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Chapter Authors: John J. McArdle, James P. Smith, Robert Willis

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Cognition and Economic Outcomes in the Health and Retirement Survey

John J. McArdle, James P. Smith, and Robert Willis

Dimensions of cognitive skills are potentially important but often neglected determinants of the central economic outcomes that shape overall well-being over the life course. There exists enormous variation among households in their rates of wealth accumulation, their holdings of financial assets, and the relative risk in their chosen asset portfolios that have proven difficult to explain by conventional demographic factors, the amount of bequests they receive or anticipating giving (Smith 1999), and the level of economic resources of the household (Smith 1995). The premium on cognitive skills in economic decision making may also be increasing, as individuals are increasingly asked to take greater control of or to adjust prior decisions relating to their household wealth, their pensions, and their health care. These may be cognitively demanding decisions at any age but especially so at older ages.

This research will examine the association of cognitive skills with wealth, wealth growth, and wealth composition for people in their pre- and post-retirement years. Our analysis will rely on selective waves of the Health and Retirement Survey (HRS), a nationally representative panel survey of Americans who are at least fifty years old. This analysis will be supplemented

John J. McArdle is senior professor of psychology at the University of Southern California. James P. Smith is a senior economist and holds the Distinguished Chair in Labor Markets and Demographic Studies at RAND Corporation. Robert Willis is professor of economics at the University of Michigan.

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by a cognitive economics survey (CogEcon) that measured several dimensions of cognition in more depth.

The HRS is well-known for its high-quality measurement of many key socioeconomic status (SES) outcomes, including income and wealth (see Juster and Smith [1997] and Juster, Smith, and Stafford [1999]). In addition, HRS includes in some waves several salient dimensions of cognitive skills. These cognition constructs start with immediate and delayed memory recall and the Telephone Interview of Cognitive Status (TICS) battery, as these have been established psychometrically to capture cognitive constructs of episodic memory and intact mental status (see McArdle, Fisher, and Kadlec 2007). Another key aspect of cognition included in recent HRS waves is numeracy, a simple summary measure of respondents' numerical ability. We also present data on two additional measures of numerical reasoning and retrieval fluency, both recently introduced into the HRS as experimental modules, to examine if these dimensions of cognition are associated with significant improvements in the ability of cognition to predict economic outcomes.

The chapter is organized into five sections. The next section presents the main conceptual components of cognition that may potentially influence economic outcomes. The following section describes the main data that we will use and the cognition variables available in the HRS. The third section highlights results that are obtained relating individual attributes, including their cognitive ability, to their total wealth, total financial wealth, and the fraction of wealth held in stock. The next section contains complementary results obtained from the cognitive economics survey (CogEcon), which has a more expansive list of cognitive variables. The final section highlights our main conclusions.

7.1 Cognition and Economics

The mechanisms responsible for cognitive development over the life course that are related to economic outcomes may be the long-term result of many individual and group factors. It is established that children exposed to very serious environmental deprivation show markedly reduced cognitive abilities (Rutter 1985), but detectable effects of normal-range environments on cognitive ability are typically smaller. This is not surprising, given the large number of environmental risk factors and the small effect expected for any particular factor, and that the genetic contributions vary as well (Harden, Turkheimer, and Loehlin 2007). Specific factors associated with lower cognitive performance include low socioeconomic status, birth complications, poor early nutrition, family conflict, and many others (Conger et al. 1994; Ramey et al. 2000).

In a classic analysis of data from the Berkeley Studies, Elder (1974) found that effects of economic deprivation on adult functioning varied with gender and birth cohort. For males in the older cohort (OGS, born 1920 to 1922), being reared in a family with low SES during the Great Depression was associated with higher resilience in adulthood compared to males reared in more favorable circumstances. In contrast, for boys in the younger cohorts (BGS and GS, born 1928 to 1930) being reared in economic adversity was associated with lower psychological functioning in adulthood. These processes applied equally well to behavior of mothers and fathers, as well as sons and daughters. Lee et al. (2003) investigated the relation of educational attainment, husband's education, household income, and childhood socioeconomic status to cognitive function and decline among community-dwelling women aged seventy to seventy-nine years. Among well-educated women, educational attainment predicted cognitive function and decline, although other measures of socioeconomic status had little relation.

Whatever the origin of adult cognitive skills, financial matters are often not straightforward for most individuals and may depend in part on their ability to invoke several dimensions of cognitive skills. One needs to be interested in economic problems and feel comfortable in understanding the choices that are available amidst a wide array of options and feel confident about the computations involved in contrasting alternative rates of return of different assets often calculated over different time dimensions (Banks and Oldfield 2007). This may involve aspects of (a) retrieving relevant prior financial information from *memory;* (b) using one's accumulated knowledge and skills (*crystallized* intelligence [Gc]); and (c) the ability to draw inferences about what is the best solution to a novel problem (*fluid* intelligence [Gf]). (For details, see Cattell [1987]; Horn and McArdle [2007]; McArdle and Woodcock [1998]).

A useful shorthand division of the principal dimensions of intelligence is to separate them into fluid intelligence (Gf) and crystallized intelligence (Gc). Fluid intelligence is the thinking part—memory, abstract reasoning, and executive function. In contrast, crystallized intelligence is the knowing part—the main accumulation of influence from education and lifetime experience (for more details, see McArdle et al. [2002]).

A parallel has been drawn between the psychological theory of fluid and crystallized intelligence and economic theories of investment in human capital. In the formulation of Willis (2007), based on the Ben-Porath human capital production function, fluid intelligence can be thought of as the ability parameter and crystallized intelligence as the accumulated stock of human capital. To be more concrete, the conceptual relationship between these aspects of cognition and human capital knowledge might be summarized as

$$Q_t = B_0(s_t K_t)^{B_1} D_t^{B_2}. \tag{1}$$

In this model a production function relates the amount of learning or increments in human capital (Q_t) to ability (B_0), investments from existing stock of human capital (K_t), and purchased market inputs (D_t). Given its emphasis on ability to think and execute, fluid intelligence (Gf) most closely corresponds to the ability parameter B_0. In this production function the crystallized intelligence (Gc) role as a surrogate for accumulated knowledge is a close parallel to the existing stock of human capital or knowledge (K_t). If we think of the output in equation (1) as increments in knowledge about financial matters, elements of cognition that mimic Gf and Gc will both affect this accumulation and affect financial outcomes. Of course, most everyday cognitive tasks have elements of both fluid and crystallized intelligence so there is not yet an established tight connection between cognitive measures and underlying parameters of the production process.

In an insightful application, Delevande, Rohwedder, and Willis (2008) consider an individual's knowledge of finance to be a component of human capital—or crystallized intelligence—that allows people to achieve a higher expected return on their assets, holding risk constant. They assume that an individual produces additional financial knowledge by combining his or her fluid intelligence or ability, crystallized intelligence, and effort according to a human capital production function (Ben Porath 1967; Cunha and Heckman 2007). The motivation to acquire financial knowledge depends on an important scale economy in this investment process. While increased knowledge raises the feasible expected return per dollar, the total value of the investment depends on the number of dollars to which the improved return is applied.

Thus, other things equal, the value of acquiring financial knowledge is higher for persons who desire higher levels of retirement wealth because of a higher lifetime income, a lower rate of time preference, or lower defined-benefit pension wealth. Similarly, investment will be greater among persons who have lower costs or greater efficiency in acquiring additional knowledge because of greater fluid intelligence or because they have more financial knowledge obtained in their formal education or on the job.

Moreover, these issues may become increasingly salient as the population ages because many aspects of these basic cognitive skills are known to begin to deteriorate from different levels and at varying rates for individuals, starting in middle age and often at even earlier ages. Figure 7.1 plots a simple summary of these age patterns, separating out life cycle paths of intelligence, as well as its fluid and crystallized intelligence components. As in other forms of human capital, crystallized intelligence is believed by cognitive psychologists to grow rapidly with age, but at a decreasing rate plateauing somewhere in the age fifty range. In contrast, elements of fluid intelligence are believed to peak relatively early in life (during adolescence) and then steadily decline with age thereafter.

Problems associated with declines in fluid intelligence with age may be compounded if older individuals are asked to take more personal control of their accounts and the financial decisions about their wealth holdings

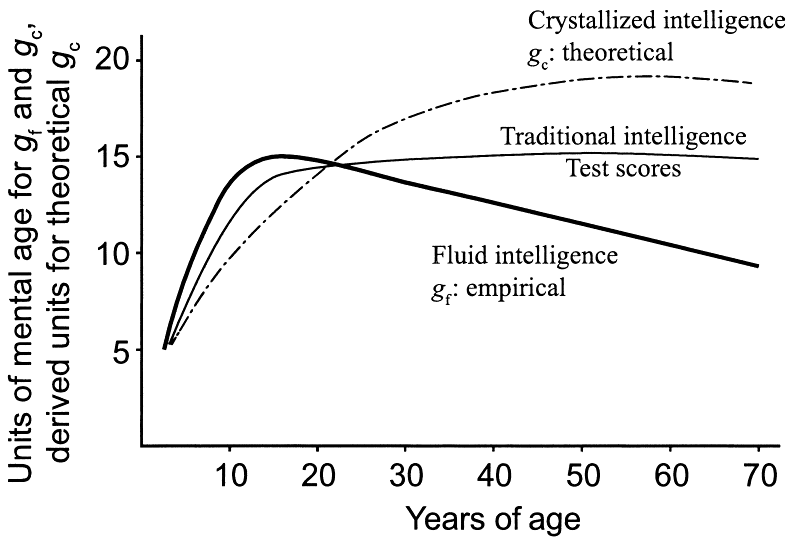

Fig. 7.1 Life cycle pattern of fluid and crystallized intelligence
Source: Cattell (1987, 206): Figure 1. A theoretical description of life span curves of intellectual abilities. (Reprinted with permission.)

and its future trajectory (Hershey et al. 2007). It is possible that the recent financial collapse may place even greater demands on the ability of individuals to make good financial decisions about their wealth holdings in order to maintain income security during their retirement years. For many of these individuals there was little reason to acquire financial knowledge beforehand and they may now be left in a situation of relatively low levels of Gc coupled with rapidly declining levels of Gf.

7.2 Data and Measures of Cognition in the Health and Retirement Survey

This research will rely on a subset of surveys from the Health and Retirement Study (HRS), a nationally representative longitudinal survey of the population of the United States who are over fifty years old. The overall objective of the HRS is to monitor economic transitions in work, income, and wealth, as well as changes in many dimensions of health status among those over fifty years old. The current version of HRS is representative of all birth cohorts born in 1947 or earlier. Follow-ups of all surveys have taken place at approximately two-year intervals.

In HRS, questions were included in each core interview on demographics, income and wealth, family structure, health, and employment. An important advantage of these surveys is that they all contain high-quality wealth modules. In HRS, a very comprehensive and detailed set of questions was asked to measure household wealth. In addition to housing equity, assets were separated into the following eleven categories: other real estate; vehicles; business equity; IRA or Keogh; stocks or mutual funds; checking, savings, or money market funds; CDs, government savings bonds, or treasury bills; other bonds; other assets; and other debt.

The subsets of HRS that we used are dictated by the types and availability of cognition measures in HRS (see Herzog and Wallace 1997; Herzog and Rodgers 1999; and Ofstedal, Fisher, and Herzog 2005). The HRS cognition variables were intended to measure episodic memory, intactness of mental status, numerical reasoning, broad numeracy, and vocabulary. More recent work indicates that measures of cognitive speed can be obtained directly from the HRS, but these measures are relatively new and not yet available for this research.

We rely on two memory measures—immediate and delayed *word recall* available in HRS in every wave in the same form since 1995. Respondents are read a list of ten simple nouns and are then asked to immediately repeat as many of these words as they can in any order. After a five-minute measurement of self-rated depression, they are then asked to recall as many of the original words as possible.[1] Following the analysis of McArdle, Fisher, and Kadlec (2007), we form an episodic memory measure as the average of immediate and delayed recalled results. *Episodic memory* may be a necessary component of reasoning (both *fluid and crystallized intelligence*).

Our second cognitive measure is the mental status questions of the Telephone Interview of Cognitive Status (TICS) battery, established to capture intactness or mental status of individuals. The TICS questions consist of the following items—serial 7 subtraction from 100 (up to five times), backwards counting (from 20 to 1), naming today's date (month, day, year), and naming the president and vice president of the United States. Answers to these questions are aggregated into a single *mental status* score that ranges from 0 to 10. The same form of mental status scores have been available since Asset and Health Dynamics Among the Oldest Old (AHEAD) 95 and HRS 96 (Herzog and Rodgers 1999).

The third cognition measure available is a *number series* test adapted from the Woodcock-Johnson (WJ-R) battery of tests for *fluid reasoning* (McArdle, Fisher, and Kadlec 2007). This test was administered in a 2004 experimental module to a random sample of over 1,200 respondents. This represented an attempt to achieve test scores from a subset of items from the *number series* test of WJ III using an adaptive testing methodology. Each respondent was asked no more than six items where the subsequent sequence of items at each point was determined by correctness of each answer. This test was administered again in a 2006 experimental module where roughly

1. In HRS 92 and 94, the original set consisted of twenty words. The same word list is not repeated in the next three subsequent rounds and husbands and wives were given a different list (see Ofstedal, Fisher, and Herzog 2005).

half of respondents who were tested in 2004 were tested again. Fifty percent of those given the test in the 2006 experimental module had not been tested previously. For each respondent, a score was created on the W-scale (logit metric) where higher scores indicate better performance. Because this numerical reasoning test has not yet been placed in the HRS core, sample size is smaller and statistical power may be fairly low. To mitigate these problems, we maximized number of observations with a score by taking an available score from either the 2004 or 2006 experimental module if available. If respondents were tested twice, scores were averaged.

The fourth measure deals with a WJ form of *retrieval fluency,* which was administered in an experimental module in HRS 2006. Respondents were given a category and asked to mention as many items as they could within a forty-five second time frame (shorter than the typical WJ format). The number of correct and incorrect answers was counted by the interviewer.

Starting with HRS 2002 and then asked in alternative waves for repeat interviews, three questions were added to the core interview to measure *numeracy* (respondents' numerical ability). These questions involve the computation of three mathematical computations and one is scored as either correct or incorrect on each of them.[2] Four scores are possible, running from zero to three depending on the number of correct answers.

Thus there are five different measures of cognition available in the HRS that we use in this analysis. While the *episodic memory, mental status,* and *numeracy* are available in multiple core waves in the same form, the other two measures are in an experimental module in a specific wave (*number series* and *retrieval fluency*). This form of availability determines the types of analysis that are possible with the full cognition measures.

A very simple schematic of the translation of these HRS cognition measures into the Gf and Gc components of intelligence is provided following. *Episodic memory* is a very general measure of an important aspect of fluid intelligence since access to memory is basic to any type of cognitive ability. Most of the HRS variation in this measure is picking out the low end—people with bad memory. Similarly, fluid reasoning, as captured by the *number series,* is perhaps our best measure of Gf for numerical ability skills most relevant for financial decision making. *Numeracy,* the actual ability to perform numerical skills mostly learned in schools, represents our preferred measure of Gc for numbers. *Retrieval fluency* is possibly another proxy for Gc since it measures our retrieval of elements of accumulated knowledge, although in this application it captures the retrieval of verbal knowledge (e.g., the number of animals one can name in forty-five seconds) and not

2. Another cognition measure is only available for the original cohort of HRS (those fifty-one to sixty-one years old in 1992) and was a onetime measure. In HRS 92, a modified version of the similarities subscale of the Wechsler Adult Intelligence Scale was revised (*WAIS-R*). This was used to access higher level abstract reasoning by comparing a list of seven pairs of words and then describing how they were alike.

financial knowledge. We will deal with the ability to retrieve financial knowledge, a broader measure of math achievement, and general intelligence when we discuss the cognitive economics survey (CogEcon) later. Finally, the TICS score contains elements of both Gf and Gc—cognitive skills needed for everything but specific to nothing. The types of questions asked are not specific to the financial domains of life.

Types of Cognition Measures Available in the Expanded HRS

- Episodic memory—*short-term memory*
- Telephone Interview of Intact Cognitive Status (TICS—Gf and Gc—needed for everything but specific to nothing
- Number series—Fluid Reasoning close to Gf for numerical ability
- Retrieval fluency—Gc—ability to retrieve long-term storage
- Numeracy—Gc for numbers or quantitative ability—Gq

Additional Measures in CogEcon

- Calculation—Gc—math achievement or general quantitative ability Gq
- Matrix reasoning—Gf—nonverbal reasoning and general intelligence
- Financial literacy—Gc—knowledge of financial matters, especially at the high end

The cognitive measures listed above are intended to indicate different aspects of the adult cognitive profile (see McArdle et al. 2002). Prior research has suggested strong normative age declines in most of these cognitive functions, but a hierarchy of cognitive strengths and weakness of any individual are indicated in many aspects of adult daily functioning. At a most basic level, the need for an intact neurocognitive system is thought to be necessary to deal with everyday issues in communication and learning in the simple judgments needed for survival (e.g., gathering food and water). At another step up in everyday complexity, the ability to remember to complete tasks, to be able to react to simple stimuli, and the ability to deal with simple numerical problems are important skills in the consideration in successfully dealing with everyday challenges (see Farias et al. 2008) Higher order aspects of cognitive skills, such as having expertise in a specific area (i.e., *crystallized intelligence*), or in reasoning in novel situations (i.e., *fluid intelligence*), will be necessary fundamentals in the ability to deal with more complex economic challenges (Hershey et al. 2007; McArdle, Fisher, and Kadlec 2007).

As pointed out by Banks and Oldfield (2007), there are several credible reasons why numeracy, a score representing knowledge about numerical problems, may be related to financial outcomes. More numerate individuals may be more adept at complex decision making, including those involved in financial decisions (Peters et al. 2006). More numerate individuals also appear to be more patient and thus are more likely to have saved and invested in the past (Parker and Fischhoff 2005) and perhaps less risk averse (Benjamin, Brown, and Shapiro 2006).[3]

The use of more abstract reasoning with numbers, as in the simple *number series* puzzles, is intended to represent a different form of cognition (i.e., fluid intelligence), and it is not clear how these abilities are useful in the accumulation of wealth). Examining results from a twenty-five-item test of financial knowledge on the Cognitive Economics Survey, Delevande, Rohwedder, and Willis (2008) find that the *number series* score has a strong and significant effect on the test score, as does educational attainment and number of economics courses the respondent has had.[4] In addition, they find that women, especially older women, have considerably lower test scores than men, probably reflecting a household division of labor about household financial decisions that was especially sharp in earlier cohorts. These ideas about the independent impact of different forms of cognition are directly examined in this research.

7.3 Individual-Level Analysis in the HRS

In this section, we report our main empirical results describing the relation of these dimensions of cognition to wealth accumulation among middle-aged and older adults. Table 7.1 lists means, medians, and standard deviations of variables that enter into the statistical analysis. Mean household wealth in this sample is about $500,000, but wealth has its well-known features of high variability and skewness as the median is just under $200,000. Similarly, total financial wealth is around $313,000 and is even more highly skewed as the median financial household wealth is only $56,000. On average, 9 percent of all financial wealth is held in stock. Mean household income is about $62,000, but income is also very unequal across these individuals (but not as much as wealth is).

Two-thirds of these individuals live as couples, 59 percent are female, and the average age is sixty-eight years old. In these birth cohorts, the typical sample member is a high school graduate. Nine percent of the sample is Latino and 16 percent are African American, reflecting oversamples of both groups in the HRS.

On average, HRS respondents remembered half of the ten words spoken to them in immediate and delayed recall with two-thirds of the sample being able to recall between three and seven words. The HRS respondents were able to correctly compute only a bit more than one answer correctly in

3. Reverse causality is possible where greater involvement in complex financial decisions improves numerical ability.

4. The Cognitive Economics Survey, designed by a team of economists led by Willis, was administered during 2008 to a national sample of 1,222 persons, age fifty-one and older (and their spouses regardless of age), who are participants in the National Change and Growth Survey, a cognition survey designed by McArdle and colleagues (2002).

Table 7.1 Means and standard deviations

Variable	Mean	Median	Standard dev.
Total household wealth[a]	498.9	198.0	1,228.83
Total financial wealth[a]	312.7	55.9	1,039.9
Percent of financial wealth in stocks	8.96	0.0	20.86
Percent couples	0.65	n.a.	0.487
Total income[a]	62.18	37.00	173.22
Female	0.589	n.a.	0.492
Hispanic	0.093	n.a.	0.290
Nonwhite	0.163	n.a.	0.369
Education	12.31	12.00	3.40
Age	68.0	68.0	11.1
Cognition variables[b]			
Number series (W-scale)	498.8	507.5	40.2
TICS mental status (0–10)	8.85	10.00	2.16
Word recall (0–10)	4.85	5.00	1.73
Numeracy	1.19	1.00	0.90
Retrieval fluency (W-scale)	496.0	499.6	12.05

Note: n.a. = not applicable.

[a]Thousands of dollars.

[b]Defined over cases asked the cognition questions.

the three question *numeracy* sequence. The experimental HRS measures of *number series* and *retrieval fluency* are both calculated as W scores (McArdle and Woodcock 1998). Each W score is artificially centered at 500 based on the ten-year-olds in the norming sample. The W scoring metric is used so that the change in the probability of getting an item right increases by 25 percent for every 10-point change in the W score. In this W score metric, the resulting average of *number series* and *retrieval fluency* are slightly below 500 and distribution in scores are approximately normal.

We estimate models for three financial outcomes at the individual level: total household wealth, total financial wealth, and the fraction of financial wealth held in stocks. These models are estimated both in level form (in 2006) in table 7.2 and as changes from a year 2000 base in table 7.3. The estimated coefficients and associated *t* statistics based on robust standard errors are also listed in these tables. Noncognition variables included in these models are standard: gender of the respondent (1 = female), race (1 = African American), Hispanic (1 = Latino), a quadratic in age, marital status (married = 1), a quadratic in household income, and years of schooling. The only nonstandard demographic variable is an indicator variable for whether the respondent was the financial respondent—the partner who was most knowledgeable about financial matters and who answered all household-level financial questions in the HRS survey.

The full set of available cognition variables is included in all models. As described before, some cognition variables such as *number series* and

Table 7.2 **Relationship of household wealth holdings to cognition 2006 individual sample—robust regression (wealth in thousands of dollars)**

	Total wealth		Total financial wealth		Percent in stock	
	Coef.	*t*	Coef.	*t*	Coef.	*t*
Female	5.04	1.39	–0.69	0.46	0.63	1.72
Hispanic	–7.44	1.21	–16.48	6.46	–1.61	2.43
Nonwhite	–60.23	12.86	–24.71	12.71	–3.36	6.68
Age	18.13	11.21	6.13	9.13	–0.59	3.47
Age squared	–0.10	9.16	–0.03	7.22	0.01	5.54
Couple	52.01	11.96	14.38	7.97	–0.16	0.36
Education	10.94	18.08	3.86	15.35	1.00	15.71
Fin. resp.	–20.74	5.02	–7.96	4.64	–1.24	3.01
Total income	2.20	109.0	0.76	90.06	0.01	5.47
Income squared	–0.000	66.63	–0.000	58.55	–1.02e–06	5.83
Cognition variables						
Number series W	0.14	1.19	0.03	0.67	0.02	1.26
TICS mental status	2.41	2.26	0.34	0.77	–0.02	0.14
Word recall	7.63	6.67	3.77	7.92	0.17	1.47
Numeracy	20.09	8.92	7.38	7.89	1.65	7.23
Retrieval fluency W	0.59	1.18	0.42	1.99	–0.07	1.33
Total wealth					0.002	15.39
Cons	–1206.59	4.62	–512.56	4.73	28.83	1.09
N	18,382		18,382		16,220	

retrieval fluency are only present in experimental modules and administered to about 1,000 respondents in each wave. Other cognition variables such as *memory recall, mental status (TICS items),* and *numeracy* were given to all HRS respondents. Missing value indicators are included in all models for people who either did not answer or who were not asked specific questions involved in the construction of the right-hand side variables. By design, the large proportion of missing values for the *number series* and *retrieval fluency* measures in the experimental modules are missing at random.

Results obtained in the 2006 level analysis for noncognitive variables, presented in table 7.2, are consistent with those widely reported in the literature (Smith 1995). Wealth levels, both total and financial, are higher for couples than for single-person households, are lower for minorities, increase at a decreasing rate with age, rise steeply with education and with family income, but with the latter at a decreasing rate. Individuals with higher education, income, and wealth hold more of their financial wealth in stock while minorities hold less in this more risky asset even at the same age, income, and wealth.

Our main interest in this chapter centers on estimated impacts of cognitive variables. The strongest and most consistent results obtained were for the *numeracy* and *memory recall* cognition measures. Answering each

Table 7.3 Relationship of change in household wealth holdings (2000–2006) to cognition 2006 individual sample—robust regression (wealth in thousands of dollars)

	Total wealth		Total financial wealth		Percent in stock	
	Coef.	*t*	Coef.	*t*	Coef.	*t*
Female	–5.80	1.93	–2.09	1.45	0.27	0.52
Hispanic	24.67	4.62	–5.02	1.96	1.57	1.53
Nonwhite	–3.26	0.83	–10.34	5.47	0.32	0.42
Age	3.74	2.34	2.44	3.21	–0.32	1.10
Age squared	–0.27	2.34	–0.17	3.00	0.00	1.15
Couple	20.75	25.16	8.78	5.03	–1.04	1.63
Education	3.10	6.24	1.34	1.59	–0.65	0.72
Fin. resp.	–7.21	2.12	–4.28	2.62	–0.12	0.20
Total income	0.72	25.16	0.15	10.87	–0.01	2.39
Income squared	–0.00	9.96	0.00	53.62	–6.48e–06	1.61
Cognition variables						
Number series W	0.16	0.17	–0.02	0.44	–0.02	0.89
TICS mental status	–0.68	0.74	–1.19	2.69	–0.00	0.02
Word recall	4.84	5.17	3.05	6.80	–0.41	0.25
Numeracy	8.26	4.46	6.05	6.80	0.49	1.55
Retrieval fluency W	0.21	0.52	0.49	2.48	–0.05	0.79
Total wealth—2000	–0.24	147.2	n.a.		–0.00	1.65
Total fin. wealth—2000	n.a.		–0.53	558.51		
Cons	–275.93	4.62	–326.63	3.17	28.83	1.09
N	14,270		14,270		12,058	

Note: n.a. = not applicable.

question correctly in the three question numeracy sequence is associated with a $20,000 increase in total household wealth and about a $7,000 increase in total financial wealth. Enhanced *numeracy* is also associated with a larger fraction on the financial portfolio held in stocks. All these results are strongly statistically significant.

Similarly, improved *episodic memory* is associated with higher levels of household and financial wealth but not with how risky (stock intensive) the financial asset portfolio is. While it is difficult to compare units across cognitive measures, these results imply that remembering three additional words in the *word recall* is associated with total household wealth equivalent to answering one additional question correctly in the *numeracy* sequence. Our three other cognitive measures—*number series, TICS mental status,* and *retrieval fluency*—are not consistently related to these financial outcomes. Part of the lack of statistical significance for *number series* and *retrieval fluency* may well be due to the lower effective sample size for those measures.

The extreme degree of heterogeneity and right skewness in financial outcomes implies that estimated mean effects may not characterize many individuals in the sample. With that caution in mind, table 7.4 (for total

Table 7.4 **Relationship of total household wealth holdings to cognition 2006 individual sample—quantile models (wealth in thousands of dollars)**

	25th quantile		Median		75th quantile		90th quantile	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Female	6.130	2.65	6.794	1.79	12.043	1.52	14.393	0.92
Hispanic	–2.244	0.56	–3.970	0.62	5.199	0.40	–40.208	1.66
Nonwhite	–23.415	7.62	–50.352	10.25	–92.724	9.37	–182.266	9.81
Age	13.050	13.53	20.016	11.81	30.426	7.88	32.186	4.08
Age squared	–0.075	11.11	–0.113	9.54	–0.171	6.40	–0.173	3.18
Married	31.281	11.16	44.719	9.81	40.073	4.19	59.891	3.17
Education	4.530	12.30	9.621	15.15	16.019	11.22	23.883	8.00
Financial respondent	–10.263	3.87	–22.722	5.24	–41.095	4.57	–58.543	3.30
Income	1.914	127.99	3.542	167.89	7.107	160.26	12.093	148.76
Income squared	–0.000	87.63	–0.000	127.14	–0.000	140.75	–0.001	136.52
Number Series W	0.093	1.27	0.211	1.70	0.233	0.89	0.453	0.82
TICS mental status	0.497	0.75	0.686	0.61	0.475	0.19	4.614	0.93
Word recall	4.758	6.64	5.956	4.96	8.243	3.21	6.892	1.36
Numeracy	12.078	8.49	27.235	11.52	48.547	9.62	76.988	7.72
Retrieval fluency W	0.571	1.84	0.572	1.09	2.541	2.23	1.935	0.89
Cons	–951.354	5.90	–1319.679	4.83	–2720.457	4.55	–2613.225	2.28
N	18,382		18,382		18,382		18,382	

household wealth) and table 7.6 (for total financial wealth) lists estimates from quantile regressions, estimated for the first and third quartile, the median and the ninetieth percentile. As expected, estimated effects of most of the noncognitive variables increase as we move up toward higher quantiles in the total wealth and nonfinancial wealth distribution.

Numeracy, the key cognitive variable identified in table 7.2, behaves precisely this way—estimated impacts of numeracy increase as we move up the total wealth quantiles, from an estimated impact of $2.6K at the first quartile, to almost $12K for the median household, and $52K at the ninetieth percentile. A similar pattern is found in table 7.6 when the outcome is total financial wealth. The other key variable, *episodic memory,* does the same but at a far less dramatic rate. Especially for total financial wealth, the estimated impacts of *episodic memory* are fairly uniform across these percentiles. Compared to *Numeracy, episodic memory* may be relatively more important at lower values in the wealth distribution.

The results summarized thus far pertain to wealth levels and composition in calendar year 2006. The panel nature of HRS allows us to examine the association of these cognition measures with changes in wealth observed for individuals in the panel. Tables 7.3, 7.5, and 7.7 list results obtained from models where the outcome is the change between years 2006 and 2000 in total wealth, total financial wealth, and the fraction of financial wealth held as stocks. All right-hand side variables are the same as in the level analysis, but a control is added for year 2000 total household wealth or financial wealth depending upon the financial outcome under investigation.

Not surprisingly, estimated effects of all noncognitive variables are similar to those obtained from the 2006 level analysis but are much smaller in magnitude since now we are predicting changes between the 2006 and 2000 HRS waves. In particular, numeracy and word recall are consistently related to wealth increases over this six-year period, while the estimated impacts of the other cognitive variables are quite weak. Answering each numeracy question correctly is associated with an $8,000 increase in total household wealth.

7.4 Individual-Level Analysis in CogEcon

The data used in this section are the result of collaboration between the National Growth and Change Study (NGCS)+HRS Cognition Study and the Cognitive Economics Survey (CogEcon).[5] A goal of NGCS+HRS is to conduct detailed measurement, through telephone and personal interviewing, of cognitive abilities of a sample of older Americans in the same fifty-plus age range of the HRS by developing data to help understand the

5. The NCGS+HRS was led by McArdle and CogEcon was led by Willis. The design, contents, and field outcomes of CogEcon and NCGS+HRS surveys are described in detail in Fisher and Helppie (2009).

Table 7.5 **Relationship of changes in total household wealth holdings (2000–2006) to cognition 2006 individual sample—quantile models (wealth in thousands of dollars)**

	25th quantile		Median		75th quantile		90th quantile	
	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*
Female	0.183	0.09	–1.247	0.59	–2.272	0.60	–4.452	0.54
Hispanic	3.803	1.01	13.139	3.49	21.113	3.09	66.162	4.50
Nonwhite	–4.677	1.66	–0.840	0.30	2.445	0.49	7.984	0.75
Age	6.472	6.05	3.763	3.38	–1.466	0.72	–7.326	1.60
Age squared	–0.046	5.86	–0.025	3.06	0.010	0.71	–0.057	1.72
Married	17.408	6.67	7.999	3.12	11.760	2.56	29.766	2.97
Education	1.210	3.57	1.216	3.47	2.466	3.70	6.974	4.54
Financial respondent	–4.9940	2.07	–5.494	2.29	–2.105	0.49	–3.660	0.38
Income	0.881	43.44	1.515	76.45	2.394	69.93	3.404	45.14
Income squared	–0.000	14.76	–0.001	28.93	–0.001	32.14	–0.002	27.38
Number series W	0.024	0.37	–0.000	0.01	–0.050	0.42	0.102	0.40
TICS mental status	–0.905	1.43	–0.901	1.39	–1.370	1.19	–5.912	2.36
Word recall	3.257	4.99	3.221	4.88	2.218	1.86	2.149	0.84
Numeracy	7.968	6.15	8.770	6.71	12.939	5.41	24.624	4.71
Retrieval fluency W	0.342	1.29	0.281	0.98	1.020	1.87	3.352	2.69
Wealth 2000	–0.573	414.48	–0.285	301.56	0.031	23.24	0.401	139.79
Cons	–439.476	3.14	–302.051	2.00	–450.567	1.58	–1447.415	2.23
N	14,272		14,272		14,272		14,272	

Table 7.6 **Relationship of total financial wealth holdings to cognition 2006 individual sample—quantile models (wealth in thousands of dollars)**

	25th quantile		Median		75th quantile		90th quantile	
	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef	*t*
Female	0.894	1.27	2.208	1.28	4.510	1.02	5.737	0.57
Hispanic	–3.196	2.58	–6.898	2.35	–18.900	2.67	–47.886	3.14
Nonwhite	–7.863	8.39	–19.616	8.76	–53.412	9.86	–114.563	9.65
Age	4.422	15.15	8.884	11.48	14.514	6.88	19.143	3.85
Age squared	–0.026	12.88	–0.051	9.43	–0.081	5.58	–0.099	2.87
Married	–0.213	0.25	0.508	0.24	–0.566	0.11	6.725	0.55
Education	0.739	6.48	2.762	9.54	5.803	7.45	13.375	7.05
Financial respondent	–2.649	3.28	–7.915	4.00	–18.973	3.82	–39.262	3.44
Income	0.825	207.93	2.234	232.18	5.432	217.38	9.898	173.15
Income squared	–0.000	160.79	–0.000	195.68	–0.000	202.25	–0.001	165.84
Number series W	0.005	0.21	0.102	1.81	0.222	1.50	0.173	0.50
TICS mental status	–0.179	0.89	–0.668	1.31	–0.127	0.09	0.015	0.00
Word recall	0.906	4.15	2.069	3.78	1.399	0.99	2.350	0.73
Numeracy	2.605	6.00	11.847	10.99	27.192	9.78	52.309	8.13
Retrieval fluency W	0.179	1.95	0.696	2.91	1.630	2.60	2.356	1.63
Cons	–285.730	5.95	–798.977	6.41	–1558.952	4.76	–2105.232	2.77
N	18,382		18,382		18,382		18,382	

Table 7.7 **Relationship of changes (2000–2006) in total financial wealth holdings to cognition 2006 individual sample—quantile models (wealth in thousands of dollars)**

	25th quantile		Median		75th quantile		90th quantile	
	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*
Female	–0.186	0.307	0.525	0.66	–0.810	0.64	2.887	0.55
Hispanic	0.348	0.31	0.678	0.485	1.972	0.89	1.092	0.12
Nonwhite	–4.119	4.99	–2.935	2.81	–2.652	1.64	–14.561	2.29
Age	1.361	4.29	1.343	3.20	0.200	0.30	–3.735	1.37
Age squared	–0.010	4.26	–0.009	3.00	–0.001	0.24	0.033	1.65
Married	1.484	1.95	0.151	0.16	–1.023	0.68	14.807	2.39
Education	0.214	2.13	0.281	2.14	0.738	3.42	3.354	3.55
Financial respondent	–0.835	1.19	–0.851	0.94	–2.094	1.46	–2.229	0.38
Income	0.249	38.60	0.652	87.16	1.459	126.89	2.771	59.78
Income squared	0.000	17.81	–0.000	23.76	–0.000	18.28	–0.001	30.78
Number series W	0.007	0.35	0.030	1.18	–0.014	0.35	0.105	0.62
TICS mental status	–0.531	2.87	–0.977	4.01	–1.078	2.85	–2.018	1.30
Word recall	0.741	3.88	0.755	3.04	0.446	1.13	0.610	0.37
Numeracy	1.743	4.60	2.879	5.85	4.484	5.71	10.426	3.16
Retrieval fluency W	0.162	2.08	0.226	2.09	0.841	4.66	2.243	2.98
Financial wealth-2000	–0.708	1530.60	–0.385	867.41	–0.040	67.39	0.359	142.31
Cons	–134.091	3.25	–176.743	3.12	–419.487	4.47	–1046.97	2.67
N	14,272		14,272		14,272		14,272	

cognitive bases of economic decision making. To do so, a detailed questionnaire containing measures of wealth and portfolio allocation, self-rated and objective measures of financial knowledge, measures of risk tolerance, use of financial advice, and other variables were administered by mail and Internet survey to participants in the NGCS+HRS.

The combined NGCS+HRS/CogEcon data set provides a combination of psychological and economic measurements on the same people with greater detail than any other data set. The CogEcon survey invited 1,222 individual members of the NGCS+HRS sample whose cognitive ability were assessed in face-to-face interviews to participate in the CogEcon mail/Internet survey. Of these, 985 returned surveys, implying a final response rate of 80.6 percent, including age-ineligible spouses. The CogEcon sample consists of individuals who range in age from thirty-eight to ninety-six years, with a mean age of 64.0 years.

The telephone component of NGCS+HRS repeats HRS cognition measures (episodic memory, mental status, numeracy, and adaptive number series measure) used before. The personal interview is an intensive three-hour cognitive measurement of a large number of ability components. These include number series, retrieval fluency, verbal analogies, spatial relations, picture vocabulary, auditory working memory, visual matching, incomplete words, concept formation, calculation, word attack from WJ III (Woodcock, McGrew, and Mather 2001); vocabulary, block design, similarities, and matrix reasoning from the *Wechsler Adult Intelligence Scale* (WAIS) (plus a switching task), and a vigilance task (McArdle and Woodcock 1998).

There are advantages and disadvantages of the CogEcon survey. The principal disadvantage is that sample sizes are much lower than in the core HRS, and with outcomes as heterogeneous as wealth, which may lead to results that are less robust. The principal advantage is that CogEcon is able to measure in far greater depth dimensions of cognition than may be relevant to economic decision making, including wealth accumulation. We view the HRS and CogEcon as complementary sources of relevant information.

Tables 7.8 and 7.9 present results for three regression prediction models of ln current wealth based on data from the CogEcon survey (n = 942). In all models, the same demographics as in the core HRS analysis—age (quadratic), education, couple status, and income (quadratic)—are included. These results uniformly show significant positive differences in wealth for persons with increased income (up to a point; $t > 8$), and for persons in intact couples, but no statistically significant independent increments based on age or education. Education does increase wealth in models where we delete all cognition variables.

In the first model in table 7.8, these predictions are estimated in tandem with five cognitive variables derived from the telephone testing alone, which also correspond to cognition variables available in the core HRS. In these data, the five cognitive variables improved the prediction with significant

Table 7.8 Total wealth model in the CogEcon sample

	Coef.	*t*	Coef.	*t*	Coef.	*t*
		A. Log wealth				
Age	.052	0.45	.047	0.41	.062	0.50
Age squared	.000	0.22	.000	0.31	.000	0.22
Couple	.979	4.14	.949	4.01	.758	3.07
Education	.053	1.02	.017	0.32	–.083	1.41
Income	.000	8.43	.000	8.26	.000	7.78
Income squared	–1.93e–11	7.32	–1.87e–11	7.08	–1.80e–11	6.82
Cognition variables						
Telephone number series W	.004	1.02				
Face-to-face num series			.019	3.00	–.007	0.81
Episodic memory	.017	2.49	.017	2.53	.012	1.59
TICS mental status	.023	2.00	.018	1.48	.008	0.59
Numeracy	.315	2.20	.199	1.34	.207	1.33
Retrieval fluency	–.037	1.46	–.036	1.44	–.036	1.36
Calculation					.015	1.62
Matrix reasoning					.082	3.43
Mean financial literacy score					.280	2.83
Cons	17.980	1.40	10.860	0.82	14.399	0.98

Table 7.9 Predicting financial literacy

	Coef.	*t*
Age	.1067	2.32
Age squared	–.0007	2.05
Couple	.1493	1.64
Education	.0640	2.98
Income[a]	.0033	3.78
Income squared[a]	–0.330e–07	3.42
Cognition variables		
Face-to-face num series	.0082	2.72
Episodic memory	.0048	1.75
TICS mental status	.0024	0.51
Numeracy	.1318	2.31
Retrieval fluency	.0058	0.59
Calculation	.0065	1.91
Matrix reasoning	.0067	0.77
Cons	–8.048	1.49

[a]Income measured in thousands of dollars.

positive independent contributions of episodic memory ($t > 2$), numeracy ($t > 2$), and mental status ($t > 2$), but neither retrieval fluency nor number series. These results parallel reasonably well those found for the same set of cognitive constructs using the HRS in table 7.2.

The *Number Series WJ-III test* (WJ III) used to measure numerical reasoning was administered in two different forms. The face-to-face test is the standard WJ III forty-seven item version presented using standard WJ rules, with an expected internal consistency reliability of $r_{ic} > .95$ (Woodcock, McGrew, and Mather 2003). The telephone version is a much shorter adaptive form of the same test, where up to six items are presented in three to five minutes (McArdle 2008). The items chosen are selected based on prior performances on earlier items (i.e., harder items are selected if the participant has given correct answers earlier), with an expected internal consistency reliability of $r_{ic} > .85$. In the CogEcon study (NGCS+HRS) the participants were administered the telephone test first and then administered the face-to-face test in standard testing conditions from one to fourteen days later. After taking into account some expected differences due to time-lags, the average test-retest correlation was $r_{tr} > 0.72$ (McArdle et al. 2009).

The second model in table 7.8 substitutes the longer (and more reliable) face-to-face number series test for the telephone version used in the first model. The face-to-face version of the number series score now offers a strong incremental prediction ($t > 3$), and reduces—but does not eliminate—the estimated effects of *numeracy* and *episodic memory.*

In the third model of table 7.8 three new cognitive tests are added—calculation, matrix reasoning, and mean financial literacy score. These tests are not currently available in the HRS. *WJ-III Calculation* is a test of math achievement measuring the ability to perform mathematical computations from Woodcock-Johnson Scales (Woodcock, McGrew, and Mather 2003) with an expected internal consistency reliability of $r_{ic} > .95$. Initial items in calculation require an individual to write single numbers. The remaining items require a person to perform addition, subtraction, multiplication, division, and combinations of these basic operations, as well as some geometric, trigonometric, logarithmic, and calculus operations. The calculations involve negative numbers, percents, decimals, fractions, and whole numbers. Because calculations are presented in a traditional problem format in the test record form, the person is not required to make any decisions about what operations to use or what data to include. *Calculation* is similar to *numeracy* in intent in that they both attempt to measure aspects of Gc applied to numbers.

WASI Matrix Reasoning measures nonverbal fluid reasoning and general intellectual ability from the abbreviated form of the Weschler Adult Intelligence Scale (WAIS III, Wechsler 1997). These twenty items require participants to look at each set of symbols (arrayed in a vector or matrix) with one missing location, and then they are asked to fill in "the best option for the missing piece." The person is not asked or required to make any decisions about reasons why this choice is best. Given its use of abstract and spatial symbols, *matrix reasoning* can be thought of as a dimension of Gf.

CogEcon Financial Literacy/Financial Sophistication are twenty-four items (true/false and confidence). These measures signify the belief that these questions have more sensitivity at the "high" end of the scale (when compared to measures in HRS and many other surveys). These questions have two versions each, one which is "true" and one which is "false," but ask a very similar question. True/false measures of financial sophistication are on a scale ranging from 100 percent to 50 percent confidence that the statement is "false," and 50 percent to 100 percent confidence that the statement is "true." For example, the "true" version (Q17) is: "An investment advisor tells a 30-year-old couple that $1,000 in an investment that pays a certain, constant interest rate would double in value to $2,000 after 20 years. If so, that investment *would* be worth $4,000 *in less than* 45 years." The "false" version reads: "An investment advisor tells a 30-year-old couple that $1,000 in an investment that pays a certain, constant interest rate would double in value to $2,000 after 20 years. If so, that investment *would not* be worth $4,000 *for at least* 45 years." The italics are added to indicate parts of questions that differ. The respondent is instructed to decide whether the statement is "true" or "false," and to indicate their confidence in this answer.

In the third model in table 7.8, when these additional cognitive tests are added as predictions, matrix reasoning is the strongest independent predictor ($t > 3$), and financial literacy is next ($t > 2$), but the calculation test is not a statistically significant predictor. All statements about tests of significance must contain the caveat of relatively small sample sizes in CogEcon.

Including measures of financial literacy in models of wealth accumulation is a bit odd. Financial literacy is not manna from heaven enabling one to successfully navigate the complicated and dangerous waters of financial success. Those with more of an interest or opportunity to invest in financial markets have more of an incentive to invest in acquiring the knowledge of how to successfully operate in these markets or to become financially literate. This view argues that models in table 7.8 have it all wrong and that financial literacy is an outcome that should be studied. Table 7.9 does just that by predicting levels of financial literacy with the same set of personal attributes and set of cognitive variables discussed earlier.

Financial literacy increases with age and with income, but at a decreasing rate, and increases with years of schooling. All these predictive effects are statistically significant. Once again, intact mental status (the TICS score) and retrieval fluency appear to be aspects of cognition that are not related to financial decision making. In contrast, all aspects of cognition related to numerical ability—number series, numeracy, and calculation—are all strongly predictive of better financial literacy. These results point to one possible pathway through which cognitive ability related to numbers may promote wealth accumulation, making it easier to acquire relevant financial knowledge. It also suggests that we may be overcontrolling by including financial literacy in the models in table 7.8, as this may suppress the effects of cognition. The final model in table 7.8 removes the financial literacy variable. Estimated effects of both the number series and calculation are increased by its removal.

These new results broadly highlight the fact that the individual cognition tests can add to the individual-level descriptive predictions of our basic understanding of differences in wealth. There appear to be independent benefits of having both higher financial literacy (i.e., Gc) and higher ability to reason in a nonquantitative fashion (i.e., Gf).

7.5 Conclusions

Inclusion of individual cognitive measures in prediction of economic outcomes has turned out to be useful. While the importance and the pattern of effects needs to consider the specific sources of information (i.e., the entire HRS, individual modules, or CogEcon), these cognitive measures appear to meet minimal standards of being descriptively informative.

Numeracy, as measured by answers to three simple mathematical questions, is by far the most predictive of wealth among all cognitive variables in the HRS sample. This is thought by cognitive psychologists to be a direct measure of a specific and practical form of numerical knowledge (i.e., a form of *crystallized intelligence*). We found independent impacts that were statistically significant for all three financial outcomes. *Numeracy* had more of a problem maintaining statistical significance in the CogEcon sample when tested against other more complex and time intensive measures (*number series* and *calculation*) that in part attempt to measure similar things. Still, one has to be impressed with the ability of the three simple questions in the numeracy sequence to capture the core elements in predicting wealth accumulation.

The independent impact of *number series* has similar characteristics in its relationship to the financial outcomes, but these relationships are not as important with the strong qualification that there currently exists more limited data on this measure in the HRS. The number series is not simply a measure of numerical knowledge, but is a broader measure of numerical reasoning (i.e., an indicator of *fluid intelligence*), and this is not a pure indicator of the acquisition of wealth. The more complicated and time intensive measurement of number series in the face-to-face component of the CogEcon sample does considerably better in predicting wealth.

Episodic memory (or *word recall*) also appears to be related to the total and financial wealth holdings of the family. The remaining two cognitive measures—*mental status* and *retrieval fluency*—have very weak and erratic relationships with these financial outcomes. *Mental status* is statistically significant in only two of six cases and *retrieval fluency* in only one of six cases.[6]

Although these specific cognitive measures were useful in predictions of

6. Remember that retrieval fluency is only available in an experimental module in the 2006 wave, so that statistical significance is a more difficult hurdle for this variable.

measures of accumulated wealth, it is certainly possible that other financial outcomes will be better predicted by different indicators of cognitive functions. Additional analyses of HRS data and other data can be conducted using this basic approach, including cognitive speed measures, and all available cognitive measures for different outcomes.

The type of unabashedly exploratory and descriptive analysis in this chapter cannot establish causal pathways for these associations. There is no randomization in the cognitive ability of HRS respondents and one can easily think of correlates of these cognitive measures that may offer plausible reasons for these associations. Nor can it be easily dismissed that a history of lifetime interests and investments in the stock market, for example, could lead to improved numerical ability. Yet, the presence of these estimated effects of numeracy on total and financial wealth at lower wealth quartiles where levels of commitment of investors is relatively modest should caution at least against a purely reverse pathway from investments to cognitive ability. For some cognitive functions, such as numerical ability, the cognitive training of these skills seem to be readily attainable by most persons, and the returns seem high. At a minimum, the type of strong associations in descriptive analysis in this chapter is a signal that one may want to pursue studies that may offer more discriminating tests of whether these associations can be thought of as plausibly causal.

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Comment Finis Welch

I should begin by saying to Mr. McArdle that while I do not know you, I know your coauthors. Someone should have warned you!

Actually this chapter follows a series of papers by Jim Smith that concentrate on wealth. I believe he has done more in this area than any other, especially in studying inequality and in validating the sequential series of questions HRS uses to elicit responses and in comparing the wealth levels in HRS to those of other sources. When Jim talks about wealth (aside from his own) we all listen. When he talks about his own, you should listen, but should not believe.[1] The chapter's innovation is the addition of the cognitive measures as they relate to the levels of wealth in HRS. To someone as old as I am, that is a scary issue. When I saw the title I expected the chapter to begin with a profile of cognitive measures across age that showed physical skills are not the only things that recede with age.

In fact, my main criticism of the chapter is that there are too few descriptive tables. I would love to have seen an age profile of wealth levels as well as one for the 2000 to 2006 changes that, along with 2006 levels of wealth, are analyzed in the chapter. Although I assume that there is a substantial literature on spending down, nothing would be lost if it were addressed here. We understand that the cross-sectional age profiles confuse age and cohort, but we ought to see what we are to be confused about. More important, it would be very nice to see the age profiles of test scores. In this case there would be no confusion between age and cohort.

If scores for older respondents are lower, it is cohort. If scores are higher

Finis Welch is president of Welch Consulting, distinguished professor emeritus of economics at Texas A&M University, and professor emeritus of economics at the University of California, Los Angeles.

1. I have known Jim for almost forty years. If he says "up" it is probably "down."