The neurological basis of occupation

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ABSTRACT: The purpose of the present paper was to survey the literature about the neurological basis of human activity and its relationship to occupation and health. Activities related to neurological function were organized into three categories: those that activate the brain’s reward system; those that promote the relaxation response; and those that preserve cognitive function into old age. The results from the literature review correlating neurological evidence and activities showed that purposeful and meaningful activities could counter the effects of stress-related diseases and reduce the risk for dementia. Specifically, it was found that music, drawing, meditation, reading, arts and crafts, and home repairs, for example, can stimulate the neurological system and enhance health and well-being. Prospective research studies are needed to examine the effects of purposeful activities on reducing stress and slowing the rate of cognitive decline. Copyright © 2007 John Wiley & Sons, Ltd.

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Introduction

With the advancement of medical technology in the last decade, neurological imaging scans have enabled researchers to examine human brain function while people are engaged in activity (Nattkemper, 2004). Functional magnetic resonance imaging (MRI) and positron emission tomography (PET) are two types of imaging technologies that provide detailed information about the neurological mechanisms underlying human activity. Electroencephalographs (EEGs) also enable researchers to identify neurological electrical activity while people are engaged in occupations (Bankman and Morcovescu, 2002). Such research has facilitated a greater understanding of the nature of human occupation and its relationship to health.
The current literature about the neurological basis of occupation is organized into three primary categories: activities that activate the brain’s reward system; activities that promote the relaxation response and reduce stress-related disease; and activities that preserve cognitive function into old age. Although scholars have argued that the terms ‘occupation’ and ‘activity’ have distinct meanings, they will be used interchangeably in the present paper to represent the desired participation in behaviours and events that are mediated, to a large degree, by the neurological system.

Activities that are intrinsically rewarding to the brain

The human brain is wired to interpret all activities as rewarding or aversive through the mechanism of the brain’s reward system (Berns et al., 2001). The brain’s reward system, formally called the ‘mesocorticolimbic system,’ is an evolutionarily old mechanism that enhances human survival by distinguishing activities that are pleasurable and should be repeated from those which are harmful and should be avoided (Schultz, 2000). The mesocorticolimbic system is composed of interconnected anatomical structures located in the cortex (conscious decision making), midbrain (maintenance of vital functions) and limbic system (emotional system). The structures of the brain’s reward system include the frontal cortex, ventral tegmental area, nucleus accumbens, anterior cingulate cortex, amygdala and hippocampal formation (Figure 1) (Nestler, 2001; Nestler and Malenka, 2004).

FIGURE 1: The mesocorticolimbic system is the brain’s reward centre.
The primary neural pathway of the mesocorticolimbic system originates in the ventral tegmental area of the midbrain and sends projections to the nucleus accumbens – a structure located deep beneath the frontal lobe. The subcortical structures – the amygdala, ventral tegmental area and nucleus accumbens – have a primary role in the interpretation of activities as rewarding or aversive. The anterior cingulate and the prefrontal cortices receive projections from the subcortical structures and are involved in the conscious decision to engage in or avoid continued activity participation (Nestler, 2001; Nestler and Malenka, 2004; Hyman et al., 2006).

The amygdala also has connections with the hippocampus – a limbic system structure located in the temporal lobe (Figure 1). The hippocampus records and stores memories of emotionally laden events; for example, the sensory memories of eating a favourite food or of ingesting food that caused illness. Such memories enhance human survival by motivating people to repeat pleasurable activities that promote survival and avoid activities that can cause harm (Skuse et al., 2003).

The primary neurotransmitter used by the brain’s reward system is dopamine. Most pleasurable activities increase dopamine levels in the mesocorticolimbic system. Dopamine release has been shown to trigger the brain’s reward system through activities such as food intake, sex and ingesting addictive substances (Hyman et al., 2006). However, dopamine release has also been shown to occur in response to reading humorous cartoons (Mobbs et al., 2003), viewing beautiful faces (Blood and Zatorre, 2001), listening to favourite musical pieces (Aharon et al., 2001) and playing video games (Koepp et al., 1998). Glutamate is another neurotransmitter within the brain’s reward system and appears to have a role in promoting the associations between the pleasurable feelings invoked by a specific activity and its sensory cues (e.g., the smell of freshly cut grass and the pleasure associated with playing ball in a park) (Naranjo et al., 2001).

Musical activities

Music is one of the most pleasurable activities experienced by the brain’s reward system. The human brain is designed to experience music as gratifying; however, cultural factors influence which type of music activate the brain’s reward system (Menon and Levitin, 2005). Stimulation of mesocorticolimbic structures, in response to playing, listening to or singing favourite musical pieces, is often accompanied by the experience of chills or shivers down the spine (Brown et al., 2004). The vestibular stimulation that occurs as people move synchronously with rhythm (e.g., during dancing) also activates the brain’s reward centre (Blood and Zatorre, 2001).

The brain's response to music is influenced by our degree of musical training. Musicians show greater bilateral activation of both hemispheres when listening to music in comparison with non-musicians. Musicians also demonstrate greater left hemisphere dominance when engaged in musical tasks, whereas non-
musicians display greater right hemisphere dominance (Ohnishi et al., 2001; Seung et al., 2005). This suggests that musicians, by using both hemispheres, are able to analyse the logical and emotional aspects of music. The logical, or left brain, aspects of music include skills such as reading and sequencing notes and analysing the timing of rhythm. The emotional, or right brain, qualities of music include skills such as evaluating timbre, pitch and resonance.

Neuroanatomical data from functional imaging scans have also shown that music with words activates the left hemisphere – which is largely responsible for concrete language interpretation. Non-verbal music, however, activates the right hemisphere – which is responsible for the interpretation of emotion, whether of a person’s voice, a piece of music or someone’s body language (Halpern and Zatorre, 1999).

The above findings offer a greater understanding of the neurological basis for the ability of music to evoke pleasure in the brain’s reward system. That the human brain is designed to induce pleasure in response to music suggests that, although music may not be essential for survival, it may possess significant benefit to emotional well-being. In therapy music is often used to motivate patients to engage in activities that are physically painful or challenging. Music has been found to help patients with Parkinson's disease to move with greater ease when physical exercise cannot do so (Thaut et al., 2001). It has also been used to enhance expression in patients who have difficulty verbalizing their emotions (Clement-Cortes, 2004). Researchers have similarly shown that music can help patients with aphasia to enhance verbal communication (Koelsch et al., 2004). When people engage in musical activities they may be able to access alternate neural pathways that can stimulate brain functions, otherwise inaccessible due to pathology. The stimulation of alternate pathways may facilitate functions such as the fluidity of physical movement and communication (Thaut et al., 2001; Koelsch et al., 2004).

**Drawing**

Drawing is another therapeutic activity that stimulates the brain’s reward system. Although activation of the mesocorticolimbic structures have not been analysed during drawing – as drawing cannot be performed adequately within the confines of fMRI and PET scanners – drawing has been assessed with regard to changes in electrical brain waves. Electroencephalograph (EEG) studies have shown that artists are able to generate both theta and delta waves when engaged in drawing (Bhattacharya and Petsche, 2005). Beta, alpha, theta and delta waves are specific electrical patterns that are measured in cycles per second (CPS). Beta waves, which occur at 14 CPS and above, are produced in conscious daily routine activities (e.g. driving to work). Alpha waves (14–7 CPS) occur during daydreaming and in states of relaxation. Theta (7–4 CPS) and delta (4 CPS and below) wave patterns occur during sleep but have also been shown to be present when people are engaged in activities of deep concentration.
such as meditation, drawing and writing (Cantero et al., 1999; Bhattacharya and Petsche, 2005).

In therapy, drawing has been shown to effectively help patients with aphasia to retrieve desired words (Sacchett, 2002). Drawing may improve speech production by providing an alternate neural strategy to access the semantic system. Because drawing largely activates the right hemisphere, it may also recruit right hemisphere semantic networks that can aid in word retrieval when left hemisphere language functions are damaged (Fornazzari, 2005). Like music, drawing can also serve as a means of expression in patients who have difficulty verbalizing their feelings, or who may have repressed unacceptable emotions (Clements-Cortes, 2004).

Studies on artists and musicians who have experienced flow while engaged in creative endeavours support the idea that the mesocorticolimbic system responds positively to activities involving the desire to express creative impulses (Csikszentmihalyi, 1998). Flow is an optimal experience in which people feel intense pleasure and satisfaction while deeply engaged in desired activity (Csikszentmihalyi and Csikszentmihalyi, 1988). That artists, writers and musicians commonly report flow during creative work suggests that such activities positively activate the brain’s reward system.

**Activities that elicit the experience of flow**

In the late 1980s Csikszentmihalyi (1990) used the term ‘flow’ to describe the state in which people experience deep feelings of gratification and elation in response to engagement in highly desired activity. Csikszentmihalyi initially studied flow in chess players, mountain climbers, dancers and surgeons. He found a set of characteristics common to the flow experience that included the following.

- Complete absorption in the activity and diminished awareness of the external environment.
- A sense of oneness with the activity.
- Total immersion in the present moment and a lost sense of time.
- Lost fear or anxiety – everyday worries fade as people become increasingly engrossed in the activity.
- Immense feelings of personal satisfaction – the activity is rewarding in itself.

In addition to artists, musicians and writers, people who commonly experience flow include athletes, surgeons, Buddhist monks, craftspeople and dancers (Csikszentmihalyi, 1990, 1998; Jackson, 1996). These people regularly engage in activities which require disciplined practice over time, deep levels of concentration, an ability to screen extraneous stimulation and a commitment to master
the skills of an activity. Such commitment originates from an intrinsic sense of joy derived from the activity. Anyone, however, can experience flow in all activities that are experienced as deeply rewarding and engrossing. Knitting, needlework, gardening, hiking and cooking are also activities that can elicit the flow response (Csikszentmihalyi and Csikszentmihalyi, 1988).

Although no researcher to date has measured the neurological changes that occur during flow, it is theoretically plausible that the phenomenon results from activation of the brain’s reward system and increased levels of dopamine. The deep mental concentration that is characteristic of flow may also produce the theta and delta brain wave activity that is observed during creative endeavours.

Can patients be taught to use desired activity to elicit flow – just as they have been taught to use cognitive behavioural techniques to effect change? Learning to use activity to elicit flow may be able to offer patients a non-pharmaceutical means to self-regulate emotions such as anger and obsessional phobias. Flow could potentially help patients to dampen internal chaos and extraneous environmental stimulation that could trigger sensory overload. The ability to learn to use activity to elicit flow may help patients with remitted depression to reduce their risk of relapse – just as researchers have shown that a short programme of mindfulness training can reduce our risk of depression relapse (Astin, 1997; Teasdale et al., 2000). Such studies of the flow phenomenon have shown that the use of activity in human life is critical to well-being, emotional health and emotional equinamity.

The similarity between flow and meditation

In many ways the experience of flow is similar to meditation. Common features of both include:

- increased levels of concentration
- complete absorption in the experience and lost awareness of the external environment
- a feeling of oneness with the larger world
- immersion in the present moment and an ability to release worries about the future and regrets about the past
- the attainment of contentment and well-being.

There is a large body of research documenting that meditation activates the structure of the brain’s reward system – in particular the left frontal lobe, which has been correlated with elevation in mood (Aftanas and Golosheykin, 2005). Many studies have also shown that highly practised meditators are better able to maintain emotional equinamity in response to negative stimulations (Newberg et al., 2001). They also score lower than control subjects on instruments measur-
ing levels of negative emotions. When exposed to a stressful event, highly practised meditators are better able than control subjects to return to a state of emotional equilibrium (Ritskes et al., 2003).

Meditation, however, does not have to be practised in a traditional cross-legged position to attain the above-mentioned benefits. Many practitioners recognized the potential for meditation to be achieved through the engagement in dynamic activity, such as in Buddhist walking meditation (Kabat-Zinn, 1995), yogic flying meditation (Ascott, 2000), traditional Native American ecstatic dancing (Oesterley, 2002) and Taoist sand painting (Huntingdon and Bangdel, 2004). Some Buddhist schools of thought suggest that all human occupation should be carried out as a form of meditation, or deep engrossment and heightened awareness in everyday activity. This is one meaning underlying the Buddhist adage attributed to Lao Tse: before enlightenment chop wood and carry water; after enlightenment chop wood and carry water (Mitchell, 1998). In other words, enlightenment is not a state that should be separated from our everyday ordinary activities; rather, everyday activities can be opportunities for meditative practice. Csikszentmihalyi (1990) advocated the same philosophy when he proposed that people can improve their quality of life by eliciting flow in ordinary daily occupations. He proposed that people learn to discipline the mind to enter a state of deep concentration during daily activity that is similar to levels generated while engaged in favoured hobbies.

If patients can be taught to engage in occupation as a form of meditation, might they be able to use occupation to experience the same benefits observed in highly practised meditators? Can patients use occupation and the flow experience to be less emotionally affected by aversive and stressful events? Can patients use occupation as a tool to return to states of greater calmness in response to stress? The use of occupation as a meditative practice to manage stress, anxiety and emotional reactivity could be as valuable a practice to ease daily life stress as meditation and mindfulness training have been.

Activities that elicit the relaxation response

Both meditation and mindfulness training cause precise physiological changes in the human body:

- decreased blood pressure, heart rate and respiration (Newberg et al., 2001)
- increased alpha, theta and delta wave patterns (Aftanas and Golosheykin, 2005)
- increased immune system response (Jacobs, 2001).

Progressive relaxation (Ghoncheh and Smith, 2004; Scheufele, 2000), visualization and guided imagery (Lutz et al., 2004) and flow experience (Jackson, 1996)
also produce these physiological changes. All of these techniques evoke the relaxation response – a term first coined by Herbert Benson in the 1970s (Benson et al., 1974; Benson and Klipper, 2000). Benson et al. (1974) suggested that the relaxation response occurs in all activities that share specific common elements. These include the following.

- The activity is performed in a quiet environment.
- It enhances our ability to focus inwardly and concentrate on the demands of a specific task.
- It encourages disregard of everyday worries.
- It involves focused attention on a repetitive mental stimulus or activity.

The similarity of physiological responses in the relaxation response and the flow experience suggest that both possess common underlying neurological mechanisms. It is highly likely that a common element shared by the relaxation response and flow is the activation of the brain’s reward system.

Benson and colleagues (Benson et al., 1974; Benson and Klipper, 2000) also suggested that the relaxation response is the physiological counterpart to the body's stress response, or the fight/flight syndrome. The fight/flight syndrome, which is mediated by the autonomic nervous system, is the body's evolutionary response to stress. Heart rate, respiration and pulse increase to prepare the body to fight or flee. Increased blood flow travels to the skeletal muscles, heart and lungs to prepare these systems for action. Simultaneously, blood flow decreases to the intestines to slow their function (Jacobs, 2001). Excessive activation of the fight/flight response is often caused by modern-day stress that we cannot fight or flee from. There is a large body of research linking excessive activation of the stress response with disease, illness and injury. Stress has repeatedly been correlated with hypertension (Sower, 2002), increased cholesterol production (Yasunari et al., 2002), coronary disease (Colak et al., 2005; Yudkin et al., 2000), gastrointestinal disorders (Keefer and Blanchard, 2001, 2002), autoimmune disorders (McLean et al., 2005; Picardi et al., 2005), chronic pain (Blackburn-Munro and Blackburn-Munro, 2001), decreased immune system responses (Segerstrom et al., 1998) and the occurrence of accidental injuries (Schnyder et al., 2001).

**Activities that activate the left hemisphere**

Researchers such as Benson et al. (1974), Kabat-Zinn et al. (1992) and Csikszentmihalyi (1990) have begun to build a growing body of research demonstrating that activities which elicit flow and the relaxation response can offer a non-pharmacological means to manage stress. The work of Kabat-Zinn et al. (1992), demonstrating the benefits of mindfulness training, has now been replicated in similar studies (Davidson et al., 2003; Teasdale et al., 2000; Williams et al., 2001). Mindfulness training is a Buddhist practice in which people learn to heighten their awareness of the present moment and conscious thought.
Rather than seeking to stop thought, mindfulness practitioners learn to mentally catch negative thoughts and challenge their validity. Such thoughts are, over time, replaced with less judgemental and critical thoughts that support the practitioner’s ability to make adaptive responses. This is particularly helpful with people whose worries tend to escalate when allowed to engage in uncontrolled rumination.

Short, eight-week programmes of mindfulness training have been found to reduce anxiety, elevate mood and increase antibody levels (Antoni, 2000; Bedard et al., 2003; Davidson et al., 2003; Teasdale et al., 2000; Williams et al., 2001). One reason accounting for the ability of mindfulness training to reduce anxiety and elevate mood may lie in neurological mechanisms. Mindfulness training has been shown to increase cerebral bloodflow in, and activation of, the left prefrontal cortex – an area associated with positive mood (Davidson et al., 2001; Davidson et al., 2003). The two hemispheres of the brain appear specialized for the processing of distinct emotions. Whilst left hemisphere activation is associated with elevated mood and feelings of emotional well-being, right hemisphere activation is correlated with depressed mood and pessimism. Right hemisphere infarctions disable right brain functions and allow the left hemisphere to control emotional processing. Patients in acute stages of right hemisphere infarctions often display euphoria and an emotional dissociation from their illness. Conversely, left hemisphere infarctions disable left brain functions and allow the right hemisphere to control emotional processing. Patients in the acute stages of left hemisphere infarction commonly display severe depression and anhedonia (Astin, 1997; Davidson et al., 2000; Newberg et al., 2001; Ritskes et al., 2003).

Left frontal lobe activation is associated with a greater ability to react to stress with adaptive responses that promote survival. People who typically display greater left frontal lobe activation are more able to return to a neutral emotional state after exposure to a stressful event (Davidson et al., 2003). Repeated transcranial magnetic stimulation (rTMS) is a clinical technique that effectively reduces depression in some patients by increasing activation of the left frontal lobe. Repeated TMS involves placing an electrical magnetic coil on the head through which stimulation is administered to the left prefrontal cortex (Paus and Barrett, 2004). Both mindfulness training and rTMS have been shown to elevate mood through increased activation of the left hemisphere. The question must be asked, then, whether occupation that stimulates the left hemisphere could be used to alleviate depression, prevent relapse, or both. Activity that stimulates the left hemisphere commonly involves logic, sequencing and categorization skills. The concrete interpretation of language and mathematical skills are also functions of the left hemisphere. Solving puzzles – such as crosswords and word-finding games – are examples of left brain activities. So, too, are card games requiring analysis and calculation, reading mystery novels, and games needing the translation of codes and symbols (Barzilai et al., 2004).
Cognitively stimulating activity: protection against dementia

There is growing evidence that cognitively stimulating activity not only induces flow and activates the brain's reward centre but also reduces the risk of Alzheimer's disease and other forms of age-related dementia. Some of the strongest research supporting the protective factors of mentally stimulating activities have emerged from the Nun Studies—a body of research demonstrating that nuns who remained intellectually active throughout life and who displayed high linguistic and verbal reasoning skills were significantly less likely to develop Alzheimer's disease in later life (Snowdon et al., 2000). Maintaining intellectually stimulating activities into old age and mastering verbal reasoning were significantly associated with higher brain weight, less cerebral atrophy and reduced neurofibrillary pathology (Riley et al., 2005).

Similarly, researchers found that participation in mentally stimulating leisure and social activities significantly decreased one's risk for Alzheimer's disease and related dementias (Friedland et al., 2001; Scarmeas et al., 2001; Verghese et al., 2003; Wilson et al., 2002). Although the exact mechanism of this protection is unknown, some have suggested that synaptic complexity and neuronal reserve—which both result from participation in intellectually stimulating activities—may play a role. Synaptic complexity occurs when neurons build greater connections with each other as the brain learns new skills and associates newly learnt skills with mastered ones having existing neuronal pathways. Neuronal reserve involves the preservation of functioning neurons that are silent or non-active. Neuronal reserve allows the brain to remain plastic and flexibly adapt to change—whether from the natural ageing process, illness or accident. The more a person builds new neuronal connections and preserves existing neurons, the less likely it is that neurodegeneration will occur (Kempermann et al., 2002).

Conversely, participation in mentally passive activities has been found to significantly increase one's risk for the development of Alzheimer's disease and related dementias. Several studies have shown that television viewing actually heightens one's risk for dementia. In one study (Lindstrom et al., 2005), the risk for developing Alzheimer's disease increased 1.3 times for each daily hour of television viewing a person engaged in. In contrast, for each hour spent engaged in intellectual activities per day, the risk of developing Alzheimer's disease decreased by 16%.

Gerontologists suggest that participants in intellectually and socially stimulating activities throughout the lifespan provides protection against age-related dementias (Lehmann, 2000; Barzilai et al., 2004). Intellectually stimulating activities include reading, completing crossword puzzles, playing a musical instrument, engaging in crafts and fine arts, writing, playing cards and board games, participating in needlework and completing handy work and home repairs. Researchers suggest that in addition to these activities people can participate in intellectually stimulating activities by learning new skills and hobbies.
taking educational courses, participating in book clubs and travelling to new places (Fillit et al., 2002).

As the population in many industrialized countries ages, therapists can help patients to use occupation to preserve mental function into old age. Such preservation of cognitive capabilities can help people to maintain their independence for longer, thus avoiding the high costs of nursing homes and medication. Daily engagement in intellectually stimulating activity that elicits flow and the relaxation response may have the potential to preserve mental and physical health as effectively as pharmacological intervention.

The use of occupation to enhance health: the legs of a stool

The research discussed in this paper underscores the idea that humans are occupational beings who require constant engagement in activity to maintain health. This research also reinforces the idea that the human brain is designed to respond positively to activities that produce flow, promote the relaxation response and enhance mental stimulation—which, in turn, preserve physical and emotional health. The use of occupation to preserve health and emotional well-being may be viewed as the legs of a stool. One leg involves activity that elicits the brain's reward system and produces enjoyment, pleasure and flow. A second leg involves activity that facilitates the relaxation response and decreases the risk of stress-related health concerns. A third leg involves activity that stimulates mental reasoning and preserves cognitive function into old age. A fourth leg, although not addressed in this paper, would probably involve activity that enhances the musculoskeletal and cardiovascular systems of the body. Occupation addressing these essential areas may have the potential to be used as a non-pharmacological alternative to maintain cognitive, physical and psychosocial function throughout the lifespan. Prospective research is needed to promote the growing body of evidence demonstrating the health benefits of daily occupation. Additionally, as medical technology advances, greater understanding will continue to emerge about the neurological basis of occupation and the relationship between occupation and health.

References


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