3. OUTLINE OF THE STUDY

The primary goal of the present study was to examine how young and older adults allocate resources when performing a sensorimotor and a cognitive task simultaneously. To this end, the research question was: If a cognitive and a sensorimotor task are paired in a dual-task setting, do the two tasks interfere and if so, is the amount of this interference larger in older or in younger adults, in the cognitive or in the sensorimotor domain? The specific aim of the current research was to determine whether individuals are able to deliberately control the resource allocation when performing a sensorimotor and a cognitive task simultaneously. To this end, the research questions were: If deliberate control of resource allocation is possible, is it more pronounced in the cognitive or in the sensorimotor domain? What role does the increment of resource demands play for the ability to deliberately control resource allocation? Do young and older adults differ in this ability? In the following, I develop the research predictions of the current investigation. A list of hypotheses is provided at the end of this section.

Theoretical considerations as well as empirical research show that reduction in general and function-specific resources is especially pronounced in old age. Defining resources as processing speed, working memory, or general capacity, several studies could demonstrate age-related difference in performance. As dual tasks are supposed to demand more resources in comparison to single tasks, and, because of their limited capacity, older adults are especially penalized in situations where they have to perform two tasks simultaneously. That is why one of the predictions of the present study was that the decrease in performance of the dual task, relative to the single-task condition (i.e., dual-task costs) should be higher in older than in younger adults.

Previous studies reported dual-task interference as well as age-related differences in the amount of this interference for the concurrent performance of a sensorimotor and a cognitive task. The empirical picture of the domain-specific locus of the dual-task interference provided by these studies is inconsistent. Some authors found higher DTCs in the cognitive domain, whereas others obtained the opposite results. One of the reasons for this conflicting evidence might be the nature of the experimental tasks. Because measures of balance during quiet stance may be not representative for sensorimotor functioning, I included a balance task that allowed the measurement of body's equilibrium in a reactive mode. Specifically, using a balance platform that can produce controlled unpredictable perturbations (i.e., external disturbance to balance), balance threats were simulated and

participants were forced to react to them. By including a balance task with high ecological validity (i.e., an unexpected external disturbance of balance demanding quick reactive control of the body's equilibrium), I supposed that individuals anticipate possible losses due to falls and are therefore highly motivated to avoid them. According to the SOC-model, loss-based selection plays an important role in the face of anticipated losses. That is why dual-task costs were expected to be greater in the cognitive than in the balance domain. This domain-specific asymmetry should be more pronounced in the difficult condition, that is, when the system is pressurized to protect its stability. Given that the consequences of falls may be more dramatic for older than for younger persons, older participants in particular were expected to have higher dual-task costs in the cognitive than in the balance domain. In other words, older adults should prioritize balance. This behavioral pattern should be more pronounced in the difficult condition.

An alternative explanation for the inconsistency in findings with respect to the domain-specific asymmetry might be the fact that previous studies applied either the secondary task technique or the technique of equal prioritization of both tasks. Performance was measured in just one arbitrary condition of resource allocation and there was no control of the individuals' relative priorities in a dual-task situation. It is an open question whether adults are able to change their selected priorities when given instructions not only to perform both tasks equally well, but either to focus on the sensorimotor or the cognitive task.

From the developmental point of view, and particularly within the framework of the selective optimization with compensation model, resources are limited, but organisms have the capability to employ available resources in ways that produce desired developmental outcomes while minimizing undesired outcomes. Similarly, the cognitive perspective in general, and resource theories in particular assume that human capacity is finite, however, controllable and divisible. A good deal of research has demonstrated that individuals can deliberately control their mental resources (i.e., flexibly vary attentional emphasis according to instructions) if two cognitive tasks are paired. Therefore, participants of the present study should be able to adjust their cognitive performance to the differential emphasis in the instructions. Given that a more difficult task demands more resources, which are limited, I supposed the flexibility in resource allocation to be reduced in the difficult condition.

The question, however, of how flexible individuals can be in the sensorimotor domain has not yet been touched upon. Sensorimotor behavior in general and balance in

particular have been demonstrated not to be completely automatized, but rather abilities in which the cognitive system is strongly involved. Hence, one can expect a certain degree of flexibility in the sensorimotor domain. Nevertheless, it is also conceivable that balance belongs to the processes that are only to some extent cognitively accessible. Accordingly, I expected that the differential emphasis in the instructions has more influence on the cognitive performance than on the performance of the sensorimotor task.

Young and older adults differ not only in the amount of resources they possess but also in the efficiency with which they use their resources. The available findings from the cognitive research are inconclusive with respect to the ability of older adults to deliberately control their mental resources if two cognitive tasks are paired. There is empirical evidence that the flexibility of older adults is reduced and that this deficiency is more pronounced when tasks are more complex or demanding. For this reason, my hypothesis was that, in a dual-task situation involving a cognitive and a balance task, task-priority instructions would influence the performance of older adults less than the performance of younger adults. This pattern should be especially pronounced in the difficult condition.

Young and older adults differ in balance control (e.g., reacting appropriately to balance disturbances, being able to reverse movement direction rapidly), readiness to risk increased sway, and the consequences of falling. Given these age-related differences, one of the hypotheses of the present study was that there are age-group differences in the ability to deliberately control one's balance performance. The process of lifelong learning and the gradual adaptation to the biological changes and constraints should prevent older adults from changing their balance behavior according to the experimental instructions. Therefore, older persons should show adaptive behavior by focusing on and redirecting their resources to the sensorimotor task, regardless of instructional manipulations.

To this end, I conducted an experiment in which the performances in a balance and a reaction-time task were measured. My choice of the component tasks was motivated by two arguments. First, the experimental tasks should assess abilities that are particularly relevant in complex "real-world" situations. Therefore, I tried to find tasks that would possess some similarity to everyday life activities (e.g., reacting to hoots while crossing a busy street). Second, tasks should provide sensitive measures for assessment of a graded resource allocation. For this purpose the component tasks should be of a continuous nature (see Section 2.2.1.2 for the definition of continuous tasks) and should force the system to work in a reactive rather than a self-generated mode. That is why the two serial tasks, which are composed of many intermittent decisions and are regarded as a type of

continuous tasks, were included. The balance task consisted of standing on a dynamic force platform and maintaining upright stability despite unpredictable perturbations. The reaction-time task demanded quick and correct manual responses to acoustic stimuli presented via headphones. Eighteen young (mean age: 24.5 years) and 18 older (mean age: 75.9 years) participants performed the experimental tasks separately (i.e., single-task condition) and concurrently (i.e., dual-task condition).

In order to challenge the available resources, a difficulty condition was introduced to the study design. In the easy dual-task condition, the participants performed a one-choice reaction-time task while maintaining the body's equilibrium on the balance platform as it made unpredictable small perturbations. In the difficult dual-task condition, the participants performed a two-choice reaction-time task and simultaneously maintained balance, despite unexpected large perturbations of the balance platform. To investigate whether individuals are able to deliberately control the resource allocation, an experimental technique from resource theories – manipulation of task priorities within a dual-task context – was applied. In both dual-task conditions (easy and difficult), young and older adults were given three different instructions that varied in their emphasis: "Focus on Balance", "Focus on Reaction Time (RT)", and "Focus equally on both tasks (Equal Emphasis)". The single- and dual-task performances were practiced extensively.

In order to find out whether the manipulation of condition and difficulty worked, a 2 (age groups: young vs. old) x 2 (conditions: single- vs. dual-task) x 2 (difficulty levels: easy vs. difficult) mixed design was used. Age group was a between-subjects factor. Condition and difficulty level were within-subjects factors. To check whether the manipulation of instruction and difficulty worked, a 2 (age groups) x 3 (instructions) x 2 (difficulty levels) mixed design with age group as a between-subjects factor and instruction and difficulty as within-subjects factors was used.

In short, the underlying research strategy in the present study differs from previous work in the following respects: First, the influence of the task-emphasis manipulation on the simultaneous performance of the balance and the RT task was assessed. Second, the experimental manipulations of differential emphasis and varying difficulty were combined. As task novelty has been shown to play a crucial role in age-related differences in the performance of experimental tasks, the inclusion of single- and dual-task practice prior to the experimental assessment of task performance was another important component of this study. I will now summarize the empirical predictions of the present study.

I. How Do Individuals Allocate Resources in Dual-Task Situations?

1a: Domain-Specific Asymmetry in Resource Allocation

Level of Raw Scores

1a-1 In both the RT task and the balance task, young and older adults perform at a lower level in dual- than in single-task situations (main effect of Task).

1a-2 In both the RT task and the balance task, young and older adults perform at a lower level on a difficult than on an easy task (main effect of Difficulty).

1a-3 In both the RT task and the balance task, the performance of both young and older adults is at a lower level in a dual-task situation when the tasks are difficult (Task x Difficulty Interaction).

Level of Dual-Task Costs

1a-4 Dual-task costs in young and older adults are higher in the cognitive than in the balance domain (main effect of Domain).

1a-5 This domain-specific asymmetry is more pronounced in the difficult condition (Domain x Difficulty Interaction).

1b: Age-Related Differences

Level of Raw Scores

1b-1 In both the RT task and the balance task, older adults perform at a lower level than younger adults do in both single- and dual-task situations (main effect of Age Group).

1b-2 These age-related differences are more pronounced in the difficult than in the easy tasks (Age Group x Difficulty Interaction).

1b-3 These age-related differences are more pronounced in the dual-task than in the single-task situations (Age Group x Task Interaction).

1b-4 These age-related differences are even more pronounced in the dual-task than in the single-task situations when the tasks are made more difficult (Age Group x Task x Difficulty Interaction).

Level of Dual-Task Costs

1b-5 Dual-task costs are larger in older than in younger adults (main effect of Age Group).

1b-6 These age-related differences are more pronounced in the cognitive than in the balance domain (Age Group x Domain Interaction).

1b-7 These age-related differences are more pronounced in the cognitive than in the balance domain when the tasks are made more difficult (Age Group x Domain x Difficulty Interaction).

II. Can Individuals Deliberately Control Resource Allocation?

2a: Experimental Manipulation of Instruction and Difficulty in the Cognitive and Balance Domains

2a-1 Individuals can adjust their performance in the RT and the balance task according to the differential emphasis in the instructions (main effect of Instruction). This means that the poorest performance is in the task from which resources (e.g., attention, effort) is distracted, and the best performance is in the task to which resources are directed. Under the instruction "Equal Emphasis", the performance is on an intermediate level (a priori defined contrasts for the factor Instruction).

2a-2 Individuals can adjust their performance according to the differential emphasis in the instructions better when tasks are easy than when tasks are difficult (Instruction x Difficulty Interaction).

2a-3 Individuals can adjust their performance according to the differential emphasis in the instructions better in the cognitive than in the balance domain (Instruction x Domain Interaction).

2b: Age-Related Differences

2b-1 In comparison to older adults, younger individuals can better adjust their performance according to the differential emphasis in the instructions (Age Group x Instruction Interaction).

2b-2 These age-related differences are more pronounced with the difficult tasks than with the easy tasks (Age Group x Instruction x Difficulty Interaction).

2b-3 These age-related differences are more pronounced in the balance domain (Age Group x Instruction x Domain Interaction).