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Research Article

MENTAL REPRODUCTION OF A DANCE CHOREOGRAPHY AND ITS EFFECTS ON PHYSIOLOGICAL FATIGUE IN DANCERS

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ABSTRACT

As stated at the start of this article, psychological and physical demand states can be understood as the effects and consequences caused by loads. To deduce the physiological characteristics of psychophysical demand, theoretical concepts like the load/demand concept are commonly used as a basis. Since demand itself is not directly quantifiable, reference must be made to demand indicators. This means measurement regulations determine what we define as psychophysical demand. The experiment described in this article falls under the category of mental (cognitive) demand that assumes knowledge exists about a dance choreography in the case of the persons being tested. This knowledge includes in particular, as well as conscious sense perceptions about events in the external world and one's own body, mental activities such as thinking, imagining and remembering using emotional and motivational powers. These accentuate the focus for conscious actions. Particularly for the processes of thinking and remembering, attention increases concrete states of consciousness, which also manifest themselves in an increase in electrical activity of neurons in the β frequencies. These phenomena could be discerned in all dancers and manifested themselves in similar ways. The states of consciousness are regenerated in the close interplay between cortical and limbic structures and are ultimately dependent on the function of the neuron collections. These functions are not only affected by external excitement, but also excite one another and combine with other cognitive excitement patterns such as memories, sensations, perceptions and imagination. At the same time, the neural states influence other vegetative functions such as heart, respiratory and muscle activities. In light of the question stated at the outset, the tendencies in the results confirm similar investigations proving that mental reproduction of motor actions affect all association areas of the cortex, despite the performance part of the action in the sense of its execution not being included. Since a large number of neural connections exist between the cortices, we can assume that the moment mental reproduction of a chain of actions takes place, such as a dance, a self-contained association area comes into being, in which the complex movement structures of the dance appear clearly in the form of increased beta activities. Furthermore, the increased neural activity due to mental concentration also leads, via the relevant vegetative connections, to a change in cardiac, respiratory and muscle activity. In this way, events experienced in the past can lead to similar mental and vegetative reactions such as exist under the actual conditions of a dance. As mental demand increases, the physiological reactions return to a lower level due to fatigue. The intensity of the reactions seems to depend on individual aspects of those taking part in the experiment however. Mental load situations cannot be stimulated and represented in isolation, they are further inextricably bound up with matters of a socio-emotional and energy-efficiency nature.

Key words: *Dance, fatigue, mental, physiologic*

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INTRODUCTION

The extent to which subject experience of dance is reflected in the imagination of dancers is a question of great interest to movement science. Knowledge regarding dance can be recalled from what we call the explicit memory and further enhanced by means of sensory elements from the emotional memory. Mental evaluation of the results can be seen, amongst other places, both in neural activity in the brain and in the physiological functions of cardiac and respiratory activities (Roth, 2001). In neuropsychology, conscious reproduction of an event such as a dance is known as representation. Damasio (2000) uses this term as a synonym for imagination and neural patterns. As imagination, this manifests itself in cognitive processes. As neural patterns, it is evident in the neural connections. Dance techniques, with their temporal, spatial and dynamic structure, are one example of the object of representation of this type. Techniques can be recalled from the memory when required. Because of the many parallels between the cognitive and neural processes, brain processes, which are associated with thoughts, imagination and attention can be made visible due to the electrical activity of the neural networks involved. Intensive reproduction of experiences also has an effect on other physiological functions, making these another sign of heightened mental processing. Bearing in mind these premises and in relation to the more general question posed at the outset of this article, we can thus derive the following, more specific question:

Does the process of imagining a dance choreography in the mind over and over again produce changes in the cortical and neural activities of dancers as a result of the related demand placed on the CNS, and to what extent does this imagining affect activities in the cardiac, respiratory and muscular systems?

The demand and load concept from Romert's occupational physiology (1984) makes a useful theoretical starting point when attempting to answer this question. According to this concept, load is the cause of demand. Loads and load components have an effect upon human beings. This produces demands, which may be represented bymeans of certain demand indicators. In 1991, at a conference of the Deutsche Ver-einigung für Sportwissenschaft (German Association for Sport Science), Willimcik, Daugs and Olivier suggested this concept be transferred to the field of motional sports science. With reference to Laurig, the authors cited the well-known phenomenon from occupational science which states that when mental and physical resources diminish as a result of fatigue, demand increases though load stays the same. In the years that followed, their suggestion had an increasing influence on teaching of performance and training. Schnabel (2003) proposed in the same way for instance that when a load occurs in training, a demand is triggered, which in turn produces fatigue. In this way, the increase in deviation from the homeostasis then leads to diminished performance capability at times. This leads to diminished concentration, reaction and movement regulation resulting in less control over actions as well as a reduction in positive regulation and energy mobilisation.

The following heuristic model of mental reproduction of a dance choreography can be used as a basis for explaining these ideas (figure 1):

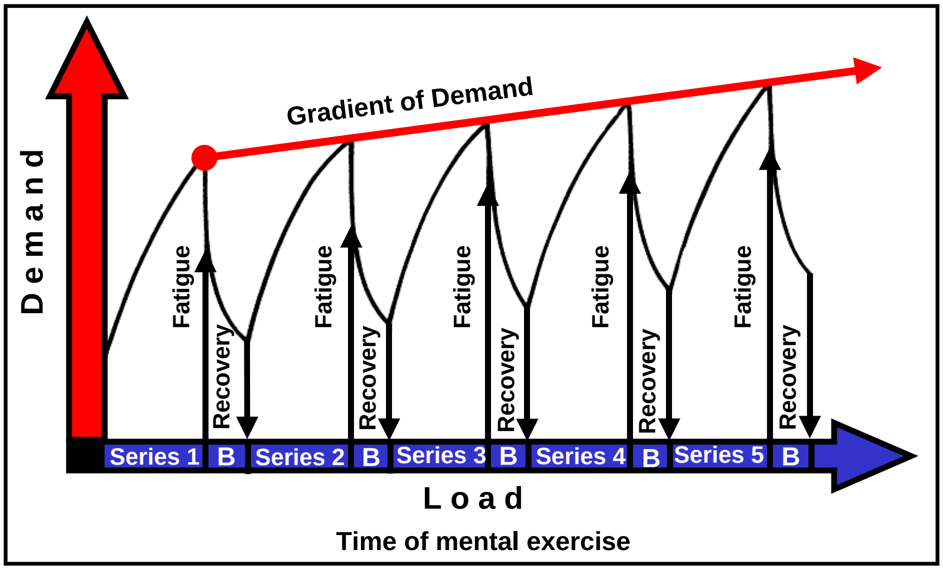

Figure 1. *The relationship between load and demand under the condition of mental exercise.*

According to Schönpflug (1987), demand can be understood as the engagement of a function which is limited in terms of capacity. Activation of the memory function during mental association allots a specific amount of the function's capacity for the task. Thereafter, the function is only available for other activities in relation to the remaining unengaged capacity. A diminishment in the function's capacity can be discerned for a limited period of time depending on the intensity and duration of demand. With regards to the question in the following investigation, we are concerned with mental (cognitive) demand.

METHOD

Investigations were conducted on seven members of a dance troupe. The dancers were given the task of carrying out a dance mentally in their imagination with their eyes shut. The same dance choreography was used for all dancers. Duration of each load period was the same as length of the dance, i.e. 120 seconds. A total of 8 load periods were specified. Time between the load periods was 5 minutes. The load period requiring the greatest concentration at the start of the investigation was set in relation to the average for the total demand. After the experiment, dancers gave reports on how they had experienced the demand.

Cortical surface activity was chosen as an indicator for central nervous demand. In academic papers dealing with experiments in occupational science, there are many instances of the reaction of different EEG frequency bands depending on load size in relation to speed and difficulty of task (Luczak, 1987). To detect surface activity, the CATEEM (COMPUTER AIDED TOPOGRAPHICAL ELECTRO ENCEPHALO METRY) tool system from the MediSyst company was used (fig. 2).

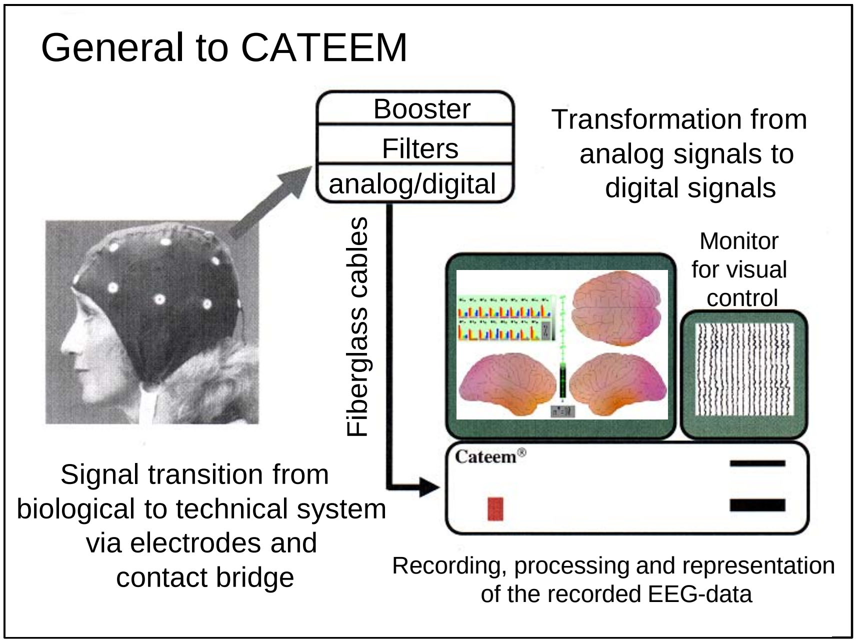

Figure 2. *Schema of bioelectric signal take-up from top of skull.*

During the EEG, surface electrodes through the top of the skull were used to measure the electrical activity of a large number of nerve cells (Cooper et al., 1984; Mühlau, 1990; Ebe & Homma, 1994). Subcortical processes cannot be detected directly by the EEG. By using an EEG, excitation disruption in the cerebrum cortex during cognitive performance can be represented precisely in terms of time. It is also possible to measure parameters of cardiac, respiratory and muscle activity for use as additional indicators of psychophysical demand using the CATEEM system and to place these within the context of cortex activity. Determining the exact location of excitation on the cortex surface is, in comparison to image-based methods, less precise however. When a brain area is activated, an electrically-charged negative energy field develops in the surface cortex layer of the brain. This consists mainly of neural cell processes (dendrites). The energy field can then be deflected from the top of the skull using electrodes and special amplifiers (fig. 2). Electrophysiological occurrences are deflected in CATEEM using an electrode cap, which covers the appropriate cortex area. In research literature, it is suggested the cortex be split into the frontal, parietal, temporal and occipital lobes (Gevins & Schaffer, 1980; Black, 1993; Thomson, 1994; Rohen, 1994; Kolb & Whishaw, 1996). This enables activity in the lobes to be detected using electrodes located at these points. When signals are amplified, power density in βV2/Hz for each electrode across the corresponding cortex area can be determined according to the international standard frequency spectrum. This frequency spectrum can be interpreted as follows: delta (1.25-4.50 Hz) deep sleep; theta (4,75-6,75 Hz), drowsy yet awake or asleep, state of deep relaxation; Alpha 1 (7,00-9,50 Hz) / Alpha 2 (9,75- 12,50 Hz) from eyes closed in relaxed state to heightened attention; Beta 1 (12,75-18,50 Hz) / Beta 2 (18,75-35,00 Hz) tensified, from concentrating and attentive to agitated and nervous (Cooper et al., 1984; Mühlau, 1990; Zuckermann, 1991; Ebe & Homma, 1994; Mechau, 2001).

Measurements were conducted in what is known as initial reference mode. In this mode, absolute power density is displayed in relation to a reference value. In order to determine a reference value, measurements were taken over a period of 10 minutes. During this time, the person being tested should feel completely relaxed inside. This produces temporal reference data as a percentage. Each new data unit is set in relation to a reference value (output or rest value) and then represented. Reference is made for each electrode and frequency band. When measuring potential, conditions for each factor of the experiment (imagining a dance choreography) are set in relation to reference values. Differences can then be represented and interpreted. Using the relative values, it is possible to compare different persons and experimental factors.

Empirical values were represented and interpreted with reference to the surfaces of the prefrontal (electrodes F7, F8), premotoric (electrodes F3, FZ, F4), motoric (electrodes C3, CZ, C4), parietal (electrodes (P3, PZ, P4), temporal (electrodes T3, T4, T5, T6) and occipital cortices (electrodes O1, O2). Because of the neural networking of these association cortices, we can assume that, during mental association, we will receive the highest frequencies as a result of heightened concentration and tension. In accordance with this assumption, only frequencies of the beta band are used for evaluation purposes.

The CATEEM system measures in 4 second intervals according to the artefact minimisation principle. With a load duration basis of 120 seconds, this meant 30 measurement periods could be used to assess each dancer. Data measured was then processed further with regards to the 7 dancers and 8 series using descriptive statistics. Finally, using the concluding statistics method, differences between measurement periods under the condition of heightened concentration (for each initial period of load) and diminished concentration due to increase in demand, were examined for significance. Resulting data sets used the framework of demand on normal distribution.

EVALUATION AND INTERPRETATION

Figure 3 shows colour maps under the conditions of concentration and fatigue. On a general level, we can discern immediately that concentration on the task diminishes as a result of demand. For interpration purposes, it is important to note that the blue-coloured areas symbolise beta frequencies ($\beta 1$ = 12.75 – 18.50 Hz; $\beta 2$ = 18.75 – 35.00 Hz) for the range of heightened concentration (figure 3). In the concentration phase, the map is therefore a deeper shade of blue.

Under the conditions of the same load but increased demand, the appropriate map contains more and more colours from lower frequencies. This is a sign that concentration on the task is diminishing. Diagrams for the individual areas of the brain provide more precise insight into statuses of concentration and fatigue.

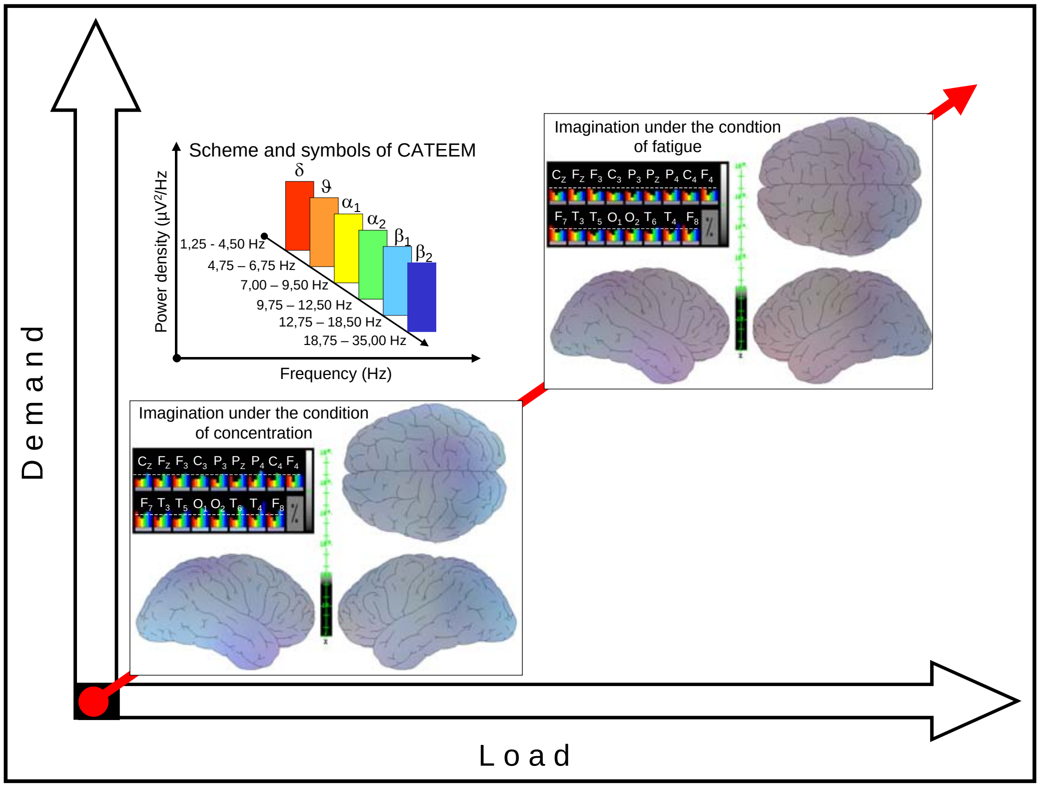

Figure 3. *Colour map for imagination under the conditions of concentration and fatigue.*

The F electrodes are laid out spatially to cover areas of the prefrontal and premotoric cortex (Kolb & Whishaw, 1996) in particular. The view exists that the prefrontal cortex (electrodes F7, F8) is responsible for the temporal and spatial structuring of sensory perceptions during normal memory performance. This is where the planning and preparation of actions, as well as the solving of problems, supposedly takes place. The prefrontal cortex also plays a similar role with respect to recollection, imagination, thinking and the carrying out of actions (Roth, 2001). In addition emotional and motivational components of behaviour involving the limbic system are produced here. It is therefore especially important for the creation and reproduction of movements in the imagination. From the point of view of motion, imaginary movements are individual items of information stored in the memory using structural characteristics of a motional sequence. These are acquired by means of various sense perceptions during practical motor activity. Imaginary movements are also made up of experiences and emotional tones and values concerning internal and external conditions whilst a movement is carried out (Schnabel & Thieß, 1993). No single description exist for mental portrayals of this kind and the many different types are portrayed in the corresponding association areas in the cortex. With this in mind, imaginary movements could be understood as a characteristic of mental processes that enables these to produce new cognitive and motional patterns, by linking together information that was hitherto unconnected (Pauen, 2001). These representations can then be recalled from memory as required. As can be seen in figure 4, particularly under the condition of concentration, an activation level in excess of the reference level, can be discerned at electrodes F7 and F8. When demand continues, there is a significant reduction in beta activity as a result of fatigue.

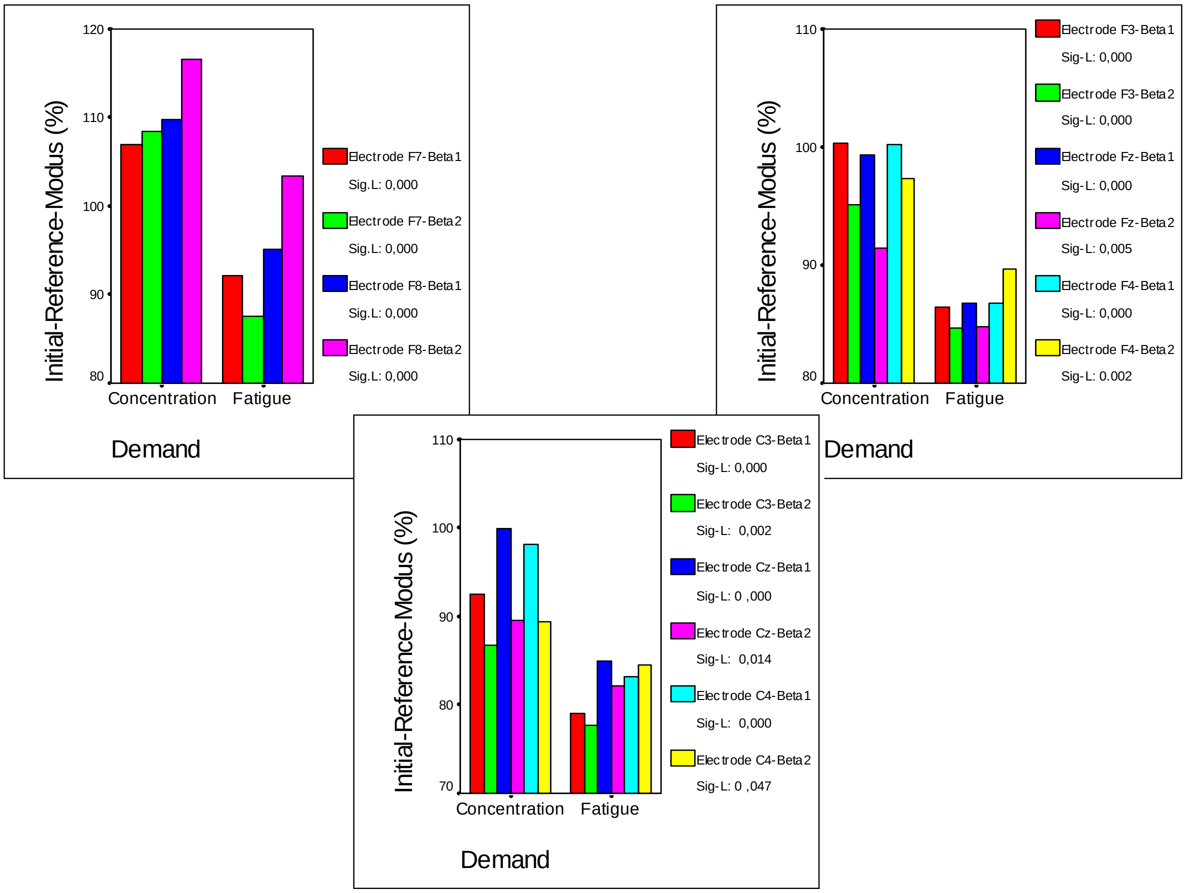

***Figure 4.** Beta frequencies under the electrodes of the prefrontal, premotoric and motoric cortex.*

Electrodes F3, FZ, and F4 are situated above the supplementary motoric and premotoric area of the premotoric cortex at the frontal lobe. By using electroencephalogy, Kornhuber et al. (1965), were able to demonstrate many years ago that between 0.5 and 2 seconds before carrying out a spontaneous movement, a willingness potential is produced in the premotoric and supplementary motoric area, that is transmitted to the frontal and parietal cortex just prior to the movement. This is at its most powerful across these areas, although it is also noticeably strong across the conjoining motoric and parietal cortices. It also tends to become particularly powerful across the conjoining region of the motoric cortex. The authors of this paper therefore conclude that mental reproduction of a motoric action has an influence across very wide areas of the cerebrum.

Mental association of a dance under the condition of concentration produces a frequency level in relation to the premotoric areas, which barely exceeds the reference values (figure 4). It is worth noting the drop in beta frequency when fatigue continues. Differences between the states of concentration and fatigue are of great significance.

The primary motoric cortex is covered using electrodes C3, CZ and C4. The view exists that neurones in this area have a considerable influence on motor output. It seems that for an imaginary movement, efferent and reafferent commands used to carry out a real movement are also associated here. This subjectively-experienced voluntary action can be seen clearly by the electrical activity transferred from premotoric (F electrodes) to motoric cortex (C electrodes). In this area too, we can see that, as a result of association, beta band frequencies do not exceed reference data (figure 4). As there is no motor output, it can be assumed that, with respect to the focussing of attention, these areas are not engaged above rest level. Under the condition of fatigue, the frequency spectrum clearly drops significantly however.

The P electrodes (P3, PZ, P4) cover the parietal lobes. Roughly speaking, the parietal association cortex is divided into front and rear parts. Bodily perceptions such as feelings related to skin, joint placement, balance and temperature are contained in the front part. This is also where a three-dimensional world is constructed and where specific sense stimulate are localised, of one's own body and one's movement in the environment. As such human beings acquire perceptions and knowledge about their location and the position of objects (Anderson, 1996). As Kolb and Wishaw (1996) also emphasise, the function of the rear parietal lobe consists mainly in the construction of space in the mind. There are close connections here to the prefrontal cortex. It is possible that therefore both cortices communicate with each other during mental association. Since a dance that is portrayed mentally also incorporates pseudo-conscious kinaesthetic and tactile events that occur during the movement, as well as the space within which a motor event occurs under real conditions, it is understandable that beta activities under the condition of concentration are for the most part above reference values (figure 5).

Beta frequencies of the two temporal lobes are considerably above the reference range during mental association under the condition of concentration (figure 5).

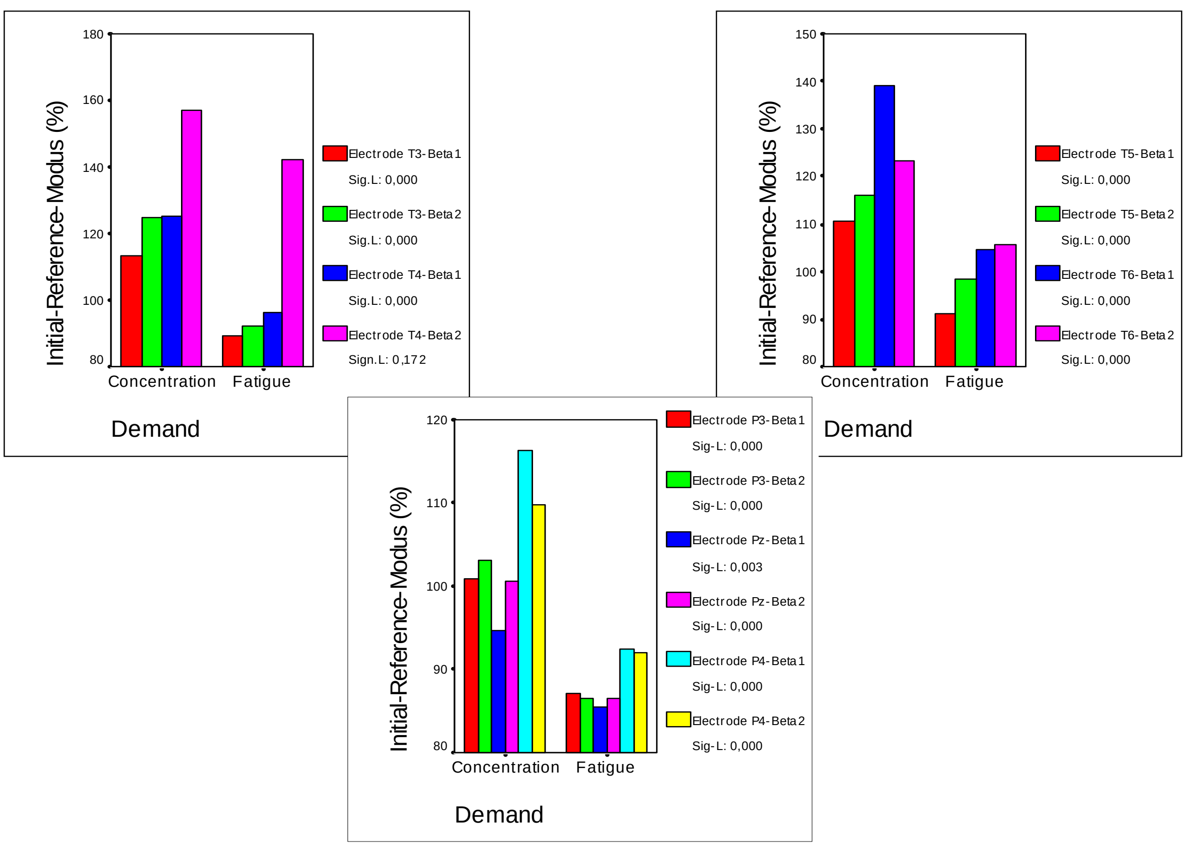

Figure 5. *Beta frequencies under the electrodes of the parietal and temporal cortex*

The function of the temporal association cortex consists in the processing of auditory und visual information. The perception of musical sounds is primarily a function of the right temporal lobe (Kolb & Whishaw, 1996). This enables volume, tone colour and pitch to be distinguished during listening. The ability to perceive auditory and visual objects also includes the identification and categorisation of objects and scenes and the resulting ability to decodify this information (Roth, 2001). Left-sided speech representation (T3 and T5 electrodes across the Wernicke centre) is also supposed to be involved in the hearing of sound sequences. The motor conversion of dance choreography as well as the synchronized movements of dancers is to a great extent affected by the music. This probably explains the high beta frequencies as a result of audiation. Audiation is the process of activating an acquired mental representation in relation to music that has been heard and understood previously (Gordon, 1980). Only when musical elements have been represented and understood musically in one's imagination beforehand is audiation possible and this can be seen by the different way in which the neural networks of the temporal lobe are activated. As a result of central nervous demand, beta band frequencies mainly drop below the rest values (reference values) during the condition of fatigue (Figure 5).

Beta frequencies can also be observed exceeding the rest level under the electrodes of the occipital lobe (O1, O2). At the start of the load, these are way above the reference marker (Figure 6).

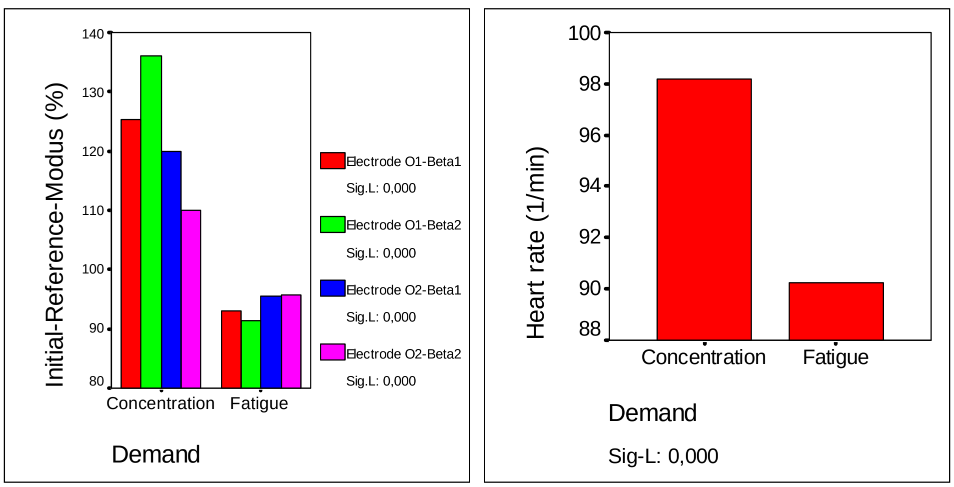

Figure 6. *Beta frequencies under the electrodes of the occipital cortex and heart rate under the conditions of concentration and fatigue*

The occipital lobe is known to contain primary and secondary visual areas, the function of which is to analyse colours and movements. It should also be noted that there is no distinct anatomical division between the occipital, temporal and parietal cortices. Although sight is the only function of the occipital lobe, large parts of other areas of the cortex (parietal and temporal lobes) also full fill visual functions that are closely related to the occipital regions (Farah et al., 1988; Kolb & Whishaw, 1996). In the mental reproduction of a dance, spatial aspects of movements are without doubt depicted mentally too. This means the occipital cortex is also involved in the imagination process to a great extent. This is evident, among other things, from the high frequency rates. As seen in figure 6, frequencies drop significantly below the rest level under the condition of increasing demand.

The post-reports given by dancers after the investigation are also interesting for the context. The following are some of the comments they made on the imagination process:

- I had to concentrate very hard to imagine both the music and the dance together as one entity.
- When I did turns, this involved my feet and my toes to a great extent, but when jumping I put my mental focus on my lower leg and thigh.
- The longer the experiment went on, the harder it became to concentrate.
- At the start, I imagined the dance from a birds-eye perspective, but gradually I saw it more and more from my own perspective.
- I felt so relaxed during the rest phase I could almost have fallen asleep.
- I counted the beat in my mind for all the movements.
- By counting the beat in my mind, I was able to emphasise certain movements.
- Musical emphases provided me with reference points for specific parts of the dance.
- I concentrated mainly on the works of my legs - my arms moved automatically.
- In my mind, I always evisaged myself dancing with another person or in front of a mirror.
- During the dance, my upper body was always in the foreground in my mind. My legs moved virtually automatically.
- When I imagined the dance, I tried to incorporate the music too.
- The dance occurred in front of me and I danced along with the group.

These statements clearly indicate cognitive reproduction of spatial, temporal, kinaesthetic and linguo-symbolic elements of the dance movement structure. The findings confirm the theory that cognitive content recalled from memory is reflected in neural activities.

The heart rate demand indicator is particularly significant with respect to determining psycho-physical demand status. It is a very sensitive indicator, particularly in the case of motor demand. Effects of mental and emotional demand are, by contrast, less easy to determine for the most part, and are reproduced less by heart rate behaviour. This means psycho-physical demand status can often not be discerned for energetic loads or motor actions (Luczak, 1987). As can be seen from figure 6, the heart rate under the condition of concentration is significantly above that under the condition of fatigue. Since motor actions do not occur during mental reproduction of a dance, this high level would seem to be indicate increased cognitive and emotional demand, which then decreases during the course of continuing load, due to fatigue. The post-report stating "I often felt my heart was beating faster because of the tension also supports this theory".

In experiments carried out under laboratory conditions, it was possible to prove that heart rate only becomes significant as a demand indicator if a high emotional load component exists due to a particular informational requirement structure (such as time pressure, information density) due to penetration of the border regions of informational processing (see Luczak, 1987, and references to other authors). With respect to our investigation, this could be a sign of the effect of neurophysiological processes on the heart rate within the context of heightened concentration, as when demand continues to occur, heart rate drops due to fatigue (Figure 6).

Mental association appears to have only a very minor influence on respiration (Figure 7). Differences between diaphragm and stomach respiration under the conditions of concentration and fatigue are insignificant. The increased heart rate under the condition of concentration does not necessarily mean an increase in respiratory rate during the demand period.

Another picture emerges entirely however when we look at neuromuscular factors. The gastrocnemius muscle on the left and right leg was used for the experiment. This muscle, which mainly consists of FT muscle fibres, plays a significant role in sudden jumping movements. Action potential of this muscle was measured at the same time as other measurements by an EMG using surface electrodes. In accordance with the dance choreography, jumps and turns mainly occurred on the left leg. As can be seen from Figure 7, there are significant differences as regards left leg muscle activity between the states of concentration and fatigue.
It seems that, when concentration on the imaginary dance increases, commands are released from the primary motoric cortex which cause minor contractions in the muscle fibres. The statements in the post-report also support this view. It is claimed that neurons in this area receive proprioreceptive and tactile information regarding position of body parts and their speed of movement by means of sensory inputs. This information comes from somatosensoric areas of the parietal cortex and from channels of the thalamus (Ghez & Gordon, 1996). When imagining a movement, it seems that efferent and reafferent commands are also associated as a result of the sensory inputs. These are also present when real movements are carried out. This subjectively-experienced voluntary movement is evident from transfer of electrical activity from premotoric (F electrodes) to motoric cortex (C electrodes). Activity in the motoric cortex is not thought to be the cause of volunatary movements however, this area is supposedly controlled by the premotoric cortex and supplementary motoric cortex.

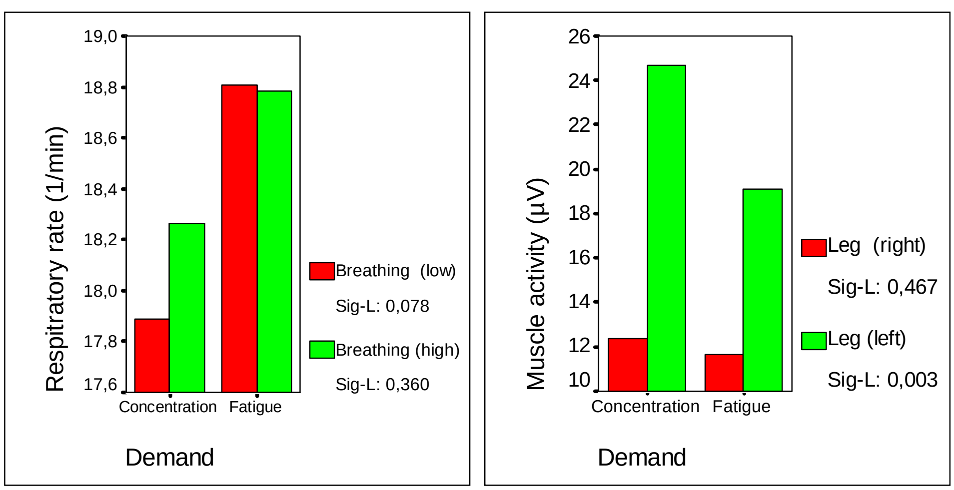

Figure 7. *Respiratory rate and muscle activity under the conditions of concentration and fatigue*

These areas are also affected by the basal ganglions and the cerebellum (Küchler, 1983; Roth, 1998). In much of the research literature in occupational science, it has been noted with respect to this matter that significant changes may be observed in the EEG as a result of the demand situation. This is true both for reduced vigilance in vigilance experiments and for mental demand due to mental activity or sensomotoric activity as well as for emotional demand by stress stimulae for instance (Luczak, 1987).

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