(Neuroepidemiology OR Neuropsychology OR Annals of Neurology OR Neuron OR Journal of Neuroscience OR Nature Neuroscience OR EMBO Journal OR Nature Reviews Neuroscience OR NeuroImage OR Stroke OR Biological Psychiatry OR Annals of Neurology OR Trends in Neurosciences OR Trends in Cognitive Sciences OR Pain OR Journal of Neurophysiology OR Annual Review of Neuroscience OR Cerebral Cortex OR

Annals of the New York Academy of Sciences OR PLoS Biology OR Journal of Neurochemistry OR Progress in Neurobiology OR Current Opinion in Neurobiology OR Neuroscience "AND" Biobehavioural Reviews OR Neuroscience OR Investigative Ophthalmology "AND" Visual Science OR Journal of Cognitive Neuroscience OR Journal of Comparative Neurology OR Molecular Psychiatry OR Cellular "AND" Molecular Life Sciences OR European Journal of Neuroscience OR Brain Research OR Neuropsychologia OR NeuroReport OR Journal of Cerebral Blood Flow "AND" Metabolism OR Epilepsia OR Journal of Abnormal Psychology OR Human Brain Mapping OR Movement Disorders OR Experimental Neurology OR Cognition OR Neurobiology of Aging OR Schizophrenia Research OR Clinical Neurophysiology OR Neuroscience Letters OR Experimental Brain Research OR Journal of Neuropathology "AND" Experimental Neurology OR Behavioural Brain Research)

Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2009-2019

Gerontology and Occupational Health Outlets. SO=(Journal of Occupational Health Psychology OR Work Aging "AND" Retirement OR Journal of Epidemiology "AND" Community Health OR Journal of Occupational "AND" Environmental Medicine OR American Journal of Industrial Medicine OR Journal of Geriatric Psychiatry "AND" Neurology OR Journal of the American OR Geriatrics Society OR International Psychogeriatrics OR Alzheimer's Research "AND" Therapy OR Journal of Applied Gerontology OR Journal of the American Geriatrics Society OR Journals of Gerontology Series A Biological Sciences "AND" Medical Sciences OR Neurobiology of Aging OR Psychology "AND" Aging OR Journals of Gerontology Series B Psychological Sciences "AND" Social Sciences OR Age "AND" Ageing OR The Gerontologist OR International Journal of Geriatric Psychiatry OR Critical Reviews in Oncology/Hematology OR American Journal of Geriatric Psychiatry OR Journal of Alzheimer's Disease OR Dementia "AND" Geriatric Cognitive Disorders OR Alzheimer Disease "AND" Associated Disorders OR Alzheimer's "AND" Dementia OR Drugs "AND" Aging OR Parkinsonism "AND" Related Disorders OR International Psychogeriatrics OR Gerontology OR Aging "AND" Mental Health OR Journal of Nutrition Health "AND" Aging OR Ageing "AND" Society OR Clinics in Geriatric Medicine OR Biogerontology OR Journal of Geriatric Psychiatry "AND" Neurology OR Journal of Aging "AND" Health OR Aging Clinical "AND" Experimental Research OR Archives of Gerontology "AND" Geriatrics OR Research on Aging OR Clinical interventions in aging OR BMC Geriatrics OR Aging Neuropsychology "AND" Cognition OR Rejuvenation Research OR American Journal of Alzheimer's Disease "AND" other Dementias OR Journal of Aging "AND" Physical Activity OR International Journal of Aging "AND" Human Development)

Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2009-2019

Scientific Mapping Using VOSviewer

We subjected all of the articles that we obtained from our full review process to a scientific "bibiometric mapping process," which represents connections in a structure to visualize a focal research area and its evolution (Cobo et al., 2011; Ding & Yang, 2020). The maps in the current paper visualize the strengths of associations between scientific terms such that larger terms represent higher frequency in the included articles. We followed recommendations by van Eck and Waltman (2014) regarding proper use of VOSviewer, and the grouping processes we used follow similar steps to those utilized in extant publications. Relatedness among terms is indicated by position and relative distance. Shorter distances between terms co-occur more frequently than terms at a distance; terms in more central positions in the map (vs. the periphery) co-occur with more terms; and clusters of similar terms are designated by color (see van Eck & Waltman, 2010, 2014, for a more detailed explanation of VOSviewer parameters). The VOSviewer map in the current paper was based on references that included one of the following terms in the title or abstracts: "autonomy," "control," "complex," "demand," "feedback," "resource," or "support." Co-occurrence of terms was 10, attraction 10, repulsion of 1, and VOSviewer cluster resolution was set to 3, which asked VOSviewer to increase number of clusters by increasing level of detail for each cluster. As per the VOSviewer manual, this was set iteratively based on how logical the clusters appeared, considering the articles that were input to VOSviewer (van Eck & Waltman, 2010); minimum cluster size was set to 4 (meaning at least four constructs needed to co-occur in each cluster), resulting in the emergence of five clusters. Irrelevant words such as “paper” and “way” were excluded. Based on analysis of the resulting VOSviewer findings, paired with inspection of each article included in our review (e.g., its approach, journal of publication), we identified multiple disciplinary perspectives linking work design and cognition.