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EHT

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Capturing Human Data Stream Outputs with Virtual Reality

EXECUTIVE SUMMARY

Virtual reality (VR) possesses unique characteristics of immersive and engagement that are a boon to one of VR's most powerful commercial uses – VR training.

By pairing VR's effective "learning by doing" experiences with its platform's ability to capture detailed trainee data securely and easily, the resulting wealth of information includes usage, personal, performance, and attention/engagement metrics.

The amount of data and level of detail that can be collected for a user in a virtual simulation closely resembling the real world and eliciting actual responses is challenging or nearly impossible to gather via traditional methods. VR data capture thus provides unprecedented insights that can be used for both analysis and real-time feedback to dynamically adapt the VR experience.

This report will provide a general overview of the metrics that can be collected by VR application software, VR base hardware, and additional equipment that provides body/object tracking and biometrics. It will conclude with a note about the key benefits and considerations for data collected in VR training experiences.

"Training scenarios that take place in VR offer the opportunity for an entirely new level of assessment and data collection."

- TechNative

INTRODUCTION

VR and other immersive technologies are moving beyond entertainment applications and gaining mainstream acceptance in other industries. Healthcare is ranked as the sector to be most disrupted and expected to grow to nearly $11B by 2025, according to the Fourth Annual Augmented and Virtual Reality Survey.

Focusing on VR training, healthcare use cases include learning how to operate specialized equipment, perform a specific sequence of tasks for a complex procedure, and respond in high-risk scenarios involving medical triage, biosafety handling, and surgery prep.

These skills are challenging to teach in a classroom setting and difficult to quantify. True observation of learning achievement requires an appropriate instructor-trainee setup and employing several observers per user to walk around and manually record aptitude, a method prone to human error and inconsistencies.

In contrast, VR training offers the opportunity to capture a trainees' every action with measurable outcomes. The cumulative data can provide insights beyond paper tests and computer-based training, such as mastery of each required activity, identifying opportunities for improvement, and assessing task suitability.

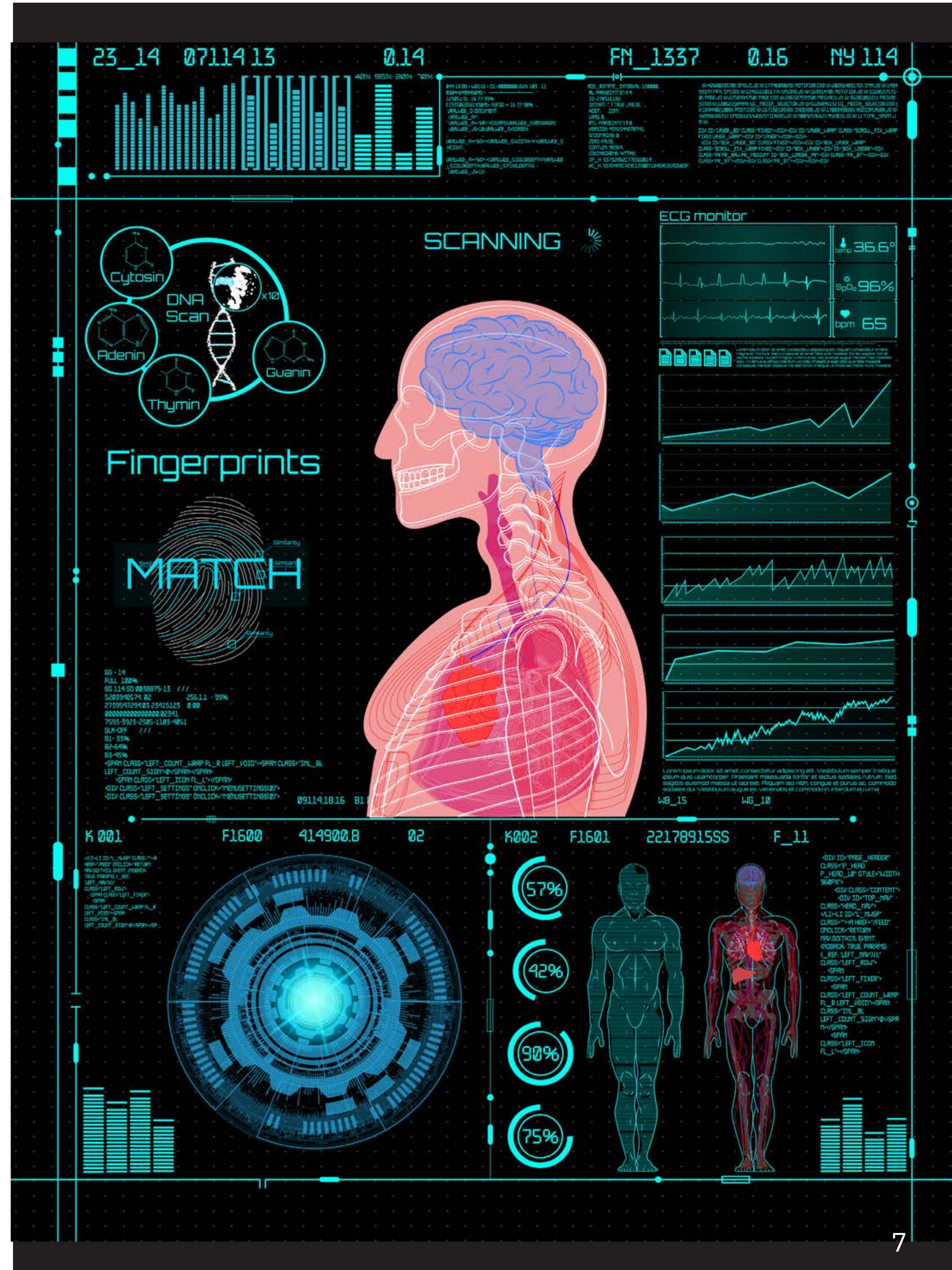
USER EXPERIENCE AND DATA CAPTURE

Unlike desktop viewing, training in VR is governed by stereoscopic vision and the complex orientation of the head, gaze, and other kinematic constraints. VR also creates presence, embodiment, and autonomy in an environment that closely simulates the dynamics in the real world. In response, users experience actual emotions, and their behavior will likely reflect what they would actually do.

Wearing a VR headset eliminates visual distractions and increases engagement, while collecting the user’s head-oriented output. Hand controllers and additional equipment for body/object tracking and biometrics can also track interactions and physiological responses.

With commercial VR systems typically tracking body movements 90 times per second and high-end systems recording 18 types of movements across the head and hands, a 20-minute VR experience can produce 2M unique recordings of body language, according to a study published in JAMA Pediatrics in 2018.

In general, data capture for users in VR can be done via VR application software, VR base hardware, and additional equipment that provides body/object tracking as well as biometrics.



VR SOFTWARE ANALYTICS

A VR application's out-of-box software can generally capture user's actions automatically upon activation. When customized with extra coding, it can collect even more data.

Cross-platform game engine Unity, for example, has a Unity Analytics dashboard showing default metrics such as number of active users per a set time period, number of sessions per user, total time spent in VR experience, and user segments. Some add-on metrics can track onboarding, progression, heatmaps showing time spent at specific points, and percentage completion.

This data provides user behavior insights that can inform how to improve the VR experience to boost retention and engagement.

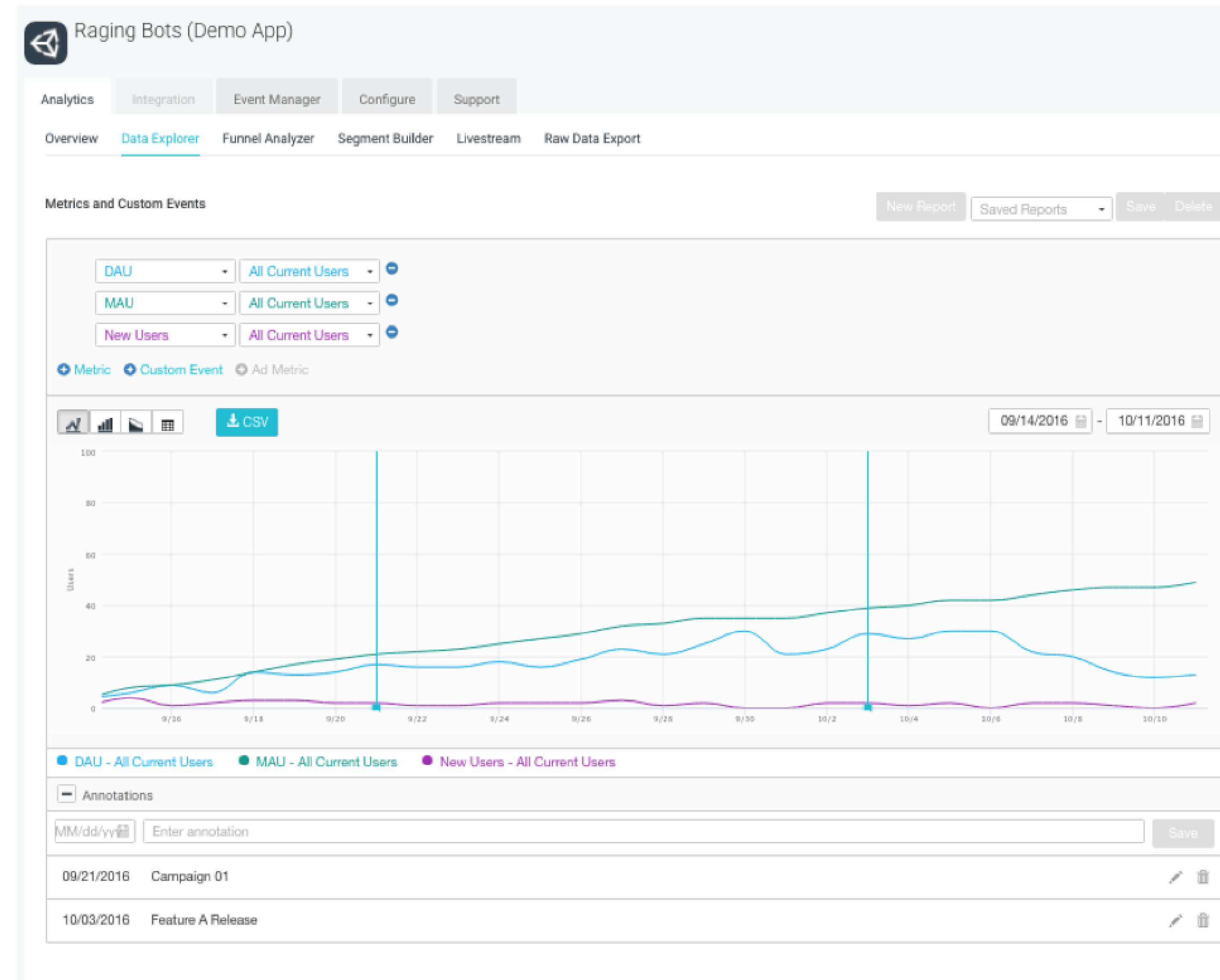


Image: Unity

VIRTUAL REALITY HARDWARE TRACKERS

Headset and Camera Tracking

VR base hardware includes a headset and usually two hand controllers. The types of movement that can be detected in these devices are referred to as "degrees of freedom" or DoF.

DoF is an essential concept in VR that allows a user's movement to be converted into movement within the virtual environment. There are two categories: 3DoF and 6DoF.

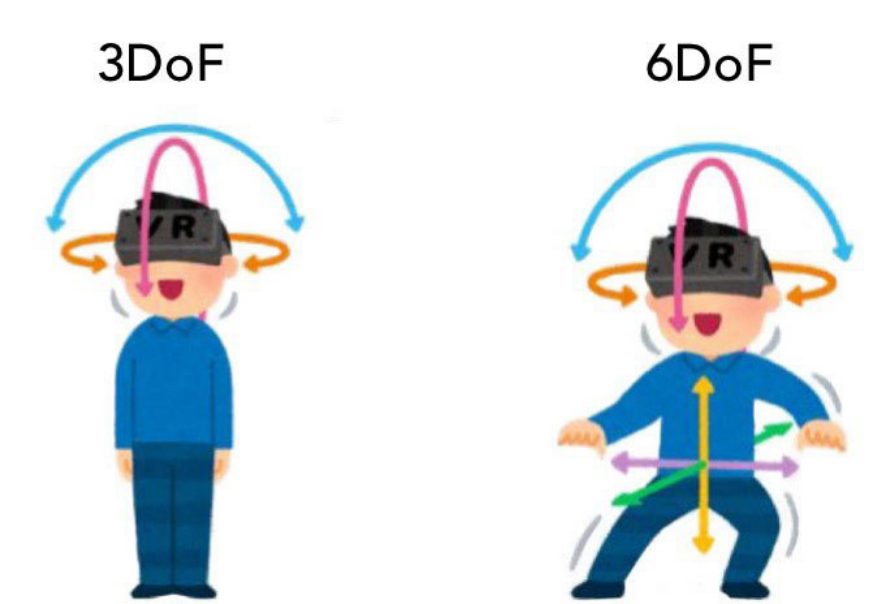


Image: Toast

3DoF tracking allows rotational movement, such as looking left, right, up, and down, and head-tilting from side to side, but not translation movement or whether the user moved around.

3DoF headsets, like Google Cardboard and Samsung Gear VR, provide the simplest form of user tracking in VR and rely on built-in sensors typically found on devices like smartphones to measure movement.

6DoF builds on 3DoF by allowing movement going forwards and backwards, left and right, crouching, and standing up. 6DoF headsets, like HTC VIVE Pro and Oculus Quest 2, allow the user to explore locations, inspect details, and perform real-life tasks.

In 6DoF, the user's movement in the real world and translation into the virtual one is possible by outside-in or inside-out tracking.

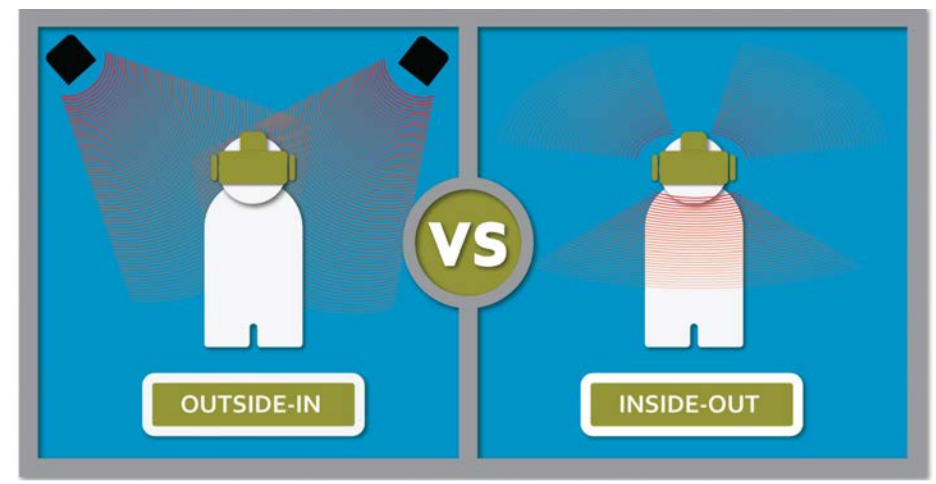


Image: Sensory Technologies

Outside-in tracking involves placing cameras or lasers in stationary locations around a room to monitor receivers on the VR headset. In contrast, inside-out tracking has cameras and sensors integrated into the VR headset itself.

The following sections will cover data capture from specifically 6Dof VR headsets and compatible equipment.

VIRTUAL REALITY HARDWARE TRACKERS

Head Orientation

The VR headset is the center of all positional tracking for the user's virtual body in VR. It can reveal accurate 3D coordinates representing the actual location of the user's head. Feet position can also be calculated by subtracting the user's height, which is pre-configured in the VR system on initial setup.

Head orientation is also the default way to capture the user's gaze or where a user is looking at. VR makes this possible through ray casting, a feature that shoots a virtual laser beam from the center of the user's gaze until it hits the nearest virtual object. The target indicates the object that the user was most likely focused on.

Benefit:
Uncovering areas of the VR experience that get the most attention can help determine whether trainees were looking with understanding, distraction, or confusion.

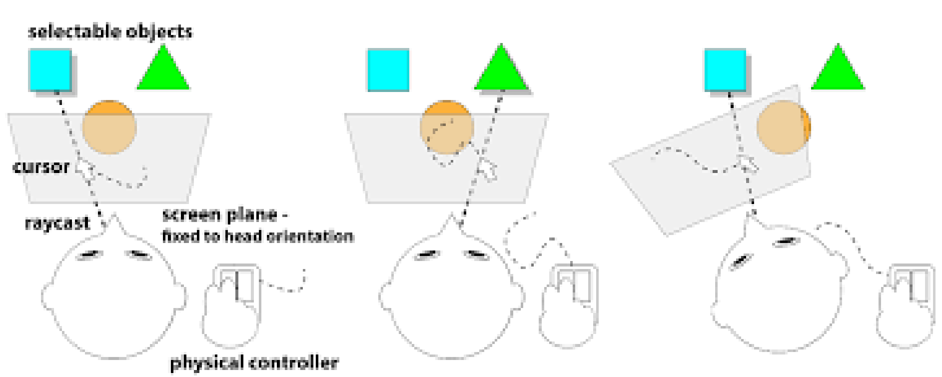


Image: EZ Cursor VR

VIRTUAL REALITY HARDWARE TRACKERS

Hand Tracking

VR headsets typically come with two controllers with triggers and buttons. Some even provide haptic feedback. Like VR headsets, hand controllers have positional tracking. So, data capture can include trigger/button clicks for specific actions and the user's hand positions, rotations, and movements.

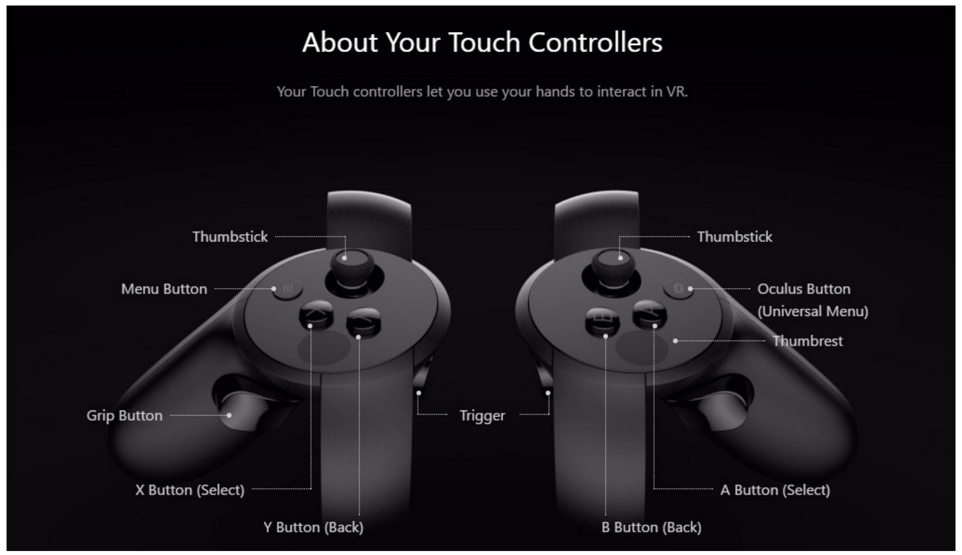


Image: Road to VR

There are also VR systems that enable the user to see their virtual hands so they can virtually pinch, grab, and make a fist.

Image: Neowin

Hand controllers and virtual hands, however, do not currently track individual digits like the thumb and their dexterity. Instead, there are other solutions that do, such as VRfree and Ultraleap.

Image: VRfree

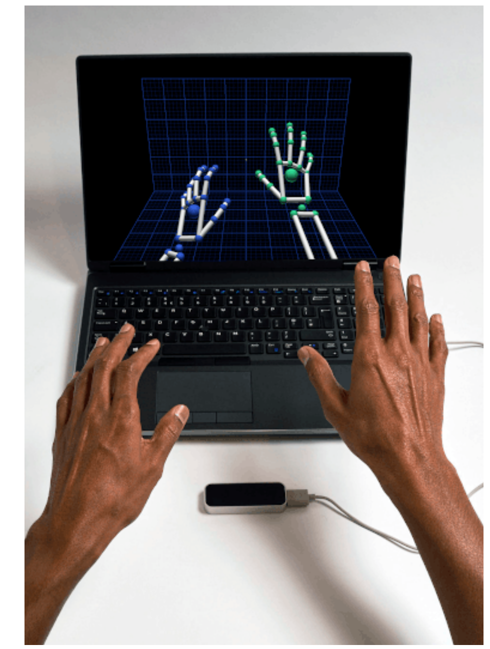


Image: Ultraleap

VRfree combines a pair of lightweight, fingertip-less gloves and a head mount attachment for the front of a VR headset that are fully integrated with six sensors to enable hand and finger tracking. Ultraleap has skeletal tracking software that uses images to generate a virtual model of palms, fingertips, joints, and bones.

Benefit:
Hand tracking and hand gestures can indicate the user's manual navigation and skill, showing their actions in the real world.

VIRTUAL REALITY HARDWARE TRACKERS

Voice Capture

Most VR headsets have a built-in microphone that can record what users are saying. This feature is valuable for voice-directed VR simulations requiring users to vocalize their actions, such as addressing team members by name.

Benefit:
Listening to a user's responses, including self-talk, during VR training can support assessing their effectiveness and tone.

Eye Tracking

Instead of relying on unnatural movements with the head or controller to indicate direction of interest, eye tracking can capture the user's gaze more accurately by knowing where the user's eyes were looking and the exact orientation of their pupils. Some software can assess pupil dilation. Also, if gaze is used as an input for navigation, it can be used to monitor selection.

Image: Tobii

Eye tracking also enables foveated rendering, which mimics how the human eye works by making the center of vision very detailed and crisp while blurring the periphery. This alleviates the user's cognitive overload and can calculate their inter-pupillary distance (IPD), which can be a unique biometric identifier.

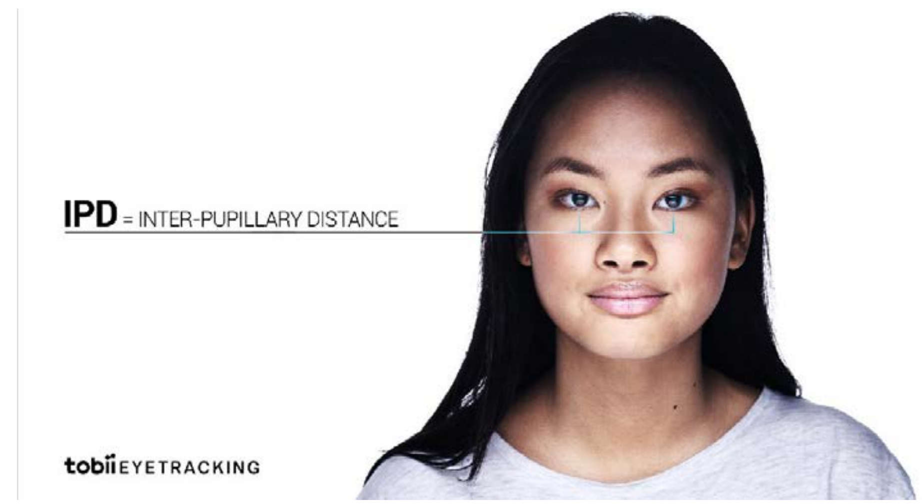


Image: Tobii

Headsets with built-in eye tracking include the HTC VIVE Pro Eye, Varjo VR-3, and Pico Neo 2 Eye. Headsets without eye tracking can upload kits from Tobii VR and Pupil Labs.

Benefit:
Eye tracking records eye positions and movements and gaze positions, making it possible to assess a user's eye-mind relationship. These metrics are important for assessing a user's responses in high-risk scenarios, like surgery, where it matters how they are processing visual information or how they are feeling (e.g., level of focus or fatigue) as they perform complex tasks.

ADDITIONAL EQUIPMENT FOR BODY/OBJECT TRACKING AND BIOMETRICS

Tracking a user's movements occurring between their head and feet can be done via sensor-equipped partial- to full-body gear and/or using actual or replica objects that provide a more realistic experience and thus more natural responses. Data capture with exact positions and rotations can also be used to reproduce a body and/or objects during VR training application development.

Wearable Trackers

Trackers are small wireless devices that can be strapped, velcroed, taped, tied, or somehow adhered to any bodily limb or physical object to integrate them into the VR experience.

Image: HTC

Image: Shadow

HTC VIVE makes a popular palm-sized tracker or "puck" that enables motion capture from wherever it is attached. Shadow offers 17 inertial sensors embedded into a strap system. Hand controllers can theoretically double as a tracker "hack" too. Individual data collection points can include limbs, such as arms, elbows, legs, knees, hips, and feet – all of which can be combined to constitute an entire body.

Trackers attached to an external object, like a surgical hammer, tennis racket, fire hose, or minesweeper, can enable calculations such as the angle of hitting a virtual knee with a surgical hammer or the speed of hitting a virtual ball and where it hits the racket.

Image: Tom's Hardware

Benefit:
Using trackers on a user's limbs, body, and objects in hands or on feet to monitor their interactions and capture motion data, such as posture, joint angles, and strike direction, can indicate level of ease or discomfort and influence how they can improve their performance – both of which could be significant for emergency response training and medical rehabilitation.

ADDITIONAL EQUIPMENT FOR BODY/OBJECT TRACKING AND BIOMETRICS

Haptic Touch Devices

Technological devices that simulate sensory interactions related to touch are called haptics, kinesthetic communication, or 3D touch.

The most familiar haptics is force feedback expressed as vibrating notification alerts on mobile phones. It also includes sensations like surface texture, temperature, hardness, weight – to name few. Including haptics in VR training, users can have a more realistic experience with parts of or all their body feeling the virtual world.

Haptics can range from physical gear like gloves, vests, and full-body suits or exoskeletons to using ultrasound which bypasses the need to wear or touch anything.

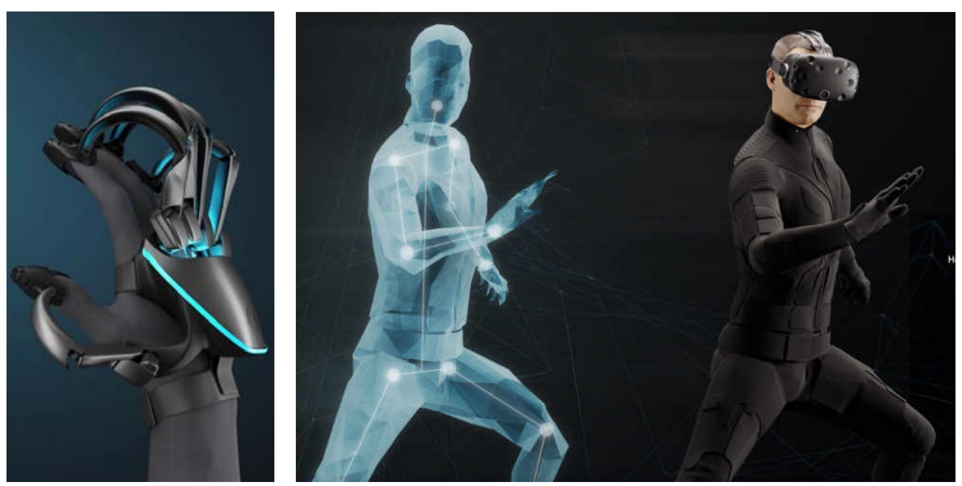


Image: Teslasuit

Haptic gloves can have advanced feedback where the user feels virtual objects. Haptic vests can vibrate in time to audio enabling users to feel sound. Full-body haptic suits can respond to temperature, physical exertion, and touch.

Image: bHaptics

Ultrasound does not use a physical garment and instead creates 3D shapes and textures that project sensations through the air and directly onto the user. Ultraleap specializes in devices with mid-air haptics that can be felt but not seen.

Data capture of a user's responses to haptic feedback can include the position and pressure of every finger or their body's physical response to emotion and stress during a VR training experience.

Benefit:
Haptics provide insights that can indicate how a user may be affected by or react to tactile stimuli applied directly or in proximity to their body, a data type that can be difficult to quantify.

ADDITIONAL EQUIPMENT FOR BODY/OBJECT TRACKING AND BIOMETRICS

Biometric Scanners

With wearable technology on the rise, biometrics, or body measurements and calculations related to human characteristics, can also be programmed for data capture in VR.

Smartwatches and fitness trackers such as the Zephyr BioModule can be added into the VR ecosystem. There are VR applications, like PowerBeatsVR, a high-intensity VR fitness game where users box, dodge, and squat to energetic music, that offer integration of Bluetooth-compatible heart rate monitors.

Image: Zephyr

Electro-cardiovascular (ECG) and electroencephalogram (EEG) biosensors can also monitor a user's physiological responses in VR. For instance, Wearable Sensing's DSI-VR300 headset is a research-grade electrode EEG system designed for VR integration. Neurable also outfitted an HTC VIVE Pro headset with EEG sensors before expanding into brain-computer interface (BCI) in December 2019.

Image: Wearable Sensing

BCI is a powerful technology that commonly uses scalp electrodes to record electrical signals in the brain, then software to translate them into commands for external devices. NeuroSky has VR-compatible EEG headsets that makes this "brain control" possible.

Benefit:
Biometrics provide insights into a user's body functioning with variables like blood pressure, muscle contraction, heart rate variability, and brainwave bands, being monitored in real-time and later analyzed to assess their nervous systems' responses.

CONCLUSION

Key Benefits

Raw data collected from VR application software, VR base hardware, and additional equipment for tracking and biometrics can be further extrapolated for more information.

Data collected on user-centric metrics in VR surpasses what is currently feasible from live and computer-based training. Thus, it provides an unprecedented look into:

- Usage: Quantitative data about user, e.g., login/logoff times
- Attention/Engagement: Where and how user pays attention
- Performance: Mastery and aptitude for a given skill
- Person: Location, social ties, search queries, preferences

VR data tracked for one user can also be tracked simultaneously for each user in a multiplayer experience, allowing group comparisons.

This data can further enhance VR training when developed in convergence with AI and human performance optimization. AI can leverage the information to personalize training events. Human performance optimization incorporates the physical, nutritional and cognitive components of the whole body.

The most significant benefit of data capture during VR training is the breadth and precision of information that can be collected from tracking user's actions and analyzed within the context of a specific experience, providing unique and accurate insights about performance and validating how to personalize learning objectives.

Key Considerations

The vast collection of data types, especially if health care-related, warrants considering the following.

- Subject Matter Expertise (SME)
  If collecting biometrics, SMEs will be needed to interpret health data and contextualize the results. A rapid heart rate could indicate a user's stress, but also poor cardiovascular health.

- United Data Management
  A holistic approach to managing metrics from disparate sources will require a single data pipeline to provide one "source of truth."

- Privacy and Security Policies
  To the extent that data in VR is recorded and kept, its access and usage need to be examined against privacy and security laws.

FEATURED APPLICATION: HAPTX AND FUNDAMENTAL VR

HaptX and FundamentalVR showcased how trainees and surgeons can use their entire hand and fingers for VR training via the Fundamental Surgery platform at the annual meeting of the American Association of Orthopedic Surgeons in March 2019.

The HaptX-FundamentalVR integration allows users to see hands naturally in a virtual world, but also feel the presence of bony growth around the rim of the hip socket when in the Fundamental Surgery platform's anterior total hip arthroplasty training module.

The data captured during the VR experience can provide a user with precise performance metrics, indicating when and where exactly they have mastered a skill or need improvement. This detailed feedback optimizes and personalizes subsequent sessions.

HaptX's haptic gloves use microfluidic technology with 130 tactile actuators that press the user's skin to replicate the sensation of touching a physical object. A force feedback exoskeleton applies up to 4 pounds of force per finger, enhancing perception of shape and rigidity, while motion capture technology tracks the user's hand movements with submillimeter precision.

The Fundamental Surgery platform provides a scalable experience with visuals, sounds, and feelings reminiscent of a real surgical procedure, and is designed to be compatible with any laptop, VR headset, or haptic device.

HARDWARE AND SOFTWARE REFERENCED IN REPORT

3DoF

- Google Cardboard
- Samsung Gear VR

6DoF

- HTC VIVE Pro
- Oculus Quest 2

Hand Tracking

- VRfree
- Ultraleap

Eye Tracking

- HTC VIVE Pro Eye
- Varjo VR-3
- Pico Neo 2 Eye
- Tobii VR
- Pupil Labs

Trackers

- HTC VIVE Tracker
- Shadow

Haptics

- Teslasuit
- bHaptics
- Ultraleap

Biometrics

- Zephyr BioModule
- PowerBeatsVR
- Wearable Sensing
- Neurable
- NeuroSky

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