RSI prevention by changing computer input devices
- Study by TU Darmstadt investigates the pen tablet as an ergonomic alternative to the computer mouse -

Introduction

Users of computer work stations often suffer from painful health problems in musculoskeletal and supporting systems. Pain is mainly felt during movement without any recognisable physical cause. A chronic painful syndrome dependant on movement can thus develop. It can still limit the patient’s workflow even if the actual micro injury is already healed.

Therapy and prevention of the so-called RSI-syndrome (Repetitive Strain Injury, also called “mouse arm”) have proven to be difficult, since the basic problem, the repetition of similar movements, is one of the performance features of computer work stations. In most cases this burden cannot be reduced without considerable additional expenditure on ergonomic office equipment (furniture and hardware).

In recent years, doctors have noticed an increase in RSI complaints among a lot of workers who spend several hours working on a computer every day.

On this basis, under the direction of Prof. Dr. Hardo Sorgatz, clinical psychologist at TU Darmstadt (Germany), it was objectively investigated whether the ergonomic properties of the pen tablet made it a possible alternative to the mouse at computer work stations and also whether the pen could help reduce or prevent RSI complaints.

Basis and preliminary investigations

General requirements for a gentle posture: the position of arms and legs should be as neutral as possible. This means an upright posture with the arms hanging relaxed down your sides, the palms of the hands should be against the body, i.e facing towards each other.
While working at a computer, the actual posture differs from this neutral form: the forearm can become twisted and the wrist bent back. The fingers can also be stretched, bent and twisted to the side and the elbows and shoulders can become twisted. For this reason, an input device is optimal that allows as little deviation from the neutral posture as possible.

In 2003, a research team (Ullman et al.) was already concerned with developing an input device with the best possible ergonomic design. Requirements for this device aroused from the results of previous investigations on RSI.

Hence, the development of a biomechanically optimal input device should take the following points into consideration:

- Extreme positions such as flexing of the wrist, pronation (turning inwards) and deviations from neutral posture should be avoided as far as possible.
- Accuracy and precision tasks requiring the application of pressure should be able to be carried out without involving the upper arm and shoulder muscles, i.e. they should be able to rest on the surface of the desk.
- For clicking movements it should also be possible to use flexors other than just the index fingers, in order to reduce the strength applied per muscle.
- To reduce static tension on the extensor it should be possible to click without stretching the fingers.
- Handling should be based on abilities already learned to minimise learning effort.
- Minimal mental demand should be required for the input device, i.e. a preferably intuitively learnable handling.

The Ullman study also showed that lower muscle activity was needed when working with the pen on the computer than working with the mouse. The use of the digital pen showed an extreme reduction in muscle tension, particularly with test persons who worked with the mouse every day.
Likewise, in 2003, in addition to muscular strain Kotani & Horii examined performance data with pen and mouse. To examine the processing of different types of tasks comparing the pen and the mouse, two different types of tasks were developed, which the test persons had to perform on five consecutive days, each using both of the input devices. One task was characteristic of a mouse (frequent clicking, Drag&Drop), the other was suited to a pen (tracing of polygons, fine motoric abilities).

From the first day on, the values for the latter task for the pen were clearly better than those for the mouse. On the first day, the values for the other task, typical of mouse work, were much better when performed with the mouse; from the second day on, however, the values were better for the pen than for the mouse, mainly due to the lower error rate when using the pen. The author interpreted the fast learning achievements with the pen as an indication that the ability to write can be effectively transferred to working with the pen.

**Test Arrangement**

Building on the pre-studies described above, the TU Darmstadt compiled a new study under the direction of Prof. Dr. Hardo Sorgatz. In this study, the transition from the PC mouse to the pen tablet was investigated among 60 students over a three-month investigation period in office-like working conditions. The test persons each had over approx. 10 years of experience using a mouse, but no experience whatsoever with cable and battery-free tablet pens as computer input devices.

Against this background, they first had to practise using the pen prior to the commencement of the investigation, in which it was not expected that performance with the use of the mouse and pen would be fully brought completely into line in just a few hours of practice. The main test was preceded by a training unit of approx. 2 hours; the participants did not have any further opportunity to practice using the pen between the training and the main test.
Already in the training (Figure 1) the performance value in training tasks carried out using the pen and tablet was increased by around 300%. In contrast to the beginning of the training, participants were only making around a third as many errors while solving navigation tasks by the end. After the training, the overall performance with the pen amounted to 90 percent of the performance with the mouse.

Figure 1 Training room with test subjects

In the main test, high stability of the training effect was proven. Here, performance with the pen, e.g. with a comparable Drag & Drop task was still 84% of the performance with the mouse, even though the participants had not had the opportunity to work with the pen in the four-week intermediary period.

In order to investigate the productivity and effects on the musculature, many comparison tasks were set in the main test that each had to be solved using both the pen and the mouse. In addition, auditory and visual distractions (Figure 2) typical for the everyday life in an office were simulated. Pressure to perform was generated using piece-work tasks. This was also done to show whether additional distractions influenced the stability of results with the pen and the mouse in different ways.

Figure 2 Visual distraction: six spotlights and one flashlight
In total, three different tasks had to be performed by the subjects on the PC, each with a standard mouse and a Wacom pen tablet. For each input device, every type of task had to be completed six times non-stop:

1. Tracking: A red line had to be copied as closely as possible with black by applying constant pressure to the pen or mouse button so that ideally only the black line would be visible at the end.
2. Clicking task: Icons (smileys) appearing on the screen had to be clicked away, 40 smileys were clicked away per test.
3. Drag & Drop: Icons (smileys) appearing on the screen had to be dragged to an area in the middle of the screen (slot) and dropped there. Again, 40 smileys were to be moved per test.

During the exercises, the speed and sometimes also the accuracy of processing the task were measured. With the clicking and the drag & drop tasks, the processing time per test was measured, with the tracking task an error value was calculated for each deviation from the line that had to be followed in addition to the processing time.

Before the test started, an EMG baseline (the load value of the muscles at rest) was established with an arm resting on the desk in three postures: In one (lying flat on the desk) posture of the hand and respectively with the input device in the hand. According to the test condition, the appropriate distraction was set up before the task began. The visual distraction was simulated by a continuously flickering light and flashing LEDs on the edge of the screen. The auditory distraction consisted of a tape with unintelligible speech (played backwards).

After the conclusion of the three task blocks described above, a resting EMG was taken with the arm lying relaxed on the desk for 30 seconds with the pen and the PC mouse in the hand.

In addition, on the basis of the NASA Task Load Index (TLX) the mental state of the participants was taken before and after the tests, a multi-dimensional evaluation instrument providing information on mental, physical and time demands, performance, exertion and level of frustration from the participants’ point of view.
Furthermore, the results were divided into two groups: those who had already complained about RSI problems (an appropriate index was also created for this) and those who had not shown any symptoms so far.

**Results of the investigation**

Irrespective of the input device, after the first and second phases of processing (therefore after the completion of each task with the current input device) higher values were recorded than for the EMG at rest. As the tests proceeded, there was a significant increase in mental state values in the areas of under-arm prickling, neck-shoulder prickling and neck-shoulder numbness.

The assessment of musculoskeletal paraesthesia (feelings of pain in the musculoskeletal system) in subjects at risk of RSI (RSI index high) produced slightly higher values for the neck-shoulder area when using the mouse than when using the cable and battery-free pen (Figure 3). Use of the mouse thus subjectively led to more neck complaints than the use of the pen tablet.

![Figure 3 Paraesthesia: Total values for neck-shoulder area in relation to the input device and RSI index.](image)

Untrained pen users initially developed – in comparison to using a mouse –just as high stress and paraesthesia values as with the mouse. This was expected due to the unfamiliar situation of using the pen tablet. Based on the assumption of a reduction of these feelings with progressing automation of movements with the pen, the pen tablet can be designated the less demanding device.
After a two-hour training session with the pen tablet, results showed a 300% increase in performance. In comparison to their navigation performance with the PC mouse, the shortfall was adjusted by 10 to 20% so that the tracking exercise was completed by the subjects in almost the same time using the pen tablet as using the mouse, although with significantly fewer errors. With the use of the mouse, error value and time value were close together meaning that less speed created more mistakes. Pen usage did not show any such correlation.

It can be assumed that through more frequent usage, full compensation or even a performance advantage could be achieved with the pen rather than with the mouse.

For the navigational clicking and Drag & Drop tasks managed by all the experienced mouse users, the time required was significantly lower for the mouse than when the pen tablet was used. However, it must be taken into consideration that the click function of the pen tip had to be deactivated during this experiment for the comparison of EMG values and for other reasons. A considerably higher performance is to be expected with an activated pen tip rather than with the “characteristic mouse click button” on the pen used in this study.

When the visual and auditory distractions described above were implemented, there was no significant difference in performance values for the individual input devices.

In addition to the EMG baseline with each input device in the hand, the EMG values for both input devices were recorded again after the tasks were completed (Figure 4). In this way, the EMG baseline showed that both the mouse and the pen caused an increase in tension on the extensor musculature, which was however significantly higher with the mouse. In contrast, the tension on the flexor musculature declined irrespective of the input device in use.

The EMG at rest taken after the tasks were completed, showed that the mouse created higher stress levels on the musculature than the pen tablet
Figure 4 EMG for resting position of mouse and pen (upper graphics) and after 25 minutes of using the mouse and pen (lower graphics).

**Synopsis**

In comparison to other input devices, the pen tablet has the advantage of practice at an early age with the acquisition of handwriting and a completely different sequence of movements compared to most PC mouse variants. The pen tablet has more ergonomic properties than the mouse and according to these results it serves as an ergonomic navigation alternative to the computer mouse. Even after relatively short training periods, comparably good - after longer usage probably better - performance could be achieved. Frequent changing of the input device is recommended to avoid RSI complaints. Due to the significant reduction in muscle tension with the pen, the switch from the PC mouse to the pen tablet adds another element to the prevention and reduction of RSI complaints.
In conclusion, the pen tablet has proven itself, ergonomically superior in subjective and objective indicators, compared to the mouse.

The participants of the study found that the “unfamiliar” pen tablet as such was less demanding than the “familiar” computer mouse.

According to the results of this far-reaching and realistic experimental investigation through the simulation of normal work pressure to perform and office-like distraction conditions, mouse users – with and without typical RSI complaints – are advised to switch to the pen tablet more frequently.