Intelligence 37 (2009) 600–606

Contents lists available at ScienceDirect

Intelligence

Level of cognitive performance as a correlate and predictor of health behaviors that protect against cognitive decline in late life: The path through life study

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ARTICLE INFO

Article history:
Received 23 June 2008
Received in revised form 26 August 2008
Accepted 4 October 2008
Available online 5 November 2008

Keywords:
Physical activity
Smoking
Complementary medicine
Cognitive decline
Epidemiology
Antihypertensives
Cholesterol

ABSTRACT

There is a lack of information on how cognitive ability relates to both health behaviors and change in health behaviors over time. This study examined verbal ability and processing speed as predictors of health behaviors in the PATH Through Life Study that includes cohorts aged in their 20s, 40s and 60s. Higher cognitive scores were associated with higher levels of physical activity, greater likelihood of taking vitamin and mineral supplements, reduced likelihood of current smoking and not abstaining from alcohol. However, lower level of verbal ability and processing speed were associated with higher levels of use of cholesterol lowering medication in the 60s cohort. Physical activity, consumption of vitamins and minerals and taking cholesterol lowering and antihypertensive medication over the four-year follow-up period increased in this cohort. The likelihood of adopting healthier behaviors was greatest for those with the lowest cognitive scores. We conclude that while higher levels of cognitive performance are associated with health promoting behaviors, improvements in health behavior are more likely to be due to non-cognitive, contextual and societal factors.

The association between several modifiable health behaviors and risk of cognitive decline and dementia has been established through recent meta-analyses and systematic reviews. For example, smoking has been associated with increased dementia risk in older adults (Anstey, von Sanden, Salim, & O'Kearney, 2007); physical activity has been associated with reduced cognitive decline (Kramer, Erickson, & Colcombe, 2006); and low levels of alcohol consumption appear to protect against cognitive decline (Peters, Peters, Warner, Beckett, & Bulpitt, 2008).

There are risk factors for cognitive decline and dementia that are modifiable by medication. Examples of these risk factors include hypertension and hypercholesteremia, both of which have been shown to increase the risk of cognitive decline and dementia when they are present in mid-life (Anstey, Lipnicki, & Low, 2008; Qiu, Winblad, & Fratiglioni, 2005). These conditions are usually treated for the prevention of cardiovascular disease. The taking of medications to prevent such conditions is a health behavior that ultimately may contribute to brain health and prevention of later cognitive decline.

There may be health behaviors that are precautionary or aimed at preventing disease, such as taking vitamin and mineral supplements. It is unknown whether any such supplements prevent cognitive decline or dementia (Ancelin, Christen, & Ritchie, 2007) and recent reviews have shown that they do not promote longevity (Bengmark, 2006).

In addition to cognitive impairment and decline being important outcomes in epidemiological research, cognition may also influence the extent to which individuals manage their own risk for cognitive decline. Therefore, the relationship between risk factors and cognition may be more complex than between risk factors and other medical outcomes.

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doi:10.1016/j.intell.2008.10.001

Instead of a unidirectional direct or indirect effect between exposure and cognitive decline, there may be an interactive cycle involving cognition, self-management of health, and ultimate cognitive outcomes. We have argued previously that the association between cognition and mortality may be in part explained by the tendency for better health behavior and chronic disease management to occur in groups with higher levels of education and better cognitive performance (Anstey, Mack, & von Sanden, 2006). However, there has been little empirical evidence on which to base this view.

One of the few studies to examine cognition as a predictor of health behavior showed that smoking cessation reported in mid-life was associated with higher IQ at age 11 (Taylor et al., 2003). However, we are not aware of any study that has examined cognitive function as a predictor of change in other health behaviors such as taking vitamins or prescription medication for cardiovascular risk factors, or for engaging in physical activity. It is also unknown whether cognitive ability has a greater effect on health behavior at different stages of the life-course.

Use of prescription medication differs from health behaviors that occur as part of lifestyle such as physical activity and smoking. This adaptive behavior depends on the individual having been prescribed medication by their physician, and hence is the outcome of a series of events whereby the individual must either seek medical attention or experience a medical event, obtain a diagnosis and then follow this up by taking prescribed medication. Since higher levels of education and cognitive ability are associated with better health, and are also expected to be associated with higher levels of help seeking and diagnosis, it is difficult to predict which direction the net effect of cognition on medication use (for high cholesterol and blood pressure) will take.

The present study investigates how cognitive function in adulthood is associated with health behaviors that may influence chronic disease and cognitive development and decline in late life. The health behaviors studied include physical activity, smoking and alcohol consumption, taking cholesterol lowering and antihypertensive medication, and taking vitamin or mineral supplements. The study aims to a) determine the extent to which cognitive function is associated with health behaviors that have been shown to protect against cognitive decline or that modify risk factors for dementia; b) determine whether cognitive function is associated with the uptake of positive health behaviors or cessation of negative health behaviors over a four year follow-up period.

Analyses were conducted using a measure of verbal intelligence because it was hypothesised that higher levels of verbal intelligence would be associated with greater general knowledge about healthy life-styles, and in turn, more beneficial health behaviors. To determine whether this was an effect restricted to knowledge, or whether it was associated more broadly with fluid type abilities, we also evaluated a measure of processing speed as a correlate and predictor of health behaviors. The main variables that could potentially confound any association between cognitive function and health behavior include education and physical health, both of which may influence both verbal intelligence and health behaviors. These factors were therefore controlled for statistically in all analyses.

1. Method

1.1. Study design and participants

The sample came from the PATH Through Life Project, a large community survey concerned with the health and well being of people aged 20 to 24 (20s), 40 to 44 (40s), and 60 to 64 (60s) years who live in Canberra or the neighbouring town of Queanbeyan, Australia (Jorm, Anstey, Christensen, & Rodgers, 2004). Each cohort is to be followed up every 4 years over a total period of 20 years. Results presented here concern the first and second wave interviews with 20- to 24-year-olds being conducted in 1999–2000 and 2003–2004, 40- to 44-year-olds, which were conducted in 2000–01 and 2004–05, and with 60- to 64-year-olds, conducted in 2001–02 and 2005–06 respectively. Participants had to be in their respective age group on the 1st January 1999 (for 20-to 24-year olds) 2000 (for 40- to 44-year-olds), or 2001 (for 60- to 64-year-olds). The sampling frames were the electoral rolls for Canberra and Queanbeyan, Australia. Registration on the electoral roll is compulsory for Australian citizens. At Wave 2, of the 20–24 year old cohort, 1061 had moved, 2190 could not be found, 1701 refused or had poor English, and 2404 were interviewed (58.6% of those found and in age range). In the 40–44 year old cohort, 280 had moved, 612 could not be found, 1389 refused or had poor English, and 2530 were interviewed (64.6% of those found and in age range). For the 60- to 64-year-olds, there was a change to the law allowing the Australian Electoral Commission to release more specific age group information. Letters were sent to 4832 persons, 34 were out of the required age range, 182 had moved, 28 were dead, 209 could not be found, 1827 refused or their English was too poor to allow an interview, and 2551 were interviewed (58.3% of those found and in age range). At Wave 2, 2139 of the 20s, 2354 of the 40s, and 2222 of the 60s were reinterviewed.

1.2. Measures

1.2.1. Education

Highest level of education was measured using six questions assessing (i) the amount of primary (elementary) and secondary schooling, (ii) the highest level of post-secondary/tertiary education attained, (iii) the number of years taken to complete post-secondary/tertiary education, (iv) present courses of study, (v) time taken on present courses of study, and (vi) whether present study is being completed on a full- or part-time basis. Responses to these items were combined into a single variable corresponding to the highest level of education attained, ranging from 4 to 18 years.

1.2.2. Spot-the-Word task

Lexical decision performance was measured using the Spot-the-Word Test Version A (STW), which asks participants to choose the real words from 60 pairs of words and nonsense words (Baddeley, Emslie, & Nimmo-Smith, 1992).

1.2.3. Symbol–Digit Modalities Test

The Symbol–Digits Modalities Test (SDMT, (Smith, 1982) was administered as a measure of mental speed that is highly sensitive to the effects of cognitive aging. The participant was required to substitute as many digits as possible for symbols in 90 s. Symbol–digit pairs to be used were available throughout the task on a code sheet.

Self-rated physical health was measured by the Component Summary of Physical Health Scale the SF-12, with higher scores reflecting better health (SF12) (Ware, Kosinski, & Keller, 1996).

Self-report information was obtained from participants on whether they had heart trouble, cancer, arthritis, thyroid disorder, epilepsy, cataracts or glaucoma or other eye disease, asthma, chronic bronchitis or emphysema, diabetes (Social, Psychiatry, Research, & Unit, 1992). The total number of conditions reported from this list was calculated.

For vitamins and minerals (VitMin), participants were asked "In the last month, have you taken any vitamins or mineral supplements? (Yes/No).

For cholesterol lowering medications, participants (in the 60s cohort only) were asked "In the last month have you taken or used any medications (including herbal remedies) to lower your cholesterol? (Yes/No). For antihypertensives, participants were asked if they have ever suffered from high blood pressure. For those who answered yes, they were asked "Are you currently taking any tablets for high blood pressure" (Yes/No).

Physical activity was assessed by asking participants to record the average number of hours and minutes per week they spent on each of the following levels of activity: mildly energetic (e.g. walking), moderately energetic (e.g. dancing, cycling) and vigorous activity (e.g. running, squash). Based on coding from the UK Whitehall II study (Marmot et al., 1991), participants were categorised as undertaking none-mild (<2 h a week of moderate or vigorous exercise), moderate (≥2 h of moderate and <2 h vigorous activity a week) or vigorous physical activity (≥2 h vigorous exercise per week). Dummy coded variables for mild versus moderate and mild versus vigorous activity were used in the analyses.

Smoking status was derived from questions on current and past smoking habits that yielded two dummy coded variables (current versus never, past versus never).

Alcohol consumption was assessed using the Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). Categorical estimates of weekly consumption were derived from the quantity and frequency items of the AUDIT. For men, weekly alcohol consumption was categorized as light (1–13 units), moderate (14–27 units), hazardous (28–42 units) or harmful (>42 units). For women, weekly alcohol consumption was divided into light (1–7 units), moderate (8–13 units), hazardous (14–28 units) or harmful (>28 units) categories where a unit equates 10 g of pure alcohol. Participants were classified as abstainers if they reported abstaining from drinking alcohol in the past and present. In these analyses light or moderate consumption was compared to abstainers.

1.3. Statistical analysis

The dependent variables in all analyses were binary and the data did not meet the assumption of multivariate normality. This assumption is desirable for random effects models and hence the longitudinal analyses were conducted with marginal models with a binomial distribution and a logit link function. These models obtain parameter estimates using generalized estimating equations (GEE) which do not require distributional assumptions for the observations (Fitzmaurice, Laird, & Ware, 2004). The within-subject association among the vector of repeated outcomes was assumed to have an exchangeable correlation structure (Twisk, 2003). This approach allows for health behavior data over both occasions of measurement to be modeled using all available data. For example, if an individual was missing data for a health behavior at Wave 2 or was no longer in the sample at Wave 2, their Wave 1 data would still be included in the analysis and they would be retained in the sample.

For each health behavior, a model was tested that included the cognitive predictor (either STW or SDMT) at Wave 1. These models were adjusted for age, gender, number of medical conditions and the SF12 physical health score. A main effect of the cognitive variable in the model indicates an overall association that variable and the health behavior that is being predicted. A main effect of wave indicates that there was a change in the level of the behavior from Wave 1 to Wave 2. Models were also tested that included a wave by cognitive predictor interaction. A significant interaction between the wave and cognitive predictor would indicate that the level of performance on the cognitive predictor influenced the probability of change in health behavior between Wave 1 and Wave 2. Analyses were conducted in SPSS 15.0 using the GEE procedure.

2. Results

2.1. Descriptive statistics for cognition and health behaviors

Table 1 shows the descriptive statistics for the cognitive measures at Wave 1. Results confirm the usual pattern of lack of age-differences in verbal ability but poorer scores on processing speed (SDMT) in the older cohorts. The correlation between STW and SDMT was .113 ($p<.01$). Table 2 shows the frequencies of health behaviors by cohort at Waves 1 and 2. The significance of change in the level of health behaviors between waves was evaluated in the GEE models and is reported below.

2.2. Effect of verbal intelligence on health behaviors and change in health behaviors

Table 3 shows the results for the GEE models of STW as a predictor of health behavior, adjusted for age, education,

Table 1
Descriptive statistics (means and standard deviations, frequencies) for demographics and cognitive predictors at Wave 1.

	20s ($n=2404$)	40s ($n=2530$)	60s ($n=2551$)
Age	22.6 ± 1.5	42.6 ± 1.5	62.5 ± 1.5
Female	1242 (51.7%)	1337 (52.8%)	1232 (48.3%)
Years education	14.6 ± 1.6	14.6 ± 2.3	13.8 ± 2.8
Spot the Word	47.6 ± 5.3	50.5 ± 5.7	51.8 ± 5.8
Symbol digit modalities	63.9 ± 10.2	59.9 ± 9.3	49.7 ± 9.8
SF-12 physical health	53.0 ± 6.8	51.6 ± 8.0	48.1 ± 10.2
Medical conditions	1.14 ± 0.4	1.23 ± 0.5	1.59 ± 0.8

Table 2
Frequencies of health behaviors at Wave 1 and Wave 2.

	20s		40s		60s	
	W1 (n = 2404)	W2 (n = 2139)	W1 (n = 2530)	W2 (n = 2354)	W1 (n = 2551)	W2 (n = 2222)
Vitamin/minerals	1049 (44.0%)	1175 (55.1%)	1011 (40.0%)	1063 (48.2%)	1051 (41.3%)	1176 (53.0%)
Cholesterol lowering	N/A	N/A	N/A	N/A	584 (22.9%)	718 (32.4%)
Antihypertensives	8 (0.3%)	14 (0.7%)	133 (5.3%)	215 (9.1%)	827 (32.5%)	931 (42.0%)
Physical activity						
Mild	971 (42.5%)	386 (18.4%)	891 (37.9%)	763 (33.0%)	1211 (53.8%)	763 (35.7%)
Moderate	524 (22.9%)	748 (35.6%)	888 (37.8%)	996 (43.0%)	744 (33.1%)	1067 (50.0%)
Vigorous	792 (34.6%)	969 (46.41%)	571 (24.3%)	555 (24.0%)	294 (13.1%)	305 (14.3%)
Smoking						
Previous	273 (11.5%)	320 (15.0%)	754 (29.8%)	720 (30.7%)	951 (37.3%)	854 (38.7%)
Current	750 (31.5%)	585 (27.4%)	481 (19.0%)	399 (17.0%)	276 (10.8%)	176 (8.0%)
Alcohol use						
Abstinence	200 (8.4%)	141 (6.6%)	237 (9.4%)	231 (9.8%)	356 (14.0%)	300 (13.5%)
Occasional	572 (24.0%)	4.6 (20.4%)	466 (18.5%)	389 (16.5%)	418 (16.4%)	334 (15.1%)
Light/moderate	1453 (61.0%)	1405 (65.6%)	1652 (65.5%)	1544 (65.7%)	1615 (63.5%)	1472 (66.4%)
Heavy/hazard	157 (6.6%)	148 (6.9%)	168 (6.7%)	186 (7.9%)	154 (6.1%)	111 (5.0%)

gender, number of medical conditions and the SF12. There was a main effect of STW on cholesterol medication in the 60s, indicating that those with lower verbal ability were more likely to be taking cholesterol medication. There was also a main effect of wave for cholesterol medication reflecting the significant increase in participants reporting consumption of cholesterol lowering medication at Wave 2. However there was no STW by Wave interaction for cholesterol medication, showing that the increase in use was not related to verbal ability.

There was a main effect of STW on VitMin in the 20s indicating that those with higher levels of STW were also more likely to take vitamins and minerals, but in the 60s, there was a main effect of STW in the opposite direction. There were main effects of wave for the 40s and 60s for VitMin, showing that in both these age-groups there was an increase in use of vitamins and minerals from Wave 1 to Wave 2 (see Table 1 also). A significant interaction between STW and wave was found for VitMin in the 60s cohort such that those with lower scores on STW at Wave 1 were more likely to change from not using vitamins or minerals at Wave 1, to using them at Wave 2. For example, in the lowest quartile compared to the highest quartile group, there was a change from 30.5% to 49.8% compared to 42.9% to 53.3% in those reporting using vitamins or minerals respectively.

Table 3
Effect of verbal ability on health behaviors by cohort adjusting for covariates (coeff [CI]).

	Vitamins and minerals	Cholesterol lowering	Antihypertensives	Physical activity (mod/mild)	Physical activity (vig/mild)	Smoking (curr/never)	Smoking (past/never)	Alcohol use (lightmod/abst)
20s								
STW	−.033**	Not asked	.031	−.033	−.033**	.022*	.007	−.061 **
	(−.046, −.019)		(.126, .403)	(−.016,13.732)	(−.050, −.016)	(.004, .039)	(−.013, .027)	(−.089, −.033)
Wave	0.031		.709*	1.176**	1.286 **	−.132 **	.291**	.280 **
	(−v.074, .135)		(.170, 1.247)	(1.032, 1.319)	(1.126, 1.446)	(−.208, −.056)	(.159, .423)	(.118, .442)
STW x	−.011		−.018	−.035	−.045*	−.011	.011	−.020
Wave	(−.032, .009)		(−.123, .086)	(−.007, 5.943)	(−.074, −.015)	(−.026,.044)	(−.015, .036)	(−.051, .011)
40s								
STW	−.006	Not asked	−.009	−.025 *	−.019*	.000	−.019*	−.077**
	(−.020, .007)		(−.036, .017)	(−.045, −.005)	(−.033, −.005)	(−.020,.019)	(−.037,−.001)	(−.102, −.052)
Wave	.227**		.619**	.105	.276 **	−.119*	.008	−.041
	(.134, .319)		(.472, .765)	(−.024, .234)	(.152, .401)	(−.195, −.044)	(−.049, .061)	(−.152, .071)
STW x	−.008		−.015	−.012	−.038**	−.002	−.008	−.004
Wave	(−.024, .008)		(−.042, .013)	(−.039, .014)	(−.061, −.015)	(−.015, .011)	(−.018, .002)	(−.022, .015)
60s								
STW	−.007	.027**	.008	−.016	−.020*	.010	−.033**	−.053**
	(−.020, .007)	(.011, .043)	(−.007. .022)	(−.041, .008)	(−.034, −.005)	(−.015, .035)	(−.050, −.015)	(−.073, −.033)
Wave	.500**	.539**	.466**	.348**	.804**	−.299**	.026	.031
	(.405, .596)	(.453, .625)	(.393, .540)	(.197, .500)	(.682, .926)	(−.417, −.180)	(−.026, .078)	(−.067, .130)
STW x	−.018*	−.002	−.006	−.006	−.029*	.007	.004	−.012
Wave	(−.035, −.001)	(−.017, .012)	(−.020, .007)	(−.034, .022)	(−.052, −.007)	(−.016, .030)	(−.007, .015)	(−.029, .006)

Note. STW = Spot the Word. All models adjusted for age, gender, years of education, number of medical conditions and the SF12. $^{**}p \leq 0.01$, $^{*}\ p \leq 0.05$.

No association between STW and antihypertensive medication was observed, although a main effect of wave in all cohorts showed that there was an overall increase in use between Wave 1 and Wave 2.

There were main effects of STW on mild versus moderate physical activity in the 40s, indicating that those with higher scores on STW engaged in higher levels of physical activity. In all cohorts, there were also main effects for STW for mild versus vigorous activity with higher verbal ability being associated with high levels of vigorous activity. There was a main effect of wave for both moderate and vigorous activity compared to mild for all age-groups except for moderate in the 40s, showing that overall the sample became more physically active from Wave 1 to Wave 2. In all cohorts, significant interactions between STW and wave showed that the increase in vigorous physical activity was greater for those with lower levels of verbal intelligence. However, even though those in the lowest quartiles showed the greatest increase in level of activity, those in the highest quartile of STW still had higher overall levels of activity.

There was a main effect of STW on smoking (current versus never) in the 20s, with lower STW scores being associated with higher rates of current smoking. There was also a main effect of STW on smoking (past versus never) in the 60s, with higher STW associated with higher rates of never smoking. Finally, main effects of STW on alcohol consumption were found in all age groups such that lower STW scores were associated with higher rates of abstention from alcohol. There were no interactions between alcohol consumption and wave.

2.3. *Effect of processing speed on health behavior and change in health behaviors*

Overall there were fewer significant effects found for processing speed than for verbal ability. Table 4 shows the results of the adjusted multilevel models including SDMT as the cognitive predictor. There was one or more main effect of SDMT on physical activity in each cohort with higher levels of SDMT being associated with higher probability of undertaking more activity and one interaction between SDMT and wave for the 20s consistent with results for STW.

There was a main effect of SDMT on smoking in each cohort with higher scorers being more likely to report being 'never' smokers. One interaction between SDMT and wave for smoking emerged as statistically significant, but the interaction did not remain when evaluating quartiles of SDMT performance using GEE procedures, suggesting it was not reliable. Finally there was a main effect of SDMT on alcohol consumption with higher scorers less likely to report abstention.

Models were also evaluated for SDMT that included STW as a covariate to determine the effect of SDMT that was independent of STW. For VitMin, cholesterol lowering medication and antihypertensives, the pattern of results was identical. However, for moderate versus mild activity, the main effects in the 20s and 40s became non-significant after adjusting for STW, but the interaction between SDMT and wave became significant in the 60s [β=.015 (.001, .028), p=.04] with greater increase in activity evident in lower end of the distribution of SDMT. For vigorous versus mild activity, the main effect in the 60s became non-significant, and the interaction between SDMT and wave became significant in the 20s [β=.02 (.005, .034) p<.01], with greater increase in activity level seen in the lowest quartile of SDMT performance.

For smoking, inclusion of STW as a covariate resulted in no changes in patterns of results for past versus never smokers, but the main effect of current versus never in the 60s became non-significant. For alcohol use, the main effect in the 60s became non-significant.

3. Discussion

The present study demonstrated several associations between both precautionary and adaptive health behaviors

Table 4
Effect of mental speed and wave on health behavior by cohort (coeff [CI]).

	Vitamins and minerals	Cholesterol lowering	Antihypertensives	Physical activity (mod/mild)	Physical activity (vig/mild)	Smoking (curr/never)	Smoking (past/never)	Alcohol use (lightmod/abst)
20s								
SDMT	.001	Not asked	.002	−.028**	−.010*	.023**	.009	−.006
	(−.006, .008)		(−.065, .068)	(−.037, −.019)	(−.018, −.001)	(.014, .032)	(−.002, .020)	(−.022, .011)
Wave	.036		.699 *	1.197**	1.291**	−.140**	.306**	.314**
	(−.068, .141)		(.154. 1.243)	(1.051, 1.343)	(1.130, 1.452)	(−.217, −.064)	(.174, .438)	(.152, .476)
SDMT x Wave	−.009		−.058 *	−.020*	−.012	−.009*	.010	−.015
	(−.020, .001)		(−.112, −.005)	(−.035, −.006)	(−.028, .005)	(−.018, −.001)	(−.002, .023)	(−.033, .002)
40s								
SDMT	−.005	Not asked	.005	−.013*	−.004	.014 *	−.008	−.028**
	(−.013,.002)		(−.010, .019)	(−.023, −.002)	(−.012, .004)	(.002, .025)	(−.018, .002)	(−.042, −.014)
Wave	.221**		.611**	.112	.273**	−.115*	.004	−.055
	(.128, .313)		(.465, .756)	(−.016, .240)	(.149, .396)	(−.190, −.039)	(−.050, .058)	(−.166, .056)
SDMT x Wave	.006		.015	−.006	.004	.001	−.003	.006
	(−.004, .016)		(.000, .031)	(−.020, .008)	(−.009, .018)	(−.008, .009)	(−.009, .003)	(−.007, .019)
60s								
SDMT	.000	.000	.002	−.003	−.009*	.011*	−.007	−.021**
	(−.007, .008)	(−.009, .009)	(−.006, .011)	(−.017, .011)	(−.018, −.001)	(−.004, .026)	(−.016, .048)	(−.034, −.008)
Wave	.498**	.523**	.459**	.349**	.796**	−.280**	−.029	.032
	(.403, .593)	(.438, .608)	(.386, .532)	(.199, .499)	(.676, .917)	(−.397,−.162)	(−.023, .081)	(−.066, .129)
SDMT x Wave	−.010*	−.005	.002	−.012	−.013	.007	.003	−.007
	(−.021, −.00002)	(−.015, .004)	(−.007, .010)	(−.028, .005)	(−.027, .000)	(−.007, .021)	(−.004, .009)	(−.018, .004)

Note. All models adjusted for age, gender, years of education, number of medical conditions and the SF12. **$p \leq 0.01$, * $p \leq 0.05$.

and cognitive performance. In general, higher levels of verbal ability and processing speed were associated with higher levels of physical activity, greater likelihood of taking vitamin and mineral supplements, reduced likelihood of current smoking and abstaining from alcohol. However, lower levels of verbal ability and processing speed were associated with higher rates of cholesterol lowering medication use in the 60s. This may have been because persons with lower cognitive function were more likely to have hypercholesterolemia. Cognitive function was not associated with taking antihypertensive medication or past smoking.

More significant effects were found when STW was used as a predictor than when SDMT was used as a predictor, consistent with the view that verbal knowledge is more specifically associated with health literacy than fluid abilities, and that this may influence health behavior. An alternative explanation for the different strength of results for these two variables is that the variance in STW does not reflect age-related decline in this ability whereas some of the variance in SDMT does. It may be that the peak level of cognitive ability but not cognitive decline is associated with health behavior. If this were the case, then as the influence of age-related decline on variables increases, their association with the health behaviors may decrease. However, we did not find stronger associations between SDMT and health behavior in the younger cohorts prior to age-related decline so our data do not support this alternative explanation.

The results involving main effects reflect associations among variables and hence do not indicate directions of effects. They could be interpreted to suggest that higher cognition leads to better health behaviors, that better health behaviors have resulted in higher cognition or that a third variable produces both better health behavior and higher levels of cognitive test performance.

The results for the effect of cognitive function and change in health behaviors were more complicated than the results for main effects. Overall, the cohorts improved in their adaptive health behaviors significantly over the four years of follow-up and increased their intake of antihypertensive medication, cholesterol lowering medication, vitamins and minerals. There was a consistent pattern for greater change in health behaviors (in the positive direction) to occur at the lower end of the distribution of cognitive scores. This was particularly noticeable for physical activity. The fact that two interactions between wave and SDMT became significant after adjusting for STW, suggests that the association between cognition and increased levels physical activity is not fully explained by higher levels of verbal ability. The effect may be explained by the greater capacity for increase in activity levels in the lower end of the distribution of SDMT scores.

The results of this study show that cognition interacts with health behaviors and change in health behaviors in a systematic yet complex manner. Those with higher verbal ability are more likely to engage in behaviors that are beneficial for health (including cognitive health) that are widely recommended and adaptive, such as engaging in physical activity and not smoking. However, the larger change across four years in probabilities of undertaking such behaviors found at the lower end of the cognitive distributions suggests that this pattern is not necessarily stable. If the trajectories observed in this study maintain longitudinally, then the differences in health behavior based on cognitive scores will ultimately disappear. It is possible that this result reflects greater awareness in the Australian public as the result of campaigns, school and employer programs relating to physical activity and general self-care. Alternatively, participation in the baseline assessment may have prompted participants with lower cognitive test scores to take better care of their health as there were more visits to general practitioners in the three months following the baseline assessment than in the preceding three months (Parslow, Jorm, Christensen, & Rodgers, 2004).

Unlike the Scottish midspan studies (Taylor et al., 2003), this study did not find that higher levels of cognitive function predicted smoking cessation. There was only one significant wave by cognitive measure interaction predicting smoking status out of 12 analyses suggesting that this result was not reliable. This may reflect differences in study design and follow-up period, and historical differences between the Scottish study and the present one. Cognition was measured in the Scottish cohorts prior to the developments in public health that recommend against smoking. It is possible that the high level of public awareness of risks of smoking in Australia at the time these data were collected mitigate against the influence of cognitive ability on smoking cessation. Younger persons in the PATH study may never have started smoking, and older participants may have already given up smoking before commencing the study.

The present study did not find any interaction between cognitive function and change in the probability of taking cholesterol lowering medication or antihypertensive medication, despite large increases in the number of participants taking these over the study period. This suggests that the chance of obtaining a prescription for and taking of such medications over the follow-up period was not influenced by level of cognitive function. Persons with higher cognitive ability may have lower rates of hypertension or hypercholesterolemia and hence fewer may have started taking medication for these conditions. Alternatively, those with higher cognitive ability may be more likely to manage those conditions using non-pharmacological means such as diet and exercise. In comparison, those with higher verbal ability were more likely to increase precautionary health behaviors (start taking vitamin or mineral supplements) over the follow-up period. Thus it appears that change in precautionary health behaviors, as opposed to adaptive health behaviors are influenced by cognitive ability.

Health behaviors may be directly or indirectly associated with cognitive decline. Taking a medication or vitamin (the behavior) must have an indirect effect via the change caused by the active ingredient in the medication or vitamin. Physical activity may have both indirect and direct effects on brain function (Kramer et al., 2003). The indirect effects are through the benefits of exercise for reducing other risk factors which have been associated with dementia and cognitive decline such as obesity (Wolf et al., 2007), diabetes and hypertension (Qiu et al., 2005). The direct effects of physical activity may result from increased cerebral blood flow and oxygenation (Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004).

This study was limited by the self-report nature of the health behaviors, and the availability of only two waves of data collected over four year from which to evaluate change. Information was not collected on whether the vitamins or minerals taken were prescribed by physicians so that the classification of these behaviors as precautionary may be overinclusive. The results must also be interpreted in the social and historical context of the public health and media foci that influence the messages and information that is available regarding health in Australia.

Overall this study shows how difficult it is to establish causal relationships involving cognitive function and behavior given that cohort effects are likely to be strongly influenced by social, demographic and historical factors. Although the study is observational, it illustrates the potential complexities of the interaction of cognitive function with contextual factors. Study designs with multiple cohorts of different ages that provide data on development within an age-range but at different times in history may allow for some of these issues to be investigated.

We conclude that higher levels of verbal ability and to a lesser extent, higher levels of processing speed, are associated with higher levels of health behavior at the population level, particularly precautionary behaviors such as taking vitamins and minerals and physical activity. This means that the association between early and late-life cognitive abilities may to some extent be moderated by health behaviors.

The fact that in the period in which this cohort has been studied, greatest improvement in health behavior is seen in those with the lowest level of cognitive ability suggests that other contextual influences strongly influence *change in* health behavior. This means that the association between cognition and health behaviors must be viewed in a social–historical context. Factors such as increasing levels of education in the population, greater affluence, greater availability and quality of health information, and societal attitudes that support individuals to engage in health behavior may contribute to change in health behaviors and these factors may have a greater benefit for individuals with lower cognitive test scores.

Acknowledgements

We thank the study participants, PATH Interviewers, Patricia Jacomb, Karen Maxwell, Bryan Rodgers and Tony Jorm. The first two waves of the PATH Through Life Study were funded by the National Health and Medical Research Council Grants #229936 and #179839. Anstey, Low and Christensen are funded by NHMRC fellowships # 366756, #455377, and #366781.

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