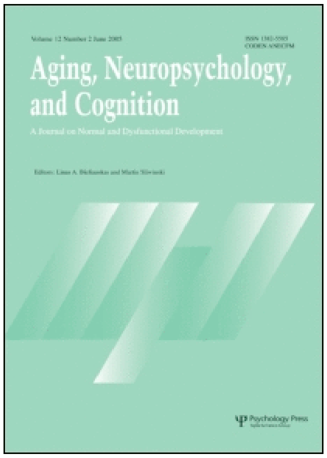

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Cognitive and Non-Cognitive Factors Contributing to the Longitudinal Identification of Successful Older Adults in the *Betula* Study

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ABSTRACT

Studies of successful aging have typically defined elderly who fall in the upper end of a distribution of test scores as successful. A different definition of successful aging requires that older adults fall at or above the mean level of younger adults and maintain this level over time. Here we examined this definition of successful aging in a sample of 1463 individuals between the ages of 50 of 85. Based on principal coordinate analysis of cognitive and non-cognitive variables, we identified a group of 55 (8.3%) 70–85 years olds that were high functioning. This group of elderly showed elevated performance on a range of cognitive tasks. Non-cognitive factors that characterized this group included education and subjective health. The participants were retested 5 years later and the same type of analysis was repeated. Of the remaining individuals who initially were classified as high functioning, 18 (35%) remained high functioning and thus met the definition for successful aging. Years of education was a significant predictor of who remained successful over time.

In a highly influential article, Rowe and Kahn (1987) introduced a distinction between *usual* and *successful* aging. In a heterogeneous group of non-diseased elderly, individuals classified as usual are those who exhibit typical nonpathologic age-determined losses. Individuals classified as successful are those who exhibit minimal loss, or none at all, when compared to the average of their younger counterparts. A key component of Rowe and Kahn's (1987, 1997) definition of successful aging is that elderly individuals

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need to be compared with a younger cohort. However, past studies have typically identified successful aging by selecting the best performing subjects from a sample consisting of *only* elderly individuals. In these studies, successful aging is often defined as those who perform in the top-third of the entire sample of older adults (Andrews et al., 2002; von Faber et al., 2001). A potential risk with identifying successful aging in this manner is that even those elderly performing in the top-third of the sample may perform below the mean level of younger individuals. Another key component of Rowe and Kahn's (1987, 1997) definition that distinguishes successful from usual aging is the distinction between nonpathological age-determined losses and minimal loss or none at all. In support of this distinction, Liang et al. (2003) mapped the trajectories of change in cognitive and health status over a 12-year period (1987–1999). They identified successful aging with a group that showed minimal decrement over this time. A more unlikely scenario is when elderly individuals transition from usual to successful status. Rowe and Kahn (1987) noted that transitions in the positive direction are poorly understood but may have substantial applied value. The main purpose of the present study was, therefore, to use longitudinal data from the Betula Prospective Cohort Study (Nilsson et al., 2004, 1997) to identify a set of cognitive and non-cognitive variables that separate older adults into usual and successful categories based on the two-pronged definition of successful aging (mean performance level of younger adults and transition over time) proposed by Rowe and Kahn (1987, 1997).

Previous studies of successful aging have begun to identify variables that differentiate elderly that have aged successfully from elderly that have not aged successfully (usual aging). In keeping with the original proposal by Rowe and Kahn (1987), both cognitive and non-cognitive factors have been found to be important (Andrews et al., 2002). However, a full appreciation of the factors that predict successful aging is still lacking, and as Rowe and Kahn (1987) indicate ". . . extrinsic factors that influence successful aging should be studied in interdependent combinations as well as singly." Therefore, rather than selectively focusing on candidate factors, we used a statistical technique known as *Q-mode analysis* (Reyment & Jöreskog, 1996) to identify successful elderly in the Betula dataset based on an extensive battery of cognitive tasks and non-cognitive questionnaires.

The objectives of the Betula study were fourfold: 1) examine the development of health and memory in adulthood and old age, 2) determine early preclinical signs of dementia, 3) determine risk factors for dementia, and 4) assess premorbid memory function in subjects who are in accidents or acquire diseases during the study. To achieve these objectives, data from 3000 individuals, randomly drawn from the population at large, between the ages of 35 and 90, were initially measured between 1988 and 1990. This group was retested between 1993 and 1995, and again between 1998 and 2000. During each wave of data collection, subjects took part in an extensive health and memory examination, and were interviewed about social factors influencing their life. Thus, while the Betula study was not originally designed to examine successful aging, because of its longitudinal nature, large number of subjects, and selection of cognitive (memory), health, lifestyle, and social variables, it is in a unique position to both identify those elderly that have aged successfully and identify factors that may have contributed to it.

The Betula project includes almost 2000 measurement variables. While many are not relevant to the issue of successful aging, a subset was included in the present study that has previously been linked, either empirically or theoretically, to a distinction between successful and usual aging. Thus, Albert et al. (1995) report that education, strenuous activity in and around the home, peak pulmonary flow rate, and self-efficacy were found to be direct predictors of change or maintenance of cognitive function in elderly adults. Years of formal education was included in the present study. For a measure of strenuous activity around the home, we included Katz's Activities of Daily Living (ADL) scale. This scale assesses functional status as a measurement of the person's ability to perform activities of daily living (e.g., dressing, bathing, feeding) independently. Peak pulmonary flow rate is a predictor of cardiovascular mortality. While objective measure of cardiovascular health were not available to us, responses to questions about various medical conditions (including cardiovascular), as well as overall well being, were included in the analyses. Rowe and Kahn (1997) report that emotional support from family and friends as well as being part of a social network is a significant determinant of longevity and maintenance of physical function. Accordingly, responses to questions about close relationships (friends, family, visitors, etc.) and the nature of living conditions (the number of rooms in place of residence) were included. Finally, stress, and perhaps more importantly, resilience to stress, have been implicated in determining an elderly individual's success status (Rowe & Kahn, 1997). Assessment of stress as well as overall mood (low mood, worry, often tired, etc.) were included in the present analysis. With regards to maintenance of cognitive function, while the majority of tests in the Betula dataset are targeted at episodic memory function, several tests of semantic memory (vocabulary and word fluency) were also included, as was the Mini-Mental State Exam (MMSE) and the Block Design subtest of the Weschler Adult Intelligence Scale (WAIS). Thus, many of the variables included in the present study have previously been associated with successful aging. On the other hand, some others were of an exploratory nature (e.g., alcohol and tobacco use, use of vitamin and mineral supplements, dental status, incidence of sleeping difficulties, marital status, etc.). The inclusion of this set of cognitive and non-cognitive variables in the present study will permit us to determine the role they play in successful aging.

Q-mode analysis techniques were used to identify usual and successful aging by examining longitudinal change in performance across this set of cognitive and non-cognitive variables. Unlike traditional analysis techniques that operate on the columns (variables) of a dataset, and are referred to as *R*-mode analyses (e.g., principal components analysis, factor analysis), *Q*-mode analyses portray the interrelationships (similarities and differences) between cases by operating on the rows of a set of data (McKeown & Thomas, 1988). While factor scores from a traditional principal component analysis (PCA) or factor analysis can be used for studying interrelationships between cases, *Q*-mode is preferred because the correlation or covariance matrix that is decomposed by PCA or factor analysis may not be the best criterion for judging the similarity between cases (Reyment & Jöreskog, 1996). *Q*-mode analysis was originally developed by Stephenson (Imbrie, 1963; Reyment & Jöreskog, 1996; Stephenson, 1935) to enable psychologists to systematically study subjectivity, but it has since been adapted to help identify heterogeneity within a multivariate dataset through the classification of cases based on objective criteria (for example, geologists have relied on *Q*-mode techniques to help identify the source of rock specimens based on their mineral composition). Here, *Q*-mode analysis was used to explore heterogeneity amongst the elderly individuals in the Betula dataset in order to classify them into two hypothetical end points—successful and usual aging. Additionally, because *Q*-mode analyses are data reduction techniques similar to PCA and factor analysis, it was used to reduce the total set of 138 cognitive and non-cognitive variables into a smaller number of latent factors (roots) that most strongly predicted success. We expected that cognitive performance, educational level, and health status would be among those factors that predicted successful aging.

METHODS

Participants

Participants in the present study were community-dwelling individuals from the Betula project (Nilsson et al., 2004, 1997). The ongoing Betula project includes several independent samples. All participants in the present study were from samples 2 and 3, initially tested between 1993 and 1995, and retested between 1998 and 2000. The participants were recruited by random selection of names from the population registry in Sweden and were between 50 and 85 years of age at the time of initial testing (35-, 40-, and 45-year-old individuals were not included in the present analyses). For the purpose of subsequent description and analysis, the participants were classified into two age groups: middle age and elderly. During the initial testing phase, middle age was defined as participants between the ages of 50 and 65, whereas elderly was defined as participants 70 years and older. During the second testing phase, middle age was defined as participants between the ages of 55 and 70, whereas elderly was defined as participants 75 years and older. The change in the definition of the two age intervals was necessary to allow us to study transitions over time. Sample characteristics are summarized in Table 1.

Measurement Variables

Performance on 23 tests of cognition and responses to a series of questions aimed at disclosing the participants' subjective health and description of disease, lifestyle, and socio-economic factors were used to identify high functioning elderly individuals during the first (1993–1995) and second (1998–2000) phases of testing (for a detailed summary of these tests, see Nilsson et al. (1997, 2003). These variables were selected based on previous research, theoretical reasoning, or for exploratory analysis of successful aging. While the majority of cognitive variables measured episodic memory, variables assessing semantic memory and general cognitive abilities were also included. During each phase, the cognitive battery was administered during two sessions, both of which lasted between 1.5 and 2 h for each participant. The collection of cognitive variables is summarized in Table 2. The variables used to assess health, lifestyle, and socio-economic factors are summarized in Table 3.

Statistical Procedure

Principal coordinate analysis (PCO), a form of *Q*-mode analysis, was performed on the 23 variables listed in Table 2 and the 115 variables listed in Table 3 in a single combined analysis. The analysis was performed separately on data collected during the first and second phases of testing. The purpose of these analyses was to identify in each phase high functioning elderly individuals within the Betula dataset. This was achieved by comparing a

TABLE 1. Sample Characteristics

			Education[1]		MMSE	
Group	Sample Size	% Male/Female	M	SD	M	SD
Phase 1 (1993–1995)						
Middle age	800	46/54	10.0	3.8	27.9	1.6
Elderly	663	38/62	7.6	4.5	26.5	2.2
Phase 2 (1998–2000)						
Middle age	675	49/51	11.3	3.9	27.9	1.5
Elderly	403	41/59	7.8	4.3	26.2	2.3
Drop-Out						
Middle age	125	38/62	8.6	3.6	27.3	1.7
Elderly	260	35/65	7.1	4.8	25.9	2.2

MMSE = Mini-Mental State Exam (Maximum = 30).
[1]Formal schooling (in years).

TABLE 2. Descriptions and Labels of Cognitive Variables Used to Identify Successful Aging

#	Description	Label
Tests of Episodic Memory		
1	Free recall of enacted events (e.g., lift the ball)	FR Actions
2	Category cued recall of enacted events (e.g., toys)	CCR Actions
3	Recognition of enacted events (e.g., ball)	RN Actions
4	Verb cued recall of enacted events (e.g., lift ___)	VCR Actions
5	Source recall of enacted events (i.e., enacted or verbal?)	SRC Actions
6	Free recall of verbal events (e.g., read the paper)	FR Sentences
7	Category cued recall of verbal events (e.g., reading material)	CCR Sentences
8	Recognition of verbal events (e.g., paper)	RN Sentences
9	Verb cued recall of verbal events (e.g., read ___)	VCR Sentences
10	Source recall of verbal events (i.e., enacted or verbal?)	SRC Sentences
11	Free Recall with no concurrent task at encoding or retrieval	FR FF
12	Free Recall with concurrent task at encoding only	FR DF
13	Free Recall with concurrent task at retrieval only	FR FD
14	Free Recall with concurrent task at both encoding and retrieval	FR DD
15	Recall of activities (i.e., what did you do during the session?)	FR Activites
16	Recognition of names (4-item forced choice)	RN Names
17	Recognition of faces (yes/no)	RN Faces
Tests of Semantic Memory		
18	Word Comprehension (30 item multiple-choice synonym test)	VOCAB
19	Generate words beginning with the letter “A” in 1 min	FLUA
20	Generate five-letter words beginning with the letter “M” in 1 min	FLUM
21	Generate names of profession beginning with the letter “B” in 1 min	FLUB
Other		
22	Mini-Mental State Exam	MMSE
23	WAIS Block Design	BLOCK

composite measure reflecting cognitive, health, lifestyle, and socio-economic factors derived from PCO between elderly individuals and their middle-aged counterparts. Elderly individuals were classified as either successful or usual based on 1) their level of performance during each phase of testing, and 2) the change in their performance level across the two phases of testing. Thus, high-functioning elderly individuals (those elderly who performed above the mean level of the middle-aged subjects) were deemed successful if they remained high functioning during the second testing phase (their performance remained high over 5 years), whereas high functioning elderly individuals whose performance declined or those who were not high-functioning during both phases were deemed usual. We also considered improvement in performance between the first and second phase of testing; at present, however, it is unclear whether these individuals should be classified as usual or successful, or whether a separate category needs to be developed for such positive transitions in status.

Principal coordinate analysis is similar to an inverted PCA. That is, PCO is analogous to a principal component analysis that is carried out across the rows instead of the columns of some type of similarity matrix (Reyment &

TABLE 3. Description of Non-Cognitive Variables Used to Characterize Successful Aging

#	Description
0	Chronological age
1	Gender
2	Marital status
3	Are you a twin?
4	Years of education
5–8	Living conditions (e.g., # of rooms in apartment/house)
9	Activities daily living (ADL)
10	Do you feel healthy?
11	Do you have sleeping problems?
12–16	Close relations (often alone, friends, visitors, family)
17–19	Mood related factors (often tired, low mood, worry)
20–21	Vision and hearing
22–24	Substance use (alcohol, smoking, snuff)
25	Dental status (false teeth & mercury fillings)
26–28	Receive medical treatment within last 3 months (hospitalized, seeing doctor, seeing psychologist)
29	Medical procedures (# of operations)
30–34	Vitamins & minerals (B, C, E, ginseng, selenium)
35–36	Stress
37	Rate memory change in last 5 years
38–50	Having medical condition (heart, back, stomach, digestion, joints, skin, breathing, extremities, breathlessness, swollen legs, dizziness, poor appetite, urinate)?
51–77	Having had disease (heart/circulation, stroke, memory, dementia, high blood pressure, diabetes, neurological disease, blood disease, tumor, psychiatric, thyroid, hormonal, unconsciousness, head injury, exposure to toxic substances, intestinal, skin, allergy/asthma, lung, eyes, ear/nose/throat, arthritis, back pain, broken bones, infection, encephalitis, handicap from birth)?
78–115	Mother, father, or sibling having had disease (heart/circulation, stroke, memory, dementia, high blood pressure, diabetes, neurological disease, blood disease, tumor, psychiatric, thyroid, hormonal, unconsciousness, head injury, exposure to toxic substances, intestinal, skin, allergy/asthma, lung, eyes, ear/nose/throat, arthritis, back pain, broken bones, infection, encephalitis, handicap from birth)?

Jöreskog, 1996). The procedure consists of extracting the first *k* eigenvalues and eigenvectors of an *N*-by-*N* matrix of associations derived from the raw data, where *N* represent the number of cases in the data. The raw data can consist of quantitative, appropriately coded qualitative, and dichotomous variables.

In the first step of the PCO, the 23 variables listed in Table 2 and the 115 variables listed in Table 3 were standardized (Z transformation) in order to eliminate scaling differences. The second step of the PCO analysis involves computing the association matrix $H_{(NxN)}$:

$$h_{mn} = \left(1 - \sum_{i=t}^{p} \left| x_{mi} - x_{ni} \right| / R_i \right)$$

where R_i is the range of variable i. The association matrix $H_{(NxN)}$ consists of coefficients of association, h_{mn}, between the mth and nth individuals of the sample (rows of the data matrix). The diagonal elements of this matrix, $h_{mn} = 1$, is the similarity between an object and itself and is equal to 1.

Next, the association matrix, H, is centered to yield H*:

$$h_{mn}^{*} = h_{mn} - h_{m*} - h_{*n} + h_{**}$$

where $h_{...}$ represents the grand mean of H, and h_{m*} and h_{*n} the mean of row m and column n, respectively. The association matrix, H*, is decomposed with singular value decomposition (SVD):

$$H^{*} = U \Lambda U'$$

where U is the matrix of eigenvectors and Λ is the diagonal matrix of associated eigenvalues. The coordinates of the N points on each latent root can be computed as $U\Lambda^{1/2}$. The profile of each latent root with respect to the original variables can be computed as $X'U$, where X is the original matrix of raw data. Principal roots, principal coordinates, and principal root profiles in PCO are analogous to factors, factor scores, and factor loadings in principal components analysis.

Principal Coordinate analysis is appropriate for quantitative, and suitably coded qualitative and dichotomous variables. Prior to the analysis, the data should be standardized (a Z-transformation is used here) in order to remove differences in mean and standard deviations across the variables. As in principal components analysis, the principal roots that are extracted in PCO are orthogonal to one another. For the orderings of observations on a principal root to be stable (i.e., the cases are sorted in a meaningful and reproducible manner), that root should account for a sizable portion of the overall experimental variance. In PCO, typically, only the first three roots provide meaningful ordering of the observation in a dataset (R. Reyment, personal communication, April 7, 2005). In the present study, PCO analysis of data from the first wave of testing resulted in 1463 principal roots, whereas PCO analysis of the data from the second wave of testing resulted in 1078 principal roots. The number of latent roots that were extracted from each analysis was determined by the amount of variance each accounted for. Additionally, in view of our focus on successful aging, chronological age needed to be a variable that loaded on a given root for that root to be considered. Violations of multivariate normality do not adversely affect the outcome of the PCO analysis (R. Reyment, personal communication, April 7, 2005). While the presence of outliers is an issue that needs to be addressed in other multivariate tests, PCO, in a sense, is designed to search for outliers. That is, the aim of PCO is to identify heterogeneity amongst the observations within a sample (Reyment & Jöreskog, 1996). Indeterminacy of the principal coordinates could arise if the percentage of variance accounted for by the roots decrease very slowly. In that case, PCO would not be an appropriate tool (R. Reyment, personal communication, April 7, 2005).

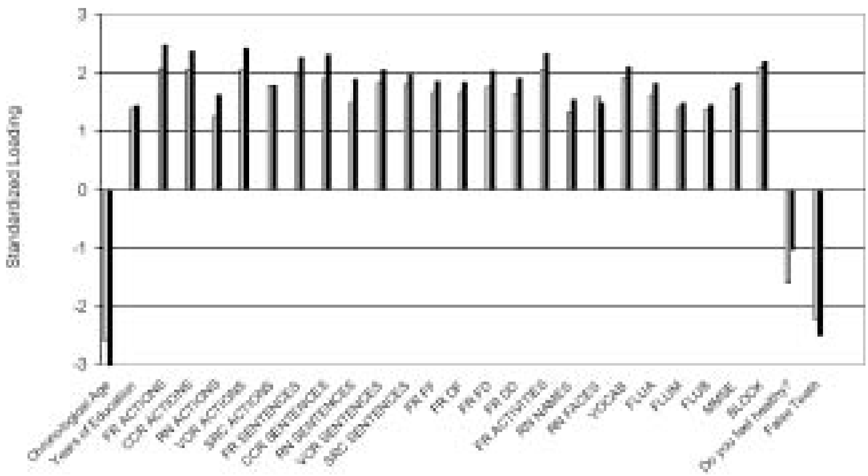
In relation to successful aging, PCO analysis can be helpful in distinguishing between usual and successful aging. The first step involves identifying a principal root at each time point which expresses a dimension on which successful aging will be defined. Ideally, this root will be the same or as similar as possible at each time point; otherwise, the analysis of transition over time will likely not be valid. For example, a principal root may contrast episodic memory variables and Katz's ADL from semantic memory variables and self-reported health variables; a different root may contrast the MMSE and years of education from the remaining cognitive factors and use of vitamin supplements. Based on theoretical grounds, success can be defined with respect to longitudinal change on any one of these principal roots. Once a principal root of interest is identified, the principal coordinates on that root at each time point can be computed. For a given principal root, the principal coordinates provide a metric that is proportional to each participant's performance on the variables that define the root. Participants that perform better or have higher scores on those variables will have larger principal coordinates than participants who perform worse or have lower scores. Thus, if a principal root represents the distinction between long-term and working memory, then an individual that has a greater principal coordinate will demonstrate this distinction more strongly than an individual that has a smaller principal coordinate. Finally, principal coordinates can be compared between individuals. Therefore, it will be possible to compare the principal coordinates of elderly individuals to the principal coordinates of their middle-aged counterparts. Because success is determined by transition over time, high-performing elderly individuals who remain high-performing are labeled successful, whereas either high-performing individuals who decline or those who were not high performing at either time make up the usual group. This is the approach we have adopted in this article.

RESULTS

Cross-Sectional Identification of High Functioning Elderly

The profiles from the first principal root of the PCO analysis of the 1993–1995 and the 1998–2000 datasets are shown in Figure 1. The most salient variables—those whose standardized root profile loading exceeded $Z = \pm 1$ in *both* analyses—are listed in Table 4. Importantly, age was one of

FIGURE 1. The figure displays the standardized loadings on the first latnet root for the variables listed in Table 4. Cross-hatched bars reflect loadings from the analysis on the 1993–1995 phase of data collection, whereas the solid black bars reflect loadings from the analysis on the 1998–2000 phase of data collection



the strongest contributors to the pattern in both analyses. In addition, for both analyses, the table reveals that all of the cognitive variables (Table 2) loaded positively on the first root. Furthermore, for the 1993–1995 dataset, a series of non-cognitive variables (Table 3) loaded on the first root. A subset of these non-cognitive variables also loaded on the first root of the 1998–2000 analysis. The set of cognitive and non-cognitive variables reported in Table 4 are those that together will be used to define successful and usual aging.

For the 1993–1995 dataset, the first principal root accounted for 33.4% of the overall experimental variance, whereas for the 1998–2000 dataset this value was 43.0%. The second strongest principal root in each dataset accounted for 12.9% (1993–1995) and 11.6% (1998–2000) of the overall experimental variance. Together, the first two principal roots accounted for approximately 50% of the overall experimental variance in each analysis, whereas the remaining 1461 roots in the 1993–1995 PCO analysis and the 1076 roots in the 1998–2000 PCO analysis each shared the remaining 50% of the overall variance, suggesting that they individually represented less stable orderings of the subjects in each analysis. In both analyses, gender contributed strongly to the pattern of loadings of the second principal root, whereas age played only a minor role. Hence, although the second root accounted for a sizable portion of the variance and reflected a stable effect, because it was an effect that was largely independent of age, it will not be discussed further here.

Figure 2 displays the principal coordinates from the first principal root of each PCO analysis as a function of age. This figure reveals that the principal

TABLE 4. Loadings from the First Principal Root of the PCO Analysis of the 1993–1995 and 1998–2000 Datasets. Variables Whose Standardized Root Profile Loading was Greater than ±1 at Both Test Occasions are Listed

#	Description/Label	Loading 1993–1995	Loading 1998–2000
Cognitive Variables			
1	FR Actions	2.1	2.5
2	CCR Actions	2.0	2.4
3	RN Actions	1.2	1.6
4	VCR Actions	2.0	2.4
5	SRC Actions	1.8	1.8
6	FR Sentences	2.0	2.2
7	CCR Sentences	1.9	2.3
8	RN Sentences	1.5	1.9
9	VCR Sentences	1.8	2.0
10	SRC Sentences	1.8	2.0
11	FR FF	1.6	1.9
12	FR DF	1.7	1.8
13	FR FD	1.8	2.0
14	FR DD	1.6	1.9
15	FR Activities	2.0	2.3
16	RN Names	1.3	1.5
17	RN Faces	1.6	1.5
18	VOCAB	1.9	2.1
19	FLUA	1.6	1.8
20	FLUM	1.4	1.5
21	FLUB	1.4	1.4
22	MMSE	1.7	1.8
23	BLOCK	2.1	2.2
Non-Cognitive Variables			
0	Chronological Age	–2.6	–3.0
4	Years of education	1.4	1.4
10	Do you feel healthy?	–1.6	–1.0
25	False teeth	–2.2	–2.5

coordinates decreased across the life-span in both the 1993–1995 and 1998–2000 datasets. These observations were confirmed by a significant negative Pearson correlation coefficient between the principal coordinates and age in the 1993–1995 ($r = -0.71$) and 1998–2000 ($r = -0.75$) datasets. Importantly, though, despite the overall negative effect of age, Figure 2 shows that some older adults scored at a very high level. Reference lines on each plot indicate the mean principal coordinate for middle-aged participants. High functioning elderly are those whose principal coordinate is greater than the mean coordinate of middle-aged individuals. From a total of 663 elderly individuals (70–85 years of age) during the first phase of testing, 55 (8.3%) were classified as high functioning. During the second testing phase, of the 403 remaining elderly individuals (75–90 years of age), 25 (6.2%) were classified as high functioning.

FIGURE 2. The figure displays the principal coordinates from the first latent root for each subject as a function of age. Vertical lines identify the cut-offs of the mean of middle-aged subjects. The figure on the left represents principal coordinates from the 1993–1995 phase of data collection. The figure on the right represents principal coordinates from the 1998–2000 phase of data collection.

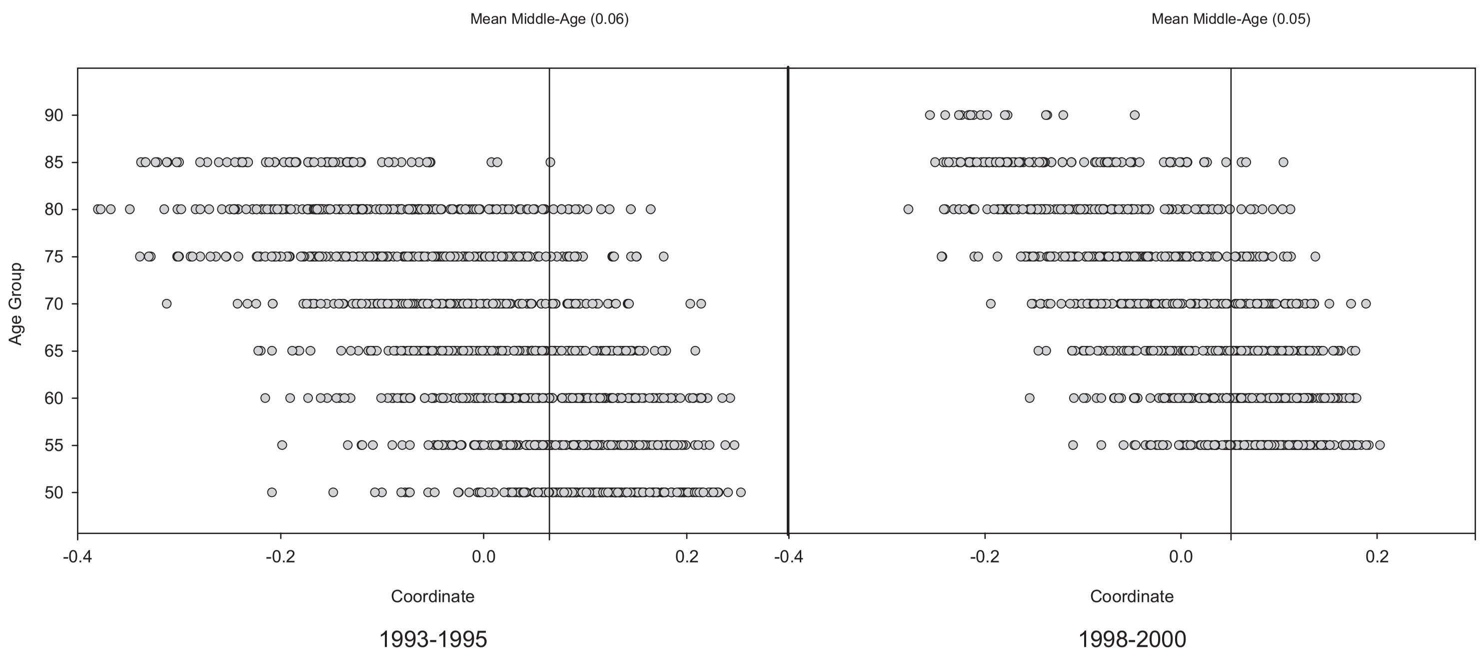


TABLE 5. Incidence of Successful and Usual Aging as Defined by Level of Function During Each Wave of Testing

		1998–2000		
		High	Lower	Grand Total
1993–1995	High	18 (35%) Successful	33 (65%) Usual	51
	Lower	7 (2.0%)	345 (98.0%) Usual	352
	Grand Total	25 (6.2%)	378 (93.8%)	403

Longitudinal Change and the Identification of Successful Aging

To explore longitudinal changes in the high-functioning elderly identified in the cross-sectional analyses for the purpose of classifying subjects as usual or successful, we examined the change in status between the initial and second phase of testing. The results are shown in Table 5. Of the 55 high-functioning elderly individuals identified during the first testing phase, 51 (93%) were retested during the second phase of testing. Of these 51, 35% (18) remained high functioning 5 years later and can thus be labeled successful, whereas 65% (33) did not meet the criterion. From the remaining 608 elderly individuals identified during the first testing phase, 352 (58%) were retested during the second phase of testing. Of these 352, 2.0% (7) actually achieved high-functioning status during the second phase of testing. The remaining 98.0% (345) maintained their status and thus were labeled as usual.

To examine the predictors of successful aging, we compared those elderly classified as successful to a subset of elderly classified as usual (those whose performance declined between the first and second testing sessions) on the cognitive and non-cognitive variables that differentiated the two groups (Table 4). We first conducted a MANOVA on the cognitive test performance measured during the first test wave, and found a nonsignificant effect of group ($p > .10$). Next, responses recorded during the first test wave to the four non-cognitive variables listed in Table 4 were analyzed with parametric or nonparametric tests. Only one significant difference was observed, showing that successful aging was associated with a higher level of education (M = 12.1, SD = 5.3) than usual aging (M = 9.6, SD = 3.7), t (49) = 1.91, $p < 0.05$ (one-tailed).

DISCUSSION

The first purpose of this study was to use *Q*-mode analysis to classify elderly individuals into successful and usual aging. Rowe and Kahn (1997) were careful to emphasize that aging successfully is more than maintaining high cognitive capacity. For this reason, we applied a data-reduction technique—principal coordinates analysis—to a set of 138 cognitive, health, lifestyle, and socio-economic variables in order to identify a small set of factors that predicted successful aging. In both data sets, we found that the first principal root could be interpreted in terms of an effect of age on the performance of all cognitive tests and also the scores on a set of non-cognitive factors. Importantly, however, although age strongly contributed to this pattern and there was a significant age-principal coordinate correlation ($r < -.7$ in both datasets), the plot of principal coordinates revealed that a subpopulation in each dataset could be classified as high functioning (performing above the mean of their respective middle-aged counterparts). Specifically, in the analysis of the first dataset, from a total of 663 elderly individuals between 70–85 years of age, 55 (8.3%) were classified as high functioning. Five years later, from the 403 remaining elderly individuals now between 75 and 90 years of age, 25 (6.2%) were classified as high functioning. Based on Rowe and Kahn's definition of successful aging, we found that 18 (2.7%) individuals could be classified as having aged successfully (i.e., were high functioning and maintained this level 5 years later).

The results of the analyses showed that the successful older adults performed at a higher level than the population of usual elderly on a selection of cognitive measures. This set of variables, while weighed towards measurement of episodic memory, did assess semantic memory (vocabulary and fluency) and general cognitive ability (MMSE and block design) as well. This is in keeping with the findings of several previous studies of successful aging, in which it was found that successful elderly had elevated performance on several different cognitive tasks (Andrews et al., 2002; Inouye et al., 1993; Ylikoski et al., 1999). That all included cognitive tests contributed to the separation of elderly into successful and usual indicates that the effect is stable.

In addition to the differences in cognitive ability between the successful and usual elderly, the analyses revealed that these two groups differed on level of education. Much prior research has indicated a positive correlation between education and cognitive ability (e.g., Albert et al., 1995; Nyberg et al., 1996; Phelan & Larson, 2002; Rowe & Kahn, 1997; Ylikoski et al., 1999). While our findings appear consistent with reports that education is a protective factor in older age (Albert et al., 1995; Ylikoski et al., 1999), we cannot determine whether the successful elderly already in their youth differed from the general population and therefore tended to continue with higher education, whether their longer education by itself has had a positive effect on their neurocognitive status later in life, or whether some combination of these possibilities is the best explanation.

Finally, two health-related variables contributed to the identification of successful aging. Elderly participants classified as successful reported feeling healthier than elderly participants classified as usual. This finding is in agreement with past studies that have shown both crosssectionally (Andrews et al., 2002; von Faber et al., 2001) and longitudinally (Liang et al., 2003) that successful elderly tend to report feeling healthier than the usual elderly group. A larger percentage also reported having only their own teeth as opposed to some number of false teeth—possibly a marker of overall health (Budtz-Jorgensen et al., 2000; Kiyak, 2000). The relationship between cognition and dentition is examined in more detail in a separate article (Bergdahl et al., submitted).

Rowe and Kahn's (1987) definition of successful aging implies minimal loss over time, but few studies have studied successful aging longitudinally (for an exception, see Liang et al., 2003). Of the elderly that initially were defined as high functioning, 93% were retested 5 years later. The corresponding figure for the nonhigh-functioning group of elderly was 58%. Hence, the level of function had a substantial influence on attrition over 5 years. To the extent that high function is a necessary component of successful aging, this observation underscores the validity of separating these subgroups of elderly adults.

We found that 2.7% (18/663) of high-functioning individuals remained high functioning, and thus were classified as successful, 5 years later. We also found that the performance of 5.0% (33/663) of high-functioning individuals declined over the course of 5 years; these individuals were members of the usual aging group. Years of formal education was related to the transition such that the successful elderly had, on average, more education than those whose decline in performance led to a usual classification. As stressed by Rowe and Kahn (1987), understanding transitions in later life is a significant task for aging researchers. The majority of past research has focused on the transition from usual to pathological aging, but the present finding that about 5% of high-functioning elderly adults could not maintain that level 5 years later highlights another transition that reflects loss of function.

Evidence for distinct transition functions was also provided by the finding that a minority of elderly individuals (7/663 = 1%) achieved high-functioning status over the course of 5 years. Most work on rehabilitation/training in older age is done with the purpose of reducing or preventing decline, and the potential for individuals to transition in the positive direction is little understood. While we caution that a very small proportion of individuals showed this pattern, and that this finding may simply reflect regression to the mean, to our knowledge their transition provides the first demonstration of what Rowe and Kahn (1987) termed a "positive reversal."

One note of caution about these transition trajectories needs to be raised at this juncture. In our data, 93% of elderly that were high functioning but only 58% of those that were not returned for the second wave of testing.

The greater attrition rate for lower-functioning elderly may arise from the greater likelihood for this group to transition to pathological status. Despite the greater attrition rate amongst the lower-functioning elderly, the rate of functional decline is greater in the high-functioning group. That is, only 35% of the high-functioning elderly from the first wave of data collection remained high functioning at the second wave (and hence were classified as having aged successfully). This is in contrast to 98% of lower-functioning elderly maintaining their status. There are several reasons for this. The first is that "lower functioning" is a "catch-all" category for elderly that were not classified as high functioning. Therefore, if an individual is not high functioning, they are "lower" functioning. Because a third category was not considered (e.g., pathological functioning), almost all "lower" functioning elderly that return will remain in the "lower" functioning group (unless they achieve high-functioning status). Furthermore, because of the negative correlation between age and cognition and health, it is more difficult for the high-functioning elderly to maintain their high-functioning status 5 years later, and thus be classified as successful, when they are compared to the mean of their younger counterparts. Because of these factors, the possibility exists that the difference in transition rates between the usual and successful elderly may be somewhat exaggerated. To assess this, future studies on successful aging need to consider a third category, pathological aging, in addition to usual and successful. Only then will it be possible to compare the transition rates between usual and successful elderly.

CONCLUSION

In conclusion, our results support the distinction that Rowe and Kahn (1987, 1997) introduced between usual and successful aging. This distinction is important because it focuses attention on the heterogeneity that is present within samples of elderly individuals. Our findings suggest that nearly 3% of individuals 70 years or older can be classified as successful. Years of formal education seems to be the best predictor of high-functioning elderly individuals who remain high functioning and have thus aged successfully.

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