Terminal Change: Cognitive Function, Cognitive Style, and Sociodemographic Variables in the Seattle Longitudinal Study

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ABSTRACT

Terminal change still remains a controversial issue and was examined in this study using data from the Seattle Longitudinal Study (SLS). Terminal change refers to the relationship between cognitive performance and mortality. Terminal change was examined in a sample of 605 decedents (n = 343 males; n = 262 females; M = 73.73 years of age) and 613 survivors (n = 299 males; n = 314 females; M = 71.91 years of age). Using a series of ANCOVAs, we examined how level and change over time differed between decedents and survivors in cognitive functioning and cognitive style. Decedents had lower levels of Verbal Meaning, Spatial Orientation, Numerical Ability, Delayed Word Recall, Identical Pictures and Psychomotor Speed and greater declines on Psychomotor Speed and Verbal Meaning over seven years. After controlling for the presence of prior chronic diseases (i.e., cardiovascular disease, diabetes, arthritis, cancer, sensory disorders and respiratory disorders), decedents still had lower levels on Verbal Meaning and Identical Pictures. Terminal change was found to characterize the older adults better and was not a pervasive phenomenon; specific abilities were affected by terminal change. There was greater evidence of males experiencing terminal change than women. Using trend analyses it was further observed that 'terminal decline' (i.e., linear decline) better characterized the trajectory of cognitive decline for decedents than did 'terminal drop' (i.e., quadratic decline). Age-related changes in fluid ability appear to be normative with aging whereas changes in crystallized abilities and perceptual speed may signify impending mortality.

KEY WORDS: TERMINAL CHANGE, COGNITIVE PERFORMANCE, MORTALITY, ELDERLY

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Longitudinal studies of intellectual ability have shown stability prior to 60 years of age but by age 70 and older, reliable decrements may be found (Schaie, 1996). A fundamental question remains as to how the deterioration should be explained? One explanation for cognitive decline in old age may be a result of what has been referred to as 'terminal drop' or 'terminal decline.' The term terminal change will be used throughout this paper to refer to the association between cognitive measures and mortality and will include both the terms 'terminal decline' and 'terminal drop'. Terminal change is characterized by some individuals experiencing a period of behavior change that is quantitatively greater and/or qualitatively different from normal age changes. This period of time may range from months to years; it is distinguished by cognitive decline from previous levels of performance that brings about greater losses than expected in age-sensitive variables as well as losses in variables usually regarded as age-insensitive (Birren & Cunningham, 1985).

Schaie and Willis (1993) reported that the magnitude of age differences between young adults and the oldest age cohort varied from about 3/4 standard deviations (SD) for Verbal Ability to more than 2.5 SD for Perceptual Speed. A proportion of this age difference may be accounted for by the presence of terminal change. Siegler (1975) argued that under the assumption that decreases in intellectual performance are related to proximity to death rather than

to the age of the individuals, it stands to reason that the time to death should be an important variable in assessments of change in intellectual function.

Despite the implications that terminal change may explain age differences in cognitive performance, there are still problems and conflicting findings in the literature. Previous researchers (e.g., Swan, Carmelli, & La Rue, 1995) have only looked at how single measures of cognitive ability or a relative few abilities predict the time to death (e.g., White & Cunningham, 1988). Many of these studies have examined how level of performance is related to mortality but have neglected to examine how magnitude of change is related to mortality.

Another problem with earlier studies is that some have not included women in their sample (i.e., Kleemeier, 1962; Swan, Carmelli, & LaRue, 1995). The exclusion of women in studies of terminal change is problematic because there are systematic gender differences in cognitive performance (Schaie, 1996). Past studies have also disagreed as to whether terminal change is pervasive for cognitive abilities or restricted to specific abilities (e.g., White & Cunningham, 1988). Furthermore, there is a disagreement as to which age groups are more likely to experience terminal decline or terminal drop.

Additionally, past studies, with the exception of more recent epidemiological studies, have been based on relatively small samples and have not always specified subjects' medical problems and custodial care needs (e.g., Kleemeier, 1962; Lieberman, 1965). Berg (1996) suggested that the contradictory evidence of whether terminal change is a global or specific cognitive phenomenon is likely due to differences in methodology and health profiles. Consequently, it becomes difficult to separate whether preexisting conditions are predictive of

cognitive decline and eventual mortality or whether cognitive decline is predictive of a premorbid state and subsequent death.

With the exception of some of the more recent epidemiological studies (i.e., Perls, Morris, Ooi, & Lipsitz, 1993; Swan et al., 1995), potential confounds of the cognitive decline-mortality relationship such as age, education and illness have not been well controlled. The literature on age changes in cognitive abilities is extensive and findings indicate that cognitive function declines with age and the rates of decline differ across intellectual abilities (Schaie, 1996). Educational history has been one of the most consistent predictors of cognitive change with higher levels of education being associated with greater maintenance of cognitive performance (Schaie, 1996).

Illnesses also influence cognitive function. Investigators (e.g., Hertzog, Schaie, & Gribbins, 1978) have reported decreases in intellectual test scores associated with various forms of cardiovascular disease (CVD). Diabetes may also be involved with changes in the circulatory system and indirectly affect cognition (Perlmutter, Tun, Sizer, McGlinchey, & Nathan, 1987). Visual and hearing deficits may directly affect cognition. Lindenberger and Baltes (1994) found in a sample of very old adults, visual and hearing deficits accounted for almost half of the total individual variance in cognitive performance. Finally, arthritis may lead to indirect changes, such as lifestyle, alterations that may directly affect cognitive behavior.

Past research has provided evidence that attitudinal-rigidity is also related to attrition and health. For instance, Cooney, Schaie, and Willis (1988) reported that personality dimensions of ill individuals who dropped out of the panel because of illness or death tended to be more rigid

than other groups prior to attrition. Cooney et al. (1988) attribute their findings to the fact that attitudinal rigidity contributes to illness and deterioration which often result in nonparticipation. Individuals who are inflexible might be relatively unwilling to change their lifestyles and behavior in order to avoid certain biologic conditions.

The Seattle Longitudinal Study provides an opportunity to explore how various cognitive abilities and styles are related to mortality. The SLS data set also contains information on potential confounds of the cognition-mortality association such as age, gender, education and the presence of prior illnesses.

The first goal of this study was to elucidate the differences between cognitive functioning and cognitive style of deceased subjects and surviving individuals. Past research has indicated that subjects prior to death perform worse on cognitive abilities in comparison to participants who are known to survive. It was therefore hypothesized that decedents would show lower levels of cognitive abilities and cognitive style than survivors at individuals' last measurement. In addition, it was hypothesized that decedents would still maintain lower levels of performance after controlling for the presence of prior health conditions. There is also relatively little known about how the rates of decline may differ between survivors and decedents. It was hypothesized that decedents' rates of decline would be significantly greater than that of survivors.

Another goal of this study was to address whether the removal of data of individuals who have died within two years of their last measurement decrease cognitive performance and flexibility differences between the two samples. It was hypothesized that lower levels and declines observed in a sample are accentuated by the inclusion of premorbid individuals.

The second major question of this study attempted to clarify the theory of terminal change and factors related to this phenomenon. Specifically, this study sought to determine whether terminal decline (i.e., linear decline) or terminal drop (i.e., quadratic drop) is a better descriptor of the pattern of cognitive decline before death. It was hypothesized that terminal decline would best characterize the relationship between cognitive decline and mortality in this study since the time interval between each measurement is relatively too long to observe any actual declines attributed to terminal drop. Moreover, terminal change was hypothesized to be pervasive across all cognitive abilities and cognitive style measures. Another question examined was whether or not terminal change occurs in specific age groups. There are conflicting findings among age groups of when this phenomenon may occur. It was hypothesized that younger adults would be more likely to experience terminal drop as opposed to older adults who are more likely to experience terminal decline. Younger adults are more likely to die of acute disorders while older adults are more likely to suffer from chronic illnesses. The final question studied was whether the pattern of terminal change differed for males and females. It was hypothesized that men were more likely to experience terminal drop because they may be at an increased risk of more acute illnesses (i.e., myocardial infarctions and strokes) whereas women were more likely to suffer from chronic diseases (i.e., arthritis) and subsequently display terminal decline.

METHODS

The Seattle Longitudinal Study has collected data on more than 5,000 participants between the ages of 22 and 95. Subjects were selected randomly from within gender and age/cohort groups from membership in a large Health Maintenance Organization (HMO) in the Seattle, Washington area. The sampling frame was a community dwelling population representing a wide range of occupational, educational, and economic backgrounds. Data were collected in six waves (1956, 1963, 1970, 1977, 1984, and 1991). With each new wave tested, an additional seven year age interval was added to match the age range of the original samples up to 81 years of age (See Schaie, 1996 for greater details).

Decedents

There were 605 individuals located who were tested successfully at least once and for whom there are known death dates by December 1995. Dates of death were obtained from the subjects' HMO records or by checking individuals' social security records which lists the exact day and year of death. Table 1 summarizes the demographic information for both decedents and survivors while Table 2 contains information on gender frequency for the two groups. A subset of the 605 decedents (n=105) had medical data available.

Insert Tables 1-2 about here

Survivors

A second sample consisted of survivors (N=613) who were selected to be of similar age, gender, and education levels as the decedents. Medical data were abstracted for 151 of these 613 individuals (see Table 1).

Materials

Personal Data

Various demographic and personal information has been obtained since the inception of the SLS project (see Schaie, 1996, for greater detail). This information included subjects' age, family income, gender, and education.

Cognitive Abilities

Thurstone Primary Mental Abilities (PMA)

The 1948 PMA 11-17 version of the Thurstone's Primary Mental Abilities test was used in this study. This test includes the following subtests: Word Fluency, Number, Inductive Reasoning, Spatial Orientation, and Verbal Meaning. The Primary Mental Abilities Word Fluency, Verbal Meaning, and Numerical Ability composed crystallized abilities, while Spatial Orientation and Inductive Reasoning comprise fluid ability. Crystallized abilities are the formation of skills and strategies that people have acquired through experience while fluid ability is the ability to deal with novel problems and to perceive and discriminate relations. Fluid abilities tend to decline earlier than crystallized abilities (Schaie, 1996).

Word Fluency measures the ability to retrieve words from long-term storage, based on a lexical rule. Subjects are asked to list as many words that begin with the letter "S" as they can in five minutes.

Number involves addition skills. Solutions to addition problems are given, and subjects decide whether the problem was solved correctly or not.

Inductive Reasoning involves logical problem solving, foreseeing and planning. This test measures the ability to identify patterns in a letter series.

Spatial Orientation refers to the ability to think about objects in two-dimensional space and to mentally rotate them.

Verbal Meaning is a test of recognition vocabulary. It is a multiple-choice test in which subjects must identify one of four choices as a synonym of the presented word.

Semantic Memory

Starting in 1984, semantic memory was assessed by means of two word recall tasks. In an Immediate Recall task, participants study a list of words. They are then given an equal period of time to recall the words in any order. In the Delayed Recall task, the same list of words used for Immediate Recall is to be recalled by the participant after an hour of intervening activities (Zelinski, Gilewski, & Schaie, 1993).

Perceptual Speed

Perceptual speed was assessed by three measures, all from the Educational Testing Service factor reference kit (Ekstrom, French, Harman, & Derman, 1976). The Finding A's task and Identical Pictures measure have been collected since 1975, whereas the Number Comparison measure has been collected since 1984. All three measures are timed tasks.

Finding A's task requires the cancellation of the letter 'a' in a column of words.

Identical Pictures involves identifying which of five numbered shapes or pictures in a row is identical to the model at the left of the row.

Number Comparison requires comparing two sets of numbers and marking pairs that are not identical.

The Test of Behavioral Rigidity (TBR)

The TBR contains three dimensions that will be used in this study: Motor-Cognitive Flexibility, Attitudinal Flexibility, and Psychomotor Speed (see Schaie, 1996 for greater details).

Motor-Cognitive Flexibility indicated individuals' ability to shift from one task to another.

Attitudinal Flexibility measures the ability to perceive and adjust to new and unfamiliar patterns and interpersonal situations.

Psychomotor Speed indicates the individual's rate of emission of familiar cognitive responses.

Medical Data

Complete medical histories are available for participants because participants in the SLS were recruited from a Seattle area Health Maintenance Organization. Medical technicians abstracted the medical data for some individuals and organized it according to the diagnosis made by physicians at each clinic visit (Parham, Gribbin, Hertzog, & Schaie, 1978). The medical data were then coded using the International Classification of Diseases (ICD-8, U.S. Public Health Service, 1968) for each year between 1956 and 1991. Interrater reliabilities for coded medical histories in earlier studies on this sample have ranged from .93 to .99 (Hertzog, Schaie, & Gribbin, 1978).

Specific Diseases

Specific diseases that will be referred to in this study are cardiovascular disease (CVD), diabetes mellitus, arthritis, neoplasms, sensory disorders and respiratory disorders (see Table 3 for ICD codes).

Insert Table 3 about here

RESULTS

The first method used for assessing differences between survivors and decedents last time of measurement was a series of 2 (Gender) by 2 (Status) by 4 (Age Groups) Analyses of Covariances (ANCOVAs) for the cognitive abilities and cognitive styles while controlling for education. Education was treated as a covariate since it was correlated with the independent

variables. Status represented survivors or decedents and age groups referred to middle-aged (<65 years of age), young-old (65-74 years of age), old-old (75-80 years of age), and oldest-old (>81 years of age). Studentized Tukey's post-hoc test was used to examine the differences between means. Gender and age group main effects will not be discussed in this paper since these two variables have been studied extensively (see Schaie, 1996 for more detail). Table 4 summarizes the results of the ANCOVA models for level of cognitive performance and cognitive style.

Insert Table 4 about here

Survivors had higher levels of Verbal Meaning, Spatial Ability, Numerical Ability, Identical Pictures and Psychomotor Speed performance than decedents. In addition to these significant survivorship effects, significant interactions between survival and age groups indicated that middle-aged and young-old decedents had significantly higher levels of Word Fluency than their surviving counterparts. However, old-old decedents had significantly lower levels of Verbal Meaning, Numerical Ability, Reasoning Ability, Word Fluency, and Psychomotor Speed while the oldest-old decedents had significantly lower levels of Verbal Meaning, Numerical Ability, Word Fluency, and Psychomotor Speed than their surviving counterparts.

In addition to these survivorship by age group interactions, survivorship by gender interactions were observed for Numerical Ability and Psychomotor Speed. Surviving males had significantly higher levels of performance than male decedents.

Cognitive Abilities at Last Measurement After Controlling for the Presence of Prior Illness

Table 5 summarizes the results of the 2 (Gender) by 2 (Survivorship) by 4 (Age Group) ANCOVA for cognitive abilities at last measurement after adjusting for education and presence of prior illness. Adjusting for the presence of prior illness eliminated the survivorship main effect for Spatial Ability, Numerical Ability, and Psychomotor Speed, the age group by survival interaction observed for Verbal Meaning, Inductive Reasoning, Word Fluency, and the gender by survival interaction found for Numerical Ability and Psychomotor Speed observed above. For memory and perceptual speed, only the interaction between survivorship and age groups was analyzed because the higher level interactions required more power than was available.

Insert Table 4 about here

After adjustment for prior illness, survivors continued to show significantly higher levels of Verbal Meaning and Identical Pictures performance relative to decedents. A survivorship by age group interaction was observed for Numerical Ability, Immediate Recall, Number Comparison, and Psychomotor Speed. Middle-aged decedents had significantly higher levels of Numerical Ability than did their surviving counterparts. Similarly, the young-old decedents had significantly higher levels of Number Comparison than their surviving counterparts. Old-old survivors had significantly higher levels of Immediate Recall and Psychomotor Speed than their decedent counterparts while the oldest-old survivors had significantly higher levels of Numerical Ability, Number Comparison, and Psychomotor Speed than their respective decedent counterparts. In addition to these survivorship by age group interactions, a gender by

survivorship interaction for Word Fluency indicated that male survivors had significantly greater levels of performance than male decedents.

Seven-year Cognitive Ability and Cognitive Style Change

A 2 (Gender) by 2 (Status) by 4(Age Group) ANCOVA controlling for education was used to examine how magnitude of changes in cognitive function differed between gender, survivorship, and age groups across the last two measurement periods (seven years). Change was operationalized as a difference score. Table 6 summarizes the results for cognitive function and cognitive style.

Insert Table 6 about here

Decedents declined significantly more on Verbal Meaning and Psychomotor Speed than did survivors over the seven years between individuals' last two measurements before death. Significant interactions between survivorship and age groups were found for Spatial Orientation and Numerical ability. For Spatial ability, the oldest-old survivors declined significantly more than their decedent counterparts and the old-old decedents declined significantly more than their surviving counterparts. For Numerical ability, only the old-old decedents had significantly greater decline than their respective surviving counterparts.

Differences Between Survivors and Decedents with Premorbid Individuals Removed at Last Measurement

A series of 2 (Gender) by 2 (Survivorship) by 4 (Age Group) ANCOVAs were conducted with the removal of individuals' data who had died within two years after their last measurement. Education was treated as a covariate in these analyses. Table 7 summarizes the results of the ANCOVA for the cognitive ability and cognitive style variables.

Insert Table 7 about here

Survivors had significantly higher levels of Verbal Meaning, Inductive Reasoning, Numerical Ability, Identical Pictures, and Psychomotor Speed than decedents after the removal of premorbid individuals. Significant survivorship by age group interactions were observed for Verbal Meaning, Inductive Reasoning, Numerical Ability, Word Fluency and Psychomotor Speed. The interactions for these abilities were characterized by the old-old and oldest-old decedents having significantly lower levels of performance than their respective surviving counterparts.

Survivorship by gender interactions were observed for Numerical ability and Psychomotor Speed. The interaction between gender and survivorship indicated that surviving males had significantly higher levels of performance than male decedents.

Decedents in the premorbid-removed sample did have slightly higher levels of Spatial Ability, Immediate Recall, Delayed Recall, Number Comparison, Attitudinal Flexibility relative to the full sample of decedents. Middle-aged adults in the premorbid-removed sample had higher

levels of Verbal Meaning, Inductive Reasoning, Numerical Ability, Immediate Recall, Delayed Recall, Motor-Cognitive Flexibility and Psychomotor Speed in comparison to the full sample. Young-old adults in the premorbid-removed sample had higher levels of Immediate Recall, Delayed Recall, Finding A's task and Psychomotor Speed relative to their counterparts in the full model. The old-old in the premorbid-removed sample had higher levels of Spatial ability, Word Fluency, Immediate Recall, Delayed Recall, Identical Pictures and Attitudinal Flexibility performance than their counterparts in the full sample. The oldest-old in the premorbid-removed sample had higher levels of Spatial ability, Identical Pictures, Motor-Cognitive Flexibility and Attitudinal Flexibility than their counterparts in the full mode.

Testing Terminal Drop Versus Terminal Decline

To examine whether terminal decline or terminal drop best characterizes the relationship between mortality and cognitive functioning, trend scores were computed for those individuals who had three or more measurements and died within seven or fewer years after their last measurement. These linear and quadratic trend scores were then regressed onto a constant to test if they were significantly greater than zero. Trend scores significantly greater than zero indicated that either a linear function (i.e., terminal decline) or a quadratic function (i.e., terminal drop) described the average performance of the decedents. Both linear and quadratic trend scores were computed for each measure separately. Table 8 displays both cognitive ability and cognitive style linear and quadratic results for the full sample, each age group and for males and females.

Insert Table 8 about here

Terminal decline (i.e., linear decline) was pervasive across all cognitive abilities and cognitive styles; however, there was less consistency for terminal drop. For instance, there was no evidence of terminal drop for Word Fluency in the full model but there was evidence of terminal decline for the ability.

The results indicated that there was little evidence for either terminal decline or terminal drop for middle-aged adults. With the progression of age, terminal decline seemed to better characterize the changes in cognitive ability and cognitive style trends. Overall, there was little evidence of terminal drop across the four age groups. The one exception was Psychomotor Speed which was better described as a quadratic trend than a linear one with increasing age. Women did not display any evidence of terminal drop. Men, on the other hand, exhibited both terminal drop and greater amounts of terminal decline then their female counterparts.

DISCUSSION

There was support for the hypothesis that decedents as compared to survivors would show lower levels of cognitive performance and less flexibility at individuals' last measurement. The hypothesis that decedents would continue to show lower levels of performance after controlling for the presence of prior adverse health conditions was partially supported. From these initial findings, however, it appears that terminal change is ability specific.

There are at least two explanations that could account for disagreement in the literature on whether terminal change is specific or pervasive. One explanation can be attributed to the use

of fluid abilities. Cooney et al. (1988) proposed that because fluid abilities decline for almost everyone across old age, additional effects related to attrition factors, such as illness or impending death, may be obscured. There were no clear differences on fluid abilities between the survivors and decedents because both groups experienced age-related declines on these abilities.

A second explanation may be the failure in some studies to control for prior health conditions (Berg, 1996). Findings in this study concur with this observation. Without adjusting for status on health related measures, the phenomenon of terminal change is more likely to appear pervasive as Berg (1987) observed. Biological factors, as indicated by the presence of prior health problems, explained a considerable amount, but not all of the terminal change in psychological functions.

Age Group Differences

As expected, differences between survivors and decedents at their last measurements revealed that there were age differences in experiencing terminal change. There were typically no significant differences between middle-aged and young-old decedents and their surviving counterparts. However, the old-old and oldest-old decedents had consistently significantly lower levels of cognitive performance and in many cases greater declines than their respective surviving counterparts.

The findings in this study appear to support Cooney, Schaie, and Willis's (1988) contention that the prediction of mortality on the basis of intellectual functioning may be more

accurate in older adults. A possible explanation for these age group findings can be attributed to chronic disease among older adults which is associated with deterioration prior to death. This is in contrast to younger adults, where death is usually a consequence of accidents or acute diseases that strike suddenly and hence produce limited intellectual decline prior to death. Furthermore, since a majority of the middle-aged adults died more than eight years after their last testing, it is likely that many individuals in this age group had not experienced any significant terminal change at the time of their last measurement.

If younger adults' deaths are more likely to be attributable to specific diseases, physiological or environmental accidents, it stands to reason that the time interval between measurements was too long to capture acute declines that may have inflicted the younger adults. Support for this possibility comes from the analyses in which premorbid individuals were removed from the sample. The findings indicated that middle-aged adults maintained higher mean levels on many cognitive abilities once premorbid middle-aged adults who were likely to experience acute illnesses were removed from the sample.

Presence of Diseases and Terminal Change

Similar to past studies (e.g., Hertzog, Schaie, & Gribbins, 1978), a significant relationship between health conditions and cognitive performance was found; however, this relationship varied across specific abilities. As Berg (1987) suggested, the time to death can be regarded as an overall measure of health or biological aging. It may, however, be hard to prove a specific disease-related cause of the decline. Many of the individuals suffered from more than one

disease condition. For example, 85% of the 105 decedents and 71% of the 151 survivors with medical data suffered from some type of CVD.

Change in Performance

Previous terminal change research has been predominantly concerned with differences in performance levels while giving little attention to rates of change. There was only partial support for the proposition that decedents' rates of decline would be significantly greater than that of survivors. It seems that what really matters for survival is not one's baseline performance, but one's level of performance at the conclusion of the study. However, with only one measurement available for the majority of those who died (52%), there is no way of determining how their cognitive function and cognitive style changed and how this change was related to their longevity. The rate of change observed in the study sample is likely to be an underestimation of the rate of change experienced by the total initial sample. It is also likely that those individuals who remained in the study for seven or more years possessed certain characteristics that differentiated themselves from those who had only one measure. Furthermore, memory and perceptual speed were only available for two measurement periods and relatively few individuals had multiple measures.

Removal of Premorbid Individuals

There was a lack of consistent support for the hypothesis that there would be fewer differences on cognitive performance and cognitive styles between survivors and decedents once

premorbid individuals were removed. There were specific premorbid-removed age groups that exhibited increased levels of performance at last measurement and decreased magnitude of change. The inclusion of premorbid individuals may lead to an overestimation of developmental change and this overestimation may differ significantly across various abilities and age groups.

Terminal Decline versus Terminal Drop

Despite past inconsistent findings as to which abilities are predictive of terminal change, it was clear that for those decedents who had three measurements, changes in cognitive abilities and cognitive style could be characterized as both linear (i.e., terminal decline) and quadratic (i.e., terminal drop). Overall, terminal decline best characterized the relationship of cognitive decline and mortality.

One possible explanation for why terminal decline better characterized terminal change was that the distance between each measurement was perhaps too long to observe declines attributable to terminal drop. Another possible explanation for the past inconsistent findings may be the range of different age distributions examined in prior studies. Evidence of terminal decline and terminal drop differed across age groups in this study. In this study, changes in middle-aged adults were not well characterized by either terminal decline or terminal drop while changes in the oldest-old were indicative of both terminal decline and terminal drop.

There was also support for the hypothesis that men would be more likely to exhibit terminal drop. It can be inferred that men were more likely to suffer from more acute disorder which resulted in significant changes at last measurement. However, women were more likely

to experience a gradual decline which could be associated with age-related changes and/or presence of chronic, progressive debilitating disease.

A concern of assessing terminal change was the issue of generalizability. The analysis of terminal change required that individuals have at least three time measurement points and died within seven years of their last measurement. There were 371 individuals (61% of the decedent sample) who died within seven years of their last measurement, but only 128 (21% of the decedent sample) of these individuals had three or more measurements. There was no significant difference in age, gender distribution, level of education and time to death when those individuals who had three measurements and died within seven years and those who died within seven years were compared to those persons who had less than three measurements but died within seven years.

In addition to generalizability, dementia is a concern when exploring the relationship between cognition with mortality. Dementia is related to increased rates of mortality and the disease is characterized by cognitive impairment. The Seattle Longitudinal Study does not contain any formal neuropsychological screening measures for dementia. However, the test battery before 1984 consisted of one test battery that extended over two and half hours. The battery, as of 1984, consists of two two-and-half-hour testing sessions using paper and pencil tests. As a result of the mental demands of the test battery, individuals who are likely to be suffering from severe to possibly moderate dementia typically chose not to participate. Empirical evidence supports this conclusion; out of the approximate 4,000 subjects tested in the SLS, about 500 have had at least seven or more years of medical data abstracted and only 6 of these 500

subjects have a diagnosis of dementia. In addition, 107 of the 602 subjects who have died had their medical data abstracted up to or within two years of their death and only two were believed to have symptoms of a type of dementia. Furthermore, there are approximately 650 individuals who provided information for why they chose to drop out of the SLS study, of these subjects, only 24 dropped out because of dementia.

Cross-Sectional Analyses Versus Longitudinal Analyses With Longitudinal Terminal Data

In this study, many cross-sectional findings obtained from mean level of analyses (i.e., ANCOVAs) were not replicated in longitudinal findings. Terminal change may offer an alternative explanation for the observed discrepancy between cross-sectional findings and longitudinal findings. Riegel and Riegel (1972) suggest that older individuals may be closer to death and the proportion of persons close to death increases with age. This may be responsible for the age difference in intellectual abilities and differences between cross-sectional and longitudinal findings.

The Relationship Between Attrition and Terminal Change

There was evidence that individuals who experienced terminal change may represent a unique group of individuals and subsequently this phenomenon has an important role in selective survival. The present findings caution against treating samples of elderly as being homogenous and that in normative samples of elderly, there is likely to be an appreciable number of individuals experiencing terminal change that could bias results. Since there was little indication

of terminal change in younger samples this conclusion also questions many of the results found in experimental cognitive studies where young and old individuals have been examined.

Conclusion

Past researchers have clearly indicated that there is observable cognitive decline with increased age (Schaie, 1996) which is indicative of primary or normal aging. Terminal change, on the other hand, was found to affect specific abilities, certain age groups and men and women differently, subsequently this phenomenon is likely to be characterized by secondary or pathological aging. Thus, averaging the performance of both healthy and dying individuals may lead to erroneous belief that everyone (including healthy older adults) declines in intellectual abilities. In addition, including individuals experiencing terminal change may inflate the actual interindividual differences observed and the inclusion of premorbid individuals may decrease observed levels of cognitive performance and increase rates of cognitive decline for older samples.

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Table 1: Summary Demographics for Samples

Sample	Variable	N	M	S.D.	Range
Decedents	Age	605	73.73	9.57	34-93
	Education		12.83	3.43	1-20
	Time in Study (months)		79.97	56.55	1-264
Survivors	Age	613	71.91	9.27	34-95
	Education		12.97	3.13	4-20
	Time in Study (months)		179.58	90.48	1-480
Decedents w/ medical data	Age	105	75.98	9.36	52-93
	Education		14.05	3.26	8-20
Survivors w/ medical data	Age	151	73.20	8.62	39-95
	Education		13.59	2.99	7-20

Table 2: Sample by Gender Frequency

Sample	Male	Female
Decedents	343	262
Survivors	299	314
Decedents with Medical Data	65	40
Survivors with Medical Data	83	68

Table 3: ICD codes for five disorders

Disease	ICD Code
Neoplasms	140-329
Cardiovascular disease	394 to 459
Diabetes mellitus.	250.9
Respiratory disorders	460-519
Arthritis.	710-718

Table 4: Summary of Significant Univariate F Ratios for Cognitive Abilities and Cognitive Styles at Last Measurement Adjusted for Education

Main Effects & Interactions	Verbal Meaning	Space	Reasoning	Number	Word Fluency
Gender		58.20*** (1, 1119)		4.12* (1, 1198)	30.94*** (1, 1198)
Survival	17.58*** (1, 1174)	3.75* (1, 1119)		3.72* (1, 1198)	
Age group	87.68*** (3, 1174)	66.24*** (3, 1119)	75.70*** (3, 1185)	38.14*** (3, 1198)	35.41*** (3, 1198)
Gender*Survival				4.24* (3, 1198)	
Gender*Age group					
Survival*Age group	5.56*** (3, 1174)		2.75* (3, 1185)	3.12* (3, 1198)	8.48*** (3, 1198)

Main Effects & Interactions	Immediate Recall	Delayed Recall	Finding A's	Identical Pictures	Number Comparison
Gender	13.48*** (1, 242)	17.63*** (1, 243)	8.65** (1, 367)	4.14*** (1, 427)	6.37* (1, 238)
Survival				24.62*** (1, 427)	
Age group	5.07** (3, 242)	5.45*** (3, 243)	4.56** (3, 367)	25.11*** (3, 427)	4.77** (3, 238)
Gender*Survival					
Gender*Age group					
Survival*Age group					

Note: *** = p<.001, ** = p<.01, * = p<.05
Degrees of Freedom in Parentheses; F Ratios above Parentheses

(Table 4 continued onto next page)

Table 4 (continued)

Main Effects & Interactions	Motor-Cognitive Flexibility	Attitudinal Flexibility	Psychomotor Speed
Gender		5.54*	48.02***
		(1, 1099)	(1, 1077)
Survival			7.12**
			(1, 1077)
Age group	27.18***	26.41***	46.81***
	(3, 1092)	(3, 1099)	(3, 1077)
Gender*Survival			5.38*
			(3, 1077)
Gender*Age group			
Survival*Age group			4.23**
			(3, 1077)

Note: *** = p<.001, ** = p<.01, * = p<.05
Degrees of Freedom in Parentheses; F Ratios above Parentheses

Table 5: Summary of Significant Univariate F Ratios for Cognitive Abilities and Cognitive Style Measures at Last Measurement Adjusted for Education and Presence of Prior Illnesses

Main Effects & Interactions	Verbal Meaning	Space	Reasoning	Number	Word Fluency
Covariates					
Education	49.67***		23.55**	8.09*	16.61***
CVD					
Cancer					
Respiratory	4.46*				
Sensory					
Diabetes					
Arthritis					
Gender		6.61* (1, 228)			15.08*** (1, 239)
Survival	4.41*** (1, 239)				3.23* (1, 239)
Age group	18.79** (3, 239)	20.18*** (3, 228)	18.84*** (3, 240)	7.97*** (3, 240)	5.73** (3, 239)
Gender*Survival					3.76* (1, 239)
Gender*Age group					
Survival*Age group				2.94* (3, 240)	

Note: *** = p<.001, ** = p<.01, * = p<.05
Degrees of Freedom in Parentheses; F Ratios Above Parentheses

(Table 5 continued onto next page)

Table 5: (continued)

Main Effects & Interactions	Immediate Recall	Delayed Recall	Finding A's	Identical Pictures	Number Comparison
Covariates					
Education	9.38**	9.86**	8.98**	23.44***	11.11**
CVD					
Cancer					
Respiratory					
Sensory					
Diabetes					
Arthritis					
Gender		4.67* (1, 89)	4.43* (1, 194)		
Survival				7.81** (1, 198)	
Age group				16.63*** (3, 198)	5.52** (3, 91)
Survival*Age group	2.66* (3, 89)				4.52** (3, 91)

Note: *** = p<.001, ** = p<.01, * = p<.05; Degrees of Freedom in Parentheses

(Table 5 continued onto next page)

Table 5 (continued)

Main Effects & Interactions	Motor-Cognitive Flexibility	Attitudinal Flexibility	Psychomotor Speed
Covariates			
Education	13.44**	13.54***	40.55***
CVD			
Cancer			
Respiratory			
Sensory			
Diabetes			
Arthritis			
Gender			21.64*** (1, 209)
Survival			
Age group	13.72*** (3, 209)	8.14*** (3, 209)	11.84*** (3, 209)
Gender*Survival			
Gender*Age group			
Survival*Age group			2.94** (3, 209)

Note: *** = p<.001, ** = p<.01, * = p<.05
Degrees of Freedom in Parentheses; F Ratios Above Parentheses

Table 6: Summary of Significant Univariate F Ratios for Cognitive Abilities and Seven Year Change Before Last Measurement Adjusted for Education

Main Effects & Interactions	Verbal Meaning	Space	Reasoning	Number	Word Fluency
Gender					
Survival	11.43^{***} (1, 553)				
Age Group	4.42^{**} (3, 553)	2.58^{*} (3, 535)		5.29^{***} (3, 541)	
Gender*Survival					
Gender*Age Group					
Survival*Age Group		3.17^{*} (3, 535)		3.43^{*} (3, 541)	

Main Effects & Interactions	Immediate Recall	Delayed Recall	Finding A's	Identical Pictures	Number Comparison
Gender					
Survival					
Age Group				3.01^{*} (3, 194)	
Gender*Survival					
Gender*Age Group					
Survival*Age Group					

Note: $^{***} = p<.001$, $^{**} = p<.01$, $^{*} = p<.05$
Degrees of Freedom in Parentheses; F Ratios above Parentheses

Table 7: Summary of Significant Univariate F Ratios for Cognitive Abilities and Cognitive Style Measures at Last Measurement with the Removal of Premorbid Individuals and Adjusting for Education

Main Effects & Interactions	Verbal Meaning	Space	Reasoning	Number	Word Fluency
Gender		44.65^{***} (1, 1000)			26.52^{***} (1, 1061)
Survival	15.68^{***} (1, 1054)		3.33^{*} (1, 1061)	3.48^{*} (1, 1075)	
Age group	83.16^{***} (3, 1054)	55.96^{***} (3, 1000)	71.36^{***} (3, 1061)	8.54^{***} (3, 1075)	28.66^{***} (3, 1061)
Gender*Survival				3.86^{*} (1, 1075)	
Gender*Age group					
Survival*Age group	5.37^{***} (3, 1054)		2.76^{*} (3, 1061)	4.63^{*} (3, 1075)	5.57^{**} (3, 1061)

Main Effects & Interactions	Immediate Recall	Delayed Recall	Finding A's	Identical Pictures	Number Comparison
Gender	9.53^{**} (1, 203)	12.40^{**} (1, 204)	4.02^{*} (1, 328)	5.24^{*} (1, 371)	6.39^{*} (1, 208)
Survival				10.55^{***} (1, 371)	
Age group	5.67^{***} (3, 203)	4.87^{**} (3, 204)	4.23^{**} (3, 328)	28.69^{***} (3, 371)	10.22^{***} (3, 208)
Gender*Survival					
Gender*Age group					
Survival*Age group					

Note: $^{***} = p<.001$, $^{**} = p<.01$, $^{*} = p<.05$
Degrees of Freedom in Parentheses; F Ratios above Parentheses

(Table 7 continued onto next page)

Table 7: (continued)

Main Effects & Interactions	Motor-Cognitive Flexibility	Attitudinal Flexibility	Psychomotor Speed
Gender		7.06* (1, 990)	45.03*** (1, 968)
Survival			8.87* (1, 968)
Age group	24.05*** (3, 983)	20.87*** (3, 990)	38.32*** (3, 968)
Gender*Survival			5.34* (3, 968)
Gender*Age group			
Survival*Age group			2.47* (1, 968)

Note: *** = p<.001, ** = p<.01, * = p<.05
Degrees of Freedom in Parentheses; F Ratios above Parentheses

Table 8: Test of Terminal Drop and Terminal Decline

		Terminal Decline		Terminal Drop	
Model	Variable	Parameter Estimate	T for HO:	Parameter Estimate	T for HO:
Full	Verbal Meaning	-.05	-9.04***	.03	5.45***
	Space	-.06	-6.54***	.02	2.32*
	Reasoning	-.08	-6.09***	.05	4.01***
	Number	-.06	-7.72***	.02	3.64**
	Word Fluency	-.03	-18.9***	.001	1.32
	Motor-cognitive Flexibility	-.03	-3.87**	.003	.48
	Attitudinal Flexibility	-.04	-3.55**	-.001	-.25
	Psychomotor Speed	-.01	-1.18	.04	4.42***
Middle-aged	Verbal Meaning	-.02	-.63	.02	.64
	Space	.02	.54	.02	.12
	Reasoning	-.06	-.85	.09	4.64*
	Number	-.07	-2.11*	.007	.41
	Word Fluency	-.03	-4.35**	.01	.86
	Motor-cognitive Flexibility	-.05	-1.58	.02	.61
	Attitudinal Flexibility	-.03	-3.00	-.005	-.21
	Psychomotor Speed	.01	-.23	.05	1.96
Young-old	Verbal Meaning	-.06	-6.74***	.03	3.10*
	Space	-.06	-3.75***	.01	.69
	Reasoning	-.10	-3.95**	.04	2.09*
	Number	-.07	-4.03**	.02	1.69
	Word Fluency	-.04	-10.9***	.0002	.02
	Motor-cognitive Flexibility	-.02	-.87	.02	1.00
	Attitudinal Flexibility	-.07	-3.16*	.001	.05
	Psychomotor Speed	-.02	-1.56	.02	1.20

Table 8: (Continued)

		Terminal Decline		Terminal Drop	
Model	Variable	Parameter Estimate	T for HO:	Parameter Estimate	T for HO:
Old-old	Verbal Meaning	-.05	-5.08***	.04	3.15*
	Space	-.06	-4.99***	.02	1.58
	Reasoning	-.06	-3.20*	.04	1.54
	Number	-.04	-4.06**	.03	2.40*
	Word Fluency	-.03	-11.0***	.02	1.48
	Motor-cognitive Flexibility	-.05	-3.86**	.02	1.76
	Attitudinal Flexibility	-.02	-1.02	-.002	-1.37
	Psychomotor Speed	-.01	-.08	.04	2.29*
Oldest-old	Verbal Meaning	-.05	-5.46***	.03	3.42*
	Space	-.06	-4.05**	.03	2.24*
	Reasoning	-.09	-3.72**	.06	2.27*
	Number	-.06	-5.15***	.03	2.56*
	Word Fluency	-.03	-12.0***	.001	.49
	Motor-cognitive Flexibility	-.02	-1.25	-.02	-1.59
	Attitudinal Flexibility	-.04	-2.25*	-.002	-.21
	Psychomotor Speed	-.01	-.62	.06	3.50*
Male	Verbal Meaning	-.05	-6.56***	.05	5.63***
	Space	-.05	-4.73***	.02	2.28*
	Reasoning	-.09	-4.14***	.08	4.17***
	Number	-.06	-5.96***	.03	3.90***
	Word Fluency	-.04	-14.58***	.01	1.83
	Motor-cognitive Flexibility	-.04	-3.36**	-.005	-.51
	Attitudinal Flexibility	-.04	-2.86**	.004	.43
	Psychomotor Speed	.006	.46	.06	5.08***

Table 8: (Continued)

		Terminal Decline		Terminal Drop	
Model	Variable	Parameter Estimate	T for HO:	Parameter Estimate	T for HO:
Female	Verbal Meaning	-.05	-6.21***	.02	2.59*
	Space	-.06	-4.51***	.009	.83
	Reasoning	-.08	-4.50***	.06	1.91
	Number	-.06	-4.87***	.01	1.31
	Word Fluency	-.03	-12.84***	.001	.04
	Motor-cognitive Flexibility	-.03	-1.96	.02	-1.52
	Attitudinal Flexibility	-.03	-2.10*	-.01	-.94
	Psychomotor Speed	-.03	-2.35*	.02	1.39

Note: ***=p<.001; **=p<.01; *=p<.05; T for HO is the significant test for the trend score