Requirement analysis and sensor specifications – First version

D3.1 Requirement analysis and sensor specifications – First version

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Wearable Experience for Knowledge Intensive Training
Project No 687669

Revision History

Version	Date	Contributor(s)	Modification
0.1	13-08-2016	Puneet Sharma Fridolin Wild	Methodology,System Engineering process Transfer Mechanisms
0.2	20-08-2016	Puneet Sharma Roland Klemke	Microphone, Kinect, Myo, POV camera Body posture, Leapmotion, RealSense
0.3	28-08-2016	Puneet Sharma	Introduction
0.4	29-08-2016	Puneet Sharma	Executive Summary, Conclusions
0.5	31-08-2016	Kaj Helin VTT	Wearable displays, Wearable controls
0.6	05-09-2016	Tre Azam	EEG, Device info, Intro add,
0.7	10-09-2016	Tre Azam	MyndPlay EEG added, others amended
0.8	19-09-2016	Puneet Sharma	Eye tracking
0.9	20-09-2016	Puneet Sharma	Recommendations & Considerations
0.10	22-09-2016	Roland Klemke	Formatting References, Including sensor data descriptions
0.11	22-09-2016	Fridolin Wild	Editing suggestions for sections 1, 2, 3, 4 & 5.
0.12	22-09-2016	Puneet Sharma	General editing, formatting, and adding details in Section 4, Executive Summary
0.13	26-09-2016	Tre Azam	Added citations, updated EEG section and table. More citations added.
0.14	28-09-2016	Puneet Sharma	Minor edits in Section 4 and 5.
1.0	30-09-2016	Cinzia Rubattino	Formatting, style and final edits

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WP 3 | D3.1

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Deliverable number	D3.1
Dissemination level	Public
Version	1.0
Status	Final
Date	30.09.2016
Due date	30.09.2016

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Executive summary

In this first version of the deliverable, we make the following contributions: to design the WEKIT capturing platform and the associated experience capturing API, we use a methodology for system engineering that is relevant for different domains such as: aviation, space, and medical and different professions such as: technicians, astronauts, and medical staff. Furthermore, in the methodology, we explore the system engineering process and how it can be used in the project to support the different work packages and more importantly the different deliverables that will follow the current.

Next, we provide a mapping of high level functions or tasks (associated with experience transfer from expert to trainee) to low level functions such as: gaze, voice, video, body posture, hand gestures, bio-signals, fatigue levels, and location of the user in the environment. In addition, we link the low level functions to their associated sensors. Moreover, we provide a brief overview of the state-of-the-art sensors in terms of their technical specifications, possible limitations, standards, and platforms.

We outline a set of recommendations pertaining to the sensors that are most relevant for the WEKIT project taking into consideration the environmental, technical and human factors described in other deliverables. We recommend Microsoft Hololens (for Augmented reality glasses), MyndBand and Neurosky chipset (for EEG), Microsoft Kinect and Lumo Lift (for body posture tracking), and Leapmotion, Intel RealSense and Myo armband (for hand gesture tracking). For eye tracking, an existing eye-tracking system can be customised to complement the augmented reality glasses, and built-in microphone of the augmented reality glasses can capture the expert's voice. We propose a modular approach for the design of the WEKIT experience capturing system, and recommend that the capturing system should have sufficient storage or transmission capabilities.

Finally, we highlight common issues associated with the use of different sensors. We consider that the set of recommendations can be useful for the design and integration of the WEKIT capturing platform and the WEKIT experience capturing API to expedite the time required to select the combination of sensors which will be used in the first prototype.

1. Introduction

As outlined in the WEKIT project description, the objective of this deliverable (D3.1) is to specify the sensor technology needed for experience capturing. It involves scouting and selecting the sensor technology based on requirements formulated in particular in the deliverables D1.1/1.2, D1.3, and D1.4 (from WP1) and an early draft of d5.1 (from WP5). The results of this deliverable will be used to develop the wearable hardware prototype and design the experience capturing platform (D3.2) and the experience capturing API (D3.3).

The rest of this deliverable is organised as follows. In Section 2, we outline the methodology used for the sensor technology specification associated with experience capturing. We provide a brief description of the underlying system-engineering process and provide an explanation on how we deploy it in WP3.

In Section 3, we decompose the different transfer-mechanisms for capturing knowledge as unobtrusively as possible from experts and then engaging novice trainees in knowledge reconstruction through re-enactment, connecting the transfer-mechanisms to lower level functionality required of associated sensors.

In Section 4, based on these low level functions defined above, we give an overview on the state-of-the-art in sensor technology.

Finally, in Section 5, we express preliminary recommendations on sensor choice that can be used in the first development and evaluation cycle and discuss open issues.

2. Methodology

In WP3, the requirement analysis and sensor specifications should lead to conception, design, and development of a system for capturing experience. Any such system is complex and must be organised in a modular way, using several subsystems and components (e.g., sensors), resolving and managing conflicts arising in, e.g., processing. The expertise to be observed (and the development of which shall be supported) introduces additional complexity, as it stretches across heterogeneous domains such as mechanical, software, electrical, and electronics engineering. Human factors such as design of devices, ergonomics, safety, security, or performance introduces additional concerns. Essentially two core user groups introduce additional challenges to design and development, as they are composed of both experts (teachers, tutors, peers) and non-experts (trainees). Conflicting constraints, multiple, sometimes orthogonal interests threaten to prevent the development of a safe and balanced design.

Methodologically, this degree of complexity can be handled by using a system-engineering perspective, such as the one proposed in [1]. The term system engineering was first used in the 1940s at the Bell Labs [1]. Here a system is defined as a collection of different components that together produce results not achievable by individual components. The components include: people, hardware, software, facilities, policies, and documents, In other words, all things required to produce system-level results [2]. System-engineering process has been deployed in relevant areas such as defence [3], space [2], medical [4], or engineering, including industrial, software, safety reliability, mechatronic, civil, and aerospace [5][6]. Furthermore, it is used by The National Aeronautics and Space Administration (NASA) [2] and Department of Defense (DoD) [3].

In the context of the WEKIT project, the system-engineering process is conducive to the interests of the industrial training providers, i.e., Altech (space), Ebit-Esaote (medical) and Lufttransport (aerospace).

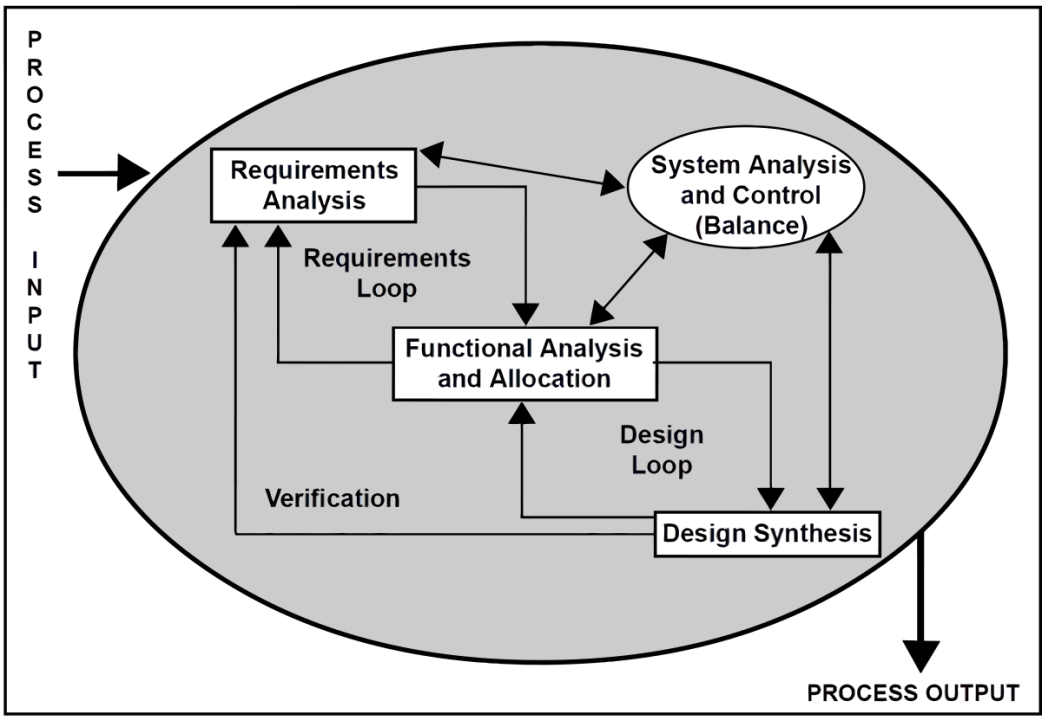

Figure 1: Different stages of the systems engineering process by [3].

The systems engineering process (as shown in Figure 1), is a comprehensive, iterative, and recursive problem solving process that is applied sequentially in a top-down manner [3]. It consists of process inputs, process outputs, requirements analysis, functional analysis & allocation, requirements loop, design synthesis, design loop, verification, and system analysis and control.

Process inputs consist of the customer's requirements, measures of effectiveness, environments, available technology base, objectives, and project constraints [3]. Once the process inputs are complete, they are sent to requirement analysis.

In requirements analysis, process inputs are analysed to develop functional and performance requirements and design constraints. In other words, customer requirements are translated into a set of requirements that define what the system should do and how well it should perform, requirements analysis also clarifies and defines the quality, quantity, timeline, availability, operating conditions, threats, problems and regulatory standards pertaining to the system [3].

In functional analysis and allocation, tasks or higher level functions are decomposed into lower level functions based on requirements analysis. The performance requirements associated with the tasks are allocated to lower functions. This phase results in description of the system in terms of what it does logically and in terms of the performance required. In other words, functional analysis and allocation allows for a better understanding of what the system has to do, in what ways it can do it, its priorities and conflicts associated with lower-level functions [3].

In design synthesis, the product or system is defined in terms of the hardware and software components which together make up and define the system. The result of this phase is the process output in the form of the physical architecture, or the system prototype where each component must meet at least one functional requirement, and any component can support many functions [3].

In systems analysis and control activities such as: trade-off studies, effectiveness analyses, design analyses, risk management, configuration, management, data management, and performance-based progress measurement are performed.

The requirements loop represents the iterative process of revisiting requirements analysis as a result of functional analysis[3]. The design loop allows reconfiguration of the system's objectives, and helps to optimize the system design (from design synthesis) [3]. The verification loop is used to check each requirement at each level of development. Verification is performed by examination, demonstration, analysis (including modeling and simulation), and testing [3].

The requirement analysis part of the system engineering process has been performed in WP1. The WP1 requirement analysis is based on use cases, community ideas, and technical features based on the WEKIT framework. The requirement analysis used house of quality [7] metric that compares the technical features with use cases and community ideas. It specified the tasks that should be captured by the system in a high level description.

In this deliverable, we focus on the functional analysis and allocation phase of the system engineering process. We aim to decompose higher level functions (i.e., tasks) into lower level functions. Furthermore, we will provide a description of the lower levels functions in terms of what they do, comment on their performance, attributes, constraints, and limitations.

The outcomes of this deliverable will be used in the design synthesis for the creation of a wearable hardware platform for capturing user experience (D3.2) and for the development of the underlying experience capturing API (D3.3). Moreover, the deliverables of WP3 will be used in system analysis and control phase (performed in WP2 and WP4) of the system engineering process. As system-engineering process is iterative, throughout the duration of the project WP2, WP3, and WP4 will work in sync fulfilling the roles of functional analysis & allocation, design synthesis, and system analysis & control phases of the system engineering process.

3. Transfer Mechanisms

In WP1, the Deliverables 1.3 & 1.4 specify different transfer mechanisms for transferring knowledge from expert to novice (and allowing a learner to review/replay their learning experience) and provide a high level description of the mechanisms. The transfer mechanisms include: remote symmetrical tele-assistance, virtual/tangible manipulation, haptic hints, virtual post its, mobile control, in situ real time feedback, case identification, directed focus, self-awareness of physical state, contextualisation, object enrichment, think aloud protocol, zoom, and slow motion. In this section, we decompose the different transfer mechanisms to low level functions and their associated state-of-the-art sensors.

Table 1: Transfer mechanisms, low level functions, their associated state-of-the-art sensors and key products.

Relevant Tasks	Low-level functions	Sensors	Key Products
Tele-assistance	View and capture the activity of another person from their perspective: transmit video & audio.	Smart/ augmented reality glasses	Moverio BT-200/2000, Microsoft Hololens, Sony SmartEyeglass, Google Glass, Meta 2, Vuzix M-100, Optinvent Ora-1, ODG R7.
Tele-assistance, realtime feedback,	Capture from the perspective of the user.	Point of view camera	GoPro Hero, Panasonic A500 Camera, Smart Glasses Custom integrated camera
Think aloud, Remote symmetrical tele-assistance	Capture voice of the user.	Microphone	Cochlea Wireless Mini Microphone, built-in microphone of Camera/Smart Glasses, Wireless Microphones (e.g. from AKG)

Remote symmetrical tele-assistance	Capture and model animation of hand movement or gestures	Optical tracking using depth scanner, Smart armband sensing muscle movement	Myo Gesture control armband, Leap Motion controller
Contextualisation, in situ realtime feedback, virtual post its	Object tracking in environment	Smart glasses, Tablet Computer or Mobile Phone (all + AR tracking toolkits, e.g. Vuforia, Alvar, ARToolKit)	
Contextualisation, in situ realtime feedback, virtual post its	Location tracking in environment	Outdoors: GPS Indoors: wifi triangulation, beacons, optical location tracking	Find the direction of the object: Beacons such as Estimote or Tile Locate object: computer vision + AR tracking Find the location on a map: GPS
Virtual/ tangible manipulation	Hand movement tracker, accelerometer, gyroscope	Depth camera, smart armband	Myo Gesture control armband, Leap Motion controller, Smart Glasses
Haptic hints	Vibrations on arm or fingers	Vibrotactile bracelets	(MYO), magic ring
Virtual Post Its	Place and see virtual post its	Smart Glasses / Tablet computer	
Mobile Control	Control dials / other UI elements	Computer vision	Hand controller API for Unity (e.g. Augmenta)
In Situ Real Time feedback	Provide step by step instruction	Computer vision, activity detection	Bespoke software solution in AR software
Case Identification	Link with existing cases, link with error knowledge	CBR reasoning component	No sensor required

Directed focus	Direct focus of technician	Gaze direction / object recognition EEG (attention/focus/mental effort)	Smart Glasses (or gyroscope only) MyndPlay MyndBand Interaxon Muse EEG Neurosky Mindwave Emotiv EEG
Directed focus	Reduce distraction	Eye tracking, EEG for attention monitoring	Attention Protocols in EEG are ideal for this, any of the above EEG SMI eye gaze tracker, Tobii eye tracker, Eyetribe eye tracker, Pupil labs eye tracker
Self-awareness of physical state	Fatigue level, vigilance level	EEG (e.g. p300 response) Papers on EMG with GSR GSR has best references and more published papers for fatigue	MyndPlay MyndBand, Neurosky Mindwave Emotiv Readiband system as used by BBMV EMG through EEG
Self-awareness of physical state	Time on task, time of day (morning shift, evening shift)	Can be done by AR vision system	
Self-awareness of physical state	Capture body posture: ergonomics (e.g. lean back, forward) Capture gestures and movements (hand positions, finger positions)	Camera-based systems for non-wearables, gyroscope, accelerometer, magnetometer for wearables	Kinect, RealSense, LeapMotion, Myo, check alternative body-worn system on spine (Lumo),
Self-awareness of physical state	Biodata (like steps, sleep, heart rate, GSR)	Smart wristband, smart watch	Fitbit, apple watch, other health devices

		Smart shirt	Multiple sensors available
Contextualisation	Recognise environment	Smart glasses or other AR camera Meta-data model for contextual data	See Smart Glasses
Object enrichment	Recognise objects, augment them	Smart Glasses, Tablet computer	
Object enrichment	State proofing	Smart objects	Fit objects with Arduino logic, Raspberry Pi, microbit
Zoom	Zoom in and get details	Smart glasses / tablet with high resolution camera Light field camera 360 cameras	See above
Slow motion	Allow replay at slower speed	High frame rate camera (warning: high frame rate often comes at price of resolution with smart glasses; and vice versa)	

4. Review of available sensors for capturing

In this section, we review state-of-the-art sensor technology such as: smart glasses, smartwatches, point of view camera, microphone, body posture, eye tracking, and EEG Brainwave that are associated with low level functions defined in Section 3.

4.1 Smart glasses

Smart glasses can be categorized based on optical systems: (1) Monocular system is arranged to utilize one of the observer's eyes and it has a single optical axes pointing to view one target in space, (2) bi-ocular system utilizes both of the observer's eyes and the optical axes is bifurcated but still pointing to view one and same target in space, and (3) binocular utilizes both eyes, has two optical axes as well, but is pointing to two laterally displaced target points in space. There are also software-simulated variants of (1) and (2) that provide limited 3D effects, sometimes useful in capturing 3D experiences economically.

An augmented or mixed reality application requires some representation of the real world. That representation can be obtained with video or optical see-through display. Video see-through displays usually have stereo or single camera placed on the user's line of sight to capture images of the real world and present it on screen. (1) Stereo camera - two cameras can simulate human binocular vision and provide depth cues and (2) Single camera - can be used in monocular, low cost or mobile (smartphone-based) HMD. Optical see-through displays utilize semi-transparent mirrors to reflect computer-generated images into user's eyes and show real world at the same time.

In the following section, smart glasses are classified in three different categories: virtual reality, binocular augmented reality, and monocular augmented reality.

4.1.1 Virtual reality glasses (none or unconfirmed see-through capabilities)

Table 2: Virtual reality glasses, their specifications, compatibility, requirements, availability and price.

Name and Manufacturer	Specifications and Features	Compatibility and Requirements	Availability and Price
Oculus Rift DK 2 [8] **Oculus**	1920x1080 low persistence OLED display 75 Hz refresh rate ~110° FOV	Windows 7/8 2 USB 2.0 ports Nvidia GTX 600 /AMD Radeon HD 7000	Available **$350**

	IMU orientation + IR LED Position tracking Built-in latency tester	DVI-D/HDMI Unity 4/5, Unreal Engine 4, CryEngine	
HTC Vive [9] **HTC**	2160x1200 low persistence OLED display 90 Hz refresh rate ~110° FOV Lighthouse room scale laser tracking system with 2 base stations Fresnel lenses Trackable input controllers with tactile feedback	Windows 7/8, OS X, Linux USB 3.0 port HDMI 1.3 SteamVR, SteamOS Unity 4/5, Unreal Engine 4, CryEngine	April 2016 **$799**
FOVE [10] **FOVE**	2560x1440 5.8" low persistence display 60 Hz refresh rate ~100° FOV IMU orientation tracking Two small-scale infrared eye tracking systems with 120 fps per eye refresh rate	Unity 4/5, Unreal Engine 4, CryEngine USB 3.0 Display Port Unity 4/5, Unreal Engine 4, CryEngine	Pre-order offers expected, release target Q4 2016 **$400 -** **$500**
AntVR "Universal" VR headset [11] **ANTVR**	1920x1080 display ~100° FOV IMU orientation tracking, built-in position tracking Aspherical lenses, multiple platform support	PC, XBOX, PlayStation, Blu-ray, Android	Pre-orders **$250**
eMagin 'Flip Up' prototype [12] **eMagin**	2048x2048 2x OLED microdisplays 85 Hz refresh rate ~100° FOV IMU orientational tracking	Windows 7/8, nVidia GTX 960 (60 Hz mode) Display Port	Unknown **TBA**

	'Flip-up' design Adjustable IPD and diopter settings Integrated electronics		
Sensics dSight [13] **Sensics**	1920x1080 dual LCD display ~130° FOV IMU orientation tracking Standalone video-based augmented reality, eye, hand and finger tracking, wireless video solutions available	Windows 7/8, USB port, Dual HDMI video input	Contact Sensics for the demo and availability information **TBA**

Oculus Rift DK 2	HTC Vive	Fove	AntVR "Universal"
			
eMagin "Flip-up"	Sensics dSight		
			

4.1.2 Virtual reality glasses (none or unconfirmed see-through capabilities)

Table 3: Virtual reality glasses, their specifications, compatibility, requirements, availability and price.

Name and Manufacturer	Specifications and Features	Compatibility and Requirements	Availability and Price
GameFace [14] **Gameface Labs**	2560x1440 OLED display 75Hz refresh rate 140° FOV IMU orientation tracking + Valve Lighthouse position tracking nVidia Tegra SoC-based untethered head-mounted console, Stereo 3D cameras for hand tracking, AR & holographic experiences	Android OS, HDMI MicroUSB v3.0 MicroSD storage slot 3.5mm audio jack Unity 4/5, Unreal Engine 4	Pre-orders expected to start soon, **TBA**
Sulon Cortex [15] **Sulon Technologies**	Untethered headset with option to run programs from device or streams from cloud, sensors to scan environment to create augmented VR experiences, Built-in hand tracking	TBA	Pre-order **$499**
Totem [16] **Vrvana**	2560x1440 low-persistence OLED display 75 Hz refresh rate ~105° FOV 1440p 90hz dual frontal cameras with 105° FOV 2x 3.5 mm jacks Surround sound over stereo Integrated buttons Diopter adjustment	PC (Windows, Mac, Linux) Playstation 3 & 4, OSVR Xbox One & 360 USB, HDMI Unreal, Unity	Pre-order **$450**

Pro G1 HMD | HUD[17] **Immersion-** **Vrelia**	1080x1920 dual display 123° FOV Dual front-facing cameras for augmented reality applications Wi-fi streaming	Android HDMI	Pre-order **$550**

GameFace	Sulon Cortex	Totem	Pro G1 HMD | HUD
			

4.1.3 Binocular augmented reality glasses (optical see-through)

Table 4: Binocular augmented reality glasses, their specifications, compatibility, requirements, availability and price.

Name and Manufacturer	Specifications and Features	Compatibility and Requirements	Availability and Price
Epson Moverio BT-2000 [18] **Epson**	960x540 qHD display Brightness 1350 cd/m2 5 Mpix adjustable stereo depth-sensing camera Flip-up feature, industrial grade IMU sensor, local voice control, hot swappable battery	Android-based OS Wi-Fi, Bluetooth	Available **$3,750**

ODG R-7 [19] **Osterhout Design Group (ODG)**	720p dual see-through displays 80 Hz refresh rate Qualcomm Snapdragon 805 2.5GHz quad-core processor Dual Haptic Feedback in Temples Autofocus camera (1080p @ 60fps, 720p @ 120fps)	ReticleOS (Android-based) Bluetooth 4.1 USB OTG GNSS (GPS/GLONASS) Qualcomm Technologies Vuforia SDK for Digital Eyewear	Pre-order **$2,750**
Microsoft HoloLens **Microsoft**	Untethered computer with multiple sensors and dedicated sensor fusion processing unit, gesture and speech recognition, built-in speakers with spatial sound support	Windows 10	Pre-order **$3000**
Vuzix Wrap 1200DXAR **Vuzix**	852 x 480 dual LCD displays 35° FOV (75" at 10′) Two discrete VGA (640x480) video cameras Independent left and right eye focal adjustment, approximately +2 to -3 diopter Adjustable eye-separation, display angle adjustment Compatible with all HDMI-compliant video sources	Windows based personal computer with HDMI compliant port Windows XP, Vista, 7, and 8 (32 or 64-bit) USB	Available **$1499**
Seer AR headset [20] **Caputer**	100° FOV (200" at 8′) Smartphone-based binocular AR headset with wide field of view Additional screen for image streaming from PC and consoles	Smartphone up to 6" HDMI Wi-Fi	Pre-order **$219**

Seebright Wave [21] **Seebright**	Smartphone-based binocular AR headset with wide field of view Wireless controller	Android, iOS	Kickstarter campaign planned **$39.9**
Meta 2 [22] **Meta**	2550x1440 resolution (60 Hz refresh rate) Large field of view (90°) Four speaker near-ear audio system Nine-foot HDMI cable for video, data & power 720p front-facing camera Sensor array for hand interactions and positional tracking Meta operating environment	Windows 8.1 or newer.	Pre-order **$949**
Spectacles [23] **Snap**	Field of view (115°) Wireless video cameras Bluetooth or Wi-Fi Circular video format AR support in later versions	TBA	TBA **$130**

Epson Moverio BT-2000	ODG R-7	Microsoft HoloLens	Vuzix Wrap 1200DXAR
			
Seer AR headset	Seebright Wave	Meta 2	Spectacles

			

4.1.4 Monocular augmented reality glasses (optical see-through)

Table 5: Monocular augmented reality glasses, their specifications, compatibility, requirements, availability and price.

Name and Manufacturer	Specifications and Features	Compatibility and Requirements	Availability and Price
Optinvent ORA [24] **Optinvent**	4:3 33 pixels/degree display 24° FOV (84" at 5m) orientation tracking ~3h battery life Sunglasses w/ photochromic lenses AR and glance modes Built-in 5 Mpix camera with autofocus	Bluetooth, Wi-Fi, GPS Miracast display mirroring Android	Available **$799**
Recon Jet [25] **Recon Instruments**	16:9 WQVGA display (30″ at 7′) 1 GHz dual-core ARM Cortex-A9 swappable batteries with ~4h lifetime Dual microphones Integrated speaker	Recon OS (Android-based operating system) GPS Bluetooth 4.0 (Bluetooth Smart) ANT+™ Wi-Fi (IEEE802.11a/b/g/n) Micro USB 2.0	Available **$699**
Vuzix M100 [26] **Vuzix**	16:9 WQVGA display 15° FOV (4″ at 14″) 4 Control buttons	Fully optimized Android ICS Left or right eye usable processor	Available **$1079**

	Remote control app, runs on paired Android device Supports customizable voice navigation Supports gesturing	OMAP4430 at 1GHz 1GB RAM 4GB flash 5 Mpix camera	
Vuzix M2000AR [26] **Vuzix**	Full color or monochrome 1280 x 720 HD display 30° FOV (64″ at 10′) 1.4mm thin Waveguide display Electronic shutter to control shading Color or monochrome modes for outdoor readability	Mobile display, connection to source over HDMI type A USB 2.0 host connection 15v DC power source 5 Mpix camera	Available **$5999**

Optinvent ORA	Recon Jet	Vuzix M100	Vuzix M2000AR
			

In the WEKIT project, based on the use cases from our stakeholders and project partners, we plan to use binocular augmented reality glasses (optical see-through). Binocular augmented reality glasses provide a better field of view and are better suited to the requirements of the WEKIT project.

4.2 Smartwatches

Table 6: Smartwatches, their specifications, compatibility, requirements, availability and price.

Name and	Specifications and	Compatibility and	Availability and Price

Manufacturer	Features	Requirements	
Moto 360 [27] **Motorola**	1.56" 320 x 290, 205 ppi Backlit LCD 320mAh battery, ~15 hours battery life IP67 water resistance Pedometer Optical heart rate monitor (PPG)	Android Wear OS, compatible with Android 4.3 and higher Touchscreen Single physical button Vibration motor Dual microphones Wi-Fi Bluetooth 4.0 Low Energy	Available **$149**
Apple Watch [28] **Apple**	38mm: 340x272, 290 ppi (42mm: 390x312, 302 ppi) pixels display ~18 hours battery life Apple S1 computer-on-a-chip 8 GB total storage 2 GB for music 75 MB for photos	WatchOS Capacitive touchscreen with Force Touch Digital Crown & physical button Microphone, speaker Wi-Fi Bluetooth 4.0 Low Energy	Available **$349 and more**
LG Urbane [29] **LG**	1.3” Full Circle P-OLED, 320 x 320 pixels 410 mAh battery 1.2 GHz Qualcomm Snapdragon 400 512 MB / 4 GB eMMC IP67 water resistance Gyro/Accelerometer/Compass/ Barometer/PPG	Android Wear OS, compatible with Android 4.3 and higher Touchscreen Single physical button Bluetooth 4.1 LE, Wi-Fi	Available **$349**
Samsung Gear S [30] **Samsung**	360 x 480 pixels (~300 ppi) Curved Super AMOLED 2.0" display	Tizen OS Bluetooth 4.1 LE, Wi-Fi, microUSB 2.0	Available **$199**

	Dual-core 1 GHz CPU Accelerometer, Barometer, Gyro Sensor, Geomagnetic Sensor, HR Sensor, Light Sensor 300 mAh battery, ~1 day battery life 4GB internal memory	Nano-SIM, microphone, speaker GSM, A-GPS, GLONASS S-Voice natural language commands and dictation	
Pebble Time [31] **Pebble**	144 x 168 pixels 182 ppi Color ePaper display Up to 7 days battery life 100 MHz single-core ARM Cortex M4 Accelerometer Ambient Light Sensor Compass Gyrometer Magnetometer Pedometer	Pebble 3.0 OS No touchscreen, 4 physical buttons Android & iOS compatible Bluetooth 4.0+ Microphone Proprietary USB charging cable	Available **$249**
Asus Zen Watch [32] **Asus**	1.63-inch, 320 x 320, 278 ppi AMOLED display ~1 day battery life Qualcomm Snapdragon 400 1.2GHz CPU 4GB / 512MB Ram Accelerometer Gyro Magnetometer Biosensor	Android Wear OS, compatible with Android 4.3 and higher Bluetooth 4.0+ Microphone microUSB charging cable Touchscreen Single physical button	Available **$199**
SmartWatch 3 SWR50 [33] **Sony**	1.6″ 320×320 px TFT LCD display 1.2 GHz, Quad-core ARM Cortex A7	Android Wear OS, compatible with Android 4.3 and higher Bluetooth 4.0,	Available **$300**

	420 mAh battery, up to 2 days battery life 4BG eMMC/512 MB RAM Accelerometer, Ambient Light Sensor, Magnetometer, Gyro	Wi-Fi, NFC, USB Touchscreen, single physical button Voice & gesture input recognition	
Microsoft Band [34] **Microsoft**	0.43" x 1.30" Touch-enabled TFT full-colour display 64MB internal storage ARM Cortex M4 MCU Optical heart rate sensor Accelerometer Gyrometer, GPS Ambient light sensor Skin temperature sensor UV sensor, Capacitive sensor Galvanic skin response	Compatible with Windows Phone 8.1, iOS 7.1 and 8, Android 4.3-4.4 devices with Bluetooth Bluetooth 4.0 (Low Energy) Touchscreen, 2 physical buttons Microphone, voice recognition	Available **$199**

Moto 360	Apple Watch	LG Urbane	Samsung Gear S
			
Pebble Time	Asus Zen Watch	Sony SmartWatch 3	Microsoft Band

			

4.3 Point of view camera (as add-on/alternative to Smart Glasses)

While a traditional camera captures the scene from an external perspective i.e., the viewer watches the subject in the environment from a distance, a point of view camera is used to capture the perspective of the subject in the environment [35]. In other words, a point of view camera enables the viewer to see what the subject sees and how the subject interacts with objects in the environment.

Point of view camera is typically worn on the body of the user. Head mounted point of view cameras, such as, GoPro Hero4 are capable of capturing high definition quality videos and provide different angles of view (Wide, Medium, and Narrow) [36,37]. Point of view cameras are normally used in sports, outdoor activities, and movies, however, in the past few years, their application areas have expanded to professional-skills areas such as medicine, where they are used to capture the surgeon's perspective [36,38].

In the WEKIT project, for Industrial scenarios (especially indoors), we aim to use the point of view camera associated with smart glasses (such as, Moverio BT-300 [39], Meta 2 [39,40], Google Glass [39–41]), however, for outdoor scenarios where the device might come in contact with an environment containing rain, hail, or snow, head mounted point of view cameras can be used.

4.4 Microphone

Capturing the point of view of the sensory impressions associated with an experience implies recording every one of the implicated senses. For example not only the details of what a user sees (POV camera) but also the stereophonic, frequency and other details of what a user hears, via a suitable design of microphone. For all senses, learners aiming for mastery may need to discern and pay attention to subtle sensory signals, which were rarely made explicit in pre-WEKIT training.

Microphones can be classified based on their pickup pattern i.e., their ability to capture the direction of the sound source [42]. These classifications include: omnidirectional (pickup is equal in all directions), bidirectional (pickup is equal in two opposite directions only), and unidirectional (pickup from primarily one direction only) [42]. Omnidirectional pickup is obtained by so called pressure transducers in which the diaphragm has only one surface

exposed to sound waves. Directional pickup is obtained by using velocity or gradient transducers in which the effective sound is measured as the difference between two points, for instance, front and rear end of the diaphragm. Directional microphones are typically used to achieve noise cancellation by placing the front end towards the desired sound source and the rear away from the source. As a result of that the gradient between the front and the rear ends of the diaphragm is higher which creates a stronger signal as compared to ambient noise which affects both the front and rear ends approximately equally [43].

Traditionally sound is captured by using contactless microphones (close talk or directional). In environments with high levels of background noise, this leads to noise in the captured sound of the user. To this end, contact microphones based on bone, myography, and throat have been suggested in the literature. For example, by using sensors worn around the neck, throat microphones capture sound directly from the user's throat based on vibrations of the vocal cords, thereby, minimizing the background noise [44]. On the other hand, throat microphones cannot capture parts of speech that are associated with unvoiced consonants, thus, leaving a lot of gap in the speech to be filled in or inferred by the listener. This means that the captured sound quality of throat microphones is poorer as compared to that of the contactless microphones [44]. In order to keep a balance between reducing the background noise and maintaining the quality of sound, attempts have been made by [45,46] to combine the information from the traditional contactless microphone with that of the throat microphone.

Based on the application, microphone can be used as an independent component (e.g., mini microphone, and tabletop microphone), or as part of another system, for example, wearable headsets, and smart glasses such as, Microsoft Hololens 1.0 which has an array of four microphones [47]. Tabletop microphones are typically directional and used for conference and indoor communication where the user remains at a fixed location. Most mini microphones are wearable, this allows the user to move and narrate at the same time. Array microphones can be part of a wearable device such as, Microsoft Hololens 1.0, or a part of regular motion sensing hardware such as, Microsoft Kinect Sensor [48].

In the WEKIT project, microphones will be used to capture key sounds such as the voice of the user. Here the user can be novice or expert. In the context of industrial training scenarios pertaining to Aviation, Space and Medical use cases, background noise can be significant in the case of Aviation (where the technicians work with aircrafts) and Medical (where the technicians work with MRI devices). For these scenarios, the user should be mobile, therefore, a wearable mini microphone can be used. We believe that throat microphone can increase the computational and hardware complexity of the proposed experience capturing system, therefore, as an alternative, in order to reduce the noise levels in the background, Cochlear™ Wireless Mini Microphone 2 [49] can be used.

4.5 Body posture

Human mentors can spot and interpret subtle changes in the posture of a trainee during a task, and can give appropriate advice. This is difficult for personalised training systems. To

discern in experience-captured traces WEKIT extends the state of the art in combining advice-giving with the automatic recognition of human activity, posture or gesture.

Recognition is mainly performed by one of two approaches [50][51] [52]: (1) camera-based approaches, relying on computer-vision, and (2) wearable physical sensor-based approaches, which attach sensors to humans or objects.

Camera-based approaches use image processing technologies based on video data provided by cameras. These cameras are usually statically mounted in the environment of the person to be tracked. No wearable device is needed but the participant needs to be within the range of the camera. The resulting quality of the recognition task is delimited by the quality of the camera used, the lighting conditions and other environmental factors (such as size of the area, overlapping objects). Existing commercial components within this category comprise [Microsoft Kinect, 2016], [Intel RealSense, 2016], and [LeapMotion, 2016].

Sensor-based approaches either use specific wearable devices [53] including data gloves [54] or body suits [55], smartphone-based sensors [55,56], or object embedded sensors [57]. These approaches require the participant to wear or carry specific hardware during the monitoring period. While wearable devices generate a bigger independence from mounted environmental cameras, issues of battery lifetime, environmental noise in sensor data, and comfort of wearable devices arise. Commercial components in this category comprise the Myo [58] control for gesture recognition, fitness trackers such as Fitbit [59] or Jawbone [60], as well as smart watches such as Samsung Gear S2 [61], Apple Watch [62], or Pebble Watch [63].

4.5.1 Camera-based systems

Kinect is a body posture sensing device by Microsoft [64]. The first generation of Kinect was introduced in 2009 and the second generation with higher resolution cameras was announced in 2014 [65]. It comprises of an infrared projector, a color camera, and an infrared camera that provide a three-dimensional full body posture of the user in the environment [65]. Furthermore, it has an array of microphones that can provide voice recognition [65].

Kinect's body posture sensing is based on a two stage process: first, capturing a depth map, and second, estimating body position [65]. The infrared projector displays a speckle dot pattern in the environment that is invisible to the human eye [66,67]. By analyzing the deformation of the speckle pattern and performing triangulation on the data from the infrared and color cameras, kinect generates a depth map of the user in the environment [68,69]. Using a machine learning method called randomized decision forests [70], it computes the position of the different body parts of the user in the environment, thereby, generating a full body capture [66].

At present, three software frameworks: Microsoft SDK [71], OpenKinect [72], and OpenNI [73] are available for Kinect [74]. The Kinect sensor captures images at the frame rate of approximately 30 fps and has an operating range from 0.5 meters to 5.0 meters for the Microsoft SDK [75]. By using OpenKinect and OpenNI frameworks depth range can be extended to up to 9 meters [74]. The depth sensors field of view is 43° in the vertical

direction and 57° in the horizontal direction [75,76]. Owing to the use of infrared based sensors, Kinect is not suitable for outdoor use and cannot be used with other infrared devices.

Intel RealSense is a platform for gesture-based human-computer interaction. It consists of specific 3D camera-based hardware and an SDK. RealSense delivers a variety of hardware devices, from standalone systems to be used with standard PCs or laptops to frontview/rearview cameras to be built into smartphones, tablets and other mobile/wearable devices.

The different hardware alternatives cover different application scenarios: front facing cameras are built for close object recognition, gestures, and face recognition and cover a smaller visible range. Rear facing devices cover object tracking and 3D scanning and provide a bigger visible range. The quality achievable with RealSense-based applications varies with the hardware used. Front-facing devices operate on objects in the range of 20-180 cm, rear-facing devices cover approximately 50-500 cm.

The original, native Intel SDK for RealSense is available on Windows platforms and offers APIs/libraries for C++, .Net/C#, Unity3D, Java, JavaScript, and Processing. An inofficial cross-platform library (librealsense) supports C/C++ development on Windows, Linux, Mac OS X.

LeapMotion is a camera-based finger and hand-tracking device used as input device for computers and VR environments. The device can be connected via USB to any computer using a supported operating system (Windows 7 or higher, Mac OS X 10.7 or higher). LeapMotion uses infrared cameras and infrared LEDs to observe a hemispherical area of a maximum of one meter with an average precision of roughly 0.7mm at a framerate of 200 fps.

4.6 Sensor-based systems

Myo is a gesture detection and recognition device that is worn on the arm and is manufactured by Thalmic Labs [77]. Myo uses eight proprietary electromyography based sensors along with an inertial measurement unit, a three-dimensional gyroscope, a three-dimensional accelerometer and magnetometer for detecting gestures made by the hand of the user [77][78]. The sensor data is transmitted using Bluetooth [78]. Before using Myo each user should calibrate to account for their individual differences, such as, skin type, muscle size, and weight [79].

Surface electromyography (which is the basis for Myo gesture detection) is a technique for recording electrical activity of muscle cells typically using electrodes attached to the skin [80,81]. The electrodes placed on the surface of the muscles measure the electric potentials which are used for determining the muscle activity [80,81]. It should be noted that surface electromyography is restricted to superficial muscles and is less reliable with increase in the depth of the subcutaneous tissue (i.e., body weight) [80,82].

Computer vision based hand gesture estimation is influenced by factors such as, occlusion from body and other objects and is influenced by the lighting conditions, Myo on the other hand can be more reliable under these circumstances [83]. Although the proprietary

software of Myo detects up to 5 hand gestures [84], using machine learning methods such hidden Markov model high accuracy can be achieved for upto twelve gestures [85].

Table 7: Sensors, Standards, Platforms. Technical specifications

Sensors	Standards	Platforms	Technical specifications
Microsoft Kinect 2	Native API, Unity 3D, C#, C++	Microsoft SDK (Windows 8 and 10), KinectOpen (Open), OpenNI (Mac OS X/Windows/Linux)	Range: 0.5 to 9 meters (approx.), Max frame rate: 30 fps, field of view 43° (vertical) and 57° (horizontal).
Intel RealSense	Native API Support for C++, .Net/C#, Unity3D, Java, JavaScript, Processing	Official support for Windows on Intel hardware Open library for Linux/Mac OS X available (librealsense)	Range: front-facing: 20-180cm, rear-facing 50-500 cm. Depth camera with 640x480 resolution (30 fps)
LeapMotion	Native API Support for C++, C#, Unity3D, Objective-C, Java, Python, JavaScript, Unreal Engine	Windows 7 or higher, Mac OS X 10.7 or higher	Range: 1m, Frame rate: 200 fps, precision: 0.7 mm.
Myo	Native API, C# (MyoSharp)	Windows, Linux, Mac OS X	Sampling data rate for electromyography is 200 Hz, sampling date rate for Inertial Sensor is 50 Hz.

4.7 Eye tracking

Eye tracking is the process of measuring where a person is looking in the environment, moment-by-moment. The measurements can be correlated with the details of human performance e.g. to provide analytics on study tasks. Eye tracking is used routinely in lab-based research on learning, as well as in lab studies in nearby domains such as: linguistic research, sports research, human factors, human computer interaction [86], and neuroscience [87,88].

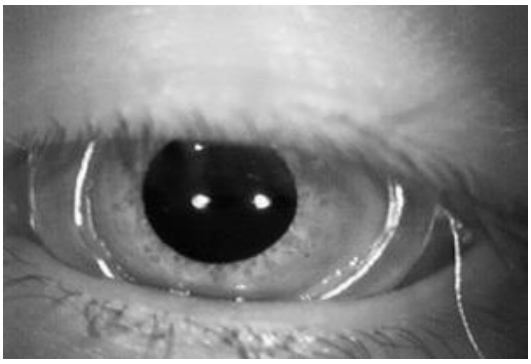

Figure 2: Magnetic coil based eye tracking [89].

Figure 3: Electric potential based eye tracking [90].

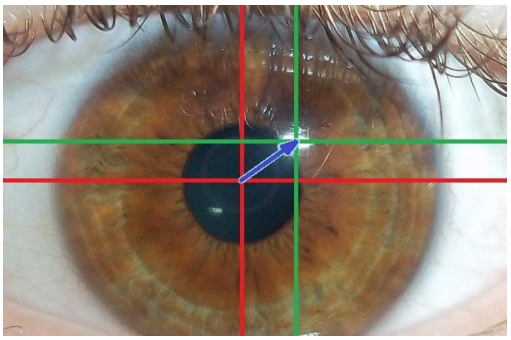

Figure 4: Optical video based eye tracking [90,91].

Eye tracking can be performed using the following techniques: magnetic coils, electric potential, and optical. In magnetic coil based technique (as shown in Figure 2), a tightly fitted contact lens is used to generate orthogonal magnetic fields [92]. The movement of the eye is estimated based on the changes in the magnetic flux. This technique has high frequency (1000 Hz), high spatial resolution (0.01 degree of the visual angle) and is robust to slight head movements, however, it is quite cumbersome and uncomfortable to wear for long durations [93]. In electric potential based eye tracking (as shown in Figure 3), a number of electrodes are placed near the eye that measure the electric potential generated

by a dipole (e.g., the cornea acts as positive and the retina as negative) [92] . As the eye moves it creates a potential difference which is measured by the electrodes. The accuracy of electric potential based system depends on the number of electrodes placed close to the eyes. It has high frequency and moderate spatial resolution (0.1 degree), however, is sensitive to head movements [94]. Optical eye tracking technique (as shown in Figure 4) uses Infrared and camera based systems to estimate the eye movements [93]. This technique has moderate frequency, moderate spatial resolution (0.1 degree) and is robust to slight head movements. Owing to contact free eye tracking and ease of use, this is the most commonly used eye tracking technique[93,94].

In the WEKIT project, eye tracking will be used to provide directed focus to the trainee. As eye tracker records the points in the scene where the expert looks, this information will be recorded during a trial activity and will be presented to the trainee such that, she or he can replicate the steps based on how and where the expert looked, and performed the activity. Furthermore, by knowing the correct direction of gaze obtained from the expert and using that as a reference, the trainee can quickly align her/his focus towards the task at hand in a cluttered environment (such as an airport hangar or spacecraft). For this, we need a wearable eye tracking system that can work in conjunction with the augmented reality/ smart glasses.

4.8 EEG Brainwave Sensors

EEG (Electroencephalography) Brainwave sensors are used to monitor and track changes in brainwave activity, EEG can also be used to train brain activity to regulate the brain's response to stimuli giving greater control over attention and awareness [95].

EEG sensors fall into two categories; wet sensors and dry sensors. Wet EEG sensors require a gel or saline solution to maintain conductance, these are not practical for long term wear or for noisy electrical environments as they are very sensitive to environment and movement [96]. Wet sensors also require calibration and constant connection monitoring.

Dry sensors do not require any gel or saline solution however they are restricted to a specific part of the brain in the prefrontal cortex where hair is not an issue. Dry sensor EEG headsets are usually, 1, 2, 5 or 6 sensor maximum.

For WEKIT the objective is to monitor activity in industrial environments, this eliminates wet sensor EEG options so these have not been assessed for the purpose of this deliverable.

Recent developments in EEG have lead to the development of state based algorithms which can provide real-time data relating to focus, concentration, relaxation and other emotions. [97] [98]

Single sensors EEG devices can also be used to measure p300 response [99] which has been linked to fatigue and awareness [100–102]

4.8.1 MyndPlay MyndBand EEG - Raw and Processed Data

The MyndBand is a customisable single dry sensor EEG headband based on the Neurosky chipset. It was developed to be embedded or integrated into a number of form factors including combination with AR/VR devices [97].

The MyndBand is a research grade EEG headset providing raw data at a sampling rate of 512Hz and also provides processed data for attention, relaxation, joy and a number of other algorithms, some of which are proprietary [97].

The MyndBand is compatible with Mac, PC, iOS, Android and Linux and has an open SDK for use. The MyndBand can also be used for EMG and blink detection [103].

The MyndBand and Neurosky chipset are favoured for the WEKIT project due to the processed data meaning no additional algorithms or data analysis is required to get real time feedback.

4.8.2 NeuroSky MindWave EEG - Raw and Processed Data

MindWave Mobile is the world's least expensive research-grade EEG headset available. Designed for interface with mobile devices (iOS and Android) and desktop (Win and Mac), it can be used with a wide variety of games, brain training and education applications [104]. It's clear brainwave signal is based on the TGAM [105] .

The MindWave Mobile safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc), NeuroSky eSense meters (attention and meditation) and eye blinks [106] [106,107]. The device consists of a headset, an ear-clip, and a sensor arm. The headset's reference and ground electrodes are on the ear clip and the EEG electrode is on the sensor arm, resting on the forehead above the eye (FP1 position). It uses a single AAA battery with 8 hours of battery life and allows for hours of prefrontal activity recording [108].

Measures

• Raw-Brainwaves

• Processing and output of EEG power spectrums (Alpha, Beta, etc.)

• Processing and output of NeuroSky proprietary eSense meter for Attention, Meditation, and other future metrics [109].

• EEG/ECG signal quality analysis (can be used to detect poor contact and whether the device is off the head)

The Mindwave mobile chip technology provides a measure of attention in real time which makes it advantageous over some of the other headsets however the limitation is the form factor. It is bulky and uncomfortable for long term use due to its metal sensors and ear clip.

4.8.3 Interaxon Muse EEG

Muse: the brain sensing headband, is an electroencephalography (EEG) technology. EEG is a well-established, non-invasive, harmless method of recording the electrical activity of groups of brain cells. EEG provides robust real-time insight into the brain [110].

Muse is used in hospitals, clinics, and universities worldwide as a research tool. The research domains extend from cognitive neuroscience, to brain health, psychotherapy, music cognition, and more. Institutions currently using Muse in research include Harvard, Stanford, MIT, Mayo Clinic, NYU, McMaster University, University of Toronto, University College London, and many others.

The MUSE has 4-6 active sensors across the forehead and ears and a sampling rate of 600Hz. The SDK is compatible with Windows, Mac and Linux.

For use in WEKIT the drawback of the Muse is the data format and the fact it only provides RAW data which require processing to derive any useful information and cannot provide any realtime information on attentional or state response.

A major benefit of the MUSE is that it has an accelerometer and Gyroscope built in which are useful for WEKIT however from our experience the connection is not very stable. This needs further testing.

4.8.4 Emotiv Insight EEG

Emotiv Insight is a 5-channel mobile EEG headset that records your brainwaves and translates them into meaningful data you can understand. Designed for extended use in field research, BCI and advanced self assessment use-cases, Insight boasts advanced electronics that are fully optimized to produce clean, robust signals anytime, anywhere. [109] [111]

Emotiv Insight is the only device in its category that offers 5 EEG sensors + 2 reference sensors. This high spatial resolution provides in-depth information on your brain activity. Leveraging years of science-backed research and experience to create the next generation brainwear®, the Insight features an elegant, lightweight and user-friendly design. [112]

Emotiv currently charge a subscription to access raw data and also require a proprietary dongle to use with any devices not support Bluetooth SMART. Emotiv have been successfully used to monitor P300 response which relates to fatigue. [113] [114]

The Insight has a sampling rate 128 samples per second per channel and includes 3 x accelerometers, 3 x gyroscopes and 3 x magnetometer. The headset support: [115] Windows Vista, 7, 8, 10, Linux (Ubuntu, Fedora), Max OS X, iOS 5+, Android 4.4.3+ (excluding Android 5.0).

5. Recommendations & considerations

In this section, we will express preliminary recommendations on sensor choice that can be used in the first development and evaluation cycle and discuss open issues. Please note that for the first cycle, we will focus on a few selected sensors outlined in Section 4, that are most important for the transfer mechanisms. In the later cycles of this work package, we will focus on the rest of the sensors pertaining to the transfer mechanisms.

Table 8: Sensors, Support for Raw/Processed/Interpreted Data, Developer Support, Comments

Sensor / Device	Data			Developer Support	Comments
	Raw	Processed	Interpreted		
Microsoft Hololens	Not accessible via official API	Spatial data, Orientation, Gaze	Gesture	Windows SDK as Plugin for Unity3D game engine	Requires Windows 10 for developmen t
Leap Motion	Raw sensor images	Hand model data	-	Developer API for several programming environments (including Unity)	
Myo	Raw EMG data available	Orientation and acceleration	Detected pose	Myo SDK available	
Microsoft Kinect	Depth Image, Video Image	Skeleton Data	-	Windows SDK for Kinect	
Intel RealSense	RGB stream, depth stream, infrared stream	3D Scan, Face Tracking,	Face recognition, Object recognition, Speech recognition, Gesture Recognition	RealSense SDK, Unity SDK	
MyndPlay MyndBand	512Hz Raw	Bandwidth spectrum	Attention, meditation,	Windows, Mac, Linux, Mobile and	

		0.5Hz - 100Hz. Delta - Mid Gamme	zone, mental effort, familiarity	multiple dev platforms inc. Unity	

For the WEKIT project, we aim to use binocular augmented reality glasses. For this, there are a number of glasses such as: Epson Moverio BT-2000, ODG R-7, Microsoft HoloLens, Vuzix Wrap 1200DXAR, Seer AR headset, and Seebright Wave that can be used. However, this also depends on their availability in the market, technical attributes, platform, standard, and compatibility with other hardware components to be used in the project.

Taking into consideration all the factors, **Microsoft Hololens** with features including: environment capture, gesture tracking, mixed reality capture, Wi-Fi 802.11ac, and fully untethered holographic computing, is the best candidate for the project. However, as Hololens is quite new (at the time of writing of this report), it has not been tested for compatibility with other sensors, as a source of interference for other sensors, and connectivity with different standards/devices. Furthermore, extensive testing is needed to see if Hololens can be used as a stand alone system for capturing all the data (both raw and processed) from different sensors.

For EEG, the **MyndBand and Neurosky chipset** are favoured for the WEKIT project due to the processed data that is, no additional algorithms or data analysis is required to get real time feedback. In addition, the MyndBand is a research grade EEG headset providing raw data at a sampling rate of 512Hz and provides processed data for attention, relaxation, joy and a number of other algorithms. For the EEG sensors, the WEKIT capturing system should account for the interference owing to the augmented reality glasses (such as Microsoft Hololens). Furthermore, quality of the data from the EEG sensors is dependent on the correct placement of the sensors on the head of the user, therefore, in the design of the WEKIT capturing system this should be taken into consideration.

For eye tracking, we need a wearable eye tracking component that can work in conjunction with the augmented reality/smart glasses. At the moment, there are few solutions available for using eye tracking with augmented reality glasses, for example, Pupil labs[116], provide eye tracking add-ons for Oculus Rift DK2, HTC Vive Binocular, and Epson Moverio BT-200. However, there are no eye-tracking solutions available for Microsoft Hololens.

To this end, we have to **customize an existing eye-tracking system** to meet the requirements of the WEKIT project. There are a number of challenges associated with this task: first, compatibility issues between eye tracker and augmented reality glasses. Second, the eye tracking system should not obstruct the view of augmented reality glasses. Third, the eye tracking system should be a wearable to allow mobility of the user in the environment.

For capturing the point of view of the expert or trainee in the the Industrial scenarios (especially indoors), we aim to use the point of view camera associated with augmented reality glasses (e.g., Microsoft Hololens), however, for outdoor scenarios where the device might come in contact with an environment containing rain, hail, or snow, head or body mounted point of view cameras can be used. In order to use a point of view camera, the WEKIT capturing system should be able to store the video feed at an acceptable resolution for the duration of the activity under consideration. For this, the system should have **sufficient storage or transmission capabilities**.

For capturing the voice of the expert or novice, a microphone will be used. In the context of industrial training scenarios pertaining to Aviation, Space and Medical use cases, background noise can be significant in the case of Aviation (where the technicians work with aircrafts) and Medical (where the technicians work with MRI devices). For these scenarios, the user should be mobile, therefore, a **wearable mini microphone** can be used. We believe that throat microphone can increase the computational and hardware complexity of the proposed experience-capturing system. Therefore, as an alternative, in order to reduce the noise levels in the background a **Cochlear™ Wireless Mini Microphone 2** [49] can be used. To further reduce the complexity of the system, the **built-in microphone of the augmented reality glasses** can be used.

For estimating the body posture of the user in the environment, camera based system such as **Microsoft Kinect** [71] can be used. However, Microsoft Kinect[71] can only be used indoors and cannot detect the posture accurately in a cluttered environment. For outdoor use, a sensor based system such as: **Lumo Lift** [117] can be employed. It should be noted that there is a need to evaluate both the camera and sensor based systems for body posture tracking to determine their accuracy, usability, complexity, compatibility, and relevance for the use cases under consideration in the project. For detecting hand movements and gestures, camera based sensors such as: **Leapmotion** [118] and **Intel RealSense** [119], can be used. For sensor-based arm (and, to a limited degree also hand-gesture) tracking, the **Myo armband** [84] can be employed.

In the design of a system recombining the various different sensors identified above (all using different data rates and different standards for storage and communication), several notable challenges arise:

- Compatibility and support of Unity development engine across different hardware sensors
- Support of sensors across different operating systems and programming platforms
- Compatibility of the different hardware drivers associated with the sensors.
- Interference due to, e.g., noise generated by sensors.
- Local and efficient storage of raw and processed data of the various sensors.

- Synchronization of data owing to different data rates of the sensors (e.g., EEG, Augmented reality glasses, microphone).
- Compatibility of the communication standards and protocols (for instance, Bluetooth, and WiFi) and their data transmission range.
- The computational complexity and processing load needed for processing the data associated with different sensors.
- Design of the WEKIT capturing system that integrates all the sensor hardware as a wearable system.

These challenges will have to be resolved when turning to software and hardware integration.

6. Conclusions

In this first version of the deliverable we make the following contributions: first, to start the process of design for the WEKIT experience capturing platform and the WEKIT experience capturing API, we extend and deploy a methodology that we developed in prior EC projects for system engineering. The approach has previously be refined and validated in different domains relevant to WEKIT such as: aviation, space, and medical and different professions such as: technicians, astronauts, and medical workers. Furthermore, in the methodology, we explore system engineering process and how it can be used in the project to support the different work packages and more importantly the different deliverables that will follow the current deliverable. Then, we provide a mapping of high level functions or tasks (associated with experience transfer from expert to trainee) to low level functions such as: gaze, voice, video, body posture, hand gestures, bio-signals, fatigue levels, and location of the user in the environment. In addition, we link the low level functions to their associated sensors. Additionally, and by way of a ”snap-shot” of the types of experience-relevant sensors and systems currently available in the marketplace, we provide a brief overview of the state-of-the-art sensors in terms of their technical specifications, possible limitations, standards, and platforms. Every week sees large changes in the devices/sensors/functionalities on the experience-capturing market and specifications are not yet available for a mass-market experience-capturing system announced on 26/9/16 by the Snap corporation (and designed for use with their SnapChat ecosystem). To avoid the ”noise” of continual product announcements, we outline a set of recommendations pertaining to the sensors that are most relevant for the WEKIT project and highlight common issues associated with their useage. We believe that the set of recommendations can be useful for the design and integration of the WEKIT capturing platform and the WEKIT experience capturing API.

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WEKIT

Wearable Experience for Knowledge Intensive Training
Project No 687669

WEKIT project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687669. http://wekit.eu/