Theories on the Scientific Principles applicable to the Reviver

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About the Author

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Introduction

Thus far, self-reports by users of the Reviver exercise machine and simple observations by Isodynamics center staff indicate a myriad of benefits. A number of users demonstrate immediate and marked improvements in walking and posture, which persists through regular use. Regular use also produces visually evident increases in muscle tone, and some users report improvements in memory and reduction in pain symptoms from pre-existing ailments.

In what follows, the probable scientific basis of the observed improvements are explored. The physical benefits obtained from use of the Reviver derive from improvements in both muscular and neural systems. These improvements can be explained by a number of principles; neuroplasticity, neuromodulation, assisted motion, recruitment of full-body automatic/reflex actions and utilisation of gravity.

1. Muscular Effects

Muscular atrophy is the reduction in muscle mass, caused primarily by lack of physical activity. Use of the Reviver has the ability to reverse this effect considering the following principles.

1.1 Assisted Motion

For elderly people, or people with a physical impediment, a large range of natural motions and muscular activation patterns will not be available to them. Assisted motion is a prominent technique used in neuromuscular rehabilitation whereby some

mechanism is used to help the person perform a motion that they would otherwise be unable to perform. For example, robotics are used in treatment of chronic stroke patients to aide in limb motor control, and has been shown to increase motor control (Kwakkel et al., 2008; Prange et al., 2006). In some studies, this improvement is greater than conventional movement therapies (Lum et al., 2002).

The Reviver machine fully supports the participant whilst moving them through a range of body positions. These body positions engage strongly and simultaneously a set of core and peripheral muscles required to keep the body upright. This engagement will strengthen those muscles and strengthen the neural pathways from the brain to those muscles, which may have weakened through non-use.

1.2 Automatic Responses

There are some cases in neurology where a specific function may be impaired, but if that function is part of a distinct or more complex process, then the impaired function can nevertheless be recruited. For example, some patients in advanced stages of Alzheimer's disease may have impaired speech and communication, but can nevertheless sing along to familiar songs, and experience temporary improvements in communication (anecdotal) and reduction in agitation and anxiety (Gerdner, 2005) subsequent to music therapy.

The self-righting reflex in response to falling is an automatic reaction requiring minimal conscious decisions or actions. The Reviver activates this response by placing the participant on positions at the edge of, and beyond their balance. This strong survival response appears to be recruiting motor patterns and muscles which had become weak through lack of use and reduced signaling, and which are no longer activated through the participants other physical activities or daily living.

1.3. Gravitational effects

All natural human movements evolved within the constraints of gravity and counteracting the force of gravity is a major component of these movements. The most striking example of the necessity of gravity in human physical function is the dramatic wastage of muscle tissue in astronauts exposed to periods of zero gravity.

One of the major design principles of the Reviver is to maximise the effects of gravity, and to maximise the participants' counter-reaction to gravity. In an upright position, as utilised in most physical activities and sports, minimal force is required to counteract gravity as the center of gravity is directly above their support base. In a tilted position, the participant has to counteract torques (rotational forces), due to their center of gravity being displaced from their support base. Counteracting these torques requires substantial muscular activation, yet due to the support of the machine, this muscular

activation is possible for most participants, even those with substantial movement impairment.

2. Neurological Effects

All motion other than simple reflexes originate in the brain. The brain and the body work as a single integrated system, and many physical impairments have origins in the brain. In fact, improvement in any movement or action, from hitting a tennis ball to walking up the stairs result from refining and strengthening of the neural circuits which compute and execute these actions. The strengthening of these circuits comes about by repetition and adaptation in response to external feedback.

2.1. Neuromodulation

The drastic improvements observed after relatively short periods of use on the Reviver exercise machine are most likely due to a process of neuromodulation. Neuromodulation is the alteration of nerve activity through targeted delivery of a stimulus, such as electrical stimulation or chemical agents, to specific neurological sites in the body. In the context of therapy, neuromodulation is primarily used as a means of inducing neuroplasticity, which is described in the following section.

Neural activation is crucial for neuroplasticity to occur. For example, stem cells can replace damaged oligodendrocytes and re-insulate axons, but will only do so if the neuron is active, which is often not the case for damaged or disused tissue. Neuro-modulation for therapeutic purposes artificially activates natural intact pathways, and synchronises healthy neural tissue, leading to stronger connections and healthier neurons within these pathways (Kuo et al., 2014; Ridding and Ziemann, 2010). Neuromodulation can also enforce reconnection in malfunctioning tissue.

Neuromodulation has been used effectively for Parkinson's Disease patients, whereby an implantable pulse generator is implanted in areas identified via Magnetic Resonance Imaging as defective. This treatment generally reduces motor symptoms and most patients can reduce medication (Benabid et al., 2009). Neuromodulation has also been used effectively for Epilepsy patients, where the vagus nerve is stimulated, and 30-50% of patients experience a reduction in seizure frequency and severity (Ben-Menachem, 2002). These therapies are quite invasive and require the implantation of a device. Less invasive methods involve application of a miniature electrode array to the tongue, a technique developed by the Neurorehabilitation group at the University of Wisconsin. This group applies the stimulation to the tongue at the same time as the patient carries out a movement task (Cranial Nerve, Non-Invasive Neuromodulation; CN-NINM). This combination is thought to be highly efficient at stimulating neuroplasticity (Danilov et al.,

2007; Wildenberg et al., 2010). This technique yields large and rapid improvements in walking capabilities of traumatic brain injury and multiple sclerosis patients.

We have documented equally large and rapid improvements in low-mobility elderly participants, and in one case a cerebral palsy patient. The Reviver uses a very similar principle to CN-NINM, but is even less invasive. The stimulus is the periodic perturbation of the vestibular system via circular motion at a tilted angle. Such a stimulation does not occur in day-to-day life. Although the input stimulus is not electrical, the stimulus (motion) will generate an electrical impulse in the vestibulocochlear (ear) nerve in much the same way as the microelectrode array in CN-NINM generated an electrical impulse in the hypoglossal (tongue) nerve. The combination of a targeted stimulus (the circular motion) with physical activity (the contracting and relaxing of muscles required to maintain equilibrium), is likely to enhance neuroplasticity in damaged or disused motor and balancing circuits. In fact, given the strong neural interconnections between balancing and motor systems, we hypothesise that the vestibular system is a particularly appropriate target for neuromodulation.

2.2. Neuroplasticity

The brain has an innate ability to heal itself, and to compensate for lost function by strengthening existing pathways, or recruiting new pathways should an existing pathway be irrevocably damaged. There are a large number of mechanisms contributing to this ability, which are collectively termed neuroplasticity, and are described below.

1) Structural plasticity

- Neurons themselves can change structurally.
- Requires neighbouring neurons to fire in synchrony.
- Receiving (postsynaptic) neuron can increase the length and number of dendrites (the branches of the neuron which pick up incoming signals)
- Transmitting neuron can create more axonal branches and terminals.

2) Synaptic plasticity

- Neuroplasticity can occur at the terminal between two neurons.
- When a neuron is repeatedly active
- The amount of neurotransmitter released for each impulse (action potential) increases
- The number of receptors on the receiving neuron can also increase

3) Myelination

- Communication between neurons is critically dependent on the insulation of the wiring (axon)
- Axon is covered in myelin.
- Speed of electric signal dependent on amount of myelin.
- Use of a pathway increases the amount of myelin.

4) Neurogenesis

- Thousands of new neurons are produced each day from stem cells
- In the event of injury, stem cells migrate from their origin in the brain to damaged areas.
- It is not yet known whether and under what conditions these stem cells can repair damaged tissues.

We cannot say which of the above mechanisms are specifically targeted by the Reviver machine, but any alteration to brain function will be a result of one or multiple of the above mechanisms.

2.3. Exercise Effects on Brain Health

Some of the brain benefits from use of the Reviver can be attributed simply to the more general benefits of any exercise to the brain. Humans evolved as a nomadic specie, constantly on the move, and today's sedentary lifestyle does not provide the brain with the activity and nourishment needed for optimal performance. Physical activity is extremely beneficial for brain health via a number of mechanisms. Exercise increases the creation of new brain cells (neurogenesis), increases production of neutrophic factors, which support the growth and survival of neurons and exercise increases blood flow to the brain (Hillman et al., 2008).

The primary cell in the brain is the neuron. Neurons consist of a cell body which receives signals and performs calculations, and axons, which relay signals to other neurons. Grey matter is the term used to refer to the cell bodies of neurons. Exercise increases the volume of grey matter in the hippocampus, the area of the brain responsible for memory formation, and the prefrontal cortex, involved in working memory, attentional control, decision making and behavioural inhibition. White matter is the term used to refer to the axons of the neurons, and more specifically, the myelin which insulates the axons and improves conduction of electrical signals. Exercise improves the structural integrity of the white matter tracts in the brain, and thus

improves communication between different regions of the brain (Sexton et al., 2016). These positive effects of exercise on brain anatomy and physiology are accompanied by improvements in cognition, in particular executive function (Hillman et al., 2008; Hotting and Roder, 2013), which includes functions such as attentional control, planning and working memory.

It should be noted that the vast majority of studies looking at the effect of exercise on brain health consider aerobic exercise. The effects of resistance training are much less well documented. However, resistance exercise has been seen to improve executive cognitive function (Liu-Ambrose et al., 2012; Nagamatsu et al., 2012).

Since the Reviver allows people to perform movement they may otherwise be unable to perform, then a large part of the benefit of the Reviver derives from allowing people to tap in to these benefits of exercise which were previously unavailable to them. Furthermore, the improvements in muscle tone and balance acquired from using the Reviver can allow elderly people to subsequently engage in more demanding activities, and thus further the neurological benefits of exercise.

2.4. The Motor System

The neural apparatus for executing movements is distributed throughout the brain. The primary motor cortex sends signals to the muscles via motor neurons telling them to contract. If the strength of this signal reduces, the efficacy of contraction reduces. But before this signal is sent to the muscles, a complex system of planning, feedback and modulation takes place in the brain. The premotor areas plan sequences of movements and integrate movements with sensory information, the cerebellum calibrates the timing and precision of movements, the basal ganglia modulate and smooth movements. Damage to any of these areas, or the connections between them will result in sub-optimal movement. Additionally, non-use of these areas and circuits, either through physical impairment or changes in lifestyle will weaken the connections and excitability between the involved brain regions (Facchini et al., 2002; Kaneko et al., 2003). Conversely, the motor system displays a high degree of plasticity and can be strengthened through motor training (Adkins et al., 2006; Boroojerdi et al., 2001).

3. Summary

In summary, early observations indicate that the Reviver is extremely promising as an exercise machine and even as a therapeutic tool. Objective measurements and follow ups will be needed to validate its efficacy and determine in which conditions it is most effective. These trials are currently in planning stages. At this point we can say with very little speculation that the Reviver machine is particularly adept as a tool for elderly users with reduced function, as the machine assists them to perform motions beyond their

current physical capabilities, and activates muscles which are rarely used in day to day activities and are thus subject to atrophy.

Rapid improvements in some users are best explained in terms of neurological, rather than muscular phenomena. The closest precedent in the scientific literature is the emerging field of neuromodulation. The Reviver inputs a strong, targeted and novel stimulus simultaneously to the user being engaged in some task, which is a hallmark of a number of more high tech neuromodulation strategies. This combination is thought to optimally stimulate neuroplasticity and strengthen the users' natural neural systems, which could explain the rapid improvements in walking and posture in some users.

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