

ERGONOMIC REDESIGN AND EVALUATION OF PERSONAL COMPUTER MICE: ADDRESSING MUSCULOSKELETAL INJURIES AND ENHANCING USABILITY

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A B S T R A C T

The extended use of the classic computer mouse is strongly linked to muscle pains and injuries to the hand, wrist, and forearm, especially in tasks that require an individual to operate a point-and-click input device frequently. This work describes the design, manufacturing, and experimental validation of a slanted ergonomic mouse with a focus on improving comfort, usability, and commercial feasibility, considering variations in hand size and grip behaviors. A structured product development process was adopted, which involved the clarification of work, development of the concept by use of morphological matrix and clay modeling, 3D prototyping, and refinements by repetitively enhancing the design with regard to ergonomic needs.

A prototype with a 42 ° angle and curved palm support was the final prototype, and it was put into a user study where 53 people were involved in performing drafting activity on AutoCAD. The determination of usability, ergonomic efficacy, and commercial potential was done through a 27-item Likert-scale questionnaire. The statistical findings indicated that the survey tool was excellent in internal coherence and acceptable level of item validity. The results demonstrated that the users positively rated the ergonomics comfort, ease of use, grip stability, and commercial potential, with the majority of the mean scores being above the neutral mark. The perceived ease of movements, the ease of clicking, and the perceived comfort were highly accepted (>80%), which means that the perceived strain was successfully removed. Though minor aspects involving error prevention were also noticed, the general outcomes prove the reliability, validity, and ergonomic efficiency of the provided mouse design. The study offers empirical evidence on inclined mouse geometry as an innovative way of eliminating musculoskeletal pain. It also gives a strong research foundation, which can be developed and experimented with in the long run.



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1. INTRODUCTION

The use of computers can be linked to pain in the upper extremities, particularly musculoskeletal pain in the hands and forearms caused by prolonged mouse use (Vulpoi, Bistriceanu, Bîrsanu, Palade, & Cuciureanu, 2025). According to various researchers, ergonomic computer mice with an inclined design are less likely to cause musculoskeletal injuries compared to traditional designs (Feathers, Rollings, & Hedge, 2013). Even with the growing use of touchscreen computers, a prolonged dependency on personal computer mice (PCM) is expected to persist in the present and in the future. This is because in professions such as design engineering, banking (Uddin & Barai, 2022), graphic design (Koranteng, Ismaila, Toffah, & Okyere-Kwakye, 2025), and robotic applications (Panwar et al., 2024), touchscreens are not yet the dominant technology. Several studies conducted by researchers have highlighted the need for improvement in the design of ergonomic computer mice (CMs) (Gaunekar, 2025). The hand size of the subjects makes a difference during mouse usage, affecting both grasp position and the level of muscle activity. The notable causes of Carpal Tunnel Syndrome (CTS) include musculoskeletal disorders to hand, wrist, palm, etc. (Chandra & Arora, 2024). One of the measurable factors, which is highly influenced by the inappropriate design of CM, is hand grip strength. The design may cause unnecessary strain to the muscles and tendons of the forearm and the hand when the design is not the best. These findings were in agreement with previously conducted studies where a standard PC mouse showed a significant relation between the width of the hands and the ability to drag targets using the middle button of the mouse (scroll button).

Ergonomic and usability concerns regarding computer mouse designs were addressed in research conducted by Chen and Leung (2007). This study examined the impact of various design characteristics on user comfort and efficiency. It included a discussion on the advantages of slanted mouse designs compared to traditional horizontal mice in reducing musculoskeletal disorders, based on ergonomic benefits. The comparison of various ergonomic designs of different mice and their effect on user comfort, as demonstrated by slanted and vertical mice, has been presented. It was highlighted that the mouse with slanted designs is more comfortable to use. Different ergonomic improvements in the design of computer mice, inspired by natural designs, have been demonstrated (Foorginejad & Lakhi, 2019). Tian et al. (2024) also conducted an assessment of a mouse, along with other interaction devices such as a touchscreen and trackball, for fatigue and usability under ship vibrations. Among the assessed devices, the mouse demonstrated the best usability performance. The researchers (Threesittidath, Chaibal, & Nitayarak, 2024) and (Nitayarak et al., 2025) have presented the work related to the grip strength and forearm strain and

suggested solutions based on the ergonomic changes. A structured research study has been conducted to investigate the impact of computer workstation design on the body discomfort experienced by online gamers (Urbiztondo, Josue, Salazar, Cruz, & Gumasing, 2022). This demonstrated a very high correlation in the mouse design and the user comfort. A comparison of the ergonomic and traditional designs of computer mice has been conducted to assess their impact on user comfort and efficiency. It included a discussion on the effects of ergonomic mouse designs on user performance and health, and provided information on how they can be improved (Kim, Kim, & Kim, 2024). Different computer mouse models, based on their ability to prevent repetitive strain injury, were tested (Bhatnagar, 2024), and the potential for incorporating ergonomic design elements into computer mice was explored. Liu and Fan (2014) presented research on the ergonomic design of the computer mouse, emphasizing the importance of ergonomic characteristics in reducing discomfort. Comparisons of computer mouse designs (vertical and inclined) were conducted, and an evaluation of their ergonomic performance and impact on user comfort was carried out (Liu, Huang, Chen, & Yang, 2016). The researchers have also explored ergonomic computer mouse models from children's perspectives to prevent the onset of musculoskeletal disorders (Mahpirat, Zhou, Mamat, & Ubul, 2018). An analysis of the impact of ergonomic aspects of computer workstations on musculoskeletal disorders was shown (Lotfollahzadeh et al., 2019). It was suggested that ergonomic design interventions can help minimize the health impact.

The objective of the presented work is to apply a structured approach to design a customized mouse that can help reduce musculoskeletal issues by seeking empirical validation through a survey of participants.

2. METHODOLOGY

2.1 Product development operational model

A customized design approach was developed and implemented to help the current study achieve its objectives. By defining the product goals, analyzing and defining the requirements, and establishing the product specification with the help of the literature review, a task clarification for the product under development was completed. The concept for the new model was developed using sketches, clay models, and a study of various literature sources. In the evaluation and refinement step, the best concept was selected, an evaluation matrix was created based on the specifications, and mockups were developed. These mockups were then improved and refined. The complete design process was conducted with an emphasis on ergonomic analysis, usability testing, and prototyping. Figure 1 shows the approach employed in the study, based on earlier literature.

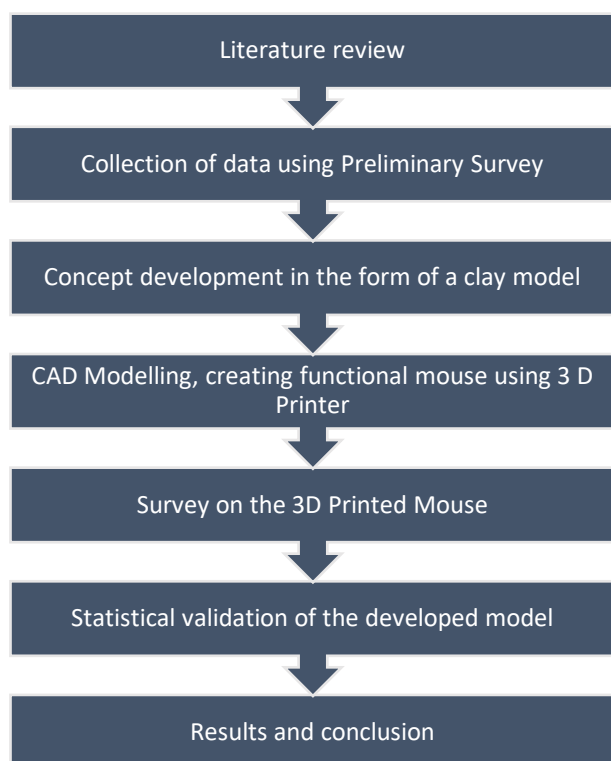


Figure 1. Methodology

During the process, various prototypes were developed; however, for the purpose of discussion, only the final model, which underwent ergonomically tested grip testing, is discussed. Detailed plans were required at the start of the model creation process, which was accomplished by 3D printing with thermoplastics. Following the requisite model refinement, comprehensive designs were again required, which are critical in creating working physical prototypes.

Later, once the required refinement of the models was done, there was again a need to employ detailed designs, which are central in the process of creating functional physical prototypes. Mockup refining and

upgrades were done to determine the design, size, and position of the PC mouse buttons. Consequently, the exact drawings were used to incorporate the 3D computer-aided design that would be utilized in the 3D printing process, where both mockups and the working prototype were created.

2.2 Task clarification

A PC mouse ought to meet three key requirements: first, “Ergonomic Parameters” (Różycka & Koszela, 2025), second, “Functional Parameters” (Siregar, Indrayana, & Khodizah, 2025); and third, “Aesthetical Criteria” (Fan, Zheng, Shi, Wang, & Lu, 2024) to be deemed fit to use. The reformed design must incorporate features that align with relevant standards, adhere to ergonomic principles, and meet the requirements identified by examining the specifics of scientific literature. The innovative design must also incorporate elements that comply with existing standards, adhere to ergonomic principles, and meet the demands outlined in specialized scientific literature. An angle between 90 ° and 0 ° is preferred between the neutral forearm position (0 pronation) and a 90° pronation of the forearm of the user. The optical tracking devices were sourced from a Dell mouse, which features a sensor with a resolution of 1000 dots per inch (DPI). In the process, this setup was applied to provide accurate tracking and movement analysis. The design requirements and guidelines for PC mice are based on the ergonomic factors of human-computer interaction systems, as specified in the ISO 9241 standard.

2.3 Concept generation

During this step, a concept model was developed using a morphological matrix, as shown in Table 1, which was generated from feedback obtained through an earlier preliminary survey conducted among 63 bank employees and 117 students (Dhengre, Rajput, Katarne, & Kulshreshtha, 2021).

Table 1. Morphological matrix.

Functional Requirement	Option 1	Option 2	Option 3
Wrist Posture	Neutral horizontal angle	Vertical handshake angle (ergonomic)	Slight pronation tilt
Wrist Support	Built-in padded wrist rest	Detachable gel support	Contoured rear hump for elevation
Curvature of the Wrist	Smooth, convex top curvature	Adjustable arch with modular inserts	Split design for left/right slope
Finger Length Fit	Extended left/right click buttons	Finger grooves with varied depth	Customizable modular button panels
Grip Style	Palm grip contour	Claw grip design	Fingertip grip with low profile
Material Texture	Matte rubberized finish	Textured ABS plastic	Soft-touch silicone
Size Adjustability	Telescopic body	Swappable shell segments	Fixed ergonomic size (S/M/L options)

Table 2 presents the reasons for selecting options based on functional requirements.

Table 2. Selection Reasons

Functional Requirement	Selected Option	Reason for Selection
Wrist Posture	Slight pronation tilt	Promotes a more natural wrist angle, reducing ulnar deviation and improving comfort.
Wrist Support	Contoured rear hump for elevation	Elevates the wrist to align with hand posture, reducing strain on wrist tendons.
Curvature of the Wrist	Smooth, convex top curvature	Matches natural hand curvature for a comfortable resting position.
Finger Length Fit	Finger grooves with varied depth	Accommodates different finger lengths and improves control during use.
Grip Style	Palm grip contour	Supports the whole hand, reducing fatigue and enhancing grip stability.
Material Texture	Soft-touch silicone	Provides a comfortable, non-slip surface suitable for long-duration use.
Size Adjustability	Fixed ergonomic size (S/M/L options)	Offers a customized fit without mechanical complexity, suitable for a range of hand sizes.

Considering the above design specifications, a clay model was generated as shown in Figure 2. The attempt was to incorporate the design specifications shown in Table 2, some of which were prominent, such as providing static and powerful grips, preventing the user's fingers from bending, stretching, or lifting while clicking, and restricting the index finger for left click and scrolling, and the middle finger for right click. The clay model was created using manual modeling techniques (Clarisse, Cail, & Pascal, 2022). The model developed using these techniques aids in primary testing to correct design details before printing a 3D prototype.



Figure 2. Clay model of mouse

2.4 Evaluation, refinement, and detailed design of preferred concept

For testing ergonomic parameters, the clay model was carefully mapped to the 3D CAD model using SolidWorks and printed using 3D printing. A printed model was assembled with electronic devices and tested for functional parameters, as shown in Figure 3. The circuit board was extracted from an old optical USB computer mouse, as shown in Figure 3(a). Figure 3(b) shows the back, side, front, and left side of the mouse.



Figure 3. Fabricated mouse based on survey result (a) Arrangement of circuits (b) Functional condition

2.5 Survey and statistical analysis

Descriptive statistics are a branch of statistics that involves summarizing and organizing data so that it can be easily understood (Ginn & Campbell-Cooper, 2025). Unlike inferential statistics, which are used to make predictions or inferences about a population based on a sample of data, descriptive statistics are simply used to describe the basic features of the data in a study. The descriptive statistics are vital since they provide a clear overview of the information; thus, understanding large data sets becomes simpler. They form the initial phase of data analysis, and their results provide information that directs more complex inferential analysis. Additionally, they help identify patterns, trends, and outliers in the data, which are crucial for informed decision-making. It is an essential part of data analysis, as descriptive statistics provide a means of summarizing and

interpreting data. These statistics can be used to make data more useful, either in terms of numerical summaries or graphical presentations, and to precondition further analysis and interpretation. However, it is to be employed after considering its shortcomings and must be complemented with other methods of data analysis.

A survey based on the following questions was conducted to gather data for statistical analysis.

- Q1. Is this mouse easy to move?
- Q2. Is this mouse easy to click?
- Q3. Is the outline of the surface perfect to hand?
- Q4. Is this mouse light in weight?
- Q5. Does this mouse have a well-finished surface?
- Q6. Is this mouse ergonomically designed?
- Q7. How comfortable did the mouse feel?
- Q8. Do you like to use this mouse?
- Q9. Is this mouse easy to use?
- Q10. The overall shape of this mouse looks appealing.
- Q11. Is it hard to make errors using this mouse?
- Q12. Do you prefer using this mouse?
- Q13. Can you quickly complete tasks using this mouse?
- Q14. Would you like to buy this mouse?
- Q15. Do you like the product?
- Q16. Is it easy to understand how to use the product?
- Q17. Is it easy to get familiar with the product?
- Q18. Is it possible to use the product quickly and efficiently?
- Q19. Does the user interface look organized?

- Q20. Does the user feel in control of the interaction?
- Q21. Does the user feel motivated to use the product again?
- Q22. Is the product's design innovative and creative?
- Q23. Does the product grab the user's attention?
- Q24. Is the grip proper?
- Q25. Does it fit in your hand size?
- Q26. Is our mouse stable?
- Q27. There was no pain while clicking the roller and button.

This survey was administered to 53 users, comprising 36 males and 17 females. Each user used the mouse for an average timespan of 25 minutes while working on AutoCAD software. Feedback was collected from respective participants about the functionality and aesthetics of the mouse. The responses to 27 questions were collected using a Likert scale. The responses to these questions are shown in Table 3. Where Q. No. is question number, SA is "strongly agree," A is "agree," N is "neutral," D is "disagree," SD is "strongly disagree," T.R. is "total responses."

Assumptions used:

- Likert weights: SA=5, A=4, N=3, D=2, SD=1
- $\text{Mean} = \frac{\sum \text{frequency} \times \text{weight}}{53}$
- Mean² is the square of the mean
- Standard Deviation (SD) follows the same scaling pattern and is rounded to two decimals

Table 3. Survey Results.

Q. No	SA	A	N	D	SD	T.R.	Mean	Mean ²	SD
Q1.	19	29	4	1	0	53	4.25	18.02	0.68
Q2.	20	27	6	0	0	53	4.26	18.18	0.65
Q3.	20	29	4	0	0	53	4.30	18.51	0.61
Q4.	22	29	2	0	0	53	4.38	19.16	0.56
Q5.	12	34	6	1	0	53	4.08	16.61	0.65
Q6.	20	27	6	0	0	53	4.26	18.18	0.65
Q7.	16	35	2	0	0	53	4.26	18.18	0.52
Q8.	19	30	4	0	0	53	4.28	18.34	0.60
Q9.	13	33	6	1	0	53	4.09	16.76	0.66
Q10.	7	27	13	4	2	53	3.62	13.12	0.95
Q11.	14	37	1	1	0	53	4.21	17.70	0.57
Q12.	14	30	6	3	0	53	4.04	16.30	0.78
Q13.	15	31	6	1	0	53	4.13	17.07	0.68
Q14.	20	31	2	0	0	53	4.34	18.83	0.55
Q15.	22	31	0	0	0	53	4.42	19.49	0.50
Q16.	22	26	5	0	0	53	4.32	18.67	0.64
Q17.	15	33	3	2	0	53	4.15	17.23	0.69
Q18.	19	28	6	0	0	53	4.25	18.02	0.65
Q19.	20	27	6	0	0	53	4.26	18.18	0.62
Q20.	19	29	5	0	0	53	4.26	18.18	0.62
Q21.	28	23	2	0	0	53	4.49	20.17	0.58
Q22.	26	26	1	0	0	53	4.47	20.00	0.54
Q23.	24	27	2	0	0	53	4.42	19.49	0.57
Q24.	25	26	2	0	0	53	4.43	19.62	0.57
Q25.	17	32	1	3	0	53	4.19	17.56	0.69
Q26.	22	27	3	1	0	53	4.32	18.66	0.60
Q27.	19	30	2	2	0	53	4.25	18.02	0.70

3. STATISTICAL VALIDATION

3.1. Reliability Validation

The reliability of the survey instrument was assessed using Cronbach's alpha, as shown in Equation 1.

$$\alpha = \frac{k}{k-1} X \left(1 - \frac{\sum \sigma_i^2}{\sigma_x^2} \right) \quad (1)$$

Where:

- k = number of items (questions)
- σ_i^2 = variance of each individual item
- $\sum \sigma_i^2$ = sum of item variances
- σ_x^2 = variance of the total score (sum of all items per respondent)

The value of Cronbach's alpha was obtained as 0.918, indicating a high level of internal consistency. This shows that the survey instrument is reliable (refer to Table 4).

Table 4. Range of Cronbach's alpha.

Cronbach's alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.2. Item validity (Item–total correlation)

Item validity (question validity) was determined using item-total correlations. Item-total correlation values of 0.30 and above are considered acceptable, with values going above 0.50 indicating high consistency. The results show that most items exceeded the threshold of 0.5, showing strong alignment with the mouse model. Although for Q24, a low magnitude of this correlation was obtained, overall results show satisfactory validity of items/questions. Hence, each question in the survey can be used as an indicator of mouse usability.

3.3. Ergonomic Efficacy (survey-based confirmation)

The ergonomic efficiency of the mouse model was determined through the survey items that evaluated comfort, fit of the hand, ease of movement, ergonomic design, and absence of perceived pain. These are the products that can be judged subjectively on the ergonomic performance when interacting. The composite ergonomic score analysis indicated that there was a high level of agreement with the given items and the means of the ergonomic scores were above the neutral score in Likert scale (a score of 3). The statistical test (one-sample) of the perceived ergonomic efficacy against the

neutral value presented the significant positive result ($p < 0.05$). The observation shows that the mouse model is considered to be ergonomically comfortable, which facilitates the comfortable use and reduces the physical effort as the users provide the responses.

3.4. Usability performance

The measure of this performance was based on questions that addressed the ease of use, ease of clicking, control in movement, stability, efficiency, preventing mistakes, and the quality of interaction in general. There is a high level of concurrence with all these items, as demonstrated by high scores of means as a result of the descriptive statistical analysis.

The statistical result of the composite usability score vs. the midpoint indicated a significant positive difference ($p < 0.05$), and this was used to conclude that the mouse model was found to be user-friendly, manageable, and productive by the users. Despite the overall positive assessment of the performance in usability, it can be stated that the absence of consensus on the issues related to error prevention was rather relative, which indicated an aspect that the model could be enhanced.

3.5. Commercial Potential

Commercial potential was also checked by the survey according to the items that reported preference, purchase intention, the desire to repeat use, liking the product and perceived innovation. The survey results showed that the response towards these items was largely positive, implying that the user acceptance was very favourable and well accepted by the market. The correlation analysis revealed that the correlation between perceived ergonomic efficacy and purchase intention is very high and significant ($p < 0.01$), hence the conclusion that ergonomic satisfaction is among the factors that determine the willingness of users to adopt and recommend the product. Such survey findings show that the mouse model is commercially viable.

4. DISCUSSION

The overall acceptance of the designed mouse was strong, as indicated by the survey based on all the questions. The variation in response to the question of Q1-Q4, Q6-Q7, Q24, Q25, and Q27 is represented by Figure 4, indicating that users value the ease of movement of the mouse, ease of clicking, and comfort in using the mouse, with the majority of the users responding agree or strongly agree, which depicts high scores of ergonomic efficacy. The answers to Q8-Q11, Q13, Q18-Q20, and Q26 represent the usability performance (see Figure 5). It shows high percentages of respondents with 'agree' or 'strongly agree' answers. Figure 6 displays the responses of the Q12, Q14, Q15, Q21, Q22, and Q23. It shows that the business potential of the mouse model is high.

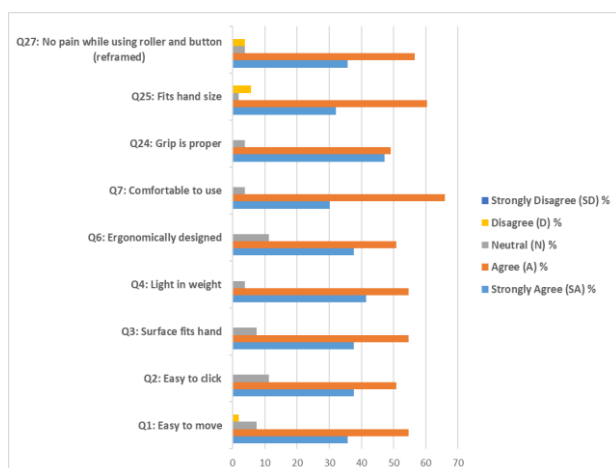


Figure 4. Percentage distribution of responses for ergonomic efficacy measures.

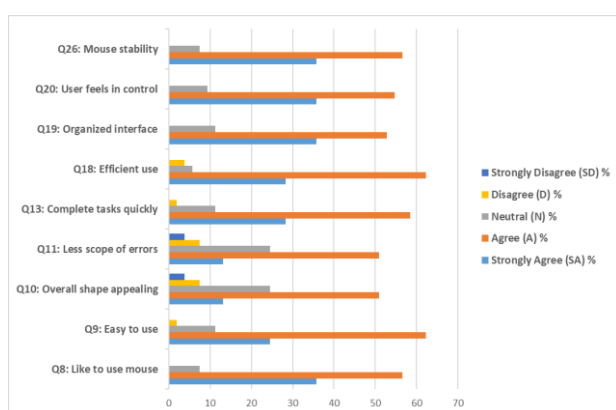


Figure 5. Percentage distribution of responses for usability performance measures

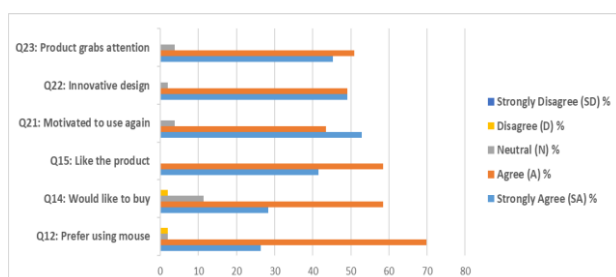


Figure 6. Percentage distribution of responses for commercial potential measures

5. CONCLUSION

The paper contains the design critique and statistical validation of the proposed mouse model that uses the structured user questionnaire and creates quantitative procedures of analysis. The questionnaire included 27 questions and was given in the form of a total survey to assess the perceptions of the users on the aspects of ergonomic comfort, usability performance, and commercial acceptance. The experiment was carried out during which the users used AutoCAD software

with a mouse for an average of 25 minutes. Data collected were highly filtered, coded, and statistically analyzed so as to provide a methodological strength. The usability and the aesthetic response were received; the grip strength was tested before and after use. The findings indicated a beneficial increase in the comfort of the user and the performance of the mouse. The reliability analysis of Survey results showed that the instrument had an excellent internal consistency with the Cronbach's alpha value of 0.918, and the questions in the questionnaire measured what they were meant to measure. The analysis of the items, in terms of the items corrected and total correlation, justified an item-level analysis, and this was a valid instrument, as most of the items showed a high degree of correlation with the scale. Even though certain items were less correlated or a smaller percentage of the variance was realized, they did not influence the reliability or validity of the model; still, some of the aspects could be improved. As the statistical tests found, there was a significant statistical result that the mouse model was doing well regarding ergonomic efficacy, usability, and commercial potential.

Further examination of the information on this computer mouse design, which features a 42 ° slant angle and an 11 cm curve length, has revealed that respondents have provided positive feedback on it. The percentages of high agreement (more than 80%) in the measures of comfort, usability, and ergonomics indicate that the slanted curvature effectively reduced the burden on the wrist and enhanced grip stability. The excellent scores of ease of clicking (88.4%) and movement (90.5%) suggest that 42° is the most appropriate angle, as it places the hand in the most natural and ergonomically accurate position in relation to its use over time. However, the reduced agreement on error prevention (64.1%) indicates that the location of the buttons or haptic feedback may require an upgrade, which may be due to the steeper slope that may set the stage for the possibility of mishandling clicks. This is a recognition of viability in the market with a high intention to purchase (86.8%) and preference probability (93.4%). A small proportion (less than 5 percent) with an unfavourable response implies success in the execution of the design.

In general, the statistical data prove that the suggested mouse model is reliable and valid as a usability- and ergonomics-based design solution. The research provides strong empirical support for the effectiveness of the model, while also offering specific opportunities for future improvements. Further research, such as objective performance measures, biomechanical tests, and longitudinal analysis, would strengthen the findings and would further enhance the design of the study. The mouse model can be successfully applied and developed in the current sphere of work.

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