A Practical Guide to Good Mouse Keeping!

Since its invention in the early sixties the computer mouse has taken on an increasingly significant role as an input device, becoming key to many new applications and central to user-software interactions. This has resulted in both greater usage of and dependency upon the computer mouse.

A major contribution to this fact is the perception that keyboards cause impairment, exhibited as a wide range of syndromes known as Musculoskeletal Disorders (MSD). The assumption that MSDs, in relation to computer input, result from repetition may come to be viewed as undue.

The use of "system failure" statistics, clinical consequence, to identify cause in a complex dynamic, such as the human musculoskeletal system, is not an indicator or linear diagnostic. Years after the "Repetitive" assumption was acted upon to produce a wide range of ergonomic keyboards, MSDs, rather than decreasing, continue to increase and "more than 50% of computer users report MSD's during the first year after starting a new [computer related] job." (1)

The use of the Repetitive Strain (or Stress) Injury (RSI) has lead to an undue emphasis being placed on the word "Repetitive" as the agent by a lay community that understandably has no actual concept of what "physiological strain" is. Understanding the word strain at a biomechanical and physiological level may provide more insight and

be more effective for designing tools for the management of the mousing task. The assumption that repetition by itself is an agent makes no allowance for the biomechanics, physiology and the biochemistry that are not user variables, relative to the only variables of use-verses design of the mouse input device.

By the age of 70 the average human heart will beat about 3 billion times: that is repetition! “Repetitive Beat Syndrome” is not a clinical condition because premature failure is attributable to physiological changes that are coincidental to “use”, the actual failure and changes being examined at the time by post mortem analysis. In the heart there are no cognitive user variables to alter so it should be safe to assume that if the right work is done in the right way repetition need not be indicative of premature failure. Therefore the “agent” must involve other issues, which may or may not include repetition.

There is no defined “test” for RSI; it is categorized (scored) by the diagnosis of physiological change, impairment and, frequently, employment profiling. Biomechanics can provide quantitative tools for making objective comparisons of various postures by dynamic assessment. These tools aid in understanding the physics that applies as much to our “human structure” as it does to the structures humans build. In the pursuit of the “agent” of computer input MSD’s, a lowest common denominator, it should be remembered that behind all biomechanics there is biochemistry as there is no physics without physiology. So we should not only examine the macro level; posture and the biomechanics of mousing, but also its impact at the micro and sub micro levels; our

physiology and biochemistry. Posture impacts biochemistry, ergo ergonomics manages molecules [(2)].

Work analysis can provide insightful feedback regarding the magnitude of the task of mousing, both in load and repetition. The data presented below is empirically derived, based upon certain assumptions for the purpose of example only and can be disputed or emphasized unduly. It is presented to demonstrate that computer mouse users annually perform an amount of work (muscular activity) that is not fully appreciated on a minute by minute basis, especially when perceived as being "sat at a desk" work.

Holding Mouse Devices:

Grasping any device to control it requires muscular activity above that of being at rest. Muscles can be compared to engines, at rest they "idle". The body in most cases has two sets of opposing muscles and even when at rest "they are busy doing nothing" and "working the whole day through'. Therefore ANY variance from a resting posture results in activity of one of the two muscle groups. Applying grip to an object can be likened to increasing the "RPMs" on that muscle group "engine" and proportionately more fuel is consumed and exhaust produced as a result.

The finger extensor muscles open the hand, in opposition to the flexor muscles that close it, so facilitate grip. If the flexor muscles are used (some degree of grip applied) significantly more than the extensor muscles then, in relation to the extensors, the flexors develop more muscle tone. This is not uncommon in the hands of mouse users, resulting

in mousing hand fingers curling inwards towards the palm (when at rest) more than those of the other hand. Known as “claw hand”, this can usually be remedied by orthotic hand exercisers. This condition demonstrates that repetition of an imbalance (the overuse of grip in this case), can amplify small actions to the point of clinical consequence. In this example, grip is the agent and repetition only a factor.

Grip Force:

The amount of force used to grip mice will vary with each individual’s method. Any degree of grip requires hand muscles to work. To better appreciate this point, rest and relax your hand in the handshake position on a surface. Curl you index finger in by one quarter to one half of an inch and see how long you can hold it there and note the sensations experienced. Observe by looking or touching the inside and topside of the forearm as you flex fingers, you should notice how much reaction there is along the inside of your forearm for just a small movement of the index finger. Most mouse grip force is applied between the thumb and little finger. The thumb, designed solely as an opposing surface, has low dexterity as it is there to resist the force applied by the fingers and so provide grip for object manipulation.

Under mechanical advantage law, a one ounce force applied to the thumb tip is equivalent to 10 ounces of load at the Carpal Meta Carpal (CMC) joint of the base of the thumb. If applied for 3 hours per day over 222 days (We’ll define as a “mouse year”) this equates to 750 Tons of force applied through the CMC joint. That is to say that a one

ounce of force, applied for a mouse year, is equivalent to the CMC joint moving a mouse weighing 750 Tons for one second.

Click Frequency:

This is application dependent, so in the interest of scientific inquiry Solitaire was played. Nib click less software (Designer Appliances Inc) was used to count clicks and perform all click and drag functions. A game that played out to completion required a total of 250 clicks, and took approx. 4 minutes; one click per second! Avoiding work? Solitaire isn't; a 2 hour session will likely consume 7,000 clicks or 1,598,400 clicks in a mouse year!

(Insert "A typical Click Day)

In real work scenarios a click count of 8,000 to 10,000 per day is normal. Web browsing for just a few hours can easily double that figure (16,000 / day); so more than 3.5M clicks a mouse year are likely,

Cursor Distance:

Movement is dependant upon the type of input device used and the cursor acceleration and speed settings chosen. If the average distance the mouse is moved between clicks is 2 inches, a user who clicks 16,000 times a day will travel a distance of 112 miles (180 Km) in a mouse year.

Mouse Manipulation:

Generally there are 3 methods of input device manipulation. Devices other than conventional mice are not included in this comparison.

Single Digit Manipulation (Trackball/Roller Devices): These typically place the entire movement load on a single digit, often the thumb; the least dexterous of them all. They are commonly used (and indicated) as assistive devices from a perception that immobilizing an injured limb provides relief or aids in recovery, some have built in wrist rests (see Wrist Rests below). While the short term use of a different posture can provide temporary relief (see New Posture Syndrome below) in the long term they can have unforeseen impacts, especially on the joints of the one finger that is now bearing the brunt of the work. It is also likely that a loss of muscular tone will result in those muscles that are now due to immobilization of the hand. Single-digit devices can have efficacy under a well managed break regime for those who have finger mobility but limited or no arm mobility. Use of the palm to "roll" the trackball may produce better results, but this still promotes a palm-down posture.

Wrist/Elbow Manipulation ("Palm-Down" mousing): This group includes the majority of mouse products currently sold. All create varying degrees of wrist pronation (twist) away from the neutral, mid-pronated or handshake position. Though recent designs have become more vertically (handshake position) oriented they are still many degrees away from the desired neutral position. In addition to twisting the wrist they also require grip. Mouse grip, while mostly employing the little finger and thumb, due to mouse size and shape, still causes the other fingers to "claw" so as to stabilize it. The amount of grip

varies by mouse design and from the working habits of the user. The wrist is unsupported, and the wrist is often bent upwards and so the weight of the user's arm presses down up on the carpal tunnel as it pushes the wrist into either the mouse itself or, with small mice, the mousing surface. This is also the point where the main blood vessels to the hand are closest to the surface. While it is possible to employ the upper arm for manipulation and keep the wrist off the mouse or mousing surface, these designs do not inhibit or discourage such bad practice. Typically some or most of the fine lateral (east west) movement is performed by deviation of the wrist in the directions of the radius and ulna (beyond advisable angles) and coarser movement by pivoting the elbow. Up/Down (North / South) movement is by using the upper arm.

Upper Arm Manipulation (Upright or Vertical Mice): The primary design objective of most of these devices is to remove wrist twist that is intrinsic to "ordinary" mouse use. Most include a surface which the hypothenar eminence (the fleshy pad between the base of the little finger and the wrist) rests upon. This prevents the wrist from being dragged across the mousing surface and because the wrist has a lesser degree of "flex" in the radial/ulna plane the user will more instinctively set a more optimum (based on comfort) mousing height. Most Uprights do not have a method of limiting wrist movements in the horizontal plane however and so can still be manipulated by flexing the wrist to the left or right. Upright mice are necessarily larger by design and the impact this has on free flexing wrists has yet to be established. By prescribing a posture that encourages the forearm and elbow to be above the working surface they encourage the use of larger and more resilient upper arm muscles, while the shoulder acts as the fulcrum, the pivotal

point of manipulation. While all these devices place the hand in a mid-pronated position to eliminate wrist twist, all but one requires the use of grip to manipulate them. Most use a joystick type of design requiring a claw grip or cause the extension of fingers into an extended pinch grip. While undoubtedly an improvement over other designs, they do not deal with the grip and wrist flex issue but focus on solving one aspect of a multifaceted problem (wrist twist).

Insert Hand at Rest

Insert Functional Neutral Hand at Work

Mouse Related Devices.

While analyzing mousing it is appropriate to consider other related products:

Mouse Mats: Used to a lesser extent with the advent of optical mice (in favor of using the desk surface), these have an impact and continuing role in the mousing process. Older style mouse mats, with cloth or hard vinyl surfaces, were designed to generate friction and thus traction for the roller ball that moved the cursor. If used with an optical mouse the need for roller ball traction is not required and creates unnecessary friction between mouse feet and the mousing surface. They should be replaced with a smoother mousing surface, designed for lower friction / improved maneuverability, thus reducing mousing effort. The advantage, compared to mousing on desk surfaces, is the ability to replace the mouse mat (and if wear occurs, mouse feet) so any gradual deterioration of

the mousing surface that increases resistance or creates optical flaws can be corrected and restored to “as new” under an ergonomic optimization program.

Wrist Rests: These have no measurable ergonomic benefit, and create a dependency upon them by undermining the user’s ability to work without them. Wrist rests do nothing more than increase the pressure in the carpal tunnel by 50% [(2)]. They act as partial tourniquets because the weight of the user’s own wrist pushes it into the surface of the rest, impeding blood flow through it. The inactivity the use of wrist rests encourages may cause muscles to loose tone and weaken as a result, causing the user to bear down even harder. Dependency on rests can therefore make it more difficult to adapt to new and better postures.

Categories of Mouse Users:

When designing computer mice we must take into consideration the needs of the individuals who will use them. This is to ensure that not only do we design out MSD’s but that we design in accessibility, but interestingly enough, as will be seen, these two objectives converge.

Disability or Clinical Impairment (D/CI): Persons with disability who have an underlying clinical condition that directly impairs their use of conventional mousing systems.

Functional Impairment (FI): Persons diagnosed with a computer related disability while having no underlying clinical condition that could anticipate or explain their impairment.

Functional Fatigue (FF): This may or may not be diagnosable as FI so sub-clinical insofar as their condition is manageable, bearable or not recognized as anything other than work fatigue. This includes those who exhibit end-of-day aches to those who self administer therapies including exercise regimes and non-prescription medications. A website survey conducted at www.quillmouse.com/survey suggests that at least 60% of FF individuals could be diagnosed as FI if they attended a physician. If this ratio holds true it would mean there is at least a 100% understatement of the extent of the FI reported.

At Risk (AR): this must include everyone else not categorized above simply because there is no definitive understanding of cause so no one can be ruled out from entering the FF or FI categories.

Posture:

Functional Neutral: The Convergence of Biomechanics and Biochemistry.

Functional Neutral is being at “Biochemical idling”; in neutral yet still working productively. Muscles are “engines” that are never turned off, so if we can find a posture

that allows them to “idle” and still work, then they are more likely to deliver years of problem-free service and keep valuable and experienced people off disability and in the work pool. Functional Neutral allows definable ergonomics standards to be set. It is better understood by an appreciation of the two “Functionally Active” postures called Static and Dynamic Posture.

Dynamic Posture (DP) is a regime in which muscles are tensed and relaxed within a relatively small time cycle. Though this may be very repetitive the fact that muscles are not held under constant load means that there is a rest interval between each muscle contraction. This cycling allows blood circulation to return and with it near or actual biochemical re-equilibration. When muscles contract blood is squeezed out, and a working muscle uses up to 50x more oxygen than one at rest. When muscles relax fresh blood is drawn in, so each contraction/relaxation cycle pumps blood in and out of the tissues in its vicinity so as to maintain aerobic conditions.

Keyboarding and clicking mouse buttons employs DP. It is now believed that DP in isolation is more likely to tire (resource depletion) than cause injury. On the basis of biochemical review it may be downgraded as an agent of MSD, though DP may be a factor in the presence of other injuries and act to aggravate them. While some will strongly argue for DP and keyboarding’s complicity in MSD there is one piece of evidence that seems to go unnoticed, validated herein by the quillmouse.com survey and that is, predominantly, the mousing hand becomes injured first and worst!

Postural Compensation: The body's automatic response to damage in one muscle group is to use different muscle groups and postures to compensate. A limp is an example of postural compensation. Many neck and shoulder problems often cited as having no connection with mousing maybe explainable if considered in mouse usage and postural compensation terms. A study of two Thoracic Outlet Syndrome patients produced an observation of a noticeable degree of elbow abduction when using a computer mouse. The observation was that a lack of wrist twist, due to impairment, was compensated for by elbow abduction (sticking out) making it possible to place the hand flat upon a palm down mouse. Continuous abduction puts strain on the rotator cuff, and so if the wrist injury is not treated and this posture maintained then new damage can occur in the rotator cuff and further postural compensation may cause a migration into the shoulder and neck. Upon switching to a mid pronated position, by way of (in this case) a Quill-Aerobic Mouse (Designer Appliances Inc), this abduction was removed.

Static Posture (SP): SP is working under conditions in which muscles are tensed and held tense, which is the posture adopted when constant grip is applied to anything. There is probably no other "non computer" task performed in a resting posture, that can motivate individuals to maintain grip for so long as does mousing, web surfing especially. The mousing posture does not involve the larger muscle groups that consume enough oxygen to precipitate an increase in circulation or invoke feelings of fatigue. Tensed muscles limit blood flow; an obvious clue being that mouse user's hands often become cold. Hand muscle activity is not sufficient to self-heat them so most is "piped' from the body cavity.

From a biochemical perspective, low blood flow and above "idle" and static muscle activity is at odds with our design. We always assume that we work aerobically as we typically only experience acute, "fall over", non-aerobic states. Can our biochemistry describe a sub-acute mechanism that is slow and progressive that may explain or be the agent of change, shedding light on the root cause of MSDs and thus how to avoid them?

The "Not So Secret" Agent! Once a cell reaches a critically low oxygen level its' biochemistry switches to an anaerobic process known as the Lactic Acid Cycle (LAC). Switching to LAC is an "involuntary respiratory decision" and occurs in the event of overexertion and/or inadequate respiration or circulation. It provides a "last ditch" shot at cellular survival by producing energy in the absence of oxygen, and is a process that can only be sustained for a few minutes. LAC results in the muscle contraction that can lock up muscles as in a "Charlie Horse".

Oxygen monitoring is by a sensor in the brain that depends upon the impact of total muscle activity to lower oxygen levels sufficiently to be noticed. If only the small muscles are being used, even if they are working constantly and near to exhaustion, by themselves they do not impact oxygen levels at the sensor sufficiently to initiate an increase in heart rate and respiration.

Therefore in response to low oxygen levels in <u>each individual cell</u>, LAC is initiated in that cell (it is not a "whole muscle response"). It is reasonable to suspect that in a

sedentary posture for extended periods those cells furthest from the blood vessels and the available oxygen supply are more prone to the effects of reduced circulation, entering into or perhaps cycle in and out of, an LAC mode. LAC toxin build up will likely impact cell wall permeability and so normal cellular function.

Speculating as to possible scenarios:

Progressive Scenario; cell membrane function degrades resulting in cellular fragility or "reduced cell life expectancy" due to a diminished ability to take up oxygen, nutrients or expel waste.

Event Based scenario; which may include aspects of the "Progressive Scenario", a point is reached at which cells are not re-equilibrated or re-aerated in time, that time.

As well as the "Charlie Horse" reflex, LAC toxins produce the burning sensations felt during a heart attack and the "burn" in muscles undergoing "fatigue" work outs. It is likely that the amount of lactic acid produced if localized in a few cells is not sufficient to produce sensations sufficient to raise our awareness. Indications of damage could therefore take a long time to show, be accumulative, mostly covert until a chronic, or what seems to be most frequent, an acute stage is reached precipitating what might be called a "system crash". At such times soreness becomes pain and impairment and a "quality of life impacting" condition requiring fulltime management that is costly to individuals in many ways.

MSD's are not analogous to a piston breaking, a total and obvious failure; it is a factor of time and the agent is a work habit that is at odds with the way our bodies are designed. In making a mouse that better accommodates this design constraint what choices do we have, what objectives do we set and how do we achieve them?

The amount of work people do is likely to increase and the resource to do it decrease. Throwing away hundreds, possibly thousands of millions of computer mice that represent old knowledge and work habit won't happen tomorrow; unless of course "passive MSD" is discovered in which case it will happen tonight! What is called MSD is an incompatibility between how we perform work and the way our biochemistry works. It cannot be repaired, it can only be removed. This allows any therapy received an opportunity to work so breaking the cycle of injury, therapy, and re-injury. This cycle is why treatment costs are spiraling out of control as sufferers become recipients of Long Term Care and not short term cure.

New Posture Syndrome:

It is worth speculating as to why some "new" ergonomic products, after a time, fail to fulfill their promise. This has lead to erosion in the value of the word "ergonomic" besides its inappropriate and excessive overuse.

Changing to a new posture (using a device of a different tool design) will relieve, short term, the stress on "distressed" tissues. Any initial relief masks any early indications of

fatigue or sensations that would indicate yet another bad posture. It is the technology equivalent of Postural Compensation.

In Summary of a "Practical Guide To Good MouseKeeping"

We seek to maintain productivity which, to be effective, must include devising a method of work that keeps qualified people comfortable and fit to work. The objective is to apply technology so as to work around the most likely MSD agent, working under anaerobic conditions. This means removing Static Posture and setting up systems that employ Functional Neutral postures wherever possible and where not devising a regime of Dynamic Postures.

In the case of mousing a combination of a hardware and software solutions makes it possible to achieve a Functional Neutral Posture for the entire mouse input task, in relation to those muscles forward of the elbow that are most prone to damage.

A "Virtually Hands Free™" mousing system (Designer Appliances Inc) has been developed that removes the needs to grip (Static Posture) or click (Dynamic Posture) effectively eliminating the need for any voluntary / coordinated muscle activity forward of the elbow. This is noted simply because it is the first Functional Neutral mousing system, which, in meeting that objective, also brings it into compliance with standards set [(3)] under Section 508 of the US Governments 1998 amendments to the Rehabilitation Act [(4)]. It is also the first system, following an independent study, to receive a commendation

for Ease of Use for persons with arthritis by the Arthritis Foundation in the US. As an applied Functional Neutral design it is Universally Assistive Technology in that it does not discriminate by its appearance or by its use.

In conclusion: The principles embodied in mousing under Functional Neutral, that seek to protect individuals MSD's and the consequences of "Static Strain Injury", also provide persons with disability or functional impairment with performance equality whereby many can be brought into the IT work pool in a strategy that may also include other assistive and / or preventative technologies.

As a practical guide to mousing and without apology!:

It isn't where your hands are in the air that counts:

It is where the air is in your hands!

A first step maybe to rename Repetitive Strain Injury to a more aptly titled

Static Strain Injury

or the more descriptively;

The Lack of Repetitive Stretch Injury!

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