Influence of Impending Death on the Mini-Mental State Examination

By

Jing Ee Tan
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Supervisor: Dr. Esther Strauss

ABSTRACT

A cross-sectional, retrospective study, using data from the Victoria Longitudinal Study, was conducted to investigate the impact of impending death on test performance on the Mini-Mental State Examination (MMSE), a measure of general cognitive functioning. Test score on the MMSE of individuals collected between one to five years before death was compared to the MMSE test score of individuals who are still alive. Results revealed a significant difference between the MMSE total score of individuals who died within three years post-measurement and survivors, and those who died between three to five years after measurement. When the individual items were analyzed, only the "WORLD" and "copy pentagon" items obtained results similar to the total score, providing support for the specificity of impending death effect on fluid abilities. The cause of death (Cardio/Cerebro-vascular disease and non-Cardio/Cerebro-vascular disease), however, did not differentiate the groups, suggesting that the mechanism of impending death may not be disease-related. Our results revealed that the influence of impending death on cognitive functioning could be observed on the MMSE; the source of the influence is still unknown, however. Despite the statistical significance, our findings did not appear to be clinically meaningful. As a result, our findings suggest that it may not be necessary to collect new normative data that are removed of the effects of impending death.

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Dedication

Dedicated to my beloved family.

For without their love and encouragement, none of this would have been possible.

Chapter I

INTRODUCTION

Numerous studies have shown that aging is associated with cognitive decline. However, the literature suggests significant variability with regard to the extent and nature of this decline. A number of factors have been shown to influence individual differences in the extent of decline. These include age, education, lifestyle, and health-related factors (Bosworth & Schaie, 1997; Bosworth & Schaie, 1999; Bosworth, Schaie, & Willis, 1999; Botwinick, West, & Storandt, 1978; Christensen et al., 2001; Christensen et al., 1997; Smits, Deeg, Kriegsman, & Schmand, 1999). As early as 1962, researchers suggested that impending mortality may also have an impact on performance (Kleemeier, 1962). Indeed, there is evidence of a relation between impending mortality and cognitive functioning (Bosworth & Schaie, 1999; Botwinick et al., 1978; Hassing et al., 2002; Johansson & Berg, 1989; Small & Bäckman, 1997; Small, Fratiglioni, von Strauss, & Bäckman, in press). The nature of this relation, however, is uncertain.

In 1962, Kleemeier noted that among individuals of varying ages, there was a change in the rate of decline of their IQ scores after the second measurement point. Instead of attributing the gradual decline to age-related loss, he suggested that the curves are influenced by individuals experiencing a "terminal drop." Indeed, a plot of individual curves revealed a marked drop in performance, independent of their age, among all decedents tested shortly before their death. This was in stark contrast to those who did not die shortly after the last testing session, whose performance was relatively stable.

To test his "terminal drop" hypothesis, Kleemeier then analyzed data from 70 individuals (mean age = 79 years) who had been assessed at least twice, half of whom were living at the time of analysis. Using a score representing the mean annual rate of decline on the Wechsler-Bellevue Intelligence Scale for Adults, he obtained results showing a significant difference in the performance IQ score, with decedents performing lower than survivors. Given the small sample size, and the relatively similar distance to death among survivors and decedents, the results are considered conservative estimates of the effects of impending death on intellectual abilities among the aged. Since Kleemeier's original study, a number of other reports have appeared in the literature, confirming his findings.

Despite many years of research, a number of important issues remain to be solved. First, is the influence of impending mortality constant across the lifespan? Second, is the effect of impending mortality on cognitive performance specific or pervasive? Finally, is the cause of death related to cognitive functioning? These issues are discussed in turn.

This study focuses specifically on the influence of impending mortality on the MMSE (Folstein, Folstein, & McHugh, 1975), a commonly used test of general cognitive functioning. Specifically, we explore whether impending death impacts performance on this test. The MMSE is widely used as a screening tool for the diagnosis of dementia. Thus, norms are crucial to its diagnostic accuracy. To the extent that impending death exerts a negative effect, inclusion of individuals experiencing impending death in normative data sets may result in misleading interpretation. This document will begin with a review of relevant literature concerning the cognition-mortality relations, as well as the MMSE. Following the literature review, hypotheses of the research will be outlined. Analyses to be conducted to answer the research questions will then be presented.

Chapter II

REVIEW OF THE LITERATURE

Is the influence of impending mortality constant across the lifespan?

Knowledge of the cognition-mortality association serves to enhance our understanding of the sources of cognitive decline that is associated with aging. It has been observed that samples participating in research on aging tend to be positively biased because of reasons such as death and refusal to volunteer due to poor health (Siegler, 1975); that is, because healthy individuals tend to participate in studies, results often represent performance of an elite group rather than of the general population. Therefore, results of such studies may mask declines that are in fact present in the population. Given that samples are highly selected, Siegler hypothesized that changes in mental performance observed likely reflect sudden degeneration that occurs prior to death. A second factor was also identified by Siegler from her review of eight longitudinal studies on impending mortality. Higher baseline performance was observed among those farther from death, providing evidence for the relation between distance to death and cognitive performance.

Research has provided support for the relation between distance to death and cognitive performance over and above age (Bosworth et al., 1999); however, past studies have not been able to pinpoint the exact length of the period prior to death during which decline can be detected. Studies have reported mortality-related deficits within two years after baseline assessment (White & Cunningham, 1988), within three years after initial measurement (Hassing, Small, von Strauss, Fratiglioni, & Bäckman, 2002; Small & Bäckman, 1997; Small et al., in press), and four years prior to death (Johansson & Zarit, 1997). Although some researchers agree that decline can be seen within a five-year period (e.g., Jarvik & Falek, 1963; Riegel & Riegel, 1972), some studies did not find mortality-related deficits among those who died within 5 years of baseline assessment (Johansson & Berg, 1989). Other studies reported mortality-related deficits between 5-10 years after baseline measurement (Johansson & Berg, 1989), and even as early as 14 to 21 years after initial measurement (Bosworth & Schaie, 1999). As the ages of the participants in these studies are varied, an investigation into the effects of impending death across the lifespan may tell a different story.

Riegel and Riegel (1972) suggested that it is easier to predict deaths among those below 65 years old, because those who died are "less able"; on the other hand, Riegel and Riegel suggested that death is a random occurrence among people older than 65, as there are no distinct psychological factors (not more or less able) that differentiate survivors from non-survivors. Riegel and Riegel found a higher rate of refusal among older adults, which is consistent with Siegler's (1975) observation. Those who refused to participate in the study appeared to be below average in performance or behavior. Therefore, the research sample was positively biased with increasing age (i.e., it includes a higher proportion of above average individuals), and results in an underestimation of decline at an older age: Superior adults live longer because they take longer to reach the "lethal limits" that denote chances of survival. But differences among the groups (non-survivor, 'resister', retestee) become smaller with increasing age until 75 years old, when the groups were no longer different. A sharp drop in performance was observed among both the young-old and old-old adult decedents who died within 5 years after retest. Among survivors, a sharp drop was also observed among old-old adults. These results suggest that individuals do not experience decline in performance in the early period of old age, and that decline before age 65 indicates impending mortality. Similarly, White and Cunningham (1988) agreed with Riegel and Riegel (1972) that death in the old-old is random, whereas a psychological difference must determine death among the young-old. Their results also differentiated performance of surviving young-old from deceased young-old (before 70 years old).

Even though Riegel and Riegel (1972) suggested that the effects of impending mortality are attenuated in old-old adults, recent research suggests otherwise (e.g., Bosworth & Schaie, 1999; Hassing et al., 2002; Johansson & Berg, 1989; Johansson & Zarit, 1997; Maier & Smith, 1999; Small & Bäckman, 1997). Mortality-related differences on cognitive measures have been shown among very old adults - greater than 75 years old (Bosworth & Schaie, 1999; Bosworth et al., 1999; Johansson & Zarit, 1997; Maier & Smith, 1999; Small & Bäckman, 1997). In particular, old-old decedents (80-95 years old) were found to perform significantly worse than survivors of all ages and young-old decedents (MacDonald, 2002).

A number of models explaining the phenomenon have been proposed. Cunningham and Brookbank (1988) hypothesized that death among the young-old must be due to a “specific disease state, physiological or environmental accidents”. On the other hand, death among old-old must be due to generalized decline in physiological vigor in which a weakened system results in death due to heart failure, blood vessel rupture or failure of immune system (a random occurrence). Likewise, Berg (1996) suggested two models in which disease-related terminal decline is typical among young-old, whereas the general biological system breakdown is frequent among old-old. Given these models, knowledge of the effects of impending mortality across the life-span may begin to shed light on the source of mortality-related deficits. To augment this knowledge, investigation of how impending death exerts its influence on cognitive function will assist in our understanding of the mechanism behind aging and impending death.

Is the effect of impending mortality specific or pervasive?

Some have argued that the magnitude of deficits due to impending mortality is largest in abilities that are typically well-preserved in old age (Bosworth & Schaie, 1999; Bosworth & Siegler, 2002; Bosworth et al., 1999; Jarvik & Falek, 1963; Small & Bäckman, 1999; White & Cunningham, 1988), particularly vocabulary (Jarvik & Falek, 1963; White & Cunningham, 1988). For instance, Small and Bäckman (1997) reported worse baseline performance in measures of word recognition, which is thought to be resistant to aging, among decedents. Other aging-resistant abilities that were reported to show mortality-related deficits include verbal meaning and numerical ability (Bosworth & Schaie, 1999). This is crucial, because the emergence of reduction in functions that are generally performed well in old age may indicate that death is imminent (White & Cunningham, 1988).

However, several studies obtained results that suggested otherwise (e.g., Hassing et al., 2002; Small et al., in press). In one study (Hassing et al., 2002), fluid ability, thought to be most sensitive to aging, was the strongest predictor of mortality. In another study (MacDonald, 2002), vocabulary, which was thought to exhibit the largest magnitude of mortality-related deficit (Jarvik & Falek, 1963; White & Cunningham, 1988), was the only measure given that did not differentiate survivors from decedents. Similarly, worse performance among decedents than survivors was also reported on measures showing age-related declines such as abstract reasoning (Bosworth et al., 1999; Hassing et al., 2002) and spatial ability (Bosworth et al., 1999; Hassing et al., 2002). The pattern that emerges from these latter studies, therefore, is that impending death exerts an influence on more fluid abilities.

Overall, studies have been inconclusive with regard to the specificity of the effect of impending death. The question then remains is what causes the decrease in performance.

Is cause of death related to cognitive functioning?

In 1963, Jarvik and Falek described a *critical loss* in speeded tasks. They suggested that the loss may be due to circulatory changes that come with cardiovascular or cerebrovascular diseases (CVD). Most studies support a disease-related mechanism by which the CVD-mortality association operates (Fahlander et al., 2000; Hassing et al., 2002; Small & Bäckman, 1997). For example, MacDonald (2002) reported that individuals who died of CVD performed worse on measures of verbal speed, working memory and episodic memory, but not semantic memory or verbal ability. By contrast, one recent study (Small et al., in press) did not find effects of cause of death on cognitive ability using the Mini-Mental State Examination as well as a battery of cognitive measures. Individuals who died of CVD were not significantly different on measures of episodic memory, visuospatial ability, verbal fluency, and primary memory when compared to those who died of other causes. The authors suggested that "the mechanism by which impending death exerts an impact on cognitive functioning may be generic in nature, rather than being tied to the pathology of a specific disease." By contrast, an earlier study reported a non-significant association between mortality and cognitive performance (i.e., crystallized knowledge and inductive reasoning) once CVD was adjusted for (Hassing et al., 2002). Given the limited research available, no conclusions can yet be drawn about the impact of cause of death on cognitive function. This is unfortunate, given the well-documented link between chronic disease and cognitive function (Hertzog, Schaie, & Gibbin, 1978; van Boxtel et al., 1998), and the prevalence of CVD among the aged (Heart and Stroke Foundation of Canada, 2003).

From knowledge to application: Why the MMSE?

The Mini-Mental State Examination (MMSE; Folstein et al., 1975) is the most widely used brief measure for assessing global cognitive functioning, particularly in the elderly (Lezak, 1995; Spreen & Strauss, 1998). It was originally designed to differentiate organic from functional psychiatric patients, but has since been adapted to identify patients with a variety of neurological conditions, including Alzheimer's Disease. Because it takes only 5-10 minutes to administer the MMSE, it is often used for the preliminary diagnosis of dementia.

The MMSE, however, is affected by variables other than cognitive abilities. For example, some evidence suggests that there are race/ethnicity and social class differences in performance on the MMSE (Escobar et al., 1986; Espino, Lichtenstein, Palmer, & Hazuda, 2001; O'Connor, Pollitt, Treasure, Brook, & Reiss, 1989). Of note, age and education have consistently accounted for performance on the MMSE (e.g., Butler, Ashford, & Snowdon., 1998; Anthony, LeResche, Niaz, von Korff, & Folstein, 1982; Magaziner, Bassett, & Hebel, 1987; O'Connor et al., 1989). For that reason, age- and education-based cut off scores provide better sensitivity to screen for progressive decline in cognitive performance than cut-off scores that are not corrected for age and education

(Crum, Anthony, Bassett, & Folstein, 1993). Cut-off scores based on age- and education-corrected normative data have also been provided to describe the presence and severity of dementia (e.g., Bleecker, Bolla-Wilson, Kawas, & Agnew, 1988; Bravo & Hebert, 1997; Crum et al., 1993).

Empirical research also suggested that the MMSE demonstrates good reliability and validity (e.g., Lezak, 1995; Mitrushina & Satz, 1991; Spreen & Strauss, 1998; Tombaugh & McIntyre, 1992), at least in those with moderate to severe impairments. Its utility, however, is limited in those with mild impairment or focal neurological deficits (Feher et al., 1992; O'Connor et al., 1989; Tombaugh & McIntyre, 1992; Wells et al., 1992). Spreen and Strauss (1998) suggested that the limited utility in mild impairment or focal neurological deficits may be due to the MMSE's focus on verbal as opposed to other skills. The reliability and validity of the MMSE are discussed in turn.

Reliability

The reliability of the MMSE is somewhat compromised because its administration was not standardized. Molloy, Alemayehu, & Roberts (1991) reported that standardized administration improved inter-rater reliability from .69 to .90, as demonstrated in their sample of nursing home and chronic care hospital unit residents with a variety of conditions (i.e., Alzheimer's Disease, stroke, arthritis and osteoporosis).

Additionally, reliability estimates varied as a function of the sample examined, thereby limiting cross-study comparisons. Estimates for internal consistency (Cronbach's alpha) for the whole test ranged from .31 in a sample of community dwelling, non-demented, very old adults (Hopp, Dixon, Grut, & Bäckman, 1997) to .89 in a mixed sample of geriatric hospital in-patients, patients in supervised living, and elderly community-dwelling volunteers (Braekhus, Laake, & Engedal, 1992). The differences are likely due in part to differential variability among different samples. Community dwelling samples likely do very well on the MMSE, and their ceiling effect will produce very low variability compared to patient groups. This will dramatically affect estimates of reliability and validity for the various groups. Braekhus et al. (1992) suggested that an estimate for the internal consistency of the MMSE may be improved by using a subset of 12 items (Cronbach's alpha =.92), without compromising its utility (Braekhus et al., 1992).

Depending on the sample and re-test interval, test-retest reliability estimates generally ranged from .38 to .87. For example, estimates for test-retest reliability were reported as .87 for AD patients and .67 for normal controls (reflecting limited range due to ceiling effect) in CERAD clinical sites throughout the US over a one-month period (Clark et al., 1999). Over a two-year period, estimates for test-retest reliability ranged from .38 (Mitrushina & Satz, 1991) to .80 (Hopp et al., 1997) among healthy community-dwelling elderly volunteers. The results obtained by Clark et al. (1999) suggested limited utility if used in a follow-up within three years because of high measurement error and wide variation in rate of change. Because of such variations, Iverson (1998) suggested that test-retest reliability needs to be taken into consideration when interpreting retest scores to determine decline in order to ensure than the change is real and not due to measurement error.

Validity

The validity of the MMSE is discussed in three parts. First, the validity of the MMSE total score is reviewed, and this will be followed by a review of the subtest scores. Finally, the validity of the individual items is presented.

Total score. The MMSE total score correlated with a variety of cognitive measures, including other brief screening tests such as the Mattis Dementia Rating Scale and the Information-Memory-Concentration test (Salmon, Thal, Butters, & Heindel, 1990). In terms of other cognitive measures, Horton & Alana (1990) reported concurrent validity between the MMSE total score and expressive language, motor, and tactile scales of the Luria-Nebraska Neuropsychological Battery. They used a sample, which was controlled for age, of probable AD and Multi-infarct dementia patients. The total score also correlated positively with other neuropsychological tests such as the Wechsler Memory Scale – Mental Control, tests of word list generation (a measure of executive function), the Boston Naming Test, and the California Verbal Learning Test (Jefferson et al., 2002). Correlation with the WAIS-R, ranging from .36 to .57, was also reported in a sample of community-dwelling, non-demented, very old adults (Hopp et al., 1997). The correlations of the MMSE with an extensive array of tests suggest that the MMSE is a measure of general cognitive ability.

The sensitivity (ability to identify those who are impaired) and specificity (ability to identify those who are not affected) of the MMSE are highly dependent on the sample examined. As a result, reported classification rates have been variable in the literature. Some researchers reported that the MMSE lacked specificity for identifying dementia from a sample of healthy elderly population and was only adequate for measuring cognitive status of patients with mental or neurological disorders (Commenges et al., 1992). However, in general, most researchers agree that the MMSE demonstrates acceptable sensitivity (85%-87%) and specificity (82%-92%) at a 23/24 cutoff for identifying cognitive impairment (Anthony et al., 1982; Grigoletto, Zappala, Anderson, & Lebowitz, 1999; O'Connor et al., 1989; Tierney, Szalai, Snow, Fisher, & Dunn, 1997). To improve the classification accuracy, suggestions had been made to increase the number of items (e.g., 3MS; Teng & Chui, 1983) or to use a subset of the test.

Subtests. In the original paper, Folstein et al. (1975) organized the MMSE into six subtests (i.e., orientation, registration of three words, attention, recall of three words, language, and visual construction) purported to examine different cognitive domains. Whereas a few studies (e.g., Braekhus et al., 1992; Giordani et al., 1990) obtained a two-factor solution, the original organization was supported by recent factor analytic findings using community-dwelling older adults. A five-factor solution was obtained, with items loading on components representing concentration, language and praxis, orientation, memory, and attention (Jones & Gallo, 2000). These subtests appeared to have some concurrent validity with other neuropsychological tests (Giordani et al., 1990). For example, Jefferson et al. (2002) reported that the orientation subtest correlated with tests of memory (i.e., CVLT) and naming (i.e., Boston Naming Test), and the memory subtest correlated positively with measures of memory and executive function (i.e., WMS and tests of letter word list generation).

Because some research has supported the concurrent validity of the subtests, it is tempting to use the MMSE subtests to describe the specific cognitive profile of patients. However, despite adequate concurrent validity, these subtests do not provide sufficient divergent validity to establish domain specificity (Tierney et al., 1997). For example, the subtest on the MMSE measuring attention correlated moderately (*r* = .53) with the Wechsler Memory Scale Mental Control test, a neuropsychological test for attention. However, it also correlated with the Rey Auditory Verbal Learning Test (*r* = .48) that measures memory, and the Boston Naming Test [short form] (*r* = .47) that measures naming. Also, not only is the language subtest weakly correlated with the verbal scales of the Wechsler Adult Intelligence Scale – Revised (Hopp et al., 1997), but four out of five items on the language subtests appear to be highly insensitive to impairment (Feher et al., 1992). As a result, it was concluded that the language items were not useful for the early diagnosis of Alzheimer's Disease (Galasko et al., 1990). Finally, the subtests only modestly differentiated patients with Alzheimer's disease, Ischemic Vascular Dementia, and Parkinson's Disease, which suggests that these indices cannot replace comprehensive assessment (Jefferson et al., 2002). Consequently, the subtests should not be used alone as a measure of the domains they appeared to examine.

Nevertheless, use of a subset of the MMSE may serve to improve classification accuracy. Indeed, use of a subset of seven items, which correlate highly with the total score, have been shown to improve the sensitivity and specificity to almost 100% (Magaziner et al., 1987). Use of a subset of nine items best discriminated dementia patients from community controls at 91% sensitivity and 88% specificity. Patients with Alzheimer's Disease were distinguished from controls with 96% sensitivity and 98% specificity (Wells et al., 1992). When a subset of 12-items was used to detect cognitive impairment in a mixed elderly sample, sensitivity and specificity remained high at 98% and 91%, respectively. Similar findings were obtained when the sum of the '3-word delayed recall' item and 'orientation to place' item, was used in the classification of

Alzheimer's Disease (Galasko et al., 1990). These studies suggest that the use of subset composite scores holds promise for improving classification of cognitive impairment.

Individual items. Studies on the utility of the individual items are scarce. In one study, community-dwelling, healthy, old adults who developed dementia three years after baseline assessment were significantly more likely to perform worse on the items 'Day', 'WORLD', '3-word delayed recall', and 'write sentence'. The items, 'state', 'town', 'name a pencil', 'name a watch', 'read and obey', and 'immediate recall', on the other hand, had low predictive utility (Braekhus, Laake, & Engedal, 1995). In another study, it appeared that the naming item is so simple that most people are able to respond correctly (O'Connor et al., 1989), thus reducing its usefulness as a measurement tool. Overall, three items (i.e., 3-word delayed recall, Serial 7/spelling WORLD backwards, and Copy pentagons) consistently demonstrate satisfactory specificity and sensitivity for identifying patients with dementia (Commenges et al., 1992; Feher et al., 1992; Solfrizzi et al., 2001). The sole use of these three items may be sufficient for identifying impairments.

A caveat about one particular item is noted. Since several researchers consider the 'serial 7s' item as occasionally intimidating, spelling 'WORLD' backwards had been used in place of 'serial 7s' whenever respondents fail the 'serial 7s' item. These two items, unfortunately, are not equivalent tasks (Galasko et al., 1990; O'Connor et al., 1989). Some participants who failed 'serial 7s' were able to obtain full points when asked to spell 'WORLD' backwards, which suggests that the two items are not interchangeable.

Finally, performance on each item is also influenced by the age, education and gender of the respondent (Anthony et al., 1982; Magaziner et al., 1987; O'Connor et al., 1989). For example, Anthony et al. (1982) reported that those with less than an eighth-grade education performed significantly worse than others with more than an eighth-grade education on the 'orientation to time', 'attention and calculation', 'recall', and 'copy pentagon' items. Similarly, individuals younger than 60 performed better on the 'recall' item than those older than 60. Females were less able to name the county and copy pentagon than males, but were better at 'No ifs, ands, or buts' (O'Connor et al., 1989). As a result, age, education and gender must be taken into consideration when interpreting performance on these individual items.

In short, the evidence indicates that cognitive performance is influenced by impending death, and that the MMSE is a widely-used screening measure for cognitive impairment. Accordingly, the question arises whether the utility of the MMSE is compromised by the impending death phenomenon.

Linking impending mortality with the MMSE

There are a limited number of studies that examine the relation between the MMSE and mortality. Some research showed that MMSE total score is weakly predictive of mortality (Smits et al., 1999). For example, in one study, 'registration' and 'language' items predicted mortality even after all covariates and other MMSE components were controlled (Andersen et al., 2002). In another study, Small et al. (in press) found significant results regarding their mean-level analyses: survivors obtained higher MMSE total scores than did decedents. Moreover, longitudinal analysis of the MMSE scores indicated an interaction of mortality group and time. Decedents experienced a decline in MMSE total scores from time 1 to time 2, but not survivors. As the authors looked only at total scores, it is unknown which particular items differentiate survivors from decendents.

An investigation of the relation between the MMSE and cause of death is prompted by Nilsson, Fastbom and Wahlin (2002), who found that diabetes-related CVD variables were negatively associated with MMSE total score (R^2=.042), 'copy a design' (R^2=.058), and 'attention and calculation' (R^2=.029) among a sample of individuals with and without diabetes. To date, only one study (Small et al., in press) looked specifically at the association between MMSE and cause of death. Using data from a longitudinal population-based study of aging and dementia, the researchers did not find a significant correlation between cause of death and MMSE total scores, in terms of both cross-sectional and longitudinal comparisons.

In short, there is a documented cognition-mortality association. This association is, however, dependent on age. Despite the well-documented association, the specificity of the effect of impending mortality on cognitive performance is inconclusive, as is the relation between cause of death and cognitive functioning. As a measure of general cognitive functioning, the MMSE is the most widely used tool despite its limited utility. Past studies revealed that the MMSE is affected by factors other than cognitive ability. Even though there are reports on the relation between impending mortality and cognitive performance, few studies have examined the contribution of impending death to performance on the MMSE. The next section begins with a description of the significance and rationale of this study. Research questions and hypotheses will then be presented.

Chapter III

OVERVIEW, OBJECTIVES AND HYPOTHESES

Significance of research

The MMSE (Folstein et al., 1975) is a commonly used test to identify individuals who may be suffering from dementia. However, normative samples consist of individuals who are healthy, as well as individuals whose health may be declining prior to their death. Inclusion of the latter individuals in the normative samples lowers the cut-off scores for identifying impairment, thus failing to detect impairment when it, in fact, exists. If support for the hypothesis that impending death affects MMSE scores is found, then current cut-off scores will need to be revised.

Research rationale

In light of the evidence that performance on the MMSE is affected by one's proximity to death (Small et al., in press), it may be necessary to collect a new set of normative data that is free of impending death effects. By removing the effects of impending death from the norms, classification of cognitive status based on the MMSE may be more accurate.

Research question #1: Is the MMSE affected by mortality status?

As demonstrated by Kleemeier (1965), performance IQ score is lower for decedents than survivors, indicating that cognitive functions may be affected by mortality status. His hypothesis was supported in later studies on impending mortality (Bosworth & Schaie, 1999; Botwinick et al., 1978; Hassing et al., 2002; Johansson & Berg, 1989; Small & Bäckman, 1997; Small et al., in press). The influence of impending mortality was initially thought to be attenuated in old-old adults. However, recent studies have found mortality-related differences among the very old adults (Bosworth & Schaie, 1999; Hassing et al., 2002; Johansson & Berg, 1997; Johansson & Zarit, 1997; Maier & Smith, 1999; Small & Bäckman, 1997). In addition, the effect of mortality status on cognitive function was further affected by distance to death (e.g., Bosworth et al., 1999), since individuals examined closer to their death performed worse than those examined farther from their death. Given the influence of impending death on cognitive function, it is likely that effects of impending death may be observed on the MMSE, a widely used measure of general cognitive ability, consistent with the findings of Small et al. (in press).

Hypothesis #1: It is hypothesized that MMSE scores will be (a) lower for decedents regardless of age, and (b) lower for non-survivors tested nearer to their death.

Research question #2: Do different causes of death similarly affect performance on the MMSE?

There is evidence (e.g., MacDonald, 2002) that cognitive functions differ depending on the cause of death. In particular, CVD appears to exert effects on cognitive functions. For instance, in comparison to non-CVD deaths, MacDonald (2002) reported that individuals who died of CVD performed worse on measures of verbal speed, working memory and episodic memory, but not on semantic memory or verbal ability. Accordingly, for this study, decedents are grouped according to their cause of death (CVD vs non-CVD) and their MMSE scores will be compared.

Hypothesis #2: It is hypothesized that individuals who died of CVD will likely obtain lower scores on the MMSE.

Research question #3: How are individual items on the MMSE affected by impending death?

Individual items on the MMSE are differentially affected by various factors such as age, education and gender. For example, adults younger than 60 were better at the recall item than those older than 60 (Anthony et al., 1982). Adults with less than an eighth-grade education performed worse on 'orientation to time', 'attention and calculation', 'recall', and 'copy pentagon' items. Lastly, females were able to repeat 'No ifs, ands, or buts' better than males, but they were less likely to name the county and copy pentagon accurately in comparison to males (O'Connor et al., 1989). Apart from these variables (i.e., age, education and gender), other variables such as impending death may also influence individual items on the MMSE.

The influence of impending death has been demonstrated on the total score of the MMSE (Small et al., in press). Analysis at the individual item level, however, has not been conducted. Mortality status as well as cause of death appear to exert their effects in different cognitive domains. Some studies suggest that mortality-related deficits appear only on abilities most resistant to aging (Bosworth & Schaie, 1999; Bosworth & Siegler, 2002; Bosworth et al., 1999; Jarvik & Falek, 1963; Small & Bäckman, 1999; White & Cunningham, 1988). Other studies (Hassing et al., 2002; Small et al., in press) provide evidence that suggests otherwise. To this end, 3 items that appear to provide the most robust classification rates of impairment will be investigated: the 'delayed recall of 3 words' measures episodic memory; attention is measured by 'serial 7s/WORLD spelled backwards'; and finally, 'copy pentagon' measures visual construction.

Hypothesis #3: It is hypothesized that (a) young-old adults will perform better on all 3 items than old-old adults (b) decedents will obtain lower scores on all 3 items than survivors because impending death is thought to exert a pervasive influence on cognitive functioning (c) adults farther from death will perform better than those nearer death on all 3 items, and (d) adults who die of CVD will perform worse on the 3 items than those who will die of non-CVD causes.

Chapter IV

METHOD

The analyses are based on data from the Victoria Longitudinal Study (VLS). The VLS consists of longitudinal sequences of multiple cross-sectional samples of middle-aged and older adults, initially from 55-86 years old. Participants are retested at intervals of three years. New samples are added every six years. Only cross-sectional data from Sample 1 Wave 5 and Sample 2 Wave 3 are used in the this study, because data on the Mini-Mental State Examination (MMSE) were not collected prior to these Waves. The complete methodology of the VLS can be obtained from Hultsch, Hertzog, Dixon, and Small (1998), and Dixon and de Frias (in press). Relevant information about the methodology is described as follows:

Participants

Participants in the VLS were community-dwelling adults living in Victoria, BC, recruited through advertisements in the public media and appeals to specific community groups. Because data on the MMSE were collected only during Sample 1 Wave 5 (S1W5), and Sample 2 Wave 3 (S2W3) between 1998 and 2000, participants for the current study were selected from the existing 462 individuals from these waves of the VLS. Because 188 participants were not contacted within the set timeline for completion of the verification process, they were removed from further analyses. It was necessary to set a time limit for the verification process in order to carry out the distance to death analysis. If the length of time between the initial contact with the participant and the analysis of the data were analyzed was too long, any possible effect of distance to death may be lessened by the time lapse. Removal of these participants resulted in a final selection of 274 participants from S1W5 and S2W3.

The primary aim of this study was to compare the MMSE scores of survivors with decedents. With this aim in mind, two specific groups of individuals were identified from the database: (1) all individuals who died after the last wave of measurement (hereafter referred to as decedents), and (2) living individuals whose demographic background matches that of the deceased individuals (hereafter referred to as survivors). Mortality status as well as cause of death information was verified by searching records at Vital Statistics in the province of British Columbia.

To identify decedents, a list of participants was submitted to Vital Statistics. The list was created when a call-back was carried out around February, 2003 for participants to return for subsequent waves of testing. During the call-back, reasons for not wanting to return for subsequent waves of testing were established. Only names of those who cited reasons such as death or health problems were submitted to Vital Statistics. Vital Statistics returned mortality information for 40 individuals. MMSE information was not available for one participant, leaving data from 39 decedents for analysis.

The survivor group was selected by matching the age and education of each decedent to the survivors because of the sensitivity of the MMSE to age and education level. Gender was not included because it has little impact on MMSE scores (Spreen & Strauss, 1998). Due to the limitations of the existing database, most survivors were selected if they were within ± two years range in age and education. In five cases where no survivors matched based on these criteria, three were matched within ± three-year range in age and a ± one-year range in education. The remaining two cases were matched based on ± one-year range in age, and years of education at a cut off of 16 years (i.e. survivors were matched if they had less or more than 16 years of education). These criteria provided the best fit between decedents and survivors in terms of age and education.

The final sample consisted of 78 elderly adults, aged 63 to 95 at time of testing. There were 39 decedents (21 females, 18 males) and 39 survivors (26 females, 13 males). An analysis of variance conducted to ensure that the groups matched in age and education did not reveal any group differences, $p > .05$. To maximize sample size of decedents for future analysis, it was necessary to collapse across both VLS samples. An analysis of variance performed on the demographic variables (age and education) justified the decision to combine the VLS samples, $p > .05$.

In order to examine the effects of age on MMSE scores, two categorical age groups were created based on age at measurement. All participants were classified as either young-old (n = 34) ranging in age from 63 to 80 ($M = 75.56$, $SD = 4.39$) or old-old (n = 44) ranging in age from 81 to 95 ($M = 84.75$, $SD = 3.37$). This age classification is consistent with past research (e.g. Dixon et al., in press; MacDonald et al., 2002).

Among the decedents, number of years to death post measurement was calculated to facilitate distance to death analysis. A total of 18 decedents died within three years after testing (hereafter referred to as deceased 1); 21 died about 3-5 years post measurement (hereafter referred to as deceased 2). The three-year cutoff was chosen because it was the median number of years to death post measurement. A three-year cutoff is consistent with past research (Hassing et al., 2002; Small and Backman, 1997; Small et al., in press).

Table 1 presents demographic information on the participants based on mortality status. The three groups did not differ in terms of age, education and gender, $p > .05$.

Participants responded to a series of questions relating to their health. In comparison to a perfect state of health, as well as to other people in the same age group, participants believed their overall health was good to very good. On both items, survivors rated their overall health higher than decedents. On measures of affect (Bradburn Affect Balance Scale; Bradburn, 1969) and depression (CES-D; Radloff, 1977), participants reported they experience positive affect and did not suffer from depression.

Table 2 displays the participants' report of select health-related conditions (diagnosed by their physician) as a function of mortality status. On the whole, they reported an average of 4.8 chronic illnesses, with survivors reporting fewer chronic illnesses than decedents.

Measures

The measures included in the original VLS measurement battery consist of multiple questionnaires, tests, and tasks designed to assess three broad areas of functioning (a) memory functions (b) other cognitive functions, and (c) non-cognitive functions. For the purpose of the current study, data from the MMSE will be analyzed.

MMSE. The MMSE is a brief screening tool for measuring global cognitive functioning. It consists of a variety of questions that potentially tap into different cognitive domains. The maximum number of points an individual can obtain is 30, the maximum score corresponding to optimal cognitive function. A copy of the MMSE is found in the appendix.

Table 1 Demographic Information for Survivors, Deceased 1 and Deceased 2 at time of measurement (N = 78)

Variable	Survivors	Deceased 1	Deceased 2
N	39	18	21
Gender (% Female)	66.7	66.7	42.9
Age	80.28 (5.88)	80.33 (5.62)	81.95 (6.54)
Years of Education	14.9 (2.50)	15.06 (3.72)	14.95 (2.76)
Years to death	--	1.5 (.62)	3.57 (.81)

Note: Standard deviations are in parenthesis. Deceased 1 denotes participants who died within three years after measurement. Deceased 2 denotes participants who died between 3-5 years after measurement.

Table 2 Percent of Select Health-related Conditions Reported as a Function of Mortality Status

	Survivors	Deceased 1	Deceased 2
Arteriosclerosis	7.69	27.78	23.81
Stroke	7.89	27.78	14.29
High Blood Pressure	33.33	16.67	33.33
Low Blood Pressure	0.00	11.11	9.52
Heart trouble	28.95	50.00	33.33
Diabetes	5.26	16.67	20.00
Depression	15.38	11.11	5.00

Note: Deceased 1 denotes participants who died within three years after measurement. Deceased 2 denotes participants who died between 3-5 years after measurement.

Cause of death. Information on the cause of death of participants was obtained from the Department of Vital Statistics in British Columbia. In order to ensure proper identification, individuals were matched based on their full names, dates of birth, gender, and last date known to be alive. For the decedents, information obtained included date of death (month, day, year), cause of death, and contributing conditions to death. Classification of causes of death by Vital Statistics was standardized using the International Classification of Disease, Injuries, and Causes of Death, Tenth Revision (ICD-10) criteria (World Health Organization, 1997).

According to the ICD-10, the cause of death selected as the primary cause was based on the rules and guidelines set out by the World Health Assembly. For that purpose, the primary cause of death was determined by the underlying cause, which is defined as "(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury". As this definition encompassed the source of the condition that brought about death, the use of primary cause of death is sufficient for the purpose of the current study. Table 3 presents the list of causes of death among the 39 decedents, categorized by cerebro- and cardio-vascular (CVD) and other conditions (non-CVD). Three reasons explain why a CVD/non-CVD category is used instead of the individual causes. First, due to a small sample size, individual causes do not provide sufficiently large cell sizes for separate analyses. Next, CVD has been the leading cause of death in Canada for many years (Heart and Stroke Foundation, 1997). Finally, CVD is implicated in poor cognitive performance (Hertzog et al., 1978; van Boxtel et al., 1998). Investigation

Table 3 Primary Causes of Death in the Sample as Recorded by Vital Statistics

Cause of Death	Number of Decedents
Total CVD (n = 18)	
Cardiac	13
Cerebrovascular	5
Total non-CVD (n = 20)	
Neoplasms	8
Endocrine	2
Respiratory	5
Nervous System	1
Gastrointestinal	0
Blood and immune system	0
Musculoskeletal	0
Genitourinary system	1
External Causes	3

Note: CVD stands for Cardio/Cerebro-vascular Disease using CVD might provide a suggestion as to the source of mortality-related cognitive deficits.

Procedures

All measures were administered to participants during four sessions spread over a month or two. Each session took about two hours to complete with a break in the middle. A full description of the VLS procedures is described elsewhere (see Hultsch et al., 1998).

Statistical analyses

Analysis of variance (ANOVA) was used as the main technique to examine the data. Group differences for three between-group variables were of interest: age group (Young-old, Old-Old), mortality status (Survivors, Deceased 1, Deceased 2), and cause of death (CVD, non-CVD). For the individual MMSE items, MANOVA was an option for an analytical strategy. Because the interest is univariate, a series of ANOVAs was used in its place. In order to protect against Type 1 error when using a series of ANOVAs, while preventing excessive Type 2 error, error rate for the individual item analysis was set at .025.

Logistic regression was used to obtain classification information for both the total score and composite score separately. Logistic regression was useful for deriving the sensitivity and specificity of each type of score. The predicted group membership of each scoring system was compared using the McNemar Chi-square Test to determine the predictive accuracy of the two types of scores.

Chapter V

RESULTS

Statistical analyses and results are reported in four sections. First, performance on the MMSE was analyzed as a function of mortality status and age group to assess the effect of impending death on general cognitive performance for different age groups. Next, the effect of impending death on the individual MMSE items was examined to assess the differential impact of impending death on four MMSE items that measure different cognitive domains. As a follow-up question to identify the source of impending death effect, performance on the MMSE was analyzed as a function of cause of death. Finally, the predictive utility of the MMSE total score and a composite score made up of three MMSE items were compared.

Performance on the MMSE as a Function of Mortality Status and Age

The means and standard deviations for the MMSE total score as a function of mortality status and age group are presented in Table 4. A 2 (young-old, old-old) x 3 (survivor, deceased 1, deceased 2) between group ANOVA on the MMSE total score yielded a significant main effect for mortality status, $F(2, 77) = 3.176, p < .05, MS_w = 1.68, \eta^2 = .081$. Neither the main effect for age nor the interaction effect was significant, $p > .05$. Independent of age group, scores on the MMSE differed as a function of mortality status and distance to death.

Post-hoc analysis of the main effect of mortality status using *LSD* revealed a significant difference between survivors and deceased 1, $t_{LSD} = .415, p < .05$. Survivors performed better than decedents who died within three years of testing on the MMSE.

In summary, individuals who died within three years of testing obtained lower MMSE total scores than those who survived or those who died over three years post measurement.

Performance on four individual MMSE items as a function of mortality status and age[1]

Table 5 displays the means and standard deviation of each of the four MMSE items as a function of mortality status and age group. Separate two-way ANOVAs were performed on each of the items.

A 2x3 between group ANOVA with age group (young-old, old-old) and mortality status (survivor, deceased 1, deceased 2) as the between-subject variables and the MMSE item "Serial 7s" as the dependent variable revealed no significant for main and

[1] ANOVA was performed on all MMSE items. Most of the items were not significant. Only the ones that are significant or near significant are reported here.

Table 4 Means and Standard Deviations of MMSE Total Scores by Mortality Status and Age Group

	Survivors		Deceased 1		Deceased 2	
M	28.64		27.72		28.05	
SD	1.09		1.87		1.12	
	Young-old	Old-old	Young-old	Old-old	Young-old	Old-old
M	28.89	28.40	28.38	27.20	28.00	28.07
SD	.94	1.19	.92	2.30	1.29	1.07

Note: Deceased 1 denotes participants who died within three years after measurement. Deceased 2 denotes participants who died between 3-5 years after measurement. Young-old consists of participants 80 years old and below. Old-old consists of participants older than 80.

Table 5 Means and Standard Deviations of MMSE individual items by Mortality Status and Age Group

		Survivors		Deceased 1		Deceased 2	
		Young-old	Old-old	Young-old	Old-old	Young-old	Old-old
"Serial 7s"							
	M	3.84	3.55	4.13	4.30	5.00	3.64
	SD	1.83	1.76	1.64	1.49	.00	1.95
"WORLD"							
	M	5.00	5.00	5.00	4.50	4.57	5.00
	SD	.00	.00	.00	.85	1.13	.00
Delayed recall							
	M	2.42	2.15	2.25	1.60	1.29	2.07
	SD	.84	.99	.71	1.17	1.11	.62
Copy Pentagon							
	M	.89	.75	.50	1.00	1.00	.71
	SD	.32	.44	.54	.00	.00	.47

Note: Deceased 1 denotes participants who died within three years after measurement. Deceased 2 denotes participants who died between 3-5 years after measurement. Young-old consists of participants 80 years old and below. Old-old consists of participants older than 80.

interaction effects, $p > .05$. The item "Serial 7s" did not differentiate between survivors and decedents, or between the young-old and old-old.

A 2x3 between group ANOVA with age group (young-old, old-old) and mortality status (survivor, deceased 1, deceased 2) as the between-subject variables and the MMSE item "WORLD" spelled backward as the dependent variable yielded a significant interaction, $F(2,77) = 4.98, p < .01, MS_w = .20, \eta^2 = .12$. Performance on the "WORLD" item changed depending on the individual's age and distance to death.

To probe the interaction, the data were split by age group, and two one-way ANOVAs were performed on the "WORLD" item as a function of mortality status. Results revealed a significant simple main effect of mortality status among the old-old, $F(2,76) = 6.09, p < .01$, but not among the young-old, $F(2,76) = 2.05, p > .05$. Post-hoc analysis of the simple main effect of mortality status in the old-old group using *LSD* revealed significant difference between Deceased 1 and Deceased 2, and Deceased 1 and survivors, $t_{LSD} = .172, p < .01$. Survivors and those who passed away more than 3 years after testing performed similarly and better than those who died within 3 years after testing.

A 2x3 between group ANOVA with age group (young-old, old-old) and mortality status (survivor, deceased 1, deceased 2) as the between-subject variables and the MMSE item "three word delayed recall" as the dependent variable did not yield significant main effects, $p > .05$, or interaction effect, $p = .046$. Mortality status and age did not influence performance on the "three word delayed recall" item.

A 2x3 between group ANOVA with age group (young-old, old-old) and mortality status (survivor, deceased 1, deceased 2) as the between-subject variables and the MMSE item "copy pentagon" as the dependent variable yielded a significant interaction, $F(2,77) = 5.82, p < .01$. Performance on the "copy" item changed depending on the individual's age and distance to death.

The interaction was probed by splitting the data according to age group. The simple main effect of mortality status by age group was examined using two one-way ANOVAs. The one-way ANOVA revealed that mortality status exerted its effect on the young-old for this item, $F(2,76) = 4.71, p < .05$. Post-hoc analysis of the simple main effect of mortality status in the young-old group using *LSD* revealed significant difference between Deceased 1 and Deceased 2, and Deceased 1 and survivors, $t_{LSD} = .173, p < .05$. Survivors and those who passed away more than 3 years after testing performed similarly better than those who died within 3 years after testing.

In summary, among the four MMSE items, only the "WORLD" and "copy pentagon" items were affected by mortality status and age group. The old-old obtained a lower score on the "WORLD" item if they died within three years of measurement. The young-olds' performance on this item was not affected by their mortality status. The young-old, however, scored lower on the "copy pentagon" item if they died within 3 years after measurement than if they survived past 3 years after measurement.

<u>Cause of death influence on the MMSE</u>

To investigate the impact of cause of death on the MMSE, a series of ANOVAs were performed. Table 6 displays the means and standard deviations on the MMSE as a

Table 6 Means, Standard Deviations and F-values of MMSE as a function of cause of death (CVD vs. non-CVD)

		CVD	Non-CVD	F-value
Total score				
	M	28.00	27.81	$F(1.38) = .15, p > .05$
	SD	1.65	1.40	
"Serial 7s"				
	M	4.56	3.81	$F(1,38) = 2.18, p > .05$
	SD	1.34	1.75	
"WORLD"				
	M	4.83	4.67	$F(1,38) = .11, p > .05$
	SD	.51	.77	
Delayed recall				
	M	1.83	1.86	$F(1,38) = .01, p > .05$
	SD	.92	.96	
Copy pentagon				
	M	.83	.76	$F(1,38) = .29, p > .05$
	SD	.38	.44	

Note: CVD stands for Cardio/Cerebro-vascular Disease function of cause of death. As displayed on table 6, performance on the MMSE was not influenced by cause of death[2].

Comparison of the predictive utility of total score and composite score

A composite score of the three MMSE items was created to examine its utility in comparison to the total score. To create the composite score, three items that have shown the best utility in the literature were used. In the past, either the "WORLD" item or the "Serial 7s" item was used in obtaining the total score on the MMSE; neither was used simultaneously. For the purpose of this study, the "WORLD" item was used instead of "Serial 7s" because the former, but not the latter, appeared to differentiate between survivors and decedents.

In order to evaluate the extent to which the total scores and composite scores could accurately predict mortality status (survivors vs. decedents), binary logistic regression was conducted. The total score and composite score were assessed separately to obtain classification information. On its own, the composite score correctly identified 60.3% of the decedents, while the total score correctly identified 57.7% of the decedents. Classification information of each predictor is provided in table 7.

Accuracy of predicted group membership using total score and composite were compared using the McNemar Chi-square test. As suggested by Tabachnick and Fidell (2001), the McNemar Test is useful to determine if the addition of predictors improves classification rate. Results revealed that addition of other MMSE items to the model beyond the composite score did not improve the classification rate, which suggest that the composite score alone was sensitive to the effect of impending mortality.

[2] To deal with the violation of homogeneity of variance assumption, Welch's test was also conducted. However, there was no difference in the results obtained; hence for practical reason, values from the ANOVA were reported instead.

Table 7 Classification Information of the MMSE Total Score and Composite Score

	χ^2	*df*	*p*	% TP	% TN	% OH
Total score	6.41	1	.01	59.0	56.4	57.7
Composite score	6.32	1	.01	43.6	76.9	60.3

Note: TP = True Positive. TN = True Negative. OH = Overall Hit rate

Chapter VI

DISCUSSION

The goal of this study was to examine the influence of impending death on the MMSE. To this end, a retrospective, cross-sectional study, using data from the VLS, was designed to answer the following research questions: (a) Is the MMSE affected by mortality status and age? (b) How are individual items on the MMSE affected by impending death? (c) Do different causes of death similarly affect performance on the MMSE? This chapter starts with a discussion of the results and a consideration of their implications, in the order of the research questions. Results are compared to previous published studies presented in the introduction section. Where discrepancies are found, possible reasons for the discrepancies are explored. The chapter concludes by addressing the limitations of this study and suggesting directions for future research.

Is the MMSE affected by mortality status and age?

The results of the current study suggest that performance on the MMSE is affected by mortality status but not age. General cognitive functioning is lower among decedents than survivors regardless of age. Moreover, the mortality-related deficit is most pronounced within three years before death, a finding consistent with that documented in the literature (Hassing et al., 2002; Small et al., in press; Small & Backman, 1997).

Contrary to expectation, age did not contribute to performance on the MMSE. The young-old obtained similar total scores on the MMSE as the old-old. This contrasts with the existing literature, as performance on the MMSE is generally found to decline with age (Antsey, Matters, & Brown, 2000; Bleecker et al., 1998; Brown, Schinka, & Mortimer, 2003; Crum et al., 1993; O'Connor et al., 1989; Tombaugh & McIntyre, 1992). It is important to note, however, the age range in our sample is somewhat narrow (range = 63 to 95). In addition, the high level of education in this sample may serve as a possible buffer for any age-related effects. The literature suggests that education has a positive association with the MMSE, with increasing education associated with higher scores (Anthony et al., 1982; Antsey et al., 2000; Brown et al., 2003; Crum et al., 1993; Tombaugh et al., 1996). Therefore, the finding that the MMSE total score did not differ among the age groups in this study is likely a result of the narrow age range and high education ($M = 14.95$).

Cognitive performance has generally been found to differ as a function of age and mortality status (Bosworth & Schaie, 1999; Bosworth et al., 1999; MacDonald, 2002; Riegel & Riegel, 1972; White & Cunningham, 1988). For instance, Bosworth and Schaie (1999) reported mortality-related deficits among the old-old (more than 75 years old) but not among the young-old. Riegel and Riegel (1972), on the other hand, found a drop in performance among young-old (less than 65) decedents but not among young-old survivors; the drop in performance was observed in both the old-old survivors and decedents. Their results indicated that the young-old experience mortality-related deficits but not the old-old. Their findings were consistent with White and Cunningham's (1988) proposal that death among the young-old is determined by a specific state, while death among the old-old is random.

By contrast, we found mortality-related deficits across both age groups in our sample. Results from this study, therefore, are not in support of White and Cunningham's (1988) proposal. The difference may be due to the old age and high education of the participants in our sample. The average age of our young-old participants is about 75, and more than two-third of our young-old participants are older than 75. It appears that our results may be considered as somewhat similar to those reported by Bosworth and Schaie (1999), whose sample of old-old was greater than 75. A different age grouping and a less restricted sample may be needed to more clearly address this issue.

The number of years before mortality-related deficits can be observed has been a topic of debate in the literature. Past studies provided evidence that mortality-related deficits can be detected about 3 years before death (Hassing et al., 2002; Small & Backman, 1997; Small et al., in press). The current study revealed mortality-related deficits within 3 years of death, but it did not detect deficits among those who were further (3-5 years) from death. Our results, therefore, suggest that deficits due to impending death may not be observed more than 3 years before death. (Bosworth & Schaie, 1999; Johansson & Berg, 1989; Johansson & Zarit, 1997). However, given the insensitivity of the MMSE to mild impairment (Spreen & Strauss, 1998), subtle deficits present more than 3 years before death may not have been detected by the MMSE. The use of other measures that are sensitive to mild impairments may provide better information for the time to death analysis than the MMSE.

Smits and colleagues (1999) suggested that the effects of impending mortality on cognitive performance are pervasive. As the purpose of the MMSE total score is to measure general cognitive ability, our results appear to suggest that impending death exerts a pervasive influence. That is, lower MMSE total scores among the decedents represent a pervasive decline in cognitive ability due to impending death, particularly among those who are within 3 years to death. As our sample is somewhat old, our results provide support for Berg's model, where a general biological-system-breakdown leads to death among the old-old.

It is important to note, however, that our findings may be statistically significant but not clinically meaningful because the greatest difference between each mortality group was less than one point. Thus, the removal of impending death effects from a normative sample may not improve the utility of the MMSE. In fact, we found that the MMSE total score was not useful for classifying decedents and survivors. However, decline on the MMSE total score may be due to decrements in specific cognitive processes that may have diagnostic significance. Examination of performance on the individual items may provide some insight into where the deficits lie.

<u>How are the individual items on the MMSE affected by impending death?</u>

Contrary to the idea that impending death exerts a pervasive influence on cognition, as presented by the MMSE total score analysis, survivors and decedents performed differently on two items of the MMSE. Depending on their age group, decedents who died within three years after testing obtained lower scores than survivors and those who died between 3-5 years post measurement on the "WORLD" spelled backward item and the "copy pentagon" item. A third item, "delayed recall", would reach significance if not for the type 1 error correction. The "WORLD" item purports to measure attention/concentration, "copy pentagon" purports to measure visual construction, and "delayed recall" purports to measure episodic memory. Survivors and decedents performed similarly on the other items, including those thought to measure language.

The above results were obtained using the analysis of variance. These results were further supported by the use of binary logistic regression analyses. That is, addition of other items to the model as represented by the total score did not improve the classification of mortality status. In other words, only three out of 20 items on the MMSE accounted for the variability in the total score. These items include "WORLD", "delayed recall", and "copy pentagon". Participants seldom got other MMSE items wrong.

Items measuring attention/concentration and visual construction are thought to reflect fluid abilities. Past studies have also reported mortality-related deficits on fluid abilities (Hassing et al., 2002). In contrast, items measuring crystallized abilities such as language and orientation did not decrease with impending death. This is an unexpected finding, because most studies have indicated mortality-related declines among abilities that are typically well-preserved in old age (Bosworth & Schaie, 1999; Bosworth & Siegler, 2002; Small & Backman, 1999; White & Cunningham, 1988).

The reason for the discrepancy is not certain but may relate to the psychometric property of the individual MMSE items. Specifically, most of the MMSE items may be too simple to detect mild deficits related to mortality status (e.g. O'Connor et al., 1989). For example, the language items were reported to be highly insensitive to cognitive impairment (Feher et al., 1992). As well, the two items that revealed mortality-related deficits appear to require a high cognitive demand, consistent with Johansson and Zarit's (1997) suggestion that the greatest difference between survivors and non-survivors is seen on tasks that have high cognitive demand. Moreover, past research has not supported the use of individual items to represent specific cognitive domains (Giordani et al., 1990; Tierney et al., 1997). Given the limited success with the prediction findings, caution should be used to interpret the specificity of impending death influence using items on the MMSE.

We found that the "WORLD" item is affected by impending death, while "serial 7s" is not. That is, the "WORLD" and "Serial 7s" items appear not to be equivalent tasks, a finding suggested by others (Galasko et al., 1990; O'Connor et al., 1989). Thus, these items should be considered as separate measures of attention. Our findings suggest that the use of "Serial 7s" may reduce misclassification of cognitive impairment due to the negative influence of impending death.

Jefferson et al. (2002) study compared the MMSE profile of patients with Alzheimer's Disease (AD), Ischemic Vascular Dementia (IVD), and Parkinson's Disease (PD) and they found that patients with IVD obtained lower scores than AD patients on "copy pentagon" and "WORLD" items, similar to the performance of the decedents compared to the survivors in our study. The implication is that, impending death may originate from a vascular source. The final section considers whether cause of death provides insight into the source of the mortality-cognition association.

Do different causes of death similarly affect performance on the MMSE?

Despite suggestions in the literature that CVD contributes to decline in cognitive performance (Hertzog et al., 1978; van Boxtel et al., 1998), none of the cause of death analyses in this study revealed differences in performance of decedents on the MMSE as a function of CVD and non-CVD deaths. Thus, our results do not support Berg's (1996) suggestion that terminal decline is disease-related. As Berg suggested that such decline is typical among the young-old, the old age of our sample could explain the lack of fit with Berg's model.

It may well be that CVD does not have any influence on performance on the MMSE prior to death, consistent with the results reported by Small et al. (in press). Likewise, the MMSE is a simple measure of global cognitive functioning, and it may not detect the mild and specific deficits presented by CVD deaths. Several issues related to the sample may also explain the null finding. A dichotomous classification of CVD vs. non-CVD may not have captured the essence of the CVD influence. CVD is a complex entity encompassing numerous disturbances (e.g. hypertension, atherosclerosis, cardiac arrest) and their effects may be diluted by other CVD causes that do not contribute to the mortality-related influence. For example, myocardial infarction may not result in cognitive deficits. On the other hand, the graduate thickening of blood vessels (atherosclerosis) might have an impact. Additionally, the classification system may be faulty. The literature suggests that diabetes may contribute to deficits due to mortality status; however, it was classified as a non-CVD in this study, and was not studied exclusively because of a limited number of cases. These issues require additional study with a larger sample.

Limitations and future directions

Several limitations may moderate the value of this study. First, results cannot be generalized to the general population, as our sample is highly educated. A different profile due to impending death may emerge in individuals with lower education. However, it should be noted that if mortality-related deficits can be found in an elite sample, a greater magnitude of impending death influence may be present among those with less education, lending support to the significance of our study. Similarly, the fact that a mortality-cognition association was found even in a small sample size supports the robustness of the impending death phenomenon. Finally, the original sample was screened to exclude those with a MMSE total score less than 24. The results, therefore, do not represent a valid picture of the influence of impending death. Neurologically healthy individuals may obtain low scores on the MMSE because of non-neurological factors, and these individuals were excluded from the study. Thus, there was limited variability in the scores. Accordingly, a firm conclusion cannot be drawn as to the specificity of impending death on cognitive domains.

In spite of the limitations, results of the current study may encourage future research in the area of "impending" research. For example, Braekhus and colleagues (1995) noted worse performance on "Day", "WORLD", and "delayed recall" items among community-dwelling, healthy, old adults who developed dementia three years after baseline measurement than those who did not develop dementia. Our results showed worse performance on "WORLD" and "copy pentagon" items among those who died within 3 years after measurement than survivors. Consequently, it would be beneficial to compare the profile of decedents many years prior to death to that of individuals many years prior to a dementia within a sample. By looking at the differences in their profiles, it may be possible to distinguish between declines due to the impending death phenomenon and declines due to neurological compromise.

The individuals in our sample should be followed over a few years to plot their longitudinal profiles, in order to identify the pattern and rate of terminal decline. Studies may follow individuals who display an "impending death" profile to see if there is a conversion to a dementia, which may indicate that terminal decline is akin to preclinical dementia and a pathway to dementia.

There is evidence of the impact of diabetes on deteriorating cognitive function (Crooks, Buckwalter, & Petitti, 2003; Grodstein, Wilson, Chen, & Mason, 2001). Investigation of the effect of diabetes as a cause of death was not carried out here. Future studies may focus on diabetes as one cause of death and a source of mortality-related deficits.

In summary, low scores on the MMSE may not indicate compromised neurological integrity; instead, other factors such as impending death may account for a low score on the MMSE. Since both neurological and non-neurological factors may contribute to performance on the MMSE, clinicians and researchers are cautioned not to use the MMSE as a diagnostic tool for dementia, but rather as a brief screening measure to identify individuals who may benefit from more detailed assessments.

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Appendix

Items on the MMSE

Orientation	Points
What is the year?	1
What is the season?	1
What is the date?	1
What is the day?	1
What is the month?	1
What country are we in?	1
In which province do you live?	1
What city are we in?	1
What place are we in?	1
What street do you live on?	1
Registration of three words	
Repeat Apple, Penny, Table	3
Attention	
Serial 7s or spell WORLD backwards	5
Recall of three words	
Recall the names of the three objects learned	3
Language	
Name objects: pencil and watch	2
Repeat "No ifs, ands, or buts"	1
Follow the three-stage command: "Take the	3

paper

in your right hand. Fold the paper in half. Put

the paper on the floor.

Write a sentence of choice 1

Read and obey: "CLOSE YOUR EYES" 1

Visual Construction

Copy the design 1