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Dual-Task – Immersion in the Interactions of Simultaneously Performed Tasks

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***Abstract*—**With a long history, dual-task has become one of the most intriguing research fields regarding human brain functioning and cognition. However, findings considering effects of task-interrelations are limited (especially, in combined motor and cognitive tasks). Therefore, we aimed at developing a measurement system in order to analyse interrelation effects of cognitive and motor tasks. On the one hand, the present study demonstrates the applicability of the measurement system and on the other hand first results regarding a systematisation of different task combinations are shown. Future investigations should combine imagine technologies and this developed measurement system.

***Keywords*—**Dual-task, interference, cognition, measurement.

I. Introduction

DUAL-TASKING has become one of the most intriguing research fields regarding human brain functioning and cognition. Since the initial findings of [1] in 1896 different experimental approaches have been developed. From a categorical point of view, one can distinguish between dual-tasking experiments using imagine techniques which focus on internal processes directly [2]-[4], and further approaches that analyse human behaviour in order to get information about the underling internal processes indirectly [5]-[7]. In contrast to a huge amount of experiments in this field, findings considering effects of task-interrelations are limited, particularly when considering the interdependencies of combining motor and cognitive tasks [8], [9]. As a consequence, a systematic analysis in face of motor and cognitive task interferences is lacking. With respect to generate a systematisation of these effects, we developed a measurement system in order to analyse interrelation effects of cognitive and motor tasks.

II. Methods

Nine healthy young women (age 22.4 ± 1.4 years) participated in this experiment. Prior to the experiment, each subject gave written informed consent to the experimental design. Subjects were asked to position themselves in a predefined distance of $d_S = 2.9m$ in front of a wall. The projected area was 2.95m x 2.22m. Two loudspeakers - placed in a distance of 1.05m behind the position of the subject - were used to apply the acoustic signals. To minimize any negative side effects, the room was darkened and the visual field of the subject was held in a monotonous white colour (Fig. 1).

Twelve cognitive tasks (Table I) with different task difficulties were presented via an auditive or visual stimulus. All cognitive tasks were combined with three different motor tasks (M1: sitting, M2: standing, M3: single-legged standing). Reaction time - measured by using two hand-triggers - was the outcome parameter. In order to avoid habituations and learning effects, task combinations and trials were presented in random order. All tasks were presented via an introductory slide in which task modalities were specified.

Before starting (with an initial trigger activation), participants were instructed to focus on the accuracy of answer as well as the reaction time. Furthermore, subjects should pay attention on both, cognitive and motor task, equally. Signals were set randomly with a duration of breaks between three to six seconds. The different cognitive tasks are characterised as follows:

Simple Reaction Tasks (visual: V1, auditive: A1) include a sequence of ten single signals (V1: black circle; A1: single ton).

Inhibition Reaction Tasks (visual: V2, auditive: A2) consist of two distinct signals which were presented in a total of 20 simple signals (ten signals plus ten inhibition signals). The subjects had to press the right trigger with the appearance of the first signal (e.g. blue circle) but not with the appearance of the second signal (e.g. red circle) (one trigger, right-handed) (Fig. 2).

Dichotomous Choice Tasks (visual: V3, auditive: A3) consist of two distinct signals which were presented in a total of 20 simple signals (ten respectively). The subjects had to press the right trigger with the appearance of the first signal (e.g. blue circle) and the left trigger with the appearance of the second signal (e.g. red circle) (two triggers, two-handed).

Combined Dichotomous Choice and Inhibition Tasks (visual: V4, auditive: A4) is composed of the procedure of V4/A4 and a third independent signal for which no action is expected (inhibition). Here, ten additional inhibition signals (V4: black circle; A4: single tone) were randomly added to 20 signals, consisting of letters or numerals.

Dichotomous Choice and Double Inhibition Tasks (visual: V5, auditive: A5) include an additional requirement to the “combined dichotomous choice and inhibition tasks”: When a vowel or an even numeral is presented, the left or the right trigger had to be activated, respectively. In case of consonants

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or odd numerals no action is expected (Fig. 2).

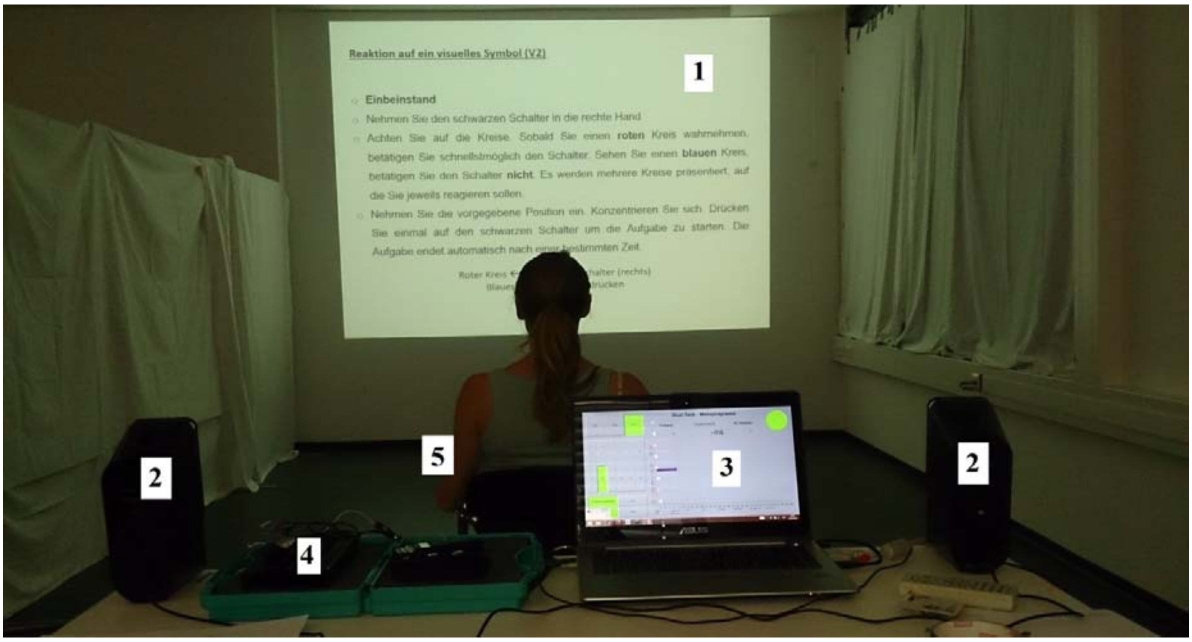

Fig. 1 Exemplary measurement condition. 1. Projected introductory slide, 2. Loudspeakers, 3. Measurement program and real-time signals, 4. Measurement box, 5. Lefthand Trigger and subject in seated position

TABLE I
DESCRIPTION OF THE VARIOUS COGNITIVE TASKS

Cognitive tasks		Task description	
		visual (V)	auditive (A)
V1 / A1	simple reaction task	appearance of a visual signal (black circle - trigger)	appearance of an auditive signal (tone - trigger)
V2 / A2	inhibition reaction task	appearance of distinct visual signals (blue circle - trigger; red circle - no action)	appearance of distinct auditive signals (high tone - trigger; low tone - no action)
V3 / A3	dichotomous choice task	appearance of distinct visual signals (blue circle - right trigger; red circle - left trigger)	appearance of distinct auditive signals (high tone - right trigger; low tone - left trigger)
V4 / A4	dichotomous choice and inhibition task	appearance of letters, numerals and a visual signal (letter - right trigger; numeral - left trigger; black circle - no action)	appearance of letters, numerals and a auditive signal (letter - right trigger; numeral - left trigger; tone - no action)
V5 / A5	dichotomous choice and double inhibition task	appearance of letters and numerals (vowel - right trigger; consonant - no action; even number - left trigger; odd number - no action)	appearance of letters and numerals (vowel - right trigger; consonant - no action; even number - left trigger; odd number - no action)
V6 / A6	mnemonic - dichotomous choice and double inhibition task	equivalent to V5 plus mnemonic task	equivalent to A 5 plus mnemonic task

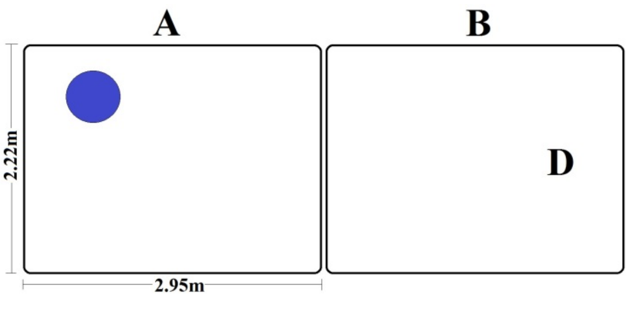

Fig. 2 Exemplary test slides. A: Test slide of V2. A blue circle is presented. B: Test slide of V5. A consonant is presented

Dichotomous choice with double inhibition tasks and additional mnemonic task (visual: V6, auditive: A6) is equal to the "dichotomous choice and double inhibition tasks" with a previous sequence of ten abstract words which had to be memorised. Subsequently, to the reaction task subjects were asked to recite as many words as possible.

III. RESULTS

The experimental setting enables to systematically vary and control task difficulty, order and combinations, respectively. Within the cognitive tasks, there is – as expected – an increase in reaction time with increasing task difficulty. Figs. 3 and 4 illustrate the development of the reaction time with respect to the three motor tasks. Considering the motor tasks, a small deterioration between M1 and M3 in A1 of 6.78% and 4.11% in V1 could be identified and a small improvement in the reaction time between M1 and M3 in both A6 (0,64%) and V6 (11,15%) became obvious (Tables II and III). Moreover f4 demonstrates that within each visual task condition an increase in the difference of reaction time occurs with increasing task difficulty.

Regarding the change in reaction time during the cognitive task, there is an increase of 113.75% in the auditive setting between A1 and A6.

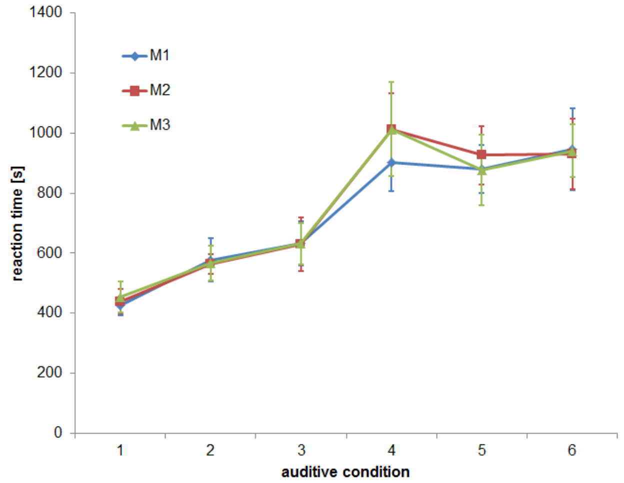

Fig. 3 Development of reaction time during the auditive-motor tasks. M1: motor condition 1 (sitting); M2: motor condition 2 (standing); M3: motor condition 3 (single-legged standing)

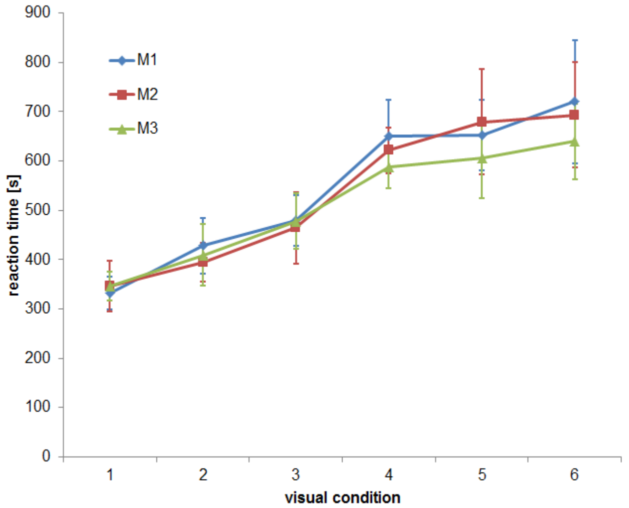

Fig. 4 Development of reaction time during the visual-motor tasks. M1: motor condition 1 (sitting); M2: motor condition 2 (standing); M3: motor condition 3 (single-legged standing)

TABLE II
REACTION TIMES IN THE AUDITIVE TASK (MEAN ± STANDARD DEVIATION)

Auditive	A1	A2	A3	A4	A5	A6
M1 [ms]	424,9 ± 30,7	577,1 ± 72,6	633,7 ± 74,1	903,7 ± 96,5	879,8 ± 80,7	947,1 ± 136
M2 [ms]	439,9 ± 51,8	563,6 ± 57,2	630,2 ± 69,4	1013,3 ± 157,1	926,3 ± 117,4	930,1 ± 87,3
M3 [ms]	453,7 ± 40,3	566,4 ± 32,3	631,5 ± 88,9	1012,9 ± 118,8	876,8 ± 96,7	941,1 ± 118,6

A similar result could be shown in the visual setting with an increase of 100.38% in the reaction time between V1 and V6. In both settings (auditive/visual) a shift in the reaction time between task 3 and task 4 could be identified independently of the motor tasks.

TABLE III
REACTION TIMES IN THE VISUAL TASK (MEAN ± STANDARD DEVIATION)

Visual	V1	V2	V3	V4	V5	V6
M1 [ms]	332,2 ± 33,8	428,2 ± 56,8	478,5 ± 51,3	650,5 ± 72,6	653 ± 71,3	720,1 ± 125,5
M2 [ms]	346,7 ± 51,9	394,9 ± 40	464,4 ± 71,8	621,4 ± 45,8	679,5 ± 106,9	693,7 ± 107,5
M3 [ms]	345,9 ± 29,3	409,3 ± 62,6	477,6 ± 56,5	588,4 ± 43,5	606,7 ± 81,8	639,8 ± 77,2

IV. DISCUSSION

The present experiment shown gives insight into the interactions of simultaneously performed motor and cognitive tasks. Concerning the different motor tasks, there was a change in the relation between these tasks with an increased task-difficulty in the cognitive situation which is in contrast to other findings. While [10] focused only on one cognitive task, our measurement system includes a test battery of twelve cognitive tasks in order to enable a more sensitive insight into the interrelations between the performed tasks and task difficulties. Using a similar cognitive task to our lowest difficulty task, [10] although showed a deterioration in the reaction time with increasing motor demand.

However, this structure changed with increasing cognitive task load, which signifies the necessity of a task systematisation in dual-task settings (i.e. modifying cognitive task difficulties under different motor tasks). The identified shift of the reaction time is a further phenomenon which probably indicates the inferior influence of unconscious tasks. Moreover it could be speculated that the shift is solely based on cognitive interferences. While task 1-3 are composed of singular (task 1) or binary (task 2 and 3) decisions, task 4-6 are based on at least three choices. Hence, the successive inclusion of further decision variables apparently leads to this nonlinear pattern in reaction time. A similar phenomenon is described in the field of synergetics in which state transition are responsible to explain shifts in brain functioning [11]. Further investigations have to concentrate on these aspects. As it has been used in other studies [12], [13], a combination of imagine technologies and the developed measurement system, should also be pursued.

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