

INTRODUCTION

The focus of the present study is on adaptive resource allocation in aging and Alzheimer's disease while performing a cognitive and a sensorimotor task simultaneously (i.e., dual-task performance). The central research question asks whether an adaptive prioritization of tasks critical to survival in a dual-task situation is preserved in Alzheimer's disease. Specifically, it was investigated whether patients suffering from Alzheimer's disease adaptively prioritize balance performance, which is considered critical to survival in old age, over cognition when the balance task is made more difficult. The argument is made that in Alzheimer's disease, as compared to normal aging, adaptive prioritization can be present despite a specific dual-task performance decrement, and independent of cognitive resources.

Dual-Task Performance in Aging and Alzheimer's Disease

Performing two tasks simultaneously (dual-task performance) is a frequent activity in human beings. Simple everyday examples stress the importance of dual-task performance for everyday functioning in aging (e.g., Park, 1999). Consider an older adult in her library standing on a ladder while searching for a book. In that specific context, a cognitive task (searching the shelves for a specific book) and a sensorimotor task (maintaining stable posture on the ladder) need to be coordinated simultaneously. There is general consensus that dual-task performance requires mental effort (Craik & Salthouse, 2000; Pashler, 1998). Numerous studies have suggested an age-related decline in the ability to perform two tasks simultaneously (for review, see Pashler, 1998).

A recent study on age-related differences in dual-task performance in a cognitive and a sensorimotor task has suggested an influence of task characteristics on dual-task performance. Li and colleagues combined a memory and a walking task; when walking was made more difficult, dual-task performance decrements increased in the cognitive as compared to the

sensorimotor task in older adults (Li, Lindenberger, Freund, & P. Baltes, 2001). Under the assumption that walking is considered a task of higher age-saliency (i.e., has a critical value for survival in old age¹) the results from this study have been interpreted as an adaptive process within the framework of selection, optimization, and compensation (SOC; P. Baltes & M. Baltes, 1990). Within the SOC framework, the notion of loss-based selection points to the concept that, in a situation of restricted resources, the selection or prioritization of specific tasks or life domains over others reflects adaptive behavior. On a micro-analytical level, this concept implies that biological losses with age and Alzheimer's disease may be contrasted with an increasing tendency to prioritize age-salient tasks (loss-based selection; compare Freund, Li, & P. Baltes, 1990). Such adaptive processes may have a considerable effect on dual-task performance with age.

In patients with Alzheimer's disease, the most common form of dementia presenting with deficits in memory (Morris, 1996) and attention (Perry & Hodges, 1999), dual-task performance decrements beyond those found in aging have been reported in a series of studies (Baddeley, 1986; Baddeley, Logie, Bressi, DellaSala, Spinnler, 1992; Baddeley, Baddeley, Bucks, & Wilcock, 2001). The question arises whether these deficits are general in nature, or whether too, in Alzheimer's disease, adaptive processes of resource allocation between tasks may be preserved. Effects of task-difficulty on the adaptive allocation of resources in patients with Alzheimer's disease, however, have not yet been investigated.

Generally, dual-task performance decrements can be expected when task demands are high and require an integrated system (Schneider & Pichora-Fuller,

¹ Falls are the primary etiology of accidental deaths in persons over the age of 65 years. The mortality rate for falls increases with age. One-third of the people over 65 living in the community and two-thirds of nursing home residents fall each year (Fuller, 2000). In Alzheimer's disease, there is a threefold risk for falls and injuries as compared to non-demented older adults (Buchner & Larson, 1987).

2000). Some researchers have argued that dual-task performance decrements should emerge only when combining two tasks that share the same resources, i.e., are from within one domain such as working memory (e.g. Baddeley, 1992; Wickens, 1998). Recent research suggests a strong connection between cognitive and sensorimotor variables with age (e.g., Anstey, Lord, & Williams, 1997; Anstey, Stankov, & Lord, 1993; P. Baltes & Lindenberger, 1997). Specifically, it has been shown that, with age, measures of general cognitive ability are strongly related to vision, hearing, and simple measures of gait and balance (Lindenberger & P. Baltes, 1994). In a study combining walking and a memory task in a dual-task paradigm, Lindenberger and colleagues further explored the connection between cognition and sensorimotor performance in an experimental setting. They were able to show that with advancing age, participants showed greater performance decrements in cognition when walking concurrently. The authors concluded that with age, sensorimotor performance is in increasing need of cognitive resources (Lindenberger, Marsiske, Freund, & P. Baltes, 2000).

However, conflicting explanations for the robust finding of dual-task performance decrements with age and in Alzheimer's disease have been put forth on a conceptual level. Attentional resource models (e.g., Kahneman, Ben-Ishai, & Lotan, 1973; Wickens & Kessel, 1980) have proposed that dual-task performance reflects the amount of cognitive resources needed for a given single-task, plus the amount of attentional resources that is required for the additional task. Limited attentional resources should thus lead to an additive decline in performance when adding a second task. Models of working memory introduced executive control as a modular component of dual-task performance (e.g., Baddeley, 1986; Shallice, 1988). In that context, executive control refers to the specific ability to allocate resources between two tasks (Lezak, 1983; Duke & Kaszniak, 2000). Baddeley (1986) proposed a specific deficit in executive control in patients suffering from Alzheimer's disease, and was able to specify this deficit in a longitudinal study (Baddeley et al., 1992). A specific deficit in

executive control should thus lead to a decline in performance beyond the effects of cognitive resources when adding a second task.

The conceptual controversy on dual-task performance with age and in Alzheimer's disease can be located within theories of normal and pathological cognitive aging. Alzheimer's disease has been conceptualized as a classical example for pathological cognitive aging, defined by specific neuropathological changes within the brain (Alzheimer, 1907; Burns, Jacoby, & Levy, 1990; M. Baltes, Kuhl, Gutzmann, & Sowarka, 1994). A recent study, however, has shown considerable overlap in the neuropathological changes in normal and pathological aging (MRC CFAS, 2001). Thus, pathological processes may exaggerate aging processes believed to be normal before Alzheimer's disease is clinically manifest (compare Sliwinski, Lipton, Buschke, & Stewart, 1997; Fozard, Metter, & Brant, 1990). Based upon such findings, it has been argued that Alzheimer's disease may be merely a form of accelerated cognitive aging (Horan & Pendleton, 1995). On a behavioral level, the concept of accelerated aging would be consistent with a linear decline in performance from older adults to patients with Alzheimer's disease. Such a prediction would be consistent with general resource models of dual-task performance (compare Wickens, 1998). On the other hand, a specific deficit in dual-task performance in Alzheimer's disease (compare Baddeley, 1992) would be consistent with an overadditive decrement in dual-task performance.

Beyond dual-task performance decrements in one domain, the comparison of dual-task performance in the two tasks performed simultaneously has been proposed as a way to measure the prioritization of one task over another. Specifically, using proportional dual-task costs as a metric for dual-task performance, the comparison of dual-task costs between the two task domains allows to identify the task in which smaller performance decrements occur. Differences in relative performance decrements between tasks can thus be interpreted as relative prioritization of one task over another (see Li et al.,

2001). From the perspective of models of successful aging, and more specifically, from the perspective of loss-based selection within the model of selective optimization with compensation (see Freund et al., 1999), the prioritization of balance over memory in older adults, and especially in patients with Alzheimer's disease, would indicate the presence of adaptive processes in these groups despite sizeable dual-task performance decrements.

Research Aims

The present work focussed on three questions central to the understanding of dual-task performance in aging and Alzheimer's disease. First, whether there is a specific deficit in dual-task performance in Alzheimer's disease. Second, whether effects of adaptive processes on dual-task performance emerge in Alzheimer's disease. Specifically, it was asked whether patients with Alzheimer's disease prioritize balance, a task critical to survival in old age, over cognition in a dual-task situation. Third, whether these effects are specific to Alzheimer's disease beyond the effect of cognitive resources.

To that end, in a first experiment, healthy young and older participants', and Alzheimer's patients' dual-task performance in a working memory task (N-Back; compare Dobbs & Rule, 1989) and a balance task was examined in a series of eight sessions. The difficulty of the balance task was continuously manipulated by introducing a balance condition that did not induce the risk of instability (standing as stable as possible on firm grounds) and a difficult condition that went along with some induction of sway (standing as stable as possible on moving grounds). Disproportional dual-task performance decrements were predicted for Alzheimer's patients as compared to healthy older adults. In the cognitive task, a disproportional dual-task deficit in Alzheimer's disease patients emerged. Results were interpreted with respect to concepts of resource models and models of executive control in dual-task performance. For the balance task, however, dual-task performance decrements decreased when the task was made more difficult. Results were interpreted based

upon the notion of loss-based selection from the framework of SOC, indicating that adaptive processes are present in dual-task performance in both older adults and Alzheimer's patients despite large dual-task performance decrements.

In a second experiment, older adults low on cognitive resources were tested using the same procedure as in Experiment 1. The aim of this experiment was to assess the effect of cognitive resources on dual-task performance in aging and Alzheimer's disease. Older adults low on cognitive resources were selected from a larger screening sample. Results were consistent with the prediction of a pattern of prioritization in Alzheimer's disease beyond the effect of cognitive resources. Specifically, overproportional decreases in dual-task performance in cognition, together with overproportional increases in dual-task performance in balance were found, indicating the preservation of an adaptive prioritization of balance over cognition in Alzheimer's disease patients independent of cognitive resources.

Overview of Literature Review

Following a review of biological and cognitive processes in normal and pathological cognitive aging, specifically Alzheimer's disease, concepts and empirical findings on dual-task performance with age and in Alzheimer's disease will be discussed. Results from a meta-analysis on dual-task performance in Alzheimer's disease will be presented. Informed by the finding of a strong connection between cognitive and sensorimotor functioning with age, empirical evidence regarding balance performance and changes in the postural system will be reviewed in normal aging and Alzheimer's disease. Based upon the framework of selection, optimization, and compensation (P. Baltes & M. Baltes, 1990), effects of task difficulty and adaptive processes on resource allocation in dual-task performance will be discussed. The theoretical background will then be integrated and restated more specifically.