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Application of universal design principles on computer mouse interface: developing a universal mouse pointing and control system to provide affordance to the left-handed users

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Abstract

The graphical user interface was introduced to democratize access to computer systems by simplifying hardware and visual interfaces. Technological advancements further reduced the constraints, primarily benefiting the mainstream users. However, the specialized needs of the critical users have always been neglected. This paper delves into the ergonomics of the mouse pointer and the computer mouse, focusing on left-handed computer users as a critical user category to develop and propose a universal design solution to integrate left-handers as a mainstream user category in a computer interface.

Keywords: universal design principles, user experience, accessibility, ergonomics, left-handers

1. Introduction

Left-handers often encounter usability challenges with both physical and digital products due to manufacturers neglecting their needs. This includes operational difficulties with right-hand-oriented tools, leading to cognitive strain and muscle fatigue. Digital interfaces, such as those on PCs and smartphones, also tend to favour right-handed users, impacting left-handers' efficiency on them. Despite the existence of accessibility settings, left-handers face obstacles in utilizing them effectively, especially in shared computing environments, where one device is accessed by multiple users in different time periods. This paper aims to explore the challenges left-handers face when using a mouse in a computer interface and proposes a universally accessible solution without the need for system-specific dexterity configurations.

2. Review of literature and available solutions

2.1. Background study

Design practices often overlook left-handers in workspaces, and studies (Coren 1992; Cakir, Hart, and Stewart 1979; Shneiderman 1987) indicate their exclusion in product design, digital interface design as well as user manual design. Research on touch-based devices found left-handed users to be slower than their right-handed counterparts, as interfaces prioritize right-handed comfort (Brush et al. 2019). Additionally, left-handers face challenges in learning to use industrial equipment efficiently, resulting in an 8 percent increase in the time required to familiarize themselves with new tools using their non-dominant hand (Salvendy 1970; Mundel and Barnes 1939).

The default mouse pointer in operating systems like macOS and Windows poses challenges for left-handers due to incorrect orientation (Basak and Roy 2019). Additionally, the default right-hand position of the mouse further disadvantages left-handed users (Hoffmann, Chang, and Yim 1996). In a controlled evaluation, four arrow pointers oriented in different directions, including the default, were compared with a circular disc pointer. Results showed that the circular disc pointer outperformed all, reducing directional bias and enhancing task efficiency regardless of the user's dexterity (Po, Fisher, and Booth 2005). Left-handers find it challenging to switch their dominant hand for mouse operation after becoming accustomed to right-hand use (Schweiger, Stone, and Genschel 2021). A study (Mouloua et al. 2017) revealed that right-handed users outperformed left-handed users when using the computer mouse with their dominant hands. This difference may be because left-handers, being used to operating the mouse with their right hands, have not developed the motor skills required for effectively controlling the computer mouse with their dominant hand.

2.2. Available solution

Apple's Magic Trackpad employs a universal design by featuring a single button for primary functions and utilizing a two-finger touch for secondary functions, accommodating both left-handers and right-handers without customizing the settings. However, there is a visual affordance issue in macOS, similar to all other operating systems including Windows, where the mouse pointer still favours right-handed users, causing visual disparity for left-handed users. In contrast, Apple's iOS and iPadOS address this by incorporating a circular disc-shaped mouse pointer upon connecting a mouse, promoting universal access and mitigating direction bias for both left-handers and right-handers.

3. Purpose of study

This study addresses the accessibility challenges faced by left-handers in computer interfaces and aims to come up with a design solution. Despite comprising around 10 percent of the population, equivalent to over 150 million global users, left-handers' needs are often overlooked by the operating system manufacturers. With users spending over 6 hours daily on computers (Sharma, 2016), especially for professional work requiring high graphics and processing capabilities, the study underscores the importance of designing inclusive interfaces across various domains. Considering the significance of tools like the mouse, mitigating the accessibility concerns at the equipment design level can enhance user experiences and improve the quality of life for all individuals. By ensuring equal access for users with alternate dexterity, the study seeks to alleviate the feeling of isolation and emotional distress (Khaliq and Torre, 2019). While left-handers may adapt to right-handed setups, exploring affordances for left-handed users remains crucial for providing a more comfortable experience.

4. Research

In order to collect valuable user insights, qualitative research was conducted in multiple phases, which involved understanding of the methodology to be used, proper planning and research design.

4.1. Research problem

Left-handed computer users do not use their dominant hands to operate the computer mouse (Leong and Ng, 2014); instead, they have to acclimatize to the default mouse setup, which is strictly designed for right-handed use, hampering the performance and increasing the learning time of left-handers. This is an example of bad user experience design where the requirements of a critical user category are neglected, causing discomfort and visual disparity. Conducting thorough research is essential to understand the specific needs of left-handed users, leading to a design solution that resolves accessibility and visibility issues. Recognizing left-handers as a primary user category in computer interfaces is crucial.

It should be kept in mind that not merely the dexterity preference, but also disability or dysfunction of the dominant limb, such as accidental limb loss or paralysis, can be a determining reason for handedness. Therefore, having a left-handed mouse operability option is vital, and the interface should be intuitive, eliminating the need for additional motor learning to be operated with the non-dominant limb.

4.2. Research methodology

This research adopts the action research methodology to address a specific problem and design a solution. It involves on-field sampling of left-handed participants, followed by an experiment. The collected usability data will be analysed to generate a concept, which will then undergo user testing for refinement and to arrive at the final design solution.

4.3. Research flow

Figure 1 contains the description of the study framework and the flow of the research.

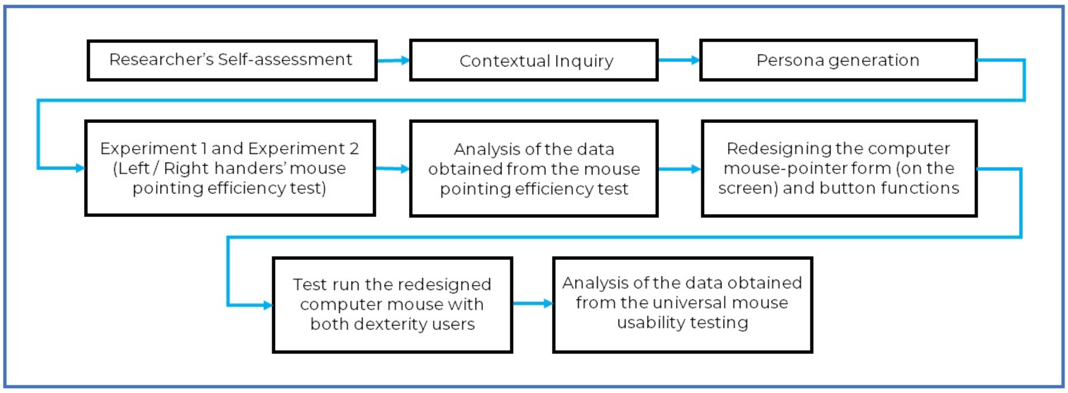

Figure 1. Study framework and flow of the research

5. Preliminary research

5.1. Self-assessment

One of the authors self-examined mouse usability by toggling the primary button for left-handed use in Microsoft Windows 10 and macOS 13 through operating system configuration setting. Despite spending considerable time on the operating systems' GUI using the left hand, several issues were identified:

- Accessibility to mouse button customization settings is unintuitive and challenging to discover.
- Changing mouse button settings does not visually alter the mouse pointer orientation on the screen, leading to a lack of proper hand-eye coordination with left-handed configurations.

The challenges presented in these examples highlight the need for improvements in user interface design to ensure a more seamless and user-friendly interaction.

Figure 2. Mouse pointer orientation remains unchanged even after configuring the left-hand mouse settings

5.2. Contextual inquiry and persona generation

A contextual inquiry session was held where eleven left-handed volunteers were interviewed while performing a mouse handling task which was provided to them for the purpose of persona generation. Among the volunteers were two users whose mouse usability examples could be considered to generate qualitative personas, as these were the only subjects who used their left-hands to operate the mouse.

- Persona 1 is a college student who operates the mouse with her left hand without changing the settings, pressing the primary mouse button with her middle finger and the secondary mouse button with her index finger.
- Persona 2 is a school pupil who also operates the computer mouse with her left hand without changing the settings. She only uses her index finger to press both the primary and the secondary buttons. It takes reaching diagonally with her index finger to press the primary mouse button.

In both instances, it is evident that the system's usability is suboptimal, leading to discomfort for the users and resulting in an overall unpleasant experience. A design intervention is certainly required to cater to the usability issues faced by the left-handers in a computer mouse interface.

6. Experiment

6.1. Experiment 1 and analysis (left-handers' mouse control efficiency)

In an experiment assessing left-handers' task performance efficiency, participants played a video game to find basic objects using a computer mouse. The game aimed to introduce beginners to mouse handling and the computer interface in a playful manner, with no prior mouse experience required. The keyboard was removed, allowing participants to choose their comfortable hand for mouse access. The mouse's dexterity and pointer orientation were adjusted using a universal customization program for left-handed orientation (Basak and Roy, 2019). Each participant played the same game level with both hands, and the results were compared. The game recorded the time taken for each participant to complete the level. Since participants were new to using a computer mouse, they were familiarized with its functionality before starting, and their mouse-handling activity was closely monitored for insights. The comparison of the task performance efficiency between dominant and non-dominant hand mouse usage of the left-handed participants is provided in Table 1.

Table 1. Performance comparison between dominant and non-dominant hand mouse usage of left-handed participants

	Dominant hand	Task completion when using the mouse with left (dominant) hand [seconds] l	Task completion when using the mouse with right (non-dominant) hand [seconds] r	Time Difference [seconds] $t_L = r - l$	percentage increase in efficiency (dominant hand) $\eta_L = (t_L/r) * 100$
P1	Left	17.39	19.89	2.50	12.57
P2	Left	25.57	29.45	3.88	13.17
P3	Left	20.00	23.82	3.82	16.04
P4	Left	21.83	26.44	4.61	17.44
P5	Left	19.19	25.58	6.39	24.98
P6	Left	18.08	22.75	4.67	20.53
P7	Left	21.35	27.93	6.58	23.56
P8	Left	16.22	19.69	3.47	17.62
P9	Left	13.68	15.16	1.48	09.76
P10	Left	17.75	22.51	4.76	21.15
P11	Left	21.97	25.27	3.30	13.06
P12	Left	18.23	20.92	2.69	12.86
P13	Left	15.75	21.70	5.95	27.42
P14	Left	18.16	23.24	5.08	21.86
P15	Left	26.62	31.78	5.16	16.24
P16	Left	27.45	30.21	2.76	09.14
P17	Left	15.35	17.15	1.80	10.50
P18	Left	27.51	28.20	0.69	02.45
P19	Left	25.21	29.43	4.22	14.34
P20	Left	17.52	20.67	3.15	15.24
P21	Left	23.48	28.56	5.08	17.79
P22	Left	15.96	20.23	4.27	21.11
P23	Left	20.45	24.28	3.83	15.77
P24	Left	16.01	21.88	5.87	26.83
P25	Left	16.89	24.59	7.70	31.31
P26	Left	22.21	25.82	3.61	13.98
Total		519.83	627.15	107.32	446.72
Avg.		19.99	24.12	4.13	17.18

6.2. Experiment 2 and analysis (right-handers' mouse control efficiency)

The usability data of left-handers was validated by comparing it with their right-handed counterparts with the default mouse settings. This experiment aims to collect accurate performance data of a computer mouse used with the left hand with required dexterity settings by left-handed beginners, which is only possible at the time of introduction to a computer interface. Once the left-handed users begin using the mouse with the wrong hand or dexterity settings, the result will never be the same as they will get acclimatized to the default mouse settings. Similarly, the comparison of the task performance efficiency between dominant and non-dominant hand mouse usage of the right-handed participants is provided in Table 2. The task completion time was recorded in seconds on the accomplishment of the game level, with both dominant and non-dominant hands of the right-handed participants.

Table 2. Performance comparison between dominant and non-dominant hand mouse usage of right-handed participants

	Dominant hand	Task completion when using the mouse with left (non-dominant) hand [seconds] l	Task completion when using the mouse with right (dominant) hand [seconds] r	Time Difference [seconds] tR = l - r	percentage loss in efficiency (non-dominant hand) ηR = (tR/r) *100
P1	Right	23.73	18.50	5.23	28.27
P2	Right	22.98	16.77	6.21	37.03
P3	Right	25.04	19.92	5.12	25.70
P4	Right	18.58	15.75	2.83	17.97
P5	Right	24.78	20.06	4.72	23.53
P6	Right	20.84	18.79	2.05	10.91
P7	Right	26.34	18.30	8.04	43.93
P8	Right	23.63	20.22	3.41	16.86
P9	Right	28.00	26.07	1.93	07.40
P10	Right	27.74	22.40	5.34	23.84
P11	Right	22.93	19.64	3.29	16.75
P12	Right	28.65	25.09	3.56	14.19
P13	Right	20.52	17.29	3.23	18.68
P14	Right	19.76	17.28	2.48	14.35
P15	Right	23.07	18.14	4.93	27.18
P16	Right	25.10	21.53	3.57	16.58
P17	Right	28.42	23.22	5.20	22.39
P18	Right	22.82	18.95	3.87	20.42
P19	Right	20.26	16.09	4.17	25.92
P20	Right	24.82	21.94	2.88	13.13
P21	Right	27.08	24.13	2.95	12.23
P22	Right	21.85	18.09	3.76	20.78
P23	Right	28.67	25.38	3.29	13.96
P24	Right	27.02	23.43	3.59	15.32
P25	Right	21.59	17.86	3.73	20.88
P26	Right	20.61	14.64	5.97	40.78
Total		624.83	519.48	105.35	547.98
Avg.		24.03	19.98	4.05	21.08

6.3. Comparison of the results of experiment 1 and experiment 2

Tables 1 and 2 highlight a notable difference in task performance efficiency for both left-handers and right-handers using the computer mouse with their dominant versus non-dominant hands. Left-handed participants took an average of 19.99 seconds with their dominant hand and 24.12 seconds with their non-dominant hand, indicating a 17.18 percent increase in performance with dominant hands. A similar trend is observed among right-handers, with an average time of 19.98 seconds using their dominant hands and 24.03 seconds with their non-dominant hands, reflecting a 21.08 percent decrease in performance when controlling the mouse with the non-dominant hand. The graph in Figures 3 and 4 shows a similar trend of performance comparison between the dominant and non-dominant hand mouse operation for both left-handed and right-handed participants.

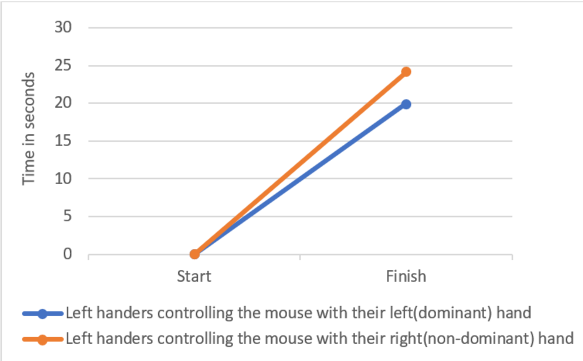

Figure 3. Performance comparison graph of left-handed participants

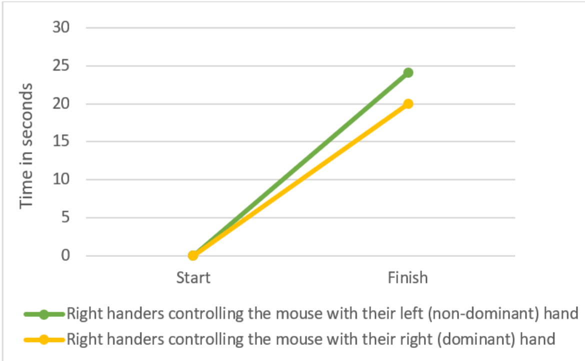

Figure 4. Performance comparison graph of right-handed participants

Notably, in Experiment 1, the left-handed participants naturally chose to hold the computer mouse with their left hand, given the absence of a mandated mouse position, unlike the default setup. Since the left hand is the dominant hand for left-handed participants, using the mouse with their left hand offers improved ergonomics as well as task performance efficiency as compared to using the mouse with their right(non-dominant) hands, as shown in Figure 3. Similarly, in Experiment 2, the right-handed participants chose their right hand to operate the computer mouse. Figure 4 shows that forcing the right-handed participants to operate the mouse with their left(non-dominant) hands restrains the ergonomics, and the task performance efficiency significantly declines as compared to using the mouse with their right(dominant) hand. These experiments thereby attain the aim of the research by manifesting the challenges faced by left-handers while beginning to learn to operate the standard mouse setup.

7. Product design and usability testing

7.1. Scope of design

Insights revealed diverse user requirements for the computer mouse, indicating that merely toggling button configurations is insufficient, as the unnoticed accessibility settings in the operating system interface, even if discovered, are impractical for frequent adjustments, especially in shared computer environments. To address the mouse dexterity issue and visual disparity, a universal design approach is recommended, which aims to conceptualize a computer mouse inclusive for both left-handed and right-handed users without relying on accessibility customization.

7.2. Concept design

Redesigning the mouse pointer's form is crucial for inclusivity among both left and right-handed computer users. Building on gathered insights, a proposed concept design replaces the arrow pointer with a circular disc pointer similar to that of iPadOS. A pointer that takes the shape of a disc has a symmetrical form and, therefore, aims to overcome issues identified in studies, such as slower movements and less efficient trajectories associated with the default arrow cursor (Phillips, Meehan, and Triggs 2003). Additionally, research (Po, Fisher, and Booth 2005) indicates that the circular disc pointer outperforms the default arrow pointer by avoiding directional bias, improving visual ergonomics, enhancing task performance efficiency for both left and right-handers, offering better precision, and covering minimal visual content. Apart from these facts, a disc-shaped pointer is compatible with the mouse hardware and is also suitable for touch-based operations on the display screen of supported hardware. The circular disc pointer's design, as universally accessible, incorporates left-handers into the computer interface without requiring additional mouse pointer configuration settings. Blue colour is used with an opacity of 50 percent to provide a translucent effect and surrounded by a white outline of 1 pixel to avoid getting it blended with the background and help the user see-through the interface elements behind the pointer by avoiding any visual hindrance. Figure 5 shows the sample screenshots of the mouse pointer operations. The pixel size of the disc pointer is set to 23x23 pixels, which is the standard protocol for mouse pointer design as per the Windows user experience guidelines[1] (Hickey et al. 2022).

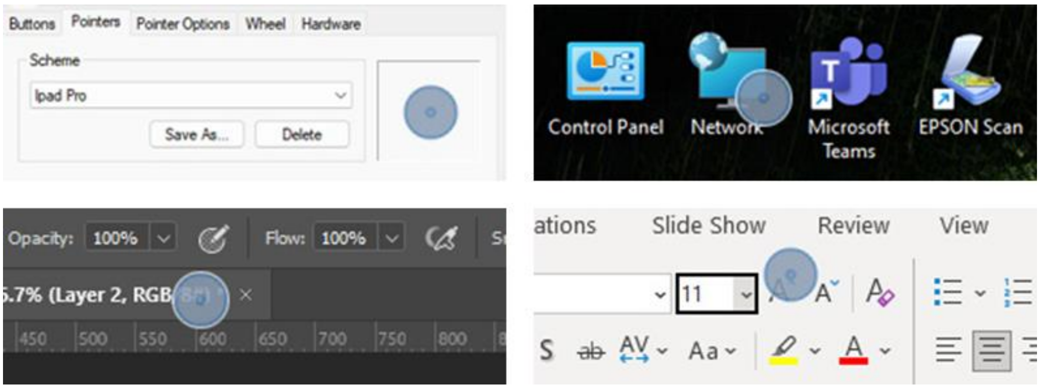

Figure 5. Concept Design - disc-shaped mouse pointer replacing the arrow pointer

7.3. Functionality

The concept proposed here is incomplete without a few minor functionality changes in the mouse hardware. Instead of having two separate buttons for primary and secondary functions, the whole clickable area of the mouse is reserved for the primary function, as represented in Figure 6. Clicking anywhere on the mouse with a single finger leads to the primary function, and a two-finger tap invokes the secondary function. This functionality is achieved with the help of haptics, where a solid-state surface is used instead of clickable buttons and the haptic sensor present mimics the feedback of clicks.

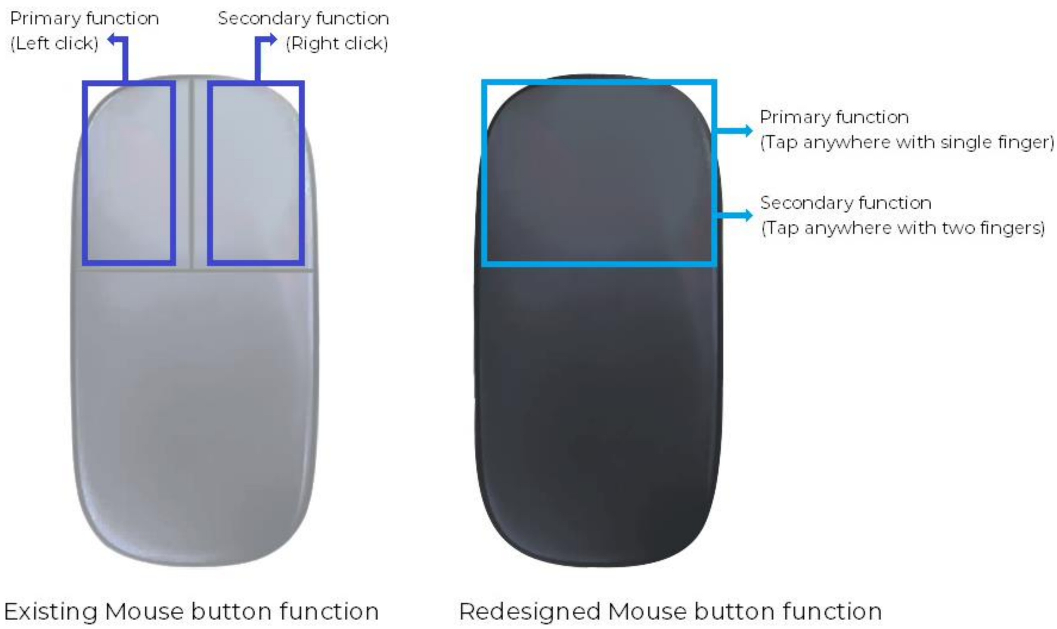

Figure 6. Concept Design - redesigned mouse button function

This way, the mouse device becomes commonly usable with both hands, thereby successfully eliminating the need to toggle the mouse buttons from the mouse configuration settings. The haptic feedback simulates the actual touch feedback of any contemporary mouse. Tactility is crucial in interface

[1] Windows UX Guidelines refer to a set of design principles and recommendations provided by Microsoft for creating user interfaces and experiences that align with the Windows operating system. These guidelines aim to ensure consistency, usability, and a cohesive experience across Windows-based applications.

design as it provides users with force or touch feedback, enabling computers to simulate confirmation for tasks and convey realistic sensations (O'Mally and Gupta 2008). This concept is inspired by the Apple Magic Trackpad device, which uses a two-finger tap to invoke the secondary function with the help of haptic sensor following the universal design approach so that both left-handers and right-handers can equally use it with their dominant hand without having to customize the dexterity configuration.

7.4. Usability testing and analysis

To evaluate the design concept's usability, participants from the mouse dexterity experiment tested the disc pointer for accessibility, affordance, visual ergonomics, precision, and learnability. A redesigned mouse, with reconfigured button functionality as outlined in the concept design, allowed participants to tap anywhere on the clickable area for primary button functionality. All 52 participants (26 left-handers and 26 right-handers) used the redesigned computer mouse with the circular disc pointer, to play the same video game (finding hidden objects) using only their dominant hand. The time taken by each participant to finish a level was recorded. Table 3 displays the task performance efficiency for both left-handed and right-handed participants using the redesigned mouse control and pointer.

Table 3. Task performance efficiency of participants with redesigned mouse pointer and reconfigured mouse button functionality

	Dominant hand	Task completion time when using the circular disc mouse pointer with left hand (seconds)
P1	Left	19.10
P2	Left	25.22
P3	Left	19.51
P4	Left	21.83
P5	Left	18.79
P6	Left	18.68
P7	Left	20.97
P8	Left	16.22
P9	Left	12.81
P10	Left	17.23
P11	Left	22.16
P12	Left	18.05
P13	Left	16.84
P14	Left	17.89
P15	Left	16.50
P16	Left	25.27
P17	Left	15.86
P18	Left	27.13
P19	Left	24.94
P20	Left	16.74
P21	Left	23.38
P22	Left	15.65
P23	Left	19.62
P24	Left	16.01
P25	Left	26.62
P26	Left	20.89
Total		513.91
Avg.		19.77

	Dominant hand	Task completion time when using the circular disc mouse pointer with right hand (seconds)
P1	Right	18.42
P2	Right	15.37
P3	Right	20.13
P4	Right	15.24
P5	Right	19.82
P6	Right	21.15
P7	Right	17.49
P8	Right	20.68
P9	Right	26.07
P10	Right	21.97
P11	Right	20.11
P12	Right	24.76
P13	Right	16.85
P14	Right	16.98
P15	Right	15.84
P16	Right	21.15
P17	Right	22.79
P18	Right	18.28
P19	Right	15.66
P20	Right	22.03
P21	Right	23.60
P22	Right	17.82
P23	Right	24.75
P24	Right	23.35
P25	Right	16.81
P26	Right	13.58
Total		510.7
Avg.		19.64

Table 3 shows that the average time taken to complete a game level for both left-handed and right-handed participants using their dominant hand with the redesigned setup is comparable to the time taken with the reconfigured/default setup, as observed in Tables 1 and 2. This suggests that the redesigned mouse pointer and control is superior to the existing one and ergonomic for both left-handed and right-handed computer users. The slight increase in efficiency with the circular disc pointer may be attributed to factors such as more explicit tracking and improved precision. Also, the ergonomic benefits of using a mouse with reconfigured button functionality play a role in increasing task performance efficiency. Additionally, participants' familiarity with the game level likely contributed to more efficient task performance. Thus, the usability testing indicates that the concept design yields better performance for users with both dexterities, especially when introduced early in their computer interaction experience.

8. Limitation, conclusion and future scope

While universal design principles aim to make interfaces inclusive, this research focuses on critical users with different dexterity requirements and is limited to beginner computer users, as experienced users would not provide relevant data being already acclimatized to the wrong setup. The experiments and usability tests demonstrate that a universal design approach, employing a circular disc pointer and redesigned mouse button functionality, can enhance inclusivity for left-handed computer users without configuration hassles. Future research should focus on investigating the learnability of the mouse with reconfigured settings, as demonstrated in this study, and comparing the performance of left-handed users using their dominant hand with left-handed configurations against right-handers with default setup would be valuable. With over 45 years since the advent of graphical user interfaces, operating system manufacturers should reevaluate accessibility features holistically to address mouse dexterity issues and integrate left-handers as a mainstream user category in computer interfaces.

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