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The effect of physical activity breaks, including motor-cognitive coordination exercises, on employees' cognitive functions in the workplace

Sabine Buuck[a], Stefan Voll[a] and Petra Jansen[b,*]
[a]*Institute of Applied Sport Science, University of Bamberg, Bamberg, Germany*
[b]*Faculty of Human Science, University Regensburg, Regensburg, Germany*

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Abstract.
BACKGROUND: The findings of the effectiveness of physical activity on adults' cognitive abilities have not yet been transferred into corresponding fields of application.
OBJECTIVE: The present study evaluates a motor-cognitive coordination programme in a company to improve employees' cognitive performance in the short and medium term.
METHODS: A total of 67 employees — 32 men and 35 women aged between 19 and 61 years — participated in this study, and 55 completed the study. The sample was randomly divided into an experimental group, which received a motor-cognitive coordination training, and a control group, which received a relaxation and mobility training. Both groups met for 15-minute sessions three times a week for eight weeks. Before and after the intervention, working memory, attention, information-processing capacity, divergent thinking, and mood were measured. In addition, acute effects regarding attention and mood were tested.
RESULTS: The results showed that the motor-cognitive coordination break improves working memory and divergent thinking after eight weeks of intervention, whereas neither the mood nor the information processing speed improved more for the experimental group compared to the control group. The results on the acute increase in attention performance failed to reach significance.
CONCLUSION: The new approach of this study was not only the derivation and development of targeted exercises, but also their testing and evaluation in the field of application. Motor-cognitive coordination exercise in the workplace might play an important role in both occupational health management and personnel development, especially for companies that are under highly competitive and innovative pressure.

Keywords: Exercise, workplace health promotion, coordination training, cognition, executive functions, working memory, divergent thinking

1. Introduction

Empirical evidence confirms the effectiveness of physical activity on adults' cognitive abilities [1–5]. However, the effects can vary greatly and must always be considered in relation to the type of cognitive abilities and the type, duration, and intensity of physical activity. Regarding the type of cognitive ability, primarily executive functions seem to benefit most from physical activity [3, 6]. Executive functions depend on neuronal activities in the prefrontal cortex [7] and play an important role concerning higher cognitive processes, including memory, planning, problem

*Address for correspondence: Prof. Dr. Petra Jansen; E-mail: Petra.jansen@ur.de, ORCID: 0000-0002-0973-2158.

solving, divergent thinking, inhibition, mental flexibility, and multitasking [8]. These skills are of crucial importance in everyday working life because they enable us to formulate and plan relevant goals and to carry out the intended actions successfully [9]. Therefore, the main goal of this study is to investigate whether physical activity can improve basic cognitive abilities of adults in an office workplace.

1.1. Working conditions

Reduced physical activity and increased mental workloads are typical in the office workplace. Studies have shown that increasing mental demands such as performance pressure, as well as the increasing complexity of work contents, can lead to cognitive impairments, including problems in executive functions and memory [10]. Furthermore, stress can affect the frontal brain since this area of the brain reacts very sensitively to external stimuli. Particularly working memory and cognitive flexibility can be impaired by stress [11]. This can have both short- and long-term effects [12]. As cognitive demands and stress increase, on the one hand, physical activity levels decrease, on the other hand. This decrease might have additional negative consequences for the quality of life [13]. Furthermore, nutrition and physical activity interventions improve work-related outcomes [14]. Thus, organisations might be aware that the implementation of appropriate interventions to enhance the psychological and productive working requirements are important, however there are contradicting results [15].

1.2. Physical activity interventions to promote employees' health

Workplace health promotion programmes are used to promote employees' well-being and job performance. These behavioural interventions integrate physical activity because of its assumed positive effects [16]. Here, a variety of intervention approaches can be differentiated to reduce sitting times or to stimulate increased physical activity, such as the use of active workstations [17] and pedometers [18], innovative building architecture to promote stair use [19], light-intensity cycling [20], or physically active breaks from work [21]. Physical activity breaks can be effective in improving productivity and performance [22, 23]. Even the integration of short exercise-promoting interventions increase productivity and promote social contacts, which have enormous individual and organisational benefits [24].

As mentioned above, basic cognitive function, such as executive functions, are relevant for higher cognitive processes, which are important in everyday working life. For example, a promotion programme for executive functions should take up the basic needs formulated by Diamond and Ling [25] and the multifaceted training stimuli emphasised by Moreau and Conway [26]. This leads to the combination of motor tasks with cognitive challenges to the application of a motor-cognitive coordination training.

1.3. Motor-cognitive coordination training

Regarding the type of physical activity, it has been found that motor-cognitive coordination training such as juggling, balancing, and dancing has a beneficial effect on neuroplasticity and executive function [27–29]. Especially easy-to-complete motor-cognitive tasks such as juggling and balancing (e.g., standing on one leg) that are easy to complete in the workplace are of high relevance in the context of work because there were no negative effects like sweating or having to change clothes. The combination of cognitive and motor tasks may further enhance those positive effects on cognition and executive function [26]. Automated movements that require additional thinking, planning, concentration, and problem-solving improved performance in executive functions in many intervention studies [30]. It is assumed that motor-cognitive coordination training, which combines, for example, balance, spatial orientation, rhythmic, and reaction time tasks, also effectively promotes brain structure and function and is thus associated with improvements in cognitive abilities and motor performance [31]. Two studies have examined motor-cognitive coordination training regarding acute cognitive effects in the workplace: First, Niederer et al. [32] concluded that a motor-cognitive workplace intervention should be adopted as an additional enhancement in terms of varied activity. Second, Jansen et al. [33] came to a similar conclusion that this type of intervention can be a useful supplement for working environments where specific cognitive function is essential.

1.4. The main goal of this study

To the best of our knowledge, no study has investigated the effects of motor-coordinative tasks on basic cognitive functions in a working environment. Therefore, it is the main goal of this study to develop and evaluate a feasible physical activity intervention in the workplace to enhance employees' cognitive functions. As Diamond [34] points out, executive functions must be constantly challenged to produce improvements. Therefore, the developed intervention programme consists of motor tasks with cognitive challenges. This combination of cognitive and motor tasks may further enhance basic cognitive functions. As an exploratory measurement, we also measured the mood of the participants, which is related to cognition [35]. The developed intervention follows the SMART-goal approach because it was specific (elements of motor-cognitive coordination exercises), measurable (the improvement could be measured with standardised tests), attractive (a motor-cognitive coordination training is much more attractive than, for example, a running training), realistic (simple motor-coordinative exercises could be better integrated in the workplace compared to a sweetening training), and terminable (the physical activity breaks could be scheduled during the working day).

We hypothesised that the experimental group (EG), which received the motor-cognitive coordination exercises, would show greater improvement in basic cognitive functions such as working memory, attention, and divergent thinking compared to the control group (CG), which received a stretching and relaxing intervention for eight weeks. Furthermore, the acute effect on attention and mood was measured after one single intervention.

2. Materials and methods

2.1. Participants

This study was carried out in a company that develops premium products in the home entertainment sector in Germany. The sample consisted of German-speaking employees from the development department, quality assurance, and technical customer service. Participants were made aware of the study via information posters, flyers, and an internal e-mail distribution list. The study was conducted according to the ethical guidelines of the Helsinki Declaration. All participants gave their written consent for participation.

A total of 67 employees, including 32 men and 35 women aged between 19 and 61 years (M = 40.78; SD = 10.95), participated in this study. The sample was randomly divided into an EG (N = 36), which received a motor-cognitive coordination training, and a CG (N = 31), which received a relaxation and mobility training. The randomisation was done with the help of a random generator (https://pickerwheel.com/tools/random-team-generator/). Both groups had to complete a total of 24 training units within eight weeks. To determine the effectiveness of the exercise programmes, a 75% attendance rate was set, which corresponds to 18 active training sessions. Twelve participants (5 m/7 w) (six persons from each group) had to be excluded from the analysis. Seven participants completed only the pre-test and did not show up to the first training session, and three participants did not participate in the post-test measurement. Furthermore, the data of two participants for the pre-test were incomplete due to technical problems. This corresponds to a dropout rate of 17.9%. There were no exclusion criteria, so all members of the company who wanted to participate got the chance to do so. Participants did not know whether they were in the EG or CG.

The study includes the investigation of acute as well as medium-term effects, which means the effects after a training of eight weeks. The data of 60 test participants (29 men/31 women) could be included in the investigation of short-term effects (t2 and t3, see Fig. 1). Thirty-three participants (15 m/18 w; 41.58 years; SD = 11.4) of the EG and 27 (14 m/13 w; 38.67 years; SD = 11.1) of the CG participated in the first intervention. For the investigation of the medium-term effects (t1 and t4), the data of 55 test participants (27 m/28 w) were considered. Thirty individuals (13 m/17 w; M = 42.37 years; SD = 11.05) participated in the EG three times a week for 15 minutes. Twenty-five participants (14 m/11 w; M = 40.0 years; SD = 10.38) formed the CG. With a small-medium effect size of f = 0.20, an alpha-level of p = 0.05, a power of 1-ß = 0.9, and a correlation among repeated measurements of 0.6, a power analysis with G*power for the repeated measurement ANOVA resulted in N = 56 to detect significant differences between the EG and CG from the pre-test to post-test [36].

2.2. Materials

2.2.1. Attention: D2 attention test

The d2 attention test [37] determines the ability to focus on a stimulus while suppressing awareness of distracting stimuli. During this paper-and-pencil cancelation test, participants were instructed to mark all letters "d" tagged with two dashes among distractors (a "d" with more or less than two dashes, and "p" characters with any number of dashes). For each line, the participants have 20 seconds of processing time. The total test time is four minutes and 40 seconds. Dependent variables are the total number of answers (GZ), the number of all errors in relation to the total number of answers (F%), and the standardised number of correct answers minus errors of confusion (concentration-performance index, SKL). According to Brickenkamp [37], the test has high internal consistency ($\alpha = 0.95$) and retest reliability ($r > 0.80$).

2.2.2. *Affect: Positive and Negative Affect Scale*

The Positive and Negative Affect Scale (PANAS) [38] is an instrument for describing the current subjective state of mood. The PANAS questionnaire consists of a total of 20 adjectives expressing different moods that can be assigned to a positive and a negative scale. Each scale includes ten adjectives that represent the positive state of mind (e.g., active, interested, excited) and the negative state of mind (e.g., worried, angry, guilty). Each of the adjectives must be rated from the respondent on a five-level scale (1: very little or not at all; 2: a little; 3: fairly; 4: considerably; 5: extremely) regarding the current mood. The values are added within the positive and negative scales. The "positive state" (PANAS *pos*) and the "negative state" (PANAS *neg*) are recorded as dependent variables. Cronbach's alpha was 0.88 for the positive affect scale and 0.87 for the negative affect scale [39].

2.2.3. *Verbal working memory: Digit-Span Test (forward and backwards)*

Working memory performance was assessed with the Digit-Span Test (forward and backwards), which is part of the Hamburger–Wechsler Intelligence Test for adults (HaWIE-R) [40]. Participants had to repeat a sequence of digits read aloud by the investigator in identical order (forward version) and then in reverse order (backward version). The sequence of numbers was supplemented by one digit after each task. The investigator presents numerical sequences with a maximum of nine digits. Each task of the number span test consists of two attempts, each of which is evaluated with 0 (wrong) or 1 (right). A maximum of 14 points can be achieved. An incorrect reproduction of both number sequences within an item leads to the abortion of the first part of the test. This first part covers attention efficiency and capacity. In the second part, the presented number series must be repeated in reverse order, for example, backwards. This is an executive task particularly dependent on working memory and requires more complex operations of information processing. A total of 14 number series are presented again. The maximum length of the number series persists from eight characters. Both parts of the test are scored as one summary value. The value points are considered a dependent variable, which result from the maximum number of points of the two single (forward and backward) tasks. The split half reliability for the forward task is 0.76; for the backward task it is 0.78 [40].

2.2.4. *Information processing capacity: Digit-Symbol Test*

Information-processing capacity was assessed with the Digit-Symbol Test (DST) of the German version of the Wechsler Intelligence Scale for adults (HaWIE-R) [40]. The DST is a paper-and-pencil test that corresponds to a coding task in which numbers and symbols are paired by an assignment key. Each participant must compare symbols with numbers according to a key and then copy the symbol into the spaces below a series of numbers. The number of correct symbols within the given time, usually 90 to 120 seconds, is the result. The procedure takes about four minutes. The maximum number of points is 93, and the evaluation is based on the correctness and speed of the assignment. The number of correct number-symbol assignments is used as a dependent variable. For the subtests, the internal consistencies [40] are between $r = 0.71$ and $r = 0.96$.

2.2.5. *Divergent thinking: Phonemic verbal fluency – Regensburger Wortflüssigkeitstest*

The Regensburger Wortflüssigkeitstest (RWT) [41] measures the ability to think divergently. Divergent task structures represent open problems for which as many different solutions as possible should be found [42]. The test consists of a formal lexical and a semantic task. For both tasks, participants were asked to verbally generate as many different words as possible according to given conditions. In the first test, the letter "S" was given (RWT I). The second part of the task involved the alternating recitation of words beginning with the letters, "G" and "R" (RWT II). In the follow-up measurement, the letter "K" was given for the first task and the letters "H" and "T" for the second task. Test participants worked on different test tasks at both measuring times. The formal lexical area was checked at the first test time by enumerating words with the initial letter "S". The letter "K" was used for the post-measurement. It can be assumed that the generation of words with one of the letters is generally easier. To relativise this heterogeneous requirement, the raw values were transferred to percentile ranks and considered descriptively. The analysis of variance (ANOVA) requires interval scaling. For this purpose, the determined percentile ranks were transformed into z-values for further analysis. The change of letters represents an additional requirement for reactive cognitive flexibility. The number of words correctly named within two minutes was given in the percentile ranks based on the norm sample and included in the evaluation as a dependent variable. The retest reliability over three weeks varied between rtt = 0.72 and rtt = 0.89 for the individual subtests [41].

2.2.6. *Training sessions: Motor-cognitive coordination exercises (EG)*

After an extensive literature review of the effect of an active break in the workplace [43] and following the study by Jansen et al. [33], the motor-cognitive coordination training was developed by Buuck [43]. In the newly developed programme, some elements of the study by Jansen et al. [33] were used and partly improved. Each active work break contains basic motor components with the possibility of cognitive components such as counting, naming, and categorising words, or perceiving visual, tactile, or acoustic signals and inhibiting or reacting accordingly. The use of different materials ensures a great number of variations. The complex learning of movements is carried out by means of versatile exercises from the field of sensory training and requires constant updating of the working memory regarding existing experiences, mental flexibility, and impulse control. The additional external stimuli perceived via the senses are processed in interaction with the muscles, which leads to motor realisation. The exercises also integrate the sensitisation of different types of perception with corresponding tasks: visual perception (e.g., different optical stimuli should lead to different answers, looking at one point and perceiving peripheral things visually, etc.; eye gymnastics, moving the eyes in different directions, closing the eyes, perceiving signs), acoustic perception (acoustic signals, rhythms and melodies), tactile perception (mostly in the form of partner exercises: touching, massaging, pressing, pushing, pulling), kinaesthetic perception (change of direction, rotational acceleration, head movements; different force doses; different widths, distances, materials), and static and dynamic perception (instability, one-legged stand, various support surfaces: soft, firm, wobble, bobble).

The following is a sample task: Two people face each other and walk on the spot. They are given the task to count to "three" alternately. Person A counts "one", Person B counts "two", Person A counts "three", and then Person B counts "one", and so on, while they walk. In the next step, the number "one" is replaced by two jumping jacks. The task starts again from scratch. But instead of Person A saying the number "one", she/he must perform two jumping jacks. So, the person must inhibit and not say the word but express it by movement. One after the other, numbers are replaced by movements and combined differently.

Progressive improvement is carried out according to methodological–didactic principles: from easy to difficult, from the known to the unknown, from simple to complex, from stable to unstable support surface, from visually controlled to visually independent movement, from standardised to variable conditions. An overview of the different tasks is presented in Table 1.

2.3. *Stretching and relaxation sessions (CG)*

An active work break with stretching and relaxation exercises was chosen as the control programme. The participants took part in this programme three times a week for 15 minutes. Each unit had the same schedule. At the beginning of each unit, a short yoga exercise was always performed. Afterwards, different muscle groups were stretched under the supervision of the instructor. At the end, a relaxing exercise was performed. The flexibility exercises were based on the Booster Break programme from Taylor et al. [21, 44]. Each session consisted of four main phases: warm-up, stretching, cool-down, and relaxation. The focus of the session was on movement and stretching and was designed to enhance participants' flexibility and relaxation in a socially supportive context. Each session ended with a quiet time for visualisation and self-enhancement [44].

2.4. *Procedure*

To assess the short-term effects, the d2 and the PANAS scale were used as a group test immediately before the first training session (t2) with the respective groups. Directly after the first unit, the participants worked on the d2 and PANAS again (t3). For the measurement of the medium test effect, each participant

Table 1
Progressive structure and variety of the physical activity programme

Sequence/ condition task	Task	Motor execution	Exercise	Target area
1 **Introduction of basic movement patterns**	Unilateral, bilateral, cross-coordinated movements	Sitting Standing Walking Change of direction Change of pace Stabilise Throwing Catching	***1.1 "Up and down"*** ***1.2 "Back and forth"*** ***1.3 "Back and forth II"*** ***1.4 "Crisscross"*** ***1.5 "Stop and go"*** ***1.6 "Jumping jack2.0"*** ***1.7 "Forward - backward ball"***	Movement experience Joy of movement Readiness for activity Curiosity
2 **Perception training**	Perceiving and processing visual and acoustic signals	Sitting Standing Walking Change of direction Change of pace Stabilise Throwing Catching (execute after signal processing)	***2.1*** "***React***!" ***2.2 "Leap of faith"*** ***2.3 "Touch and go"*** ***2.4 "Flying ball"*** ***2.5 "Switch"*** ***2.6 "HipHop"***	Curiosity Reaction Attention Working memory Mental flexibility Processing speed Inhibition
3 **Rhythm training**	Perceiving rhythm and implementing and maintaining it in movement	Clapping Marching Jumping Bouncing	***3.1*** "***Jump***" ***3.2*** "***Rhythm***" ***3.3*** "***Tempo***" ***3.4*** "***In*** & ***out***" ***3.5*** "***Rhythm ball***" ***3.6*** "***Pendulum***"	Movement experience Joy of movement Joy of being active together Rhythmisation Inhibition Mental flexibility Processing speed Update
4 **Complex motion sequences**	Perform basic movement patterns smoothly under conditions 2 and 3	Sequences of steps Rotary motion Lateral movement Movement flow	***4.1*** "***Corporate dance***" ***4.2*** "***Movement chain***" ***4.3*** "***X***" ***4.4 Update***"	Concentration Working memory Creativity Mental flexibility
5 **Reaction and inhibition**	Perform or suppress movement	Perform basic motor movements or suppress and/or replace the execution	***5.1*** "***1,2,3***" ***5.2*** "***Stop it***!"	Reaction Inhibition, impulse control Attention
6 **Balance training**	Balance, maintaining balance under variable conditions Static, dynamic stable, unstable base	One legged stand Unstable support surface Intermuscular coordination	***6.1 "Balance*** ***6.2 "Bar turner"*** ***6.3 "Twister"*** ***6.4 "Statico-dynamico***" ***6.5 "Juggling 5"***	Balance ability, concentration, body awareness
7 **Fine motor skills**	Execute movement purposefully with a high degree of accuracy	Finger and hand games Foot gymnastics	***7.1*** "***Fingertip***" ***7.2*** "***Tip top***" ***7.3*** "***Targeting***"	Ability to differentiate
8 **Social interaction exercises**	Performing movement with each other, with partner/group	Simultaneous, mirrored, synchronous movements	***8.1*** "***Synchro time***" ***8.2*** "***Mirror***"	Joy in moving together, Communication, intellectual flexibility
9 **Juggling**	Learning the cascade and other tricks	Pre-exercise Practice Tricks	***9.1 "Juggling 1"*** ***9.2 "Juggling 2"*** ***9.3 "Juggling 3"*** ***9.4 "Juggling 4"*** ***9.5 "Juggling 5"***	Working memory, mental flexibility, creativity

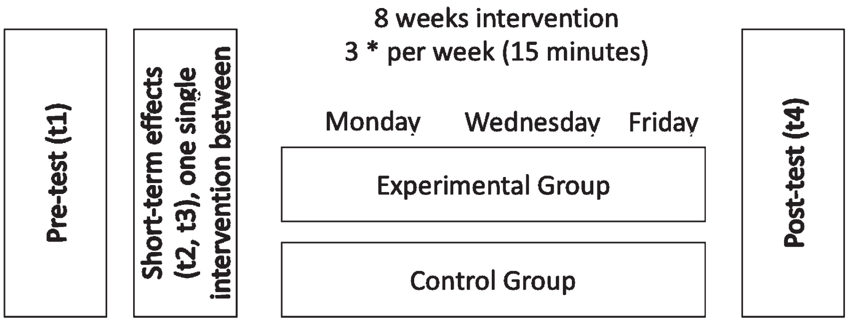

Fig. 1. Timetable of the procedure.

completed the various tests under the supervision of a test supervisor in a quiet, well-ventilated room in the company building (t1). The tests were always performed in the same order: d2 attention, Digit-Span Test, PANAS, RWT, and DST. The individual tests lasted about 40 minutes. All tests were conducted in one of two quite rooms of the company so that the environment was the same for all participants. The tests were administered by trained student assistants of the research institute. The students were carefully trained by the supervisor of the study and did not know which group the participants belonged to. At the end of the eight-week intervention phase, the participants were tested again in individual sessions (t4) (see Fig. 1).

The participants were randomly assigned to the EG and CG. Both groups took part in the interventions three times a week for 15 minutes. On Mondays, Wednesdays, and Fridays, the programme was offered to the employees both in the morning and in the afternoon. The programme was offered several times a day (eight identical units in total). This gave employees the opportunity to spontaneously select the most suitable date from many available dates and to take the best time for their break. All exercises could be completed in normal clothes. All training sessions were taught by one female trainer who developed the tasks and had a lot of experience (15 years) in teaching physical exercises as a fitness instructor (CrossFit trainer, weightlifting coach, etc.). She was not blinded regarding the EG and CG. Possible training effects at home were not controlled for.

2.5. *Statistical analysis*

Regarding short-term and medium-term effects, which means after the 8 weeks training, this study had a pre–post design with two different groups, an EG and a CG. Statistical data analysis was performed using IBM SPSS Statistics 23. A 2×2 mixed factor ANOVA was used to test for differences between pre- and post-test (within factor TIME) and differences between the EG and the CG (between factor GROUP). The dependent variables were represented by the dependent test variables of the respective test procedures. All analyses were performed after checking the underlying assumptions (variance homogeneity, normal distribution) for parametric testing. The application prerequisite for variance analyses is therefore given. For all analyses performed, the significance level was set at $p <= 0.5$. The effect sizes are determined by means of variance analysis and classified into small ($\eta^2 \geq 0.01$), medium ($\eta^2 \geq 0.10$), and strong effects η^2 (≥ 0.25). Partial eta square was presented.

3. Results

3.1. *Results on short-term effects*

The descriptive values for each group and each measurement point are given in Table 1.

3.1.1. *Attention*

Two participants had to be excluded from the analysis of the d2 attention test because pre-test data were missing. The analysis revealed a significant main effect of the factor TIME for the variable GZ of the d2 attention test ($F(1,56) = 144.91$, $p < 0.001$, $\eta^2 = 0.72$). Both groups showed an improved working speed, but the interaction effect between TIME and GROUP was not significant ($F(1,56) = 1.14$, $p = 0.29$, $\eta^2 = 0.02$). The main effect of GROUP also was not significant ($F(1,56) = 0.229$, $p = 0.634$, $\eta^2 = 0.004$).

For the measurement of the number of all errors in relation to the total number of answers

(F%), both groups worked more carefully and are less prone to errors ($F(1,56) = 23.91$, $p < 0.001$, $\eta^2 = 0.29$). However, neither the group effect ($F(1,56) = 0.229$, $p = 0.634$, $\eta^2 = 0.004$) nor the interaction effect between TIME × GROUP became significant ($F(1,56) = 3.33$, $p = 0.07$, $\eta^2 = 0.05$).

Regarding the concentration performance score, SKL, there was a main effect of TIME ($F(1,56) = 296.41$, $p < 0.001$, $\eta^2 = 0.84$) but not of GROUP ($F(1,56) = 1.12$, $p < 0.001$, $\eta^2 = 0.02$). However, the interaction between TIME × GROUP was significant ($F(1,56) = 7.20$, $p = 0.01$, $\eta^2 = 0.11$). The SKL increased in the EG from $M = 104.19$ ($SD = 6.16$) to $M = 112.72$ ($SD = 7.50$), and in the CG it increased from $M = 103.5$ ($SD = 6.16$) to $M = 109.73$ ($SD = 7.50$).

3.1.2. Mood

PANAS pos. There was a main effect of TIME ($F(1,58) = 179.17$, $p = 0.000$, $\eta^2 = 0.76$) but no significant main effect of GROUP ($F(1,58) = 2.64$, $p = 0.10$, $\eta^2 = 0.04$). However, the interaction between TIME × GROUP was significant ($F(1.58) = 4.55$, $p = 0.04$, $\eta^2 = 0.70$). The interaction was due to the fact that both groups did not differ in the pre-test ($t(58) = 0.34$; $p = 0.73$) but in the post-test ($t(58) = 2.98$; $p = 0.004$). The EG improved more ($M = 6.33$; $SD = 1.08$) than the CG ($M = 4.60$; $SD = 1.15$).

PANAS neg. The observation of the mean values shows an improvement from pre- to post-measurement for both groups, which was confirmed by the main effect of the factor TIME ($F(1,58) = 49.62$, $p < 0.001$, $\eta^2 = 0.46$). The interaction effect between TIME × GROUP was not significant ($F(1,58) = 0.103$, $p = 0.75$, $\eta^2 = 0.002$). There was no significant result for the group comparison ($F(1,58) = 0.47$, $p = 0.49$, $\eta^2 = 0.008$).

3.2. Results on medium-term effects

The descriptive values for each group and each measurement point are given in Table 2.

3.2.1. Attention

The analysis revealed a significant main effect for the factor TIME for the variables GZ ($F(1,53) = 71.78$, $p < 0.001$, $\eta^2 = 0.57$), F% ($F(1, 53) = 14.29$, $p < 0.001$, $\eta^2 = 0.21$), and SKL ($F(1,53) = 77.18$, $p < 0.001$, $\eta^2 = 0.59$), pointing to improved performance in working speed and concentration performance. Both groups work more carefully and were less prone to errors from pre- to post-test. For the factor GROUP, however, the inferential statistical analysis showed no significant effect for any variable ($p > 0.05$). Furthermore, the analyses showed no interaction between the factors TIME × GROUP for GZ ($F(1,53) = 0.015$, $p = 0.903$, $\eta^2 < 0.001$), F%, ($F(1,53) = 0.025$, $p = 0.874$, $\eta^2 < 0.001$), and SKL ($F(1,53) = 2.44$, $p = .124$, $\eta^2 = 0.044$).

3.2.2. Mood

PANAS pos. The mean values of the variable PANAS pos. remain approximately unchanged for both groups over the intervention period. Accordingly, there was no main effect for the factor TIME ($F(1,53) = 1.97$, $p = 0.17$, $\eta^2 = 0.036$). There was no main effect of the factor GROUP ($F(1,53) = 0.54$, $p = 0.46$, $\eta^2 = 0.010$), and the interaction between TIME × GROUP ($F(1,53) = 0.12$, $p = 0.72$, $\eta^2 = 0.002$) showed no significant effects.

PANAS neg. The observation of the mean values showed an improvement from pre- to post-measurement for both groups for the factor TIME ($F(1,53) = 46.36$, $p < 0.001$, $\eta^2 = 0.47$). The interaction effect between TIME × GROUP was not significant ($F(1,53) = 0.21$, $p = 0.65$, $\eta^2 = 0.004$).

Table 2

Means and standard deviation of the pre- and post-test for the d2 and PANAS test score for each group (short-term effects)

Measure	Pre-test *M (SD)*		Post-test *M (SD)*	
	EG	CG	EG	CG
Attention (d2)				
SKL	104.19 (7.57)	103.50 (6.16)	112.72 (7.50)	109.73 (5.14)
GZ		480.96 (52.48)	538.38 (63.74)	526.31 (59.67)
F%	3.91 (3.08)	3.57 (3.67)	1.71 (1.23)	2.57(2.02)
Affect (PANAS)				
PANAS pos	29.67 (3.90)	29.33 (3.55)	36.00 (2.82)	33.93 (2.48)
PANAS neg	13.76 (3.33)	13.26 (3.09)	11.36 (1.74)	11.07 (1.23)

Notes: M = means, SD = standard deviation, SKL = the standardised value of the number of correct responses minus errors of confusion, GZ = total number of responses, F% = the number of errors related to the total number of responses.

There was also no significant result for the factor GROUP ($F(1,53) = 0.28$, $p = 0.64$, $\eta^2 = 0.004$).

3.2.3. Verbal working memory

The overall ANOVA showed a main effect for the factor TIME ($F(1,53) = 52.67$ $p < 0.001$, $\eta^2 = 0.49$), indicating that the participants improved from pre- to post-test. There was no main effect of the factor GROUP ($F(1,53) = 1.12$, $p = 0.294$, $\eta^2 = 0.021$). Moreover, there was a significant interaction between the factors TIME × GROUP ($F(1,53) = 5.30$, $p = 0.02$, $\eta^2 = 0.09$), which can be attributed to the greater improvement in the EG compared to the improvement in the CG (see Fig. 2). Both groups did not differ in the pre-test ($t(53) = 0.34$; $p = 0.77$), but they almost differed significantly in the post-test ($t(58) = 1.88$; $p = 0.06$).

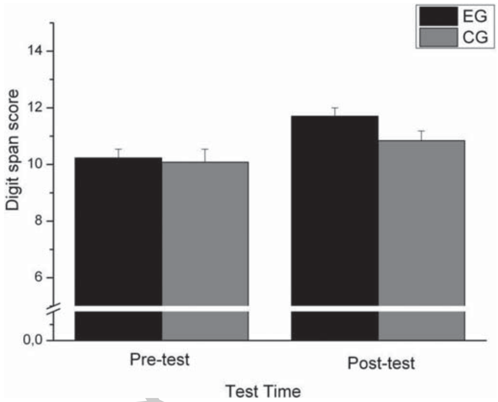

Fig. 2. Performance improvements (mean, standard error) in the Digit-Span Test (DS) from pre- to post-test for the experimental group (EG) and the control group (CG).

3.2.4. Information-processing capacity

The analysis revealed a significant main effect for the factor TIME ($F(1,53) = 74.77$, $p < 0.001$, $\eta^2 = 0.59$), indicating that participants improved from pre- to post-test. However, no interaction between TIME × GROUP ($F(1,53) = 0.480$, $p = 0.491$, $\eta^2 = 0.009$) and no effect of GROUP ($F(1,53) = 1.14$, $p = 0.291$, $\eta^2 = 0.021$) could be detected.

3.2.5. Divergent thinking

First of all, there were no significant group differences ($t(53) = 0.48$; $p = 0.31$) for the first test ($t(53) = 0.57$; $p = 0.28$) nor for the second task “letter change” at the first measurement time, and thus there was a homogeneous starting point for both groups.

There were no main effects for TIME or GROUP for both tests (all $p > 0.13$). Whereas the interaction effect TIME × GROUP is not significant for RWT I ($F(1,53) = 1.35$, $p = 0.25$, $\eta^2 = 0.025$), a significant interaction effect for the factors TIME × GROUP ($F(1,53) = 5.57$, $p = 0.02$, $\eta^2 = 0.095$) was shown for RWT II. Both groups did not differ in the pre-test ($t(53) = 0.45$; $p = 0.65$) but in the post-test ($t(53) = 2.51$; $p = 0.01$). The EG improved more than the CG ($t(53) = 2.52$; $p = 0.015$) (see Fig. 3).

Table 3
Means and standard deviation of the pre- and post-test for the RWT, d2, PANAS, DS, and DST test score for each group (medium-term effects)

Measure	Pre-test *M (SD)*		Post-test *M (SD)*	
	EG	CG	EG	CG
Verbal fluency				
RWT I	21.9 (5.47)	21.2 (5.23)	24.1 (6.30)	21.64 (5.23)
RWT II	20.67 (4.93)	19.88 (5.28)	23.07 (4.63)	19.84 (4.54)
Attention (d2)				
SKL	98.03 (7.72)	97.20 (10.72)	109.03 (10.72)	104.88 (9.14)
GZ	423.50 (79.85)	416.28 (67.18)	493.13 (102.08)	487.96 (75.28)
F%	6.32 (7.89)	5.28 (3.45)	4.70 (7.94)	3.79 (3.66)
Affect (PANAS)				
PANAS pos	32.73 (5.31)	32.04 (4.39)	33.80 (5.25)	32.68 (5.09)
PANAS neg	17.13 (4.35)	16.48 (4.30)	13.33 (3.15)	13.16 (2.89)
Verbal working memory (DS)				
Digit span (DS)	10.23 (1.69)	10.08 (2.32)	11.70 (1.66)	10.84 (1.72)
Information-processing capacity				
Digit Symbol Test (DST)	12.20 (2.68)	14.30 (3.15)	11.68 (1.88)	12.96 (2.38)

Notes: M = means, SD = standard deviation, SKL = the standardised value of the number of correct responses minus errors of confusion, GZ = total number of responses, F% = the number of errors related to the total number of responses.

Table 4
Mean values of the RWT for the experimental and control groups (z values)

Measure	Pre-test *M (SD)*		Post-test *M (SD)*	
	EG	CG	EG	CG
Z-value (RWT I)				
RWT I	–0.33 (0.79)	–0.38 (0.76)	–0.11 (0.77)	–0.38 (0.74)
RWT II	–0.44 (0.89)	–0.55 (0.91)	–0.18 (0.75)	–0.72 (0.82)

Notes: *M* = means, SD = standard deviation.

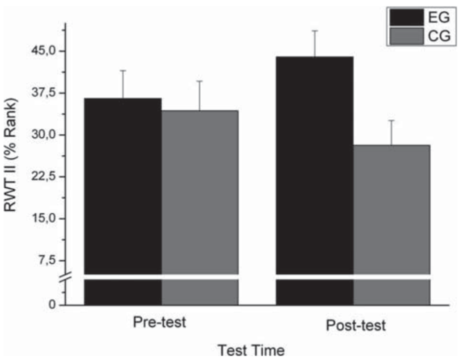

Fig. 3. Performance improvements in % ranking (mean, standard error) of RWTII from pre- to post-test for the experimental group (EG) and the control group (CG).

4. Discussion

The aim of this study was to investigate the effectiveness of motor-cognitive coordination training on cognitive abilities in the workplace of one company in a field experiment. The results showed that the motor-cognitive coordination break improves working memory and divergent thinking after eight weeks of intervention, whereas neither the mood nor the information processing speed improved more for the experimental group compared to the control group. The participants in the study were employees who completed the intervention programme directly in their workplace. The results on the acute increase in attention performance failed to reach significance.

4.1. Physical activity breaks

The results showed that the format of the physical activity break with motor-cognitive exercises is feasible in the workplace and can promote aspects of cognitive performance. In general, the active work break concept has also been proven in other studies regarding increasing physical activity [23, 45] and could be confirmed as an effective method for increasing work performance and productivity [22, 24]. Compared to other intervention strategies in the form of standing or dynamic workplaces, which are effective on the physical level because they are a change from predominantly sedentary behaviour [25], the motor-cognitive coordination programme in this study is particularly effective in terms of work-relevant abilities. In general, dynamic workplaces (e.g., integrated bicycle or treadmill solutions) may be associated with performance losses and may, for example, restrict working memory, attention, and motor skills (e.g., mouse handling and typing speed and errors) [16, 20]. Therefore, the motor-cognitive coordination programme introduced here might be a purposeful practical concept for physical recovery and mental reorientation since the work activity is interrupted only for a short time. This enables cognitive distancing and emotional deactivation in the sense of the recovery and activation functions from the preliminary examination of this work, so that the work process can be resumed afterwards with a new focus and new energy. However, it should be emphasised that precisely this aspect is often criticised in research on work breaks [46]. A break always interrupts a productive work step and requires additional effort to resume and continue it. To avoid this, the motor-cognitive coordination programme was offered several times a day (eight identical units in total). A creative and productive phase did not have to be interrupted, as the opportunity to participate was offered again later.

Some of the test participants worked in customer service. Work performance does not only refer to speed and quantity. Rather, the aspects of satisfaction and friendliness are important in the emotional area, but also in the cognitive area, involving the quick comprehension of customer inquiries regarding technical problems. Therefore, we assume that physical activity breaks in general at work can be used not only as a physical compensation measure (as regularly used to improve workers' health), but also for personnel development. However, this assumption must be investigated in more detail. The short-term effects showed that the positive mood increased, but only after a single bout of the motor-cognitive coordination intervention. To summarise, employees benefit from the motor-cognitive coordination programme in some different areas depending on their work setting.

4.2. Effects on basic cognitive functions

The significant improvement in the Digit-Span Test and in the divergent thinking test suggests that active work breaks including motor-cognitive coordination exercises can improve employees' working memory and divergent thinking. The results are in line with other studies [31, 32, 47, 48], as well as the study by Hötting and Röder [49], who were able to show that coordinative exercises can be equally effective on cognitive functions as cardiovascular training. Similar interventions often include exercises from the Life Kinetics programme, which also combines motor and cognitive tasks [33, 50] or juggling exercises [51, 52]. Further intervention studies investigating coordinative exercises, like balance or dance training, also confirm positive effects on executive functions and memory performance [30, 53, 54].

Regarding the results of a single bout of the motor-cognitive coordination intervention, participants of the EG showed greater acute improvements in concentration performance compared to the CG. This is in line with the results of the meta-analysis by Chang et al. [55], who confirm that short physical activities lead to positive and immediate effects on cognition. Concerning the type of activity, this is comparable to studies by Wollseiffen et al. [56] and Mullane et al. [57], who report acute positive effects of coordination exercise on concentration.

The positive influence of the motor-cognitive coordination training on divergent thinking can be seen as partly comparable to the results found by Frith and Loprinzi [58], who pointed out that physical activity in general induces the synaptic release of neurotransmitters such as dopamine, which, in turn, affect mood and arousal. According to Frith and Loprinzki [58], the modulation of the dopaminergic systems associated with physical activity in general can partially promote creative abilities. This area is equally important for goal-oriented planning and problem-solving thinking at work. Since working conditions have changed and stress in organisations is a growing phenomenon, with severe economic consequences, more emphasis should be placed on the cognitive abilities of employees. However, the specific effect of a motor-cognitive coordination training in comparison to a stretching training, which also includes physical activity, must be investigated in more detail.

4.3. Limitations

In this study, stretching and relaxation exercises were examined in addition to motor-coordinative cognitive exercises. The study lacks a group that is inactive or complete a work break without physical activity to differentiate that the effects of physical activity can be effective on cognitive functions. Future studies should include other measures, such as mindfulness exercises or other work break activities, in addition to the various movement activities to better demonstrate the effectiveness. In addition, even though the motor-coordinative training was not exhaustive, it might be worth registering the physical activity level and the "liking" of sportive activity of all participants to exclude, for example, motivational effects. In addition, to emphasise the field character of the study, no exclusion criteria beside chronic diseases, were applied and the groups were not blinded because an exchange during work could not be prevented. Also, the study did not control for diurnal variations of physical activity in the intervention as well as the CG and diet. Furthermore, availability sampling was used, which reduces the claim of generalisation, and a sociability and reactivity bias is possible. In line with this, preregistration should be applied in further studies in this area.

5. Conclusion

This study was able to show that physical activity breaks, which focus on motor-cognitive coordination exercises, can be established in the workplace but can also be used for personal cognitive development. The new approach of this study was not only the derivation and development of targeted exercises, but also their testing and evaluation in the field of application. Motor-cognitive coordination exercise in the workplace might play an important role in both occupational health management and personnel development, especially for companies that are under highly competitive and innovative pressure. So far, however, very little experimental creativity research has been conducted in relation to different types of physical activity as a potential predictor and the underlying mechanism, although there is significantly more research on the effects of exercise on other cognitive functions. A corresponding focus of future research on this relationship is therefore desirable, as well as the examination of video-based physical activity breaks [45].

Ethical approval

The experiment was conducted according to the ethical guidelines of the Declaration of Helsinki. Ethical approval for this study was not required in accordance with the conditions outlined by the German Psychological Society, where research that carries no additional risk beyond daily activities does not require research ethics board approval. We communicated all considerations necessary to assess the question of the ethical legitimacy of the study.

Informed consent

All participants gave their written consent for participation.

Conflict of interest

None to report.

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