Technology-enabled Cognitive Resilience: What Can We Learn From Military Operation to Develop Operator 5.0 Solutions?

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Abstract
Supplementary materials for the article “Technology-enabled Cognitive Resilience: What Can We Learn From Military Operation to Develop Operator 5.0 Solutions?”.

KEYWORDS
Industry 5.0; Operator 5.0; cognitive resilience; military operation; human-centric

S.I. The search query and selection criteria

In line with the Preferred Reporting Items for Systematics Reviews and Meta-Analyses (PRISMA) guidelines [*S1*], the search was conducted in the Scopus database. Four groups of keywords have been identified as illustrated in Figure 1:

- The first group of keywords indicates the human users, involving terms: “military”, “soldier”, “army”, “police” and “firefighter”.
- The second group contains only the term “technolog*”, to look for evidence of supporting technologies.
- The third group contains the terms “task”, “operation”, and “mission” to look for the usage context of technology. The term “resilien*” is added to specifically consider the studies with resilience aspect if there is any.
- The fourth group indicates the expected effect of technology on human users: “cognitive” and “cognition”.

Search terms with **Scopus** syntax:
(TITLE-ABS-KEY(cognitive OR cognition) AND TITLE-ABS-KEY(military OR soldier OR army OR police OR firefighter) AND TITLE-ABS-KEY(technolog*) AND TITLE-ABS-KEY(task OR operation OR mission)) AND PUBYEAR > 2009 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE,“English”))

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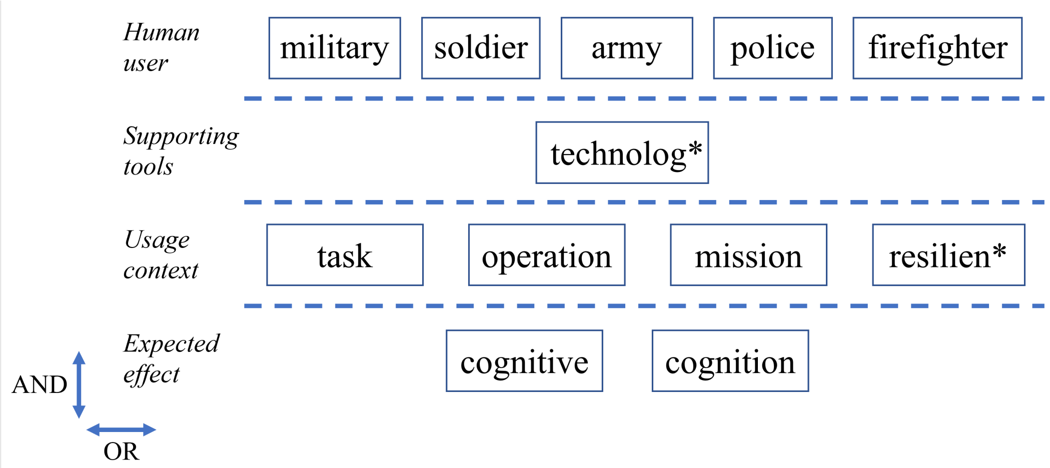

Figure S1: The group of keywords for the search.

There are agreed screening criteria between the authors as follows:

- The military operations are considered as activities that are performed physically and mentally during training or operating of surveillance, law enforcement, search and rescue, navigation and assembly, assault and ambush, and defense missions, which involve but are not limited to shooting, moving, communicating, making decisions, surviving, and sustaining operation tasks. Tasks that require other specialized knowledge (i.e., medical task [*S2*], combat life-saving [*S3*,*S4*], vessel design [*S5*]) and abstract task without any specific description or human users is excluded [*S6*].
- To narrow down the usage of human-centric technology in the military operation to a compatible scale with an industrial context, only the tasks performed by individuals are considered, including tasks related to human-machine interaction such as military surveillance, system operation, remote control, and cyber operation which requires high mental workload [*S7*]. Management tasks such as controlling battle [*S8*,*S9*] or managing troop [*S10*,*S11*], or cooperative tasks that involve multiple personnel [*S12*], or squad collaboration [*S13*] are excluded. Technical development that does not mention the cognitive aspect of human users [*S14*], or merely about automation without the consideration of human factors [*S15*] are excluded.
- Given that not all studies explicitly mention the resilience aspect, the authors decided to scan all studies aiming at enhancing or improving the human cognitive ability by human-centric technological support inspired by the O4.0 concept [*S16*]. Other technology developments that do not involve human performance [*S17*] or cognitive aspect [*S18*] are excluded. Afterward, to look for evidence of cognitive resilience influences from technological support, different types of cognitive abilities [*S19*] of the users are scrutinized, including the emerged auditory ability [*S20*].

S.II. General characteristics of included studies

Table S1: The general characteristics of included studies.

Operation / Task	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
Not specified task	-	-	-	virtual advisor in mobile health app with bluetooth-based heart rate monitoring, and heart rate variability biofeedback with portable heart rate monitor (test [*S21*])	support stress relaxation and psychological resilience training with self-paced breathing exercise (training)	67 military personnel and 48 civilian first responders, age: $18-42$, male/female: 69/28
	-	individual performance during law enforcement task	aiming with rifle, fast-roping	wearable robotic arm (prototype [*S22*])	perform auxiliary tasks such as keep the riffle steady, hold the rope (operation)	14 university students, male/female: 5/9
	-	-	rifle shooting in kneeling position	adaptive peak performance trainer with multi-modal feedback of breath and trigger control (test [*S23*])	guide the trainee into pre-shot peak performance state of expertise (training)	51 civilian, age: 24.78(6.17)
	stable and controlled environment	-	visual search to input data to computer system	wearable, head-mounted brain-computer (concept [*S24*])	capture and analyze brain signals with AI, and send to human-in-the-close-loop with possible options (operation)	-
	-	-	-	wireless implantable neural interfaces to communicate with electronic devices (concept [*S25*])	increase accuracy and quality of visual or auditory information into the brain (-)	-
	-	-	-	wireless implantable neural interfaces to better retrieve memory (concept [*S25*])	perform a targeted neural stimulation for memory function restoration (-)	-
	-	-	-	multi-modal interactive platform for personal assistance robot (concept [*S26*])	natural and effective communication by speech, images and gesture, visual storytelling (operation planning and execution)	-
Combat and engagement	-	during operation with high-stakes tasks including weapon use	-	physiological wearable to predict human performance outcome (computational model and software [*S27*])	predict reaction time, executive function, and perceptuo-motor control of cognitive performance (operation)	-

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	conflict zone (-)	patrol while ready for engage	-	information exoskeleton with body-worn physiological sensors, tactical sensors (concept [*S28*])	process incoming information based on user task and operational contexts (operation)	-
	open battlefield (-)	-	performing battle drill tasks based on script	agent-assisted information support system (proof of concept [*S29*])	provide relevant information to support decision-making (training and operation)	-
		march into territorial combat or defense formations during dismounted operation or reconnaissance mission	performing topographical and tactical orientation within the operational scenario, combat activities	AR in mobile decision-support application with Geospatial Information Services (GIS) data (operation [*S30*,*S31*])	provide simplified topographical, tactical orientation, and scenario data with dynamic information on AR glasses or projection devices, support threat-level assessment, object detection and location calculation (operation)	officer cadets
		performance in hasty attack	-	position tracking, AR to see through fire section, digital foldable map (suggestions [*S10*])	increase SA with the information of the current status (operation)	-
		during combat	-	wearable sensorized garments and non-invasive physiological sensor (prototype [*S32*])	real-time assessment of mental stress and wireless communication during military activities (operation)	2 volunteers
		during combat in dismounted operation	running, jumping, climbing, balancing, kneeling, and crawling	tactile display comprises vibrating actuators that are mounted on the body (test [*S33*])	present easy-to-interpret information, offloading information from visual and auditory sensory channels (operation)	-
	urban village (VR simulation and live sessions)	team performance in platoon operation	target searching, fire engagement	immersive VR training (test [*S34*])	provide immersive training environment with detrimental stressors (training)	32 soldiers [*S34*]
	open field terrain (enclosed room with immersive 3D VR)	individual performance with search and shoot task	search and take down enemy by gun	VR scenario with adjustable enemy behavior and task complexity (test [*S35*])	provide immersive training (training)	30 civilians, male/female: 16/14, age: 20.9(1.21)

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
Extreme performance	On-air (-)	individual performance, parachute into a battlefield in unfamiliar environment	navigate and move to assembly points	multi-modal mobile navigation system (test [*S36*])	provide SA of assembly point (operation)	50 soldiers and 23 cadets
		group rescue with parachute operation	shared dynamic information for individual performance within pararescue teamwork	portable computing devices with a simplified interface (proof of concept [*S37*])	provides critical information for scene management, team coordination, role switch, and distributed re-planning (operation)	-
	On-air (enclosed room with simulation of the on-air environment)	emergency egress from an aircraft	individual tasks and decision-making process in operating a parachute	VR with simulated jigs (prototype [*S38*])	create simulated scenarios with visual and auditory cues of unexpected malfunction (training)	-
Search and rescue	residential building on fire (experiment with realistic scenario)	individual performance within team mission of two firefighters	navigating in a burning apartment, find unconscious person	augmented reality display (concept, primitive prototype [*S39*])	continuous access to graphical building information (operation)	138 firefighters
	car crash scene at an intersection of a small town (enclosed space with VR simulator)	individual performance of rescue action in standard procedure at the incident scene	quick medical interview, checking physical parameters, performing Cardiopulmonary resuscitation (CPR), transporting the victims	VR hardware with a head-mounted display (test [*S40*])	provoke emotions during training with a crucial stimulus (training)	60 firefighters, male/female: 59/1, age: 23.77(5.51), experience: $1-19$ years
	enclosed room (enclosed room with VR simulation)	individual performance in room clearing teamwork	standard content from drill documents	AR with Heads Up Display (HUD) (training [*S41*])	provide immersive experience (training)	64 soldiers, all male, age: 25.22(3.8)
On-foot navigation	open field	individual performance	perform navigation, communication, and report tasks	AR with HUD (concept [*S42*])	provide users with real-time grid coordinates, mini-map marker update with graphical overlays (operation)	-

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	open field	individual performance to assembly point	perform matching with surrounding elements (landmark, horizon, sun)	AR with head tracking sensor and night vision goggle (training and operation [*S30*])	-	-
	indoor environment with structural damages (VR)	individual performance in emergency	perform wayfinding with search and hazard identification tasks	real-time cognition-driven navigation assistive system (prototype [*S43*])	provide information based on gesture control, cognitive load and mental status of the user (operation)	31 firefighters, all male, age: 35
	indoor environment (-)	navigation with a guiding robot during a rescue mission without auditory and visual feedback	moving with robot	haptic rein (prototype [*S44*])	adaptive control and force feedback over a robot with a similar mechanism to guide dogs (operation)	-
	urban environment (enclosed room with VR)	individual performance in virtual environment	perform route following and return-to-origin tasks within the virtual city	Interactive VR with Microsoft HoloLens (test [*S45*])	provide 3D geo-visualization and 3D content manipulation to improve spatial cognition (operation)	43 students and 22 soldiers, male/female:45/20, age: 20.7 and 24.5
	complex indoor environment	individual performance in unfamiliar environment	navigate within indoor space	vibrotactile compass (test [*S46*])	provide feedback of direction (operation)	48 civilians, age: 21.73(3.43)
	open field (heavy wood terrain during day and night)	individual performance in real-life unfamiliar terrain, with secondary visual or auditory task	navigating while looking for targets, with radio communication	personal tactile navigator device (test [*S47*])	provide a tactile feedback signal with GPS data and hand-free usage (operation)	15 infantry soldiers, age: 23.8(4.63), service time: $1-15$ years
	indoor environment with heavy smoke	individual performance during rescue mission	run to target point	fall-preventing shoes (prototype [*S48*])	sensors for ultrasonic obstacle recognition, temperature, humidity and toxic gas detection, fall prevention (operation)	8 civilians, age: 20 civilians
On-foot patrol	enclosed room	individual performance with on-foot Patrol-Exertion Multitask (PEMT) task	-	provide VR environment for training and exercise (test [*S49*])	detect potential threat (rehabilitation, return to duty)	-
	conflict zone (enclosed space in simulated room)	individual performance in on-foot patrol	walking, perform target recognition and shooting	VR with physiological wearables (operation [*S50*])	provide interactive and immersive environment with terrain changes (rehabilitation; examination)	-

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	road patrol (enclosed room with step-over obstacles, varied walking surfaces)	dismounted patrol, carrying loads in rucksack marching with visual, auditory and follow tasks	perform visual scanning, answer radio request while following a confederate over obstacles	powered lower-body exoskeleton (adaptation [*S51*])	support the physical movement and reduce the burden of carrying heavy equipment (operation)	12 militants, age: 23.4(1.6), all male
Dismounted control	open field (On-field with artificial obstacles)	teleoperating UGV in reconnaissance missions	maneuver robots through terrains, negotiate around obstacles and search for targets	multisensory display with split-screen display and tactile belt (prototype [*S52*])	relieve visual information processing by tactile sensory channel (operation)	25 soldiers, age: 30(3), service time: 4(5) years
Remote control	control and gunnery station (enclosed control room)	UGV remote control with out-the-window view	gunnery targeting, teleoperating the UGV, and communication tasks	aided target recognition (test [*S53*])	deliver visual alerts and tactile cueing for human-in-the-loop control (operation)	20 students, male/female: 16/4, age: 20.95(4.62)
		Unmanned Aerial Vehicles (UAV) remote control	identify targets from UAV point-of-view video on screen	game-based VR (proof of concept [*S54*])	adaptive vigilance training based on participant performance (training)	-
			recognizing and targeting enemies by UAV	UAV threat identifying system with affect recognition sensors and database of strategies (concept [*S55*])	improve SA, suggestion on how to respond, avoid misinterpreting civilians as combatants, reducing cognitive load and missing data (operation)	-
	from the control room of the parent ship	remote control Unmanned Underwater Vehicles (UUV)	navigate UUV through minefield	ecological interface design (concept [*S56*])	displaying both physical and functional information of the vehicle, reduce the manual calculation (operation)	-
	from the cockpit of a manned craft (close space with simulator)	controlling multiple unmanned aerial systems for tactile mission	controlling and monitoring UAV, target recognition	control software (prototype [*S57*])	task-level delegation of control with aided target recognition, real-time gaze tracking feedback (operation)	16 army aviator
		control UAV with multiple platforms	-	software architectures supporting interoperability, special HMI, crew behavior modeling (report [*S58*])	autonomous tactical decision making, planning, and replanning (operation)	-

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Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	control room	individual performance in controlling of multiple UAVs on computer screen	-	3D audio system with voice recognition (test [*S59*])	differentiate critical information from distracting ones, and present to the user in different ears (operation)	24 civilians, age: 29.042(4.439) [*S59*]
		Unmanned Aerial Vehicles (UAV) remote control with control software interface	optimal route planning for multiple UAVs	detailed icon with visual information (prototype [*S60*])	-	78 university and 118 military students
Vehicle control and navigation	plane control cockpit (simulated room)	basic flight tasks with individual performance	Operating cockpit elements	VR and wearable neurotechnology (test [*S61*])	provide emersive environment (training)	-
	plane control cockpit (enclosed cockpit simulator with artificial altitude exposure)	individual performance in pilot flight maneuver tasks	perform flight turn, climb, descent, with secondary neurocognitive tasks	portable dry-EEG monitoring and biosensor to assess cognitive performance (concept experiment [*S62*])	real-time brain monitoring to detect hypoxia and cognitive performance decrement (operation)	60 military students, male/female: 30/30
	cockpit of fighter aircraft	perform an air strike and air defense in extreme situations	decision-making tasks of fighter pilots and navigators on aircraft	decision support system [*S63*]	provide relevant, updated tactical information from neighboring fighters, aircraft control system, navy ships, and ground force (operation)	33 pilots and navigators
		individual performance during air combat	-	panoramic 360-degree HMI with a helmet-mounted display, multi-sensor data fusion, battle space management software (available [*S58*])	providing the pilot with crucial flight and combat information, holographic display of aircraft data and target information, target designation with head motion (operation)	-
	engine control room (enclosed simulated room)	individual performance in monitor screen with a simulated view from engine control room	determine navigation route through outside-bridge view	navigation aid with AR interface (test [*S64*])	recognize the simulated situation, reduce the head-down time of navigator (operation)	17 nautical students and licensed seafarers, age: 28, male/female:13/4
	boat engine control room (enclosed simulated room)	individual performance in simulated virtual reality	boat pilot tasks through a marine slalom course	VR with physiological wearables (operation [*S50*])	adjusted interaction and behavior depending on user ability and familiarization level (training, rehabilitation)	-

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
In-vehicle patrol	within patrol vehicle (enclosed space with driving simulator)	in-vehicle patrol in urban setting	security scanning for local surrounding, while maintaining supervisory control over semi-autonomous vehicle	in-vehicle neuro-ergonomically-designed UI (test [*S65*])	support vehicle steering control and SA reporting on threat detection (operation)	20 participants
			maintain driving lane and velocity, while performing plate number check	enhanced mobile computer terminal interface (prototype [*S66*])	function-oriented organization of information, improved presentation format, enhanced information navigation (operation)	20 police officers, age: 24 – 54, male/female: 18/2
		following a lead vehicle through ambient traffic	perform driving and avoiding collisions	driving automation based on the surrounding terrain and psycho-physiological data from the user (test [*S67*])	the automated driving mode is suggested to take control when needed (operation)	5 civilian
	within patrol vehicle (-)	-	security scanning for local surrounding	in-vehicle display with 360-degree SA system (proof of concept [*S68*])	detection of road edges, traversable off-road terrain, automated target recognition, providing multi-modal cues (operation)	-
Surveillance and targeting	enclosed control room (enclosed room)	individual performance in Synthetic Aperture Radar (SAR) task	identify incoming aircraft based on a set of rules and procedures	tDCS for brain functioning support (test [*S69*])	stimulate the brain for enhanced learning and improve procedural memory (training)	40 active air force members
		individual performance with videos and images on computer screen	Detect potential threat from virtual reality environment [*S70*]	tDCS for brain functioning support (test [*S71*–*S73*])	stimulate the brain to accelerate learning and enhance performance (training and operation)	104 civilians [*S72*]
		individual performance in monitor and respond multi-tasking tasks on computer screen	systems monitoring, communication, targeting and resource management within Multi-Attribute Task Battery (MATB)	tDCS (test [*S74*]), tDCS and eye tracking (test [*S75*])	stimulate the brain to improve information processing capabilities, provide feedback mechanism of cognitive state (operation)	20 air force member, male/female: 16/4, age: 31.1(4.5) [*S74*], 16 air force member, male/female: 6/2, age: 30.8(5) [*S75*]

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	Combat Information Centres of ships (enclosed space with simulation)	Air target identification	identify, observe, and re-identify object, recognize and classify flight behavior	cognitive assistant system (prototype [*S76*])	visualize necessary data such as target information, identification criteria, and suggest possible actions (operation)	9 navy expert, age: $21-42$, experience: $0.5-20$ years [*S76*]
	-	munition trajectory targeting and control	direct the trajectory of munition	distributed cognition between people and machine (concept [*S77*])	support dividing the constituent tasks between aircrew, joint terminal attack controller and another system (operation)	-
	-	combat target identification through unmanned vehicles	recognize armored military vehicles on visual materials	AR vehicle model and 3D stereoscopic simulation (available [*S78*])	provide visual details of the learned vehicles (training)	-
Intelligence planning	war room (enclosed space with the simulator)	received military information and create SA of the battlefield	building terrain features, sketch map of landmarks with sand table exercise	AR sand table with 2.5D topographic projection (training [*S79*], mission rehearsal, planning and review [*S80*])	enhanced route planning with interactive 3D terrain representation	28 soldiers, age: 29(3), service time: 6.9(4) [*S79*]; 96 civilians, age: $18-35$ [*S80*]
			received intelligence information and conducting an attack	AR with Microsoft HoloLens (test [*S81*])	fully 3D immersive interface with the given terrain and associated tactical graphic (operation)	72 military students
		Intelligence Preparation of the Battlefield (IPB)	received weather and battlefield information and develop SA	interface with dynamic information visualization (testing [*S82*])	visualized tactic symbols with simple animated situational simulation (operation planning)	24 military officer, all male
System operation	control room (-)	individual performance	monitoring network security and detecting risk	change the representation of data with neural networks and visual analytics (proof-of-concept [*S83*])	reduce the amount of incoming information to human, increase reaction time, more focus on important events (operation)	-
		monitoring autonomous and automated system of unmanned vehicles	schedule vehicles	UI with trend-based icons (prototype [*S84*])	show dynamic icons with task- and mission-relevant status, hide excessive information of the process (operation)	-
		individually perform sensor weapon controller of a frigate on radar screen	threat evaluation and combat power management process	decision support system with eye tracking (prototype [*S85*])	additional temporal overview display and change-history table compared to basic interface (operation)	-

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Table S1. *Continued from previous page*

Operation / Mission	Intended work environment (studied environment)	Work context	Work content	Human-centric technology (Development status, study)	Supported functions (Intended deployment phase)	Tested population
	operation center (simulated room with sound attenuated chamber)	individual performance in management of Intelligence, Surveillance, and Reconnaissance (ISR) assets on computer screens	control ISR assets on battlefield and get updated via chat and voice communication	interactive decision support software (prototype [*S86*])	analyzing reported events based on the current context, creating meaningful information and channeling to necessary personnel, suggesting actions (operation)	6 soldiers, service time: $3.2-9.8$ years
	control center (enclosed room)	interact with a command and control system of heterogeneous platforms	manipulate objects in a 3D map of the mission area	touch-less interaction with Leap motion sensor (prototype [*S87*])	natural interaction with control system by a hand gesture in AR environment (operation)	12 armed force members, age: $32-45$

- : Not mentioned/Not specified.

S.III. Stressors, stimulus, disturbances and cognitive resilience support from technology in included studies

Table S2: Stressors, stimulus, disturbances and resilience support from technology.

Source	Stressor - Stimuli - Disturbance	Technology support - Preventive measure (Study)	Resilience effect / intervention on users
Work environment	degraded visual environment (thick forest, darkness, excessive fog, heavy rain, flat light condition, shadow-less surface, dust or snow due to rotor wash), lack of audio and visual feedback	fused data from on-board sensors such as forward-looking infrared and night vision imaging system, thermal, low-light camera, software with classification model to process data into readily interpretable picture [*S58*], vibration hint from personal tactile navigator device [*S47*]	maintain SA such as depth, distance, altitude, and motion, ascending or descending, faster navigation time, easy to regain the correct direction,
	natural and man-made obstacles, high traffic density, appearing unexpected human entities and obstacles	multi-sensor navigation with integrated terrain and obstacles database and position information from other sensors, automated flight pattern generation [*S58*], vehicle control interface support threat reporting [*S65*]	easy to perform multitasking
	noisy background sound, task-irrelevant fragmented conversations	tactile display [*S33*], robot-controlling with haptic rein [*S44*], decision supporting system with eye tracking [*S85*]	keep eyes and hands free, maintain focusing on surroundings rather than on a visual display, keeps track of important changes, enhance defensive effectiveness

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Table S2. *Continued from previous page*

Source	Stressor - Stimuli - Disturbance	Technology support - Preventive measure (Study)	Resilience effect / intervention on users
	fire, thick smoke, lack of lighting	continuous graphical information [*S39*], fall-preventive shoes with alarm signals of obstacle [*S48*]	less fear of falling, less get startled, walk naturally with shorter time
Work context	unfamiliar space of operation	building graphical information [*S39*], tactile compass hint [*S46*]	better recall-ability graphical information, better situation awareness
	enclosed space within vehicle with limited vision	In-vehicle display with 360-degree SA system [*S68*]	better SA, supported road and hazard recognition
	passive role while following lead vehicle, appearing pedestrians, possible collision	control interface show the shared co-operation between human and automated agent [*S67*]	reduced perceived workload, higher trust from user
	switch roles during missions, disrupt team coordination, degraded communication, narrowing focus under stress	intentionally designed interface [*S37*]	facilitate quick role shift and maintain big picture SA between team members during mission
	poor sensory data, intermittent and low-level data, time-lags, divided attention in multi-tasking	filtering poor sensor data, simplified UI, support multi-person operation [*S55*]	reduce low-level data overload on users, improve SA
	fast pace to make decisions	special interface with critical information to make decisions before emergent mission launch [*S37*], simplified visualization of graphical information [*S39*], a decision-making software system with suggested actions [*S86*]	fast access, quick and better comprehension, easy to recall information, fast decision making
	complex activities during crisis operation, combat	terrain feature evaluation, movement analysis, potential threat identification and estimation [*S30*], gather data and report to recognize combat situation, tactical calculation [*S31*]	support during topographical and tactical orientation task
	casualty witnessing ((e.g., sign of an injured children and brides, lost of a comrade, defensive and unintentional civilian casualties)	virtual environment and augmented effect during live environment of battlefields [*S34*], training with exposure to emotional evoking scenario [*S40*]	mental resilience training
Work content	intangible information, distractor terrains	offer tangible interaction with topographic 2.5D terrain for active learning [*S80*], immersive interaction with 3D terrain [*S81*], interface with dynamic information visualization [*S82*], a pilot associate program with knowledge-based subsystems for data filtering [*S58*]	reduce the load of deciphering the 2D map, enhance the spatial ability and comprehension, facilitate information exchange between team, quick decision making
	high density of incoming information and event occurrence, multiple overlapping events	user-adaptive display based on task-specific context and user state assessment [*S29*], dynamic knowledge-graph and interactive decision support algorithms [*S86*]	reduced attention demand, improved cognitive performance

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Table S2. *Continued from previous page*

Source	Stressor - Stimuli - Disturbance	Technology support - Preventive measure (Study)	Resilience effect / intervention on users
	multi-tasking, divided attention, roadway hazards	special design for in-vehicle mobile computer terminal interface [*S66*], vehicle control interface with threat detection report [*S65*], multi-sensory display [*S65*], interface for multitasking with information processing [*S75*], tDCS [*S74*], tactile cueing and visual alert for human-in-the-loop robot control [*S53*]	maintain high performance on main task, increased visual attention, enhanced spatial ability, effective target detection, reduce off-road glance during hazard exposure, reduce secondary task completion time, increased multitasking capability and information throughput, reduce distraction, enhanced vigilance
	multi-tasking with additional secondary visual tasks during navigation	eye-free direction hint from personal tactile navigator device [*S47*]	less distraction from environment, more focus on object recognition
	novel, unfamiliar task elements	designed interface for more team flexibility during execution, enable switching role and responsibilities [*S37*]	Reduced distress, frustration and post worry levels, increase engagement in training, focus more on tasks (room clearing)
Supporting technology	technology malfunction	practice scenarios with virtual reality [*S37*], aircraft SA system with system status monitoring [*S58*]	get used to unexpected malfunctions, detect and diagnose faults, provide corrective measures, evaluate mission and plans according to aircraft conditions
	the system can be shut down intentionally or unintentionally	practice with the powered down scenario [*S51*]	get used to with the additional load
Human user	reduced capability in fired building	haptic rein with guiding robot [*S44*]	get force feedback from the rain about the relative position and direction
	visually impaired or hearing-impaired users	multi-modal interactive interface of the robot with gestural control, haptic input/output [*S26*]	different ways of communication can be utilized on different users
	degraded capability (e.g., loss of consciousness, spatial disorientation, loss of SA)	cognitive cockpit with rule-based-decision aiding based on physiology and behavior of the pilot [*S58*]	trigger changes, deciding hazard alert and automation levels with automating tasks
	stressed user, degraded capability	user-adaptive interface [*S29*], predict reaction time, executive function, and perceptuo-motor control of cognitive performance from physiological wearable data [*S27*]	planning various tasks based on personal physical and cognitive resources, show different functions based on user stress level and preference
	surprise, fast reaction requirement	synthetic vision of AR with beacons, AR with augmented cross-hair that suggests the direction of weapon [*S42*]	quickly identify navigation beacons, fast response time for maneuver weapon and engagement
	surprise, unexpected situation of canopy malfunction	training in the virtual scenario with practice jigs [*S38*]	practice decision-making with visual and auditory cues

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Table S2. *Continued from previous page*

Source	Stressor - Stimuli - Disturbance	Technology support - Preventive measure (Study)	Resilience effect / intervention on users
	information overload of heterogeneous platforms or high-level multitasking	brain stimulation to improve information processing capabilities [*S74*], filter the incoming data and present only relevant information to the user context [*S28*], simplified the incoming data and present to the user in an easily understandable rating [*S86*], natural hand-gesture control with touchless interaction [*S87*]	quick acquisition of SA, faster decision-making, reduced system-interaction time, high immersion, higher multitasking throughput capacity
	inexperience, tired or stressed user	algorithm to capture management asset expertise from advanced users and share with users in need [*S86*]	quick response to battlefield events
	sensory overload	integration of additional modalities such as auditory and tactile [*S47*,*S68*]	maintain SA while one sensory modality becomes overused, enhance threat detection performance
	mental fatigue	UI elements and formats of the system with auto-adaptation to the real-time cognitive load and mental fatigue measure [*S43*]	better performance, reduced cognitive and mental load

- : Not mentioned/Not specified.

S.IV. Influencing factors - Side effects from technology in included studies

The included studies categorize the influencing factors and side effects of human-centric technologies by O4.0 pillars. However, there is no report or recommendation in the Analytical Operator pillar, as the authors could not find any evidence mentioning the use of analytic support with big data.

Table S3: Efficiency influencing factors and side effects from supporting technology.

Technology (study)	Usage context (study)	Influencing factors	Side effect	Prevention - Suggestion
Super-strength Operator	exoskeleton for on-foot patrol [*S51*]	non-familiarity with technology components and capability, non-adaptive parameters, individual influence, technology actuate inappropriately, inergonomic design	distraction during operation, increased visual and physical load during tasks, technology actuate inappropriately, inergonomic designs workload, divided attention, lower reaction time, physical fatigue	improve ergonomic design with human body, improve embedded controller, conduct additional training
	wearable arm for supportive tasks [*S22*]	high physical weight, low dexterity, lack of autonomy, unclear trajectory, lack of feedback	hard to balance while wearing, creating more distraction and divided attention	more ergonomic design, improved dexterity, implement multi-modality human-in-the-loop feedback control

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Table S3. *Continued from previous page*

Technology	Usage context (study)	Influencing factors	Side effect	Prevention - Suggestion
Augmented Operator	interface with dynamic information visualization [*S82*]	-	the dynamic characteristics of the symbol slightly increased visual cognition load	-
	monocular display with navigation map and night vision goggle [*S47*]	-	higher visual load on each eye	-
	interact with 3D terrain from Microsoft HoloLens [*S81*,*S88*]	lack of technology familiarity and common level of proficiency, lack of user-centric measure from technology, technology un-comfortability and intrusiveness	increased cognitive workload, more time spent on task, longer response time, less accuracy	additional training for technology familiarity, fully immersion without headset
	target recognition in AR environment [*S89*, *S90*]	-	short- and long-term risks of distraction and visual conclusion, technology-induced complacency, skill degradation	-
	touch-less interaction with hand gestures [*S87*]	low accuracy of current technology	hand fatigue and slower manipulation	improving equipment accuracy
Virtual Operator	mental or procedural training in a virtual environment [*S40*,*S41*]	training experience with the real task, simulator sickness, reduced physical demand, low quality and accessibility of intended stressor, VR headsets have a smaller field of view angle than natural range of human eye	higher mental demand than in corresponding real-world conditions	improve the solution, add more relevant items, locate stimulus in more proper positions
	flight training with EEG feedback [*S61*,*S91*]	low VR resolution, no prior VR experience, task-related cognitive process and neural responses are not fully understood, brain signals are prone to noise	interaction with cockpit elements in VR took longer time and less accurate, higher workload, frustration, and simulator sickness	advance simulation with high-quality headsets
Healthy Operator	real-time monitoring of dry EEG signal during flight [*S62*]	questionable utility of physiological signals to detect cognitive performance decrements, electrical noise from operational environment, gender influence	-	using noise reduction software of physical barriers such as copper housed sensors
	sensorized garment to recognize user status [*S32*]	hand movement during combat activities can introduce artifacts in GSR signals	-	find a suitable location to place GSR sensor
	self-adaptation of navigation assistive system according to pupillary size [*S43*]	-	unnecessary distraction during task execution, additional cognitive load, and anxiety	only use the auto-adaptation mode

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Table S3. *Continued from previous page*

Technology	Usage context (study)	Influencing factors	Side effect	Prevention - Suggestion
	stress self-management with HRV biofeedback [*S21*]	-	lightheadedness due to slow paced breathing	adjust breath pacer with longer exhalation cycles
Smarter Operator	fall-preventive shoes with alarm signal [*S48*]	low fidelity of prototype	-	-
	in-vehicle mobile computer terminal [*S66*]	prior awareness of potential distraction, familiarity with the traditional technology	-	-
Collaborative Operator	automated agent in the mixed-initiative team with human [*S67*]	adaptation to individual variability in the weight of behavior and psycho-physiological data, human users tend to ignore visual information over time, human trust on the automated agent	-	visualize the cooperation mode, use dynamic assessment to find optimal weight according to individual, use multi-modal interfaces to communicate with human
	multi-modal interactive robot software [*S26*]	complex development and implementation of human behavioral sense	-	substantial analysis and investigation
	haptic rain for guiding robot [*S44*]	force of haptic feedback should be bearable for human forearm	-	-
Social Operator	HMI interface for multi-operators in multi-platform management [*S58*]	overlapping/interdependent goals between tasks and actions over large geographic distances	-	high automation, with divided HMI according to functional roles or geographic sectors of platform clusters
	switching roles within a team during a mission [*S37*]	the roles for possible switching can be different from designed roles, lead to ineffective scene management with degraded communication	-	design with more roles considered for flexible switching
Analytical Operator	-	-	-	-
Others	tDCS during navigation	inadvertently reduced natural optimal navigation	users with high sense of direction: targeting stimulation parameters to individual difference variations [*S92*]	-
	noninvasive brain stimulation during combat [*S90*,*S93*]	equivocal effect, high variability in individual brain and behavioral responses	unknown long-term risk profile	-

- : Not mentioned/Not specified.

References

[S1] Page MJ, Moher D, Bossuyt PM, et al. Prisma 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. bmj. 2021;372.

[S2] Cannon-Bowers J, Bowers C, Stout R, et al. Using cognitive task analysis to develop simulation-based training for medical tasks. Military medicine. 2013;178(suppl_10):15–21.

[S3] Sottilare R, Hackett M, Pike W, et al. Adaptive instruction for medical training in the psychomotor domain. The Journal of Defense Modeling and Simulation. 2017;14(4):331–343.

[S4] Miller GT, Harris T, Choi YS, et al. Augmented reality and telestrated surgical support for point of injury combat casualty care: A feasibility study. In: Augmented Cognition: Intelligent Technologies: 12th International Conference, AC 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part I; Springer; 2018. p. 395–405.

[S5] Anghinolfi D, Capogrosso A, Paolucci M, et al. A system supporting the evaluation of the operational effectiveness of naval tasks based on agent simulation. Scalable Computing: Practice and Experience. 2014;15(3):201–216.

[S6] Lavigne V, Gouin D. Visual analytics for cyber security and intelligence. The Journal of Defense Modeling and Simulation. 2014;11(2):175–199.

[S7] Warm JS, Parasuraman R, Matthews G. Vigilance requires hard mental work and is stressful. Human factors. 2008;50(3):433–441.

[S8] Blasch E, Bélanger M. Agile battle management efficiency for command, control, communications, computers and intelligence (c4i). In: Signal Processing, Sensor/Information Fusion, and Target Recognition XXV; Vol. 9842; SPIE; 2016. p. 248–258.

[S9] Spencer DK, Duncan S, Taliaferro A. Operationalizing artificial intelligence for multi-domain operations: a first look. In: Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications; Vol. 11006; SPIE; 2019. p. 1100602.

[S10] van Beurden M, Roijendijk L. Towards a mixed reality platform for applied cognitive load evaluation. In: Engineering Psychology and Cognitive Ergonomics: 16th International Conference, EPCE 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26–31, 2019, Proceedings 21; Springer; 2019. p. 123–136.

[S11] Hall DS, Shattuck LG, Bennett KB. Evaluation of an ecological interface design for military command and control. Journal of Cognitive Engineering and Decision Making. 2012;6(2):165–193.

[S12] McCormack RK, Kilcullen T, Sinatra AM, et al. Scenarios for training teamwork skills in virtual environments with gift. In: Proceedings of the Sixth Annual GIFT Users Symposium; Vol. 6; US Army Research Laboratory; 2018. p. 189.

[S13] Patton D, Townsend L, Milham L, et al. Optimizing team performance when resilience falters: An integrated training approach. In: Augmented Cognition: Users and Contexts: 12th International Conference, AC 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II; Springer; 2018. p. 339–349.

[S14] Chen T, Ma X, You S, et al. Soft actor-critic-based continuous control optimization for moving target tracking. In: Image and Graphics: 10th International Conference, ICIG 2019, Beijing, China, August 23–25, 2019, Proceedings, Part II 10; Springer; 2019. p. 630–641.

[S15] Lundberg CL, Sevil HE, Das A. A visualsfm based rapid 3-d modeling framework using swarm of uavs. In: 2018 International Conference on Unmanned Aircraft Systems (ICUAS); IEEE; 2018. p. 22–29.

[S16] Ruppert T, Jaskó S, Holczinger T, et al. Enabling technologies for operator 4.0: A survey. Applied sciences. 2018;8(9):1650.

[S17] You S, Diao M, Gao L, et al. Target tracking strategy using deep deterministic policy gradient. Applied Soft Computing. 2020;95:106490.

[S18] O'Hara R, Vojta C, Henry A, et al. Effects of a new cooling technology on physical

performance in us air force military personnel. J Spec Oper Med. 2016;16(2):57–61.
[S19] Ones DS, Dilchert S, Viswesvaran C. Cognitive abilities. In: The oxford handbook of personnel assessment and selection. Oxf. Handb. Pers. Assess. Sel; 2012. p. 179.
[S20] Arlinger S, Lunner T, Lyxell B, et al. The emergence of cognitive hearing science. Scandinavian journal of psychology. 2009;50(5):371–384.
[S21] Davila M, Hourani L. Evaluation of hrv biofeedback as a resilience building intervention in the reserve component (bart). Chapel Hill, NC AD1060402. 2018;.
[S22] Vatsal V, Hoffman G. Wearing your arm on your sleeve: Studying usage contexts for a wearable robotic forearm. In: 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN); IEEE; 2017. p. 974–980.
[S23] Berka C, Behneman A, Kintz N, et al. Accelerating training using interactive neuro-educational technologies: Applications to archery, golf and rifle marksmanship. The International Journal of Sport and Society. 2010;1(4):87.
[S24] Nørgaard K, Linden-Vørnle M. Cyborgs, neuroweapons, and network command. Scandinavian Journal of Military Studies. 2021;4(1).
[S25] Puscas IM. Military human enhancement. In: Boothby WH, editor. New technologies and the law in war and peace. Cambridge University Press; 2018. p. 182–229.
[S26] Paul S. A survey of technologies supporting design of a multimodal interactive robot for military communication. Journal of Defense Analytics and Logistics. 2023;7(2):156–193.
[S27] Brunyé TT, Yau K, Okano K, et al. Toward predicting human performance outcomes from wearable technologies: a computational modeling approach. Frontiers in Physiology. 2021;12:738973.
[S28] Allen JP, Regli SH, Stibler KM, et al. The information exoskeleton: Augmenting human interaction with information systems. In: Foundations of Augmented Cognition: 7th International Conference, AC 2013, Held as Part of HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013. Proceedings 7; Springer; 2013. p. 553–561.
[S29] From J, Perrin P, O'Neill D, et al. Supporting the commander's information requirements: Automated support for battle drill processes using r-cast. In: 2011-MILCOM 2011 Military Communications Conference; IEEE; 2011. p. 1523–1528.
[S30] Chmielewski M. Situation awareness tools supporting soldiers and low level commanders in land operations. application of gis and augmented reality mechanisms. In: Proceedings of the Geographic Information Systems Conference and Exhibition "GIS ODYSSEY; 2017. p. 85–94.
[S31] Chmielewski M, Sapiejewski K, Sobolewski M. Application of augmented reality, mobile devices, and sensors for a combat entity quantitative assessment supporting decisions and situational awareness development. Applied Sciences. 2019;9(21):4577.
[S32] Seoane F, Ferreira J, Alvarez L, et al. Sensorized garments and textrode-enabled measurement instrumentation for ambulatory assessment of the autonomic nervous system response in the atrec project. Sensors. 2013;13(7):8997–9015.
[S33] White TL, Krausman AS, Haas EC. Tactile displays in army operational environments. In: Designing soldier systems. CRC Press; 2018. p. 97–116.
[S34] Ogden PM, Wollert TN, Butler P, et al. Squad overmatch: Using virtual technology to enhance live training environments. In: Virtual, Augmented and Mixed Reality: 7th International Conference, VAMR 2015, Held as Part of HCI International 2015, Los Angeles, CA, USA, August 2-7, 2015, Proceedings 7; Springer; 2015. p. 300–308.
[S35] Rao AK, Chahal JS, Chandra S, et al. Virtual-reality training under varying degrees of task difficulty in a complex search-and-shoot scenario. In: Intelligent Human Computer Interaction: 11th International Conference, IHCI 2019, Allahabad, India, December 12–14, 2019, Proceedings 11; Springer; 2020. p. 248–258.
[S36] Cummings D, Prasad M, Lucchese G, et al. Multi-modal location-aware system for paratrooper team coordination. In: Chi'13 extended abstracts on human factors in computing systems. Association of Computing Machinery; 2013. p. 2385–2388.
[S37] Militello LG, Sushereba CE, Branlat M, et al. Designing for military pararescue: Naturalistic decision-making perspective, methods, and frameworks. Journal of Occupational

and Organizational Psychology. 2015;88(2):251–272.
[S38] Hartley CA, Hurley KJ, Morganson VJ, et al. Eject, eject, eject! conducting a cognitive task analysis to assess parachute descent training simulators. Ergonomics in Design. 2022;:10648046221124786.
[S39] Weidinger J, Schlauderer S, Overhage S. Analyzing the potential of graphical building information for fire emergency responses: Findings from a controlled experiment. In: 14th International Conference on Wirtschaftsinformatik, February 24-27, 2019, Siegen, Germany; Wirtschaftsinformatik; 2019. p. 1084–1098.
[S40] Lipp N, Dużmańska-Misiarczyk N, Strojny A, et al. Evoking emotions in virtual reality: schema activation via a freeze-frame stimulus. Virtual Reality. 2021;25(2):279–292.
[S41] Lackey S, Salcedo J, Matthews G, et al. Virtual world room clearing: a study in training effectiveness. In: Interservice/industry training, simulation, and education conference; Vol. 14045; 2014. p. 1–11.
[S42] Brandão WL, Pinho MS. Using augmented reality to improve dismounted operators' situation awareness. In: 2017 IEEE Virtual Reality (VR); IEEE; 2017. p. 297–298.
[S43] Zhou T, Xia P, Zhu Q, et al. Cognition-driven navigation assistive system for emergency indoor wayfinding (cogdna): proof of concept and evidence. Safety science. 2023; 162:106100.
[S44] Elyounnss M, Holloway A, Penders J, et al. Development of an intelligent robotic rein for haptic control and interaction with mobile machines. In: Conference Towards Autonomous Robotic Systems; Springer; 2016. p. 111–115.
[S45] Gardony AL, Martis SB, Taylor HA, et al. Interaction strategies for effective augmented reality geo-visualization: Insights from spatial cognition. Human–Computer Interaction. 2021;36(2):107–149.
[S46] Weisberg SM, Badgio D, Chatterjee A. Feel the way with a vibrotactile compass: Does a navigational aid aid navigation? Journal of experimental psychology: learning, memory, and cognition. 2018;44(5):667.
[S47] Elliott LR, van Erp J, Redden ES, et al. Field-based validation of a tactile navigation device. IEEE transactions on haptics. 2010;3(2):78–87.
[S48] Park JH, Baek IJ, Han SJ, et al. Saft: Study of sensor unit for fall prevention in blocked vision. In: Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers; 2015. p. 177–180.
[S49] Scherer MR, Weightman MM, Radomski MV, et al. Measuring soldier performance during the patrol-exertion multitask: preliminary validation of a postconcussive functional return-to-duty metric. Archives of physical medicine and rehabilitation. 2018;99(2):S79–S85.
[S50] Bartlett JL, Sessoms PH, Reini SA. Strength through science: using virtual technology to advance the warfighter. Aviat Space Environ Med. 2013;84(2):165–166.
[S51] Bequette B, Norton A, Jones E, et al. Physical and cognitive load effects due to a powered lower-body exoskeleton. Human factors. 2020;62(3):411–423.
[S52] Redden ES, Elliott LR, Pettitt RA, et al. Scaling robotic systems for dismounted warfighters. Journal of Cognitive Engineering and Decision Making. 2011;5(2):156–185.
[S53] Chen JY. Effects of operators' spatial ability on their performance of target detection and robotics tasks. In: Designing soldier systems. CRC Press; 2018. p. 53–67.
[S54] Daly T, Murphy J, Anglin K, et al. Moving vigilance out of the laboratory: dynamic scenarios for uas operator vigilance training. In: Augmented Cognition. Enhancing Cognition and Behavior in Complex Human Environments: 11th International Conference, AC 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, July 9-14, 2017, Proceedings, Part II 11; Springer; 2017. p. 20–35.
[S55] Bishop J. The role of affective computing for improving situation awareness in unmanned aerial vehicle operations: A us perspective. In: Handbook of research on synthesizing human emotion in intelligent systems and robotics. IGI Global; 2015. p. 404–414.
[S56] Fay D, Stanton N, Roberts AP. Exploring ecological interface design for future rov ca-

pabilities in maritime command and control. In: Advances in Human Aspects of Transportation: Proceedings of the AHFE 2018 International Conference on Human Factors in Transportation, July 21-25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA 9; Springer; 2019. p. 264–273.

[S57] Alicia TJ, Taylor GS, Turpin TS, et al. Removing the bottleneck: utilizing autonomy to manage multiple uas sensors from inside a cockpit. In: Unmanned Systems Technology XX; Vol. 10640; SPIE; 2018. p. 130–148.

[S58] Lim Y, Gardi A, Sabatini R, et al. Avionics human-machine interfaces and interactions for manned and unmanned aircraft. Progress in Aerospace Sciences. 2018;102:1–46.

[S59] Kim S. Unmanned aerial vehicle (uav) operators' workload reduction: The effect of 3d audio on operators' workload and performance during multi-aircraft control [master's thesis]. Air Force Institute of Technology; 2016.

[S60] Brown N, Coyne J, Sibley C, et al. Human performance in the simulated multiple asset routing testbed (smart): an individual differences approach. In: Advances in Human Error, Reliability, Resilience, and Performance: Proceedings of the AHFE 2019 International Conference on Human Error, Reliability, Resilience, and Performance, July 24-28, 2019, Washington DC, USA 10; Springer; 2020. p. 95–105.

[S61] van Weelden E, Alimardani M, Wiltshire TJ, et al. Advancing the adoption of virtual reality and neurotechnology to improve flight training. In: 2021 IEEE 2nd International Conference on Human-Machine Systems (ICHMS); IEEE; 2021. p. 1–4.

[S62] Rice GM, Snider D, Drollinger S, et al. Dry-eeg manifestations of acute and insidious hypoxia during simulated flight. Aerospace medicine and human performance. 2019; 90(2):92–100.

[S63] Godé C, Lebraty JF. Improving decision making in extreme situations: the case of a military decision support system. International Journal of Technology and Human Interaction (IJTHI). 2013;9(1):1–17.

[S64] Houweling KP. Ar me hearties: An evaluation of augmented reality as a navigational aid for situational awareness [master's thesis]. University of South-Eastern Norway; 2023.

[S65] Metcalfe JS, Larkin GB, Johnson T, et al. Experimentation and evaluation of threat detection and local area awareness using advanced computational technologies in a simulated military environment. In: Unmanned Systems Technology XII; Vol. 7692; SPIE; 2010. p. 72–83.

[S66] Zahabi M, Kaber D. Effect of police mobile computer terminal interface design on officer driving distraction. Applied ergonomics. 2018;67:26–38.

[S67] Drnec K, Gremillion G, Donavanik D, et al. The role of psychophysiological measures as implicit communication within mixed-initiative teams. In: Virtual, Augmented and Mixed Reality: Interaction, Navigation, Visualization, Embodiment, and Simulation: 10th International Conference, VAMR 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part I 10; Springer; 2018. p. 299–313.

[S68] Metcalfe JS, Mikulski T, Dittman S. Accounting for human neurocognitive function in the design and evaluation of 360 degree situational awareness display systems. In: Display Technologies and Applications for Defense, Security, and Avionics V; and Enhanced and Synthetic Vision 2011; Vol. 8042; SPIE; 2011. p. 112–125.

[S69] McKinley R, Nelson J, McIntire L, et al. Improved skill learning: Enhancing formation and retention of non-declarative memories with transcranial direct current stimulation. Society for Neuroscience. 2012;.

[S70] MacMillan J, Tomlinson R, Alexander A, et al. Darwars: An architecture that supports effective experiential training. DARWARS Research Papers. 2005;.

[S71] Parasuraman R, McKinley RA. Using noninvasive brain stimulation to accelerate learning and enhance human performance. Human factors. 2014;56(5):816–824.

[S72] Clark VP, Coffman BA, Mayer AR, et al. Tdcs guided using fmri significantly accelerates learning to identify concealed objects. Neuroimage. 2012;59(1):117–128.

[S73] Falcone B, Coffman BA, Clark VP, et al. Transcranial direct current stimulation aug-

ments perceptual sensitivity and 24-hour retention in a complex threat detection task. PloS one. 2012;7(4):e34993.
[S74] Nelson J, McKinley RA, Phillips C, et al. The effects of transcranial direct current stimulation (tdcs) on multitasking throughput capacity. Frontiers in Human Neuroscience. 2016;10:589.
[S75] Nelson JM, Phillips CA, McKinley RA, et al. The effects of transcranial direct current stimulation (tdcs) on multitasking performance and oculometrics. Military Psychology. 2019;31(3):212–226.
[S76] Özyurt E, Döring B, Flemisch F. Evaluation and extension of the cognitive assistant system (cogas) for user-oriented support of air target identification. In: 2014 IEEE International Inter-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA); IEEE; 2014. p. 66–72.
[S77] Hew PC. Distributed cognition sheds light on munitions trajectories in close air support. Ergonomics in Design. 2017;25(2):12–14.
[S78] Keebler JR, Jentsch F, Hudson I. Developing an effective combat identification training. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting; Vol. 55; SAGE Publications Sage CA: Los Angeles, CA; 2011. p. 1554–1558.
[S79] Abich J, Eudy M, Murphy J, et al. Use of the augmented reality sandtable (ares) to enhance army cbrn training. In: HCI International 2018–Posters' Extended Abstracts: 20th International Conference, HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II 20; Springer; 2018. p. 223–230.
[S80] Boyce MW, Gardony AL, Shorter P, et al. Characterizing the cognitive impact of tangible augmented reality. In: Virtual, Augmented and Mixed Reality. Multimodal Interaction: 11th International Conference, VAMR 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26–31, 2019, Proceedings, Part I 21; Springer; 2019. p. 416–427.
[S81] Boyce MW, Thomson RH, Cartwright JK, et al. Enhancing military training using extended reality: A study of military tactics comprehension. Frontiers in Virtual Reality. 2022;3:754627.
[S82] Mao CC, Tseng YC, Chen CH. Dynamic information visualization on cognitive ability for intelligence preparation of the battlefield. In: Proceedings of the 6th International Conference on Information and Education Technology; 2018. p. 263–266.
[S83] Ionita MG, Patriciu VV. Cyber incident response aided by neural networks and visual analytics. In: 2015 20th International Conference on Control Systems and Computer Science; IEEE; 2015. p. 229–233.
[S84] Smallman HS, Cook MB. Proactive supervisory decision support from trend-based monitoring of autonomous and automated systems: a tale of two domains. In: Virtual, Augmented and Mixed Reality. Systems and Applications: 5th International Conference, VAMR 2013, Held as Part of HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part II 5; Springer; 2013. p. 320–329.
[S85] Lafond D, Vachon F, Rousseau R, et al. A cognitive and holistic approach to developing metrics for decision support in command and control. Advances in cognitive ergonomics. 2010;:65–73.
[S86] Buchler N, Marusich LR, Sokoloff S. The warfighter associate: Decision-support software agent for the management of intelligence, surveillance, and reconnaissance (isr) assets. In: Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR V; Vol. 9079; SPIE; 2014. p. 907902.
[S87] Zocco A, Zocco MD, Greco A, et al. Touchless interaction for command and control in military operations. In: Augmented and Virtual Reality: Second International Conference, AVR 2015, Lecce, Italy, August 31-September 3, 2015, Proceedings 2; Springer; 2015. p. 432–445.
[S88] Boyce MW, Reyes RJ, Cruz D, et al. Effect of topography on learning military tactics–integration of generalized intelligent framework for tutoring (gift) and augmented reality sandtable (ares). Army Research Laboratory. 2016;.

[S89] Schmorrow D. Foundations of augmented cognition. Springer; 2005.
[S90] Brunyé TT, Brou R, Doty TJ, et al. A review of us army research contributing to cognitive enhancement in military contexts. Journal of Cognitive Enhancement. 2020; 4:453–468.
[S91] Oberhauser M, Dreyer D, Braunstingl R, et al. What's real about virtual reality flight simulation? Aviation Psychology and Applied Human Factors. 2018;.
[S92] Brunyé TT, Holmes A, Cantelon J, et al. Direct current brain stimulation enhances navigation efficiency in individuals with low spatial sense of direction. Neuroreport. 2014;25(15):1175–1179.
[S93] Brunyé TT, Hussey EK, Fontes EB, et al. Modulating applied task performance via transcranial electrical stimulation. Frontiers in human neuroscience. 2019;13:140.