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Working memory, intelligence, and life success

Examining relations to academic achievement, job performance, physical health, mortality, and psychological well-being

Cody A. Mashburn, Alexander P. Burgoyne, and Randall W. Engle

C7P1 Some people are more successful than others when it comes to school performance, career attainment, physical health, and psychological well-being. What explains individual differences in these real-world outcomes? In this chapter, we focus on one individual difference characteristic that explains considerable variance in life success: cognitive ability. Specifically, we review evidence for the relationships between working memory capacity, attention control, and fluid intelligence, as well as their contributions to success in life. Although cognitive ability is a powerful predictor of real-world outcomes, understanding why some people excel while others do not is a complex problem that requires a complex (i.e. multivariate) solution. Thus, throughout this chapter we note just some of the other variables that may account for overlapping portions of variance in life outcomes, including socioeconomic factors such as familial income and educational attainment.

C7P2 In many senses, this chapter must be reductive. Each subtopic subsumed under the umbrella term 'life success' is sufficiently broad as to define entire research programmes and careers, and the complexities of each domain are likely to exceed the grasp of non-specialists. Furthermore, there are many domains related to success in life that we do not examine, including relationship satisfaction, happiness, and creative fulfilment, to name a few. In short, a concise *and* comprehensive treatment is impossible, though we direct interested readers to Draheim et al. (2022) for a more protracted discussion of many of the topics covered in this chapter, and several we do not (e.g. cognitive training, sports, police decision-making). Rather than attempt complete coverage, our goal is to highlight primary findings in areas of ongoing research, note complications posed by extant empirical and theoretical investigations, and suggest avenues of future research.

C7P3 We begin by discussing intelligence, broadly defined, and reviewing evidence for the relationships between working memory capacity, attention control, and fluid intelligence. Afterwards, we describe how these cognitive abilities relate to real-world

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outcomes, including school performance, career attainment, physical health, and psychological well-being.

C7S1 Intelligence

C7P4 What is intelligence? On the face of it, this question may seem trivial for readers of this book. And yet, despite over a century of research on 'modern' intelligence tests (Binet & Simon, 1916), reasonable scientists and laypeople still disagree about what intelligence is, how it ought to be measured, and even whether it should be studied at all (e.g. Ritchie, 2015). From a conceptual standpoint, we think of intelligence as the ability to reason, solve problems, learn quickly, remember, plan, attend to what matters, and adapt to one's environment. From a technical or psychometric perspective, intelligence refers to one's level of performance on cognitive ability tests, and *general intelligence* refers to the higher-order *g* factor extracted from a battery of diverse cognitive tests (Figure 7.1). The *g* factor explains (or emerges as a result of; see Burgoyne et al., 2021; Kovacs & Conway, 2016; van der Maas et al., 2006) the positive correlations observed among broad cognitive abilities, representing what is common or shared across cognitive tests tapping different abilities (e.g. problem-solving, memory, processing speed) and content areas (e.g. verbal, numerical, visuospatial). *Broad* cognitive abilities refer to general classes of cognitive abilities, which, as one moves down the hierarchy from the *g* factor, can be further decomposed into more specific abilities, mechanisms, or processes measured by various cognitive assessments.

C7P5 For this chapter, we focus on three highly correlated domain-general cognitive abilities and their relationships to real-world outcomes. Specifically, we consider *working memory capacity*, which refers to the ability to maintain and manipulate information; *attention control*, the ability to focus attention on task-relevant information while resisting interference and distraction by having attention captured by task-irrelevant thoughts and events; and *fluid intelligence*, the ability to reason to solve problems novel to the individual. As we will discuss, there is considerable theoretical and empirical overlap between working memory capacity and attention control (e.g. Engle, 2002, 2018). In the next section, we review evidence suggesting that attention control is important to measures of working memory capacity and plays a large role in explaining working memory capacity's relationship with other constructs, including fluid intelligence.

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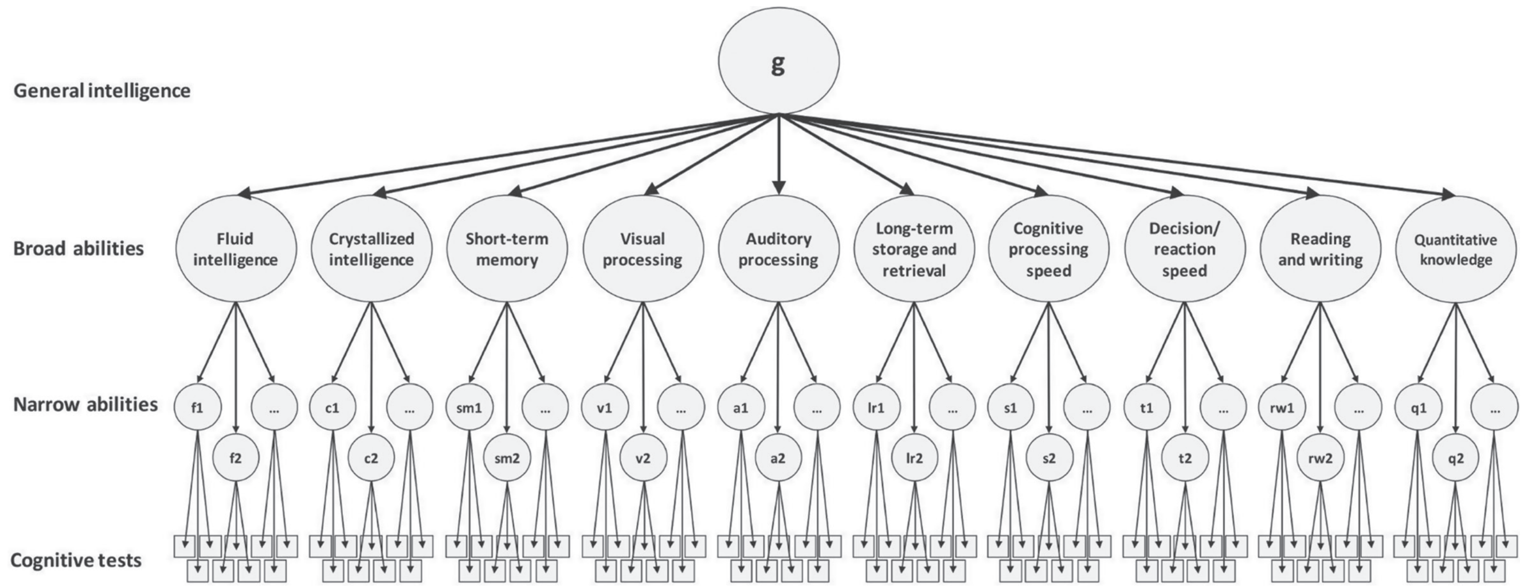
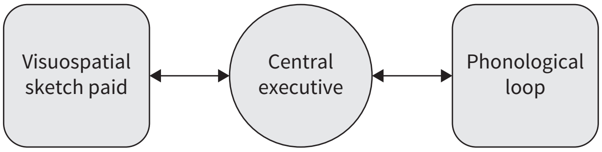


Figure 7.1 Hierarchical factor structure of intelligence based on the Cattell–Horn–Carroll (CHC) framework (McGrew, 2009). Circles represent latent factors; rectangles represent observed measures of performance on cognitive tests. Ellipses (. . .) indicate that there are more narrow abilities than could be depicted. The higher-order *g* factor represents general intelligence and explains the positive correlations observed among broad cognitive abilities. Adapted from Burgoyne et al. (2022).



C7F2 **Figure 7.2** Baddeley and Hitch's (1974) classic model of working memory.

C7S2 Working memory capacity, attention control, and fluid intelligence

C7P6 *Working memory* refers to the cognitive system that allows us to temporarily maintain information in a readily accessible state and manipulate it to serve task goals (Baddeley, 1992). For example, solving the mental arithmetic problem '(3 × 17) + 2 =?' requires working memory because one must compute and temporarily store the product of '3 × 17' in order to add '2' to it. In classic models, the working memory system includes a controlled attention component and a short-term storage component, or components (Figure 7.2; Baddeley, 1992; Baddeley & Hitch, 1974; Cowan, 1988). Although some researchers argue that the term is antiquated (e.g. Logie, 2016), the controlled attention component is often called the *central executive*, and it is responsible for coordinating the flow of information into, out of, and between the short-term storage components. Whereas the central executive is domain general, the short-term storage components are modality specific. For example, the *visuospatial sketch pad* is hypothesized to store visual information, such as mental imagery, whereas the *phonological loop* is hypothesized to store verbal and auditory information, such as speech. The phonological loop and visuospatial sketchpad are the most extensively studied of the putative storage systems, but others have been suggested (Baddeley, 2012). For the purposes of this chapter, however, we are primarily interested in working memory's interplay between controlled attention (i.e. the central executive component) and short-term memory at a more general level.

C7P7 Evidence suggests that the controlled attention component of the working memory system can largely explain the correlations between measures of working memory capacity and other abilities, such as fluid intelligence (Kane et al., 2001; Kane & Engle, 2002). Early interest in the relationship between working memory capacity and fluid intelligence was spurred on by the discovery of very strong (i.e. near-perfect) correlations between the two constructs. For instance, across a series of studies of more than 2000 participants, Kyllonen and Christal (1990) found correlations ranging from $r = 0.80$ to $r = 0.90$ between working memory capacity and fluid intelligence when measured at the *latent level*.[1] This led to an exciting possibility: if

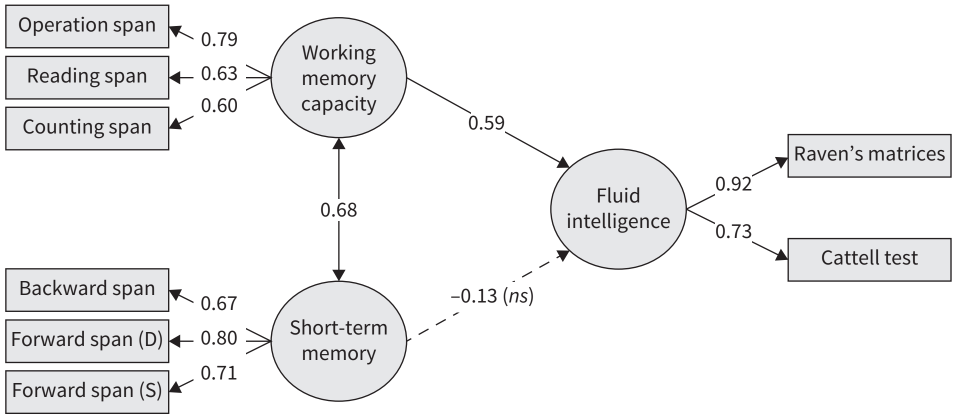
[1] By way of explanation, whereas observed measures capture both construct-relevant and construct-irrelevant variance, latent factors extract variance common to a set of measures and therefore come closer to approximating the theoretical constructs of interest. Latent variables also typically yield stronger correlations than observed measures because they are theoretically free of measurement error.

working memory could explain individual differences in fluid intelligence, then, in turn, it might also explain individual differences in *g*, because *g* and fluid intelligence are often nearly perfectly correlated (e.g. Kvist & Gustafsson, 2008).

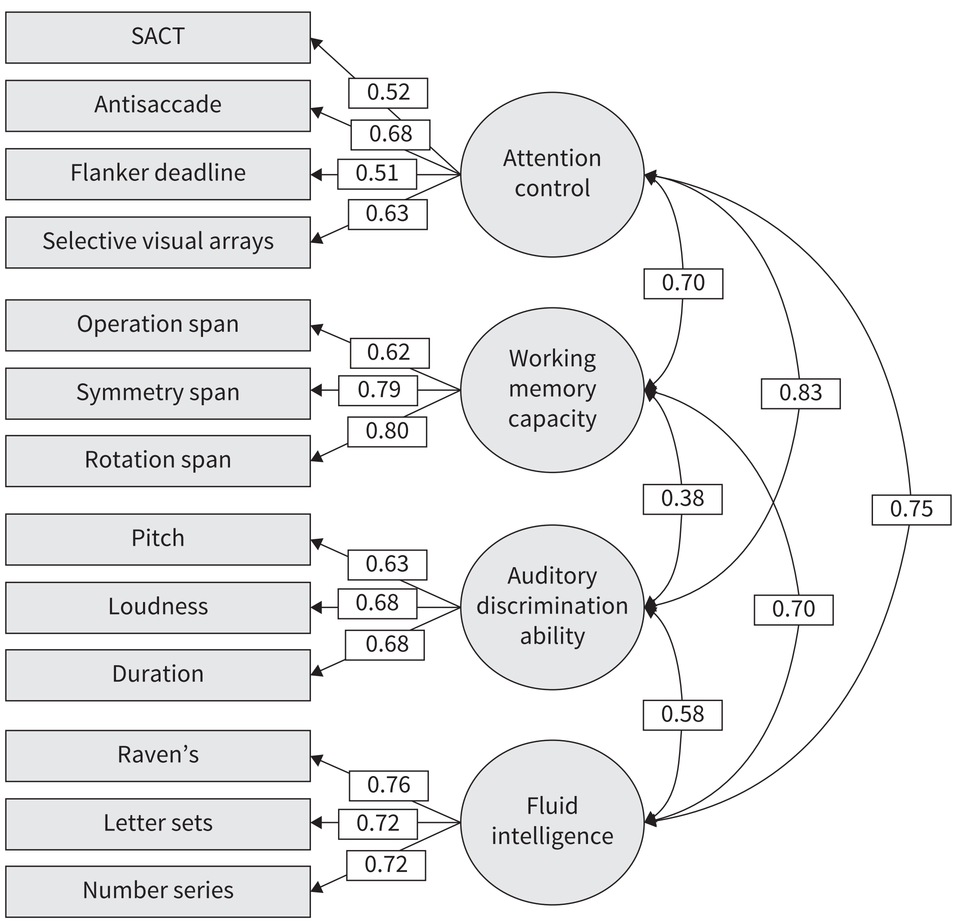
C7P8 This excitement was tempered by subsequent findings which revealed that working memory capacity and fluid intelligence were highly correlated, yet distinct. Meta-analyses indicated that the correlation between the two constructs at the latent level was probably closer to $r = 0.70$ than 1.00, indicating that working memory capacity and fluid intelligence shared approximately 50% of their reliable variance (Ackerman et al., 2005; Kane et al., 2005; Oberauer et al., 2005). Nevertheless, this raised the question of what cognitive construct (or constructs) could account for the relationship between working memory capacity and fluid intelligence.

C7P9 Our position is that most of the variance shared between working memory capacity and fluid intelligence is attributable to attention control (Burgoyne & Engle, 2020; Draheim et al., 2021; Engle et al., 1999). That is, if working memory capacity reflects the interplay between a central executive component and short-term storage components, then it is individual differences in the functioning of the central executive that largely drive the correlations between working memory capacity and other abilities and life outcomes. To test this idea, Engle et al. (1999) measured working memory capacity, short-term memory, and fluid intelligence at the latent level, using multiple tasks to measure each construct. They found that working memory capacity predicted fluid intelligence even after accounting for individual differences in short-term memory. That is, while the path from short-term memory to fluid intelligence was not significant after accounting for working memory capacity, the path from working memory capacity to fluid intelligence was substantial and significant after accounting for short-term memory (Figure 7.3). This result was corroborated and extended by Conway et al. (2002), who found that working memory capacity predicted fluid intelligence after accounting for both short-term memory and processing speed. Taken together, these findings indicated that it was not short-term storage or processing speed that explained working memory capacity's relationship with fluid intelligence, but rather, the fact that tests of working memory capacity, short-term memory, processing speed, and fluid intelligence all require controlled attention.

C7P10 More recently, we examined the relationships between working memory capacity, attention control, fluid intelligence, and auditory discrimination ability, which was operationalized as one's ability to distinguish between different tones in terms of pitch, loudness, and duration (Tsukahara et al., 2020). We found that latent factors representing each broad cognitive ability were moderately to highly correlated with each other (Figure 7.4; Burgoyne et al., 2021), corroborating over a century of intelligence research (Spearman, 1904). Next, we modelled a higher-order *g* factor, which was specified to explain the relationships among the broad cognitive ability factors. We found that attention control had the highest loading on the *g* factor (i.e. a loading of 0.98), indicating that the domain-general ability to control attention



C7F3 **Figure 7.3** In this structural equation model adapted from Engle et al. (1999), working memory capacity predicted fluid intelligence after taking into account the independent contribution of short-term memory.



C7F4 **Figure 7.4** In this correlated-factors model adapted from Burgoyne et al. (2022), latent factors representing attention control, working memory capacity, auditory discrimination ability, and fluid intelligence are moderately to strongly related to each other.

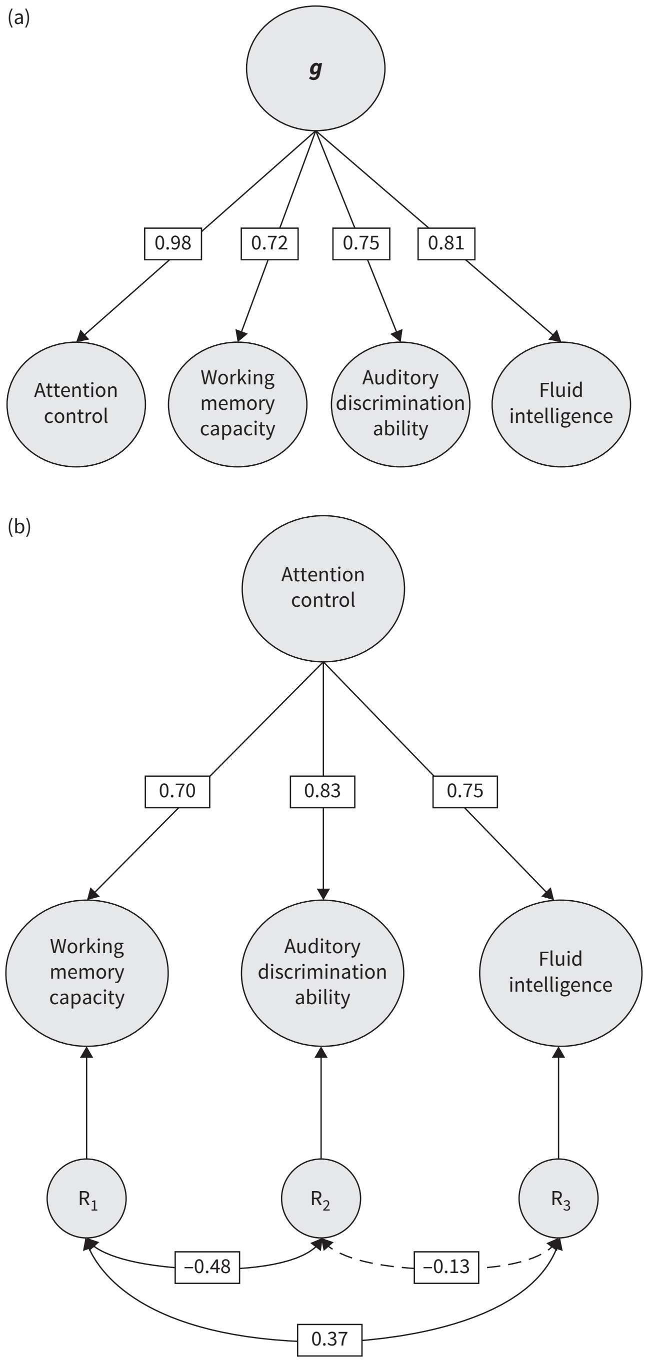
is closely related to *g* (Figure 7.5a). Finally, we put attention control in place of the *g* factor, and found that once variance in attention control had been partialled out of the broad cognitive ability factors, the residual correlations between working memory capacity, fluid intelligence, and auditory discrimination ability were significantly reduced, at times to non-significance (Figure 7.5b). Taken together, these results suggest that attention control is a key construct for explaining individual differences in cognitive ability, although it is almost certainly only one piece of a more complicated puzzle.

C7S3 Maintenance and disengagement

C7P11 If attention control is indeed key to explaining individual differences in cognitive abilities and the relationships between them, one might wonder *how*, on a mechanistic level, it supports cognitive functions such as problem-solving and remembering salient information. We have proposed the *maintenance and disengagement* theory of attention control to explain these phenomena (Burgoyne & Engle, 2020; Shipstead et al., 2016). Just as the central executive in Baddeley's working memory system is responsible for controlling what enters and exits short-term storage, we think of attention control in similar terms; it is responsible for *maintaining* information that is useful to current goals, and *disengaging* from information that is no longer useful, or was never useful to begin with. Maintenance and disengagement are brought to bear on a wide range of tasks, helping to explain why attention control is closely related to the *g*-factor, or general intelligence.

C7P12 For example, maintenance and disengagement both contribute to problem-solving. As we hypothesize about potential solutions to a problem, we must keep track of the constituent ideas pertaining to each hypothesis and also remember which hypotheses we have tested and which we have not, both of which require information maintenance. Even the act of hypothesis testing requires keeping track of a prediction and comparing it against evidence, another role for maintenance. However, once a hypothesis has been tested and rejected, we must abandon it in pursuit of other hypotheses (i.e. disengagement). People who are able to flexibly attend to what matters and discard what does not are better able to solve novel problems than those who are less able to control their attention (see Krieger et al., 2019; Shipstead et al., 2016).

C7P13 Maintenance and disengagement also play an important role when completing working memory tests. For instance, in the Operation Span task (Turner & Engle, 1989; Unsworth et al., 2005), participants must solve maths problems (e.g. 'Does (4 × 2) + 2 = 10?') while remembering letters, which are presented in an interleaved fashion between each maths problem. The primary task is to memorize the letters, placing a clear burden on information maintenance. The challenge is that participants must attend to the maths problems to solve them, and then rapidly disengage



C7F5 **Figure 7.5** (a) This panel shows that when the latent factors depicted in Figure 7.4 are modelled under a higher-order *g* factor, all cognitive abilities load significantly on the *g* factor, with attention control having the highest loading (0.98). (b) This panel shows that when attention control is modelled as a higher-order factor that explains the covariation between broad cognitive abilities, the residual correlations between the broad cognitive abilities—representing the variance in each ability not accounted for by attention control—are significantly weaker than before, and at times reduced to non-significance. For example, compare the residual correlations depicted in Figure 7.5a to the correlations depicted in Figure 7.4. These figures were adapted from Burgoyne et al. (2022).

from the arithmetic solution to attend to and remember the next letter in the sequence. This dual-tasking is a key feature of complex span tests of working memory capacity, and places a strong burden on the ability to control one's attention (Draheim et al., 2021; Kane et al., 2004).

C7S4 Interim summary

C7P14 Thus far, we have discussed individual differences in intelligence, with a focus on three highly correlated cognitive constructs: working memory capacity, attention control, and fluid intelligence. We presented evidence for the executive attention view, which places attention control at the centre of individual differences in working memory and helps explain why working memory capacity and other broad cognitive abilities are related to one another. In the next sections, we review evidence for how individual differences in cognitive ability are related to real-world outcomes, including school performance, career attainment, physical health, and psychological well-being.

C7S5 Predicting life outcomes from cognitive abilities

C7P15 Psychological science, done well, is a resource-intensive affair. Scarcity of time and money limits the quality of data generated by researchers. Unfortunately, some of the most sought-after data, such as those from national or internationally representative samples or from longitudinal studies, are also the most resource intensive to obtain. However, numerous longitudinal cohort studies, which often follow large, representative samples over time, have been conducted or are currently under way. While limited in their own respects (e.g. studies that began decades ago are limited by the knowledge and methods available at the start of data collection), these studies are treasure troves. Since they are often overseen by a national government, researchers have been able to track individual participants for follow-up testing for decades. This also enables researchers to link participants' data with governmental records, including health status, census data, and death records. These investigations have several obvious strengths. First, the sheer size of the samples, sometimes numbering in the tens of thousands depending upon the specific study, obviates usual concerns about power and type I (i.e. false positives) and type II error (i.e. false negatives). Second, longitudinal studies mitigate concerns about cohort effects threatening internal validity (although cohorts may still meaningfully differ from one another), while also making issues of causality easier to parse due to temporal precedence. Third, these studies often have recruitment strategies that create more representative samples than typical laboratory investigations, reducing selection effects and threats to external validity. That said, some (see Batty, Mortensen, & Osler, 2005; Calvin et al., 2011) are heavily biased by participant characteristics such as sex.

C7P16 These investigations have revealed several notable findings. First, cognitive ability is quite stable over time. One study in which 101 participants tested at age 11 were retested almost *seven decades* later revealed a test–retest correlation of $r = 0.73$ after correcting for measurement unreliability, indicating astonishing consistency in rank ordering over time (Deary et al., 2000). This provides some confidence that when researchers attempt to measure intelligence, they are measuring a stable, persistent trait, or at least a facet of one. This finding was replicated with a separate set of 550 participants (316 women) at age 80: the disattenuated test–retest correlation was also $r = 0.73$. Bifurcating the sample by sex led to a disattenuated test–retest correlation of $r = 0.71$ for men and $r = 0.78$ for women, providing further evidence that intelligence tests are estimates of stable individual differences (Deary et al., 2004). Finally, Deary (2014) reviewed evidence from several other studies which administered intelligence tests to the same individuals several decades apart. In each case, the correlation was strong, with scores at each occasion correlating around $r = 0.70$.

C7P17 This long-term stability provides reassurance that those studying the relationships between intelligence and life outcomes are not doing so in vain. A recent study by Brown et al. (2021) provides even more encouraging news. They analysed the relations between intelligence test scores and life outcomes (vocational/financial, social, and health outcomes) using data gleaned from four large cohort studies conducted in the UK and the US. In particular, they tested whether there were curvilinear relations which would lead to different effects of intelligence across the range of test scores. For instance, many laypersons believe that being too intelligent may actually lead to worse life outcomes, or at least that being intelligent past a certain point confers no additional advantage, a position sometimes called the threshold hypothesis (Gladwell, 2008; Robertson et al., 2010). However, the Brown et al. findings showed that intelligence tended to be a positive linear predictor of a range of outcome measures. Although intelligence test scores did not predict every outcome tested, there was little evidence that greater intelligence was ever harmful. Furthermore, where relationships with intelligence were detected, there was no evidence to support the threshold hypothesis. Even among high-intelligence subsamples, higher intelligence continued to confer benefits (Brown et al., 2021; Robertson et al., 2010).

C7P18 In the following sections, we review evidence from large, longitudinal studies wherever possible. Due to the relative recency of theoretical and measurement developments in working memory capacity and attention control, many studies focus primarily or exclusively on cognitive ability as measured by intelligence tests, intelligence being the eldest of the three main constructs of interest. However, we supplement these longitudinal intelligence studies by also describing smaller laboratory-based studies of working memory capacity and attention control where possible.

C7S6 Academic achievement

C7P19 When it comes to academic achievement, why do some people rapidly progress through challenging courses while others struggle to master basic concepts? Individual differences in intelligence explain considerable variability in school success, with correlations typically ranging from $r = 0.50$ to $r = 0.70$ (Jensen, 1998; Rohde & Thompson, 2007). Of course, intelligence is only one piece of a complicated puzzle, and other factors such as motivation, socioeconomic status, and school quality certainly play a role (Fortier et al., 1995; Heyneman & Loxley, 1983; Sirin, 2005). Nevertheless, individual differences in cognitive ability become increasingly consequential in school as life trajectories diverge. Not only do people find their interests and begin to pursue them in earnest, but many career prospects are constrained by measures of academic achievement, including grade point averages and standardized test performance. We begin this section by reviewing evidence from longitudinal studies and meta-analyses suggesting that working memory capacity and attention control have an early influence on maths and reading achievement, followed by a discussion of potential mediating mechanisms.

C7P20 Differences in cognitive abilities such as working memory and attention control are detectable early on, and they predict subsequent academic achievement. As one example, Blankenship et al. (2019) examined the development of attention control in infants and its relationship to reading achievement at age 6 in a longitudinal study of 157 children. The researchers first measured the attention control abilities of 5-month-old infants by showing them a 45-second video clip from the children's television show *Sesame Street*. The researchers estimated individual differences in attention control by measuring the longest duration the children looked at the video as well as the number of times they shifted their gaze.

C7P21 Blankenship et al. (2019) found that infants who were better able to control their attention while watching *Sesame Street* performed better on a test of executive functioning called the A-not-B task 5 months later. In the A-not-B task, the infants were challenged to find a toy placed in a new location. To do so, they needed to avoid perseverating on a previously learned location. The researchers also found that individual differences in executive functioning were reliable across development; they measured executive functioning at ages 3, 4, and 6 using memory span tasks and tests of attention control and found that each measure of executive functioning was significantly related to the measure collected before it. Moreover, the relationship between the infants' ability to control their attention and their reading achievement at age 6 was mediated by executive functioning, a result which held even after controlling for verbal intelligence. This suggests that individual differences in the domain-general ability to control attention can be detected at an early age and contribute to reading achievement above and beyond domain-specific verbal abilities.

C7P22 As another example, Ahmed et al. (2019) longitudinally tracked 1273 children from preschool (age 4.5) to high school (age 15) to examine the effects of working memory capacity, other executive functions, and the home environment on maths and literacy achievement. They measured working memory capacity at age 4.5 using a language recall task, in which the children were presented words, phrases, and sentences, and asked to repeat them after a delay. The other measures of executive functioning included a test of sustained attention, in which the children viewed pictures of common objects and pressed a button when a target stimulus appeared, and a test of inhibition called the Children's Stroop task, in which they were shown pictures of daytime and night-time scenes and asked to say the word 'day' in response to night-time scenes and 'night' in response to daytime scenes (Gerstadt et al., 1994). The researchers also measured the preschoolers' academic performance using a picture vocabulary test and an applied maths test designed for young children.

C7P23 A number of control variables were also examined to help disentangle the effects of cognitive ability from environmental effects. For instance, Ahmed et al. (2019) measured the mothers' educational attainment, the household income-to-needs ratio, the amount of learning materials in the home, the parents' level of involvement and responsivity to the child's needs, and whether the children were ever placed in child care. They also collected demographic information such as race and sex.

C7P24 Children with greater working memory capacity and other executive functions had significantly better academic performance in preschool. Furthermore, childhood working memory and executive functions predicted adolescent academic achievement at age 15 as measured by tests of reading comprehension, applied maths problems, verbal analogies, and picture vocabulary. That said, these results were qualified by including other predictors in the model, suggesting that some of the variance accounted for by cognitive ability was shared with other factors. For example, academic performance at age 4.5 accounted for meaningful variance in academic achievement at age 15, but it also reduced the effects of most of the cognitive ability predictors to non-significance. In particular, only working memory capacity remained a significant predictor of paragraph comprehension at age 15 after accounting for childhood academic achievement. Nevertheless, working memory capacity at age 4.5 remained a significant predictor even after also accounting for demographic and home environment covariates, suggesting that it captured unique variance in adolescent academic performance. Thus, measures of working memory predicted children's academic achievement more than 10 years later.

C7P25 Ahmed et al. (2019) report more modest findings regarding executive functions, but they should be interpreted cautiously. They found that childhood executive functions measures were no longer significant predictors of adolescent achievement after accounting for covariates. However, this *does not* indicate that executive functions are unimportant in the early stages. To the contrary, all the childhood executive function measures were significantly related to maths and vocabulary achievement at age 4.5. One interpretation of these results is that the predictive variance of the executive function measures may have been captured by childhood academic performance. Another possibility is that the childhood executive function measures were not as reliable as the working memory measure was, and, as a result, had attenuated predictive validity. Indeed, working memory capacity at age 4.5 predicted working memory capacity at age 15, whereas the other executive function measures were not significantly correlated across timepoints. This suggests that the test–retest reliability of some of the measures may have been low, a common problem in developmental studies of cognitive ability and in the executive function literature more broadly (Beck et al., 2011; Draheim et al., 2019).

C7P26 Meta-analytic evidence also indicates that individual differences in working memory capacity predict reading achievement. Early evidence was provided by a meta-analysis of 77 studies (Daneman & Merikle, 1996), which revealed that complex span measures of working memory capacity predict reading comprehension to a considerable degree, with correlations ranging from $r = 0.30$ to $r = 0.52$. Daneman and Merikle (1996) also showed that complex span tasks with *verbal* stimuli yielded the strongest relationships between working memory capacity and reading comprehension, although even complex span tasks that do not use verbal stimuli for the processing subtask also predict individual differences in reading comprehension (Turner & Engle, 1989). More recently, Peng et al. (2018) meta-analysed 197 studies and found an average correlation of $r = 0.29$ between working memory capacity and reading abilities. The magnitude of the correlation was fairly similar across types of reading skills, and ranged from $r = 0.26$ for vocabulary to $r = 0.34$ for phonological coding. Like Daneman and Merikle (1996), Peng et al. (2018) also found that verbal tests of working memory had the numerically largest correlation with reading abilities, but that tests of working memory that used non-verbal stimuli also predicted individual differences in reading skill. These results suggest that tests of working memory capacity tap a domain-general ability, which we would identify as attention control, that is important for language processing.

C7P27 Meta-analytic evidence also indicates that individual differences in working memory capacity predict mathematics achievement (Spiegel et al., 2021). For example, a meta-analysis of 110 studies by Peng et al. (2016) found an average correlation of $r = 0.35$ between working memory capacity and measures of maths ability. An examination of specific maths domains revealed that the largest correlation was between working memory capacity and word-problem solving ($r = 0.37$), whereas the smallest correlation, though still significant, was between working memory capacity and geometry ($r = 0.23$).

C7P28 Although we have reviewed some evidence for the relationship between academic achievement and cognitive abilities such as working memory capacity and attention control, the specific mechanisms by which these cognitive abilities exert their influence has not been discussed. In light of our maintenance and disengagement framework, we now provide illustrative examples suggesting that working memory capacity and attention control contribute to school performance by supporting the maintenance of relevant information and disengagement from irrelevant and no longer relevant information.

C7P29 Being able to follow instructions is critical for students to learn new skills in the classroom. Engle et al. (1991) investigated why some children are better able to follow directions than others. Their sample consisted of 120 students from first grade, third grade, and sixth grade. They asked students to follow 45 sets of directions varying in complexity, such as 'Point to the picture at the top of page three and copy it twice' (p. 256). They found that working memory capacity was significantly related to students' ability to follow directions, and it also predicted their performance on a reading comprehension test. Furthermore, Engle et al. (1991) found that as the directions became more complicated, the gap in performance between students with the highest and lowest working memory capacity increased. One interpretation of this result is that students with greater working memory capacity were better able to ignore distractions and maintain focus on task instructions. Furthermore, it seems that attentional abilities were especially important when dealing with more complex information processing demands, which would have implications for learning complicated course content. For a more comprehensive review of research on following instructions, see Allen et al., Chapter 10, this volume.

C7P30 The hypothesis that individual differences in attention control explain why some students are better able to maintain focus on task-relevant information was later corroborated by a study of mind wandering, attention control, and reading comprehension (McVay & Kane, 2012). The researchers had more than 200 participants read passages of text ranging from a short article on volcanoes to five chapters of *War and Peace*. As the participants read, they were intermittently asked to report instances of task-unrelated thoughts and to describe what they were focusing on before they were interrupted. McVay and Kane (2012) found that attention control was a strong predictor of reading comprehension. Furthermore, participants with greater attention control had fewer task-unrelated thoughts, indicating that they were better able to focus on the reading material and were less susceptible to distractions. In turn, task-unrelated thoughts partially explained the relationship between attention control and reading comprehension performance, although the direct path from attention control to reading comprehension remained significant even after accounting for task-unrelated thoughts. This suggests that the ability to maintain focus and resist mind wandering captured part, but not all, of the covariation between attention control and reading comprehension.

C7P31 As a final example, Tolar et al. (2009) examined the contributions of working memory capacity, computational fluency, and three-dimensional spatial visualization to algebra achievement and performance on a standardized maths test, the SAT, in a sample of over 100 undergraduate students. They found significant relationships between the measures of working memory capacity and maths achievement. Furthermore, using latent variable analyses, they found that working memory capacity had significant relationships with computational fluency and three-dimensional spatial visualization, which in turn explained the relationship between working memory capacity and maths achievement. Thus, two mechanisms by which working memory appeared to contribute to maths achievement was via computational fluency (e.g. being able to solve arithmetic problems such as 64 ÷ 4), which would facilitate solving algebra problems, and three-dimensional spatial visualization (e.g. being able to mentally rotate shapes), which may be useful for solving geometry problems.

C7P32 Individual differences in intelligence, and, in particular, working memory capacity and attention control, explain considerable variance in academic achievement. Evidence suggests that differences in these cognitive abilities can be detected at an early age and that they are relatively stable across development. The ability to control attention to maintain and manipulate information in service of goals appears to influence academic achievement via mediating mechanisms such as following directions, resisting mind-wandering during task performance, computational fluency, and spatial visualization, to name a few. In the next section, we discuss how individual differences in cognitive abilities such as working memory capacity and attention control contribute to success in the occupational sector.

C7S7 Job performance

C7P33 It is well established that measures of cognitive ability predict job performance, training success, and career attainment (Bobko et al., 1999; Hunter, 1986; Schmidt, 2002). Indeed, companies and organizations use cognitive ability tests to select and classify personnel because it increases the productivity of the organization (Schmidt & Hunter, 1998). In this section, we review evidence for the relationship between cognitive ability and job performance, paying close attention to the roles of working memory capacity and attention control.

C7P34 In now classic work, Schmidt and Hunter (1998) synthesized 85 years of research on the validity of personnel selection assessments for predicting job performance and training success. Job performance was primarily measured using supervisor ratings of worker performance, whereas training success was typically defined as the amount learned on the job. Schmidt and Hunter (1998) found that *general mental ability*, a term frequently used by industrial/organizational psychologists to refer to general intelligence, was the single best predictor of job performance ($r = 0.51$) and training success ($r = 0.56$) after correcting for the attenuating effects of criterion unreliability and restriction of range among incumbent workers. Furthermore, Schmidt and Hunter (1998) reported that the relationship between cognitive ability and job performance was moderated by job complexity; for highly complex professional/managerial jobs, the average correlation was as high as $r = 0.58$, whereas for completely unskilled jobs, the average correlation was somewhat lower, though still meaningful: $r = 0.23$.

C7P35 The validity of cognitive ability for predicting job performance remains substantial even as workers gain experience on the job. McDaniel (1985) found that as the level of job experience increased, the validity of cognitive ability did not decrease. At 0–3 years of experience, the correlation was $r = 0.35$, whereas at 9–12 years of experience, the correlation was $r = 0.44$. This result runs counter to the *circumvention of limits hypothesis* (Hambrick & Meinz, 2011; Salthouse, 1991; Schmidt et al., 1988), which suggests that cognitive ability will cease to predict job performance after people have acquired domain-specific knowledge, skills, and strategies. Although domain-specific knowledge and skills may enable performers to bypass reliance on capacity-limited aspects of cognition in relatively simple, consistent tasks (Ackerman, 1988), these results do not appear to generalize to real-world jobs, which are often more complicated and change over time (see Hambrick et al., 2019). Thus, cognitive ability often remains a significant predictor of job performance even after years of training.

C7P36 In addition to predicting job performance, measures of cognitive ability also predict career attainment, operationalized as occupational level or prestige within a field. For example, in a longitudinal study of over 3000 young adults (National Longitudinal Survey—Youth Cohort; Center for Human Resource Research, 1989), Wilk et al. (1995) found that general mental ability predicted subsequent job movement 2–7 years later. Higher-ability people tended to move up the job hierarchy during the intervening years, whereas lower-ability people moved down the job hierarchy. Additionally, Judge et al. (1999) found that measures of cognitive ability at age 12 predicted occupational outcomes 30–40 years later ($r = 0.51$), as well as adult income ($r = 0.53$).

C7P37 Interestingly, the relationship between cognitive ability and career attainment cannot be fully explained by socioeconomic factors or other environmental variables such as school quality or differential access to opportunities. Murray (1998) controlled for these variables by sampling full biological siblings, who shared the same parents and home environment but differed in cognitive ability. Despite being raised in the same household, siblings with higher levels of cognitive ability were far more successful in the academic and occupational sectors than their lower-ability counterparts; they received more years of education, entered more prestigious professions, earned a higher income, and had more regular employment. Thus, the relationship between cognitive ability and career attainment is not merely a consequence of environmental factors such as socioeconomic status; cognitive ability apparently exerts an influence on career attainment above and beyond these factors. Taken together, the prevailing conclusion to emerge from this research is that people with greater cognitive ability learn more from job training programmes, acquire job-related skills faster, perform better, and move up the professional hierarchy more than individuals lower in cognitive ability.

C7P38 Presumably, measures of specific cognitive abilities such as working memory capacity and attention control should also predict job performance to a considerable degree, given their strong relationships with general intelligence (Burgoyne et al., 2021; Conway et al., 2003). That said, while there is more than a century of evidence supporting the use of intelligence tests for personnel selection, research on the predictive validity of working memory capacity and attention control is, by comparison, still in the early stages.

C7P39 Researchers have begun investigating working memory capacity and attention control tests as candidates for personnel selection assessments because they may reduce adverse impact relative to traditional tests, which often focus on acquired knowledge and demonstrate substantial differences between majority and minority groups (Burgoyne et al., 2021). *Adverse impact* refers to the disproportionate selection or promotion of members of one group over another. For an example, consider the Armed Services Vocational Aptitude Battery (ASVAB), the standardized test taken by all US military applicants. Due to mean differences in performance on the ASVAB, the selection rate for Black applicants is less than 80% of the selection rate for White applicants (ASVAB Enlistment Testing Program, 2020). Although the ASVAB predicts performance in the military to approximately the same degree for White and Black enlistees (Wise et al., 1992), its use results in the inequitable selection of Black applicants and women (see, e.g. Held et al., 2014).

C7P40 One potential reason why the ASVAB results in adverse impact is because it heavily emphasizes acculturated knowledge. Although acculturated knowledge such as automotive and shop information is clearly relevant to some military jobs, Outtz and Newman (2011) found that the subtests of the ASVAB with the largest differences between White and Black applicants were those that measured technical knowledge and those that measured verbal abilities. Along similar lines, Hough et al. (2001) found that tests of acquired knowledge (e.g. verbal ability, science knowledge, and quantitative ability) tended to result in larger group differences in performance than tests of memory, processing speed, and spatial abilities. As an explanation for these differences between groups, others have argued that measures of acculturated learning may be especially sensitive to socioeconomic status and educational opportunities (Bosco et al., 2015; Outtz & Newman, 2011; Sternberg & Wagner, 1993). Taken together, some personnel selection tests result in less equitable outcomes than others, and so a critical goal for industrial/organizational psychology is to find tests that maintain or improve the prediction of job performance while also reducing adverse impact.

C7P41 Preliminary evidence suggests that working memory capacity and attention control tests may predict job performance nearly as well as traditional tests while minimizing group differences in performance. For example, Nelson (2003) examined the relationships between working memory capacity, general intelligence, and job performance in a sample of 378 insurance agent support staff. Job performance was measured using supervisor ratings, whereas working memory capacity was measured using a reading span task and another verbal span task. Nelson (2003) found that the working memory capacity measures had good internal consistency reliability (αs = 0.85 and 0.86) and significantly predicted a cognitive job performance composite variable (average $r = 0.17$; $r = 0.24$ after correction for criterion unreliability). For comparison, the correlation between general intelligence and cognitive job performance was only slightly larger, $r = 0.22$ (or $r = 0.31$ after correction for criterion unreliability). Importantly, subgroup differences were smaller for the working memory measures than for general intelligence. Specifically, the standardized mean difference in performance on the working memory measures was $d = 0.40$ for White and Black participants and $d = 0.31$ for White and Hispanic participants, whereas the difference in performance on the general intelligence measure was $d = 1.03$ for White and Black participants and $d = 0.73$ for White and Hispanic participants. Thus, Nelson's (2003) results suggest that tests of working memory could have less adverse impact than tests of general intelligence, while predicting job performance to a meaningful degree, perhaps due to working memory tests relying less on acquired knowledge.

C7P42 As another example, Guo et al. (2020) examined the contribution of working memory capacity to job performance in a sample of 70 high-speed railway dispatchers. Working memory capacity correlated significantly with supervisor ratings of performance ($r = 0.90$) and with an objective rating of performance, train delay times in a railway simulator ($r = -0.91$). Guo et al. (2020) speculated that greater working memory capacity allowed dispatchers to maintain salient information in mind (e.g. tracking and controlling train routes) while performing their job.

C7P43 As yet another example, Bosco et al. (2015) compared the validity of attention control and working memory tests to a conventional test of mental ability, the Wonderlic Personnel Test, for predicting supervisor ratings and performance in a management simulation. In a sample of 470 bank employees and undergraduate students, the attention control and working memory measures predicted performance just as well as the Wonderlic Personnel Test (compare $r = 0.35$ to $r = 0.33$) while reducing group differences between White and Black participants. Specifically, a meta-analysis of their results indicated that the attention control and working memory measures reduced group differences by around half of one standard deviation compared to the Wonderlic Personnel Test (compare $d = 0.68$ to $d = 1.09$).

C7P44 As a final example, Martin et al. (2020) administered an Armed Services Vocational Aptitude Battery (ASVAB) practice test, attention control tests, fluid intelligence tests, and multitask paradigms which were used as a proxy for complex work performance to a sample of 171 young adults. They found that a latent variable representing attention control accounted for nearly one-quarter of the variance in multitasking performance above and beyond fluid intelligence and the ASVAB. Furthermore, a composite variable based on the attention control measures reduced group differences between White and Black participants by three-quarters of one standard deviation compared to the ASVAB, and two-thirds of one standard deviation compared to the Armed Forces Qualification Test (AFQT) (Burgoyne et al., 2021). That is, the group difference was $d = 1.86$ (95% confidence interval (CI) 1.47, 2.33) for the ASVAB and $d = 1.74$ (95% CI 1.32, 2.23) for the AFQT, compared to $d = 1.11$ (95% CI 0.75, 1.50) for the attention control measures. Although the absolute magnitude of these group differences is quite high, the relative difference across tests revealed much smaller group differences on the attention control measures than on the ASVAB and AFQT. This suggests that attention control tasks could reduce adverse impact while improving the prediction of work performance (Burgoyne et al., 2021).

C7P45 To sum up, tests of attention control and working memory are valid predictors of job performance, with validity coefficients that are nearly equal in magnitude to those of general intelligence. While it has long been established that measures of cognitive ability predict occupational success, an exciting possibility is that tests of working memory and attention control might mitigate subgroup differences relative to traditional tests, in turn reducing adverse impact. Ultimately, this research could help attain more equitable outcomes in the world of work while continuing to benefit the productivity of organizations.

C7S8 Physical health and mortality

C7P46 Serious investigations of the link between cognitive ability and physical well-being are recent. In fact, protracted academic and epidemiological interest in the cognition–health association did not emerge until the 1990s (Deary et al., 2010; Gottfredson & Deary, 2004). Since then, however, several findings have been convincingly established.

C7P47 First, childhood intelligence predicts later morbidity. Wraw et al. (2015) analysed data from the National Longitudinal Study of Youth 1979, a nationally representative sample of adolescents and young adults in the US who were recruited in late 1978 and periodically provided information about their health, education, and other sociodemographic details. As a measure of cognitive ability, participants completed the AFQT sometime between the ages of 14 and 21, a test which is based on mathematical and verbal ability. In a sample of over 5000 participants, adolescent intelligence was associated with fewer self-reported physical ailments, greater fitness and locomotor function, and higher estimates of health status in middle age. Greater adolescent intelligence was also associated with reduced risk for specific disorders and health conditions, including cardiovascular diseases, respiratory disease, joint discomfort, and use of movement aids.

C7P48 These effects were only slightly diminished by controlling for childhood socioeconomic status, but were greatly attenuated when *adult* socioeconomic status was controlled. In fact, after accounting for adult socioeconomic status, intelligence test scores no longer significantly predicted any summary health outcome, but remained a significant predictor of some specific problems, such as cardiovascular disease—including hypertension and heart attack—as well as joint discomfort. Wraw et al. (2015) note that the attenuating effect of adult socioeconomic status on the intelligence–health relationship should be interpreted with caution, as it is ambiguous with regard to causal direction. As Deary et al. (2010) note, some researchers argue that adult socioeconomic status can serve as a proxy for intelligence, in which case the attenuation observed by Wraw et al. (2015) would be an instance of statistical over control. For instance, Kraft et al. (2018) report that, while lower educational attainment predicts greater utilization of healthcare services even in early adulthood, the effect is partly explained by intelligence measured at age 12, which necessarily predates terminal education (see also Judge et al., 1999). This would be inconsistent with a purely socioeconomic account of the cognitive ability–health relationship.

C7P49 Deary et al. (2010) review other evidence for an association between cognitive ability and health, with lower intelligence being associated with higher rates of self-harm, physical violence, cardiovascular disease (particularly coronary artery disease; see Batty, Mortensen, Andersen, & Osler, 2005; Ferrucci et al., 1993), and tentative evidence for increased rates of stomach and lung cancers, which are the cancers most associated with poor health and lifestyle decisions (e.g. smoking), and are thus arguably more preventable than other forms of cancer.

C7P50 Increased rates of disease coincide with a diminished likelihood of surviving to old age. Hart et al. (2003) found children with lower intelligence at age 11 were at higher risk of dying within the succeeding 25 years. Accounting for several possible mediators such as one's occupation and neighbourhood affluence ameliorated but did not eliminate the direct effect of low intelligence on mortality rates. These results are corroborated by a meta-analysis of 16 cohort studies (Calvin et al., 2011), and a recent follow-up to the Scottish Mental Survey of 1947, which administered the Moray House Test, a test of cognitive ability, to nearly every Scottish 11-year-old born in 1936. The sample of over 70,000 individuals replicated the intelligence–health association and also revealed that it is strongest for earlier (i.e. prior to age 66), perhaps more preventable deaths (Čukić et al., 2017). Importantly, these mortality data do not differentiate by cause of death, an interesting potential moderator of the intelligence–mortality relationship. Thus, a more fine-grained analysis examining specific terminating events would likely add complexity and nuance to the relationship between cognitive ability and longevity (cf. Deary et al., 2010).

C7P51 The preceding studies provide compelling evidence that cognitive ability predicts aspects of health and longevity. But why might this be the case? Several explanations have been proposed (Gottfredson & Deary, 2004). The first is that intelligence and health are both indicators of bodily/medical insults accumulated over the lifetime. By this account, the accrual of harm over time, such as by protracted physical inactivity or substance abuse, reduces intelligence while simultaneously leading to worse long-term health outcomes (Gottfredson & Deary, 2004). This account has some intuitive appeal, but the cohort studies previously described, in which intelligence is measured in childhood and used to predict adult health status, suggests that it cannot be the entire story. If it were, one would expect ability and health to track one another closely across time, but one would not necessarily expect earlier cognitive ability to predict later health outcomes. The fact that they do suggests that those who start with higher cognitive ability may behave differently in the intervening time, and the differences lead to health disparities.

C7P52 This suggests a second explanation which supposes that the cause of the cognitive ability–health association lies not in common causes, but that those higher in cognitive ability are more likely to engage in health-promoting behaviours, avoid harmful behaviours, and/or engage in better self-care (Gottfredson & Deary, 2004). There is strong evidence to support this position. For instance, one study found no intelligence differences between those who began smoking cigarettes and non-smokers for Scottish people born in 1926, when the health risks of smoking were less well known. However, among smokers, those with higher intelligence test scores were more likely to quit smoking in adulthood than those with lower intelligence test scores (Taylor et al., 2003). This may be rooted in a greater ability to act on emerging knowledge about the dangers of tobacco use, such as being better at resisting the urge to smoke or prioritizing long-term health over short-term pleasure, both putative functions of attention control (cf. Shamosh et al., 2008). For example, working memory tests have been shown to predict short-term relapses in cigarette smoking, particularly when no pharmacological assistance is provided to mitigate aversive withdrawal effects (Patterson et al., 2010). Those who perform more poorly on tests of working memory are more likely to relapse because they are less able to control attention capture by their impulses to smoke, making them more likely to yield to nicotine withdrawal. For a more detailed discussion of cognition and addictive behaviours see Andrade, Chapter 14, this volume.

C7P53 Working memory and executive functioning also predict aspects of healthcare management. For instance, one study found that a composite measure of working memory and executive functioning predicted medication adherence in a community sample of older adults (Insel et al., 2006). Even after accounting for variables such as age, dementia and depression symptomatology, illness severity, education, and financial well-being, the working memory/executive functioning composite measure was the sole significant predictor (Insel et al., 2006; see also Stilley et al., 2010). Moreover, interventions designed to reduce reliance on working memory and executive functioning for treatment management have been linked to improved adherence rates, particularly for lower-ability individuals (Insel et al., 2016). Finally, those with low working memory capacity have been shown to struggle to comprehend, internalize, and recall health-related information, such as that pertaining to nutrition or signs of stroke, relative to more able peers (Ganzer et al., 2012; Soederberg Miller et al., 2011).

C7P54 A third explanation for the relationship between cognitive ability and health is that they share common physiological mechanisms (Gottfredson & Deary, 2004). A recent notable example of this approach has been advanced by Geary (2021), who suggested that mitochondrial functioning provides a common basis for understanding an array of psychometric and epidemiological phenomenon, including the uniformly positive correlations among cognitive tests (Spearman, 1904). In particular, Geary (2021) notes that poor mitochondrial functioning limits the efficiency of important, long-range, energy-demanding neural networks underpinning complex cognitive processes such as working memory and attention control, providing a common limiting factor across many cognitive domains (cf. Detterman, 1991; Kovacs & Conway, 2016), health (i.e. poor cellular metabolism is linked to numerous adverse health outcomes and may be improved with lifestyle changes or harmed by unhealthy lifestyle choices), and ageing (i.e. mitochondrial functioning declines with age, contributing to joint declines in health and cognitive ability across adulthood; Geary, 2021).

C7P55 Yet another explanation for the association between physical health and cognitive ability is rooted in resource inequities across those high and low in cognitive ability (Gottfredson & Deary, 2004). That is, those with higher ability also tend to have greater monetary resources, educational attainment, occupational prestige, and so on. These material advantages confer numerous opportunities, such as greater access to nutritious food, healthcare, and health education. This would mean that socioeconomic status may serve as a common cause for both individual differences in cognitive ability and health outcomes. While they do not investigate health outcomes, Hanscombe et al. (2012) report in a large, UK-based twin study (N = 8716 twin pairs) that childhood socioeconomic status does affect individual differences in intelligence, such that children from relatively more disadvantaged homes have more variable IQ estimates than their more advantaged counterparts. After partitioning variation in intelligence into genetic, shared environmental, and non-shared environmental components, the researchers conclude that shared environmental factors account for most of the observed increase in variability. That is, for low socioeconomic status children, shared family and school environments play a larger role in determining IQ than for their higher socioeconomic status peers. Importantly, the genetic effect on intelligence differences was constant across the range of socioeconomic status (Hanscombe et al., 2012; but see Turkheimer et al., 2003). Thus, individual differences in cognitive ability cannot be dismissed merely as artefacts of socioeconomic status, since low socioeconomic status affects primarily the environmental but *not* the genetic variability in intelligence. This also clarifies how controlling for childhood socioeconomic status can have little effect on the cognitive ability–health relationship: if the association between the physical well-being and cognitive ability is mainly driven by the genetic component of intelligence, then controlling for childhood socioeconomic status should leave the relationship largely intact (cf. Wraw et al., 2015).

C7P56 In summary, high performance on cognitive ability tests is associated with reduced risk of disease, preventable death, and better functional outcomes. As with job performance, most of the research in this domain focuses on 'intelligence', broadly defined. As such, continued investigations into the specific relationships between health and working memory capacity and attention control will no doubt prove fruitful. In particular, we suspect that superior attention control may confer health benefits through better impulse control and maintenance of long-term goals, and future longitudinal studies should include valid measures of attention control to investigate this possibility. Despite this limitation, a major strength of the studies we reviewed is that they indicate that cognitive ability may play a causal role in health by showing that intelligence in childhood predicts health and mortality decades later. Nevertheless, the relationship between cognitive ability and health is likely bi-directional and influenced by other factors. Furthermore, future epidemiological research should examine not only the effects of cognitive ability and health, but also the relationship of health to other life outcomes such as education and career attainment.

C7S9 Psychological well-being

C7P57 Performance on cognitive ability tests is impaired by many psychiatric disorders as well as adverse life events. Simultaneously, high cognitive ability is a protective factor against many clinical and non-clinical psychological ailments. For instance, Batty, Mortensen, and Osler (2005) describe a study of over 7000 Danish men born in 1953 who completed an intelligence test at age 13. Participants were tracked via a government health database for incidents of psychiatric disorders occurring between 1969 and 2002. Children with lower test scores were at elevated risk of developing a psychiatric disorder in the following years compared to children with higher intelligence test scores, a pattern which held even after controlling for participants' birthweight and their father's occupation.

C7P58 Ohi et al. (2022) took a different approach by assessing whether developing major depression, bipolar disorder, or schizophrenia lowered participants' intelligence test scores. Ohi et al. (2022) estimated premorbid intelligence using the Japanese translation of the National Adult Reading Test, a measure of crystallized intelligence. Crystallized intelligence is thought to be relatively stable throughout the lifespan and is often spared in psychological disorders (Horn & Cattell, 1967; Ohi et al., 2022; Russell, 1980; Wang & Kaufman, 1993). Importantly, theorists (Cattell, 1987; Kvist & Gustafsson, 2008) have proposed a causal link between fluid and crystallized intelligence, such that higher fluid intelligence in youth coupled with more opportunities for learning and investment by the learner lead to higher crystallized intelligence: an individual's level of knowledge is a function of their fluid intelligence at the time they learned that knowledge. Thus, the use of a crystallized intelligence test to estimate premorbid intelligence appears sensible. For comparison, the researchers measured current intelligence using the Wechsler Adult Intelligence Scale, which incorporates aspects of both crystallized and fluid intelligence. Notably, fluid intelligence is more sensitive to effects of ageing, injury, and disease (Horn & Cattell, 1967; Ohi et al., 2022; Russell, 1980; Wang & Kaufman, 1993). Consistent with Batty, Mortensen, Andersen, and Osler (2005), participants with a clinical diagnosis of major depressive disorder, bipolar disorder, or schizophrenia had lower premorbid intelligence than healthy controls (Ohi et al., 2022). More strikingly, they also demonstrated marked declines from premorbid to current intelligence in participants with a clinical diagnosis, whereas intelligence estimates for healthy controls were stable across the two time points. These results held after controlling for age and sex (Ohi et al., 2022). Taken together, these results suggest that while those lower in cognitive ability are at elevated risk for psychiatric disorder, disorders themselves may also lead to further impairment.

C7P59 Further evidence for an association between cognitive ability and psychological well-being comes from the post-traumatic stress disorder (PTSD) literature. Macklin et al. (1998) found that individuals with lower cognitive ability may be at higher risk of developing PTSD. Superficially, they found that US Vietnam War veterans who scored lower on pre-combat intelligence tests were more likely to develop PTSD post combat; they also reported more severe PTSD symptomology. Importantly, these results held even after accounting for combat exposure and post-combat intelligence. This last point is crucial, since lower scores on *pre-combat* aptitude tests increase the likelihood that one will see active combat (Macklin et al., 1998). Breslau et al. (2013) also reported increased risks of PTSD symptomatology among adolescents who scored poorly on childhood intelligence tests. In their study, 6-year-olds were recruited from hospitals and administered the Wechsler Intelligence Test for Children—Revised. They were contacted again at age 17 and asked to report instances of traumatic events and completed PTSD diagnostic screenings. Of the 713 participants, approximately 75% reported some traumatizing event. Of these, 45% met criteria for a PTSD diagnosis according to the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders*. Within this subgroup, those with lower childhood intelligence scores were at higher risk, with a one standard deviation decrease in childhood intelligence being associated with approximately a 50% increased risk of PTSD diagnosis following trauma exposure (Breslau et al., 2013).

C7P60 As was the case for physical well-being, there are several non-mutually exclusive explanations for why cognitive ability predicts aspects of psychological well-being. Here, we focus on one aspect of psychological well-being in particular: *emotion regulation*. Emotion regulation is a critical life skill, and studies show that effective emotion regulation may be an important component of long-term psychological and physical well-being. For instance, a nationally representative sample of over 1100 adults in the US answered questions about daily stressors (e.g. having an argument) and negative affect (Leger et al., 2018) for 8 consecutive days. Participants' stressors and negative affect were then used to predict health outcomes 10 years later. Importantly, researchers omitted days on which participants reported experiencing a stressor from their analyses, focusing instead on lingering negative affect on the day *following* a stressor. Participants with greater lingering negative affect likely suffer from poor emotion regulation and may be at higher risk for adverse health events, perhaps due to prolonged physiological stress responses damaging biological systems (Carlson et al., 2012; Geary, 2021). Indeed, lingering negative affect predicted incidents of chronic disease and difficulties completing daily activities without assistance. Moreover, these results held even after accounting for health 10 years prior, sex, age, and educational attainment (Leger et al., 2018).

C7P61 Evidence suggests that those higher in cognitive ability may be more effective at coping with stress and regulating negative emotions. Garrison and Schmeichel (2022) probed participants to answer questions about their stress and affect as they went about their day. Participants also completed two versions of the operation span. The researchers found that, while participants generally experienced increased negative affect following stressful events, those who performed well on the operation span tasks experienced less negative affect following negative events than participants who scored lower (Garrison & Schmeichel, 2022; see also Coifman et al., 2021). Moreover, a meta-analysis conducted by Moran (2016) which included over 22,000 data points found that working memory capacity moderately predicted anxiety ($r = -0.33$). In particular, domain-general, attentionally demanding working memory tasks showed the strongest, most consistent relationship and was associated with both facets of anxiety: cognitive (i.e. worry) and affective (i.e. arousal; Moran, 2016). This suggests that attention control likely has a particularly important part to play in explaining anxiety.

C7P62 Indeed, attention control has been central to theories of emotion regulation more generally (Ochsner et al., 2012). For instance, Engen and Anderson (2018) contend that proficient control of memory is the cognitive basis of emotion regulation. They note that many affective disorders coincide with memory difficulties, including rumination (i.e. the tendency to spontaneously elaborate on or reexperience emotional thoughts and memories) and intrusive thoughts (see Buckley et al., 2000; Pe et al., 2013; Yoon et al., 2014). Moreover, they propose several mechanisms by which this may occur. The first is direct suppression, and involves preventing unwanted negative memories from entering active memory, perhaps through cognitive inhibition (Cohen et al., 2014) or memory updating (Yoon et al., 2014). A second is thought substitution, in which alternative memories to the problematic ones are retrieved. Over time, this strengthens retrieval structures for the preferable memories, increasing the likelihood that they will be retrieved in contexts which previously elicited negative memories.

C7P63 While Engen and Anderson (2018) prefer the term 'memory control', the concepts of direct suppression and thought substitution have clear conceptual overlap with working memory, intelligence, and attention control. Rosen and Engle (1998), for instance, found evidence that high-working memory individuals were superior at suppressing unwanted items from working memory. Across two experiments, participants learned three lists of paired associates. For some participants, all three lists contained unique associates (i.e. the non-interference list). For other participants, the first and third lists were duplicates, while the second list paired words seen in the

C7T1 **Table 7.1** Examples of paired associates used by Rosen and Engle (1998)

	List 1	List 2	List 3
Non-interference			
Participant #1	dust–pan	bird–dawn	eye–glass
Participant #2	dust–pan	eye–tear	bird–dawn
Interference			
Participant #3	bird–bath	bird–dawn	bird–bath
Participant #4	eye–glass	eye–tear	eye–glass

Table reproduced from Rosen and Engle (1998).

first list with new associates (i.e. the interference lists; see Table 7.1 for example list items). This should have created competition for activation between the two associates paired with the same word. After learning the lists, participants attempted to recall the correct paired associate for a given word in a given list. The main question of interest was what effect these interference manipulations would have on list recall by participants determined to be high and low in working memory capacity.

C7P64 When participants were instructed to rapidly recall items from the interference lists, high working memory capacity participants had fewer between-list intrusion errors in the second list than did low working memory participants. That is, high working memory capacity participants did a better job of *not* recalling the word that had been paired with the test item in the *previous* list. In a second experiment where participants were asked to emphasize accuracy, high working memory individuals in the interference condition were slower to retrieve items from the third list than items from the first list. Retrieval times for low working memory individuals, meanwhile, did not differ. This pattern would be expected if high working memory individuals suppressed paired associates from the first list in order to minimize interference with the new associates in the second list. Together, these experiments suggest that high working memory capacity individuals are better at suppressing unwanted items in memory.

C7P65 Rosen and Engle's (1998) results are similar to those reported by Brewin and Beaton (2002), who employed the 'white bear' paradigm. Participants were first trained on a think-aloud protocol in which they continually verbalized their stream of consciousness. Next, participants were asked to avoid thinking about a white bear. They were asked to ring a bell any time they thought about or mentioned a white bear. Participants also completed measures of working memory capacity, fluid intelligence, and crystallized intelligence, to determine whether any of these cognitive abilities predicted success at avoiding intrusive thoughts about white bears. Working memory capacity and fluid intelligence were significant independent predictors of participants' ability to avoid thinking of a white bear, with high-ability participants having fewer intrusive thoughts. Together, these results establish a clear connection between memory suppression and cognitive ability as indexed by working memory capacity and fluid intelligence tasks.

C7P66 We have argued that controlling the contents of working memory according to current goals is the key function of attention control, and that working memory capacity tasks emphasize maintenance of immediately relevant information in working memory whereas fluid intelligence tasks place greater emphasis on disengaging from or removing no longer relevant information (Shipstead et al., 2016). In our own framework, Engen and Anderson's (2018) notion of direct suppression of accords nicely with attentional disengagement, whereas thought substitution likely incorporates aspects of attentional maintenance (e.g. allocating attention to a preferable memory/interpretation rather than a psychologically distressing one) with attention control ability important to both. Engen and Anderson (2018) also nominate direct suppression and thought substitution as conjointly undergirding *cognitive reappraisal of memories*, one of the most well-studied emotion regulation strategies, in which new, more positive/adaptive meanings, evaluations, or interpretations are retrospectively made of negative experiences. This, of course, entails that effective reappraisal is related to cognitive ability as indexed by measures of attention control, working memory capacity, and fluid intelligence. This appears substantiated (Andreotii et al., 2013; Cohen et al., 2014; Gan et al., 2017; McRae et al., 2012; Ochsner et al., 2012; Zaehringer et al., 2018). For example, Pe et al. (2013) found that participants who reported engaging in more attempts at reappraising negative memories also reported lower levels of negative affect. However, this effect only held for participants who performed well on an *n*-back task that used emotionally valenced stimuli, which was used to measure working memory updating ability. Furthermore, updating ability moderated the association between negative affect and self-reported rumination, such that habitual rumination led to less negative affect for participants high in working memory updating ability (see also Cohen et al., 2014; Joorman & Gotlib, 2008; Yoon et al., 2014).

C7P67 Better emotion regulation by way of superior attention control is unlikely to be the sole explanation for why those high in cognitive ability seem to cope better with stress and have fewer instances of psychological disorder. However, it is a promising avenue of research that warrants further study.

C7S10 Conclusion and future directions

C7P68 In this chapter, we described the relationships between individual differences in working memory capacity, attention control, fluid intelligence, and general intelligence, broadly defined. We also reviewed evidence that these cognitive abilities predict four important classes of life outcomes, including academic achievement, job performance, physical health and longevity, and psychological well-being. We attempted to mitigate some common concerns about psychological research by focusing on large, longitudinal studies where possible, and relying on smaller laboratory studies to test theoretical explanations for the relationships between cognitive ability and life outcomes. Overall, the evidence suggests an association between cognitive ability and numerous life outcomes, with high cognitive ability generally conferring benefits and low cognitive ability generally entailing greater risk.

C7P69 While researchers have made efforts to control for plausible covariates, mediating factors, and alternative explanations for the cognitive ability–life success relationship, it is fair to ask how successful these attempts have been and how much we should be persuaded by these findings. While much attention is given to adequately measuring and/or manipulating independent and predictor variables, adequate control is equally important for sound interpretations of research findings. Of particular concern to many readers, no doubt, are socioeconomic factors, and the risk of perpetuating systematic disadvantages through the use of 'cognitive ability tests'. After all, some studies report that cognitive ability tests add no incremental validity for predicting some life outcomes beyond measures of adult socioeconomic status (e.g. Wraw et al., 2015). In other cases, while cognitive ability tests technically provide incremental validity over socioeconomic metrics, it is dubious whether the indicators included by researchers adequately represent the construct 'socioeconomic status', which is typically operationally defined as familial income, educational attainment, and/or occupational status. This is a clear weakness of many of the studies we reviewed, and one that future researchers ought to keep in mind. It is notable, however, that measures of adult socioeconomic status partially or completely account for the relationships between cognitive ability and life outcomes in several of the studies we reviewed, whereas controlling for measures of childhood socioeconomic status generally leaves these association intact. This is especially noteworthy in light of evidence that higher cognitive ability may lead to greater educational attainment and job success, both of which help comprise adult socioeconomic status (cf. Deary et al., 2010; Wraw et al., 2015). This is not to say that material disadvantage has no adverse effects on cognitive ability nor that poor socioeconomic conditions are merely a by-product of low cognitive ability. Indeed, low socioeconomic status can be quite limiting (e.g. Batty et al., 2006; Hanscombe et al., 2012). It does mean, however, that even within materially disadvantaged populations, greater cognitive ability is generally associated with better life outcomes.

C7P70 We would like to close this chapter with a cautionary note for well-intentioned researchers and practitioners about applying the knowledge in this chapter, particularly as it pertains to developing interventions to increase the health and success of participants who are low in cognitive ability. We sympathize with the sentiments that motivate such attempts, but warn that, if not done carefully, interventions intended to aid those low in cognitive ability may inadvertently *increase* the disparities between them and those higher in cognitive ability, a pattern referred to as the *Matthew effect* or the 'rich get richer effect' (Ceci & Papierno, 2005). While those low in cognitive ability may benefit from interventions designed to help them, they often benefit less than their higher ability counterparts if resources are allocated equally to all groups. From one perspective, this is unproblematic. After all, in this scenario, everyone benefits, even if they do not benefit equally. From another perspective, however, this pattern can be frustrating, as interventions wind up benefitting least the very people they were designed to help (Ceci & Papierno, 2005). We make no claim as to which perspective is more correct, but believe it is a complication of which everyone interested in applying psychological theory to solve human problems should be aware.

C7P71 ## Acknowledgements

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C7S11 ## References

C7P73 Ackerman, P. L. (1988). Determinants of individual differences during skill acquisition: Cognitive abilities and information processing. *Journal of Experimental Psychology: General*, *117*(3), 288–318. https://doi.org/10.1037/0096-3445.117.3.288

C7P74 Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin*, *131*(1), 30–60. https://doi.org/10.1037/0033-2909.131.1.30

C7P75 Ahmed, S. F., Tang, S., Waters, N. E., & Davis-Kean, P. (2019). Executive function and academic achievement: Longitudinal relations from early childhood to adolescence. *Journal of Educational Psychology*, *111*(3), 446–458. https://doi.org/10.1037/edu0000296

C7P76 Andreotti, C., Thigpen, J. E., Dunn, M. J., Watson, K., Potts, J., Reising, M. M., Robinson, K. E., Rodriguez, E. M., Roubinov, D., Luecken, L., & Compas, B. E., (2013). Cognitive reappraisal and secondary control coping: Associations with working memory, positive and negative affect, and symptoms of anxiety and depression. *Anxiety, Stress & Coping*, *26*(1), 20–35. https://doi.org/10.1080/10615806.2011.631526

C7P77 ASVAB Enlistment Testing Program. (2020, 13 August). *Fairness information*. https://www.officialasvab.com/researchers/fairness-information/

C7P78 Baddeley, A. D. (1992). Working memory. *Science*, *255*(5044), 556–559. http://doi.org/10.1126/science.1736359

C7P79 Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, *63*, 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

C7P80 Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *Psychology of learning and motivation* (Vol. 8, pp. 47–89). Academic Press. https://doi.org/10.1016/S0079-7421(08)60452-1

C7P81 Batty, G. D., Der, G., Macintyre, S., & Deary, I. J. (2006). Does IQ explain socioeconomic inequalities in health? Evidence from a population based cohort study in the west of Scotland. *BMJ (Clinical Research Ed.)*, *332*(7541), 580–584. https://doi.org/10.1136/bmj.38723.660637.AE

C7P82 Batty, G. D., Mortensen, E. L., Andersen, A.-M. N., & Osler, M. (2005). Childhood intelligence in relation to adult coronary artery disease and stroke risk: Evidence from a Danish birth cohort study. *Paediatric and Perinatal Epidemiology*, *19*(6), 452–459. https://doi.org/10.1111/j.1365-3016.2005.00671.x

C7P83 Batty, G. D., Mortensen, E. L., & Osler, M. (2005). Childhood IQ in relation to later psychiatric disorder: Evidence from a Danish birth cohort study. *British Journal of Psychiatry*, *187*, 180–181. https://doi.org/10.1192/bjp.187.2.180

C7P84 Beck, D. M., Schaefer, C., Pang, K., & Carlson, S. M. (2011). Executive function in preschool children: Test–retest reliability. *Journal of Cognition and Development*, *12*(2), 169–193. https://doi.org/10.1080/15248372.2011.563485

C7P85 Binet, A., & Simon, T. (1916). New methods for the diagnosis of the intellectual level of subnormals. (*L'Année Psychologique*, 1905, pp. 191–244). In A. Binet & T. Simon, *The development of intelligence in children (The Binet-Simon Scale)* (E. S. Kite, Trans.) (pp. 37–90). Williams & Wilkins Co. https://doi.org/10.1037/11069-002

C7P86 Blankenship, T. L., Slough, M. A., Calkins, S. D., Deater-Deckard, K., Kim-Spoon, J., & Bell, M. A. (2019). Attention and executive functioning in infancy: Links to childhood executive function and reading achievement. *Developmental Science*, *22*(6), e12824. https://doi.org/10.1111/desc.12824

C7P87 Bobko, P., Roth, P. L., & Potosky, D. (1999). Derivation and implications of a meta-analytic matrix incorporating cognitive ability, alternative predictors, and job performance. *Personnel Psychology*, *52*(3), 561–589. https://doi.org/10.1111/j.1744-6570.1999.tb00172.x

C7P88 Bosco, F., Allen, D. G., & Singh, K. (2015). Executive attention: An alternative perspective on general mental ability, performance, and subgroup differences. *Personnel Psychology*, *68*(4), 859–898. https://doi.org/10.1111/peps.12099

C7P89 Breslau, N., Chen, Q., & Luo, Z. (2013). The role of intelligence in posttraumatic stress disorder: Does it vary by trauma severity? *PLoS One*, *8*(6), e65391. https://doi.org/10.1371/journal.pone.0065391

C7P90 Brewin, C. R., & Beaton, B. (2002). Thought suppression, intelligence, and working memory capacity. *Behavior Research and Therapy*, *40*(8), 923–930. https://doi.org/10.1016/S0005-7967(01)00127-9

C7P91 Brown, M. I., Wai, J., & Chabris, C. F. (2021). Can you ever be too smart for your own good? Comparing linear and nonlinear effects of cognitive ability on life outcomes. *Perspectives on Psychological Science*, *16*(6), 1337–1359. https://doi.org/10.1177/1745691620964122

C7P92 Buckley, T. C., Blanchard, E. B., & Neill, W. T., (2000). Information processing and PTSD: A review of the empirical literature. *Clinical Psychology Review*, *20*(8), 1041–1065. https://doi.org/10.1016/S0272-7358(99)00030-6

C7P93 Burgoyne, A., & Engle, R. (2020). Attention control: A cornerstone of higher-order cognition. *Current Directions in Psychological Science*, *29*(6), 624–630. https://doi.org/10.1177/0963721420969371

C7P94 Burgoyne, A. P., Mashburn, C. A., & Engle, R. W. (2021). Reducing adverse impact in high- stakes testing. *Intelligence*, *87*, 101561. https://doi.org/10.1016/j.intell.2021.101561

C7P95 Burgoyne, A. P., Mashburn, C. A., Tsukahara, J. S., & Engle, R. W. (2022). Attention control and process overlap theory: Searching for cognitive processes underpinning the positive manifold. *Intelligence*, *91*, 101629. https://doi.org/10.1016/j.intell.2022.101629

C7P96 Calvin, C. M., Deary, I. J., Fenton, C., Roberts, B. A., Der, G., Leckenby, N., & Batty, G. D. (2011). Intelligence in youth and all-cause-mortality: Systematic review with meta-analysis. *International Journal of Epidemiology*, *40*(3), 626–644. https://doi.org/10.1093/ije/dyq190

C7P97 Carlson, J. M., Dikecligil, G. N., Greenberg, T., & Mujica-Parodi, L. R. (2012). Trait reappraisal is associated with resilience to acute psychological stress. *Journal of Research in Personality*, *46*(5), 609–613. http://doi.org/10.1016/j.jrp.2012.05.003

C7P98 Cattell, R. B. (1987). *Intelligence: Its structure, growth, and action*. Elsevier Science Publishers B.V.

C7P99 Ceci, S. J., & Papierno, P. B. (2005). The rhetoric and reality of gap closing: When the 'have- nots' gain, but the 'haves' gain even more. *American Psychologist*, *60*(2), 149–160. https://doi.org/10.1037/0003-066X.60.2.149

C7P100 Center for Human Resource Research. (1989). *NLS codebook*. Ohio State University.

C7P101 Cohen, N., Daches, S., Mor, N., & Henik, A. (2014). Inhibition of negative content—A shared process in rumination and reappraisal. *Frontiers in Psychology*, *5*, 662. https://doi.org/10.3389/fpsyg.2014.00622

C7P102 Coifman, K. G., Kane, M. J., Bishop, M., Matt, L. M., Nylocks, K. M., & Aurora, P. (2021). Predicting negative affect variability and spontaneous emotion regulation: Can working memory span tasks estimate emotion regulatory capacity? *Emotion*, *21*(2), 297–314. https://doi.org/10.1037/emo0000585

C7P103 Conway, A. R., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence*, *30*(2), 163–183. https://doi.org/10.1016/S0160-2896(01)00096-4

C7P104 Conway, A. R., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences*, *7*(12), 547–552. https://doi.org/10.1016/j.tics.2003.10.005

C7P105 Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin*, *104*(2), 163–191. https://doi.org/10.1037/0033-2909.104.2.163

C7P106 Čukić, I., Brett, C. E., Calvin, C. M., Batty, G. D., & Deary, I. J. (2017). Childhood IQ and survival to 79: A follow-up of 94% of the Scottish Mental Survey 1947. *Intelligence*, *63*, 45–50. https://doi.org/10.1016/j.intell.2017.05.002

C7P107 Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Memory and Language*, *19*, 450–466. https://doi.org/10.1016/S0022-5371(80)90312-6

C7P108 Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*, *3*(4), 422–433. https://doi.org/10.3758/BF03214546

C7P109 Deary, I. J. (2014). The stability of intelligence from childhood to old age. *Current Directions in Psychological Science*, *23*(4), 239–245. https://doi.org/10.1177/0963721414536905

C7P110 Deary, I. J., Weiss, A., & Batty, G. D. (2010). Intelligence and personality as predictors of illness and death: How researchers in differential psychology and chronic disease epidemiology are collaborating to understand and address health inequalities. *Psychological Science in the Public Interest*, *11*(2), 53–79. https://doi.org/10.1177/1529100610387081

C7P111 Deary, I. J., Whalley, L. J., Lemmon, H., Crawford, J. R., & Starr, J. M. (2000). The stability of individual differences in mental ability from childhood to old age: Follow-up of the 1932 Scottish Mental Survey. *Intelligence*, *28*, 49–55. https://doi.org/10.1016/S0160-2896(99)00031-8

C7P112 Deary, I. J., Whiteman, M. C., Starr, J. M., Whalley, L. J., & Fox, H. C. (2004). The impact of childhood intelligence on later life: Following up the Scottish Mental Surveys of 1932 and 1947. *Journal of Personality and Social Psychology*, *86*(1), 130–147. https://doi.org/10.1037/0022-3514.86.1.130

C7P113 Detterman, D. K. (1991). A reply to Deary and Pagliari: Is *g* intelligence or stupidity? *Intelligence*, *15*(2), 251–255. https://doi.org/10.1016/0160-2896(91)90034-B

C7P114 Draheim, C., Mashburn, C. A., Martin, J. D., & Engle, R. W. (2019). Reaction time in differential and developmental research: A review of problems and alternatives. *Psychological Bulletin*, *145*(5), 508–535. https://doi.org/10.1037/bul0000192

C7P115 Draheim, C., Pak, R., Draheim, A. A., & Engle, R. W. (2022). The role of attention control in complex real-world tasks. *Psychonomic Bulletin & Review*, *29*(4), 1143–1197. https://doi.org/10.3758/s13423-021-02052-2

C7P116 Draheim, C., Tsukahara, J. S., Martin, J. D., Mashburn, C. A., & Engle, R. W. (2021). A toolbox approach to improving the measurement of attention control. *Journal of Experimental Psychology: General*, *150*(2), 242–275. http://doi.org/10.1037/xge0000783

C7P117 Engen, H. G., & Anderson. M. C. (2018). Memory control: A fundamental mechanism of emotion regulation. *Trends in Cognitive Sciences*, *22*(11), 982–995. https://doi.org/10.1016/j.tics.2018.07.015

C7P118 Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19–23. https://doi.org/10.1111/1467-8721.00160

C7P119 Engle, R. W. (2018). Working memory and executive attention: A revisit. *Perspectives on Psychological Science*, *13*(2), 190–193. https://doi.org/10.1177/1745691617720478

C7P120 Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *Journal of Educational Research*, *84*(5), 253–262. https://doi.org/10.1080/00220671.1991.10886025

C7P121 Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*(3), 309–331. https://doi.org/10.1037/0096-3445.128.3.309

C7P122 Ferrucci, L., Guralnik, J. M., Marchionni, N., Costanzo, S., Lamponi, M., & Baroni, A. (1993). Relationship between health status, fluid intelligence, and disability in a non demented elderly population. *Aging Clinical and Experimental Research*, *5*(6), 435–443. https://doi.org/10.1007/BF03324198

C7P123 Fortier, M. S., Vallerand, R. J., & Guay, F. (1995). Academic motivation and school performance: Toward a structural model. *Contemporary Educational Psychology*, *20*(3), 257–274. https://doi.org/10.1006/ceps.1995.1017

C7P124 Gan, S., Yang, J., Chen, X., Zhang, X., & Yang, Y. (2017). High working memory load impairs the effect of cognitive reappraisal on emotional response: Evidence from an event-related potential study. *Neuroscience Letters*, *639*, 126–131. http://doi.org/10.1016/j.neulet.2016.12.069

C7P125 Ganzer, C. A., Insel, K. C., & Ritter, L. S. (2012). Associations between working memory, health literacy, and recall of stroke symptoms among older adults. *Journal of Neuroscience Nursing*, *44*(5), 236–243. https://doi.org/10.1097/JNN.0b013e3182666231

C7P126 Garrison, K. E., & Schmeichel, B. J. (2022). Getting over it: Working memory capacity and affective responses to stressful events in daily life. *Emotion*, *22*(3), 418–429. https://doi.org/10.1037/emo0000755

C7P127 Geary D. C. (2021). Mitochondrial functioning and the relations among health, cognition, and aging: Where cell biology meets cognitive science. *International Journal of Molecular Sciences*, *22*(7), 3562. https://doi.org/10.3390/ijms22073562

C7P128 Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2–7 years old on a Stroop-like day-night test. *Cognition*, *53*(2), 129–153. https://doi.org/10.1016/0010-0277(94)90068-X

C7P129 Gladwell, M. (2008). *Outliers: The story of success*. Little, Brown and Company.

C7P130 Gottfredson, L. S., & Deary, I. J. (2004). Intelligence predicts health and longevity, but why? *Current Directions in Psychological Science*, *13*(1), 1–4. https://doi.org/10.1111/j.0963-7214.2004.01301001.x

C7P131 Guo, Z., Zou, J., He, C., Tan, X., Chen, C., & Feng, G. (2020). The importance of cognitive and mental factors on prediction of job performance in Chinese high-speed railway dispatchers. *Journal of Advanced Transportation*, *2020*, 1–13. https://doi.org/10.1155/2020/7153972

C7P132 Hambrick, D. Z., Burgoyne, A. P., & Oswald, F. L. (2019). Domain-general models of expertise: The role of cognitive ability. In P. Ward, J. Maarten Schraagen, J. Gore, & E. Roth (Eds.), *The Oxford handbook of expertise* (pp. 56–84). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198795872.013.3

C7P133 Hambrick, D. Z., & Meinz, E. J. (2011). Limits on the predictive power of domain-specific experience and knowledge in skilled performance. *Current Directions in Psychological Science*, *20*(5), 275–279. https://doi.org/10.1177/0963721411422061

C7P134 Hanscombe, K. B, Trzaskowski M., Haworth C. M. A., Davis O. S. P., Dale P. S., & Ploimin, R. (2012). Socioeconomic status (SES) and children's intelligence (IQ): In a UK-representative sample SES moderates the environmental, not genetic, effect on IQ. *PLoS One*, *7*(2), e30320. https://doi.org/10.1371/journal.pone.0030320

C7P135 Hart, C. L., Taylor, M. D., Smith, G. D., Wahlley, L. J., Starr, J. M., Hole, D. J., Wilson, V., & Deary, I. J. (2003). Childhood IQ, social class, deprivation, and their relationships with mortality and later morbidity risk in later life: Prospective observational study linking the Scottish Mental Survey 1932 and the Midspan Studies. *Psychosomatic Medicine*, *65*(5), 877–883. https://doi.org/10.1097/01.PSY.0000088584.82822.86

C7P136 Held, J. D., Carretta, T. R., & Rumsey, M. G. (2014). Evaluation of tests of perceptualspeed/accuracy and spatial ability for use in military occupational classification. *Military Psychology*, *26*(3), 199–220. https://doi.org/10.1037/mil0000043

C7P137 Heyneman, S. P., & Loxley, W. A. (1983). The effect of primary-school quality on academic achievement across twenty-nine high-and low-income countries. *American Journal of Sociology*, *88*(6), 1162–1194. https://doi.org/10.1086/227799

C7P138 Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica*, *26*(2), 107–129. https://doi.org/10.1016/0001-6918(67)90011-X.

C7P139 Hough, L. M., Oswald, F. L., & Ployhart, R. E. (2001). Determinants, detection and amelioration of adverse impact in personnel selection procedures: Issues, evidence and lessons learned. *International Journal of Selection and Assessment*, *9*(1–2), 152–194. https://doi.org/10.1111/1468-2389.00171

C7P140 Hunter, J. E. (1986). Cognitive ability, cognitive aptitudes, job knowledge, and job performance. *Journal of Vocational Behavior*, *29*(3), 340–362. https://doi.org/10.1016/0001-8791(86)90013-8

C7P141 Insel, K. C., Einstein, G. O., Morrow, D. G., Koerner, K. M., & Hepworth, J. T. (2016). A multifaceted prospective memory intervention to improve medication adherence. *Journal of the American Geriatrics Society*, *64*(3), 561–568. https://doi.org/10.1111/jgs.14032

C7P142 Insel, K. C., Morrow, D., Brewer, B., & Figueredo, A. (2006). Executive function, working memory, and medication adherence of older adults. *Journal of Gerontology: Psychological Sciences*, *61*(2), 102–107. https://doi.org/10.1093/geronb/61.2.P102

C7P143 Jensen, A. R. (1998). *The g factor: The science of mental ability*. Prager.

C7P144 Joorman, J., & Gotlib, I. H. (2008). Updating the contents of working memory in depression: Interference from irrelevant negative material. *Journal of Abnormal Psychology*, *117*(1), 182–192. https://doi.org/10.1037/0021-843X.117.1.182

C7P145 Judge, T. A., Higgins, C. A., Thoresen, C. J., & Barrick, M. R. (1999). The big five personality traits, general mental ability, and career success across the life span. *Personnel Psychology*, *52*(3), 621–652.

C7P146 Kane, M. J., Bleckley, M. K., Conway, A. R., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General*, *130*(2), 169–183. https://doi.org/10.1037/0096-3445.130.2.169

C7P147 Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review*, *9*(4), 637–671. https://doi.org/10.3758/BF03196323

C7P148 Kane, M. J., Hambrick, D. Z., & Conway, A. R. (2005). Working memory capacity and fluid intelligence are strongly related constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin*, *131*(1), 66–71. https://doi.org/10.1037/0096-3445.133.2.189

C7P149 Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology: General*, *133*(2), 189–217. https://doi.org/10.1037/0096-3445.133.2.189

C7P150 Kovacs, K., & Conway, A. R. A. (2016). Process overlap theory: A unified account of the general factor of intelligence. *Psychological Inquiry*, *27*(3), 151–177. https://doi.org/10.1080/1047840X.2016.1153946

C7P151 Kraft, M., Arts, K., Traag, T., Otten, F., & Bosma, H. (2018). The contribution of intellectual abilities to young adults' educational differences in healthcare use: A prospective cohort study. *Intelligence*, *68*, 1–5. https://doi.org/10.1016/j.intell.2018.02.002

C7P152 Krieger, F., Zimmer, H. D., Greiff, S., Spinath, F. M., & Becker, N. (2019). Why are difficult figural matrices hard to solve? The role of selective encoding and working memory capacity. *Intelligence*, 72, 35–48. https://doi.org/10.1016/j.intell.2018.11.007

C7P153 Kvist, A. V., & Gustafsson, J. E. (2008). The relation between fluid intelligence and the general factor as a function of cultural background: A test of Cattell's investment theory. *Intelligence*, *36*(5), 422–436. https://doi.org/10.1016/j.intell.2007.08.004

C7P154 Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working- memory capacity?! *Intelligence*, *14*(4), 389–433. https://doi.org/10.1016/S0160-2896(05)80012-1

C7P155 Leger, K. A., Charles, S. T., & Almeida, D. M. (2018). Let it go: Lingering negative affect in response to daily stressors is associated with physical health years later. *Psychological Science*, *29*(8), 1283–1290. https://doi.org/10.1177/0956797618763097

C7P156 Logie, R. H. (2016). Retiring the central executive. *Quarterly Journal of Experimental Psychology*, *69*(10), 2093–2109. https://doi.org/10.1080/17470218.2015.1136657

C7P157 Macklin, M. L., Metzger, L. J., Litz, B. T., McNally, R. J., Lasko, N. B., Orr, S. P., & Pitman, R. K. (1998). Lower precombat intelligence is a risk factor for post-traumatic stress disorder. *Journal of Consulting and Clinical Psychology*, *66*(2), 323–326. https://doi.org/10.1037/0022-006X.66.2.323

C7P158 Martin, J., Mashburn, C. A., & Engle, R. W. (2020). Improving the validity of the Armed Service Vocational Aptitude Battery with measures of attention control. *Journal of Applied Research in Memory and Cognition*, *9*(3) 323–335. https://doi.org/10.1016/j.jarmac.2020.04.002

C7P159 McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence*, *37*(1), 1–10. https://doi.org/10.1016/j.intell.2008.08.004

C7P160 McRae, K., Jacobs, S. E., Ray, R. D., John, O. P., & Gross, J. J. (2012). Individual differences in reappraisal ability: Links to reappraisal frequency, well-being, and cognitive control. *Journal of Research in Personality*, *46*(1), 2–7. https://doi.org/10.1016/j.jrp.2011.10.003

C7P161 McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General*, *141*(2), 302–320. https://doi.org/10.1037/a0025250

C7P162 Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin*, *142*(8), 831–864. https://doi.org/10.1037/bul0000051

C7P163 Murray, C. (1998). *Income and inequality*. AEI Press.

C7P164 Nelson, L. C. (2003). *Working memory, general intelligence, and job performance* (Publication No. 305322924) [Doctoral dissertation, University of Minnesota]. ProQuest Dissertations Publishing.

C7P165 Oberauer, K., Schulze, R., Wilhelm, O., & Süß, H. M. (2005). Working memory and intelligence—Their correlation and their relation: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin*, *131*(1), 61–65. https://doi.org/10.1037/0033-2909.131.1.61

C7P166 Ohi, K., Takai, K., Sugiyama, S., Kitagawa, H., Katoaka, Y., Soda, M., Kitaich, K., Kawasaki, Y., Ito, M., & Shiori, T. (2022). Intelligence declines across major depressive disorder, bipolar disorder, and schizophrenia. *CNS Spectrums*, *27*(4), 468–474. https://doi.org/10.1017/S1092852921000298

C7P167 Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: A synthetic review and evolving model of the cognitive control of emotion. *Annals of the New York Academy of Sciences*, *1251*(1), E1–E24. https://doi.org/10.1111/j.1749-6632.2012.06751.x

C7P168 Outtz, J. L., & Newman, D. A. (2011). A theory of adverse impact. In J. L. Outtz (Ed.), *Adverse impact: Implications for organizational staffing and high stakes selection* (pp. 53–94). Routledge.

C7P169 Patterson, F., Jepson, C., Loughead, J., Perkins, K., Strasser, A. A., Siegel, S., Frey, J., Gur, R., & Lerman, C. (2010). Working memory deficits predict short-term smoking resumption following brief abstinence. *Drug and Alcohol Dependence*, *106*, 61–64. https://doi.org/10.1016/j.drugalcdep.2009.07.020

C7P170 Pe, M. L., Raes, F., Koval, P., Brans, K., Verduyn, P., & Kuppens, P. (2013). Interference resolution moderates the impact of rumination and reappraisal on affective experiences in daily life. *Cognition & Emotion*, *27*(3), 492–501. https://doi.org/10.1080/02699931.2012.719489

C7P171 Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., Dardick, W., & Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48–76. https://doi.org/10.1037/bul0000124

C7P172 Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology*, *108*(4), 455–473. https://doi.org/10.1037/edu0000079

C7P173 Ritchie, S. J. (2015). *Intelligence: All that matters*. Teach Yourself.

C7P174 Robertson, K. F., Smeets, S, Lubinski, D., & Benbow, C. P. (2010). Beyond the threshold hypothesis: Even among the gifted and top math/science graduate students, cognitive abilities, vocational interests, and lifestyle preferences matter for career choice, performance, and persistence. *Current Directions in Psychological Science*, *19*(6), 346–351. https://doi.org/10.1177/0963721410391442

C7P175 Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence*, *35*(1), 83–92. https://doi.org/10.1016/j.intell.2006.05.004

C7P176 Rosen, V. M., & Engle, R. W. (1998). Working memory capacity and suppression. *Journal of Memory and Language*, *39*(3), 418–436. https://doi.org/10.1006/jmla.1998.2590

C7P177 Russell, E. W. (1980). Fluid and crystallized intelligence: Effects of diffuse brain damage on the WAIS. *Perceptual and Motor Skills*, *51*(1), 121–122. https://doi.org/10.2466/pms.1980.51.1.121

C7P178 Salthouse, T. A. (1991). Expertise as the circumvention of human processing limitations. In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 286–300). Cambridge University Press.

C7P179 Schmidt, F. L. (2002). The role of general cognitive ability and job performance: Why there cannot be a debate. *Human Performance*, *15*(1–2), 187–210. https://doi.org/10.1080/08959285.2002.9668091

C7P180 Schmidt, F. L., & Hunter, J. E. (1998). The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. *Psychological Bulletin*, *124*(2), 262–274. https://doi.org/10.1037/0033-2909.124.2.262

C7P181 Schmidt, F. L., Hunter, J. E., Outerbridge, A. N., & Goff, S. (1988). Joint relation of experience and ability with job performance: Test of three hypotheses. *Journal of Applied Psychology*, *73*(1), 46–57. https://doi.org/10.1037/0021-9010.73.1.46

C7P182 Shamosh, N. A., DeYoung, C. G., Green, A. E., Reis, D. L., Johnson, M. R., Conway, A. R. A., Engle, R. W., Braver, T. S., & Gray, J. R. (2008). Individual differences in delay discounting: Relation to intelligence, working memory, and anterior prefrontal cortex. *Psychological Science*, *19*(9), 904–911. https://doi.org/10.1111/j.1467-9280.2008.02175.x

C7P183 Shipstead, Z., Harrison, T. L., & Engle, R. W. (2016). Working memory capacity and fluid intelligence: Maintenance and disengagement. *Perspectives on Psychological Science*, *11*(6), 771–799. https://doi.org/10.1177/1745691616650647

C7P184 Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*(3), 417–453. https://doi.org/10.3102/00346543075003417

C7P185 Soederberg Miller, L. M., Gibson, T. N., Applegate, E. A., & de Dios, J. (2011). Mechanisms underlying comprehension of health information in adulthood: The roles of prior knowledge and working memory capacity. *Journal of Health Psychology*, *16*(5), 794–806. https://doi.org/10.1177/1359105310392090

C7P186 Spearman, C. (1904). 'General intelligence,' objectively determined and measured. *American Journal of Psychology*, *15*, 201–293. https://doi.org/10.2307/1412107

C7P187 Spiegel, J. A., Goodrich, J. M., Morris, B. M., Osborne, C. M., & Lonigan, C. J. (2021). Relations between executive functions and academic outcomes in elementary school children: A meta-analysis. *Psychological Bulletin*, *147*(4), 329–351. https://doi.org/10.1037/bul0000322

C7P188 Sternberg, R. J., & Wagner, R. K. (1993). The g-centric view of intelligence and job performance is wrong. *Current Directions in Psychological Science*, *2*, 1–4. https://doi.org/10.1111/1467-8721.ep10770441

C7P189 Stilley, C. S., Bender, C. M., Dunbar-Jacob, J., Sereika S., & Ryan, C. M. (2010). The impact of cognitive function on medication management: Three studies. *Health Psychology*, *29*(1), 50–55. https://doi.org/10.1037/a0016940

C7P190 Taylor, M. D., Hart, C. L., Davey Smith, G., Starr, J. M., Hole, D. J., Whalley, L. J., Wilson, V., & Deary, I. J. (2003). Childhood mental ability and smoking cessation in adulthood: Prospective observational study linking the Scottish Mental Survey 1932 and the Midspan studies. *Journal of Epidemiology and Community Health*, *57*(6), 464–465. http://doi.org/10.1136/jech.57.6.464

C7P191 Tolar, T. D., Lederberg, A. R., & Fletcher, J. M. (2009). A structural model of algebra achievement: Computational fluency and spatial visualisation as mediators of the effect of working memory on algebra achievement. *Educational Psychology*, *29*(2), 239–266. https://doi.org/10.1080/01443410802708903

C7P192 Tsukahara, J. S., Harrison, T. L., Draheim, C., Martin, J. D., & Engle, R. W. (2020). Attention control: The missing link between sensory discrimination and intelligence. *Attention, Perception, & Psychophysics*, *82*(7), 3445–3478. https://doi.org/10.3758/s13414-020-02044-9

C7P193 Turkheimer, E., Haley, A., Waldron, M., d'Onofrio, B., & Gottesman, I. I. (2003). Socioeconomic status modifies heritability of IQ in young children. *Psychological Science*, *14*(6), 623–628. https://doi.org/10.1046/j.0956-7976.2003.psci_1475.x

C7P194 Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language*, *28*(2), 127–154. https://doi.org/10.1016/0749-596X(89)90040-5

C7P195 Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, *37*(3), 498–505. https://doi.org/10.3758/BF03192720

C7P196 van der Maas, H. L., Dolan, C. V., Grasman, R. P., Wicherts, J. M., Huizenga, H. M., & Raijmakers, M. E. (2006). A dynamical model of general intelligence: The positive manifold of intelligence by mutualism. *Psychological Review*, *113*(4), 842–861. https://doi.org/10.1037/0033-295X.113.4.842

C7P197 Wang, J.-J., & Kaufman, A. S. (1993). Changes in fluid and crystallized intelligence across the 20- to 90-year age range on the K-Bit. *Journal of Psychoeducational Assessment*, *11*(1), 29–37. https://doi.org/10.1177/073428299301100104

C7P198 Wilk, S. L., Desmarais, L. B., & Sackett, P. R. (1995). Gravitation to jobs commensurate with ability: Longitudinal and cross-sectional tests. *Journal of Applied Psychology*, *80*(1), 79–85. https://doi.org/10.1037/0021-9010.80.1.79

C7P199 Wise, L., Welsh, J., Grafton, F., Foley, P., Earles, J., Sawin, L., & Divgi, D. R. (1992). *Sensitivity and fairness of the Armed Services Vocational Aptitude Battery (ASVAB) technical composites*. Personnel Testing Division, Defense Manpower Data Center, Department of Defense. https://www.officialasvab.com/wp-content/uploads/2019/08/AS92009_Sensitivity_Fairness_of_ASVAB_Tech_Composites.pdf

C7P200 Wraw, C., Deary, I. J., Gale, C. R., & Der, G. (2015). Intelligence in youth and health at age 50. *Intelligence*, *53*, 23–32. http://doi.org/10.1016/j.intell.2015.08.001

C7P201 Yoon, K. L., LeMoult, J., & Joorman, J. (2014). Updating emotional content in working memory: A depression-specific deficit? *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(3), 368–374. http://doi.org/10.1016/j.jbtep.2014.03.004

C7P202 Zaehringer, J., Falquez, R., Schubert, A-L., Nees, F., & Barnow, S. (2018). Neural correlates of reappraisal considering working memory capacity and cognitive flexibility. *Brain Imaging and Behavior*, *12*(6), 1529–1543. https://doi.org/10.1007/s11682-017-9788-6