Research report

Exercise, mood and cognitive performance in intellectual disability—A neurophysiological approach

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Abstract

While numerous researches addressed the connection between physical exercise, changes in brain cortical activity and its relationship to psycho-physiological processes, most of these neuro-scientific studies were set up for healthy individuals. However, the benefits of exercise, such as well being, physical and cognitive health enhancements are also becoming increasingly important for intellectually disabled individuals.

This study aimed to localize electroencephalographic activity changes in intellectually disabled individuals following a moderate running exercise for 30min. An increase in cognitive performance and in mood was hypothesized to correlate with a decrease in fronto-temporal brain areas following exercise.

Significant changes in cortical current density in frontal brain areas as well as decreases in perceived physical energy could be shown. Overall motivational states (including self-confidence and social acceptance) as well as positive mood increased significantly. However, no changes could be observed for the cognitive tasks following exercise.

With respect to the data provided here there is reason to believe, that a self-selected pace running exercise, enhances self-esteem, coincided with cortical activity changes in fronto-temporal brain areas.

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1. Introduction

The connection between physical exercises, changes in brain cortical activity [1,2] and its relationship to mood [3–7] and cognition [8–10] has been addressed in several cases recently. The focus of many of these studies was to investigate the different effects of exercise intensities [11], durations [12] as well as exercise preference levels [4] on neuropsychological changes.

Most of these studies were set up for healthy individuals, such as well-trained athletes, physically active children [5] or elderly people [13,14]. However, the benefits of physical exercise, such as general well being [4], physical [15–17] and cognitive health enhancements [9], are also becoming increasingly important for intellectually disabled individuals, not only because of a general increase in life expectancy [18,19]. Several studies investigated the importance of physical exercise to achieve health benefits for intellectually disabled individuals (for an overview, please see Ref. [20] and more recently Ref. [21]) and it has been shown that physical exercising seems to contribute to well being in intellectually disabled individuals [22]. In addition, there is first evidence that physical exercising improves cognitive processes, for example reaction time [23], and supports social manners, such as friendship [24] in intellectually disabled individuals. However, yet there is rarely any evidence investigating the neuropsychological correlates of physical exercise on intellectually disabled individuals [20,25].

Therefore the aim of our study was to localize changes in brain cortical activity in relation to mood and cognition after a moderate physical exercise intervention in individuals with intellectual disability.

Although the use of electroencephalographical (EEG) analysis in the sport and exercise science has been comparatively rare to date, EEG is a well-established technique, which has been applied in the field of psychology and clinical research for several decades. There is evidence indicating that a general well being as well as cognitive and recreational processes are associated with specific changes in electro cortical activity especially in fronto-temporal regions [3,4,8,9,13,26,27]. These findings support Dietrich’s transient hypofrontality hypothesis [28] that suggests a decrease of neural activity in brain cortical regions that are rather inessential to performing the exercise.

Today’s technical innovations enable clear EEG recordings, before, after and even during exercise [10,29] and allow, in combination with a localization method (low resolution brain electro magnetic tomography, LORETA), to create mappings of the recorded brain cortical changes [3,30].

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In this study we hypothesized that (1) moderate 30 min running of intellectually disabled individuals [20–21,31] would lead to a decrease in cortical activation after exercising, particularly in fronto-temporal brain regions. Based on previous results addressing the connection of physical exercise, mood and cognition [7,9,10], (2) an increase in cognitive performance that is accompanied by an increase in mood is hypothesized to correlate with the expected changes in fronto-temporal areas.

To minimize distraction within the participating intellectually disabled individuals, we chose a field setting and tried to put few limitations as possible on their running activities [4,13].

2. Material and methods

2.1. Subjects

The University’s Human Research Ethics Committee approved this study. Voluntarily 12 male individuals (age: 22.50 ± 9.87 years, height: 177.92 ± 6.13 cm, weight: 81.50 ± 24.58 kg) participated in this study. Prior to involvement, all participants attended an informational meeting. Participants and legal guardians provided written informed consent, respectively. According to the HMB-W policy [32,33] including Metzler’s evaluation of groups with specific needs for care ‘Hilfebedarfsgruppen’ [34] all participants are considered being intellectually disabled. All participants are used to partake in physical exercise programmes (either football or running activities) and are considered being relatively fit. All procedures were in compliance with the Declaration of Helsinki for human participants.

2.2. Exercise protocol

Following a pre-exercise medical screening, participants underwent a one-time running exercise at self-selected [3], moderate pace for 30 min. Individual heart rate was recorded using a mobile heart rate monitor (Suunto, Vantaa, Finland). During each run a study operator accompanied the participants. EEG activity was recorded for 3 min sitting in an upright rest position with eyes closed prior to the exercise (EEGpre), immediately after exercising (EEGpostRUN) and after the cognitive tasks (EEGpostMOD). Following the EEGpre and EEGpostMOD recordings, participants completed a paper-pencil mood questionnaire (MoodPRE, MoodpostMOD) Fig. 1. Further details of the EEG recordings as well as the mood assessment and the cognitive tasks are provided below.

2.3. EEG recordings

A 32-channel portable EEG-System (Brain Products, Munich, Germany) was used for data acquisition (sampling rate 5000 Hz). An EEG-cap that adapted to individual head size was mounted in the 10–20 system [35] 15 min prior to exercising. The EEG-cap was built of Ag–AgCl electrodes and one reference electrode (mounted in the triangle of FP1, FP2 and FZ). EEG activity was recorded on positions FP1, FP2, F7, F3, Pz, P4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, TP9, CP5, CP1, CP2, CP6, TP10, P7, P3, Pz, P4, F8, PS9, O1, O2, O10. The EEG-cap was fixed with a chin strap to prevent shifting during exercise. In order to prevent an increase in heat during exercise the EEG-cap was permeable to air. Distances between electrodes were approximately 5 cm to avert possible cross talk after exercise due to salt bridges between electrodes. Each electrode was filled with Supravisc® electrode gel (EasyCap GmbH, Herrsching, Germany) to optimize signal transduction. We excluded electrodes from further analysis, if the impedance of an electrode exceeded 10 kΩ.

The analogue signal of the EEG was amplified and converted to digital signals using Brain Vision Recorder 1.1 Software (Brain Products, Munich, Germany).

2.4. Low resolution brain electromagnetic tomography (LORETA)

The KEY Institute for Brain-Mind Research provides the low resolution brain electromagnetic tomography analysis (University Hospital of Psychiatry, Zurich, Switzerland). LORETA enables a spatial identification and analysis of brain cortical activity, providing a three-dimensional (3D) localization based on traditional EEG recordings. This method has been thoroughly described and validated in previous clinical [36–39] and exercise studies [3–5,10,13,29,40,41]. In the present study a standard LORETA transformation was used to localize cortical current density within specific regions of interest (ROI, see Section 2.5).

2.5. EEG analysis

The EEG was low and high-pass filtered, so that a frequency range from 0.5 to 50.0 Hz (notch filter) remained for analysis (time constant 0.0455 ± 24 dB octave). Data was segmented into 4-s segments, whereby an overlap of 10% was accepted. Following an automatic artefact rejection (gradient < 35 μV; maximum and minimum amplitude between −100 μV and 100 μV), segmented data was baseline corrected and analysed by spectral analysis (FFT; resolution 0.244 Hz; Hanning window, 10%).

To determine anatomical regions of interest (ROIs) and the site-specific cortical current density values (μV2/mm4) the build in LORETA transformation of the Brain Vision Analyzer software 2.0 was used (Güching, Germany). A minimum of twenty 4-s segments of artefact-free resting EEG was used for the transformation and calculation. ROIs researched in this study are known to be located in central areas of the frontal lobe: rectal gyrus, medial frontal gyrus, middle frontal gyrus and orbital gyrus. According to the literature, identifying the relevance of medial frontal lobe regions in psychological and cognitive processing [42,43], we additionally decided, to specifically define Brodmann areas 11, 25 and 47 as ROIs respectively [44].

2.6. Mood assessment

The MoodMeter® consists of Bodyfinder and Feelfinder modules. The Bodyfinder has been developed to determine the current perceived physical state (PEPS) in traditionally more biologically oriented research (e.g., exercise physiology, internal medicine) and is very sensitive to short term alterations in mood (validated during the years 2001–2005 on a total of 645 participants; Cronbach alpha intra-rater correlation coefficient 0.82 and 0.52; [45]). The Feelfinder includes a short form of the ‘Eigenzustandsskala’ (EZ-scale [46]). Opposed to other psychological adjective scales (e.g. POMS) the EZ-scale allows the measurement of not only the emotional or psychological strain, but also a person’s motivational state. In the present study we used a short 16-item-form of the EZ-scale developed and validated by Nitsch [46], which forms eight sub-dimensions (Table 1; please see Ref. [45] for a detailed description of the development and operating mode of the MoodMeter®).

We used a modified paper-pencil version of the MoodMeter® for the intellectually disabled individuals. It contained two catalogues, each consisting of the same 32 adjectives (16 PEPS, 16 EZ-scale) presented in a random order. The first catalogue was presented before exercising (MOODPRE). Catalogue MOODpostMOD was then presented following the EEGpostMOD measurement after exercising. It took approximately 5 min (3.46 ± 1.15 min) for each catalogue to be completed. Preliminary instructions given to the participants were: “Please name, without any hesitation, to what extent the following adjective applies to your physical state at this moment.” The endpoints of a 6-step ranking scale were anchored (0 = not at all; 5 = totally). Due to relatively slow reading and understanding of the adjectives the original time limit (4 s per adjective) was excluded.

2.7. Cognitive tasks

The Vienna test system (VTS) is a standardized, computerized psychological assessment tool that has been used in sport and exercise science research earlier [47]. The VTS has been determined to assess basic cognitive functions (i.e. alertness, memory consolidation, motor functions) in particular neuropsychological impairment. It provides sectional cognitive performance tests that allow for individual levels of difficulty, referring to the participant’s clinical picture or age for example.

Table 1: The MoodMeter® (sub-) dimensions.

<table>
<thead>
<tr>
<th>MoodMeter®</th>
<th>Dimension</th>
<th>Sub-dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived physical state</td>
<td>Perceived physical state</td>
<td>Physical energy</td>
</tr>
<tr>
<td>EZ-scale</td>
<td>Psychological strain</td>
<td>Relaxation</td>
</tr>
<tr>
<td>EZ-scale</td>
<td>Motivational state</td>
<td>Self-confidence</td>
</tr>
</tbody>
</table>

Fig. 1. Experimental setup.
The cognitive performance tasks used in this study consist of a continuous visual recognition task (CVR) and a reaction time task (RT). In each task, we chose a level of difficulty, modified for intellectually disabled individuals (VTS versions: CVR-S6, RT-S1).

The continuous visual recognition task (CVR; Cronbach’s alpha reliability of 0.84) assesses memory performance and cerebral deficits of each individual participant (number of correct recognitions). Its main areas of application are in the fields of neuropsychology, clinical and health psychology as well as pedagogical psychology. CVR is based on the decision whether an item is shown for the first time or has already been presented on screen, following a button to press respectively. According to the clinical picture of our participants, we chose a total of 100 items, divided into objects, simple numbers and letters that were presented in a randomized sequence. It took approximately 4 min for each participant to finish the CVR task.

The reaction time task (RT; Cronbach’s alpha reliability 0.961) records the mean reaction time in milliseconds (ms). The RT covers the areas of alertness, the ability to suppress an inappropriate reaction, as well as vigilance and intermodal comparison. The main areas of the application for RT are clinical and health psychology, personnel psychology, sport psychology, and educational psychology. For the RT the participant was instructed to react upon a visual stimulus (appearing and disappearing yellow light), following a button to press respectively. Participants were instructed to “react as fast and as precise as possible”. Each participant took approximately 3 min to finish the RT.

Following EEGpostRUN participants completed the cognitive performance tasks. In addition the cognitive performance tasks were conducted under control conditions without a running exercise intervention.

2.8. Statistical procedures

All statistical procedures were performed using STATISTICA programme 7.1 (StatSoft, Tulsa, USA).

In order to display exercise induced changes in estimated cortical current density, one-way repeated measures of variance (ANOVA) for the factor measurement (EEGpre, EEGpostRUN, EEGpostCOG) was computed for LORETA power values. Fisher’s least significant difference served as post hoc test. Due to measuring faults only 11 out of 12 participants were considered for the statistical procedure of the cortical current density values.
4.4 Psychological strain revealed no significant changes.

Cortical current density values recorded in the middle frontal gyrus (p = 0.17712) and in Brodmann area 47 (p = 0.69759) revealed no significant changes.

3.3. Mood assessment

Although the overall dimensions perceived physical state showed no significant changes (p > 0.05) within sub-dimension physical state, the overall MoodMeter® dimensions of PEPS (perceived physical state) and EZ-scale (motivational state and psychological strain) were checked for significant changes using Wilcoxon paired samples test with the intra-individual factor measurement (MoodPRE to MoodPOST).

Cognitive performance tests CVR and RT were computed using one-way repeated measures of variance (ANOVA) for the factor measurement (intervention, control conditions).

Two-tailed level of significance was set at p < 0.05. Data in the text are presented as means (Y) ± standard deviation (SD).

3. Results

3.1. Time and heart rate

On average participants ran for 00:30.53 min (±00:00.23 min) at an average heart rate of 154.50 bpm (±14.43 bpm). The average participants' max heart rate during running was 177.58 bpm (±10.06 bpm).

3.2. Cortical current density

Although frontal lobe values of cortical current density revealed no significant changes (p = 0.76099), cortical current density values of specific frontal lobe areas (ROIs) recorded after exercising decreased significantly compared to baseline measurements prior to the exercise: rectal gyrus (p = 0.00507), medial frontal gyrus (p = 0.03249) and orbital gyrus (p = 0.00576) as well as Brodmann area 11 (p = 0.00709) and Brodmann area 25 (p = 0.03551) (Figs. 2–6, Table 2).

Cortical current density values recorded in the middle frontal gyrus (p = 0.17712) and in Brodmann area 47 (p = 0.69759) revealed no significant changes.
energy ($p = 0.003346$) the recorded values for MoodPost decreased significantly compared to the values recorded for MoodPre (Table 3). No significant changes were found in the overall dimension psychological strain ($p > 0.05$). However, sub-dimension positive mood ($p = 0.046400$) revealed a significant increase of the recorded

Table 2
Cortical current density changes in ROIs.

<table>
<thead>
<tr>
<th>Measurement ($\mu V^2/mm^4$)</th>
<th>EEGPre</th>
<th>EEGPostRun</th>
<th>EEGPostCog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectal gyrus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EGGPost (Y 0.31 ± SD 2.68)</td>
<td>0.011419</td>
<td>0.0002041</td>
<td></td>
</tr>
<tr>
<td>EEGpostRun (Y 0.37 ± SD 3.47)</td>
<td>0.011419</td>
<td>0.0002041</td>
<td></td>
</tr>
<tr>
<td>EEGpostCog (Y 0.50 ± SD 2.81)</td>
<td>0.011419</td>
<td>0.0002041</td>
<td></td>
</tr>
<tr>
<td>Medial frontal gyrus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EGGPost (Y 0.32 ± SD 1.64)</td>
<td>0.165346</td>
<td>0.006969</td>
<td></td>
</tr>
<tr>
<td>EEGpostRun (Y 0.52 ± SD 3.26)</td>
<td>0.165346</td>
<td>0.006969</td>
<td></td>
</tr>
<tr>
<td>EEGpostCog (Y 0.64 ± SD 2.80)</td>
<td>0.165346</td>
<td>0.006969</td>
<td></td>
</tr>
<tr>
<td>Orbital gyrus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EGGPost (Y 0.37 ± SD 3.12)</td>
<td>0.015191</td>
<td>0.0002122</td>
<td></td>
</tr>
<tr>
<td>EEGpostRun (Y 0.41 ± SD 4.12)</td>
<td>0.015191</td>
<td>0.0002122</td>
<td></td>
</tr>
<tr>
<td>EEGpostCog (Y 0.49 ± SD 3.29)</td>
<td>0.015191</td>
<td>0.0002122</td>
<td></td>
</tr>
<tr>
<td>Brodmann area 11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement ($\mu V^2/mm^4$)</td>
<td>EEGPre</td>
<td>EEGPostRun</td>
<td>EEGPostCog</td>
</tr>
<tr>
<td>EGGPost (Y 0.39 ± SD 1.29)</td>
<td>0.020395</td>
<td>0.002469</td>
<td></td>
</tr>
<tr>
<td>EEGpostRun (Y 0.41 ± SD 1.19)</td>
<td>0.020395</td>
<td>0.002469</td>
<td></td>
</tr>
<tr>
<td>EEGpostCog (Y 0.43 ± SD 1.48)</td>
<td>0.020395</td>
<td>0.002469</td>
<td></td>
</tr>
<tr>
<td>Brodmann area 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement ($\mu V^2/mm^4$)</td>
<td>EEGPre</td>
<td>EEGPostRun</td>
<td>EEGPostCog</td>
</tr>
<tr>
<td>EGGPost (Y 0.27 ± SD 0.92)</td>
<td>0.054887</td>
<td>0.013768</td>
<td></td>
</tr>
<tr>
<td>EEGpostRun (Y 0.30 ± SD 1.23)</td>
<td>0.054887</td>
<td>0.013768</td>
<td></td>
</tr>
<tr>
<td>EEGpostCog (Y 0.34 ± SD 1.07)</td>
<td>0.054887</td>
<td>0.013768</td>
<td></td>
</tr>
</tbody>
</table>

Displayed are intra-individual changes of cortical current density using Fisher LSD Post hoc-Test, including mean values (±) and standard deviation (SD) in $\mu V^2/mm^4$. * Indicate the level of significance ($p < 0.05$). ** Indicate the level of significance ($p < 0.01$).

MoodPost values compared to the values recorded for MoodPre (Table 3). The overall dimension motivational state showed a significant increase ($p = 0.028418$) of the recorded MoodPost values compared to values recorded for MoodPre. Additionally, sub-dimensions self-confidence ($p = 0.006040$) and social acceptance ($p = 0.020863$) both revealed a significant increase of the recorded MoodPost values compared to the values recorded for MoodPre (Table 3).

Table 3
Mood assessment’s (sub-)dimensions.

<table>
<thead>
<tr>
<th>MoodMeter® dimensions (n = 12)</th>
<th>T</th>
<th>Z</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived physical state</td>
<td>21.50</td>
<td>1.372813</td>
<td>0.169811</td>
</tr>
<tr>
<td>Physical energy</td>
<td>0.00</td>
<td>2.934058</td>
<td>$ \downarrow 0.003346$</td>
</tr>
<tr>
<td>Physical fitness</td>
<td>22.00</td>
<td>0.560612</td>
<td>0.575063</td>
</tr>
<tr>
<td>Physical flexibility</td>
<td>13.50</td>
<td>1.066228</td>
<td>0.286321</td>
</tr>
<tr>
<td>Physical health</td>
<td>18.00</td>
<td>0.00</td>
<td>1.000000</td>
</tr>
<tr>
<td>Psychological strain</td>
<td>19.00</td>
<td>0.866400</td>
<td>0.386271</td>
</tr>
<tr>
<td>Relaxation</td>
<td>26.00</td>
<td>0.152894</td>
<td>0.878482</td>
</tr>
<tr>
<td>Positive mood</td>
<td>1.00</td>
<td>1.991741</td>
<td>$ \uparrow 0.046400$</td>
</tr>
<tr>
<td>Calmness</td>
<td>10.50</td>
<td>1.050210</td>
<td>0.263222</td>
</tr>
<tr>
<td>Recovery</td>
<td>8.50</td>
<td>1.936659</td>
<td>0.052788</td>
</tr>
<tr>
<td>Motivational state</td>
<td>6.00</td>
<td>2.191483</td>
<td>$ \uparrow 0.028418$</td>
</tr>
<tr>
<td>Self-confidence</td>
<td>4.00</td>
<td>2.745626</td>
<td>$ \uparrow 0.006040$</td>
</tr>
<tr>
<td>Willingness to seek contact</td>
<td>9.50</td>
<td>1.540107</td>
<td>0.123535</td>
</tr>
<tr>
<td>Social acceptance</td>
<td>1.50</td>
<td>2.310462</td>
<td>$ \uparrow 0.020863$</td>
</tr>
<tr>
<td>Readiness to strain</td>
<td>6.00</td>
<td>0.943456</td>
<td>0.345448</td>
</tr>
</tbody>
</table>

Displayed are values of the Wilcoxon paired sample test. Arrows indicate an increased (↑) or decreased (↓) perception respectively.

* Indicate the level of significance ($p < 0.05$).
** Indicate the level of significance ($p < 0.01$).

Table 4
Cognitive performance.

<table>
<thead>
<tr>
<th>Cognitive performance – Vienna testing system</th>
<th>$F_{1,11}$</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous visual recognition task – number of correct hits</td>
<td>0.02012</td>
<td>0.88977</td>
</tr>
<tr>
<td>Reaction time task – mean reaction time</td>
<td>0.14635</td>
<td>0.70934</td>
</tr>
</tbody>
</table>

Displayed are values of the one-way repeated measures of variance (ANOVA) for the factor measurement (intervention, control conditions).
3.4. Cognitive performance

Cognitive performance values for both, RT and CVR recorded after exercise revealed no significant changes compared to values of the control measurements ($p > 0.05$; Table 4).

4. Discussion

This study aimed to localize changes in electroencephalographic activity, mood and cognitive performance in intellectually disabled individuals following a moderate running exercise. Significant changes in cortical current density of frontal brain areas as well as decreases in perceived physical energy were reported, whereas overall motivational states (including self-confidence and social acceptance) as well as positive mood increased significantly. No changes could be observed for the cognitive tasks following exercise.

The findings of our research revealed a significant decrease in cortical current density after exercise in frontal lobe regions, specifically pronounced in the rectal gyrus, medial frontal gyrus and orbital gyrus. Besides the literatures’ dominant association of the frontal lobe with emotional processes (for an overview please refer to Ref. [11]), a number of convincing neuro-scientific evidences show, that these frontal lobe gyri also play important roles in cognitive processing. Neuropsychological investigations on illiteracy for example, show evidence, that the left rectal gyrus is associated with reading and writing during childhood [48]. In addition, a comparative study on cerebral blood flow confirmed a general involvement of the right rectal gyrus and left orbital gyrus in working memory and novelty response processes as well as in cognitive and emotional processing, such as the perception of moods [49]. An fMRI study by Talati and Hirsch [42] revealed, that the medial frontal gyrus is associated with high-level executive functions and decision-related processes, such as recognition processes. Deary et al. [50] investigated the performance of healthy adults in a visual inspection time task. Their findings provide evidence, identifying the medial frontal gyrus as part of a functional connectivity network, that is possibly associated with the processing of visually degraded perceptions [50].

It seems important to stress, that the present study revealed similar decreases in cortical current density in even more precise medial frontal lobe regions, the Brodmann areas 11 and 25. Brodmann area 11 is known to relate to the rectal gyrus and orbital gyrus [49] and is, however, together with Brodmann area 25, also associated to be preferentially involved in psychological processes as compared to cognitive processes [44].

However, there is evidence suggesting new research approaches that address a connection of decreased frontal brain activity and cognitive psychology [28]. On the basis of these previous research findings and with respect to Dietrich’s transient hypofrontality theory [28], the present studies’ decrease of cortical current density in frontal lobe regions after exercise might explain a restructuring of resources, referring to mood and initial cognitive states [51].

A decrease in perceived physical energy, reported in this study, indicates that the running exercise, completed by our participants, was physically challenging and somewhat tiring. These results do not contradict other findings, relating an effect of abating perceived physical energy after exercising and brain cortical activity [4,5,7].

More interestingly, our results revealed an increase in the overall motivational state after exercise in addition. More specifically this was pronounced in the perception of self-confidence and social-acceptance of the participants. The benefits of exercise in relation to mood have been reported in previous research many times [3,6,7]. Moreover, several neuropsychological studies show evidence that exercise has an effect on both social- and self-perception [4,10,52].

There is also evidence, suggesting the social aspects of exercise to function as a motivator for an ongoing participation in exercise programmes and herewith to foster its benefits such as friendship and social connection [24]. Earlier research by Wurster et al. [53], who investigated the effects of a weight-reduction programme in an intellectually disabled individual (12 years old), reported an achievement in the participants’ self-esteem as well as a positive experience of social acceptance afterwards. On the basis of our findings of an increased motivational state, including an increased perception of self-confidence and social acceptance as well as positive mood in intellectually disabled individuals after exercise and with respect to previous research results, there is reason to believe that physical exercising, even following a one-time running exercise, enhances social- and self-perception in intellectually disabled individuals. Adding to previous research [22], that exercise seems to contribute to well being in intellectually disabled individuals, this also underlines the importance of exercise for intellectually disabled individuals, improving the quality of life and a general well being.

With respect to previous research, reporting significant improvements in reaction time following a structured physical fitness programme for 12 weeks in intellectually disabled individuals [23] we expected to observe improvements by our participants in the reaction time task after exercising. Furthermore, a most recent review on exercise and cognitive function in relation to neurological disorders show evidence that exercise improves attention processes and cognitive flexibility [25], giving reason to expect similar findings in our studies’ visual recognition task following exercise. Additionally, although a non-exercise study, Kamijo et al. [54] investigated working memory under speed and accuracy instructions, suggesting a more constant level of control in higher-fit individuals. However, our study revealed, despite promising previous research findings, no cognitive tasks changes following exercise. Although carefully chosen and modified, the cognitive tasks used in this study might still not have been appropriate for the specific needs of our intellectually disabled participants.

Today, it is widely assumed that changes in electroencephalographic activity in frontal brain regions are related to mood [7,11,51] and cognitive performance [9]. There is evidence that the influences of exercise, mood and cognitive performance can be due to an exercise-induced state of frontal hypofunction [28,55].

The present studies’ decrease in frontal cortical current density following exercise, coincided with an increase in self-esteem and mood, adds to previous research. Schneider et al. [10] for example provide evidence, that changes in brain cortical activity due to exercise may serve as a countermeasure to psycho-physiological deconditioning. In addition, exercise seems to be related to individual preferences in both, exercise intensity and duration as well as in the type of exercising, suggesting self-selected exercise conditions related to a general well being [3,4]. Furthermore, convincing evidence exists, relating academic achievement and exercise [9]. To that effect, a study by Schneider et al. [5] give reason to believe, that school children’s cognitive performance may benefit from a decrease in frontal brain areas following a moderate cycling exercise. Recently, coherences between brain cortical function and neurocognitive performances were observed, even under extreme conditions (changed gravity [40]). However, Dietrich and Sparling [56] also suggest, that non-cognitive tasks such as treadmill running, can interfere with resources that are potentially available for cognitive processes.

With respect to our findings, we are well aware that the low number of rather heterogeneous participants limits the present study. Furthermore, we experienced a considerable difficulty in finding adequate measuring devices for intellectually disabled individuals, in particular for the assessment of cognitive performances.
5. Conclusion

The benefits of physical exercise on mood and cognitive performance have been investigated in several neuropsychological studies [5,7,9]. With respect to the data provided here it could be assumed, that a moderate self-selected pace running exercise for 30 min, enhances self-esteem, coincided with cortical activity changes in fronto-temporal brain areas. However, no effects on cognitive performance were observed.

Following this neuropsychological approach, there is a need for future studies, evaluating the specific needs to enhance mood in intellectually disabled individuals. In addition, further investigations of neurocognitive processes should take the clinical picture's diversity of intellectual disabilities into account, if possible in more homogeneous participants.

Acknowledgments

This study was funded by the German Sport University Cologne awarding a research grant to the authors of this publication – Tobias Vogt in collaboration with Stefan Schneider and Vera Abeln.

We would like to thank all our participants for being part of and spending some of their valuable time for this study. Everybody looked extremely beautiful with the cap!

A special thanks goes to the parents and the administration of the ‘Heilpäädagogisches Therapie- und Förderzentrum St. Laurentius-Warburg‘ as well as the executive board of the ‘Caritas Wohn- und Werkstätten im Erzbistum Paderborn e. V.’ who realized the relevance of this approach and fully supported this study.

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