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ART MEETS SCIENCE – EMPOWERING STROKE PATIENTS TO REGAIN MUSCULAR CONTROL THROUGH CREATIVE GRAPHICS TECHNOLOGY, PSYCHO-PHYSIOLOGY AND NEUROPLASTICITY

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Treating patients with a cerebrovascular accident or stroke is complicated by severity and site of brain lesion. Muscular control is lost when neural pathways are interrupted or damaged due to embolus, thrombosis or ruptured aneurysm. Return of movement is further hindered by sustained spasticity of muscle groups or inflammation or severance to functionally important neural pathways. Neuro-feedback mechanisms have been explored in the past with some success. A new, improved and innovative method is presented that makes use of psycho-physiology techniques providing immediate visual, auditory and neurological feedback via a fast switching device that relays neuro-muscular movement during rehabilitative tasks and exercises. Visual and auditory signals enable the patient to make use of neurological activity in a purposeful manner, re-directing it to particular tasks. Concentrating on a series of tones elicited via a computer console and by vigilance of changing visual graphics displays allows the patient to accurately control unwanted activity and enables the body to re-learn previously damaged neural circuits. Patients gaining the ability to re-direct and re-route neural pathways have made significant gains in returning function to their leg muscles, particularly to the quadriceps group. These are very often the first groups of muscles to be affected during stroke and make the patient wheelchair-bound and often permanently disabled. Occupational and social functioning is affected and quality of life is altered. Patients who are able to re-gain posture and re-learn to walk are empowered and have a better chance of returning to social and occupational settings. Trials in the United Kingdom have shown significant benefits for patients using neuro-feedback. Significant success by these patients has provided researchers with the potential benefits of using neuro-feedback in rehabilitation and increases our scientific and clinical knowledge of neuro-plasticity in even the large muscle groups of the damaged human body. This technology bridges creative artistic graphics technology with thorough evidence-based science.

Keywords: Neuroplasticity, Proprioception, Psycho-physiology, Rehabilitation, Stroke.

Introduction

The use of cues for improving cognitive deficits following stroke have been followed with great interest by researchers over the past decade with innovative technologies enabling faster progress in the development and advancement of new rehabilitative techniques. In the past, cueing for neglect in stroke patients has been dependent upon using the modality of the cue that matches the task; for example, for a visual modality task, a visual cue should be used (Thompson, 1998). Investigations by the author have focused on the reaction times of the quadriceps muscle group, situated in the upper thigh, especially where incomplete innervation has resulted from a stroke or following a serious sports leg injury such as from a snow skiing accident.

Following extensive testing in the university, field tests were carried out on selected patients who had been admitted as out-patients to the occupational therapy department of Queen Alexandra Hospital, Cosham, United Kingdom (Thompson, 1987a,b,c; 1999). Subsequent research involved collaboration between the University of Portsmouth; Salisbury District Hospital, Odstock, Salisbury; Nottingham City Hospital; and the Royal Naval Hospital Haslar, Gosport. Work is continuing at Bournemouth University.

After using the "quadriceps switch" which was used throughout most United Kingdom hospitals (Fig 1), the need for a faster interpreter of muscle movement was realised (Thompson & Coleman, 1987; 1989). This device had been used as basic therapy equipment in a number of hospitals in Belfast, Northern Ireland, for the rehabilitation of damaged thigh muscles resulting from gunshot wounds consequential to terrorist activity. Injuries often included head, thigh, knee cap and lower leg injury.

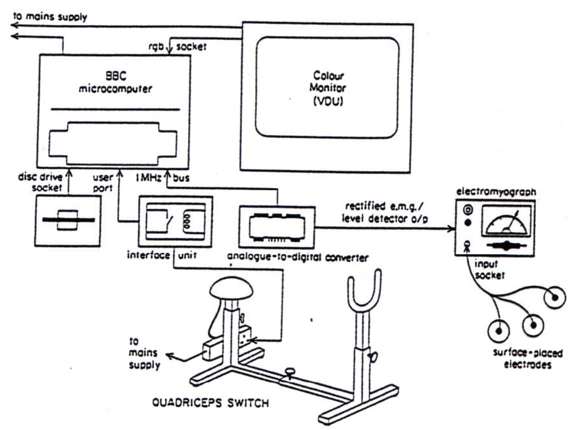

Figure 1. Interface with Thompson Digital Switch interface unit.

New Research into Stroke

Computer-assisted display techniques and electromyography (EMG) was chosen to measure muscular electrical nerve activity. These devices were also considered beneficial for those patients suffering from leg trauma acquired during sporting activities such as snow skiing, and also from some surgical interventions (Thompson & Morgan, 1996) (Fig 2). Development of this technique included a portable EMG device (Nexus-4) that can be carried or strapped around the waist of the patient. The Nexus-4 is a development of Mindmedia BV (2011) (Fig 3).

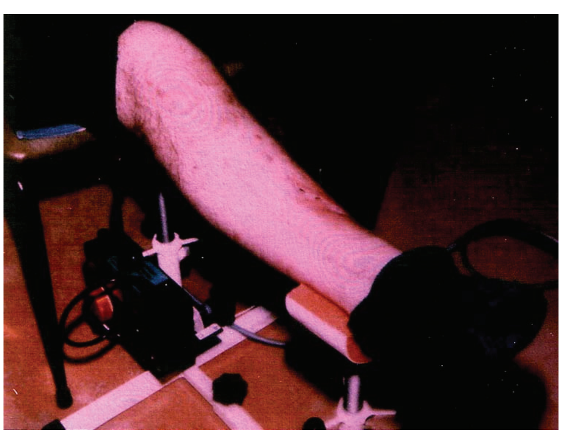

Figure 2. Snow skiing leg Injury.

Figure 3. Portable EMG (Mindmedia BV, 2011).

The Thompson Digital Switch (Thompson & Coleman, 1989; Thompson & Morgan, 1996; Thompson, 1999) was designed and developed to accurately and quickly detect and interpret very fast signals obtained from a specific neuromuscular site on the leg muscle (Fig 4). This device was marketed by Digital Services Ltd, Portsmouth, United Kingdom. The nervous electrical activity was used to produce a range of graphics displays that fed-back to the patient information about the status of the muscle group during exercise (Figs 5 & 6). Variations in displays and tones were designed and validated, in order to optimise on the best type of cue for eliciting the patient's correct response during therapy. The apparatus was successfully used with large break leg injuries, particularly, where the tibia had been broken. Leg muscle that was reduced as a result of wasting during rehabilitation, or from direct surgical intervention has also benefited from this device (Fig 7) (Thompson & Coleman, 1987).

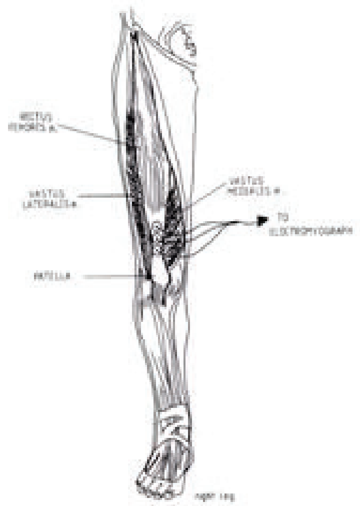

Figure 4. Three surface electrodes on quadriceps.

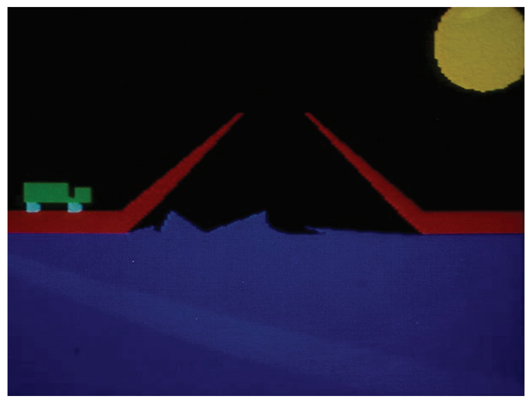

Figure 5. Opening bridge when muscles are relaxed.

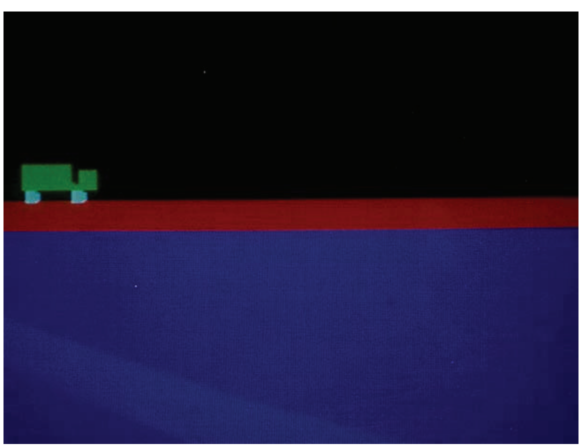

Figure 6. Closing bridge when muscles are contracted with lorry moving across.

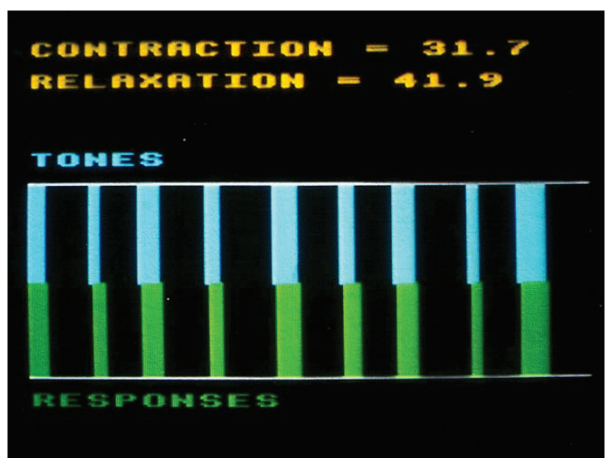

Figure 7. Audible tones (top row in blue) and patient's responses (bottom row in green).

Focus on the performance of the quadriceps has employed a computer-controlled configuration comprising an EMG, computer and quadriceps switching device as well as the Thompson Digital Switch. Initially, seventy-four therapy sessions were conducted with a team of occupational and physical therapists over a 6-week period using stroke patients at mid-stage and late stage stroke. The results from these sessions were collated and compared with controls' data obtained from hospital and non-hospital employees who were tested at various stages of the project.

Significant improvement was found (2.5% level) in the contraction scores of patients during the test period. It was noted that patients improved as they passed from the mid-stage of stroke through to the late stage of stroke with response times of the quadriceps tendon and biceps femoris improving significantly. These muscles are crucially involved in walking and therefore, the muscle tonus is important and is associated with a return in ambulatory movement. These encouraging results have led to the improvement of a configuration that can be delivered to patients in different settings and using a light weight and portable piece of equipment. Results also lend important support for the increasing belief that certain nervous tissue can regrow and re-route along same or new neural pathways.

Exploration of other neurological conditions and the possibility of neuroplasticity occurring, has led the author to also explore a commonality among many neurological disorders, repetitive yawning.

New Research into Yawning

Yawning has fascinated scientists for centuries. Hippocrates included it in his list of “useful natures” and Hindus used to regard yawning as a religious “offence”. Some ancient superstitions saw yawning as the escaping of the soul. However, scientists today are still amazed with the extent to which yawning may possibly tell us about many other neurological conditions (e.g. Thompson, 2010a, b).

The importance of yawning in helping us understand other neurological mechanisms has led to La Société Française de Neurologie et La Société des Neurosciences convening the first international conference on yawning at l’Hôpital de la Pitié-Salpêtrière, Paris, France in June 2010 to which the author was invited as one of the Invited Speakers.

It has been commonly thought that yawning replaces important oxygen in the blood by expanding the lungs and stretching the muscles. Indeed, stretching the lungs potentially increases their capacity and also increases wakefulness (Provine, 1986).

Figure 8. Fox.

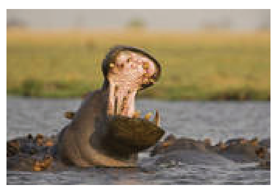

Figure 9. Hippopotamus.

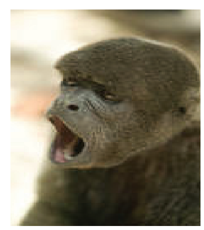

Figure 10. Monkey.

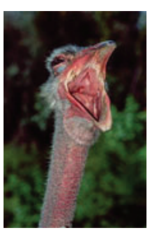

Figure 11. Osterich.

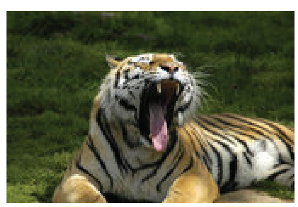

Figure 12. Tiger.

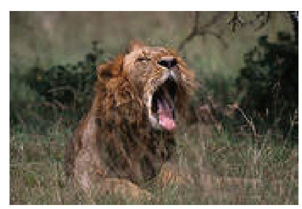

Figure 13. Lion.

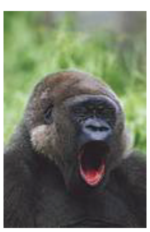

Figure 14. Gorilla.

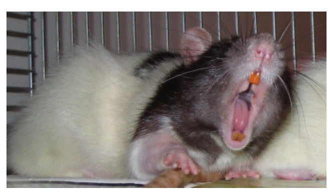

Figure 15. Rat

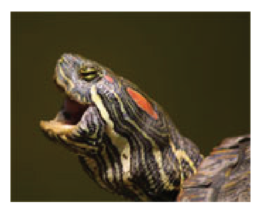

Figure 16. Turtle.

Figure 17. Pig.

The curious nature of yawning has led researchers to question these beliefs especially since yawning has been evidenced in so many animals as well as in humans (Figs 8 - 17). Yawning has been seen even in rodents (Photo 25.8), and in the order of reptiles known as the Testudines (which is the crown group of the super order of Chelonia) such as turtles (Fig 16), and in pigs (Fig 17).

A possible reason for yawing is that muscle movements and compressions stimulate the carotid body, receiving shunted blood, giving rise to an increase in pressure and hormones release (Matikainen & Elo, 2008). Stretching the muscles involved in yawning implicates the locus coeruleus, paraventricular nucleus of the hypothalamus, and reticular activating system (Provine, 1986). However, others believe that neural mechanisms are responsible for the mechanical action as well as the aetiology (Thompson, 2010a,b).

In pre-term and near term infants (Fig 18), the incidence of yawning and also the frequency, decreases during the day and with age (Giganti, *et al*., 2007). This is probably due to circadian and homeostatic control of sleep and wakefulness. In non-primates, the incidence of yawning is higher before than after sleep (Walusinski & Deputte, 2004). The yawn may be a physiological trait emerging from a vestigial reflex that coordinates aggressive social behaviour (Prasad, 2008).

However, Walusinki and colleagues (2010) have shown that the onset of yawning can coincide with involuntary rising of the paralysed arm in stroke, leading the authors to coin the term “parakinesia brachialis oscitans”. This particularly interesting given the fact that we have evidence of neuroplasticity in stroke patients and can speculate that the yawning reflex may possibly encourage neuroplasticity in this group of patients. The link between brain-stem ischaemia and excessive yawning is also well documented (Wimalaratna, & Capildeo, 1988) and suggests that neural mechanisms are involved.

Fifty per cent of us yawn within 5 minutes of seeing another person yawn. It is suggested that yawning is an innate action that recognises a particular behavioural state. Indeed, Mental Attribution Theory provides an explanation along the lines that we simulate another’s behaviour if we empathise with their perceived emotional state.

However, there is an historical lack of clarity of the neurotransmitters implicated in some neurological disorders, such as Parkinson’s disease, that makes us uncertain about the role of yawning in such diseases. Namely, dopamine was thought to be the only one implicated in the disease, and later on, also serotonin. Likewise, in Alzheimer’s disease, E2020 (acetylcholine esterase inhibitor) is known to have an effect on memory functioning and has been introduced as an “anti-dementia” drug yet E2020-induced yawning is not blocked by Scopolamine, for example.

Serotonin is also implicated in depression because of its depletion. Monoamine oxidase inhibitor-A, is active for serotonin (Jansen Steur, 1997). Dopamine is thought to be implicated in contagious yawning by activating oxytocin in the hypothalamus and hippocampus. Yawning is now thought to be influenced by the neurotransmitters acetylcholine (active in memory functioning); gamma amino butyric acid (GABA); and Adreno-Cortico-Trophic Stimulating Hormone (ACTH). Thompson has recently postulated the Thompson Cortisol Hypothesis (Thompson, 2011) in which cortisol levels may be key to triggering yawning when levels are high (Thompson, 2011). Yawning may also increase arousal and self-awareness and connects consciousness as well as unconscious interoception to higher mental functions (Walusinski, 2006).

Figure 18. Pynq Thompson, aged 28 days.

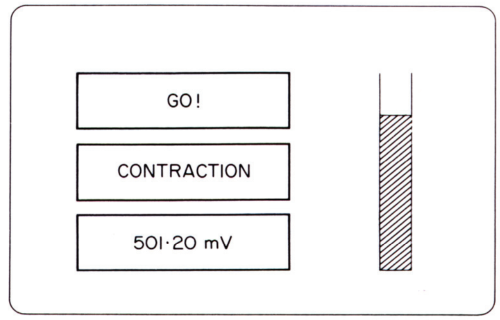

Figure 19. Alternative display.

Conclusions

Walusinski and colleagues (2010) have been influential in re-writing our knowledge of the "yawn", particularly with descriptions of parakinesia brachialis oscitans. Furthermore, the proposed mapping of the neural network for yawning may be possible from knowledge of stroke localisation. This invites an exciting new area of research potentially linking together several neurological disorders as well as re-visiting the intriguing area of neuroplasticity.

Feedback systems typically had limited application in the early 1960s but later gave clinicians more than just familiarity with this new way of representing "body waves". Subsequent modifications of the Thompson Digital Switch have included alternative interactive displays such as a rising and falling thermometer, and an alternative "microvolts" display showing electrical activity (Fig 19). Current examination is focussing on further updating the device, software and system and its use with other systems so that the concept of developing an expert system is revisited. Improvement is graphics displays is creative as well as scientific and allows science and art to come together in a meaningful and beneficial way for our neurological patients.

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