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An Overview of Gaming Peripheral and Gadgets and its Effect on Gaming Performance

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Abstract

Gaming setups are collections of hardware devices, such as joysticks, controllers, keyboards, and motion sensors that users interact with to generate visual feedback. Video games have become one of the most widely adopted forms of entertainment, engaging people of various ages and interests. Companies have developed gaming-specific versions of their products including gaming mice, keyboards, and monitors. Moreover, new types of gaming gadgets such as olfactory displays and smart lighting have emerged, although their actual impact on the gaming experience remains unclear. This study examines the importance of these gadgets in enhancing and improving gaming experience. The study provided a detailed comparison of the different types of gaming setups and present the results of an online survey aimed at validating our research findings. The survey covered all aspects of computer work and e-sports, revealing significant insights into the importance of peripheral gaming and its effects on the gaming experience and enjoyment. The survey, which included responses from 500 participants across Asia, Europe, and the Middle East, indicated that approximately 70% of the participants believed peripherals improved immersion and enjoyment, and over 90% felt that peripheral gaming positively impacted their performance. Despite less familiarity with advanced technologies, such as olfactory displays and augmented reality/virtual reality (AR/VR) devices, there is considerable interest in these innovations.

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1. Introduction

Gaming peripherals are auxiliary devices connected to a personal computer (PC) or laptop for an enhanced gaming experience. This collection includes headsets, gamepads, joysticks, tablet pens, gaming mice, keyboards, external hard drives, lighting, and olfactory displays, as shown in Fig. 1. The conventional definition of gaming setup is an electronic device that interacts with a player on a screen, often using video game peripherals. Over the years, advancements in the gaming sector have redefined video games and their peripherals, leading to more interactive setup.[1,2] The gaming (AR/VR) market grew from USD 1.1 billion in FY2019 to USD 3.1 billion in FY2023, with projections estimating it could surpass USD 7.5 billion by FY2028, reflecting a compound annual growth rate (CAGR) of around 20%.[3]

1.1 Desktop gaming

Desktop gaming refers to games played on desktop personal computers (PCs) or MACs. Apart from the traditional mouse and keyboard, the setup may include devices, such as joysticks.

1.2 Gaming consoles

These hardware devices typically work with a television and a controller-like gaming remote running games that are pre-installed, downloaded, or come on optical discs. The main manufacturers are Microsoft, Sony, and Nintendo.[4]

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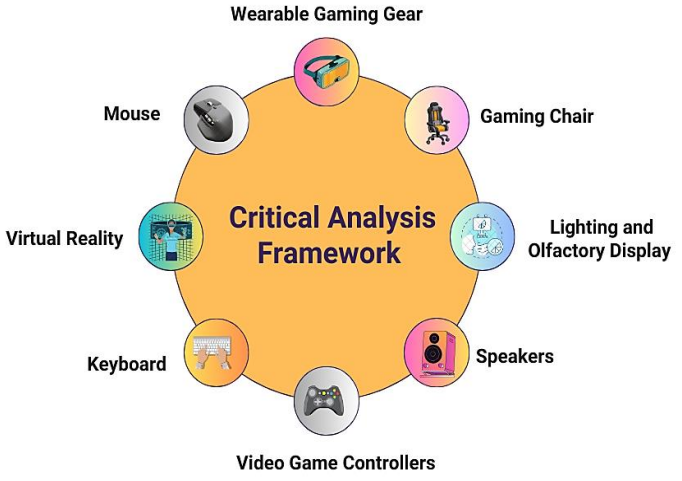

Fig. 1 Impact of gaming peripherals and gadgets on user experience and performance.

1.3 Mobile app games

Mobile games can be free or purchasable and downloaded through app stores such as Google Play or Apple App Store, or are preinstalled by the phone company by default. Major companies such as Nintendo and Blizzard are now focusing on creating mobile games.[5]

1.4 Web-games

Web-based games are popular owing to their ease of handling and accessibility. These games are mostly free and require stable Internet connections to allow gamers to interact with others.[6]

1.5 Handheld games

Handheld games are dedicated gaming devices with built-in screens, audio/visual software, and gaming control. These gadgets were portable.[7]

1.6 Augmented reality

Augmented reality-based games use computer-generated imagery superimposed on real-world scenarios. Pokémon GO is a prime example of an augmented reality (AR) game.[8]

1.7 Virtual reality

Virtual reality (VR) games use 3-D artificial rendered environments to run computer games, emulating a real-time gaming experience. The VR headsets include High Tech Computer (HTC) Corporation Vive, Oculus Rift, Microsoft HoloLens, Samsung VR, PlayStation VR, and Google Cardboard.[9]

1.8 Breakdown of various approaches to gaming

A critical analysis of a Broadband Search is presented in Fig. 2[10]. Here, we can see the percentage of gamers that use the abovementioned gaming setup. Web-based games are widely used owing to their various advantages such as adaptability to be used on any screen, availability, ease of use, budget friendliness, and ability to connect people worldwide.

Different types of console games can utilize different types of gaming devices and gadgets. It can be as simple as a gaming mouse or as complex as an olfactory display. In addition, many companies tend to add the word "Gaming" to their product names (*e.g.*, Gaming mouse and monitor). This study evaluated the actual effect on gaming experience. Moreover, the paper includes the results of a questionnaire that attempted to measure this effect, especially less popular gaming gadgets such as olfactory displays.

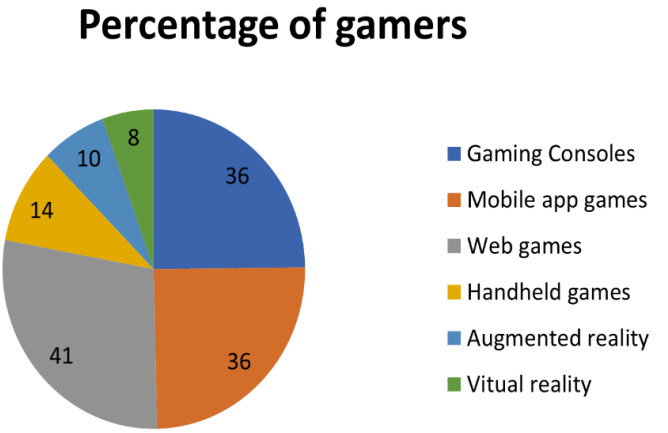

Fig. 2 Percentage of gamers using various gaming setups.[10]

2. Gaming gadgets

Gaming gadgets are electronic devices or peripherals, such as controllers and mice, that enable gaming in any setup. They act as input/output mechanics for improved playability along with the incorporation of several types of direct control feedback and haptics. The peripherals also include many types of wearable gears or gaming chairs that emulate the cues of the virtual world onto the real one.

Therefore, these peripherals are essential for enhancing gaming experience and have several other applications in the field of healthcare training and rehabilitation for gamers.

To understand the collective influence of various peripherals on the gaming experience, we introduce the Peripheral Impact

Factor (PIF). This factor evaluates how different devices, such as keyboards, mice, VR headsets, and gaming chairs, contribute to the user's overall performance and satisfaction. Mathematically, the PIF can be calculated as shown in equation (1).

$$PIF = \sum_{i=1}^{n} pi.Ii \quad (1)$$

where,

pi = weight for the impact of the ith peripheral

Ii = impact score of the ith peripheral (based on usability, latency reduction, immersion)

n= number of peripherals being analyzed

Some of the most prominent gaming peripherals and their role in enhancing the gaming experience are discussed below.

2.1 Keyboard

Keyboards are essential input devices for desktop gaming,

enabling users to control tasks with both alphanumeric and custom keys.[11] A high-quality gaming keyboard is essential for an immersive experience, and selecting one requires evaluating several key factors, as outlined below:

2.1.1 Layout
The layout of the keyboard defines the space occupied. Variants include 40%, 60%, 65%, and 1800-compact, referring to the size of the layout relative to a full-sized keyboard.[12-14]

2.1.2 Keycaps
Keycaps impact the feel and sound of the keyboard. They are categorized into several profiles, such as high/medium and spherical/cylindrical profiles.[15,16]

2.1.3 Key switches
Mechanical switches are categorized as linear, tactile, and clicky switches, each providing different feedback and sound.[17-20]

2.1.4 Haptics
With regard to keyboards, the presence of haptics is uncommon and does not serve many purposes, as shown in Table 1.

2.2 Mouse
A mouse is another essential device that functions as an input mechanism for desktop gaming. A conventional mouse has two input keys: a sensor and scroll wheel. Gaming mice generally have customizable buttons, on-board memory, and adjustable Dots Per Inch (DPI) settings.[21] To select an ideal gaming mouse, a person must know the grip type. The common ones are fingertips, claws, palms, and hybrid grips.[22-31]

2.2.1 Build
Mice exist in two main forms: Ambidextrous and Ergonomic. Ambidextrous mice can be comfortably used by both hands, whereas ergonomic mice suit only a one-hand configuration. A proper design can provide relief from carpal tunnel pressure.[23]

2.2.2 Mouse feet/skates
Mouse skates are small pads attached to the bottom of the mouse, allowing it to move freely on a mousepad or a rough surface. They are usually made of low-friction materials like Polytetrafluoroethylene (PTFE)Teflon.[24]

2.2.3 Para cording
Para cording replaces a stiff cable with a more flexible one to avoid cable drag during gameplay. A para-corded mouse, combined with a mouse bungee, provides an ideal setup for wired mouse gamers by minimizing wire presence.[25]

2.2.4 Weight
The weight of the mice was crucial. This trend favors lighter mice, especially for frames per second (FPS) games, with some models weighing approximately 60 g. However, weight preference varies among gamers, with some preferring heavier mice often with attachable weights.[26]

2.2.5 Switches
High-quality mouse switches have a long lifespan. Some manufacturers compromise the switch quality to make lighter and cheaper mice, leading to issues such as double-clicking and unsatisfactory clicks.[27]

2.2.6 Sensors
High-quality sensors provide high precision and accuracy. Optical sensors are common and influence the DPI of a mouse.[28]

2.2.7 DPI
Dots per inch (DPI) measures mouse sensitivity. A higher DPI registered minor movements as significant changes in the game. While some professional e-sports users rarely use extremely high DPI, they are often marketed as a preference feature.[29]

Table 1. Comparison of keyboard layouts.

Keyboard Type	No of keys	Function keys	Navigational keys	Number Pad (Separate)	Function Keys	Dimensions
Full sized keyboard	100-104	✓	✓	✓	✓	Standard Size
TKL [Ten-Key Less]	86-88	✓	✓		✓	Smaller than Full sized keyboard
75% Keyboard	86-88	✓	✓		✓	Smaller than TKL
65% Keyboard	66-68	✓	✓ PARTIAL			Compact
60% Keyboard	59-61					Compact
40% keyboard	39-41					Very Compact
1800- Compact	100-104	✓	✓	✓	✓	Compact version of full-sized keyboard

Table 2. Wired and wireless mouse comparisons.

Mouse type	Latency	Cable Drag	DPI (Dots Per Inch)	Weight	Haptics	Light	Cost	Range
Wired	1-5ms	Low to High	High	Moderate	NIL	varies	Moderate	3-6 Feet
Wireless	5-10ms	NIL	High	Lighter	NIL	varies	High	up to 35 Feet

2.2.8. Lighting
Most gaming mice include RGB lighting that can be customized using on-mouse buttons or software.

2.2.9. Mouse pads
A proper mousepad is essential for a smooth operation and can be categorized into speed or control variants. They help to extend the lifespan of mouse skates and provide an ideal surface for sensors.

Wireless mice have advanced significantly, with negligible latency compared to wired versions. They avoid issues such as tangled wires, which can hinder movement and create desktop clutter. Wired mouse users often use a mouse bungee to manage the cable, keeping it off the surface, and eliminating static friction, as shown in Table 2.[30,31]

Advancements in wireless technology have been extraordinary in terms of computer mouse technology. Table 2 represents the feature in which the wireless counterparts can deliver the same results when compared across different technological and fundamental use cases. This point can be further solidified, as professional sports players tend to prefer wireless mice. The only constraint that can be pointed out when compared with wireless devices is that they are expensive.

2.3 Monitor
A monitor is an output device that displays data in pictorial or video format. This is essential for the PC gaming setup. Different types of monitors include liquid crystal display (LCD), liquid emitting diode (LED), and organic light emitting diode (OLED), each with distinct characteristics, such as response time, color accuracy, and refresh rate.[32] There are many types of monitors in the current market, most of which have differences in response time, color accuracy, color gamma range, and so on.

2.3.1 Liquid crystal displays (LCD)
LCD panels are commonly used by professionals and gamers.
- Twisted Nematic (TN) Panels: Fast response times and high refresh rates but poor color accuracy and viewing angles. Suitable for desktop gaming.
- Vertical Alignment (VA) Panels: Good contrast ratios but lower response times and refresh rates make them less popular among gamers.
- In-Plane Switching (IPS) Panels: Good response times, refresh rates, color accuracy, and viewing angles. Slightly lower brightness.

2.3.2 LED panels
LEDs are used as backlights for LCDs, offering better contrast and color range. They come in two types:
- Direct-lit LED: Placed directly behind the panel.
- Edge-lit LED: Consumes less power but may have backlight bleeding issues.

2.3.3 Organic Light Emitting Diode (OLED)
OLED panels emit light individually, providing excellent color accuracy and response times; however, they are expensive. They are flexible and contain many curved variants. Console gamers also use the monitors. Most games for consoles have been capped to 60 frame per second (FPS) in recent times; however, with rapid advancements in technology, we are seeing a growing rise in support of high-fps games with the introduction of PlayStation 5 and the Xbox series. The addition of 4k screens means that conventional television sets are no longer the standard for console gaming if the user wants to experience gaming at the highest standard.

2.3.4 Framerate
The average monitor frame rate is 60 Hz, which is sufficient for general use; however, higher framerates are preferred for gaming for smoother experiences. Higher frames provide additional information, giving gamers an edge in fast-paced scenarios.[33]
- Frame Rate vs. FPS: Frame rate is the number of frames the monitor displays per second, whereas FPS is the number of frames the GPU generates per second.
- Screen Tearing: Occurs when the GPU generates more frames than the monitor can display, causing a horizontal split. Vertical Synchronization (V-SYNC) was used to prevent this. Console gamers also use monitors, especially with the rise of high-fps games and 4k screens

Screen ghosting occurs when pixels lag in rendering new images, causing the previous image to partially appear. Higher framerates reduce ghosting, thus making the display clearer.[34-37]

By selecting an appropriate monitor with high refresh rates, gamers can avoid issues such as bottlenecking and screen tearing, thereby ensuring an optimal gaming experience.[38] Gaming performance is closely linked to the responsiveness and precision of hardware, which is known as performance rate (PR). PR measures the effect of game peripherals on player performance, typically calculated by monitoring reaction time, accuracy, and overall skill in the game as shown in equation (2).

$$PR = S/RT \quad (2)$$

where, S = Score or points achieved in the game
RT = Reaction Time (time taken to respond to game stimuli)

Monitors are the primary output displays and mandatory components required for gaming. Twisted nematic (TN) panels and in-plane switching (IPS) panels are preferred because of their faster response rate and frame rate; however, on TN panels, colors may appear slightly washed out because of the lower color accuracy, which is limited by narrower viewing angles. However, VA panels are preferred by video editors or other professionals because of the sharper images that arise owing to the parameters listed in Table 3. Owing to variances in the requirements, these monitors have distinct roles.

2.4 Video game controllers

Video game controllers are widely used in gaming consoles and desktops. A typical controller has two analog sticks, a directional pad, four triggers, four control keys, and start/stop buttons, providing sufficient input for most games and allowing combinational key presses for different actions. Controllers have wired and wireless versions and offer haptic feedback, such as Sony's DualShock controllers, which respond to in-game actions.

Controllers are preferred for certain games, racing games, fighting games, platformers, and sports simulations, *etc.*, as they provide better control and a more immersive experience, especially in single-player games. Some games are designed specifically for controllers, although a mouse is often superior to first-person shooters owing to its speed and precision. Many first-person shooters optimize gameplay by matching players using the same type of input device or by adding aim assistance for cross-play.[39,40]

Newer controllers feature touchpads for swipe gestures, and potential future models may include touchscreens. Continuous improvements in technical development and ergonomic design have made controllers suitable for long gaming sessions. Some controllers have built-in audio jacks for convenient headphone use.[41]

2.4.1 Feedback in the case of controllers

Handheld controllers primarily use vibrotactile feedback, which produces a rumbling sensation that enhances the gaming experience. Prototypes for thermal feedback that simulate warmth or coldness based on in-game conditions are being developed. Skin feedback controllers, which use skin-stretch factors to simulate environmental effects, such as waves or fishing, are also being explored. Motion sensor-enabled controllers, equipped with gyroscopes, accelerometers, and sensors, can detect minor positional changes to further enhance the in-game experience.[42,43]

2.4.2 Playing sports

Popular motion-sensing controllers, such as the Nintendo Wii Remote, Xbox Kinect, and Nintendo Switch Joy-Cons, have advanced significantly with the incorporation of a gyroscope. These controllers can replicate real-life sports, such as table tennis, golf, and shooting, by translating arm movements into in-game actions, providing a more immersive experience than traditional controls. Multiplayer support allows for the virtual recreation of team sports and matches against real-life opponents, closely mimicking real-life sports.[44]

2.5 Speakers

Speakers are audio output devices available in various stereo channels such as 2.0, 2.1, and 5. The 2.1 setup, common in desktop gaming, included two speakers and a subwoofer for low-frequency sounds. The two speakers help pinpoint gaming events through positional audio. Surround sound speakers offer a 3D audio experience that enhances immersion. Some speakers feature RGB lighting that mimics an in-game environment. A sound card is essential for achieving optimal

Table 3. Types of monitors and their parameters.

Monitors	IPS	TN	VA	LED-IPS
Color Accuracy	HIGH	LOW	MEDIUM	HIGHEST
FPS (Frames Per Second)	HIGH	HIGHEST	LOW	HIGH
Response Times	HIGH	HIGHEST	LOW	HIGH
Brightness	HIGH	MODERATE	HIGH	NA
Contrast	MODERATE	MODERATE	HIGH	HIGH
Cost	HIGH	LOW	MODERATE	HIGH
Backlight Bleeding	LOW	NIL	LOW	NIL
Viewing Angles	HIGH	LOW	HIGH	HIGH

Table 4. Types of speakers and their parameters.

Channel	Number of Speakers	Surround sound	Channels	Cost	Range	Sound Quality
2.1	3	No	2 Standard +1 Subwoofer	low	Small	Average
5.1	6	Yes	5 Standard +1 Subwoofer	Moderate-High	Moderate	High
7.1	8	Yes	7 Standard +1 Subwoofer	high	High	High

speaker performance.[45-47] The types of speaker and their parameters are listed in Table 4.

2.6 Headphones

Headphones worn over the ears are crucial for gaming as they allow private listening. They are preferred owing to their flexibility and noise cancellation. Surround sound headsets provide a 360-degree soundscape, enhancing immersion.
The key parameters for gaming headphones include the following.

Build Quality: Ergonomic, well-fitting, and flexible headphones ensure comfort during long gaming sessions. Glass-friendly options are available for individuals with spectacles. Weight also played a significant role.

Earcups: Open Back: Do not cover the back of the earlobe, leak sound, or allow external noise.
Closed Back: Cover the earlobe, prevent external noise, and produce a strong bass.
Semi-open: A hybrid of open and closed backs.
The material of ear cups, such as leather, should be chosen based on comfort and preference, although leather can cause sweating.[48-50]

2.6.1 Impedance

The headphone impedance ranged from 8 to 600 Ω. High-impedance headphones require a high-voltage supply and less current; therefore, high-impedance speakers require the presence of an amplifier on the motherboard. A good amplifier and digital-to-analog converter (DAC) are essential for headphones to process high-quality sounds.[51]

2.6.2 Microphone

Gamers prefer built-in microphones for convenience and space saving. They allow communication with teammates or friends during game play. Active noise cancellation uses an internal microphone to cancel external noise by inverting audio.[52-53]

These features enable long gaming sessions without disturbing one's surroundings. Wireless headphones share advantages and disadvantages with wireless mice, but latency remains an issue. They are ideal for single-player games, but not for competitive gaming. Some wireless headphones have audio jacks for versatility. Achieving low latency in wireless headphones is challenging owing to Bluetooth limitations, codec complexities, and high costs.[52-56]

2.6.3 Headphone haptics

The most common type of direct-contact feedback in gaming headphones is vibrational feedback or haptic bass, as shown in Table 5. This mechanism creates a rumbling sensation based on audio cues, such as explosions, which enhances immersion. Although RGB lighting exists, it does not add to the gaming experience. An example is Razer Nari Ultimate, which uses smart haptic technology (Lofelt L5 haptic drivers) to convert sound waves into real-time touch sensory feedback. This technology, known as Razer Hyper Sense, transforms game audio into haptic effects, enhancing awareness and the overall gaming experience.[57]

Comfort and audio quality are paramount differentiators of headsets, such as the way they rest over an individual's ears and padding. Headphones tend to provide greater noise cancellation and immersion, along with greater audio quality, than earphones. In contrast, in-ear headphones and earbuds are simpler in structure, weigh less, and more portable. Individual preferences and use cases present us with their choice. A comparison of the headsets is presented in Table 5.

2.7 Gaming chair

Gaming chairs are essential for console and desktop gaming, providing lumbar support, and preventing back and neck pain from prolonged gaming. They offer customization in terms of height and inclination to suit the user preferences.[58,59]

Ergonomically designed for comfort, gaming chairs support proper posture with multiple paddings and layers, which differs from standard office chairs. They often have a swivel base and come in materials, such as fabric or leather, with some offering spill resistance. Appropriate seating improves gaming performance and prevents strain and fatigue.[60]

Innovative developments include gaming chairs as input control mechanisms, such as Chair IO, which acts as a joystick for virtual environments. Gaming VR chairs and rigs provide confined spaces for an immersive experience, with features such as zero gravity, allowing reclining up to 140°, enhancing the gaming experience.[61]

Table 5. Types of Headphones and their parameters.

Design	Comfort	Portability	Passive Noise Isolation	Leakage	Stable Fit	Sound Quality
Over-ear Headphones	Great	Bad	Good	Some	Unstable	Great
On-ear Headphones	Mediocre	Good	Mediocre	Some	Good	Great
In-ear Headphones	Good	Great	Great	Less	Great	Great
Earbuds	Good	Great	Great	Some	Great	Lower
Bone conduction	Great	Great	None	Less	Fantastic	Lower

Table 6. Categories of Haptic feedback and key parameters

	Ergonomics	Speakers	Haptics	Control Inputs	Cost	Comfort level
Office Chair	Moderate	Not present	Not present	Not present	Moderate	Moderate
Gaming Chair	Better	Available	Available	Available	High	High

2.7.1 Haptics

In the case of gaming chairs, haptics are vibration-based with subwoofers located within the gaming chair to help achieve this purpose. Vibrations are based on game feedback and movement. Tactile feedback is also under development for gaming chairs in which the sense of touch can be replicated. The sheer number of positions where vibrational or haptic motors are in direct contact with the user affects vibration feedback to the user.[62]

Table 6 compares different types of chairs-specifically, an office chair and a gaming chair-across various parameters related to ergonomics and user experience. Ergonomics and proper lumbar support go a long way to enhance the gaming experience. Some gaming chairs have additional perks, such as haptics, aimed at highlighting the gaming experience. A proper ergonomic chair is vital for health and for maintaining productivity in long-term desk users. The other benefits of gaming chairs are secondary benefits. A standard chair or sofa can serve the basic purposes but may come at the expense of health and diminish the overall experience.

2.8. Wearable gaming gear

Wearable technology has seen a gradual increase in its usage over the past few years. Wearable gears can be simplified as electronically equipped fabrics that can be used for the next-generation immersion in gaming. These wearables are also being used by the medical sector to accomplish various purposes, mainly related to rehabilitation with the help of this gear, as discussed below.[63]

2.8.1 Gaming gloves

Gaming gloves are the latest trend in futuristic gaming. Gaming gloves provide support for gesture recognition that can act as an input mechanism for several types of games.[64] The use of gestures makes the control mechanics more convenient and natural. Some gaming gloves are equipped with thin rubber-like microfiber sensors stitched with a glove that covers the back of the palm and all fingers. They transmitted all motions observed via the signals to the computer. These movements can also be transmitted to the healthcare staff to observe the progress of patients during rehabilitation. One example is the Peregrine glove, a contact-based glove that allows inputs through simple finger touches to a contact pad on the palm. It features up to 17 customizable touchpoints with a response time of 30 ms, making it highly advantageous for VR and competitive gaming, which requires multiple hotkeys.

Another advanced glove is the Dexmo glove developed by Dexta Robotics, which gives users the sensation of holding virtual objects by restricting finger movements according to the object's shape. This glove uses five servo motors for force feedback and is completely wireless, providing a highly immersive experience in virtual environments.[65] Prototypes of gaming gloves and wearable technology have been developed to provide an interface for virtually simulating weight and grasping objects. Gravity is a device that uses vibrotactile feedback, unidirectional brakes, asymmetric skin stretch, and a gripper-type haptic device to achieve this purpose. Vibrotactile feedback was provided during contact, high-stiffness force feedback during grasping, and weight force feedback during lifting. It can also incorporate skin-stretch feedback along with existing methods, where kinesthetic feedback is provided for contact, grasping, gravity, and inertia.[66]

Repetitive strain injury (RSI) is caused by prolonged repetitive tasks and most gamers do not take serious risks. Gloves can be used for monitoring and training during rehabilitation for RSI. Rapael smart gloves are used for the rehabilitation of Stroke Patients, and some are used for surgical training.[67]

Examples of gaming gloves are Peregrine gloves, which are contact-based gloves that can toggle inputs based on a simple finger touch of a finger to the contact pad that rests on the palm. It had up to 17 customizable touchpoints. Response times are extremely fast, with a latency of 30ms, and can be of great advantage when playing VR games and competitive games that require many hotkeys because they can be mapped onto gloves for ease of use.[68]

Dexmo gloves, developed by Dexta Robotics, provide users with the sensation of grasping virtual objects by restricting finger movements based on the object's shape or simulating the feel of a pulsating virtual heart. The gloves utilize five servo motors to deliver force feedback and operate completely wirelessly.[69]

2.8.2 Gaming suit or exoskeleton

Haptic and gaming suits have primarily been developed for VR gaming. These sensors are capable of sensing motion, fibrillation, and tactile feedback. In essence, this hardware allows the user to feel the virtual world. These suits generally resemble a chest plate that extends to the sleeves when it comes to a full-body suit. These suits can provide complete direct contact feedback for the peak gaming experience and immersion. The ARAIG (As Real As It Gets) suit is a prime example of a multisensory, multidirectional force feedback haptic gear designed for immersive gaming. Equipped with a 7.1 surround sound system, 34 vibratory devices, and 8 muscle contraction locations, it simulates various in-game actions,

such as a shoulder squeeze. The suit is compatible with several VR and PC games, and has applications in training firefighters and military personnel without exposing them to real-life dangers.[70] Everything from a bullet shot to a strong wind gust can be emulated by a suit. The thin and light nature of upcoming suits allows wearability for a long duration. Gaming suits can have up to 15 haptic sensors that target specific muscles and body parts, which is sufficient for a full-body experience. Frozen suits also exist with restricted movement at joints using variable jamming materials or motors.[71]

The ARAIG suit is a multisensory, multidirectional force feedback haptic device designed to enhance immersive gaming experiences. It features a 7.1 surround sound system, 34 vibratory actuators, and eight muscle contraction points, such as a shoulder squeeze, which respond according to the action cues performed in the game.

It provides support for several VR and personal computer (PC) games.[72] It also has an external application. It can be used to train firefighters to deal with hazardous conditions and escape from them. It can also be used for military and civilian training applications, without being vulnerable to life-threatening risks from open training.[73]

2.9. Virtual reality

Virtual reality (VR) is a computer-simulated experience delivered through a mounted head gear that completely encloses one's eyes. A well-known VR setup is Meta Quest, which includes Head-Mounted Display (HMD) wireless controllers, a power adapter, and high-specification desktop sensors. This setup ensures a fully immersive experience by allowing users to interact with virtual environments through precise head and hand movements detected by integrated sensors. In darkness, the screen embedded in the headgear serves as the user's window to the virtual world. It naturally responds to head movements by adjusting the layout orientation, creating a fully immersive experience. Also, virtual reality devices are equipped with audio-sensory features and haptic feedback capabilities to enhance the sense of presence.[74]

VR games are highly engaging so much so that a person could lose track of their surroundings and the real world, so to avoid physical or monetary losses, a playing space of 1.5X2 meter or larger is required, along with the PC which can effectively support the VR gear. External proximity sensors are required for motion detection along with accelerometers and gyroscopes. Some VR gears have a power adapter so that they can be played wirelessly.[75] A VR setup is shown in Fig. 3.

The major component of a VR setup is the head-mounted display (HMD), which is a headset that primarily has two high-resolution screens and a high refresh rate (up to 120hz) which projects separate images for each eye to achieve 3D rendering of the virtual world. Head-mounted gears usually come with wireless controllers that act as input mechanisms for the VR setup. These controllers are enabled using vibrotactile haptics. HMD is cushioned and built while considering ergonomic design. There are several adjustable straps, such that the head gear can be worn easily for long durations.[76] Haptics has seen the most advancement in VR, as every form of direct contact feedback can be seen here, varying from appliances. One of the reasons for this is the innumerable wearable-gear compatibility. Most haptic suits/exoskeletons and gloves are primarily developed and prioritized for Virtual Reality needs in comparison to desktops or consoles because of how much the immersiveness has been improved and made the virtual world more believable and the engagement rate would be increased, as measured by the level of realism and interaction in VR environments.

Fig. 3 VR gaming setup (Meta Quest) with HMD, wireless controllers, power adapter, High Specification desktop and sensors.

2.9.1 Engagement index

The Engagement Index helps us capture how deeply players are involved in their games and how peripherals, such as VR headsets or gaming controllers, enhance their engagement with virtual environments. The level of engagement that users experience during gaming is an important factor that influences their overall satisfaction. Engagement Index (EI) as a measure that combines several engagement metrics, including the time spent playing, frequency of user interactions, and intensity of focus. EI can be calculated as shown in equation (3).

$$EI = \alpha \cdot T + \beta \cdot F + \gamma \cdot I \quad (3)$$

where,

T = Time spent actively gaming,

F =Frequency of interactions (*e.g.*, mouse clicks or button presses),

I = represents the Intensity of focus or concentration during gameplay

$\alpha, \beta, and\ \gamma$ = are scaling factors that reflect the relative importance of each component

This is one of the reasons why VR has multiple uses in various fields, such as training, rehabilitation, and education.[77]

2.9.2 Limits

Playing VR games for a long duration can trigger symptoms, such as motion sickness, which is termed cybersickness. Common ailments include nausea, dizziness, and headache. This is because the vestibular system (inner balance, responsible for a sense of balance and spatial orientation) is tricked by the virtual world. Cybersickness strikes some users when perceived motion is not experienced by the body.[78]

Augmented Reality is a subset of virtual reality. Instead of virtually simulating the entire environment, AR incorporates elements of the real world and augments or simulates virtual objects in the actual world. Real-time integration of Augmented reality takes place where the position and orientation of the object in the actual world is localized and then mapped in 3D, which makes AR appear believable to the user.

The addition of augmented reality to mobile phones has seen huge growth, as it has now become widespread with some global phenomena, such as Pokémon Go, and several developmental projects by major publishers, such as Mojang. The requirements of camera-based sensors and ease of integration in mobile phones are the reasons for their success, and manufacturers have now begun selling phones with AR apps and functionalities pre-installed in the phone.[79,80]

3. Olfactory display impact on virtual reality

Developments in Immersive Virtual 6Reality (IVR) technology have recently opened a new range of empirical study opportunities for gaming technologies. Advancements in IVR provide virtual environments that simultaneously replicate the complexity of the real world and provide scientists with numerous control and monitoring capabilities. This has become a dynamic key for immersing people in an environment that is close to reality, involving more human senses.[81,82] Researchers have gained insight into olfactory devices in virtual reality environments to enhance the gaming experience. The primary objective of this technology is to make the simulation more realistic by allowing players to smell the related scene/visual object of the game or the virtual environment. The information provided by olfactory stimuli provides an immersive game experience through predefined game conditions, such as in any genre game (action or horror).[83,84] and cooking games (smell of ingredients).[85] The olfaction research on the quality of experience explored in a variety of ways, such as smell, was related to the visual object that was watched. During the visual experience, the scent added to the sense of realism, such as when it was unpleasant or when the odor was inconvenient; however, the visual clip was perceived as more realistic.[86] The scents were released using devices called olfactometers during a gaming experience, based on pictures, sounds, or videos. Olfactometers are computer-controlled devices that supply odorants to human olfactory organs. Most studies have examined different types of olfactory displays, classified as wearable and environmental, as shown in Fig. 4.

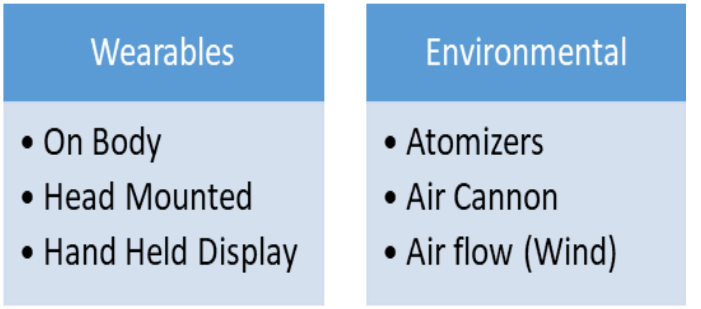

Fig. 4 Different types of olfactory display.

Various researchers have focused on the different characteristics of olfactory displays before using them in virtual environments, as mentioned below.[83,87-89]

- The quantity and range of available odors.
- The ability to adapt the scent level to the sensitivity of humans.
- The degree of odor variance in intensity and consistency as well as the continuity of odor release.
- How is smell found and diffused in the virtual world with respect to a particular object?
- How an olfactory display smells in a wide area.

The scent should be vaporized before delivering the aroma to the nose, as it is in the form of a liquid or solid liquid, but humans can experience odors in the air.[88,89] Different vaporization methods are available, as illustrated in Fig. 5.

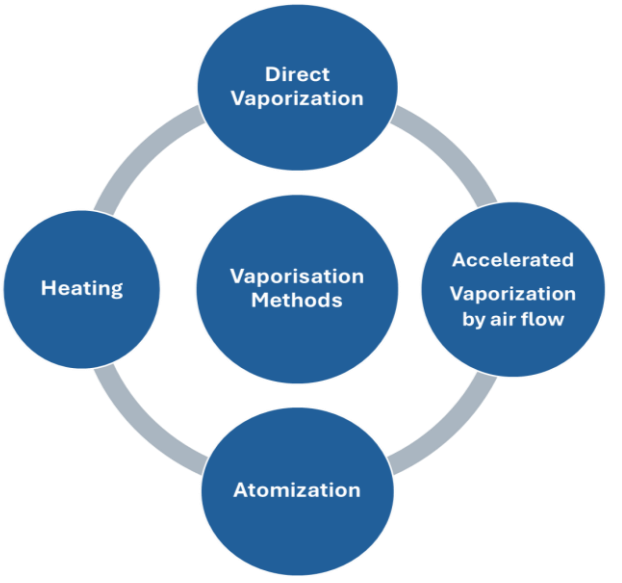

Fig. 5 Different Vaporization methods.

The natural vaporization method uses a scent generator for highly volatile chemical compounds that are not controlled during the vaporization process. Another method uses airflow, in which the vaporization process is accelerated using fans, blowers, and pumps for liquid gel or a porous material. Heating is also a method for producing aroma scents in the form of incense stick-fragrant wood. Currently, the atomization (air diffuser) process is used to deliver odors in the form of small droplets produced in the air.[88-97]

If an individual wants to experience different scents over multiple events (different ingredients for a cooking game, treatment, and fear in horror games) at different times, a mechanism to move between different time periods is needed for the individual to experience multiple scents or a scent that changes over time. To create a blended scent in real life, different fragrances are mixed to ensure that the resulting aroma contains the desired chemical compositions at the appropriate concentrations. Once vaporized, the blend is delivered to the nose through various methods, as shown in Fig. 6. These scents are then directed towards the user through an airflow system to ensure timely and precise delivery. Additionally, air cannons generate vortex rings to simulate dynamic scent bursts such as explosions or sudden smoke, adding realism to the experience. By localizing the scent release near the user's face, the olfactory display creates a multisensory interaction, enriching the overall engagement and making the virtual environment more convincing and interactive. This technology adds depth to VR by connecting users to the virtual world through their sense of smell, thereby amplifying both immersion and enjoyment.

Much effort has been devoted to the odor supply system of the device using controlled hardware and a number of odors on various subjects to make it ideal for gaming and enhance the virtual experience, as shown in Fig. 6. Various methods have been employed to integrate olfactory displays with virtual environments to deliver odorants to users, each with its unique advantages and limitations. These delivery methods range from direct airflow systems to more sophisticated solenoid valve mechanisms, each impacting the user experience differently. The number of odorants tested, and the types of scents vary widely across studies, with some focusing on single-scent experiments, whereas others incorporate a broader range of smells, from fruity aromas to more complex environmental scents. However, challenges such as scent contamination, restricted movement, and high cost of equipment remain common across many approaches. Table 7 provides a comprehensive overview of the different methods used for odorant delivery, types of odorants tested, and specific limitations observed in various studies.

4. Role of intelligent lighting for a better gaming experience

Visual comfort increases the efficiency of a person and reduces fatigue in gameplayers. When the light is too dim, we can't see the object well. On the other hand, if the light is too bright, it makes our eyes hurt. If we force our eyes open in bright light, tears may come, making it hard to see and causing discomfort. Therefore, it is necessary to design a lighting scheme such that the light is adequate for proper places. Different frequencies of light waves produce different color sensations in the human eye. The visibility of an object depends on the level of illumination, which in turn depends on the following factors.

- Size of the object
- Period of observation
- Color of object
- Background contrast.

The human eye naturally adjusts its brightness within its visual field to achieve light uniformity. Non-uniform lighting causes the iris to adjust more frequently, resulting in eye strain. To ensure uniform illumination, a combination of general and localized lighting with brightness ratios not exceeding 3:1 was implemented. The color perception of objects is influenced by the spectral characteristics of the light source. Optimal lighting composition should render colors naturally, approximating their appearance under daylight conditions. Properly designed

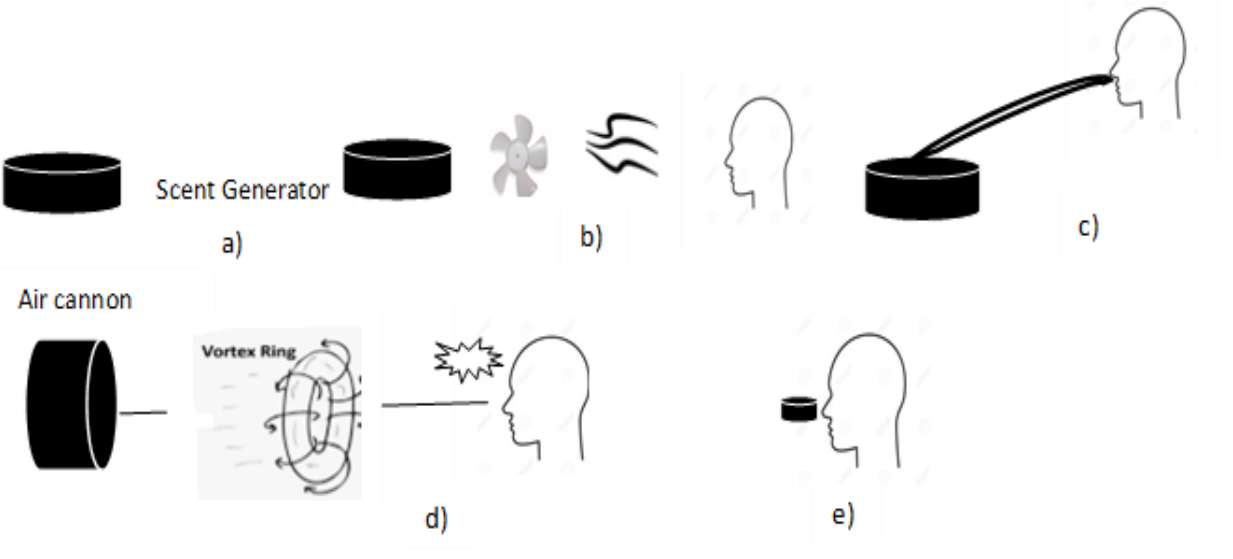

Fig. 6 Scent delivery methods: a) Natural diffusion, b) Wind, c) Tube, d) Vortex ring, e) Direct delivery.

Table 7. Different approaches for delivery of odorants, types of the odorant and their limitations.

References	Delivery method	No. of odorants	Subjects Tested	Type of odorant	Disadvantage
Sezille *et al.*[97]	Tubes and Solenoid valves	15	4	Propanol (PRO), Isoamyl acetate (ISO), Benzaldehyde (BEN), *etc.*	Chances of contamination is increased of one odorant from traces of others before it.
Nakamoto *et al.*[98]	Odorant Bearing Tubes or wearing additional headphones.	31	NA	Different gases	Chances of contamination increases when one odorant is tainted by traces of the previous one.
Sato *et al.*[99]	Direct Delivery	12	14	Lavender, lemon etc.	Restriction of head movements
Ischer *et al.*[81]	Computer controlled Solenoid valve	15	9	Soap Perfume, Jasmine aroma, chocolate, Apple aroma, Synthetic body odour, Humidity smell *etc.*	Increase in the chances of contamination when using multiple odorants, expensive design.
Tsaramirsis *et al.*[84]	Airflow (Wind)	24	15	Orange, Jasmine, Tobacco, Pine, Mountain, Ocean	Persistence times and conflict between aromas, Limited data
Al-Bahadly *et al.*[100]	Atomization	1	3	Aerosol	One scent is used for experiment.
Niedenthal *et al.*[101]	Handheld olfactory display	1	20	Lemon or Lilac	Hand movement creates turbulence which reduces the strength of the aroma, Limited data
Nakamoto *et al.*[85]	Tubes and Solenoid valves	32	NA	Cooking Ingredients such as garlic, onion, wine, spices etc.	Expensive
Tanikawa *et al.*[88]	Scent Generator	18	7	Fruit Flavoured Aroma	NA
Tiele *et al.*[102]	Aroma Generator	6	NA	Cinnamon, Lavender, Lemongrass, Orange, Grapefruit. Peppermint	Limited Data
Ademoye *et al.*[86]	Vortex Dispenser	6 categories	42	Burnt, Flowery, Fruity, Foul, Resinous, Spicy	The choice of parameters when performing user studies is more limited to smells than conventional media, such as video and audio.
Brain *et al.*[103]	Airflow (Wind)	9	22	Fruity, Foul	Limited no. of participants, Limited Data
M. Seif El-Nasr *et al.*[104]	Airflow (Wind)	12	8	Lemon, Ice cream, Cake, Apple, Grass, Banana, Mushroom, Rose, Milk, jasmine, and a Teacup	Limited no. of participants, Limited Data

task lighting can adversely impact workplace experiences. In gaming, lighting is a critical element that enhances visual aesthetics, narrative, and atmosphere. It significantly affects the game's ambiance and can alter the player's perception.

When utilized effectively, lighting can enhance the overall gaming experience. Studies have provided insights into how various lighting techniques influence the gaming environment.[105] Research has demonstrated that reduced ambient lighting intensity (compared to high intensity) increases gameplay duration.[106,107] Exposure to bright light with red undertones increased participants' perceptions of warmth, while blue-dominant light heightened anxiety. Increased light intensity amplified emotional responses. Both

light intensity and spectral composition have been shown to impact mood.

5. Survey and results

An online survey was conducted to validate the research findings and reach a consensus on the impact of gaming peripherals on a broader scale. The survey questionnaire was prepared such that all aspects related to general computer work and high-level gaming would be covered, from an average office person to a full-time e-sports player, as shown below. The insights highlighted in this paper are presented in the following section. Most responses were from Asia, Europe, and the Middle East. More than 60% of the surveyed participants were–the age group of 19-24. The sample data suggest that over 30% of the respondents were unaware of the technology of augmented reality, virtual reality, wearable gaming technology, olfactory displays, and thermal devices, whereas more than 75% were unaware of olfactory displays and 50% were unaware of the application of a thermal device. This lack of awareness has also caused people to be most interested in innovation in technology. Over 45% of the survey replies indicated that they were interested in learning about AR/VR, wearable gaming technology, olfactory displays, and thermal devices. Fig. 7 illustrates the comfort ratings against the usage time for different gaming peripherals. User experience in gaming can be scored based on several factors, such as engagement, satisfaction, and performance, often using a weighted scoring system as given in equation (4).

$$UXS = w1 \cdot E + w2 \cdot S + w3 \cdot P \quad (4)$$

where,

E = Engagement Index

S = Satisfaction Rate

P = Performance Rate

$w1, w2, w3$ = weights assigned to each factor (based on the relative importance of engagement, satisfaction, and performance)

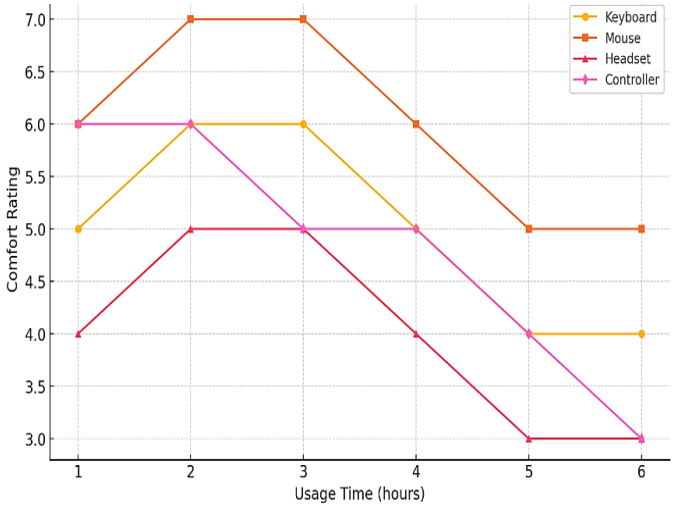

Fig. 7 Comparison of performance metrics for different gaming peripherals.

One of the key aspects of the gaming experience is user satisfaction, which we quantified using the Satisfaction Rate (SR). This rate is derived from participant feedback, and reflects how satisfied gamers have different peripherals. The SR is calculated as shown in equation 5.

$$SR = \frac{\sum_{i=1}^{m} r1}{m} \quad (5)$$

where,

ri = satisfaction rating (collected via surveys or feedback, on a scale from 1 to 10, for example)

m= number of participants

This metric provides a quantitative measure of user satisfaction, enabling the comparison of how various peripherals contribute to an enhanced gaming experience, based on data collected from survey respondents. Fig. 8 illustrates the Comfort Ratings Against Usage Time for Different Gaming Peripherals. The results indicate that while the mouse facilitates the most rapid reaction times, it is associated with a marginal decrease in accuracy compared to alternative devices, such as the controller. The controller, conversely, offers the highest level of accuracy, but demonstrates a moderate response time, rendering it suitable for tasks requiring precision. Despite its widespread utilization, the keyboard exhibits slower response times than the mouse, while maintaining adequate accuracy. The headset occupies an intermediate position, offering balanced performance. This analysis suggests that gamers may select different peripherals based on their prioritization of speed or precision in gameplay, indicating that each device excels in a distinct domain.

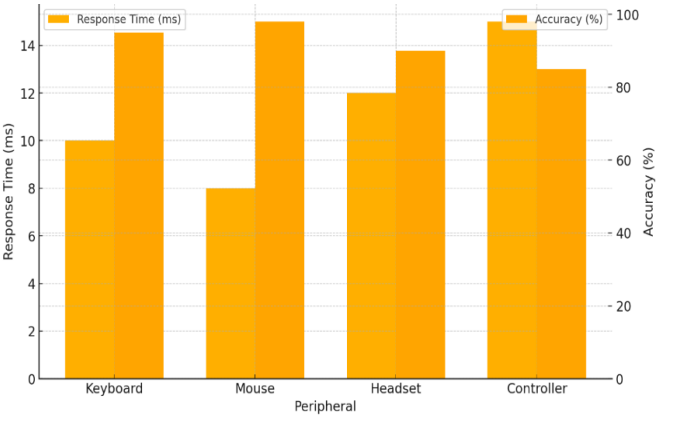

Fig. 8 Comfort ratings against usage time for different gaming peripherals.

Figure 9 illustrates the Shifts in User Preferences for Gaming Peripherals Over Time. The prevalence of keyboards and mice has exhibited an upward trend, with mice attaining nearly 40% and keyboards demonstrating steady growth to approximately 37% by 2024. Headsets have also experienced a consistent increase in preference, indicative of the growing significance of immersive audio experiences in gaming, reaching 28% by 2024. Conversely, controllers have undergone a marked and continuous decline, diminishing to 3% by 2024. This trend suggests that as gaming technology advances, users increasingly favor peripherals that offer

enhanced precision and customization, with controllers becoming less preferred in PC-dominated gaming environments.

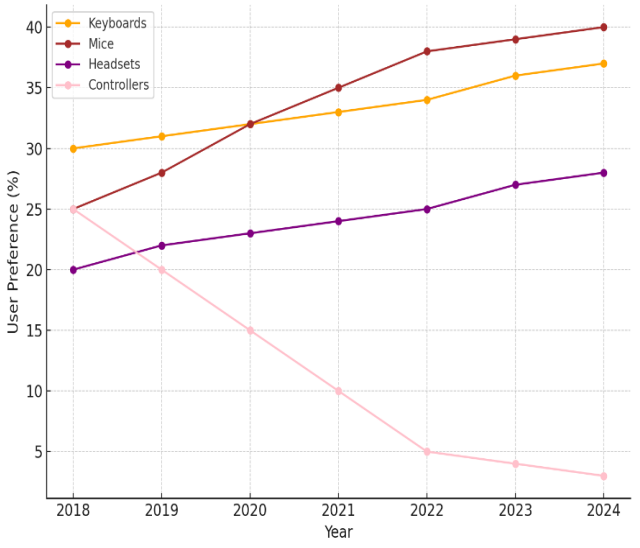

Fig. 9 Shifts in user preferences for gaming peripherals over time.

6. Conclusion

In this study, we examined various gaming gadgets and their impact on enhancing gaming experiences. From the average consumer to professional gamers, every component of a setup can significantly affect the gaming experience. The ergonomic design of controllers and wearable devices is crucial to user comfort and health. We assessed the advantages and compatibility of commonly used gaming hardware by focusing on direct contact feedback and haptics. Environmental feedback, such as olfactory setups and lighting variations, was also explored for its impact on gaming immersion. Our study suggests that high-performance gaming is enhanced by high-specification desktop setups, virtual reality integration, and haptic gears. An online survey confirmed the positive influence of peripheral gaming across a broad user base, from office workers to export participants. Despite limited data on lighting and olfaction technologies, the respondents indicated moderate to high impacts, highlighting the untapped potential in these areas. No negative responses were recorded and less than 10% felt that the hardware had no impact on gaming. The survey also suggested that aesthetics such as RGB lighting were less influential. The field of gaming peripherals has vast potential for improvement, promising lifelike gaming experiences, and applications in healthcare, nursing, and education.

Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

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