Human Factors

Designing for an Aging Workforce

Can we? Should we?

By Joel M. Haight and Umang Belwal

TODAY'S HIGH-TECH, highly productive manufacturing environment demands fast-paced, error-free operation. Youth also seems to be emphasized in today's world and in a young world, high-tech and fast-paced may be perceived as exciting. However, a phenomenon is occurring in which the people involved may not find high-tech and fast-paced to be quite so exhilarating.

This phenomenon began in 1946 and continued through 1964. It is known as the baby boom and those born during these years are part of the baby boomer generation. This large group of people is reaching an age at which society may intuitively become concerned about their declining performance in the current manufacturing environment [Haight(b); Haight and Miles]. This intuitive concern appears to be growing stronger as baby boomers move from their 40s and 50s to their 50s and 60s. This concern may be due to the fact that more people are reaching the category which may be referred to as older workers. According to current demographic trends, by the year 2030, approximately 42% of the U.S. population will be older than age 45 (U.S. Census Bureau).

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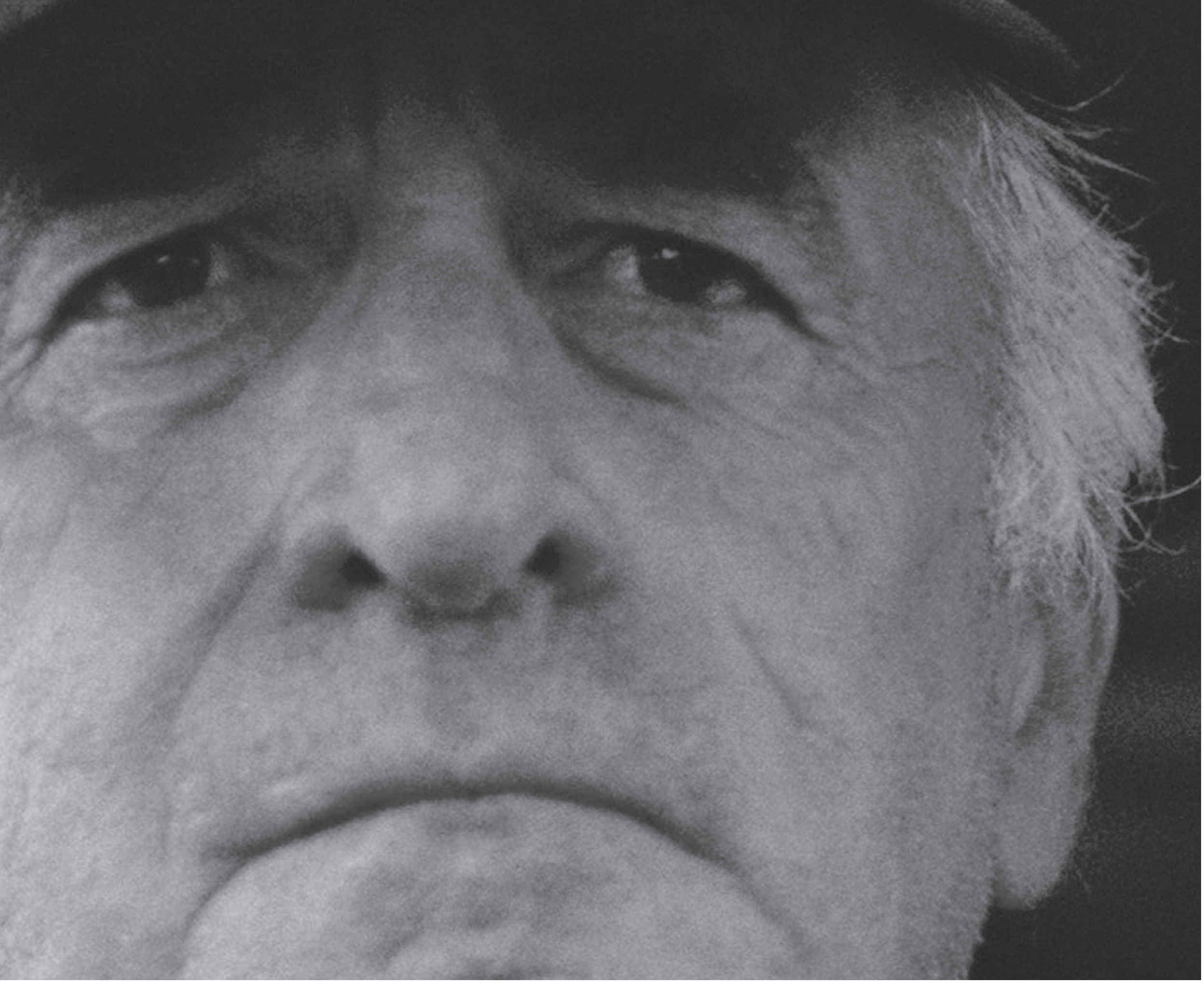
The intuitive concerns about productivity, safety and errors may be present because as people age they experience a loss of both physical and cognitive capacity [Haight(b)]. The safety and health community may be concerned that older workers are more likely to experience higher error and injury rates. The manufacturing and production operations community may be concerned that these losses could lead to lower productivity among older workers.

However, some available labor data do not appear to support these concerns. Bureau of Labor Statistics (BLS) statistics show that in 2002, those age 25 to 54 made up about 76% of the work population and experienced 75% of the recordable work injuries involving days away from work. Those age 55 and older accounted for approximately 13.6% of the working population and contributed to only 10.4% of the recordable injuries involving days away from work (Haight and Miles). The productivity data show that those in the 55+ age bracket also appear to be more productive than their younger counterparts (BLS).

How can this be? A possible explanation for this seemingly counterintuitive phenomenon may be that work and life experience help free up attention and/or physical capacity through more efficient means of task completion (Magill). Older workers learn to make accommodations that allow them to stay productive and error- and injury-free.

However, these two issues must be understood thoroughly, since it may be dangerous to rely on only experience or self-developed accommodations if in fact workers are putting themselves at a higher stress level in order to keep up. Laboratory-based research on task performance shows a decline, but it is equivocal at best and nonexistent at worst on the



Abstract: *The average age of the U.S. worker is increasing as the baby boomer generation approaches retirement. As humans age, they experience physical and cognitive capacity losses; intuitively, that may be a concern from a productivity, error rate and injury rate perspective. Bureau of Labor Statistics data seem to show that this may not be an entirely valid concern. Another concern is that older workers put themselves at risk by developing their own accommodations to keep up with younger workers. In light of such issues, more research is needed in the areas of experience and self-developed accommodations in an actual work setting while workers are performing actual work tasks. This article considers possible design solutions to help account for the loss of physical and cognitive capacities among older workers.*

subject of experience and actual work task performance. It is also equivocal on whether experience offsets error and injury rate increases [Salthouse; Haight(b); Haight and Kecojevic].

Information is lacking because it is difficult to conduct designed experiments in an actual work setting with all the same forces and variables present. Therefore, it is difficult to draw solid conclusions from such a lean information base. Labor data provide strong mathematical indication that experience plays a large role, but it is lean on the accommodations question (Belwal and Haight).

Given the uncertainty in the driving variables in the BLS data and since many unknowns remain regarding aging workers, this article examines work space design features that may make specific tasks easier for older workers. It has been informally claimed—both by attendees of aging worker presentations by the authors and by reviewers of this article—that the workforce takes care of its own by developing accommodations for its older workers. Such accommodations can range from younger workers volunteering to do more physically demanding work to supervisors selectively assigning jobs so that the more physically demanding jobs are given to younger, more able-bodied workers.

While these accommodations as well as other self-imposed accommodations may be occurring, no systematic research has been performed in a real workplace setting to fully understand this process to draw conclusions. The extensive anecdotal claims that these accommodations are occurring does, however, highlight the need to better understand why and how it is affecting work performance and injury rates, and whether it can help to explain the BLS data which appear to indicate lower injury and potentially higher productivity rates among older workers.

Understanding the Data & Framing the Concerns

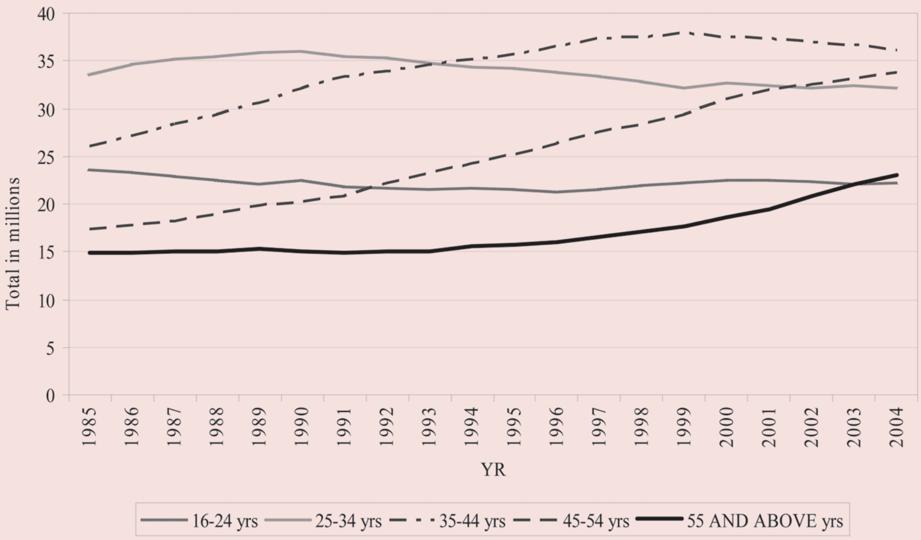
The answer to injury and productivity concerns about aging workers has not been determined. It is a complex issue and no one has systematically studied these concerns in a real plant or industry setting. Many factors prevent such an evaluation. The process of research is one of gradually uncovering answers; thus far, the physical and cognitive losses experienced by older adults are well documented. In the absence of task-specific analyses and comparison between older and younger workers, we first turn to the data available to identify general trends or indications as a way to further understand the concerns and to direct future research. This article includes discussion about the aging worker issue at this level. While the specific answers, specific accommodations and specific comparisons are not yet available, indications (even with the uncertainty) of a counterintuitive phenomenon exist.

This article aims to address two main issues:

1) While BLS data appear to indicate that older workers are safer and more productive than their younger counterparts, there is no irrefutable claim that this is true nor is there a proven reason as to why this is the case. Given the physical and cognitive capacity losses, this is counterintuitive; however, older workers are typically thought to have two factors working in their favor—experience and the knowledge to implement self-developed accommo-

Figure 1

Labor Force Distribution by Age Group



Adapted from BLS(b).

dations. Unfortunately for researchers, a quantified answer is not available as to how and how much experience helps to offset the losses, nor is it known whether the self-developed accommodations are safe and appropriate.

2) Given the uncertainty in any conclusions that can be drawn from BLS injury and productivity data, this article explores potential design solutions to help ensure that the accommodations which older workers may need are thoroughly evaluated and engineered for safety, productivity, efficiency and comfort, and do not create more problems than they solve.

Who Are Older Workers?

In this context, older workers are defined as those members of the working population who are 55 and older. However, the article also addresses those 45 and older for various illustrations and comparisons. This age is chosen as a benchmark for research purposes only (Belwal and Haight).

How is aging defined and how will the future of the U.S. workforce be affected? Statisticians may also think of aging in terms of the Gompertz curve (Kenney and Keeping). This relates aging to an increased probability of death. Simply defined, aging can be considered an increase in calendar age only. According to some physicians, aging is a process of progressive deterioration in physiological and mental function, and an increasing burden of chronic ill health (Belwal and Haight).

Intuitively, one may think that decreased physiological and mental function and increased burden of chronic ill health would threaten a worker's capacity for productive output. Given individual differences however, calendar age alone does not provide an adequate measure of injury and productivity potential. For example, a well-conditioned 48 year old may be in better physical health than an unfit 26 year old. A 55 year old who has worked in the same manufacturing environment for 30 years may not need the same amount of physical and cognitive capacity as a 30-year-old colleague to remain safe, error-free and productive (Belwal and Haight). The message is that people must exercise care when defining aging and what it means to be an older worker.

In terms of the future, the U.S. Census reports that the percentage of older workers within the working population is projected to rise from 12.9% in 2000 to 16.3% (13.3% for age group 55 to 64 and 3% for age group 65+) in 2008. Further projections reveal that this percentage will reach 19.6% in 2015 and 20.1% in 2025. This is a 38% increase over the next 10 years—and a 75% increase over the next 25 years (Belwal and Haight).

Given these projections, it is essential to better understand the needs of older workers and issues such as experience and self-developed accommodations. With such understanding, industry and society can help to ensure the well being of the workforce as well as to continue to help ensure their higher productivity.

Figure 1 shows the increases in pure numbers of workers in each age category from 1985 to 2004 (steepest slopes occur in the 45 to 54 and the 55+ categories). Figure 2 shows the increase in terms of percentage of the workforce made up of those 55+ years of age (Belwal and Haight).

Losses that Older Workers May Experience

Because of the apparent increase in the number of older workers in the workforce and the literature that documents the physical and cognitive capacity losses people experience with age, many concerns surround older workers' ability to maintain a high level of work performance. Unfortunately, no published research unequivocally concludes that a decline in physically and cognitive capacities impacts safety performance or work performance. As a result, it is helpful to review some of these losses as a way to understand how they could, or whether they do, affect work performance.

Loss of Cardiorespiratory Function

Fatigue is likely to develop if an industrial task demands more than 40% of maximal oxygen intake over the course of an 8-hour day (Bonjer; Hughes and Goldman). Currently, few occupations demand a level of aerobic energy expenditure that would cause a young male employee to surpass this ceiling [Shepard(a)]. In 1981, NIOSH set an action limit that requires either ergonomic task redesign or the spatial selection and training of workers when the energy expenditure exceeds 14.6 kJ/min—which is perhaps 80% of the fatigue threshold for a 45-year-old male, but close to 100% for the average 65-year-old worker (Belwal and Haight).

If this application of the action limit concept leads to an appropriate and corrective action by an ergonomist, then the average 65-year-old employee would be able to cope with an 8-hour day at most worksites. However, any attempts to extend the work-span further may rapidly reduce the proportion of the labor force that could meet the required standard. The inability to reduce the average energy cost of the task to 14.6 kJ/min would require shortening the workday or increasing the duration of breaks for older workers (Belwal and Haight).

Loss of Physical Capacity

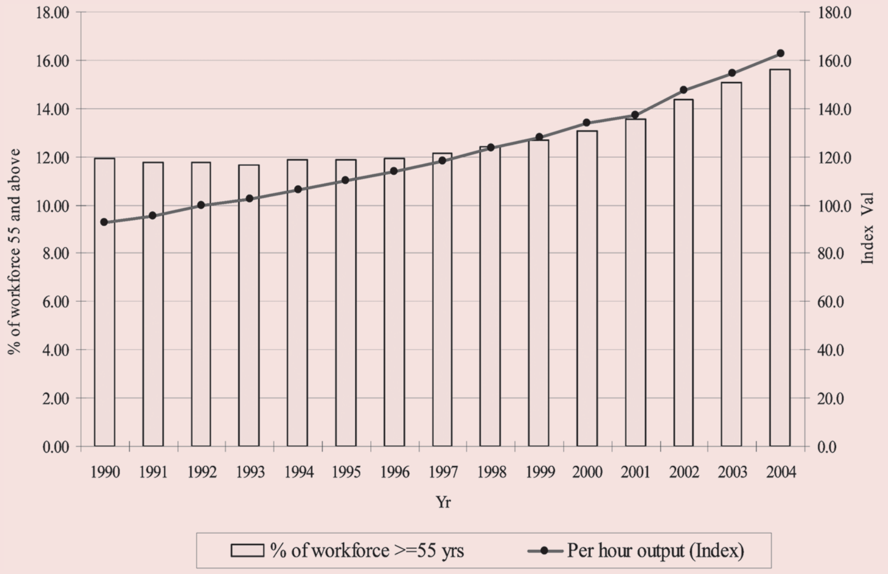
Physical capacity declines with age. Physical capacity variables that relate to work performance of industrial tasks may include strength, range of motion, speed of movement, fatigue, motor skills and healing after injury [Haight(b)].

Industrial performance is commonly limited by the ability to lift heavy objects repeatedly. NIOSH has specified an action limit that is reached when fewer than 75% of women and 99% of men can meet the job requirements safely. It has been established that 9% of young men and 99% of young women were unable to meet the lifting requirements of the Canadian army after completing basic training (Nottrodt and Celentano). Limitations exist at every age and in every population category, so it is important that appropriate data be used when comparing limitations. No matter what the comparison, however, on average, strength decreases about 25% by age 65 [Shepard(c)]. Thus, it seems inevitable that by the time the average employee reaches retirement age, s/he may have difficulty meeting the lifting requirements demanded in heavy work (Belwal and Haight).

At age 50, people begin to experience a loss of perceptive-motor capabilities (Chaffin, et al). Older drivers in a vehicle cockpit have been shown to adopt a

Figure 2

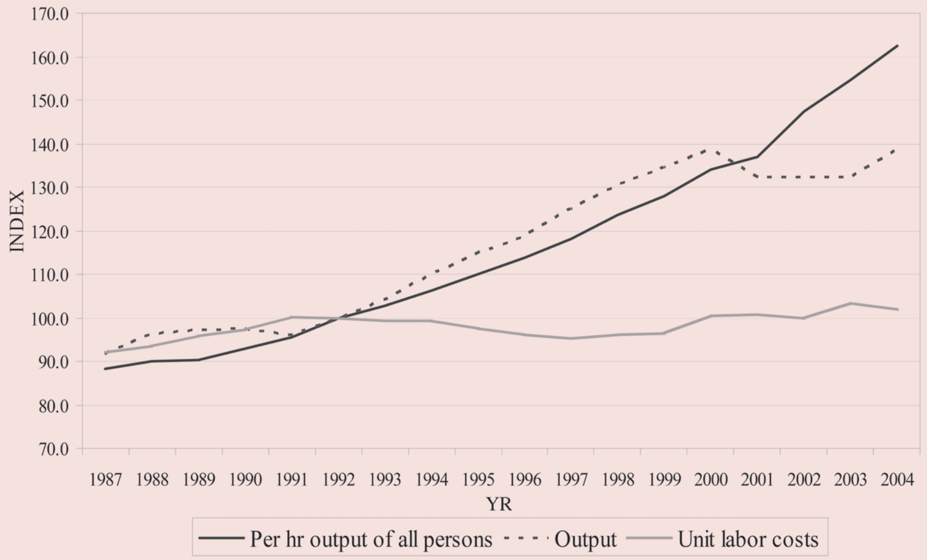
Percentage of Workforce 55+ vs. per Hour Output



Adapted from BLS(b).

Figure 3

Manufacturing Productivity Trends



Adapted from BLS(b).

more conservative reach posture than younger drivers. The mechanism for this is not well understood, but it is probably as much because of a perception of possible shoulder strain as it is because of real physical limitation or loss of strength (Chaffin, et al). This information is as helpful to engineers as anthropometric information. Engineers should consider age-related limitations in ergonomic design decisions; in the absence of adequate research in this area, an engineer might consider reducing the maximum reach extension (or even general range of motion in all body segment motion) by 20% where possible (Haight and Miles).

Stelmach and Nahom found that motor performance slows with age because of loss of sensory receptivity, decrease in muscle mass and elasticity, loss of bone mass, and reduction in central and peripheral nerve fibers. If system designers factor the slowing of age-related motor performance into design decisions, the need for fast and precise movement can be reduced. The cost of a workable solution may be high, however. For example, it may require operating two production lines as opposed to running one line at twice the rate.

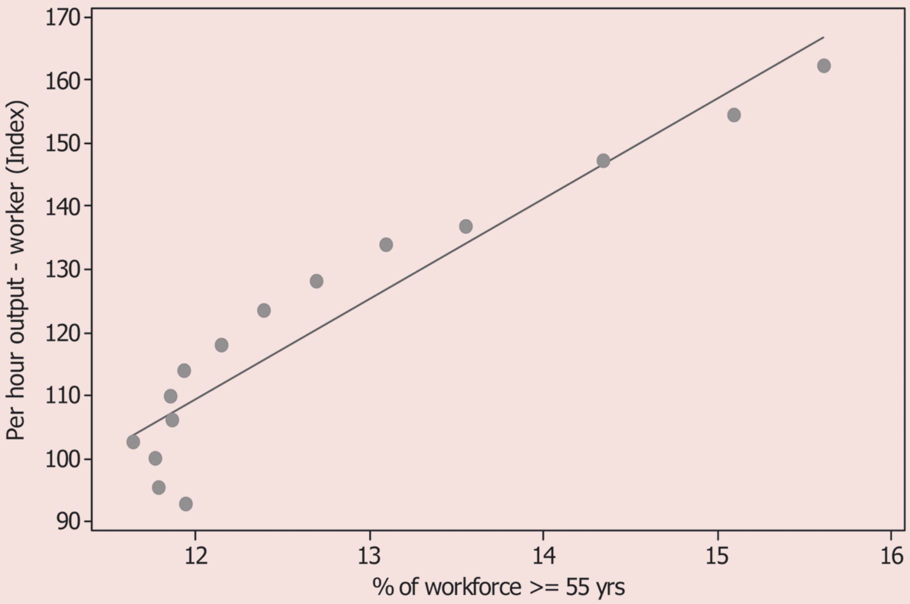
The rate of fatalities caused by falls among those over age 55 is high—accounting for 20% of the fatalities among workers in that age bracket. By comparison, falls account for only about 9% of fatalities in all other age groups combined (Agnew and Suruda). About one-third of the compensable injuries among workers over age 65 are due to falls (Root). Whether caused by loss of control of postural stability, loss of ability to recover balance, fatigue or loss of strength, engineers can help to control this (Sheldon; Spirduso and MacRae; Agnew and Suruda).

Loss of Spatial Senses

Aging is sometimes associated with a progressive deterioration in the spatial senses, as measured by standard laboratory tests. Visual acuity and hearing ability deteriorate with age (Shinar). According to Shinar, while all visual functions deteriorate with age, the amount, rate of deterioration and the onset varies depending on the specific function. This can lead to several problems, such as loss of dynamic and static visual acuity, susceptibility to screen clutter

Figure 4

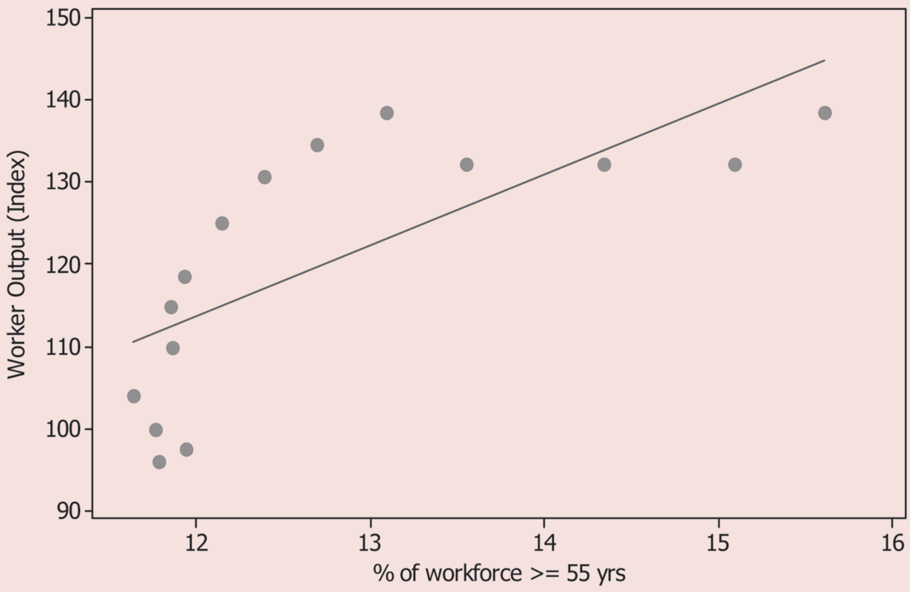
Output of Workforce vs. 55+ Age Group



Adapted from BLS(b); Belwal and Haight.

Figure 5

Output of Workforce vs. 55+ Age Group



Adapted from BLS(b); Belwal and Haight.

and reduced nighttime legibility distances (Sivak, et al) and difficulty reading critical control system readouts or important warning signs in low light [Haight(b)]. Many work tasks involve moving targets making dynamic visual acuity (ability to resolve moving targets) critical. At 65, one is less able to see at night when legibility distances are reduced by as much as 35% (Chrysler, et al). Work on an assembly line, with objects on a conveyor belt or moving data on a computer screen, make dynamic visual acuity important to safe task performance [Haight(b)].

Other problems include a weakening of recent memory and an increased rigidity of response. Research has shown that with age a person's brake response time slows. Over a driver's lifetime, there is an average of a 50 ms reduction in brake response time (Belwal and Haight).

Theoretical researchers have indicated that experience and task familiarity benefit performance. Salthouse posed some interesting questions about the attenuation or elimination of age-related differences.

Loss of Cerebral Function

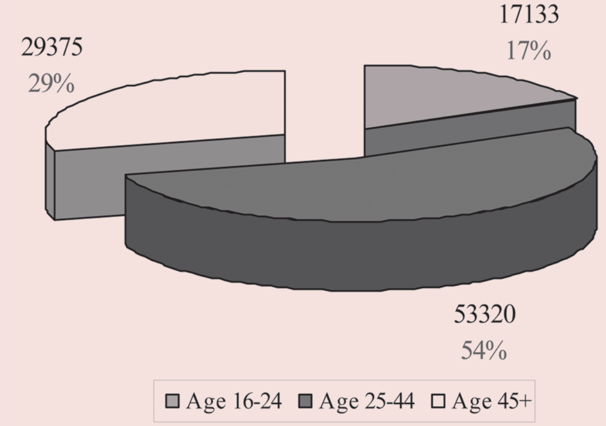
Aging is often associated with a progressive death of neurons. Since these cells cannot be replaced, some deterioration of mental function might be anticipated. Many aspects of cerebral function depend as much on the extent of interneuronal connections (which increase with age), as on the total count of living neurons. This implies that if an individual remains in good health, loss of intelligence has not been demonstrated before the 8th decade of life. This would also imply that experience (which would help to build interneuronal connections) helps in the face of dying neurons (Belwal and Haight).

While loss of intelligence is not associated with aging, Hancock, et al found a loss of ability to comprehend explicit and implied warning information. Their study was performed using household products and it showed age-related differences between older and younger subjects in comprehending the warning information in terms of inferring the correct hazard about which the information was warning. Since sensory deterioration occurs, the rate of response to some signals is slowed, and older workers may be handicapped where rapid decisions are required.

Caird, et al found that older adults (65+ years) performed significantly lower in a driving task with respect to making accurate decisions about rapidly changing requirements in the driving scene. These were reported to be due to more frequent attention failures. When responding to a control signal and selecting a response or action, older adults' performance is lower than that of younger adults, especially when an incompatibility exists between displays and controls (Proctor, et al).

Figure 6

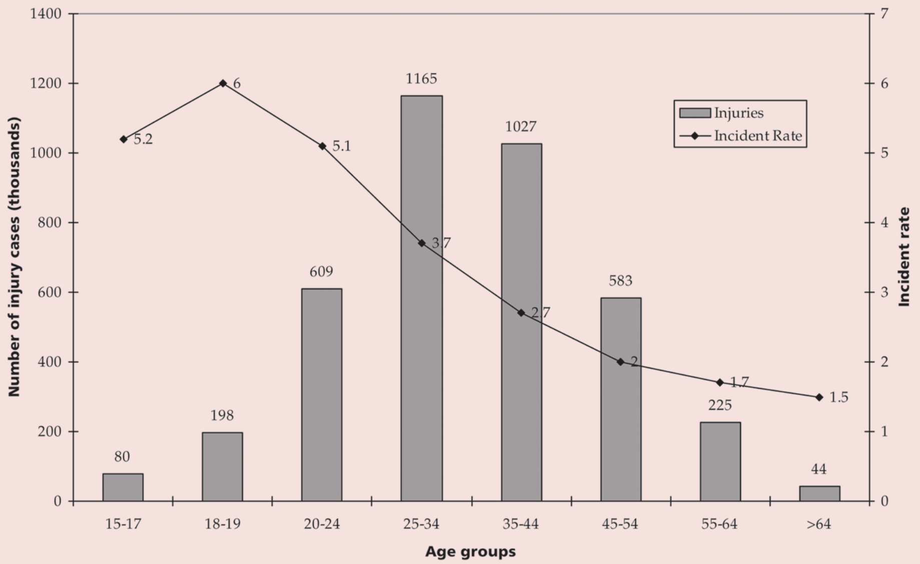
Employment in Private Industry (in Thousands)



Adapted from BLS(a).

Figure 7

Injuries vs. Age Groups, 1999



Adapted from NEISS, 2003.

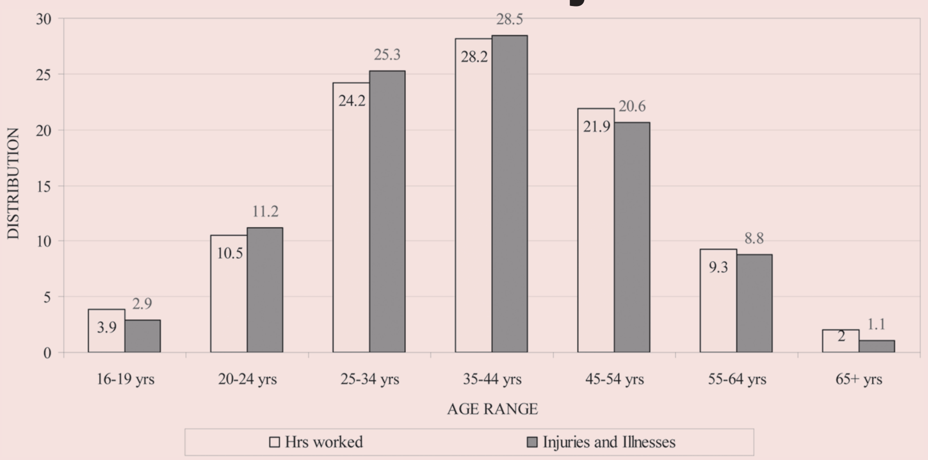
Does additional practice or training help? Do age-related differences disappear when individuals have extensive experience with relevant activities?

One concern about making judgments here is that much of the research has involved average citizens performing day-to-day life-skills-type tasks. Many researchers have shown that with age, losses occur in memory, reaction time, decision-making time and general mental processing time. These findings apply not to workers, but to experimental subjects in a laboratory setting. In a work setting, no one is sure how (or whether) these findings affect the performance of older workers [Haight(b)]. While the performance parameters have been shown to be affected by age, the question remains as to whether work performance is affected. If not, it appears that workers develop their own accommodations or benefit from the experience they have gained, allowing them to complete their tasks more efficiently or effectively (Haight and Miles).

According to some researchers, older adults have more difficulty managing multiple tasks (Sit and Fisk; Korteling). Although the mechanism is not understood, the difficulty seems to be with prioritizing tasks and keeping them all active. While production schedules or demand forecasts dictate tasks, priority and rate, task designers can influence these variables during the design phase. However, given today's complex automated control systems, task demand is not stable. The automated control system can be designed to provide task or at least alarm prioritization. For example, the system automatically opens a valve in response to high level in a vessel. But it can also provide greater emphasis on the need to open the valve by highlighting which control should be implemented first in response to a particular operational upset (Haight and Kecojevic).

Figure 8

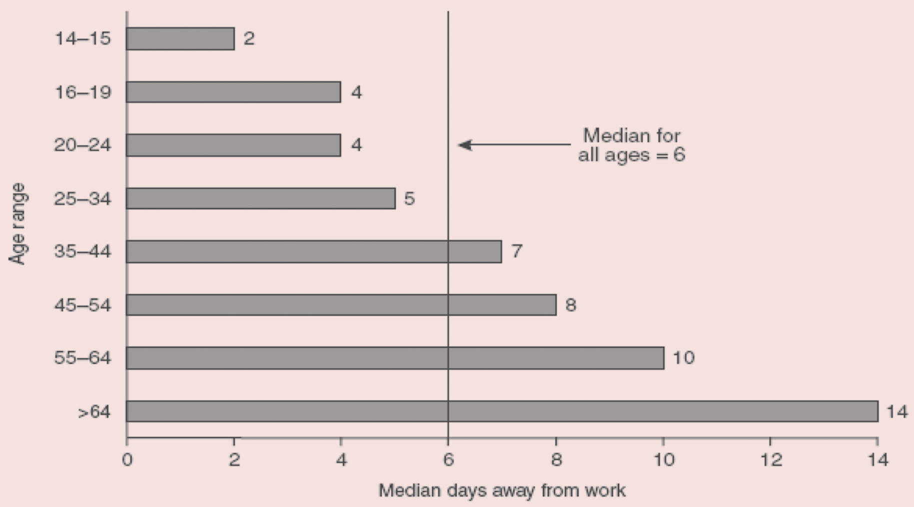
Hours Worked & Work Injuries/Illnesses



Adapted from BLS(b); Belwal and Haight.

Figure 9

Median Days Away from Work



Adapted from BLS(b); Belwal and Haight.

Age, Safety, Errors & Productivity Relationship

Given the losses described, it is tempting to believe that as the average age of the worker increases work performance will decline while error rates and injury rates will increase. While this may be the intuitive expectation, several indications suggest this intuition may not be correct. It is unfortunate that it is not yet fully understood why this is the case. However, it is still important to present available information in order to advance that understanding process.

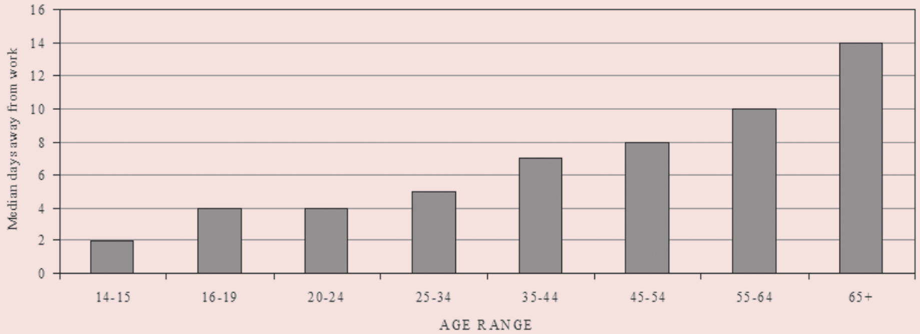
Aging & Productivity

As noted, the research is unequivocal in showing that with age, people experience age-related deterioration in the cardiorespiratory function, muscle strength, cognitive function and acuity of the spatial senses. This is in addition to increased likelihood of both acute and chronic diseases. However, the impact on productivity through age 65 or even 70 is much less clearly established. Given a good genetic makeup, a favorable lifestyle and regular physical activity, some workers may have as favorable and productive a work output as more sedentary peers who are 20 or 30 years younger (Belwal and Haight).

If a worker produces a physical product, it is possible to measure productivity directly. Mathematically, productivity can be calculated as the number of acceptable quality items produced divided by total work hours. The worker's productivity is then expressed in terms of the number of products produced per hour.

Figure 10

Median Days Away from Work



Adapted from BLS(b).

Many in manufacturing believe that unsatisfactory productivity in an average older worker would arise because of some combination of declining cardiovascular function or muscular strength, poor health with frequent absenteeism, and a deterioration of the spatial senses or cerebral function. Retirement is, therefore, demanded when a person reaches a fixed age, when certain physical or mental standards can no longer be met, or when a specific age is combined with failure to meet specified standards [Shepard(b)]. Is this really the case?

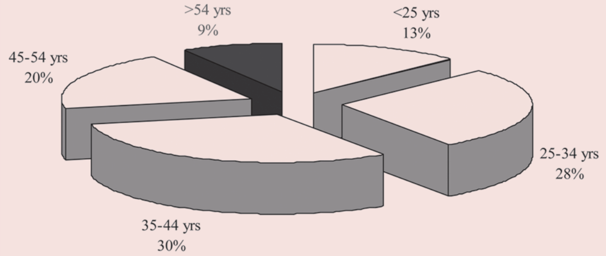
Since most physical products manufactured today are manufactured by team effort with younger and older employees working together, it is difficult to attribute a specific productivity measure to an individual worker. This article explores the effect on productivity experienced by the overall workgroup as its fractional make up of those over 55 increases.

Another difficulty in determining the productivity of a worker is that productivity may also depend on "occupancy" (how much the worker keeps him/herself occupied—whether the worker actively seeks more work or passively awaits instructions); effectiveness (the degree to which an appropriate task is selected); and efficiency (the degree to which an optimum task approach is adopted) (Belwal and Haight). The authors used the BLS output productivity index to better understand productivity impact on an increasingly greater fraction of those older than age 55. Figure 3 (pg. 23) shows the output (in terms of the productivity index) of all workers from 1987 to 2004. The productivity index value has increased dramatically (Belwal and Haight).

During the same period, the per-hour output index and the overall output index for workers indicate that as the fraction of workers over age 55 increases, productivity increases as well. As Figure 4 (pg. 24) shows, the per hour output index falls in the 90 to 110 range when the >55 fraction of the workforce is around 12%. When this fraction increases to 15 to 16%, the per-hour output of the entire workgroup increases to 150 to160. The fit of the trend line indicates (with an adjusted R^2 of about 0.88) that a positive linear relationship exists between the per-hour output index for the overall workforce and the >55 fraction of the workforce. In Figure 5 (pg. 24), the fit is not quite as strong, with about 84% of the variation being attributable to age. While it is not a linear relationship (the fit is probably more appropriately a second order polynomial), it is certainly predictable and of positive slope.

Figure 11

Distribution of Back Injury Cases by Age



Adapted from BLS(b); Belwal and Haight.

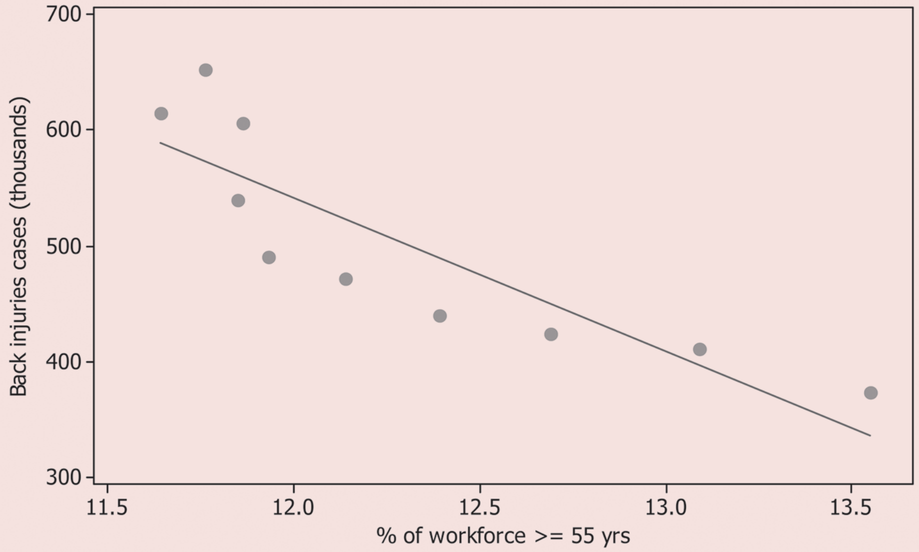
While the BLS data do not explain all the variables that may be playing a role in the increase in productivity, at least they provide a mathematically strong indication that a relationship exists and that it must be studied further to understand whether, why and how productivity increases as the >55 fraction of the total work population increases. Is it experience, a different work ethic or older workers doing a good job creating their own accommodations to remain highly productive? The questions and the strong positive relationship beg for more research.

Safety & Errors

As noted, studies have shown that with advancing age, an individual's physical and mental capacities decline (Mulligan and Sala-i-Martin). This is also thought to potentially lead to an increase in errors and injuries. However, the data presented show mixed results.

Figure 12

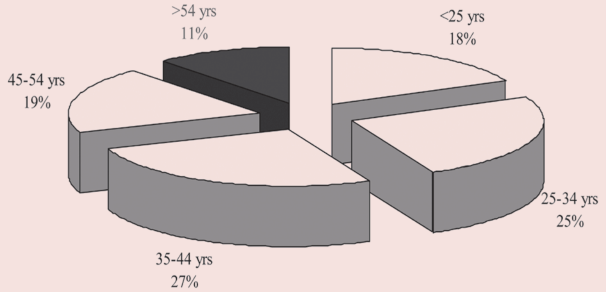
Back Injury Cases vs. Percentage Increases in the 55+ Workforce



Adapted from BLS(b).

Figure 13

Distribution of Bruise & Contusion Cases by Age



Adapted from BLS(b); Belwal and Haight.

Industrial Injuries & Illnesses: Age Groups

The data shown in Figure 6 (pg. 25) exclude cases in which the age of the injured worker was not reported. Workers age 25 to 44 were responsible for 54% of the total nonfatal injuries and illnesses reported by BLS in its annual survey of occupational injuries and illnesses. The graph is indicative of the fact that the injury and illness rate is lower in older workers compared to their younger peers (Belwal and Haight).

Based on the information in Figure 7 (pg. 25), the lowest injury and illness rates (for injuries treated in hospitals) appear to occur among those age 45 and older. An estimated 3.9 million occupational injuries and illnesses were treated in hospital emergency departments among all industry and occupation groups for workers age 15 and older. The highest number of these injuries and illnesses occurred among workers age 25 to 44, and the highest rates were among workers age 15 to 24. The overall rate was 3.0 per 100 full-time workers.

In Figure 8 (pg. 26), for workers age 20 to 44, the percentage of total injuries and illnesses was greater than the percentage of total hours worked. Together, these workers accounted for the majority of injured or ill workers. Among older workers, the percentage of total injuries and illnesses was less than the percentage of total hours worked. Workers in the 45 to 54, 55 to 64 and >64 age brackets do not experience any greater rate or ratio of injuries to hours worked than the categories of younger workers.

Injury/Illness-Related Days Away from Work

One area where an age-related increase does appear is in days-away-from-work due to an occupational injury or illness. Figures 9 and 10 (pp. 26-27) provide some insight into one possible physical loss that cannot be overcome by experience or accommodations—healing after an injury. The median number of days away from work due to nonfatal occupational injuries and illnesses increased as the age of the worker increased. The median number of days away from work was 6 for all cases in 2001. Despite the fact that older workers suffer from comparatively fewer illness and injury cases compared to their younger peers, they appear to require a longer period to recuperate and return to work. As Figure 9 (pg. 26) shows, the median days away from work exceeds 10 days for the older worker, while this value stands at 8 or fewer for their younger peers (Belwal and Haight).

Back Injuries

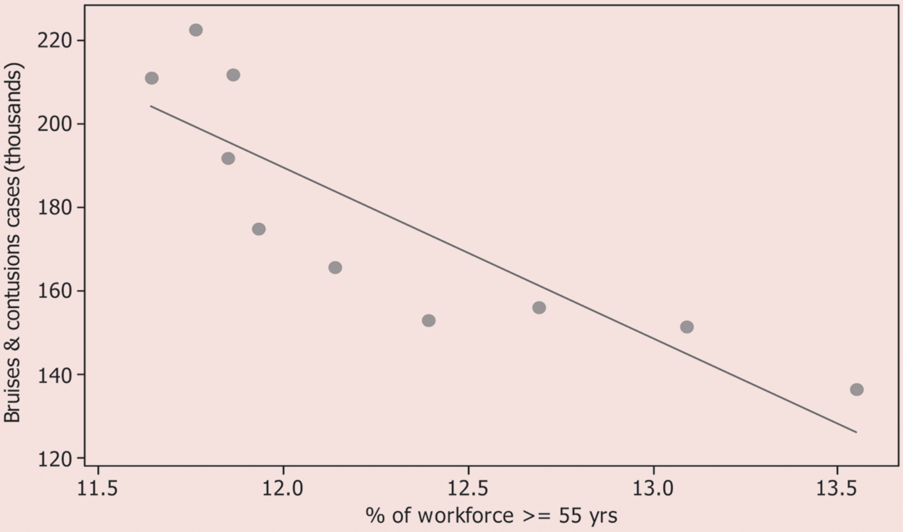
Age data are available for 369,351 of the 372,683 BLS-estimated back injury cases involving days away from work in 2001. Overall, three age groups (25 to 34, 35 to 44 and 45 to 54) accounted for 78.5% of back injury cases—slightly more than the 75.2% reported for all nonfatal injury and illness cases. As Figure 11 (pg. 27) shows, only 9% of the back injury cases occur among those over 54.

Figure 12 reflects a relatively strong negative relationship (mathematical relationship) between back injury cases and the fraction of workers over 55 in the total workforce. This strong negative linear relationship (R^2 = 0.755) is an indication (with roughly 25% uncertainty) that as the 55 and older fraction increases, the number of back injuries decreases. All variables that may influence this relationship were not available, so the authors cannot unequivocally state that 55 year olds reduce the overall back injury rate; however, it can be said that the indication which shows a positive influence on the overall workforce when more workers are older than 55 is at least mathematically strong.

Again, all the reasons for this phenomenon are not well understood (not only do >55 year olds report fewer back injuries, they may also apparently create an environment where fewer back injuries occur among the entire workforce). According to Chaffin, et al, older adults tend to adopt more conservative postures when they reach and this may also contribute to an explanation of fewer back injuries. This conservative posture may be a function of experience.

Figure 14

Bruise & Contusion Cases vs. Percentage of the Workforce 55+



Adapted from BLS(b).

Bruises & Contusions

As Figure 13 shows, age data are available for 134,783 of 136,361 BLS-estimated bruise and contusion cases involving days away from work in 2001. Overall, three age groups (25 to 34, 35 to 44 and 45 to 54) accounted for 70.5% of bruise and contusion cases compared with 75.2% of all nonfatal injury and illness cases. Among these cases, more workers were under 25 (18.1%) than among all nonfatal injury and illness cases (14.3%). Those over 55 accounted for 11% of the bruise and contusion cases.

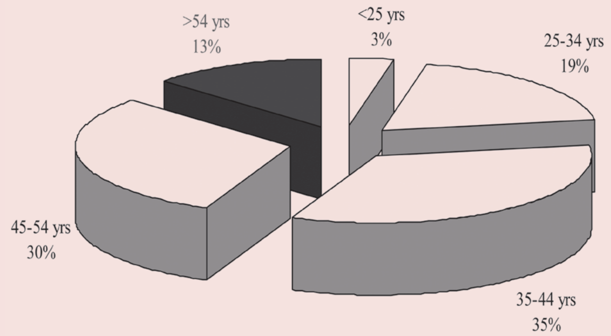
Figure 14 indicates that as the fraction of >55 workers increases, the total number of bruise and contusion injuries decreases. In this case, there is a strong negative linear relationship between these two variables (R^2 = 0.74) indicating that there may be reason to expect fewer bruise and contusion injuries in a workforce made up of a greater fraction of >55 year old people. As with back injuries, all the variables that may influence bruise and contusion injuries are not available so this is not an irrefutable claim. However, the indication is strong enough to warrant more research.

Carpal Tunnel Syndrome Cases

Figure 15 shows that those older than 54 experienced 13% of the carpal tunnel cases. Even though this is a greater proportion than for either back injuries or bruises and contusions, it is still worthy to note that with those over 55 make up about 16% of the workforce, so this is still lower than what would be statistically expected. It is also interesting to note that the 45-to-54 age group suffered 30% of the cases, while making up about 34% of the workforce.

Figure 15

Distribution of CTS Cases by Age

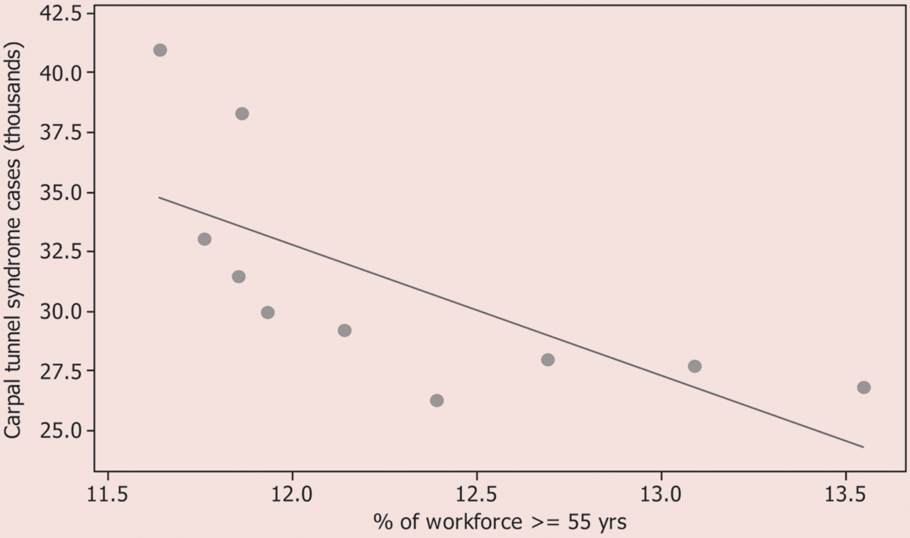


Adapted from BLS(b); Belwal and Haight.

Figure 16 presents additional evidence of the same counterintuitive phenomenon as is present with bruises and contusion and back injuries. As the fraction of 55+ workers increases, carpal tunnel syndrome cases decrease. In this case, a strong negative polynomial relationship exists between these two variables (R^2 = 0.80), indicating that one may expect fewer carpal tunnel syndrome cases within a workforce made up of a greater fraction of >55 year old workers. Again, all variables that may influence these cases are not available so this is not an

Figure 16

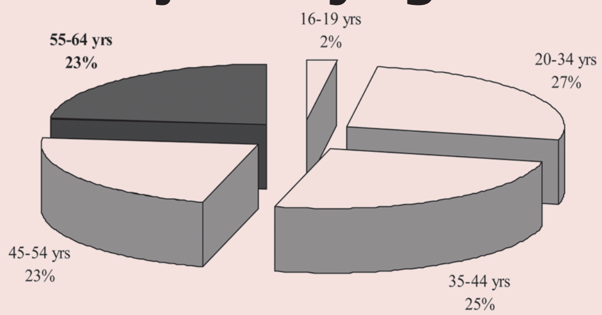
CTS Cases vs. Percentage of Workforce 55+



Adapted from BLS(b).

Figure 17

Distribution of Fatal Injuries by Age



Adapted from BLS(b); Belwal and Haight.

irrefutable claim. However, the indication is strong enough to warrant more questioning and research.

Fatal Injuries

Fatal injuries appear to be a different story than the other types of injuries. As Figure 17 shows, the 55-to-64 age group has experienced a higher percentage (23%) of the total number of fatal injuries. If those over 45 are considered, the percentage increases to 46%. About 14% of the workforce in 2002 (at the time these data were available) was made up of those 55 to 64. Figure 18 shows that workers 25 to 54 accounted for 66.5% of the 5,524 fatal occupational injuries in 2002. Fatality rates ranged from 1.1 per 100,000 among workers 16 and 17 to 11.5 per 100,000 among workers 65 and older. Fatalities among workers 65+ accounted for 9% of all fatal occupational injuries. While the rate of fatal injuries remains constant throughout the younger age brackets, a marked increase in the fatal injury rate is seen in the 55 to 64 and the 65+ age brackets.

An interesting picture emerges, however, when one looks at the scatterplot (Figure 19) of total fatal injury cases as a function of the percentage of the workforce over 55. It shows a similar relationship to the scatterplots of the other injury categories in that as the percentage of the workforce in the 55+ age bracket increases, the number of fatal cases across all age groups decreases. While not a linear, this polynomial relationship is strong (R^2 = 0.696) and lends strength to the indication that an increasingly older workforce has a positive influence on the entire workforce. It is impossible to determine what mechanism is responsible for this apparent relationship. It is also impossible to determine what other factors influence the number of fatality cases. However, the indication of positive influence exists, indicating the need for additional consideration and research.

Designing for an Aging Workforce

As this examination of available labor data indicates, older workers may not experience a decline in productivity or an increase in injury rates. This counters intuitive expectations, given the documented physical and cognitive capacity losses that aging adults experience. However, enough uncertainty exists to the indications in the data that questions must be kept on the table. Particularly important is the question about workers developing their own accommodations. Are they doing this and if so are these accommodations safe? Although much must be quantified in terms of what and how much to accommodate, could one start by considering improvements to existing design standards? A few suggestions are posed for consideration.

Currently, more importance appears to be placed on knowledge, skills and aptitude than on physical skills. Advanced technologies help to remove barriers for people with various mobility-related and sensory losses. Design of more accessible workplaces, improved lighting, cleaner control displays, automated control systems, ergonomic computers with monitors that accommodate less-than-perfect vision, and communication technology for those with hearing problems help to keep safety, satisfaction and productivity high. While these improvements can and have benefited all workers, it is not known whether enough has been done for older workers [Belwal and Haight; Haight(b)].

Most of the workplace design accommodation suggestions for older workers would not require training. Simply by considering the limitations of older workers when designing or modifying a workplace, engineers could vastly improve the work space for older workers even without quantified design criteria.

For example, in task design, consideration for manual materials handling equipment would help reduce the need for older workers to lift or carry loads over long distances. Task rotation would reduce the strain of repetitive motion and reduce static standing time. Other employee-friendly improvements might include adjustable chairs and work surfaces, large video displays, hands-free, volume-adjustable telephone or other communications equipment.

Education in the form of seminars and training programs can help all workers prevent conditions such as carpal tunnel syndrome, back strain and tendonitis, but with an emphasis on the limitations of older workers, more assurance of fewer of these types of injuries may be achieved. Various information brochures, training sessions and advisory material could be included in health plans (Belwal and Haight).

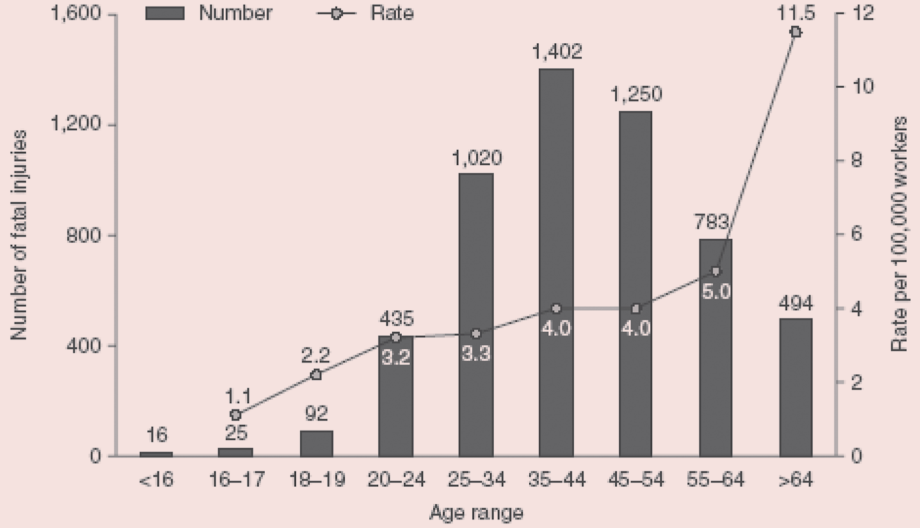
Physical design considerations may include minimizing elevated work where possible, and automating controls so that physical manipulation of the controls at elevated locations is not necessary. Other applied considerations include:

- Install chain actuators for valve hand wheels, damper levers or other similar control devices. This brings the control manipulation to ground level.
- Install skid-resistant material for flooring and especially for stair treads.
- Install shallow-angle stairways in place of ladders when space permits and where elevated access is needed to complete daily tasks.
- Install cushioned flooring where static positions are necessary. Since softer cushioning may contribute to loss of balance, some optimizing may be necessary for older workers (Redfern, et al).

Engineers should also consider the size and shape of controls (push buttons, lever handles, valve hand wheels, switches) in the interest of usability and error reduction. These features can also help older workers more easily accomplish control task objectives with less likelihood of injury and possibly less pain. One study showed that elderly females had difficulty generating adequate torque in water

Figure 18

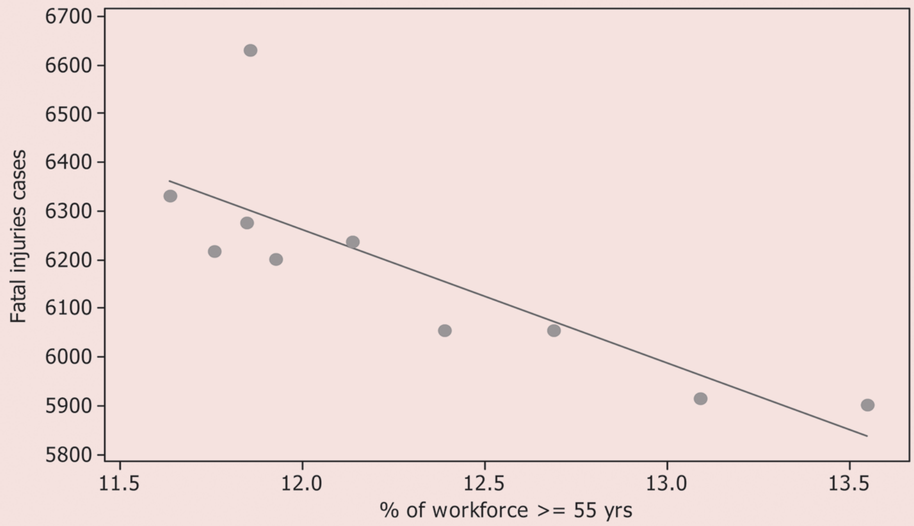
Fatal Occupational Injuries by Age, 2002



Adapted from BLS(b); Belwal and Haight.

Figure 19

Fatal Injuries vs. Percentage of Workforce 55+



Adapted from BLS(b); Belwal and Haight.

Workplaces must be prepared for the future, which involves a growing number of older workers. It has been demonstrated by many researchers that with training to maintain, update and enhance skills, older employeescan contribute significantly to productivity.

faucet handles of various shapes [Bordett, et al; Haight(b)]. Because older adults experience a loss of grip strength, a control handle that allows them to generate maximum torque with minimum effort is desirable. According to the Bordett study, a lever-type design is preferred to a knob because twice as much torque can be exerted with a lever as opposed to a knob or multipoint wheel design (Haight and Miles).

Designers of warning labels for household or industrial products should consider writing the warnings and instructions so as to minimize memory load and to maximize the opportunity for older workers to use knowledge they have to understand the nature of the hazards and the precautionary requirements (Hancock, et al).

Publicly available design codes and standards do not provide adequate consideration for the visual needs of older workers. Since information presentation and lighting can be controlled, these systems can be designed to account for age. Design engineers incorporating visual targets (e.g., controls, warning, instructional signs) into their designs should ensure adequate illumination, high contrast between monitored parameters and the background, and reduce scene clutter (Ho, et al). Lighting recommendations are available from various sources, such as manufacturers' data and professional societies. For office areas where visually difficult tasks are performed (e.g., jewelry repair, drafting), suggested illumination intensity is 75 to 100 ± 20 foot candles [Haight(a)]. If a significant number of workers are 50 or older, the design engineer might consider designing the system to provide levels in the 100 to 120 foot candles range. The average suggested process control room information panel illumination levels appear to be 50 ± 10 foot candles. In this case, the design engineer may consider providing 60 foot candles as opposed to 40 foot candles (Haight and Miles).

Sivak, et al reported that nighttime legibility distances are reduced for drivers age 65—by as much as 23 to 35% over what they are for 25 year olds. In this case, engineers may consider increasing the size of visual targets (such as warning sign lettering, control identification and procedure print) by 23 to 35%. Design engineers may also consider the placement of the visual target (e.g., sign, display panel). For example, if a worker must stand 100 feet away in work position, move the visual target to a location 65 to 77 feet from the worker (Shinar and Schieber; Haight and Miles).

According to one study, older adults need more time to make decisions than younger adults (Walker, et al). When time pressure is present, decision quality seems to suffer. In an actual production setting, sufficient or even additional time for decision making may not be available. While this has not been thoroughly researched or quantified for workers, it appears that if decision-making time can be increased, the likelihood of fewer errors among older workers could be improved. Adding 30 seconds to a task completion deadline may be all the time needed to complete the task without errors or operational upsets (Haight and Miles).

While control systems are increasingly being automated and computer screen-displayed information continues to increase, it is critical to reduce the amount of "active target information" or "must have" information shown on the screen (Haight and Kecojevic). It is not known quantitatively how much screen clutter is too much, but it would seem reasonable to design the system in such a way as to reduce the amount of process parameter information shown on the screen at any given time by 20%. An engineer can reduce alarm points to allow more time to physically respond or can provide for a "push button" response to close a valve, open a damper or slow a conveyor (Haight and Miles).

It has also been suggested that engineers consider managerial adjustments to account for the multitask environment [Haight(b)]. Possible adjustments include allowing longer response time between steps in a task or between a control signal and an action; additional practice to increase task familiarity; frequent refresher training; frequent reinforcement of task priority; reduction in the need for simultaneous performance of two or more tasks; or designing the system to be operated with low sensitivity to task order. System and task designers can also gain useful information by talking with older workers about some accommodations they already make in order to maintain task performance in the face of declining capacities (Haight and Miles).

Conclusion

As we age, we experience both physical and cognitive capacity losses. We may intuitively expect that those losses would lead to lower productivity, more errors or higher job-related injury rates.

However, available labor data indicates that this may not be the case. Unfortunately, these data and the inability to access information on all the variables that may influence productivity and injury output produce some uncertainty with this analysis. Depending on the output being evaluated, age appears to be at least mathematically related to productivity and injury rate measures (within 69 to 89% certainty bounds). Therefore, one must proceed with caution when considering these research results.

Another concern is that it is not possible to determine why productivity and injury data may increase or decrease. One can surmise that experience plays a role and it is likely that workers themselves develop accommodations to remain safe and productive, but data are insufficient to guarantee that this is the case. It is also not clear whether experience offsets some physical and cognitive capacity losses—and if it does, how much. Clearly, many questions remain.

Given these questions, it is proposed that design engineers consider the needs and necessary accommodations that can be made for older workers. Although design specifications have not been developed or tested specifically for older workers, the suggestions provided take a reasonable, practical approach to using existing design codes to help ensure that older workers do not put themselves at risk by developing accommodations without adequate engineering input.

Workplaces must be prepared for the future, which involves a growing number of older workers. It has been demonstrated by many researchers that with training to maintain, update and enhance skills, older employees can contribute significantly to productivity and may even surpass younger workers in reliability and consistency (Allen and Hart; Ennis-Cole and Allen). By implementing changes in the workplace, productivity of older workers could be enhanced (Labich; Sterns and Miklos).

Myths continue to surround older workers. The goal is to create a workplace that uses knowledge, experience and accommodations to create an environment which allows older workers to remain as (or more) productive as their younger peers. With careful consideration and additional research, scientists and practitioners can help to make this a reality. ■

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