EVALUATION METHOD WHICH PROMOTE CREATIVITY: CASE STUDY ABOUT ERGONOMIC DESIGN IN POINTING DEVICES

Namayandegi, Mohammad Hossein
Tehran University of Art, Islamic Republic of Iran

Abstract

Findings from multiple studies demonstrated large effects of using computer mouse and also some other types of pointing devices on developing Cumulative Trauma Disorders (CTD). The main cause of these injuries considered being user's non-ergonomic posture. In fact, using most pointing devices involves pressure on nerves at entrapment points, increased neural tension and use of muscles while contracted.
Accordingly, wide range of pointing devices are developed regarding to ergonomic design issues and to modify user's body posture but the classic mouse still remains the most popular device.
This paper tried to evaluate available pointing devices in the market regarding to users favorites and ergonomic design factors through an analytical process which promote creativity, and then explore the limitations and possibilities for developing new design solutions. This hypothesis also examined that the most of computer users resist any big modification in their posture; therefore they tend to use pointing devices which are more consistent with their previous daily experiences and looks more natural from their perspective.

Keywords: Evaluation, New product development, Creativity, Pointing Device, Ergonomics

Contact:
Mohammad Hossein Namayandegi
Tehran University of Art
Faculty of Applied Arts
Iran, Islamic Republic of
Design2026@yahoo.com

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

Several studies in recent years have shown that intensive use of pointing devices (such as the computer mouse) is associated with the risk of developing specific kinds of injuries, known as Cumulative Trauma Disorders[1], including carpal tunnel syndrome.

Cumulative Trauma Disorders (CTD) is unlikely to have a single reason, but posture may be highly important[2]. In particular, using most pointing devices involve postures that result in wrist extension, ulnar deviation or other non-neutral joint positions.Computer mouse usage also can generate prolonged unilateral shoulder flexion, abduction and external rotation, which lead to upper arm pain or discomfort (Karlqvist et al. 1994). (Please notice Figure 1 for definition of basic terms in kinesiology)

Mackinnon and Novak (1997) identified three potential mechanisms, through which postures during pointing devices use might contribute to the development of CTD: increased pressure on nerves at entrapment points, increased neural tension and use of muscles while contracted.

Karlqvist et al. (1996) found that operators with at least 5.6 hours/week of mouse use were more likely to report symptoms in upper limb region than those using a mouse less frequently.

The US Bureau of Labor & Statistics (2008) also reported nearly 60 percent of computer workers nationwide suffer from wrist pain. However, prevalence of reported discomfort by computer users is various and range from 15% to 70% depending upon the type of computer work demands (Fine, 1996; Faucett and Rempel, 1994).

In order to eliminate the risk factors that contribute to CTD, various solutions have been proposed, including: Modifying posture, Taking short breaks, and Setting up ergonomic workstation.

Design of pointing devices has a direct effect on user's posture as the most important cause of CTD and design modification (further than just product appearance) is possibly the main solution for posture correction in these types of products.

Accordingly, a range of pointing devices have been developed considering ergonomic design issues to achieve natural body posture, but the classic mouse still remains the most common device among the users[3], even though the majority of them complain about pain in upper limb caused by using such devices. So, this question is raised: why computer mouse is still popular, and what other possibilities are available to develop desirable and still ergonomic devices?

This paper is aimed to evaluate available pointing devices in the market regarding users' preferences and considering ergonomic design factors through an analytical and creativity-oriented process in form of case study, and then it tries to find out potentials and limitations for developing new design solutions.

The main structure of this process is formed according to the method of Quantification Type III[4] and Cluster Analysis as well as questionnaires.

Moreover, this hypothesis would be examined that most computer users resist any big modification in their posture and tend to use pointing devices which are more consistent with their daily experiences and look more natural from their perspective.

---

[1] Cumulative Trauma Disorders (CTD) or Repetitive Strain Injury (RSI) is a collective term for syndromes characterized by discomfort, impairment, disability or persistent pain in joints, muscles, tendons and other soft tissues. They may irritate or damage nerves and impede the blood flow through arteries and veins. These injuries are frequent in the hand-wrist forearm area, and in shoulder and neck. (K.H.E. Kroemer, 1989)

[2] Primary factors may include non-ergonomic workstation, prolonged periods of work without adequate breaks, repetitive and forceful activities, static muscle load, body posture, mechanical stress, vibration and a cold working environment. (Chatterjee, D.S. 1987)
Age, gender, acute trauma, chronic disease, use of birth control pills, circumstances of pregnancy, menopause, etc. are secondary factors. (K.H.E. Kroemer, 1989)

[3] Woods et al (2002) surveyed a group of users and found 97% of samples using regular computer mouse as the pointing device.

[4] "Quantification Type III is one of a set of four statistical methods developed in Japan in the 50s for the quantification of qualitative evaluations, and represents a method of pattern classification mathematically similar to Multidimensional Scaling".

To achieve these goals, this research involves four main phases:

1. Collecting samples
2. Determining evaluation factors and effective design elements
3. Design analysis
4. Users investigation

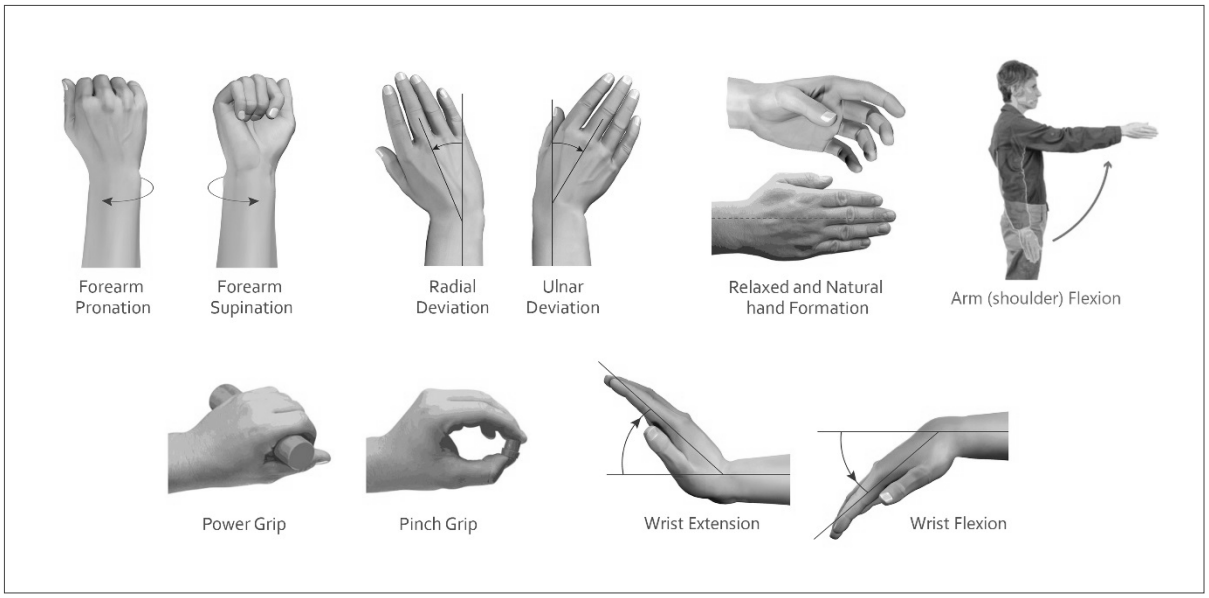

Figure 1. Definition of basic terms in kinesiology of the upper limb

2 METHOD

2.1 Collecting samples

In the first phase, 28 samples were selected from seven main groups of pointing devices (including mouse, pen mouse, graphic tablet, same input/output device, trackball, touchpad, joystick and hands free devices); these samples represent a wide range of available solutions in the market including different types of ordinary designed devices and those with some sort of ergonomic design modification or technological innovation, which have been launched as far as fall 2012. (Table 1)

2.2 Determining evaluation factors & design elements

In this phase, association of using different types of pointing devices and incidence of CTD were investigated through some relevant and reliable reports and studies.[5] Summarized outcomes of this step are reflected in Table 2. This table illustrates the main diseases caused by non-natural postures in each type of pointing devices. Accordingly, a list of ergonomic design guidelines along with some functional features that are effective on user's body posture and improve ergonomic function of the samples were identified as:

- Avoiding pressure on the base of the hand
- Avoiding pressure on the palm
- Avoiding wrist Extension / Flexion
- Avoiding wrist Ulnar Deviation / Radial Deviation
- Avoiding forearm Supination / Pronation
- Avoiding Pinch grip
- Avoiding Power Grip

[5] C.J. Snijders and P.C. Helder (2004); K.H. Kroemer (1989); Franco et al. (1992); Johnson et al. (1993); Mackinnon and Novak, (1997)

Table 1. Selected samples as the available solutions in the market for design evaluation

Device Type	Selected Samples	Device Type	Selected Samples
Mouse	*Microsoft presenter mouse 8000* *Microsoft mouse 8000* *Microsoft Natural mouse 6000* *Apple Mighty mouse* *Logisys finger mouse* *Buffalo Gyroscopic* *Perific dual mouse* *Sigma SGM2 mouse* *Logitech marble mouse* *Logitech Trackman Wheel* *Evoluent Vertical mouse* *AirO2bic mouse* *Zero tension mouse* *3M vertical mouse* *SL6169 Ergonomic Mouse*	Pen Mouse	*Salient Mouse pen* *Evergreen wow pen*
		Trackball	*Kensington Expert trackball* *Kensington Orbit trackball* *Globlink Trackball*
		Graphic tablet	*Graphic tablet*
		Hands free devices	*Foot mouse* *Smart Nav Head*
		Same input / output	*Interactive Pen Display*
		Touch pad	*Regular Touchpad* *Hela Glider touchpad* *Trackbar emotion mouse*
		Joystick	*Joystick*

Table 2. Non-neutral postures in pointing devices and associated potential disorders

Pointing Device Type	Risky Body Postures	Related Possible Disorders
Mouse, Trackball, Touchpad	Imbalanced Pronator and Supinator muscles of the forearm	Pain in forearm
Mouse, Trackball, Touchpad	Wrist Extension / Flexion	Carpal Tunnel syndrome (CTS) Guyon Tunnel Syndrome (GTS) Tenosynovitis
Mouse, Trackball	Wrist Ulnar / Radial Deviation	
Mouse, Trackball, Touchpad	Transferring the weight of arm on the wrist (Pressure on Carpal canal)	Radial nerve entrapment Carpal Tunnel syndrome
Mouse	Pressure on Guyon Canal in the palm of the hand	Guyon Tunnel Syndrome
Mouse, Joystick	Fingers Power grip	Carpal Tunnel syndrome Pain in fingers, Neck and Arm Guyon Tunnel Syndrome (GTS) Tendonitis
Pen mouse, Graphic tablet, Interactive pen displays	Fingers Pinch grip	Carpal Tunnel syndrome Pain in fingers, Neck and Arm
Mouse, Trackball, Joystick	Repetitive finger flexion (clicking)	Carpal Tunnel syndrome Pain in forearm Tenosynovitis (Trigger finger) Tendonitis
Mouse	Arm Flexion (pressure on Rotator cuff muscles)	Pain in shoulder
Mouse	Prolonged load on shoulder's muscles	Pain in shoulder and neck
Mouse, Trackball, Touchpad	Resting the elbow / forearm on desk	Cubital tunnel syndrome
Foot Mouse	Limiting users' posture	Leg cramp

- Avoiding fingers Flexion (Forceful clicking)
- Avoiding repetitive fingers movements for operation
- Avoiding arm Flexion (The devices which possible to use in small area)
- Avoiding leaning toward the computer (desk)

- And using the devices that are:
- Designed stationary [or centrally] (to avoid loading on shoulder muscles)
- Independent of the desktop (In order to avoid pressure on the base of the hand, resting the forearm on the desk and leaning toward the computer)
- Equipped with Alternative Operation Method (Makes it possible to change posture when using computers for long periods)
- Equipped with Pressure/Angle sensors (to avoid forceful clicking)
- Always ready to use without any preparation process (E.g. Some devices need to be adjusted on hand or require to define tracking point for its detector)
- Useful to perform specific tasks (E.g. Drawing, Presentation, Modelling, Gaming)
- Useful to perform General tasks (E.g. Web surfing, Multimedia, etc.)

2.3 Design analysis

In phase 3, all samples were analyzed and evaluated on the basis of determined design factors. The method used for design analysis was Quantification Theory Type III (kind of macro software for Excel). The method of Cluster Analysis was then applied to all quantified samples to draw the groupings of available devices in the market [through SPSS software].
Expected outcome of this phase would be in form of a coordinate diagram representing distribution of samples in different clusters based on their design characteristics. This diagram would be our source to evaluate current design solutions and find out potentials for further product development after considering the results of users' investigation.

2.4 Users investigation

In this phase, potential group of computer users were studied using a questionnaire in order to find out their interests and preferences about pointing devices and also to identify their pain or disease experiences resulted from computer use.
The subjects were 70 university students, aged 19-28 years, who were randomly selected from a different disciplines including Industrial design, Art, Computer, Management, Science and Technology. Fifty-one percent of subjects were female and 60 % stated that they use computer professionally.
The ultimate purpose of this phase was to identify commonalities between users' preferences and specified potentials for product development from phase 3.

3 RESULTS & DISCUSSION

3.1 Design analysis

The output of analysing the samples through the method of Quantification Type III is illustrated in Figure 2. In fact, each area of this coordinate diagram has exclusive features and distribution of the samples is on this basis (Placement of the samples and also design factors are determined by the software calculations).
Regarding to existing features in different sides of the diagram, the directions of axis are named; The right side focuses on factors that effectively help to obtain ergonomic posture in shoulders and spine (back) and also prevent pain and disease in these regions (factors such as avoiding arm flexion / forceful gripping / leaning toward the computer - possibility of using the device independently of the desktop - alternative operation method). But the left side of the diagram demonstrates the features that preserve natural posture in wrist and also in fingers (factors such as avoiding wrist extension / flexion / deviation, forearm supination / pronation - avoiding fingers flexion and repetitive fingers movements - avoiding pressure on the palm and base of the hand - stationary design).

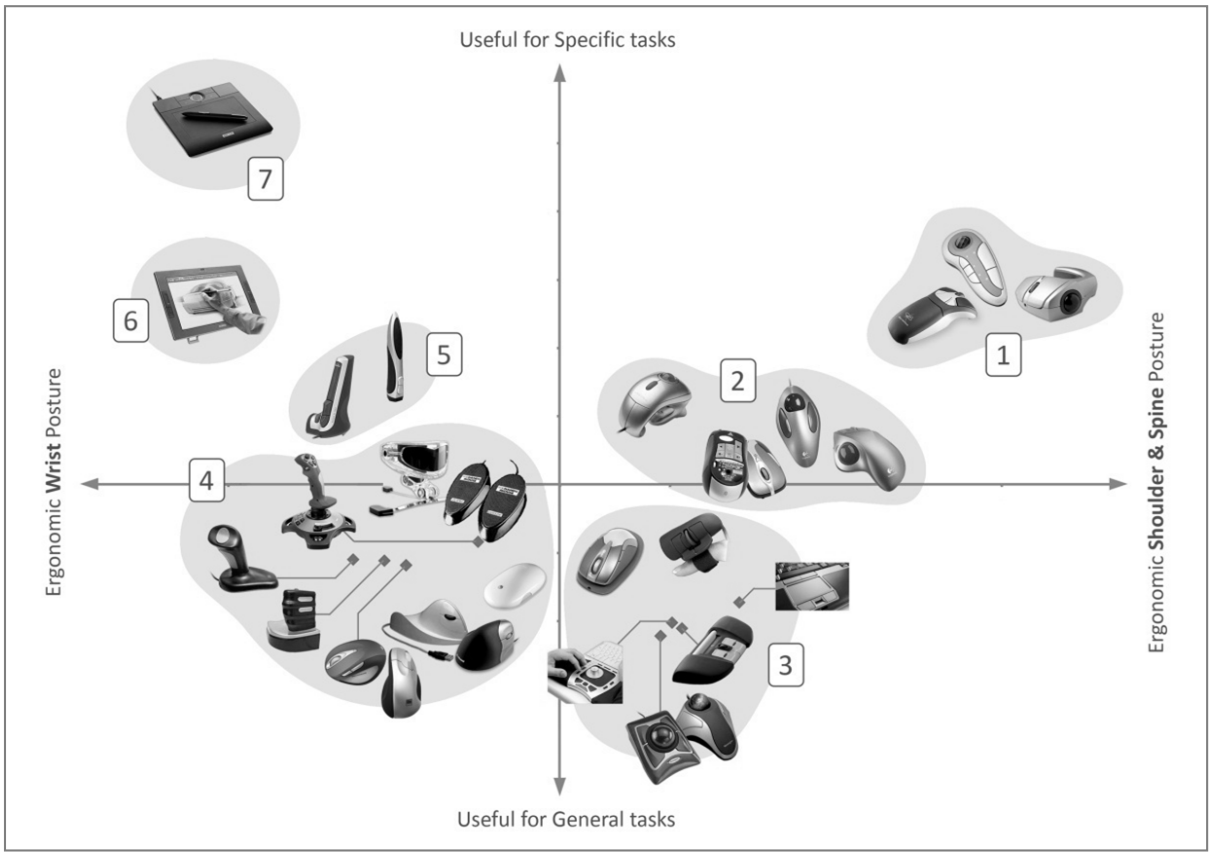

Figure 2. Distribution of the samples and seven resulted clusters from design analysis

The Y-axis includes the target group of the samples. The upper side is devoted to devices, which are useful for special group of users who performing specific tasks such as drawing, presentation or work in 3D environment, while in the contrast, samples in the lower side are suitable for general tasks such as web surfing or inputting data.

A negative feature for devices in the upper half of the diagram is their longer using process; it means some of them such as sigma mouse should be adjusted on hand and some others like pen mouse require finding, picking and dropping alternately.

In the next step and as the result of cluster analysis, all the samples are divided into 7 major clusters (Figure2). The frequency of the design factors in each cluster is considered to identify its design personality and on this basis, the clusters are named as follows:

Cluster 1 - Dual Personality: Members of the first cluster have this capability to be used off/on the desk without any restriction in user's posture. This function is suitable for tasks such as presentations and also, it avoids arm flexion and keeps wrist in natural posture. But negatively, when they are using on the desk surface, they become a typical mouse with all ergonomic design-related disadvantages. Basically, regarding to the position of this cluster (and also clusters 2 and 3), its members lack available ergonomic features, covered in the right side of the diagram. Also, since their design structure is generally derived from trackball technology, they need repetitive fingers flexion for operation. Furthermore, some people have complained about the accuracy and performance speed of these products.

Cluster 2 - Alternative Function: Most samples in the second cluster are different kinds of Trackball Mouse, which provides alternative function for operation. This would make it possible to shift between mouse and trackball use in order to avoid prolonged loading on shoulder muscles (sigma mouse in this cluster is considered an exception as it only includes trackball function)

Cluster 3 - Stationary pointing Devices: This cluster includes Trackball and some examples of "Centred pointing device" such as Touchpad. The main characteristic of samples in cluster 3 is their motionless operation method; it means they do not need to be moved on the desk in order to represent courser movement, and therefore they could be used in small area and avoid forceful gripping and also arm flexion.

It should be mentioned here that the placement of typical mouse (Microsoft mouse 8000 and Apple mighty mouse) in the centre of the diagram, [and boundary of clusters 3 and 4] without any specific similarity with other samples in these clusters is due to the absence of ergonomic design features, which are shown in the right and left side of the diagram in design structure of typical mouse.
However, using touch technology in Apple mighty mouse, which helps to avoid forceful clicking, is the main reason for displacement of this sample toward the left side of the diagram.
Cluster 4 - Wrist posture modifiers: This group of devices in the left side of the diagram are designed in a way to preserve natural posture of the wrist and forearm by placing them in sagittal plane of the body[6], or by using different organs such as feet or head for controlling the cursor and interacting with computer (Ergonomic posture of the wrist is also obvious in clusters 5, 6, and 7, which are in the same side of the diagram). Consequently, they eliminate pressure on the base of hand and palm, which is common in typical mouse and considered to be one of the main causes of Carpal Tunnel Syndrome. On the other side, some of these devices require power grip and also arm flexion for operation, which affect shoulder's muscles.
Cluster 5 - Pen Mouse: This cluster is located between clusters 4 and 6, so it enjoys the qualities of both vertical mouse and graphic tablet, it means these samples have gone one more step ahead from regular mouse toward pen devices.
Cluster 6 - Same input/output Device: Samples in cluster 6 and 7 have been developed for special group of users like designers and artists. However, they have the benefits of natural wrist posture but still require pinch grip for operation. In some of these devices, it is also possible to click just by the pen tip, which eliminates finger flexion for clicking
Cluster 7 - Graphic Tablet

3.2 Users investigation

The questionnaire initially asks about the respondent's personal information, how much time they are working with computer on a daily basis, and if they have experienced any pain or disease in wrist, fingers, shoulders and back regions (They were asked to select the two most serious problems).
The results show that 49.5 % of the samples (nearly half of them) use computer more than 3 hours per day and 27% spend 2 - 3 hours a day on computer.
According to Andersen et al. (2003), there is a significant association between mouse use >20 hours per week and possible CTS. So, it can be seen that most respondents are at risk of developing Carpal Tunnel Syndrome and the results of the next question confirms this claim; it shows that the entire questioned samples have experienced discomfort in upper limb: Shoulder has the most pain incidence rate with 37%, which is followed by back and spine, wrist, and fingers with 29%, 27%, and 7% of incidence, respectively. The main reason for these problems is considered taking non-neutral postures. High prevalence of pain in shoulder is due to prolonged gripping, arm flexion, pressure on shoulder muscles [to support the weight of arm while moving the mouse] and also finger flexion for repetitive clicking. Pain in the wrist can be a result of wrist flexion/deviation/extension, forearm supination/pronation and pressure on the base of hand, which has been mentioned before in Table 2. Discomfort in back and spine is mostly due to non-ergonomic workstation.
The results of the next question indicate that 80% of respondents are currently using mouse as the pointing device, while trackball is the least popular device (0%). Pen mouse and graphic tablet each with 6% and touch pad with 4.5 % are in the second and third place of popularity respectively. Therefore, it is possible to make a link between widespread use of mouse and high rate of complaining about pain in the upper limb region among subjects.
Another aspect, which was studied, was users' preference among available samples, so a short description along with a picture of eight different types of pointing devices were provided for the subjects and they were asked to choose two cases of their desired devices. These devices have been selected in a way to cover a wide range of available samples in the market. The result of this part is illustrated in Figure 3. On this basis, mouse is still the most desired device with 36.5% of the votes, followed by interactive pen displays and graphic tablet, with 23% and 18% of the votes, respectively.

---

[6] Sagittal plane is a vertical plane, which passes from ventral (front) to dorsal (rear) dividing the body into right and left halves. When your wrist and hand are in sagittal plane or vertical direction you use bigger muscles of hand instead of wrist movements in order to operate pointing device.

On the other hand, touchpad, vertical mouse and trackball are considered the least favourite devices among respondent (each one with just 2.5% of all votes). Interestingly, pen devices such as graphics tablets are also popular among users with no drawing activities.
Accordingly, it can be inferred that from the user's perspective, devices such as computer mouse or pen devices, which are more compatible with their daily experiences, seem to be more natural and reliable than the others. In the contrast, users could hardly accept products offering completely different methods of operation or reforming postures by improving ergonomics. This conclusion confirms our primary hypothesis about users' behaviour. On this basis, daily users' experiences of natural posters as well as real ergonomic postures should be considered either for further design modifications or development of new pointing devices.

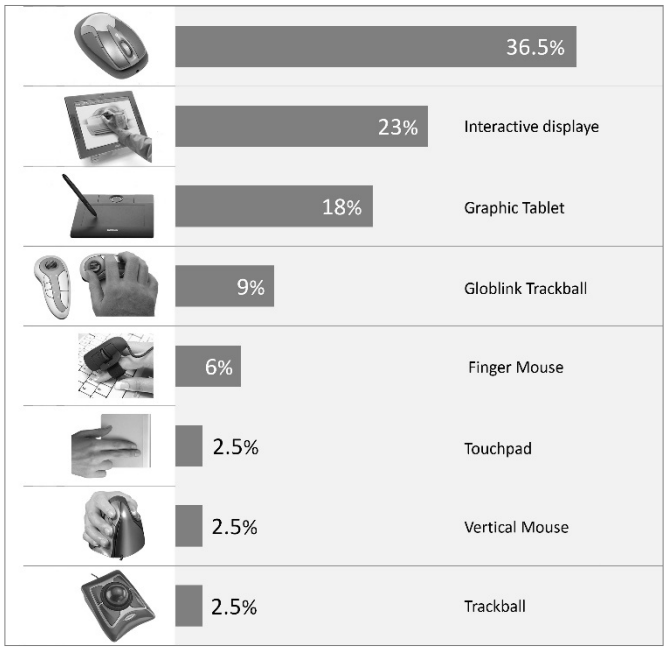

Figure 3. The most favourite pointing devices according to the questionnaire results.

One of the objectives of this questionnaire was to identify effective factors on user's decision-making process when purchasing a pointing device. In this way, participants were asked to choose 4 factors out of 10 available options according to their priorities.
"Ease of use due to the form of device (ergonomic structure of device)", "accuracy", and "attractive and functional design" were ranked as the first to third of respondents' priorities respectively. Interestingly, all three factors of ergonomics, functionality and aesthetics are among the first three choices of the users, while "price" as the economic option is placed in the fifth rank after "product technology" (being optical, laser, etc., which has direct effect on product accuracy)[7].
This outcome indicates that people look for a device, which is efficient and accurate, could be used easily, satisfies their aesthetic expectations with charming design, and finally has a reasonable price. In brief, it means users unconsciously consider usability factors for evaluating a new device and their previous experiences have direct effect on this process. Nielsen (1993, 1995) associates five attributes to usability: easy to learn, efficient to use, easy to remember, few errors and pleasant to use. He also integrates usability as one of the parameters associated with system acceptability[8]. In international standards, usability refers to effectiveness and efficiency to achieve specified goals and users' satisfaction. On this basis and considering the obtained results from Figure 3, this could be inferred that users do not trust usability factors such as accuracy or ease of use in less desired devices like vertical mouse or trackball, which modify their regular operation posture. This recent result again confirms our primary hypothesis about priority of daily users' experiences about natural posture and its effect on acceptability of new ergonomically designed pointing devices.
In fact, this is a limitation for ergonomic design in field of pointing devices: postures already accepted and adopted by user groups.

[7] Ease of transport & use in a limited area, possibility to use for drawing, possibility to use off the desk, number of buttons, and design harmony with keyboard and monitor were other options.

[8] Ana Carvalho (2001) described the acceptability of a computer system as a combination of its social and practical acceptability. If a system is socially acceptable, it is necessary to analyse its practical acceptability within categories such as cost, compatibility with available systems, reliability, etc., as well as the category of usefulness (usefulness is the issue of whether the system can be used to achieve some desired goals).

4 IMPLICATION

4.1 Potentials for Idea Generation

Resulted diagram from design analysis which illustrates design trends of the market, grouping of current solutions and users' preferences, can be considered as an idea generating source in different ways:

- The combination of factors on each side of the evaluation diagram or two clusters can be considered in order to develop new design solutions; For example, new pointing devices, which prevent arms flexion and forceful gripping and at the same time reduce the pressure on the base of the hand, palm and wrist (ergonomic factors in opposite sides of the diagram). Or developing a device based on composition of pen mouse in cluster 5 and Trackball or touchpad in cluster 3 which can be used for variety of tasks such as drawing, web surfing, gaming, presentation and 3D modelling.
- In order to generate completely new and creative solutions, new features could be defined that are not currently included on the diagram, e.g. deformable surfaces or wearable technologies.
- The empty spaces on the graph can be used as the potential areas for developing new ideas without any rival in the market.

In order to find out an acceptable range of design modifications and boundaries of new design solutions, the outcome of the users' investigation should be considered in all above mentiuoned methods. Therefore, it could be concluded that making a link between the most desired samples while combining positive features in each side of the resulted evaluation diagram is the key to generate new ergonomic and acceptable ideas (Figure 4). For example, among available samples, ergonomic vertical mouse as the least favourite sample and pen devices as the most desired samples after computer mouse seem to have more ergonomic design benefits (apart from foot/head pointing devices, which are designed for special groups of people) so combining their design characteristics is an option to develop new design solution.

(The combination of the most useful and the most favorite samples)

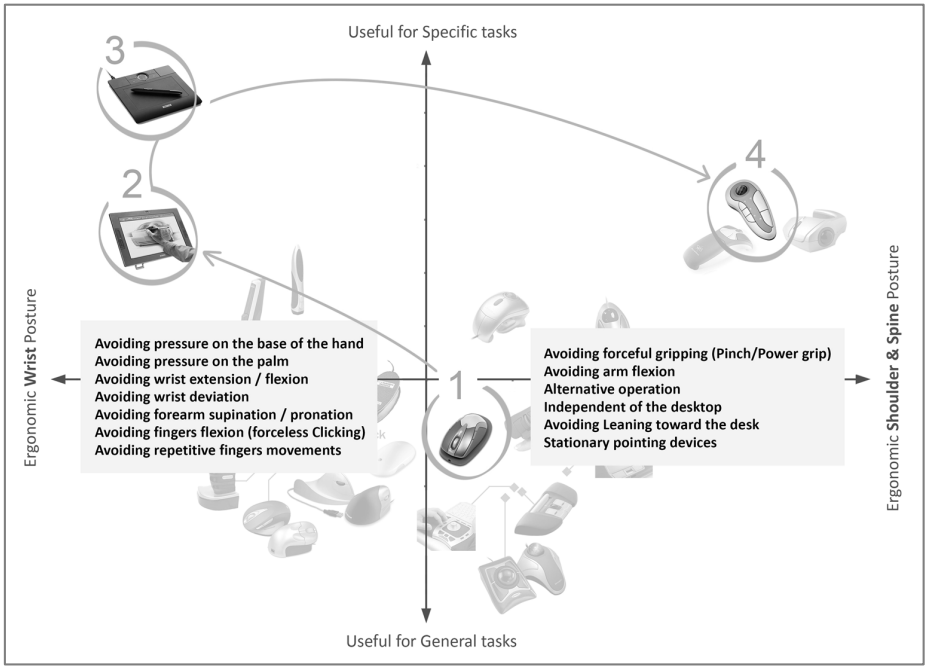

Figure 4. Combining design factors on each side of the diagram and from the most desired devices in order to generate new solutions

5 CONCLUSION

This research has aimed to evaluate available pointing devices in the market through creativity-oriented process, which could reveal potential solutions for ergonomic pointing devices, and then to clarify the limitations of ergonomic design in this group of devices on the basis of users' preferences.

The results of this research led us to the following conclusions:

First, though the majority of users complained about pain in upper limb due to use of computer mouse, it remains the most favourite pointing device followed by pen devices. On the other hand,

vertical ergonomic mouse and trackball are among the least popular devices. The main reason for this behaviour is the difference between what users define as the natural posture and real ergonomic posture. Actually, they could hardly accept devices that are not compatible with their daily experiences and offer a completely different method of operation or reform their posture even with ergonomic benefits.

Second, the results of questionnaire indicate that ease of use (resulting from ergonomic form of device), accuracy, and attractive & functional design are respectively three most important factors for users in purchasing a pointing device, while price falls to the fifth position. These are the main elements of product usability, so it can be concluded that they assume some less desired ergonomic pointing devices [such as vertical mouse] to be less usable compared to regular computer mouse or pen devices which looks more natural for them due to their daily experiences.

Third, based on the results of the design analysis, current solutions in the market have two main ergonomic design trends: ergonomic wrist posture / ergonomic shoulder posture. All the samples could also be categorized into 7 major clusters with distinctive design characteristics.

Combining these special features in each sides of the diagram and each cluster, led us to some innovative concepts for ergonomic pointing device. In order to generate innovative and creative solutions, it is advised to define new features, which are not currently available on either side of the diagram. Moreover, non-competitive part of the market for further design focus clearly illustrated.

REFERENCES

Ana Amélia Amorim Carvalho (2001), University of Minho. Usability testing of educational software

Andersen JH, Thomsen JF. (2003) Computer use and carpal tunnel syndrome: A 1-year follow-up study, JAMA, 289(22): 2963-2969.

Bureau of Labor Statistics. Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, 2007. November 20, 2008.

Chatterjee, D.S. (1987) J Soc of Occupational Med, 37, 100-105. Repetition strain injury

C.J. Snijders and P.C. Helder (2004), “A new computer mouse called Horse” University Medical Centre Rotterdam

Claudia Georgeanne Hix (2000) Constructing a Taxonomy of Use for Computer Mouse Users, University of Connecticut

Cook, CJ, Burgess-Limerick, R. and Chang, S. (2000) the prevalence of neck and upper extremity musculoskeletal symptoms in computer mouse users, International Journal of Industrial Ergonomics, 26, 347-356.

Faucett J, Rempel D. (1994) VDT-related musculoskeletal symptoms: interactions between work posture and psychosocial work factors. American Journal of Industrial Medicine 26:597-612.

Fine, L. J. (1996). Musculoskeletal disorders in office work.

Franco G, Castelli C, Gatti C, (1992) Postural tenosynovitis caused by misuse of a computer input device. Med Lav July- Aug, 83(4)" 352-5. (Abstract).

Hayashi (1950) on the quantification of qualitative data from mathematic-statistical points of view, Annals of the Institute of Statistical Mathematics, 2, 35-47

Johnson PE, Dropkin JJ, Hews J, Rempel D, (1993) Motion analysis of computer mouse usage. In Proceedings of the American Industrial Hygiene Conference and Exposition (AIHA)

Karlquist LK (1997) Assessment of physical work load at visual display unit workstations ergonomic applications and gender aspects, PhD Thesis, Department of Occupational Health, Karolinska Hospital, Stockholm, Sweden.

Karlquist et al. (1996) Musculoskeletal symptoms among computer assisted design (CAD) operators and evaluation of a self assessment questionnaire. International Journal of Occupational & Environmental Health 2"185-194

Kruskal and Wish (1977) Multidimensional Scaling, Sage Publications, Beverly Hills.

K.H. Kroemer (1989) Cumulative trauma disorders: Their recognition and ergonomics measures to avoid them. Applied Ergonomics, Volume 20, Number 4

Mackinnon, SE. and Novak. CB. (1997) Repetitive use and static postures: a source of nerve compression and pain, Journal of Hand Therapy, 10, 151-159.

Nielsen, J. (1993). Usability Engineering. New Jersey: Academic Press.

Shackleton and Sugiyama (1996) Analysis of Trends in Japanese Recreational Vehicle Design, Bulletin Of JSSD, Vol. 2, No. 46, pp. 19-28.

Woods, V., Hastings, S., Buckle, P. and Haslam (2002) Ergonomics of Using a Mouse or Other Non Keyboard Input Device, HSE Books, RR045, ISBN 0 7176 2162 6