Integrating the Mind

Domain general versus domain specific processes in higher cognition

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17 Innovation, fatal accidents, and the evolution of general intelligence

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How did humans evolve such remarkable intellectual powers? This is surely one of the most enduring and captivating questions in the life sciences, from paleoanthropology to neuroscience. Modern humans (*Homo sapiens sapiens*) far exceed all other species in their ability to learn, reason, and solve novel problems. We are, most strikingly, the only species whose members routinely use words and other abstract symbols to communicate with each other, record ideas in material form, and imagine alternative futures. Perhaps for these reasons we are the only species ever to have developed complex technologies that allow us radically to transform the physical environments we inhabit.

Human intelligence is tied in some manner to the large increase in brain size going up the human evolutionary tree (Geary, 2005; Holloway, 1996). When the encephalisation quotient (EQ; Jerison, 2002) is used to measure brain size relative to body size, modern humans are three times as encephalised (EQ = 6) as other primates (EQ = 2) and six times the average for all living mammals (EQ = 1, the reference group). This phylogenetic increase represents a disproportionate expansion of the brain's prefrontal cortex (Schoenemann, Sheehan, & Glotzer, 2005), which matures last and is most essential for the highest cognitive functions, including weighing alternatives, planning, understanding the temporal order of events (and thus cause-and-effect relations), and making decisions. Moreover, encephalisation of the human line proceeded rather quickly in evolutionary terms: after the first hominids (*Australopithicines*, EQ = 3) split off from their common ancestor with chimpanzees (EQ = 2) about 5 million years ago. Encephalisation was especially rapid during the past 500,000 to 1 million years (Aiello & Wheeler, 1995; Holloway, 1996; Ruff, Trinkhaus, & Holliday, 1997), when relative brain size increased from under EQ = 4 for *Homo erectus* (arguably the first species of *Homo*) to about EQ = 6 for living humans (the only surviving subspecies of *Homo sapiens*).

Brains are metabolically expensive. In humans they account for 2% of body weight but consume 20% of metabolic energy (Aiello & Wheeler, 1995). Hence, the rapid increase in relative brain size suggests that higher intelligence conferred a strong adaptive advantage. Attempts to identify the selection forces driving up intelligence in the human *environment of evolutionary adaptedness* (EEA) often look to the ecological, behavioural, and life history correlates of encephalisation, either in the paleontological record or through comparative studies of living species.

Evolutionary psychologists agree that increases in brain size are crucial in tracing the evolution of humans' extraordinary intelligence, but they say relatively little about what that intelligence actually is. They agree that humans have impressive reasoning abilities, which in turn confer valuable behavioural flexibility, but they conceptualise human intelligence in very different ways. The debate has focused on whether intelligence is "domain specific" (e.g., has "massive modularity") or "domain general." Proponents of domain specificity emphasise the morphological modularity of the human brain, likening it to a Swiss army knife, and argue that human intellectual prowess consists of a large collection of separate abilities that evolved independently to solve different specific adaptive problems, such as "cheater detection" (e.g., Tooby & Cosmides, 1992). Humans, they argue, have not evolved any meaningful content- and context-free general reasoning or learning ability, but are smart because the human brain evolved myriad "fast and frugal heuristics" (Gigerenzer & Todd, 1999). The domain generalists, emphasising the highly interconnected circuitry of the brain's distinct parts, argue that human intelligence is best understood as a generalised capacity that facilitates reasoning and adaptive problem solving, especially in novel, changing, or otherwise complex situations (e.g., Geary, 2005). These theorists acknowledge the modular elements of the brain and mind, but consider them subject to the more general learning and reasoning mechanisms that they believe humans have evolved.

This chapter aims to show not only that our species' distinctive intelligence is domain general at the phenotypic, genetic, and functional levels, but also how a general intelligence could have evolved. Drawing evidence from sister disciplines not often consulted by evolutionary psychologists, I first describe how general mental ability, *g*, represents a suite of generic critical thinking skills that provides individuals with pervasive practical advantages in coping with many life challenges, especially when tasks are complex. As will be illustrated, the cognitive demands of even the most mundane daily tasks are sufficient to put less intelligent persons at a higher relative risk for many unfavourable life outcomes, including premature death.

One particularly large class of deaths – fatal accidents – will be used to illustrate how individual differences in *g* might contribute to differential mortality as people go about their daily lives. The prevalence, aetiology, and demographic patterning of accidental deaths in both modern and hunter-gatherer societies provide clues to how these could have winnowed away a group's less intelligent members throughout human evolution: fatal accidents (unintentional injuries) kill a disproportionate number of reproductive-age males, their accidents are generally associated with provisioning activities, and preventing these is a cognitively demanding process. Accidents have a high chance component, are diverse in type, but only rarely result in death, which dulls our appreciation of them. These attributes are also precisely what make them a potentially powerful force for evolving a general-purpose problem-solving mechanism rather than, for example, specific hazard-detection modules.

As oft noted, there must have been something unique in the *Homo* EEA to trigger the peculiarly rapid increase in hominid brain size and mental power. That trigger may have been human innovations during the past half million years, especially since the emergence of *Homo sapiens sapiens* just 50–150 thousand years ago. My hypothesis is that innovations in obtaining and processing food (e.g., fire, weapons, tools) lowered age-specific mortality rates relative to other primates, but they also created novel physical hazards that widened *differences* in risk of accidental death within human groups. Differences in risk within a population are, of course, the engine for natural selection. With each new innovation, humans could have strengthened natural selection for *g*.

Do humans possess a domain general intelligence?

Domain specificity theories of intelligence rest on the commonsense (but mistaken) notion that different tasks require different abilities. Indeed, until the 1980s, most experts on the topic believed that good performance on mental tests, in school, and at work, required having the particular constellation of specialised skills and abilities that best matched the idiosyncratic cognitive demands posed by particular tasks in particular settings. Most assumed, for example, that tests of mathematical ability would predict achievement well in maths but not in language, whereas tests of verbal ability would do the reverse. They likewise assumed that even in the same occupation (e.g., clerk) good performance required notably different sets of abilities when the work was performed in different companies, or units within them. Most social scientists therefore explicitly rejected the notion that any putative general intelligence could be useful in many endeavours, if it even existed. The evidence contradicting these early specificity theories of cognitive ability (e.g., Jensen, 1984; Schmidt, Law, Hunter, Rothstein, Pearlman, & McDaniel, 1993) is equally relevant in refuting domain specificity theories elsewhere in psychology. I begin with evidence for generality in the cognitive abilities that humans possess, and turn later to evidence on the abilities that everyday tasks require of us.

Generality of human intelligence (g) at the phenotypic level

There are many distinct cognitive abilities, and there are large ability differences within all human populations, including hunter-gatherers (Reuning, 1988). One of the first discoveries about such variation, however, was that individuals who perform well on one mental test tend to perform well on all others, even ones often presumed not to have any mental component (e.g., multi-limb coordination and tactile–kinaesthetic sensitivity). This is the case regardless of test content or format. A century of factor analyses (Carroll, 1993, Figure 15.1) has delineated the structure underlying this covariation in cognitive abilities. Perhaps its most important finding is that, to some degree, all tests tap the same ability (dubbed *g*, for the general mental ability factor). Next, abilities are best distinguished by level of generality–specificity, with the most general (*g*) at the apex of the hierarchy and highly specific abilities along its base. The most influential hierarchical model is Carroll's three-stratum theory (1993). He confirmed only one highly general factor, *g*, at the Stratum III apex, then 8–10 narrower but still broad abilities at the Stratum II level (broad "group factors" such as spatial, memory, and auditory abilities), and many specific aptitudes at the next lower level of generality (Stratum I or "primary" abilities such as ideational fluency, perceptual speed, and absolute pitch).

Another crucial finding was that the *g* factor is not an amalgam of the narrower abilities in the strata below it, but provides the common core of them all. Each stratum dominates the composition of abilities in the stratum below. The Stratum II abilities have thus been aptly described as differently "flavoured" (spatially, verbally, etc.) versions of *g*. They, in turn, dominate the Stratum I abilities, each of which in turn represents a particular mix of the broad abilities above it, and of experience in deploying them in particular contexts. Narrower abilities are, accordingly, more content-specific and less heritable. The Strata I and II abilities, though still having a large *g* component, represent the more modularised and more environmentally sensitive ability differences among us. They illustrate that highly specialised skills (extracting armadillos from their burrows, driving a car) do not necessarily require specialised innate reasoning modules, but just sufficient practice in mobilising the pertinent combinations of abilities (cognitive, psychomotor) required to master specific tasks in specific settings.

Other research has shown that differences in *g* are manifested in behaviour as differences in generic thinking skills – such as learning, reasoning, and abstract thinking – and hence in the ability to apprehend, transform, and understand information of virtually any kind. Differences in *g* are measured well, though not perfectly, by IQ tests. Moreover, when a general factor is extracted (1) from different IQ test batteries and (2) for test takers of different ages, sexes, races, and nationalities, all the resulting general factors are nearly identical and converge on the same psychometrically "true" *g* factor (Jensen, 1998). This signals that within all groups, the *g* continuum is a shared fact of nature, not the product of any particular culture (see also Chabris, Chapter 19, this volume). Why demographic groups tend to be spread somewhat differently along this common *g* continuum is a separate issue.

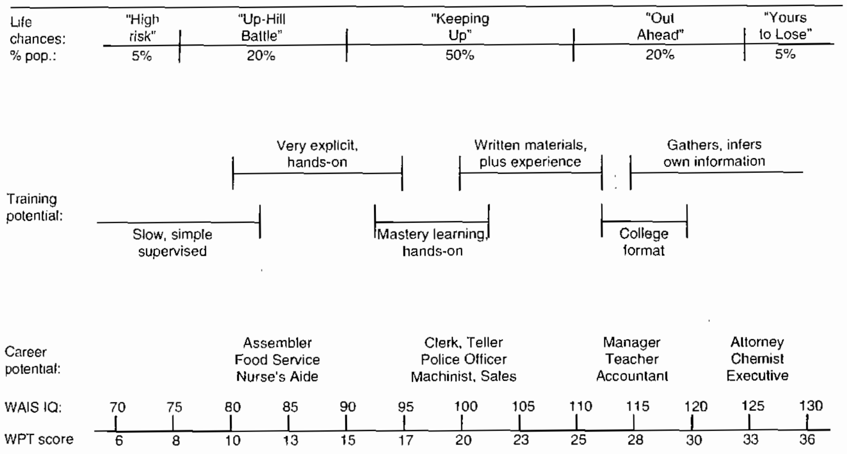
Carroll (1993) tentatively placed two highly correlated but still distinguishable *g* factors at the Stratum II level: fluid *g*, which can be conceived as raw mental horsepower, and crystallised *g*, which reflects knowledge crystallised from sustained application of fluid *g* over the life course. The former is usually found to be isomorphic with the Stratum III *g* factor, and so all references to *g* in this chapter are to fluid *g*. Of psychometricians who still use the term "intelligence," most now restrict it to the single Stratum III ability, *g*, as I do here.

Some social scientists (e.g., Gardner, 1983) ignore the general factor and label the Stratum II abilities as multiple intelligences ("linguistic," "visuospatial," "musical," "intrapersonal," etc.). Others stretch the label to include all human competencies, broad or narrow, cognitive or not ("successful intelligence"; Sternberg, 1997). Domain specificity theorists also apply the term "intelligence" to a large collectivity of abilities that are no more general than Stratum I abilities, said to be independent, and which perhaps extend outside the cognitive realm.

General intelligence is often described as the ability to learn, the implicit reference being to those natural settings in which people notice big differences in learning proficiency (school, jobs) and thus to tasks where learning well depends on reasoning well. Individual differences in *g* are most highly correlated with differences in learning proficiency when learning is intentional, hierarchical, meaningful, insightful, and age-related (easier for older than younger children), and when learning requires the transfer of prior knowledge to new tasks, allows everyone the same fixed amount of time, and is moderately difficult. Like other life tasks, learning ranges from low to high in cognitive complexity, and thus in amount of reasoning required. High *g* confers little advantage when learning must be by rote or mere association.

Figure 17.1 makes the practical consequences of ability differences more concrete: Adults near the threshold for mild mental retardation (IQ 70) can usually learn simple work tasks (mopping a floor, answering a telephone, etc.) if given sufficient hands-on, one-on-one, repetitive instruction and supervision. Persons of average psychometric intelligence (IQ 100) can learn a wide variety of routine procedures via written materials and demonstration. Individuals near the threshold for mild giftedness (IQ 130) can be self-instructing. Most individuals toward the left tail of the IQ distribution can learn simple ideas and procedures, but only individuals toward the right tail are likely to generate new ones. The latter are also the most proficient at picking up the knowledge and solving the problems that a broader culture generates, as well as being the most likely to lead it in new directions. No culture can sustain new practices, however, that impose cognitive demands on the general populace that are beyond the capacity of its large cognitive middle.

On the whole, *g* is not correlated with differences in personality, temperament, or physical strength, and it is only moderately correlated with interpersonal and psychomotor skills when all are measured in a psychometrically sound manner (Campbell & Knapp, 2001) – important because it



Out of labour force 1+ mo/yr (men)	22	19	15	14	10
Unemployed 1+ mo/yr (men)	12	10	7	7	2
Divorced in 5 yrs	21	22	23	15	9
Had illegitimate child (women)	32	17	8	4	2
Lives in poverty	30	16	6	3	2
Went on welfare after first child (women)	55	21	12	4	1
Doing time/ever incarcerated (men)	7	7	3	1	0
Chronic welfare recipient (mothers)	31	17	8	2	0
High school dropout	55	35	6	0.4	0

Figure 17.1 Training and career potential in different IQ ranges, and percentage of young white adults in each range who experience various negative outcomes. WPT = Wonderlic Personnel Test. (Adapted from Figure 3 and Table 10 in Gottfredson (1997). Copyright 1997 by Elsevier Science. Reprinted with permission.)

is easy to get falsely low or inconsistent correlations with unreliable measures or range-restricted samples. The *g* factor is therefore distinct from certain other abilities and propensities, sometimes referred to as intelligences, but for which there are no validated tests; for example, intrapersonal, emotional, kinesthetic, and Machiavellian (social) intelligence.

There is a growing tendency in evolutionary psychology, however, to equate general intelligence with a "social intelligence," said to have evolved from an evolutionary arms race to acquire skills for outwitting peers and competitors (Dunbar, 1998). The relevant set of social skills is never delineated, but they appear to range from the mostly preprogrammed (e.g., face recognition, cheater detection) to more consciously controlled, culturally recognised behaviours (e.g., coalition building). Many of the latter encompass fairly global people-related strengths, whose correlations with each other, *g*, and various forms of life success have already been charted by differential psychologists. These range from the "big five" dimensions of personality (openness, conscientiousness, extraversion, agreeableness, and neuroticism), which are mostly independent of *g*, to particular aptitudes in influencing people that depend somewhat on *g* (e.g., persuading, instructing, managing, leading; Barrick, Stewart, Neubert, & Mount, 1998; Campbell & Knapp, 2001). The skills for manipulating abstract information (*g*) and those for controlling other people (any putative social or Machiavellian intelligence) are only partially overlapping sets, and therefore can also be expected to have somewhat divergent genetic and evolutionary origins.

Divergent origins for intellectual and interpersonal competence are also suggested by the large, consistent, and worldwide sex differences in socio-emotional competencies, temperament, interests in people versus things, nonverbal behaviour and perceptiveness (including face recognition), and ways of dealing with other persons (Baron-Cohen, 2003; Campbell & Knapp, 2001). In contrast, there are at most only slight sex differences in general intelligence. The clearest sex differences in cognitive ability are seen in the narrower, more modularised abilities, such as spatial and verbal ability, some of which cluster with the sex differences in temperament and interests (Ackerman & Heggestad, 1997).

Cognitive abilities hardly exhaust the palette of human competence. But to understand the evolutionary origins of general intelligence, *g*, inquiry must target the more strictly cognitive skills by which ancestral *Homo sapiens* met its environmental challenges, both human and not.

Generality of human intelligence (g) *at the genotypic level*

Human intelligence is also general at the genotypic level (Plomin, DeFries, McClearn, & McGuffin, 2001; see also Brody, Chapter 18, this volume). The heritability of IQ is moderately high, rising from under 40% in the preschool years, to 60% by adolescence, to 80% in adulthood. The Stratum II abilities are also moderately heritable, but they share most of their heritability with *g*. The high genetic overlap of the Stratum II abilities with *g* means that the same genes are responsible for much of the variation in all of them. This means, in turn, that all the distinct, broad abilities (and any associated brain modules) tend to function either in tandem or, if functioning independently, with similar efficiency owing to common physiological constraints (e.g., neural speed) (see also Chabris, Chapter 19, this volume).

Recent brain imaging studies do, in fact, indicate that complex *g*-loaded cognitive tasks activate multiple brain areas (e.g., Gray, Chabris, & Braver, 2003). Other research confirms the human brain's great connectivity by documenting a vast neurological web for transmitting information among all its parts. Indeed, as *Homo* evolved bigger brains, white matter (in essence, the relay stations for reciprocal transmission of information throughout the brain) increased faster than grey matter in the crucial prefrontal area of the brain (Schoenemann et al., 2005). So, instead of representing either the sum total of modular processes or simply a domain specific adaptation, psychometric *g* may support or constitute a general executive or integrative capacity that selectively mobilises, inhibits, and coordinates many of the brain's more specialised functions for gathering information and acting on it (see Happaney & Zelazo, Chapter 11; McKinnon, Levine, & Moscovitch, Chapter 7; Moses & Sabbagh, Chapter 12, this volume).

A wide range of heritable metabolic, chemical, electrical, and structural features of the human brain correlate with differences in *g*, from volume of the whole brain and of its grey matter, to rate of glucose metabolism and complexity of brain waves. These features are found to correlate with *g* at the genetic level too, when the requisite behaviour genetic analyses have been possible (Jensen, 1998; Toga & Thompson, 2005). The many heritable physiological correlates of psychometric *g* have led some researchers to suspect that this represents a general property of the brain's neural substrate (nerve conduction velocity, dendritic branching, etc.) that affects how all its parts function.

Generality of human intelligence (g) at the functional level

Finally, *g* level has highly generalised effects on individuals' wellbeing, from physical health to social status (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Gottfredson, 2002). In fact, whether *g* predicts well or poorly, it is generally the best single predictor – better than socioeconomic status – of both the good and bad life outcomes that concern policy makers (e.g., success in school and work, delinquency). Figure 17.1 illustrates that *g*-related gradients of risk are much steeper for some life outcomes than others. Compare, for instance, the risks facing young white adults of very low IQ (below 75) to those of very high IQ (above 125): The former are twice as likely to become divorced within 5 years (21% versus 9%) but their risk of unemployment is 6-fold (12% versus 2%) and living in poverty is 15-fold (30% versus 2%) greater. But whatever the odds, they all tilt against persons lower in intelligence. And large or small, these greater risks to wellbeing pervade the lives of less intellectually able individuals, piling up one risk after another.

Varied kinds of evidence indicate that *g*'s role in the thick network of correlated life outcomes is causal – that differences in *g* level create differences in performance in school, work, and everyday self-maintenance, and that they do so independently of social class. For instance, not only do siblings in the same household differ two-thirds as much in IQ (for mostly genetic reasons) as do random strangers, but these within-family IQ differences portend much the same inequality in life outcomes among siblings as they do in the general population (Murray, 1998). In addition, income, occupational, and educational levels are themselves moderately heritable, respectively, 40–50%, 50%, and 60–70%, with from half to two-thirds of their heritability overlapping that for *g* (Rowe, Vesterdal, & Rodgers, 1998).

The breadth of *g*'s utility means that a wide variety of ostensibly different ecological demands could have selected for this general cognitive capacity. It is essential to note, however, that whereas higher *g* enhances performance in perhaps all kinds of instrumental tasks, its influence seems far weaker when individuals are dealing with socioemotional challenges, such as family, peer, and coworker relations. Additional personal strengths are crucial to being an effective leader, manager, salesperson, team-mate, citizen, or caregiver. This partial disjunction in the functional utility of cognitive versus socioemotional skills, together with the psychometric evidence that they are somewhat independent, suggests that *g* evolved more in response to the instrumental demands of humankind's early environment than to its social or emotional demands.

Do human environments make domain general cognitive demands?

There are excellent discussions of the generality of psychometric *g* in evolutionary psychology (e.g., Geary, 2005) as well as in psychometrics (Jensen, 1998), but neither discipline has said much about what the cognitive demands of daily life actually are. These deserve close analysis, however, because they provide the ingredients of external forces that select for *g*.

Abilities are, by definition, qualities that enhance an individual's performance in some particular range of tasks. This means that a general ability is one that is useful in a great variety of them. It is "generalisable." Much research is available for two cognitive activities, seemingly at the extremes of real-world practicality – taking mental tests and performing specialised jobs.

Task demands of mental tests

Just as humans differ in intelligence level (*g*), tasks differ in how well they call forth or measure individual differences in *g* (their *g* loadedness). More *g*-loaded tests require more complex information processing, either on the spot (tests of fluid *g*) or mostly in the past (tests of crystallised *g*), but their complexity has nothing to do with either their format or their manifest content. Nor does it depend on whether test items require some bit of cultural knowledge; are built with numbers, words, pictures, or symbols;

are administered individually or in groups; or whether test takers respond orally or in writing. Rather, complexity increases when tasks require more mental manipulation; for example, when the information to be processed is more voluminous, abstract, ambiguous, uncertain, incomplete, novel, or embedded in distracting material; and when the task requires spotting regularities, judging relevance, drawing inferences, integrating information, or otherwise evaluating and mentally transforming information to some end. Virtually any format or content, academic or not, can be used to build differentially complex cognitive tasks; for example, more versus less *g*-loaded tests of domain specific aptitudes (e.g., mathematical reasoning versus arithmetic computation; reading comprehension versus spelling), subtests on an IQ battery (digits backward versus digits forward), or items in a particular subtest (9-block versus 4-block diagrams to copy in block design). Increments in complexity can be seen in the vocabulary subtest of the Weschler Adult Intelligence Scale (WAIS), where the proportion of adults able to define common words drops as the words become more abstract: bed (a practice item; 100% get at least partial credit), sentence (83%), domestic (65%), tranquil (36%), and travesty (5%; Gottfredson, 1997). Rising complexity is also readily apparent in the following three Number Series Completion items: 2, 4, 6, __, __; 2, 4, 8, __, __; and 2, 3, 4, 3, 4, 5, __, __.

Perhaps the most important insight from psychometrics, for present purposes, is that individual test items need not measure *g* very well for a large number of them to create an excellent test of *g*. If *g* is the only thing that the items measure in common, and as long as there are enough items, the error (non-*g*) components of the different items will cancel each other out and leave the items' small *g* components to cumulate and create a highly reliable measure of virtually nothing but *g* (the Spearman-Brown prophecy formula indicates how many items are needed). In like manner, a good measure of *g* can be extracted from a broad collection of everyday knowledge tests (politics, religion, sports, health, etc.) despite none of them individually correlating highly with *g* (Lubinski & Humphreys, 1997). The lesson for evolutionary psychology, explored below, is that consistent effects, even when individually quite small, can cumulate over time to have large consequences – much as does a gambling house's small advantage at roulette (Gordon, 1997).

Complexity is likewise the active ingredient in tests of functional literacy, where items simulate everyday tasks that all adults are routinely expected to perform in modern societies (e.g., reading maps and menus, filling out bank deposit slips and job applications, grasping the main point of a short news article). The US Department of Education's National Adult Literacy Survey (NALS; Kirsch, Jungeblut, Jenkins, & Kolstad, 1993) set out to measure three separate kinds of functional literacy (prose, document, and quantitative). All three NALS scales, however, produced nearly identical results and measured virtually nothing but a single general factor. That factor was not readability, *per se* (e.g., word or sentence length). Rather, it was "processing complexity." More specifically, formal analyses showed that differences in item difficulty (percentage of people passing an item) reflected degree of inference required, abstractness, and amount of distracting information – in essence, the item's *g* loadedness.

Whether an individual is proficient at any particular NALS task seldom matters much. What does hurt a significant proportion of adults is their being routinely unable to perform a wide variety of such daily tasks. To illustrate, here are the percentages of American adults who are routinely able to perform tasks comparable in complexity to the following: locate the time of a meeting on a form – 77%; determine the correct change using information in a menu – 21%; and interpret a brief phrase from a lengthy news article – 3% (Kirsch et al., 1993, pp. 113–115).

Being highly *g* loaded, all three NALS scales not surprisingly predict socioeconomic wellbeing (whether living in poverty, utilising welfare, looking for work, etc.) in the same pattern as presented earlier for IQ (Figure 17.1). The NALS results led one national panel to conclude that almost half of American adults do not have sufficient functional literacy (Level 3 or above) to compete in the global economy, or engage their rights and responsibilities as citizens. These NALS results provide a concrete example of how the seemingly inconsequential minutiae of daily life can yield major differences in personal wellbeing when, like the items on a mental test, they consistently play to the strengths of some individuals, but not others, in avoiding common mistakes (Gordon, 1997).

Cognitive demands of work

The US Department of Labor's (1991) *Dictionary of Occupational Titles* provides separate descriptions for almost 18,000 job titles, so today's workplace might seem to represent the height of functional specialisation. Provisioning one's family in the Pleistocene clearly was not so specialised. It may even have been far less cognitively demanding than most jobs today. But we cannot thereby assume that the *distinctions* in ability that jobs render most important today were not also highly consequential throughout human evolution. Nor can we easily infer which distinctions were most important at some particular time just by comparing the cultural artifacts left behind in different epochs. Many activities leave no artifacts, and the sophistication of those that do remain may represent the ability level only of some critical mass of individuals sufficiently bright to invent (or import) and sustain those practices within the group. Moreover, any such critical mass, or carrying capacity, might sometimes have been achieved by increases in a population's size rather than its average intelligence level.

Large-scale job analysis studies routinely show that occupations today, like mental tests, differ most fundamentally in the general complexity of the work they require incumbents to perform, and not in their manifest content (medicine, law, technology, art). Content-specific task demands, such as dealing with people rather than things or data (three of the *Dictionary*'s rating scales), become important only when distinguishing occupations of similar complexity level (e.g., mid-level sales versus crafts or clerical work).

Drawing from such diverse job analyses, one study profiled the particular worker tasks, worker aptitudes, and working conditions that contribute most to a job's overall complexity (Gottfredson, 1997). A job's complexity depends on the amount, level, and variety of information processing that it requires. Specific tasks correlating highly with complexity include compiling (r = .90), analysing (.83), and transmitting relevant information, whatever form it takes (written, .84; quantitative, .68; oral, .68; behavioural, .59; pictorial, .44, etc.). Tasks involving high-level controlled information processing (e.g., reasoning, .83; analysing, .83; planning, .83; decision-making, .82) contribute more to overall job complexity than do more elemental processes (e.g., recognise, .36; remember, .40; transcribe, .51; and code/decode, .68).

Working conditions and task configurations can also increase complexity, and they include working: under distractions (.78) or time pressure (.55); in varied and changing circumstances (.41); and with much need for updating knowledge (.85) and self-direction (.88) in which tasks to perform, when, and how – all of which characterise many professional and executive jobs. Low-complexity jobs (e.g., packer, custodian, food service worker) entail quite the reverse: mostly activities that are repetitive and continuous (−.79 with complexity), highly structured (−.79), and closely supervised (.73). Middle-complexity jobs (much clerical, sales, and skilled trades work) require moderate levels of planning, analysis, judgment, and pertinent training, but their constituent tasks are narrower in scope, more fully specified, and more predictable than those in complex occupations (and hence more fully trainable).

Not surprisingly, IQ level best predicts differences in performance in high-level jobs, the correlations with IQ ranging from about 0.2 in simple jobs to 0.8 in the most complex (corrected for unreliability and restriction in range on incumbents' IQ). Being more cognitively facile aids performance at least a bit in all jobs, but these correlations show that the edge it provides grows with the complexity of a task. The same edge no doubt exists outside the workplace too, because most tasks that workers are paid to perform (transporting, instructing, advising, building, repairing, healing, etc.) mirror domestic tasks that the typical adult also undertakes.

Arvey (1986) characterised task demands more globally, showing more directly that overall job complexity calls forth the very abilities often used to describe general intelligence itself: effective learning (e.g., "learn and recall job-related information," r = .71 with the study's dominant Judgment and Reasoning factor; "learn new procedures quickly," .66), reasoning ("reason and make judgments," .69), and problem solving ("apply common sense to solve problems," .66). Perhaps more importantly, the study highlights an underappreciated contributor to the complexity and criticality of work: dealing with unexpected, lurking, and nonobvious problems ("deal with unexpected situations," .75; "identify problem situations quickly," .69; "react swiftly when unexpected problems occur," .67). That is, jobs are more cognitively complex when they require not only solving known problems, but also spotting and diagnosing new ones: not just finding solutions, but seeing the problems in the first place (see also Simonton, Chapter 15, this volume).

Indeed, aptness in conceptualising risk and opportunity, in visualising the unseen and unexpected, may be the most distinctive aspect of highly complex jobs – and of human intelligence itself. It represents what is sometimes dubbed the mind's eye: the ability that only humans have to conceptualise a world beyond the stimuli immediately in front of them, to create images of a reality not concretely present, and to realise they are effecting that separation. The mind's eye does not restrict its gaze to any particular content domain, but surveys many. It entails the ability to abstract salient features of the environment and to perceive a separate, intentional, selfdirected self within that environment. Aided by language, that uniquely human storehouse of concepts, the mind's eye confers the ability to "time travel," "read minds," and construct scenarios for any realm of life, whether physical, biological, social, or spiritual. Its breadth of vision contradicts the notion that the brain and mind consist only of specialised modules that evolved to solve highly domain-restricted problems. So does its very existence, precisely because the mind's eye represents humankind *freeing* itself somewhat from the dictates of immediate experience – dictates that modularists are probably correct in supposing would foster modularity. Importantly, it allows humans to inhibit natural reactions to present circumstances in order to enhance future wellbeing.

It seems mistaken to assume that the fundamental advantages of having a higher g than one's contemporaries are different today than during the human EEA. These advantages may also be far more elemental than most of us had supposed – namely, to infer or imagine what cannot be seen directly. *Homo sapiens* may be Man the Toolmaker, the Hunter, the Hunted, Scavenger, Warrior, Coalition Builder, and much more, but his distinctive attribute is more profound – he is an imaginist.

Does higher intelligence predict lower mortality?

Selection proceeds, however, only when there is differential reproduction or mortality of different (genetically influenced) phenotypes in the species. Data for modern populations provide valuable clues, once again, for how more proficient reasoning (higher g) in daily life might have enabled brighter individuals in the EEA to leave more genetic descendants than their contemporaries.

Modern states have lowered their overall rates of morbidity and mortality by providing better medical care and buffering their inhabitants from many kinds of illness and injury (better sanitation, immunisations, safer cars and roads). If cognitive competence helps predict mortality in modern states, then it probably predicted mortality in early human environments too, where individuals had to rely more fully than now on their own resources and good judgment.

IQ-related differences in health self-care

Cohort studies reveal robust relations between childhood IQ and adult mortality. For example, three large cohort studies in the Scottish Mental Surveys found that higher IQ at age 11 forecast lower all-cause mortality, fewer deaths from stomach and lung cancer, less late-onset dementia, and more functional independence among persons followed up at ages 55 to 70 (Deary et al., 2004). A significant association between IQ and premature death remained after controlling for confounding variables. A large cohort study of Australian male army veterans followed to about age 40 found that higher IQ at induction (~age 18) predicted lower all-cause mortality, and fewer deaths from suicide and motor vehicle accidents (the two major causes of death), even after controlling for other personal factors, including prior health (O'Toole & Stankov, 1992). Both sets of analyses reported that each additional IQ point (e.g., 97 versus 96) was associated with about a 1% reduction in relative risk of death, meaning that a one standard deviation difference in IQ (15 points) was associated with about a 15 per cent difference in mortality.

Relatively little research is available on IQ's relation to health, but much has been done in relating health to other personal attributes that provide differentially valid surrogates for IQ. The closest surrogate is functional literacy, discussed earlier. Better performance on tests of health literacy (a general capacity to learn, reason, and solve problems in the health domain) predicts lower health costs, less hospitalisation, better understanding of one's chronic disease, and more effective adherence to treatment regimens (Gottfredson, 2004). Again, differences in risk are not much reduced after controlling for income, health insurance, and other risk factors. Years of education, occupational level, and income in adulthood provide progressively weaker surrogates for IQ because they are successively weaker correlates of it (from about 0.6 for years of education to 0.3 for income). All these surrogates correlate with health knowledge, health habits, morbidity, and mortality, but in order of their validity as surrogates for IQ.

This consistent pattern for IQ surrogates, where income is the weakest, and functional literacy is the best correlate of both IQ and health, suggests that higher relative (not absolute) risk for poor health is rooted more in people's differences in mental than material resources. Health scientists often treat IQ as just a marker for socioeconomic status (SES), but the opposite is a safer bet. That is, social class may predict health differences within a population mostly because it provides a weak but valid signal for the cognitive capabilities that allow people to prevent and effectively manage illness and injury. Possessing material resources is not enough; they mean little if not exploited wisely.

Supporting evidence for the cognitive resources hypothesis comes from failed efforts to equalise health by equalising relevant material resources. For example, when Great Britain established free national health care in the 1950s, health inequalities increased rather than decreased. Although health improved overall, it improved less in the lower occupational classes than in the higher ones. Absolute risk decreased, but class-related *relative* risk (i.e., differences in risk) increased. This is also the usual effect when new preventive techniques become available (e.g., Pap smears and mammograms), even when they are provided free of charge. SES-related gaps in knowledge likewise grow when vital health information (e.g., signs and symptoms of cancer and diabetes) is disseminated more widely to the general population, as is also the case for other educational interventions. Perhaps the strongest evidence for the causal importance of cognitive resources comes from reversals in *g*-related risk gradients when new hazards are discovered. Heart disease and certain cancers once disproportionately afflicted the higher classes, who were better able to afford cigarettes and red meat, but the risk gradients flipped to disfavour the lower classes once these luxuries were found to increase the risk of chronic disease. Other research suggests why: Childhood IQ predicted who, in a cohort of individuals born in 1921, quit smoking after its dangers became known in mid-century (Deary et al., 2004).

Health literacy research converges on the same explanation for why inequalities grow even as a population's health improves. Researchers concluded that individuals who score poorly on tests of health literacy (misread medicine labels, etc.) do so primarily because they learn and reason poorly. They are thereby less able to profit from advances in health knowledge and medical technology. They less often seek the preventive care available to them, less often recognise when they need medical care, and adhere less effectively to the medical treatments they are prescribed (see Gottfredson, 2004).

In an important sense, each of us is our own primary healthcare provider. Health selfcare is a lifelong job, and it is becoming ever more complex as health information proliferates and treatments become more complicated. Arvey's (1986) job analysis, when applied to the job of health selfcare, warns that it will increasingly require us to "learn and recall job [health]-related information," "learn new procedures [treatments] quickly," "deal with unexpected situations [health emergencies]," "identify problem situations [symptoms of disease] quickly," and "reason and make judgments [in the daily management of a chronic illness]." The mind's eye is especially important in motivating adherence to treatment when deadly diseases such as hypertension have no outward symptoms or, as with diabetes, lax selfcare (blood sugar frequently too high) causes no immediate, obvious harm, but the internal damage builds inexorably toward disability and death.

SES-related risk of fatal accidents

Relatively few people in developed nations die today from infectious diseases such as malaria and cholera, which still kill many people in developing countries. Instead, they succumb to chronic diseases such as cancer, stroke, and heart disease, usually long after their reproductive years have ended. What is common to all societies, however, is that injuries are a major killer (Baker et al., 1992; Smith & Barss, 1991). These may be either intentional (homicide and suicide) or unintentional ("accidents"). In 1999, unintentional injury was the single largest cause of death in the USA for ages 1–34, and it was the second and third largest, respectively, among persons aged 35–44 and 45–54 (National Center for Injury Prevention and Control, 2002). Developing countries show the same basic pattern. In the transition from hunter-gatherer societies to modern states, death rates from homicide and warfare fall, and rates of suicide rise, and these rates vary more by nation than do rates of death from unintentional injury (Smith & Barss, 1991). The large toll from unintentional (accidental) injury thus appears to be the more stable component of human mortality.

Nations invest much less effort in preventing deaths from unintentional injury than from illness and intentional injury. Reports on the matter invariably refer to accidents as a large but neglected public health problem (National Research Council, 1985; Smith & Barss, 1991). This may be partly explained by unintentional injuries generally being thought of as accidental, as unlucky rolls of the dice. Chance plays a role, of course, but unintentional injury rates are highly patterned in all societies. They do not strike randomly by age, sex, or social class. Even death by lightning, the seemingly paradigmatic chance event, most often strikes adolescent males. As described later, human behaviour is deeply implicated in the cause and course of accidents. In fact, public health researchers describe how notoriously difficult it is to persuade people to behave in safer and more healthful ways (e.g., not smoke in bed, not drink and drive, eat right and exercise). Even laws that prohibit unsafe behaviour (speeding) and mandate protective gear (helmets, seat belts) have only limited efficacy in changing behaviour (National Research Council, 1985).

Table 17.1 outlines the pattern of injury mortality in the United States in 1986, the most recent year for which such a detailed portrait has been compiled. The last column provides death rates per 100,000 for all categories of injury. For example, it shows that 64 of every 100,000 Americans in 1980–86 died from an injury, almost two-thirds (41 per 100,000) unintentional. Whereas chronic disease typically kills late in life, injuries often

Table 17.1 Rates of death from injury per 100,000 population, and relative risk (odds ratio) by per capita income of area of residence, 69 causes,[a] 1980–1986, United States

	Per capita income of neighbourhood			*Deaths per 100,000 pop.*
	< $6K	*$10–11K*	*$14K+*	
69. Total (causes 1–68)	3.5	1.0	0.5	64.04
58. Suicide (50–57)	0.9	1.0	0.8	12.24
64. Homicide (59–63)[b]	0.9	1.0	0.3	9.15
	Unintentional injuries, total			
6. Motor vehicle accidents, traffic (1–5)	2.1	1.0	0.7	19.96
48. Other unintentional (7–47)	2.0	1.0	0.8	21.20
	Primarily the very young and old			
27. Falls (21–26) (elderly)	1.0	1.0	0.9	5.21
40. Suffocation (infants)	1.3	1.0	0.8	0.38
5. Pedestrian, traffic (elderly)	1.3	1.0	0.6	3.19
38. Aspiration, food (infants, elderly)	1.5	1.0	0.9	0.78
42. Collision w/object/person (very old)	1.8	1.0	0.8	0.11
39. Aspiration, nonfood (infants, elderly)	2.1	1.0	0.9	0.68
31. Fires/burns (28–30) (1–4 and elderly)	2.5	1.0	0.6	2.30
7. Pedestrian, non-traffic (1–4, e.g., driveways)	2.7	1.0	0.6	0.20
34. Excessive cold (infants, elderly)	3.1	1.0	0.6	0.34
33. Excessive heat (infants, elderly)	4.4	1.0	0.6	0.22
35. Exposure/neglect (infants, elderly)	7.4	1.0	0.8	0.12
	Primarily young males			
3. Motorcyclists, traffic	0.7	1.0	0.5	1.51
4. Cyclists, traffic	0.9	1.0	0.6	0.36
12. Drowning (10–11)	2.0	1.0	0.6	2.60
2. Motor vehicle, occupant	2.4	1.0	0.7	14.88
1. Motor vehicle, train	3.2	1.0	0.6	0.26
36. Lightning	3.4	1.0	0.7	0.04
32. Firearm	4.4	1.0	0.6	0.73
	Primarily adult males			
9. Aircraft (mostly small private)	0.9	1.0	1.2	0.60
18. Poisoning, solids/liquids[c]	0.6	1.0	0.7	1.57
20. Poisoning, gas/vapour[d]	1.3	1.0	0.9	0.50
8. Pedestrian, train	1.4	1.0	1.2	0.18
43. Caught/crushed	1.5	1.0	1.0	0.05
45. Cutting/piercing	2.0	1.0	0.6	0.05
47. Electric current	2.1	1.0	0.5	0.40
46. Explosion	2.9	1.0	0.6	0.12
41. Struck by falling object	4.6	1.0	1.3	0.42
44. Machinery	5.0	1.0	0.5	0.57
	Risk rises gradually with age, both sexes			
37. Natural disaster	5.0	1.0	1.0	0.06

Source: Based on Table 7 in Gottfredson (2004). Reprinted by permission of the American Psychological Association.

[a] Some of the 69 are subtotals of others.

[b] Four homicide categories are excluded here: homicide due to legal intervention with firearm (65), undetermined firearm (66), undetermined poisoning (67), and total undetermined (68).

[c] Solid/liquid poisonings include opiates (13), barbiturates (14), tranquilizers (15), antidepressants (16), alcohol (17).

[d] Gas/vapour poisonings include but are not limited to motor vehicle exhaust (19).

take people at the peak of their productive potential. Years of life lost and lifetime dollar cost per death are thus many times higher than for cancer and cardiovascular disease (Baker, O'Neill, Ginsburg, & Li, 1992). Moreover, fatalities represent only a small proportion of all injuries: Injuries can create many adaptive problems short of death. They need not be fatal to stress a family emotionally and financially, especially if the victim is permanently disabled.

Table 17.1 lists specific causes of unintentional mortality according to the age–sex groups most subject to them, because different sexes and ages perish from notably different kinds of injury (see Baker et al., 1992). Only natural disasters seem to affect age–sex groups equally. The very young and very old die disproportionately from falls, aspiration (choking), burns, exposure, neglect, and being struck by vehicles. Relative to other age groups, they are cognitively weak, physically vulnerable, and dependent on caretakers, so they have less capacity for escape and recovery from harm. Young males are the major accident victims of drowning, lightning, weapons, and vehicles of many types (motorcycles, bicycles, automobiles). Many such deaths involve alcohol and reckless behaviour, and may result from the testosterone-driven displays of masculinity that surge at this age. Adult males are the group most subject to injuries involving production-related technology and activity, about half such deaths occurring at work and half at home: vapour poisoning, piercing, crushing, electrocution, explosions, falling objects, and machinery. Not surprisingly, male provisioners die disproportionately from the hazards associated with their provisioning activities.

A second pattern in vulnerability to accidental death can be seen in the first three columns of Table 17.1, which quantify relative risk by the victim's area of residence. Relative risk is measured here with the odds ratio (OR). An odds ratio is, as it sounds, simply the ratio of two odds: the odds that members of Group A will experience versus not experience the outcome in question, divided by the analogous odds for a reference group, Group R. For example, if 25% of Group A died from a certain disease but only 20% of Group R did, then the two odds would be 25/75 (0.33) and 20/80 (0.25), producing an odds ratio of 1.33. Table 17.1 provides ratios for residents of the lowest-income and highest-income neighbourhoods relative to residents of average-income areas in 1986 in the USA. Thus, the odds ratio of 3.5 for total injury mortality among residents in the poorest neighbourhoods (per capita income under $6000 in 1986) means that those residents were 3.5 times as likely to sustain a fatal injury as residents of the reference neighbourhoods ($10,000–$11,000 per capita).

The risk gradients differ greatly depending on cause of death. They are shallow (that is, the ORs change little across the three income groups) for causes such as falls, suffocation, and gas/vapour poisoning. They are steeper – and comparable to those for most chronic diseases – for excessive cold, fires/burns, drowning, vehicle accidents (occupant or train), lightning, and being cut/pierced, electrocuted, or killed in an explosion. They are especially steep for excessive heat, exposure/neglect, firearms, falling objects, machinery, and natural disasters. Disadvantaged circumstances (poor housing, dangerous jobs, etc.) may elevate risk by exposing individuals to more hazards, but the risk gradients do not track material disadvantage, at least in any obvious way. For example, although many adult men die in accidents associated with the tools of their trade, half those accidents occur at home (Baker et al., 1992). Voluntary self-exposure is likewise indicated by alcohol abuse being a factor in many drownings, vehicular fatalities, and burns. It is also hard to find a compelling reason why differences in material resources should have their most dramatic effect on relative risk of (infants and the elderly) dying from exposure and neglect.

The relation between SES and accidental death varies in magnitude, depending on cause, but seldom in direction. Relative risk rises as neighbourhood income falls for 23 of the 29 specific causes, and it is reversed for only one (plane crashes). Mortality gradients disfavouring lower socioeconomic groups are also found worldwide for most illnesses, regardless of their aetiology, preventability, treatability, or organ system involved (Adler, Boyce, Chesney, Folkman, & Syme, 1993). Additionally, SES usually has a dose–response (linear) relation to morbidity and mortality, meaning that each additional increment in education, occupation, or income level is associated with yet better health outcomes, even beyond the resource levels that seem more than sufficient for good health. As health scientists note, social class differences in material resources cannot explain either the ubiquity or the linearity of the SES–health gradients across time, place, and malady, so they hypothesise a more fundamental cause or generalised susceptibility they cannot yet identify (Link & Phelan, 1995) but which, as discussed above, is mostly likely *g*.

The distribution of fatal accidents in human populations today reveals how these might have contributed to selection for higher *g*. First, although any one form of death may be relatively rare in any given year, accidents are a major cause of death in all societies. Second, victims are disproportionately males of reproductive age. Third, most types of accidental death strike disproportionately often in the lower socioeconomic strata, some markedly so. Because adults in the lower social classes tend to have lower IQs, and because differences in IQ are 80% heritable in adulthood (i.e., not due to social class), higher mortality in the lower socioeconomic strata may actually reflect the impact of lower *g*, not fewer material resources. Recall that IQ was the best predictor of motor vehicle fatalities in the Australian veterans study. Those IQ-related differences in mortality rate were also large: 146.7, 92.2, and 51.5 deaths per 10,000, respectively, for men of IQs 80–85, 85–100, and 100–115 (O'Toole, 1990; neither the Australian nor American militaries may induct individuals below the 10th percentile, which is about IQ 80).

Cognitive nature of accident prevention and containment

Accident researchers have concluded that the key question is not what causes accidents, but what prevents them (Hale & Glendon, 1987). Hazards are ubiquitous, surrounding us from birth, lying in wait every day of our lives. Accident prevention consists of managing hazards so that they do not cause injury. The accident process begins when a system under control (e.g., driving safely down a familiar road, one's children are playing happily) becomes destabilised. Injury actually occurs fairly late in the accident process, after someone has failed to detect or diagnose the hazard (a car is following too closely, matches are within the children's reach) and failed to take appropriate action to bring the situation back under control (move out of the car's way, remove the matches). Individual action is critical not only for preventing and containing incidents, but also for limiting the damage they do. People often fail to take advance precautions, such as wearing protective gear (seatbelt, safety goggles) or installing warning systems (smoke alarms) that could limit harm.

Catastrophic accidents (e.g., Challenger space shuttle explosion, Piper Oil platform fire) usually involve the concatenation of multiple errors by different people. Victims and their caretakers are seldom responsible for all the human errors that led to the victims' injury, but most if not all have missed opportunities to prevent or minimise it. For instance, studies of accidents involving pedestrians and workers in gold mines have documented that most victims failed to respond appropriately, if at all, to visible imminent danger (approaching vehicle, falling rock). The issue here is not who bears most responsibility for causing a given accident, but whether people routinely use what opportunities they have to protect themselves. Relying on others alone to shield us from danger is foolhardy. We must practise "defensive driving" along all of life's paths.

A recent study (Buffardi, Fleishman, Morath, & McCarthy, 2000) illustrates the importance of cognitive competence for preventing the human errors that can precipitate accidents, or fail to halt them. It found that error rates – human error probabilities (HEPs) – on work tasks in Air Force and nuclear power plant jobs generally correlated 0.5 to 0.6 with the number and level of cognitive abilities that the tasks required. This means that brighter workers are less likely than others to make errors on those tasks, an expectation that is consistent with meta-analyses showing that brighter workers outperform their coworkers (on average) in all jobs, but especially so in complex ones (Schmidt & Hunter, 2004). All people make cognitive mistakes, but higher-*g* persons make relatively fewer of them when holding difficulty level of the task constant, whether on mental tests or in real life.

Students of the accident process have long argued that accident prevention and control is a quintessentially cognitive process. Hazards are ubiquitous and many incubate without visible evidence (e.g., in a machine not serviced), so it is often unclear in the kaleidoscope of daily life what constitutes a hazard or how dangerous it might be. Avoiding accidental death, like exercising effective health self-care, thus requires the same information-processing skills as do complex jobs: continually monitoring large arrays of information, discerning patterns and anomalies, understanding causal relations, assessing probabilities, and forecasting future events. In essence, accident prevention requires imagining the unseen, the nascent, the "what-if?" Just as discoveries come more often to the prepared mind, so does effective accident prevention and containment.

The conditions that make effective monitoring, detection, and estimation more difficult mirror the factors previously discussed as contributing to job complexity: situation changing rapidly, situation not as expected, ambiguity and uncertainty, working under distractions, and nonroutine tasks (Hale & Glendon, 1987). Lack of knowledge and training for handling contingencies also impedes timely detection of, and response to, systems going out of control. Even individuals who are fully aware of a particular danger, who are trained to deal with it, and who attempt to exercise control may nonetheless fall victim if they are distracted, fatigued, stressed, or impaired by drugs or alcohol. In short, the same task requirements that typify complex jobs are also at the heart of preventing unintentional injury: dealing with unexpected situations, identifying problem situations quickly, and reacting swiftly when unexpected problems occur.

Were accidents an important cause of death in precontact hunter-gatherer societies?

Homo sapiens speciated 100,000–150,000 years ago, and then began radiating out of sub-Saharan Africa about 50,000 years ago (Sarich & Miele, 2004). Perhaps the closest we can come to observing the ecological circumstances associated with this is to study surviving hunter-gatherer societies. The Northern Ache of Eastern Paraguay provide the clearest such living window into our subspecies' EEA, because they are the only foraging group whose life before peaceful contact with the outside world has been carefully documented. Hill and Hurtado (1996) report fertility and mortality among the Northern Ache during three periods: precontact, when they lived entirely by foraging in the rainforest (before 1971); the initial period of peaceful contact (1971–1977); and after resettlement onto reservations (1978–1993). The Ache are not representative of all hunter-gatherers, current or prehistoric, but their environmental stressors and modes of adapting to them violate common presumptions about technologically primitive societies.

Pre-contact Ache lived in bands of 15–70 individuals, with bands frequently shifting in size and composition. Bands were autonomous economic and residential units, moving camp frequently (often daily) and living entirely from hunting (e.g., monkeys, peccaries, armadillos) and gathering (e.g., palm fibre, fruits, honey, insect larvae). On average, women had their menarche at age 15, their first child at age 19, their last child at age 42, and a total of eight live births by age 45. Male fertility was more variable, with men fathering their first child at mean age 24 and their last at age 48. Marriages were short, especially in early adulthood, and women averaged a total of 10 by age 30. Both the probable and possible biological fathers of each child were ritually acknowledged. Children were generally weaned around age two and a half. Half of all males and females survived to age 40, at which point they had a life expectancy of another 22 years (males) to 26 years (females).

Small groups of men hunted for game on average 7 hours a day, collected honey when available, and shared their proceeds evenly among all adults in the band. Hunters used large bows and arrows but also killed small game by hand. Meat provided 87% of the band's calories. Women spent an average of two hours per day foraging for plant and insect products, which were not as widely shared in the band. Women spent another two hours moving camp, with men cutting a trail through the dense underbrush. Adults transported all children until age five, after which children had to walk on their own to the new camp. Girls started producing as much food as the average adult woman beginning around age 10–12. Boys carried bows and arrows by that age, but they did not reach adult male production levels till their twenties.

The many hazards of forest life included, among others, poisonous snakes and spiders, jaguars, stinging insects, parasites, malaria, and warfare with non-Ache, all of which could temporarily disable individuals, if not killing them outright. Temperatures sometimes dropped below freezing at night, and children and adults lost and without firebrands risked dying of exposure if they failed to return to camp, a common hazard also among the !Kung hunter-gatherers of sub-Saharan Africa (Howell, 2000, pp. 58–59). Of the 1423 Northern Ache born between 1890 and 1994, 881 had died by 1994 (843 with cause reported), of whom 382 died during the forest period (before 1971). Most of the Ache mortality data reported in Table 17.2 were collected retrospectively in interviews during 1981–1992. Ache informants provided reliable and forthright accounts of deaths from injuries, including homicide.

Before peaceful contact, warfare (e.g., raiding) was the second most common cause of death (128 of 363), but it accounted for none of the 104 during the reservation period. The interim period is omitted here because nearly one third of all Ache died from epidemics after first peaceful contact. Even during the forest period, however, somewhat more Ache (135) died of injuries not sustained during warfare (50 from accidents and 85 from homicide by other Ache). Baksh and Johnson (1990, p. 204) likewise report a large proportion of deaths from fatal accidents among the Machiguena Indians in the Amazon Forest.

Ache rates of fatal injury, both intentional and unintentional, decreased considerably between the forest and reservation periods owing to state

Table 17.2 Number of deaths from specific causes among the Ache before peaceful contact (before 1971)

	Age 0–3			4–14			15–59			60+			Total		
	Sex F	M	T	F	M	T	F	M	T	F	M	T	F	M	T
Illness	**19**	**17**	**36**	**8**	**7**	**15**	**9**	**26**	**35**	**2**	**3**	**5**	**38**	**53**	**91**
Congenital/degenerative	**8**	**11**	**19**	**0**	**0**	**0**	**1**	**0**	**1**	**2**	**4**	**6**	**11**	**15**	**26**
Childbirth							**3**	**0**	**3**				**3**	**0**	**3**
Unintentional injury	**1**	**2**	**3**	**1**	**10**	**11**	**6**	**23**	**29**	**4**	**3**	**7**	**12**	**38**	**50**
eaten by jaguar							1	7	8	0	1	1	1	8	9
snakebite				0	3	3	3	12	15	1	2	3	4	17	21
accidentally suffocated	1	1	2										1	1	2
hit by lightning	0	1	1	0	3	3	1	2	3				1	6	7
drowned				1	0	1							1	0	1
lost				0	3	3	0	1	1	3	0	3	3	4	7
hit by falling tree				0	1	1	1	0	1				1	1	2
fell from tree							0	1	1				0	1	1
Homicide/neglect	**26**	**26**	**52**	**14**	**3**	**17**	**4**	**7**	**11**	**1**	**4**	**5**	**45**	**40**	**85**
sacrificed with adult	7	4	11	10	1	11							17	5	22
mother died	1	1	2										1	1	2
child homicide	9	15	24	3	0	3							12	15	27
infanticide	6	1	7										6	1	7
neglect	1	1	2										1	1	2
buried alive	0	1	1				1	0	1	1	0	1	2	1	3
left behind	2	3	5	1	2	3	1	0	1	0	2	2	4	7	11
ritual club fights							0	6	6	0	2	2	0	8	8
nonsanctioned murder							2	1	3				2	1	3
Total (nonwarfare)	**54**	**56**	**110**	**23**	**20**	**43**	**23**	**56**	**79**	**9**	**14**	**23**	**109**	**146**	**255**
Warfare	9	12	21	27	29	56	16	31	47	2	2	4	54	74	128

Source: Hill & Hurtado (1996, pp. 171–173), reproduced with permission.

intervention (Hill & Hurtado, 1996). Homicide fell from 33% to 9% of all nonwarfare deaths, and fatal accidents from 20% to 6%. Although their absolute number dropped, deaths from illness nearly doubled as a percentage of all nonwarfare mortality (from 47% to 85%). The Ache mortality pattern in the reservation period is quite similar to that of the Yanomamo and !Kung societies (Hill & Hurtado, 1996) and the United States (National Center for Injury Prevention and Control, 2002), where illness accounted for 80–90% of all deaths, and the remainder was split about equally between fatal accidents and intentional injury. No suicides were reported in any of the three foraging societies, but in the United States suicide accounted for almost as many deaths as did homicide.

The percentage of Ache deaths from illness did not differ by age, whether before or after contact. Fatalities from injury, however, differed greatly by both age and sex in both periods. In the forest period, as Table 17.2 shows, lethal accidents claimed more lives than did homicides during adolescence and middle adulthood (29 versus 11 deaths for ages 15–59), but the opposite was true for children (14 versus 69 for ages 0–14). This general pattern held for reservation life too: Adults died relatively more often from accidents; and children from homicide. In the United States, however, accidental injury was a bigger killer than intentional injury (suicide and homicide) at *all* ages. Perhaps the most striking difference between the two societies is the reversal in the ratio of accidental to intentional deaths among infants and toddlers: Whereas 3% of Ache nonwarfare deaths from ages zero to three resulted from accidents and 47% from homicide, the disproportion is reversed in the United States – 40% versus 5% – for a similar age group (1–4).

Both the nature and number of Ache homicides during the forest period differed by age and sex. The only three unsanctioned murders (e.g., killing a wife in anger) were of adults. Another eight intentional deaths, all of them adult males, occurred during ritual club fights. All band members who could not keep up because of age, illness, or disability (e.g., blindness) were eventually left behind (eight of the eleven being children) or buried alive (two of three being adults), sometimes at their own request (to avoid being eaten alive by vultures when left behind on the trail). Most Ache homicides, however, involved the killing of children, sometimes by parents themselves. Girls were more subject to infanticide and sacrifice at adult burials, but boys were somewhat more likely to be killed after infancy.

Table 17.2 also reveals several important age and sex differences in the cause of fatal accidents during the forest period. One pattern, which is still found worldwide (including among the !Kung; Howell, 2000), is that fatal accidents killed many more Ache males (23) than females (6) during their adolescent and middle-adult years (ages 15–59). Furthermore, the great disproportion, by sex, in fatal illnesses in this age range (26 male, 9 female), but not at other ages, suggests that many of the men's fatal "illnesses" (fevers, infections, and sores) were actually sequelae from injury (cf. Howell, 2000, Chapter 3 on the !Kung). Cuts, punctures, and bites provide entry points for infections that can debilitate or kill when modern medical treatment is not available. If the 19 surplus fatal illnesses among males (26 male minus 9 female) are reclassified as delayed fatalities from injury, then the resulting 42 (23 reported plus 19 surplus) accidental deaths among males aged 15–59 constitute 75 per cent of their 56 nonwarfare deaths, and nearly half of their total 87 for the forest period. Most accidental deaths among adults of both sexes resulted from hazards in provisioning, and from basically the same causes (e.g., snakebites). However, since women spent only a quarter as many hours foraging as men spent hunting, they exposed themselves to fewer hazards and thus were injured less often.

As occurs in the USA today, fatal accidents among adult Ache males, in the forest period, were usually associated with the trades by which men provisioned the band. Although dying at the teeth of a lurking jaguar or snake might not seem analogous to dying while using modern machines and tools, such deaths probably result from the same general cognitive failures: inexperience, and lapses in monitoring the environment for signs of imminent danger, while engrossed in one's primary activity. For instance, most snakebites occurred when the individual stepped on a snake while looking up into the forest canopy for arboreal game. This is also one of the chief hazards for primate researchers (Hart & Sussman, 2005, p. 113).

A second pattern is that older Ache children died more often from accidents than did children aged zero to three, but the age-related increase involved males only. The causes of accidental death among the older boys reflected both their inexperience in the forest (getting lost) and exposing themselves to the needless injuries associated with inattentive male provisioning (snakebites). Combining the data for ages 4–14 and 15–59, seven females died from accidental injury whereas up to 52 males did (10 boys plus 23 men plus 19 surplus "illnesses"). Accidents thus removed 45 more male than female provisioners, current or imminent, from the population. Warfare, in contrast, removed only 17 more males than females aged 4–59, because many females were captured or killed. Only homicide among older children (ages 4–14) removed more girls (14) than boys (3) from the population.

Third, from birth to age three, the two sexes died in equal number and mostly from illness and homicide. Small children rarely died of unintentional injury, despite the many hazards of forest life, because they were carefully watched by their mothers and other caretakers. Children under age one spent about 93 per cent of their daylight time in tactile contact with their mother or father, and even at age three or four they were still spending three quarters of their daylight time no more than 1 meter from the mother. Caretakers were acutely aware of common dangers to small children, and protecting them from these predictable dangers was their primary activity (cf. Howell, 2000, on similar preventive efforts among the !Kung).

Looking at the larger pattern, the two most striking epidemiological facts are the high loss of reproductive-age males to provisioning-related accidents and the even higher loss of children to homicide (respectively, 42 and 69 of all 255 nonwarfare deaths during the forest period). Each reproductive-age adult who died prematurely from any cause lost the opportunity to produce more offspring, in proportion to the prematurity of death. But the impact of such deaths was yet more profound in evolutionary terms because most child homicides followed the death of an adult (and were more sex-balanced than provisioning deaths). Important men were typically buried with a living child, usually girls under age five. The children chosen for sacrifice were usually ill, injured, defective, or orphaned, which meant they also had the fewest advocates during band discussions of whom to sacrifice. Infanticide and child homicide often followed the loss of one or both parents through death or divorce. Some of these children were killed immediately, but others later in childhood, after other band members grew resentful of being coerced into caring for them. Children without mothers were 4.5 times as likely to be killed during each year of childhood, and infants losing their mother in their first year of life had a 100% probability of being killed by another Ache. Children without fathers and those with divorced parents were, respectively, 3.9 and 2.8 times as likely to be killed in each year of childhood. Overall, death of the mother affected the youngest children primarily, but death of the father or parental divorce greatly increased the homicide rate of children at all ages. Moreover, father's death was more common than mother's death, and divorce was most common of all. As Hill and Hurtado (1996, p. 437) sum it up, "The impact of parental absence on childhood homicide rates is quite astounding." They also conclude that, in contrast, "The presence or absence or number of grandparents, aunts, uncles, and adult siblings seem to have little or no impact on child survival" (p. 424).

Loss of a provisioning adult put nutritional stress on the band, or particular families within it. A nursing infant who lost its mother lost its only possible provisioner. The more common loss, that of fathers through death or abandonment, put tremendous stress on the wife and biological children he left behind because it meant the family lost one of its two major provisioners. Recall that meat, the primary source of calories, was split evenly among *adults*, who then passed portions to their children. A child's father need not have been an effective hunter for his children to flourish, but he had to stay alive, with the band, and preferably with their mother. Children with no parents – orphans – were hated and frequently sacrificed for burial with adult males, because they were constantly begging for food (as did many fatherless children).

Thus, although the loss of a good hunter nutritionally stressed the whole band, sharing norms concentrated the band's loss on the victim's own family (cf. Howell, 2000, pp. 51–53, on the !Kung), which in turn concentrated its loss on particular individuals within the family (usually the child still requiring the most investment to reach reproductive age). A man who had fatal lapses in judgment, or in detecting hazards, not only foreclosed all future genetic contributions, but also erased some of his past contributions. Even the temporary loss of a provisioner from nonfatal injuries endangered dependents' lives (Hill & Hurtado, 1996, pp. 154–155). The forest-period Ache lived under constant nutritional stress, even if usually mild, during the study period. If they could not hunt for three days because of continuous rain, they had little food for three days. They did not live in the "original affluent society" (Hill & Hurtado, 1996, p. 320), as some anthropologists have fantasised about the foraging life.

Legal and social sanctions in state societies now discourage infanticide, although faint footprints of the practice can be observed in mortality reports, especially for developing countries. In contrast, unintentional mortality, although tending to be ignored, leaves an unmistakable swath of destruction across all societies. Accounts of injuries in developing countries (Smith & Barss, 1991) and peasant societies (Baksh & Johnson, 1990) are particularly revealing because they find that, while particular hazards differ from one time and place to another, accidents maim and kill in the same few ways: primarily, drowning (e.g., falling into ponds, wells, drainage or irrigation ditches; falling off boats and bridges), burns and scalds (e.g., hot oil, clothing or dwellings catching fire, falling into open fires), animal attacks (dog bites, goring by cattle, water buffalo, and wild pigs), lacerations and punctures (machetes, knives, spears, digging sticks, arrows shot into the air), poisoning (venomous snakes, improperly distilled alcohol, nicked by poisoned arrow), falls (off beds, bridges, and buildings; out of trees and windows), and falling objects that cause internal damage (trees being cut down, coconuts being harvested). The introduction of new technologies (e.g., electricity, motorised vehicles) produces new ways to be injured (electrical burns, fatal collisions), but even so-called technologically primitive societies pose innumerable manmade threats to life and limb.

What environmental factor was unique to *Homo sapiens* and could have accelerated the evolution of general intelligence?

Any explanation for the rapid encephalisation of *Homo sapiens*, and the remarkable intelligence of its only surviving line (*Homo sapiens sapiens*) has to provide a correspondingly unique selection agent, or confluence of them, for the evolutionary increase. It should also offer some "nitty-gritty real-life selection walks" (Holloway, 1995) for how the selection, triggered by that agent, would actually play out within a population and allow its higher-*g* members to contribute proportionately more genetic descendents to future selection walks.

Many previously proposed selection forces do not meet the uniqueness criterion, including tool use, warfare, living in social groups, cooperative predation, and climate change. Other theories attempt to meet it by proposing runaway sexual selection; for example, arms races in mating displays (Miller, 2000) or for developing a social intelligence to outwit and out-compete fellow humans (Dunbar, 1998). Runaway selection supplies a unique (species-specific) trigger by definition, because the term is a label for, not a demonstration of, selection processes that operate independently of the species' external environment.

But the runaway theories cannot explain what triggered the postulated arms races. The competition-for-mates proposals supply no trigger except chance, and the social-competition proposals supply an implausible one, namely, that within-species selection forces were unleashed when humans effectively nullified external ones by gaining "ecological dominance" (Geary, 2005). As shown earlier, however, technological feats that raise average levels of human welfare need not eliminate, and may even increase, the power of external environments to cull populations differentially by *g* level. The social intelligence hypothesis also fails to detail a "selection walk" by which spiraling intragroup competition and cooperation would have skewed mortality or reproduction by *g* level, especially when groups are said to have effectively mastered their physical environments.

More promising are hypotheses about how genes and cultures coevolve, which envision humans transacting with, not divorcing themselves from, their physical environments. Improvisation and innovation in dealing with ecological challenges are the sorts of transactions that could sustain directional selection (Lumsden & Wilson, 1983). I specify more fully below a *deadly innovations* hypothesis for how human innovation could have created, and then amplified, *g*-related relative risks of premature death.

Human innovation changes the physical environment – for better and worse

Humans have not adapted to their environments so much as they have modified them to suit their needs. The *Homo sapiens* EEA was therefore never one of extreme constancy and continuity, nor were humans ever merely passive adapters to external circumstance (Campbell, 1996). Early in the Pleistocene, humans began shaping the environments that shaped them, just as individual persons still do today (on extended phenotypes, see Bouchard, Lykken, Tellegen, & McGue, 1996; Plomin et al., 2001). Each innovation that fundamentally altered the EEA had the potential, in turn, to redirect human evolution. Lumsden and Wilson (1983) refer to this autocatalytic process as a Promethean fire, after the Greek myth.

Consider, fittingly, humankind's controlled use of fire during the past 500,000 years, one of our *Homo* ancestor's "most remarkable" achievements (Campbell, 1996, p. 47). By externalising some digestive functions (grinding, metabolising, detoxifying, etc.), cooking allowed early humans to digest a wider range of foods more efficiently. It literally transformed the human body. The gut could now be much smaller, allowing the brain to be larger for any given metabolic investment (Aiello & Wheeler, 1995; Kaplan, Hill, Lancaster, & Hurtado, 2000). This gut–brain trade-off coevolved with a suite of other life-history changes that differentiate modern humans anatomically from earlier hominids, including a longer developmental period, neoteny (more infant-like appearance), and a more gracile skeletal structure (less dense bones, thinner skull, smaller jaw and teeth, etc.). The shift was marked: the brain of the standard 65 kg modern human male weighs more than his gastrointestinal tract (1.3 versus 1.1 kg), but a nonhuman higher primate male of similar size has a brain only a quarter the size of its gut (0.45 versus 1.881 kg; Aiello & Wheeler, 1995). This is almost a gram-for-gram evolutionary trade-off between gut and brain.

Much human innovation improved the efficiency of provisioning. Cooking and hunting with fire is an early example. Projectile weapons (spears, bows and arrows, etc.) are another, because they allowed killing game quickly and at a distance, making hunting for large game both safer and more feasible. Boats, rafts, and canoes would later be yet others, because they allowed provisioners to exploit territory and food sources not otherwise readily accessible. Each innovation likely improved the general welfare and lowered age-specific mortality rates relative to other primates (Hill, Boesch, Goodall, Pusey, Williams, & Wrangham, 2001). Each, however, was a double-edged sword. Innovations in hunting, gathering, growing, storing, and preparing food created novel hazards by altering either the physical environment itself (open fires, sharp tools, weapons, enclosures, platforms) or how the body engages it (attending to the treetops rather than hazards on the trail in order to shoot arboreal game, clearing thorny or otherwise hazardous vegetation to build gardens or shelters, felling trees for fuel or shelter, navigating bodies of water). As Howell (2000, p. 55) describes, "Probably the most serious cause of hunting accidents, in the sense of injuries leading to death, is not the animals themselves, but the weapons [with poisoned shafts] that the !Kung use to kill those animals."

Altering or engaging the physical environment in evolutionarily novel ways increases the risk of incurring biomechanical and other physical traumas that exceed human limits (e.g., lacerations; drowning; falls and falling objects that break bones, crush internal organs, or slam the brain against the skull). Moreover, anatomically modern humans probably became more vulnerable to such trauma by the Late Pleistocene/Upper Paleolithic, because the long *Homo* trend toward greater body mass had reversed by then. By the time art and artifacts began to flower in Europe around 35,000 years ago, the region's *Homo sapiens sapiens* had become notably smaller, as well as somewhat less skeletally robust. This decrease in body mass was larger than the decrease in brain size, which raised EQ (Ruff et al., 1997) and perhaps reflected a new trade-off between cognitive and physical strengths in a now much-transformed human EEA.

Humans also introduced new physical hazards into their work and home environments when they domesticated animals (canines for herding and hunting; ungulates for food, transportation, and ploughing) and adopted virtually anything as pets. Dogs are still a major source of injury worldwide. And as material innovations spread to housing, transportation, agriculture, manufacture, and recreation, so did new physical hazards. There were new objects to fall from (beds, stairs, ladders, buildings or their open windows, aircraft); new ways to be crushed, pierced, or gashed (farm machinery, electric saws); new ways to be poisoned (radiation, pesticides, and even prescription medicines); and so on. Old hazards could become more lethal, as when transportation increased in velocity. Many such hazards were generated too recently in human culture to account for the evolution of intelligence in prehistoric *Homo sapiens*, but they illustrate why the species might have evolved a general protective mechanism to survive the ever multiplying, ever shifting hazards with which it was inundating its environment.

However, the distribution of manmade hazards continually changes as humans generate new ones, spread them to new sectors of the population and arenas of life, and develop cultural practices that attempt to mitigate the new risks. Because manmade hazards provide dispersed, ever-moving targets for genetic adaptation, humans cannot evolve separate adaptations to each of them (cf. Low, 1990) as they might to specific pathogens (sickle cell anaemia for malaria) or extreme climates (body shape for thermoregulation). Fiddick, Cosmides, and Tooby (2000) argue that humans have evolved a set of content-specialised inference systems for managing recurring hazards, but their conditional reasoning experiments specify no particular hazards, identify no particular forms of precautionary reasoning, rely mostly on samples restricted in range on IQ (college students), and fail to control for task complexity (abstractness, degree of inference required, etc.), prior learning, and other factors known to affect item difficulty.

Amorphous ecological challenges foil the evolution not only of physiological adaptations and innate mental heuristics, but of learned ones too. Humans are distinctive, of course, for having language, which facilitates transfer and storage of knowledge, as well as a long developmental period for learning both. Information sharing is one reason human groups can usually outrun their Four Horsemen of the Apocalypse – starvation, warfare, pestilence, and extreme weather. Food sharing also buffers all of a group's members from the inevitable shortfalls each is likely to experience from time to time. Single individuals do not die from starvation in hunter-gatherer societies, except when there is neglect or abuse (Baksh & Johnson, 1990). Accidental death is therefore quite unlike the Four Horsemen, whose stark terrors rivet attention and mobilise collective countermeasures. Hazards are side-effects of a group's survival activity, not its focus of concern. They are myriad in number, which fractures attention further, and individually they tend to be low-probability killers, which dissipates concern for any single one. By often foiling even learned heuristics, this shifting panoply of low-risk hazards puts a premium on the independent exercise of *g* by single individuals.

As reviewed earlier, the cognitive demands of accident prevention do not reside so much in the obvious attributes of situations and technologies as in what is latent, nascent, and merely possible in them. The mind's eye must imagine what one's two eyes cannot see, for example, the *possible* presence of a jaguar, an exposed electrical wire, or a faulty tire, in order to prevent a dangerous incident, rather than just waiting to escape or recover from it. It must also find portents in the physical reality that the two eyes can register; for instance, to apprehend the imminent danger of falling rocks or rising waters, which many victims fail to do.

Innovation-related hazards thus provide a plausible mechanism, though hardly the only one, for evolving a highly general intelligence in the *Homo* line. Fatal accidents are still a major cause of death in all societies, so they provide continuing opportunity for natural selection. Preventing accidents will always be cognitively demanding, so we should not presume that selection on *g* has ceased, let alone that modern humans have the same mind and brain as their Pleistocene ancestors. Recent haplotyping studies indicate, in fact, that at least two genes affecting brain size were still evolving as recently as 5,800 and 37,000 years ago (Evans et al., 2005; Mekel-Bobrov et al., 2005). Differences in relative brain size by latitude, among both archaic (extinct) and modern human groups (Ruff et al., 1997), as well as current differences by ancestral region (race) in IQ, musculo-skeletal features, and other life history traits (Rushton & Rushton, 2001), also suggest that *g* continued to evolve long after *Homo sapiens* radiated out of sub-Saharan Africa 50,000 years ago. So, rather than loosening the bonds of natural selection, human innovation may only have substituted new and potentially more powerful ones.

Human innovation magnifies g*-based differences in risk and opportunity*

Human innovation introduced evolutionarily novel risks by changing the physical environment and human transactions with it. It thereby created ecological pressure for evolving higher *g*. But how would innovation have *accelerated* selection for *g*, that is, widened the differences in mortality between individuals of higher and lower general intelligence, during the past half million years? I focus here on amplifiers that work by steepening *g*-related gradients of relative risk for accidental death, the following five being plausible candidates.

Double jeopardy

Innovations are created or imported more frequently by individuals at the top of the *g* bell curve, because they are the most able to engage in the "what if" thinking necessary for innovation – that is, for disengaging thought from the tyranny of immediate reality, in order to imagine an alternative and how to achieve it. Because humans are both verbal and social, the product or technique will soon spread, if useful. But it tends to spread from the top of the intelligence continuum downwards, because learning to replicate and effectively use an innovation – and even see its potential – also entails some exercise of *g*. To the extent that there is diffusion down *g* the continuum, replication and use will also become more error-prone and less effective. Realised benefits thus shrink as innovations diffuse down the bell curve, much as do the payoffs of schooling today (see Figure 17.1). And recall what happens when modern nations introduce new medical treatments or free national healthcare: everyone benefits, but brighter individuals capitalise more effectively on the new resources.

While benefits steadily fall, risks of fatal injury steadily increase as innovations diffuse down the bell curve. The risk gradients may be steeper for some hazards than others, but as the odds ratios in Table 17.1 illustrate, most of them tilt against persons of lower *g*. Recall also that brighter individuals exploit better even the innovations intended to mitigate the dangers of prior innovations – for example, by more often using protective gear. Fewer people die after a safety campaign, but the remaining fatalities become more concentrated at the lower end of the *g* continuum.

Innovation thus magnifies its selective power by doubly disadvantaging a group's less intellectually able members. Growing disparities in accidental injury were probably a stronger selection force than the new disparities in benefits, however, because small hunter-gatherer bands, like large societies today, redistribute the fruits of higher competence and good luck so that all can share more equally in them. In contrast, an innovation's downside in injury and death is experienced more exclusively by the direct victims of lower competence. Accidents and injuries cannot be evenly redistributed like the meat from a hunt. It might also be noted that any social or Machiavellian intelligence would affect mostly the negotiation or avoidance of sharing norms (distributive justice), but *g* would still dominate the production of benefits to be shared and the management of associated hazards.

Spearman-Brown pump

The increase in *g*-based relative risk of mortality, owing to cultural innovation, need not be large in absolute terms to drive selection, but only pervasive and persistent. The many hazards in life can be thought of as the many lightly *g*-loaded items in life's mental test for avoiding premature death (Gordon, 1997) and, as forecast by the Spearman-Brown prophecy formula for test reliability, more items would allow the test to make more reliable distinctions in ability. The test need not even be very reliable within any single generation, because when taken generation after generation, the small effects in successive generations would aggregate to produce a dramatic evolutionary shift. To illustrate, only a weak selection rate (s = 0.03) on only a modestly heritable (30%) trait could create a 1% change in a generation, which is many multiples of the rate needed for the observed evolutionary increase in *Homo* brain size (Williams, 1992, p. 132). Occasional jumps in the number of items on humans' selfmade test for hazards management could nudge up this selection ratio – imagine more instruments of death or rows in Table 17.1.

Spiralling complexity

Innovation could also amplify selection for *g* by ramping up the complexity (*g* loadedness) of individual "items" in life's test of ability for extracting the benefits of an innovation while also avoiding its new hazards. For example, a new provisioning technique (e.g., horticulture) might require higher levels of learning or reasoning than old ones (gathering) for effective reproduction, use, and selfprotection, by requiring individuals to understand longer chains of cause and effect or look more steps ahead (Gordon, 1997). Complexity could also be ramped up by new task conditions or configurations, as the job analyses showed. For instance, simply dealing with two tasks (e.g., potential hazards) at the same time is more cognitively demanding than dealing with them serially (driving and talking on a cell phone), because multitasking erodes the ability to execute each one effectively. Lower-*g* individuals are far more vulnerable to such cognitive overload than most high-*g* people imagine.

Training and practice can, of course, reduce the complexity (*g* loading) of most daily tasks, and even automatise the performance of some (e.g., aspects of driving a car, playing the piano, using a tool, following rules of etiquette), as is their purpose. Novel tasks do not long remain novel, except in the evolutionary sense, but education and training can never fully neutralise all the additional complexity that innovations pump into the cognitive environment, as the job analyses demonstrated. The large residual complexity of many already-practiced tasks explains why higher *g* (say, by one SD) – but not greater experience (say, by 3 years) – continues to yield higher average levels of job performance in successively more experienced groups of workers (McDaniel, Schmidt, & Hunter, 1988).

Contagion of error

Social processes diffuse useful knowledge through a population, but also propagate misinformation (wild rumors, health-damaging practices). Not all "help" is helpful and some is downright dangerous. Neighbourhoods often differ greatly (1–3 standard deviations) in average IQ level (Maller, 1933), so the ratio of constructive to destructive help is higher in some settings than others (Gordon, 1997). Individuals who are embedded in less favourable IQ contexts (families, tribes, etc.) are exposed more frequently, whatever their own IQ level, to the cognitive errors committed by others.

This systematic difference in exposure can be visualised by imagining that the columns of risk rates in Figure 17.1 represent different IQ contexts.

Not only do people who make stupid mistakes occasionally pay with their own lives, but sometimes so do their kin and coworkers. Mortality reports for the Ache, !Kung, and other technologically primitive groups typically include such accounts; for example, of individuals being killed by trees felled by kin, and of infants and toddlers perishing from preventable burns, falls, crushing, and poisonings (Baksh & Johnson, 1990; Hill & Hurtado, 1996; Howell, 2000). Recall also the large number of Ache infanticides and child homicides that followed the death of provisioning parents, thereby magnifying the evolutionary consequences of those deaths. The propagation of deadly error through a kin network may be the evil twin of *inclusive fitness* (assisting the survival of individuals in proportion to genes shared).

Migration ratchet

Greater population density and resulting scarcity of resources led early human groups to migrate into previously unexploited territory. The ancestors of modern *Homo sapiens* dispersed out of sub-Saharan Africa to populate North Africa and the Mediterranean, then the temperate regions of Eurasia, and eventually the Arctic regions of the world. Each higher latitude and new ice age posed new survival challenges. The brightest members of a group, though a small contingent, always constitute a cognitive surplus on which the group can draw when confronted by new threats to survival, such as colder or more variable weather or food sources. Prodded by adversity, this pool of potential imaginators developed physical techniques to make the environment less extreme and more predictable (Low, 1990). More protective clothing, better shelters, more tools for different uses, ways to preserve and store food, and much more, enabled their groups to thrive in climates for which the human body is not otherwise physiologically adapted.

Although migrating to new climates (or climate change *in situ*) may have sparked much innovation, it was these innovations that made daily life more cognitively complex. Each technological advance in taming adversity (e.g., hearths for cooking and heating inside enclosed shelters) could increase the need to anticipate, recognise, prioritise, and quickly mitigate its potential side-effects. Migration into successively less hospitable climes spurred new technologies that, individually or collectively, could ratchet up the *g*-related risk gradients for accidental death. A migration ratchet effect comports with the pattern of genetic divergence among current human populations who have ancestral origins in different regions of the world (Ingman, Kaessmann, Pääbo, & Gyllensten, 2000; Underhill et al., 2000). Increments in technological complexity need not have been large to be effective and, once again, were probably much smaller than moderns would assume necessary. For instance, it takes an extra 3 years of mental development for most children to progress from being able to copy a square (age four, on average) to copying a diamond (age seven; Jensen, 1980), the diamond being more cognitively complex for reasons that readers will readily recognise, and students of the first human tools (flaked stones) would appreciate (e.g., Wynn, 1996).

Conclusion

The deadly-innovations hypothesis is grounded in a vast nomological network of evidence on human intelligence in modern populations. It is consistent with recent evidence on trends in relative brain size and genetic divergence of human populations, archaic and modern, across time and place. But the scenario remains to be tested against competing hypotheses, such as that higher intelligence evolved as a result of sexual, not natural selection, because it signals to potential mates, not greater practical acumen, but superior genetic fitness or robust health (say, lower mutation load or greater developmental stability; Miller, 2000, Chapter 4).

Whatever its validity, the chief strength of the deadly-innovations hypothesis may lie in the counterintuitive insights it introduces from other disciplines. Theories on the evolution of intelligence have focused on the same ecological demands that our ancestors focused on, namely, how to survive the most glaring, most certain threats to survival – starvation, disease, war, predation, and the elements. A general intelligence may indeed be useful for surviving these but, by themselves, they do not seem sufficient to evolve one.

Instead, selection for a highly generalisable intelligence (*g*) may have been driven by what captures our attention least – the myriad, seemingly remote threats to life and limb that pervade the humdrum of daily life so thoroughly that they lull us into complacency. Fatal accidents pick us off one by one, unexpectedly, infrequently, and for reasons we often cannot fully control or even perceive, so we tend to chalk them up to bad luck. It also takes scarce time and energy to manage hazards effectively, especially for individuals who have few cognitive resources to spare for the task, so people often neglect it to focus on more central concerns. Moreover, such neglect seldom leads to serious injury – like playing Russian roulette with a gun having one live round and a thousand blanks – so many of us are willing to tempt fate or be goaded into doing so. But evolution works precisely by playing tiny odds in whole populations over vast spans of time. When our ancestors began increasing those odds, one hazard at a time, they speeded us on our path toward evolving a remarkable domain general intelligence.

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