

Situation Awareness in Virtual and Hybrid Care: A Systematic Mapping and Synthesis Review

by

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A Research Project in Partial Fulfillment of the Requirements for the Degree of
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We acknowledge and respect the Lək̓ʷəŋən (Songhees and X̱wsep̓səm / Esquimalt)
Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ
Peoples whose historical relationships with the land continue to this day.

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Abstract

The rapid expansion of virtual care (VC) during the COVID-19 pandemic has fundamentally transformed healthcare delivery, introducing new complexities for individuals and teams responsible for maintaining situation awareness (SA) across physical and virtual boundaries. This systematic mapping and synthesis review charts the landscape of existing literature at the intersection of SA and virtual/hybrid care (VC/HC) in clinical practice. Guided by the Population, Concept, Context (PCC) framework, systematic searches were conducted in MEDLINE, CINAHL, Embase, APA PsycINFO, Scopus, and Web of Science bibliographic databases and grey literature searches in Google Scholar and ProQuest Dissertations & Theses, seeking studies on SA in real-world clinical implementations of VC and HC. Searches were performed in September 2025. Additional references were identified by searches of reference lists. Searches identified 2,410 results. After review, 31 articles were included for analysis and synthesis.

The review reveals that while SA is widely recognized as critical for safe and effective decision-making in dynamic healthcare environments, its conceptualization, measurement, and operationalization in VC/HC contexts remain poorly defined and underexplored. Most studies rely on intuitive understandings of SA, without explicit definition or theoretical grounding, and predominantly employ descriptive, atheoretical approaches. Endsley's three-level SA framework of perception, comprehension, and projection is the dominant theoretical model cited, though distributed and system-level perspectives are increasingly acknowledged.

Thematic analysis identified 28 factors influencing SA in VC and HC, clustering into eight overarching concepts: available information, technology capabilities/performance, individual cognitive/sensory factors, teamwork, workflow, user interface, education/training, and policy. Outcomes attributable to SA are reported in a minority of studies, with positive effects of VC on SA often asserted, particularly in hybrid distributed teams, without robust empirical support. The absence of controlled vocabulary terms for SA and HC in bibliographic databases further complicates systematic identification and synthesis of relevant literature.

This review identifies that priorities for future research in this area should include extension of literature scoping to encompass studies of SA in clinical simulations and field exercises involving VC/HC; emphasis on using explicit definition and operationalization for SA in VC/HC research; articulation of consensus definitions and descriptions for hybrid models of care; and continued transdisciplinary practices of incorporating insights from scholarship in human factors, sociotechnical systems, and teamwork theory.

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List of Abbreviations

AI	artificial intelligence
APP	advanced practice provider
AR	augmented reality
CDM	chronic disease management
CDS	clinical decision support
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CMA	Canadian Medical Association
CMT	combat medical technician
COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
COVID	SARS-COV-2 pandemic
CTA	cognitive task analysis
DOI	digital object identifier
EHR	electronic health record
EMS	emergency medical services
ER	emergency room
F2F	face to face
HC	hybrid in-person and virtual care
HHR	health human resources
ICT	information and communication technology
ICU	hospital intensive (critical care) unit
IMO	input-mediator-output
IONM	intra-operative neurophysiological monitoring
I-PASS	clinical handoff mnemonic: Illness severity, Patient summary, Action list, Situation awareness & contingency planning, and Synthesis by receiver
IPO	input-process-output
IT	information technology
L1 SA	level 1 situation awareness (perception)
L2 SA	level 2 situation awareness (comprehension)
L3 SA	level 3 situation awareness (projection)
MDT	multidisciplinary team
NGO	non-governmental organization
NTS	non-technical skills
OECD	Organization for Economic Co-operation and Development
OR	operating room
PCC	population, concept, context
PII	personally identifiable information
PLoS	Public Library of Science

PRISMA	preferred reporting items for systematic reviews and meta-analyses
PRISMA-ScR	preferred reporting items for systematic reviews and meta-analyses, extensions for scoping reviews
RPM	remote patient monitoring
RQ	research question
RTVS	Real-Time Virtual Support
SA	situation awareness
SA _o	SA-output
SA _p	SA-process
SAGAT	Situation Awareness General Assessment Technique
SOF	Special Operations Forces
SPAM	Situation Present Assessment Method
STS	sociotechnical system
UK	United Kingdom
US	United States of America
VC	virtual care
WHO	World Health Organization

Chapter 1

“The medium, or process, of our time—electric technology—is reshaping and restructuring patterns of social interdependence and every aspect of our personal life. ... Survival is not possible if one approaches his environment, the social drama, with a fixed, unchangeable point of view—the witless repetitive response to the unperceived.”

*–Marshall McLuhan**

1.1 Background and Motivation

Telemedicine is a term to describe clinical service that is delivered over a distance in space and/or time via the use of enabling information and communication technologies (Gogia, 2020a). Telehealth, telecare, telenursing, telemetry, virtual health, virtual care, and other terms have variously appeared in the scholarly literature reporting on technology-mediated interactions between patients and remote providers. For the remainder of this paper, the term **virtual care** (VC) will be used preferentially to refer to this topic of interest, as it aligns with use in recent national discourse in Canada (Abacus Data & Canadian Medical Association (CMA), 2020; Canada Health Infoway, 2024a; Virtual Care Task Force, 2022). The rapid expansion of VC during the global SARS-COV-2 (COVID) pandemic continues to transform healthcare delivery (OECD, 2023). While virtual care offers benefits such as increased access, reduced travel time, and continuity of care (Eze et al., 2020), it also necessarily changes the information flow, communication patterns, and sensory cues available to clinicians with impacts on the process of care delivery (Elford, 2008; Myronuk, 2022).

In its 2023 report, *The Journey Towards Equitable, Quality Hybrid Care in British Columbia*, the Virtual Clinical Care Reference Group proposed a principle-based framework that situated VC as one component of comprehensive longitudinal care that also includes accessible in-person services (J. Pawlovich, personal communication, August 19, 2025). This concept of hybrid care (HC) emerges from consideration of the post-pandemic question of how to apportion patient services (and by extension, providers’ practices) appropriately between continued use of VC and return to traditional in-clinic face-to-face service. Licurse et al. (2020) suggested that a minimum of 50% of clinic services could remain as VC

* McLuhan, M., Fiore, Q., & Agel, J. (1967). *The medium is the message: An inventory of effects*. Ginkgo Press. pp 8-10

deliverables, and that in some specialty areas the proportion would be higher still. In the face of a national and global health human resource crisis (HHR, Sriharan et al., 2024), innovative, team-based models of care that incorporate VC have been identified as Canadian priorities (Health Canada, 2022; Lauscher et al., 2024). Deployment of HC to sustain operations at rural acute care sites has been reported in the scholarly literature (Blacklaws et al., 2025) as well as the lay press (Grant, 2025), with challenges and limitations noted in both discourses.

HC that entails an integration of in-person and virtual service delivery components requires a systematic approach to determining what patients and conditions can be managed virtually. The complex, dynamically changing nature of health conditions, their care, and treatment necessitates that continued suitability for VC/HC management is monitored and reconsidered as the clinical situation and context evolves.

Endsley (1995c) defines situation awareness (SA) as *the perception of elements in the environment, comprehension of their meaning, and projection of their status in the near future*. SA is widely recognized as critical for safe and effective decision-making in a number of complex, dynamically changing domains, including healthcare (Endsley, 2015). SA is a mental state (i.e., mental model) that is achieved and maintained through the process of *situation assessment*, which may be conflated (see, e.g., Rousseau et al., 2004). SA is conceptualized to exist at the individual level as well as something that is shared among functional teams where communication and coordination are additional requirements (Rousseau et al., 2004; Stout et al., 2011). An essential quality of SA is its veracity: "Situation awareness is not just about awareness of a situation (i.e., the mental existence of that simile), but about the accuracy of that awareness. A good match, or a close correspondence between the mental and the material, is thought to produce 'good SA'; a bad match is synonymous to bad SA, or to having 'lost SA'..." (Dekker & Lützhöft, 2004, p. 22).

For traditional in-person care, development and maintenance of SA draws from a range of explicit (conscious) and implicit (preconscious) knowledge (Croft et al., 2004) including non-verbal communication cues from patients and colleagues, direct sensory experience of environmental context (e.g., temperature and humidity; degree of noise, crowding, and care activities going on concurrently for others, etc.), more or less implicit mental models of care teams and systems learned through prior local experience, and others. When providing care virtually, immediate cues and information inputs may be altered, reduced, or substituted by digital signals, and the practitioner providing service from a distant

location may have no experience of (or mental model for) the locality where the patient is receiving care. This has potential to impact SA at all three levels:

Level 1 Perception – Changes in visibility of patient affect, subtle clinical signs, and team dynamics; perception is limited to what is within the resolving ability of the remote sensing technology in use (cameras, microphones, biomedical sensors), and the properties of these sensors may differ substantially from familiar natural human senses in sensitivity and dynamic range*.

Level 2 Comprehension – Altered interpretation of patient status in technology-mediated environments.

Level 3 Projection – Predicting clinical trajectories without full environmental and interpersonal context.

Although SA has been extensively studied across domains — notably aviation, military operations, disaster response, offshore drilling, nuclear powerplant operations, and clinical medicine (particularly in critical care areas such as ICU, surgical anesthesia, emergency trauma resuscitation) — the conceptualization, measurement, and impact of SA in virtual care remain poorly mapped. There is no consolidated understanding of how SA is defined, operationalized, and measured in VC contexts, nor how it influences patient safety, clinical effectiveness, or interprofessional collaboration. In their textbook on telemedicine and telehealth, Gogia (2020a) makes passing mention of SA in the broader context of disaster response scenarios, but do not address it specifically for VC. The only mention of SA in Koenig's (2019) textbook *Telemedicine in the ICU* comes in the chapter by Hufferberger et al. (2019) on family-centered care, but there is no formal consideration of SA theory or research.

HC introduces additional complexity: clinicians may need to maintain individual and shared team SA across alternating modes of interaction, integrate asynchronous information, and adapt to varying information richness.

A systematic mapping of the literature is warranted to scope the extant work at the intersection of VC/HC and SA research, to identify key concepts, gaps, and methodological

* Indeed, use of VC technologies could introduce use of sensing systems that bedside clinicians might not otherwise readily adopt, e.g., a digital stethoscope with signal filtering/conditioning capability, potentially enhancing level 1 SA.

approaches, and to inform future empirical studies or interventions to support SA in VC and HC service delivery models.

1.2 Problem Statement

Hybrid models of care that include a virtual component entail distributed teams that are required to maintain SA across physical and virtual boundaries, yet the mechanisms for achieving and sustaining this remain incompletely understood.

1.3 Research Aim

1.3.1 Primary Objective:

- To map and synthesize existing literature on the concept, measurement, and application of SA in VC and HC.

1.3.2 Secondary Objectives:

- To describe how SA is defined and conceptualized in VC/HC literature.
- To identify theoretical models and frameworks applied to SA in these settings.
- To categorize methodological approaches used to study SA in these settings.
- To identify outcomes for studies of SA in VC/HC.
- To identify reported barriers and facilitators to maintaining SA in VC and HC delivery models.
- To highlight gaps in knowledge and directions for future research.

1.4 Research Questions

1.4.1 Main Research Question:

- RQ1: What is known from the existing literature about situation awareness in virtual and hybrid virtual/in-person care contexts?

1.4.2 Sub-questions:

- RQ2: How is SA defined in research into VC and HC?
- RQ3: What theoretical models have been developed and applied to SA in VC/HC?
- RQ4: What methods are used to measure or assess SA in VC and HC?
- RQ5: What outcomes have been reported for studies evaluating SA in VC/HC?
- RQ6: What factors influence SA in VC and HC delivery?

- RQ7: What are the reported consequences of high or low SA in these settings?

1.5 Summary

Since its rapid expansion in adoption and use during the COVID-19 pandemic, VC has remained an ongoing option for delivery of clinical services. VC has potential to address health care system sustainability challenges arising in association with shortages in HHR, as well as inequities in access to health care for citizens in rural and remote locations. Healthcare in the 21st century is recognized to be a team endeavor, with non-technical skills (NTSs) being critical for team performance and patient safety (Flin et al., 2008).

Healthcare is a complex, dynamically changing environment that can at times become chaotic, in which timely, safety-sensitive decisions are required. In the domain of human factors studies in complex environments, achieving and maintaining SA is established as critical to the decision-making that underpins safety and productivity (Banbury & Tremblay, 2004). Adding a VC component to existing systems of care, especially when the result is a hybrid team that combines members present in-person with the patient as well as remote (virtual) providers, increases the complexity even further. The burgeoning appetite for VC and HC service delivery models brings a pressing need to understand how individual and team SA affect and are affected by VC.

This paper takes a step in that direction with a systematic literature search to establish the scope of existing work in the area. The second and third sections of the paper provide an overview of the extant work in the domains of VC and SA, as well as a summary of teamwork theory as it is applied to distributed teams. Section four will describe the details of the systematic literature search and its results, with thematic analysis synthesis. The final section concludes the paper with a discussion of the implications of the review findings, including implications for health system leaders responsible for implementation decisions about VC and HC systems, as well as opportunities for health informatics scholars to address gaps in the corpus of knowledge in future work.

Chapter 2 Nature of Problem Domain

2.1 Virtual Care

Since the outbreak of the global COVID-19 pandemic at the opening of this decade, Canadian society has become accustomed to internet-enabled computer and smart device mediated communications for personal interactions with friends and family and for a wide range of business dealings, including communicating with health care providers. Within months of the WHO declaring the presence of a pandemic, almost half of Canadians had used telephone, email, videoconference, or text messaging to access advice from a physician in what has come to be known as *virtual care* (VC, Abacus Data & Canadian Medical Association (CMA), 2020).

2.1.1 What is VC?

VC refers to the provision of health care service where the patient and provider are separated by significant distances in space and/or time, and the interaction is facilitated by information and communication technologies (ICT) such as mobile phones, internet-connected smart devices and computers, and digitalized health system infrastructure. The term VC is interchangeable with *telemedicine* and is subsumed under the broader terms of telehealth and eHealth (Gogia, 2020b).

2.1.2 Historical context

More than a century ago, radio enthusiasts were envisioning wireless communication technology that would afford rich, multi-media (sound, touch, sight, biometric measurement) real-time interaction between physicians and patients (Fips, 1924). The ensuing decades saw measured progress toward this vision, with the first wireless transmission of clinical electrocardiographic information (MacInnis, 1954) followed shortly by the introduction of portable continuous ambulatory electrocardiographic recording that was stored for later study and analysis (Holter, 1961).

Developments in remote measurement and transmission of data over distances, *telemetry*, were accelerated as part of the human space exploration efforts of the 1960s (Mayo-Wells, 1963). The first use of this technology in routine clinical care appeared in January 1965 (Rothfeld et al., 1965), and was already in widespread use when the first North American practice standards for electrocardiographic monitoring were published (Drew et al., 2004).

Closed-circuit television was in use by the Nebraska Psychiatric Institute on Omaha for neurological and psychiatric consultations by 1959 (Maxmen, 1978). However, it would not be until the available technologies had grown in capacity while falling in cost (Moore,

1965) that the Age of the Internet would dawn at the close of the 1990s laying the foundations for digital transformations that would pervade culture and society as we entered the 21st century. Bellazzi (2008) observed that VC was facing an ‘evaluation paradox’ where healthcare organizations would adopt VC with enthusiasm if shown to be clinically valuable, but would need to first adopt it in order to show such value. Presciently, the OECD Health Working Paper No.116 published 17 January 2020 (just prior to COVID-19 declaring itself) foreshadowed what would be experienced by health systems around the globe, stating “...the most successful telemedicine interventions [will be] those that emerge naturally as solutions to existing problems and with clear rationales” (Oliveira Hashiguchi, 2020, p. 34). VC it seems was ready and waiting for an impetus to drive adoption, which the global pandemic readily supplied.

2.1.3 Current status of VC

COVID did not discriminate as it swept the globe, giving everyone the same challenge of gaining access to medical advice and care without being able to attend the location where our providers were situated. Suddenly, everyone everywhere was experiencing the logistical difficulties of access to healthcare long experienced by citizens in rural and remote regions, and by those living with rare and/or complex health conditions for which specialty expertise is sparse — populations for whom pioneering telehealth VC programs had been oriented (Ho et al., 2004). In response, the provincial nurse-staffed telephone triage service in British Columbia quickly moved to incorporate real-time virtual support (RTVS) physicians who could interact directly with patients via VC when needed (Ho et al., 2021; 2025). Other Canadian provinces followed similar strategies (Fitzsimon, Belanger, et al., 2023). Health leaders worked quickly to remove organizational, regulatory, and funding barriers to VC use (Gratzer et al., 2021), and provision of VC became ensconced in published practice standards as a core component of medical care (College of Physicians & Surgeons of British Columbia, 2023). Most Canadians have now utilized VC to access healthcare services (Statistics Canada, 2023), and discourses have shifted from when and if to implement VC to questions of how to incorporate VC with other existing practices (Frew et al., 2022; Virtual Care Task Force, 2022), and how to evaluate VC to ensure it provides value (OECD, 2023).

Types of virtual care

Although various proposed taxonomies of VC have appeared in the literature (see, e.g., Bashshur et al., 2011; Colucci et al., 2019), recent systematic reviews identify three broad VC domain types of *remote patient monitoring* (RPM) including telemetry; asynchronous *store-and-forward* systems for text, medical images, and/or biometric measurements; and

real-time interactive telephone and videoconferencing systems (Eze et al., 2020; Flodgren et al., 2015). In all cases, VC deployments are embedded within wider complex, adaptive healthcare systems (Lipsitz, 2012). These services are "... both technological and service innovations. They go much further than simply digitising traditionally analogue health care processes and services, they fundamentally reorganise processes, procedures and services," (Oliveira Hashiguchi, 2020, p. 36) best understood within the eight sociotechnical dimensions of Sittig and Singh's (2010) model framework for health information technology.

Hybrid models of care

With the uncertainties and anxieties of the pandemic (at least for now) comfortably in our collective rear-view mirror, questions of blending VC with direct patient care services have come to the fore (Frew et al., 2022; Licurse et al., 2020). These considerations come at a time when society is confronting a crisis in health human resources (HHR) at national (Dash et al., 2023) and international levels (Sriharan et al., 2024), an ageing demographic (Fougère et al., 2004), and an increasingly complex patient population (Naik et al., 2024). Following pandemic success connecting patients and providers at scale when circumstances did not afford them the opportunity to meet in the same place at the same time, VC is being looked at for its potential to mitigate staff shortages by supplementing gaps in on-site provider schedules with remotely situated team members in hybrid care (HC) service models (Blacklaws et al., 2025).

HC models incorporating virtual hospitalist physicians supporting on-site advanced practice providers (APPs) were in use pre-pandemic to sustain operations at small critical-access hospitals in the US (JaKa et al., 2020; Kuperman et al., 2018; Theiler et al., 2024), and were also reported as system adaptations in the COVID surge response (Bloom-Feshbach et al., 2021). The recent rapid qualitative study of Sakumoto et al. (2024) documented broad variation in VC hospitalist models across US health systems, ranging from nonexistent to multi-site virtual hubs. No reports of Canadian implementations of virtual hospitalist HC models have yet appeared in the peer-reviewed literature, but HC is reported in the Canadian context for community-based care (Fitzsimon, Patel, et al., 2023).

Implicit in the concept of HC is the notion of *team-based care*, since the defining feature of care delivery involving both in-person and remotely provided components entails having practitioners in two different places at the same time, an impossibility for a solo provider. Historically, facility-based telemedicine services would entail having a clinician present on-site with the patient while engaging with a remote provider to support needs of the patient (technological and psychological) as well as of the provider (e.g., when effecting

required physical examination procedures). While on the face of it this would seem to meet the definition of HC insofar as there is both an in-person and a remote clinician providing care, both are engaged in a single shared activity (the virtual visit at hand), whereas HC models proposed for mitigation of HHR challenges envision the remote virtual providers as carrying out at least a portion of their activities independent of the on-site team members. In this sense, HC aligns to the concept of *partially distributed teams* that are "...configured with one or more subgroups of colocated members and isolated members" (Ocker et al., 2011, p. 273).

While much has been written on teamwork in healthcare (see, e.g., the umbrella review by Buljac-Samardžić et al., 2021), the distributed aspect of the HC team warrants special consideration of how the VC component may affect performance and function.

2.2 Distributed Teamwork

2.2.1 Working in teams

Working in teams entails the coordinated action of individuals with different skills and roles toward shared goals, supported by clear roles, communication, psychological safety, and shared mental models (Flin et al., 2008). Core teamwork processes of mutual monitoring, backup behavior, leadership, and structured communication are associated with better performance and safety outcomes (Salas et al., 2005). Interprofessional collaboration reviews further highlight the importance of trust, conflict management, and deliberate reflection on and adjustment of how work is done (Mchugh et al., 2020; Mclaney et al., 2022; Schot et al., 2020).

2.2.2 Teams in health care

Healthcare teams are interprofessional (i.e., their members are drawn from medical, nursing, pharmacy, allied health, and other disciplines) and must coordinate under dynamic conditions characterized by uncertainty, time pressure, and high stakes (Lipsitz, 2012). Reviews of teamwork and interprofessional collaboration in healthcare show that effective teams are linked to reduced morbidity and mortality, fewer adverse events, better implementation of innovations, and higher staff satisfaction (King et al., 2008; Rosen et al., 2018; Salas et al., 2018; Schmutz et al., 2019).

Characteristics of healthcare teams include tightly coupled interdependent tasks; dynamically changing members and leaders across time, space, and activities; goal-orientation; and intensive communication to maintain shared objectives and foster cooperative action (Dinh et al., 2021; Kreps, 2025; McGuier et al., 2024). Within the context

of team-based care however, there is continued need for clarity around accountability for patient outcomes and responsibility for care decisions. This has given rise to the concept of most-responsible provider (MRP), initially conceived as a physician role but subsequently broadened to encompass other providers, for example nurse practitioners (Acorn, 2015; Capen, 1996).

2.2.3 Distributed teams

Distributed teams in healthcare are dispersed across space, time, or organizational boundaries (Eid et al., 2023; Fiore et al., 2003; Sapateiro & Grosso, 2010). Empirical study of teamwork by Hutchins (1996) established that team performance depended upon distributed cognition, especially as complexity increases (Weinberger, 2011). Distributed collaboration requires explicit, intentional sharing of knowledge that would otherwise be available as tacit knowledge when team members are colocated, including knowledge of other team members and their activities (Tenney & Pew, 2011), resources (Kirsh, 2001), and context (Cramton, 2001). Transforming tacit, internal personal knowledge into an explicit form that can be communicated and shared is termed externalization, an active process that requires cognitive resources (Nonaka & von Krogh, 2009). That externalization process, the communication efforts required to initiate and receive exchanges of information through technology-mediated channels (Berry, 2011), and the maintenance of mental models with added complexity needed to incorporate the “virtualness” of the team (Schmidtke & Cummings, 2017) all contribute to increased cognitive load for members of distributed teams, with downstream implications for performance norms, system design, and potential failure modes of the team system (Cramton, 2001).

Sociotechnical systems

Healthcare teamwork in general, and distributed teamwork in particular, are performed within a *sociotechnical system* (STS), where people, teams, culture, and organizational structures represent the social components that interact with technical components such as abstract data structures (e.g., EHRs), network communication technologies, hardware devices, and computational algorithms (Sittig & Singh, 2010). STS models such as SEIPS (Systems Engineering Initiative for Patient Safety, Carayon, 2012) conceptualize how work system elements—people, tasks, technologies, physical environment, and organization—jointly shape processes and outcomes. Changes to technology (e.g., new telehealth platforms, decision support, or documentation tools) can reshape communication patterns, team roles, and workload (Marjanovic et al., 2020), and management of practice

change itself can be viewed through an STS lens (McGuier et al., 2024). From this perspective, “better teamwork” is not just about training individuals; it also requires aligning technologies, policies, and work environments to support team cognition, resilience, and safe adaptation in practice.

2.3 Situation Awareness

Situation awareness, sometimes referred to as situational awareness, refers to the ability of a person, team, or system to perceive, make sense of, and anticipate relevant elements within a dynamically changing environment. In the widely cited model of Endsley (1995c) SA is conceived as entailing three levels, each level being necessary for higher-order levels to obtain:

Level 1: perception of elements in the environment

Level 2: comprehension of their meaning

Level 3: projection of their status into the near future

Wickens' (2008) review of Endsley's work highlights three distinctions between SA and concepts with which it can be conflated. First: SA is distinct from action taken in response to that situation, analogous to the distinction between diagnosis and treatment. Second: SA is not the same as knowledge held in long-term memory, but rather applies in *dynamic* situations where variables are changing over the course of time and cannot be represented by static (declarative or procedural) knowledge. Third: The SA attained by an individual or system is distinct from the process by which it is acquired and maintained (broadly, situational *assessment*). SA is a foundational concept in the human factors literature on domains characterized by time-critical decisions under pressure of uncertainty and high-stakes outcomes, including aviation, military operations, healthcare, nuclear power systems management, and offshore oil drilling (Banbury & Tremblay, 2004; Salas & Dietz, 2011).

2.3.1 Historical overview

The concept of SA emerged in human-factors research in the 1980s–1990s, drawing from discourses in military aviation that have been traced back as far as World War I (Endsley, 1988; Stillion, 2015). Sarter and Woods (1991) observed that the term had arisen and come into widespread use as pragmatic term largely based on intuitive understandings. SA discourses were proceeding in two distinct areas, the academic literature that tended to be focused and often explicitly defined SA, and operational type flying magazines that would take a broader view of SA and often talk about it without defining it (Vidulich et al.,

1994). It was in that historical context that Endsley's two 1995 papers, "Toward a Theory of Situation Awareness in Dynamic Systems" (1995c), and "Measurement of Situation Awareness in Dynamic Systems" (1995a) emerged as foundational work that brought together more than a decade of preceding literature, formalizing the three-level SA model (Endsley, 2000; Wickens, 2008).

In 1995 SA was also entering the medical literature, where it was recognized that the domains of anesthesia and aviation shared relevant characteristics of "... dynamism, complexity, uncertainty, and risk" (Gaba et al., 1995, p. 30). Healthcare-focused reviews highlight SA's role in clinical reasoning and goal-directed performance (Fore & Sculli, 2013; Gorman et al., 2000; Green et al., 2017; Lowe et al., 2016; Schulz et al., 2013; Stubbings et al., 2012).

More recently, the notion of SA has evolved to encompass SA shared among distributed teams (Seebach et al., 2011; Seppänen et al., 2013; Stanton et al., 2006; Stout et al., 2011), as well as system-level conceptualizations where SA is an emergent property of systems incorporating both human (social) and non-human (technical) component sub-systems (Salmon & Plant, 2022; Stanton et al., 2017).

2.3.2 Types of SA

Individual SA

Individual SA refers to a dynamically changing mental model held by a single person about their environment, tasks, and possible future states. Key features include the three levels of SA outlined above: monitoring cues (level 1 perception), integrating with memory and concurrent observations (level 2 comprehension), and forecasting future states given current assessments (level 3 projection). Individual SA explicitly incorporates the concept of *preattentive processing* of sensory stimuli before they are available to conscious awareness, thus facilitating focused attention of finite cognitive resources based on salience (Endsley, 1995c). SA breakdown can occur from incompleteness or inaccuracy of mental representations (Endsley, 1995b; Endsley & Jones, 2004), and loss of individual SA is often implicated in medical error and patient safety incidents (Calder et al., 2021; Flin et al., 2009; Schulz et al., 2017; Schulz et al., 2016; van Galen et al., 2016).

Team SA

Observations of flight deck operations revealed that while all members of the team were concerned with the same broad task, i.e., keeping aircraft, crew, and payload (cargo/passengers) intact in the face of threats and changing/unforeseen circumstances while completing mission goals, each is concerned with their own role-based task

priorities and has distinct information requirements to support those tasks (Salas et al., 2011). Team SA entails the core SA of individuals working collaboratively and necessitates sharing of their SA effectively among one another (Rousseau et al., 2004; Wright & Endsley, 2008). It is more than the sum of team members' individual SA, and includes cross-monitoring and coordination among actors. "Like a Venn diagram, individuals' situation awareness must overlap in order to function together as a team" (Brindley et al., 2016, p. 29). This increases the complexity of the mental models required to maintain individual SA, as knowledge of the team and the timing of its actions has to be incorporated as part of the model (Tenney & Pew, 2011). It also increases the cognitive load entailed with acquiring and sustaining team SA, as the knowledge being shared must be made explicit in order to be communicated and hence any tacit knowledge held by individuals must first be converted to explicit form (Nonaka & von Krogh, 2009).

System SA

Given that individual SA and derivative team SA are predicated on *perception* as a necessary first stage, it is not surprising that system designs grew over time to include more and more gauges, monitors, indicators, and annunciators to the point that Lovesey remarked "... much of the design effort, so far, seems to have gone to maximising the amount of information displayed to the man. Few seemed to have questioned whether it is the correct information or how much of it a man can process" (1977, p. 30). Technology that presents more information for potential perception shifts the problem of attaining level 1 SA from being one of lack of available information to that of finding the information that is needed (Bergman, 2018; Koskinen-Kannisto, 2013). Growth of systems thinking and the emergence of the concept of sociotechnical systems (STS, Carayon et al., 2015; Pasmore et al., 1982) that embrace Hutchins (1996) notion of distributed cognition as an emergent system property allowed for the expansion of the SA concept to encompass the whole of collaborative systems that arise through the interaction of individual agents that are both human and technological (Stanton et al., 2017). Systems that are highly connected and whose actors are communicating with all others perform much less well than those with lower levels of connection (Carroll & Burton, 2000).

An example from popular culture demonstrates the readiness with which we can accept the notion that knowledge is held distributedly among humans and technology working collaboratively, and that effective performance hinges on communication to timely transfer of knowledge between agents: As the *Millennium Falcon* is escaping the attack upon planet Hoth in the first act of *Star Wars Episode V: The Empire Strikes Back* (Kershner, 1980), crisis ensues when Han Solo disregards C-3PO's attempts to alert him to the non-functional status of the ship's hyperdrive. Once the heroes (narrowly) avert disaster, Han

takes steps to re-attain distributed SA by telling C-3PO, “I need you to talk to the Falcon, find out what's wrong with the hyperdrive ... Chewie, take the professor in the back and plug him into the hyperdrive!”

System SA describes the interplay of the entire STS – humans, technologies, interfaces, and organizational processes – supports the formation and maintenance of SA. Design of displays and interfaces raise the salience of key cues (Endsley & Jones, 2004), functioning analogously to the preattentive processing described for individual SA, but occurring external to the human agent. Technical subsystems of the larger STS must have at least some capacity to alter their activity in a context-dependent manner, where context is one of several elements required to model information in systems designed to support SA (Luukkala & Virrantaus, 2014; Torell, 2005). The topic of contextually-aware “smart” technologies has its own discourses in the literature, encompassing topics such as the semantic web (Stănescu (Nicolai) & Oprea, 2025) and internet of things (Choudhary, 2024). Human agents (i.e., the social subsystems within the STS) also require context awareness that includes understanding of the structural, social, and ecological milieu (Seebach et al., 2011), as well as the task states of other actors (Kim et al., 2019). In the domain of healthcare, SA is shaped by how individuals, teams, technological tools, workflows, and organizational constructs interoperate (Cochand et al., 2023).

2.3.3 Current status of SA

In healthcare as well as other domains, SA has moved beyond individual-focused cognitive models towards distributed and ecological perspectives, with shift in emphasis to the ways in which people, artefacts, and processes interact within STS to establish and maintain distributed SA. The recent revival of interest in and rapid growth of AI following the emergence of generative pretrained transformer (GPT) machine learning models, e.g., ChatGPT (OpenAI), is stimulating inquiry into human-computer interaction and distributed SA in STS incorporating AI (Jiang et al., 2023; Srivastava et al., 2025). System SA is being utilized as a frame from which to study the rise of disinformation propagated through social media networks and the impact of dissonant mental models being algorithmically reinforced and amplified in a digitally connected society (Bunker, 2020).

2.4 Summary

The concept of SA, comprised of (1) perception, (2) comprehension, and (3) projection in successive levels arose out of the pragmatics of individual military aviators attaining adversarial advantage in the earliest air combat encounters of world war I. The centrality of dynamically changing circumstances and time-dependence to SA conceptualization

presaged the emergence of subsequent systems theoretical approaches to understanding causation in complex, dynamic non-linear systems (including healthcare systems). It has made SA a useful conceptual frame through which to consider system performance at levels beyond that of the individual*, including colocated and distributed teams, and broader sociotechnical systems.

* As a curious aside, it is also notable that all three levels of SA (perception, comprehension, and prediction) can be said to be present for subsystems *within* a given individual, as demonstrated by the clinical phenomenon of “blindsight” in the syndrome first reported by Riddoch (1917) that now bears his name. In condition of Riddoch syndrome, damage to the primary visual cortex of an individual’s brain renders them unable to see and consciously perceive visual stimuli, yet in certain circumstances still able to detect movement and avoid objects in motion without subjective awareness or knowledge of those objects. This avoidance implies at least some degree of projection of trajectories in order to take effective evasive action.

Chapter 3 Systematic Literature Review

3.1 Objectives

This systematic review was carried out to explore the scope of extant work that examines SA specifically within the context of health care delivered to patients in whole (VC) or in part (HC) via remote monitoring, real-time interactive, or store-and-forward design implementations.

3.2 Method

3.2.1 Study design

The PCC (population, concept, context) framework of Peters and colleagues (2020) organizes this work (Table 1), which was carried out following the five-stage process of Arksey and O'Malley (2005) with iterative enhancements of Levac et al. (2010). The reporting is organized in accordance with PRISMA-ScR guidelines (Tricco et al., 2018).

Table 1: PCC framework for study

PCC Framework	Focus of literature review
Population	Any healthcare providers, teams, or systems delivering care via virtual and/or hybrid virtual/in-person modalities
Concept	Situation awareness <ul style="list-style-type: none">• any level: perception, comprehension, projection• any scale: individual, team, system
Context	Implemented virtual care services including hybrid care environments integrating virtual and in-person aspects within a care pathway e.g., tele-ICU, virtual hospitalist)

3.2.2 Eligibility criteria

Utilizing the PCC framework, specific inclusion and exclusion criteria were articulated for operationalization as (1) formal reference database search strategy logic and (2) article screening and selection rules. The intent for this study was to scope the existing literature addressing SA in the real-world use of VC modalities to provide healthcare services to patients who are remotely situated relative to their providers' location(s). Studies in any healthcare setting or clinical discipline were included, and no date restrictions were applied. Peer-reviewed publications as well as relevant grey literature were included. To

focus the work on the subject of interest, studies were excluded from consideration if not situated in a healthcare setting, were exclusively focused education or training, were purely technical/engineering studies, focused on in-person care without a VC/HC component, or addressed cognitive constructs without explicit relevance to SA. Out of practical consideration and resource constraints non-English publications and studies without available full-text reports were excluded.

3.2.3 Information sources

Research librarian consultation was undertaken to identify information sources and develop an optimized search strategy (J. Mussell, personal communication, August 19, 2025). Peer-reviewed literature databases identified as relevant to the subject domain were:

- MEDLINE (Ovid) [ALL]
- CINAHL (EBSCOhost) [Complete]
- Embase (Ovid)
- APA PsycINFO (EBSCOhost)
- Scopus (Elsevier)
- Web of Science (Clarivate) [Core Collection]

ScienceDirect and PLoS were considered for inclusion but not selected as these are both publishing platforms offering only basic search capability that does not support complex logic, and the content of which will be indexed in the other databases listed.

Grey literature searches were performed in ProQuest Dissertations & Theses Citation Index (Clarivate) and Google Scholar with limits that follow the advice of Haddaway et al. (2015).

3.2.4 Search

An iterative approach was used to develop and refine the search strategy (Levac et al., 2010) in three phases.

Phase I preliminary search

Initial searches of MEDLINE and CINAHL were performed combining keywords and controlled vocabulary for core conceptual constructs (Table 2). Results from the phase I search were examined for text words used in titles and abstracts, indexing terms used, and author-provided keywords which informed the refinement of the phase II main search.

Table 2: Phase I search constructs

Construct	Example words
Situation awareness	"common operational picture" "situation awareness"
Virtual care	"telehealth" "telemedicine" "remote consultation" "remote monitoring" "video visit" "virtual care"
Hybrid care	"blended care" "combined virtual and in-person care" "hybrid care" "mixed mode care"

Preliminary searching in phase I elicited additional terms and controlled vocabulary items related to VC that included discipline- and modality-specific concepts of "telehomecare", "telementoring" and "telemetry". The term "organizational awareness" was identified for inclusion with the concept of SA. No additional terms or vocabulary emerged relative to the concept of HC.

Phase II main search

With the expanded and refined set of text words and controlled vocabulary concepts established in phase I, search logic was specified using Boolean operators, truncation, and proximity operators such that it could be implemented in the native syntax for each of the bibliographic databases being searched. The general form of the search strategy is given in Table 3, where each of the three main concepts listed is composed by the inclusive disjunction of the text words and controlled vocabulary terms listed in association with it. Database-specific implementations are included in Appendix A.

Table 3: General specification of bibliographic database search logic

Concept combination logic: [virtual care OR hybrid care] AND [situation awareness]		
Concept:	Text words	Controlled vocabulary
<i>virtual care</i>	digital consultation remote care remote consultation remote patient monitoring teleconsultation telehealth	Distance Counseling Mental Health Teletherapy Monitoring, Ambulatory Remote Consultation Remote Patient Monitoring Telecare

	telehomecare teleICU telemedicine telementoring telemonitoring teleneurology telenursing telepsychiatry video visit virtual care virtual health virtual hospitalist virtual medicine virtual MRP virtual triage virtual visits	Telehealth Telemedicine Telemetry Telenursing Telephone Triage Nursing Telepsychiatry Videoconferencing
<i>hybrid care</i>	hybrid care mixed model care combined virtual and in-person care	N/A
<i>situation awareness</i>	context awareness environmental awareness operational awareness organizational awareness situation awareness	N/A

The study design specified searching of grey literature for content such as prepress articles, government and NGO reports and policy documents relevant to the subject area. Google Scholar is included because it indexes a wide range of grey literature sources not systematically covered in traditional bibliographic databases. Its inclusion improves the comprehensiveness of the review and mitigates potential publication bias. However, the limitations of Google Scholar search interface affordances necessitated a different approach than that used in the bibliographic databases. Tailored keyword combinations for the review concepts were combined with filters for literature types and organizational sources. For example:

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("virtual care" OR telemedicine OR telehealth) AND ("situation awareness") AND (report OR guideline OR framework)
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In order to elevate the priority of government and institutional outputs, additional searches of Google Scholar were performed with site filters applied for Internet

domains .ca, bc.ca, gc.ca, .org, and .edu. Google Scholar does not provide an affordance for export of search results as structured data suitable for bringing into a research management tool, and so it was obligatory for title/abstract screening to be performed immediately on the dynamically returned search results in the Google Scholar web interface. To manage the vast number of returns from the Google Scholar search, only the first 25 pages of results from any search were screened for inclusion (250 records) as recommended in scoping review methodology (Haddaway et al., 2015). Search strings and corresponding result counts are included in Appendix A.

Phase III

The third phase of the search strategy consisted of manual review of the reference lists of all studies selected for full-text review after title and abstract screening (see below). Studies identified in this manner were then screened for inclusion using the same criteria as applied to the main phase II search results, and any articles selected for full-text also went on to have reference list review. This process repeated iteratively until no additional studies of potential relevance were forthcoming.

3.2.5 Data management

Results from the source database searches were exported and saved as structured data in standard RIS format (Yanguas-Gil, 2013) then subsequently imported into the *Covidence* cloud-based systematic review management platform (Kellermeyer et al., 2018) where automatic duplication identification and removal were performed. Retrieved items were managed in *EndNote 2025* (Clarivate). Analysis and visualization of bibliometric information and extracted data was performed using VOSviewer (Van Eck & Waltman, 2010) and Excel (Microsoft 365).

3.2.6 Study screening, review and selection

Using the Covidence tools, search results had screening of titles and abstracts for relevance according to the PCC framework, operationalized into specific criteria as shown in Appendix B. In cases where it was not possible to ascertain relevance from title and abstract content alone, the study was included for retrieval and full-text review.

Items identified for full-text review were retrieved and screened against the study inclusion and exclusion criteria (Appendix B). All articles that were excluded from study after undergoing full-text review had specific criteria used in the decision individually recorded.

3.2.7 Data items and data collection process

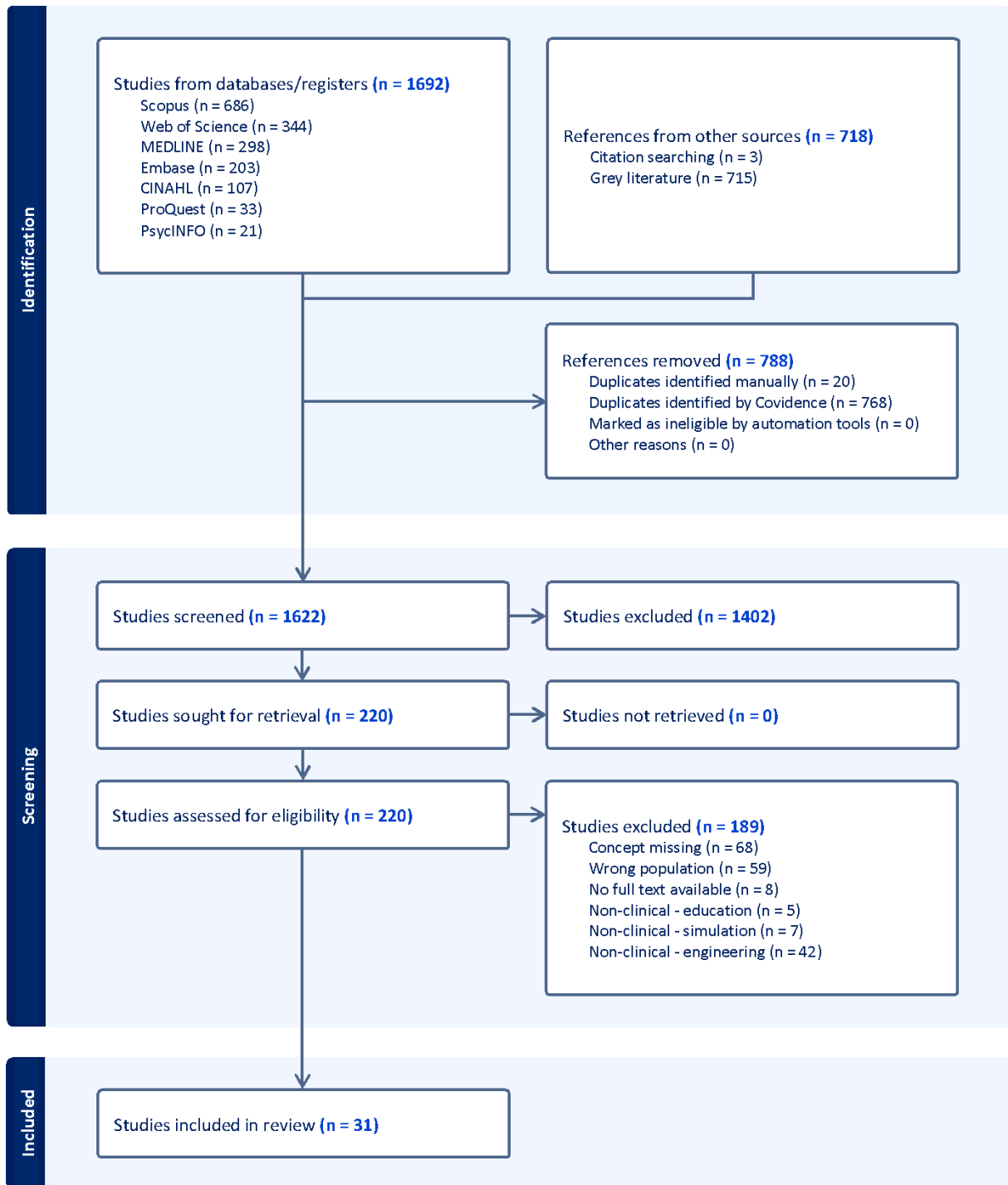
A standard template was used to extract study data into a data charting form. The charting was an iterative process that involved continuous updating of the extraction template and data charting forms, as per Levac et al. (2010). Data elements included in the data extraction template are listed in Appendix C. Template generation and form completion were both performed within Covidence. The Covidence platform enforces a second review of all data recorded from each study before the data extraction task can be marked completed for that item. This double-check is a quality assurance step that improves data quality.

3.3 Results

3.3.1 Study selection

Searches were performed in September, 2025. A total of 2,410 articles were identified, with searches of bibliographic databases returning 1,692 papers and 715 articles being returned from the grey literature search. Three additional papers were identified through manual review of reference lists in retrieved articles. Automated duplicate detection reduced the total number of items for screening to 1,622. Initial screening of titles and abstracts identified 220 to be retrieved for detailed assessment of eligibility for study inclusion, of which 212 were available in English language full text. Thirty-one articles were selected for study inclusion and data extraction. Figure 1 presents the results of the study selection process in PRISMA flow diagram format (Moher et al., 2009).

Figure 1: PRISMA flow diagram



3.3.2 Article characteristics

The 31 articles selected for study inclusion consisted of 28 peer-reviewed journal articles, one book chapter, one graduate thesis, and one article from a pre-print server. Most articles were recent, with 23 (74%) having been published within the last five years (Figure 2). Most research was situated in North America (18, 58%) or Europe (9, 29%), with the remainder coming from Australia (3, 10%), Africa, and the Middle East (1 each, 6% combined). One study (Pilosof et al., 2021) spanned international frontiers and was counted as arising from both the UK and Israel, resulting in the total number of originating countries being greater than the number of studies (Figure 3).

Figure 2: Included studies by publication year

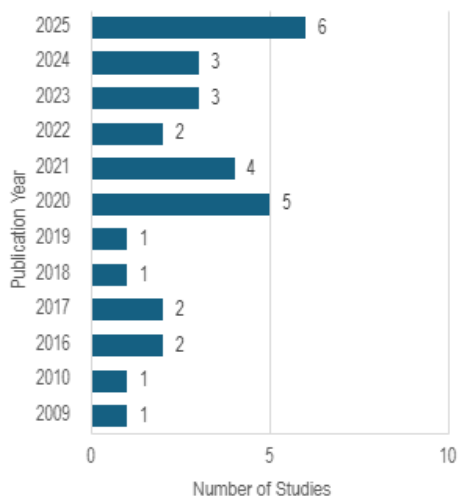


Figure 3: Included studies by country



Bibliometric analysis with VOSviewer did not reveal any network clustering of co-authorship or co-citation among the studies. Most studies were classified as experience papers (Wieringa et al., 2006) and used qualitative methods (Figure 4 and Figure 5, respectively).

Figure 4: Article type

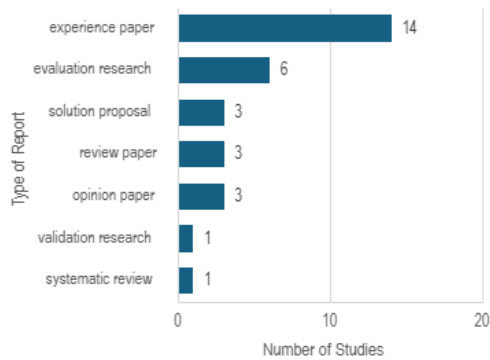
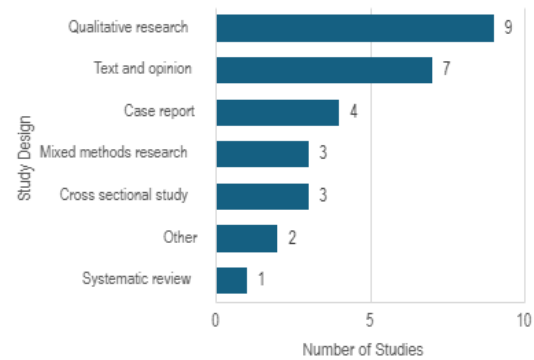


Figure 5: Study design



Reviewed studies reported on a range of VC modalities, with 15/31 papers (48%) addressing two or more VC modalities. The most often addressed VC modality was interactive videoconferencing (19/31, 61%), followed by telephone (11/31, 35%) together accounting for the majority of publication subject matter (Figure 6).

Figure 6: Article content by VC modality

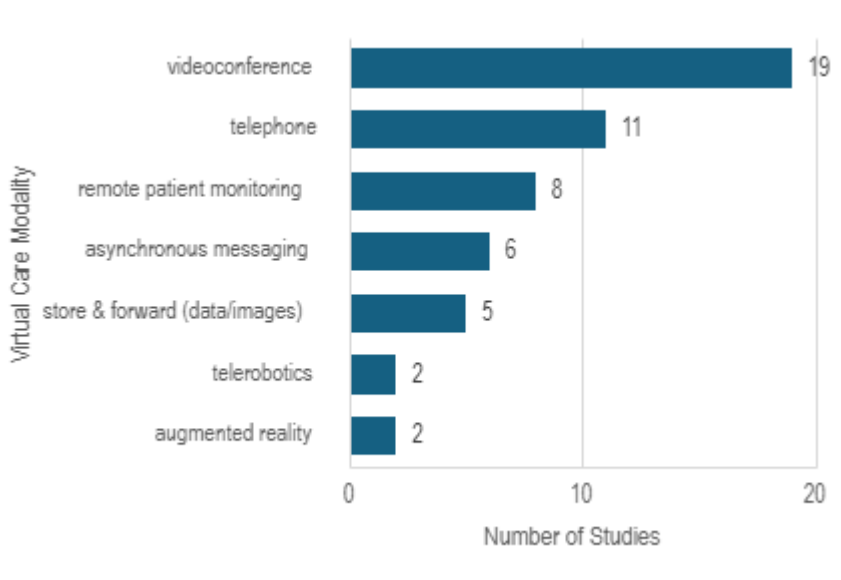
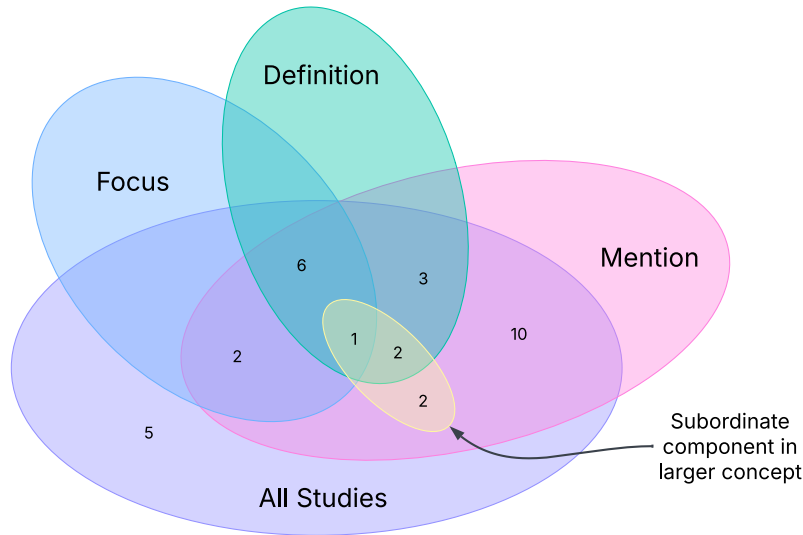


Figure 7 presents a diagrammatic representation of the semantic stance taken by authors of the reviewed papers. Most use the term SA while leaving it undefined taking an implicit stance that assumes the audience has common understanding of a shared meaning. For a few the concept of SA itself is implicit, one or more of its components (i.e., perception,

comprehension, or projection) or a synonym appearing in the text without “SA” being used specifically. Of those speaking directly to SA, only a subset have it as a central focus of the work.

Figure 7: Semantic specification of SA



Groupings show studies that mention SA explicitly in their corpus (pink); those with SA as a focus of study (blue); those providing a definition of SA and/or referencing a particular theoretical framework (green); and those in which SA is a subcomponent within a higher-order conceptual construct.

SA was a subject of specific focus in 9 studies (19%), the details for which are summarized in Table 4. Seven of these nine papers concerned themselves with SA in distributed teams: Dixit et al. (2020) address SA in teams of health system leaders, management, and operational staff who are responsible for VC systems and services utilized by direct care providers with patients. Six papers focused on SA in distributed teams with hybrid composition of in-person and remote virtual members (HC): Reports by Bavare et al. (2021) and Korentsides et al. (2025) describe HC where the virtual providers are remote from the patient bedside but still situated on the same site. The study by Santomauro et al. (2024) describes HC support of emergency rooms in rural and remote communities by remote tertiary critical care specialists. Three articles concern the specific HC context of intraoperative neurosurgical care where the operative team includes an off-site neurophysiologist engaged in remote patient monitoring (DeBruyn et al., 2024; Skinner et al., 2017; Skinner & Holdefer, 2020). Of the remaining two studies with SA as a topic focus, both consider individual SA (Rees et al., 2017; Stirling & Maclean, 2016).

Table 4: Summary of studies with focus on SA

Reference	Report type ^a	Design	Population (N ^b)	SA Concept	Context (modality)	Findings
Bavare et al. (2021)	Experience paper	Mixed methods	MDT ^c in hospital intensive care unit (114)	Distributed SA	Hybrid rounding on critical care patients with in-person and virtual participants during COVID-19 pandemic (videoconference, telephone)	<ul style="list-style-type: none"> • Teams with balanced membership of in-person and remote members had better SA than when entire team was off-unit. • Reduced SA when participating remotely was mitigated by data displays combining real-time and historical patient vital sign data.
DeBruyn et al. (2024)	Opinion paper	Text and opinion	Neurosurgical operative team	Shared SA	Hybrid team with IONM ^d provided by remote neurophysiologist OR team for patients undergoing neurosurgery (RPM ^e , videoconference, telephone)	<ul style="list-style-type: none"> • IONM^d providers supervise multiple cases concurrently across sites • Effective communication channel(s) between remote provider and OR team required in addition to the RPM^e data stream • Team members need mental models that incorporate perspectives, skills, roles, and responsibilities of other team members
Dixit et al. (2020)	Experience paper	Case report	Health system executives, mid-level managers, and operational teams (6)	Distributed SA	Health organization providing telehealth services during COVID-19 pandemic (videoconference, telephone)	<ul style="list-style-type: none"> • Operational leadership team and technical staff SA for telehealth system infrastructure performance state achieved via configurable dashboards • Metric and user control designs based on user literacy and information requirements
Korentsides et al. (2025)	Review paper	Text and opinion	MDT ^c in hospital inpatient setting	Distributed SA	Hybrid inpatient care team with bedside staff supported by telemetry technician situated remotely (RPM ^e)	<ul style="list-style-type: none"> • Loss of individual SA by telemetry monitoring technician degrades distributed team SA through failure/delay in communicating findings to floor clinicians • Cognitive overload of attentional capacity and working memory saturation reduces L1 SA resulting in missed alarms • High rates of non-actionable alarms desensitize operators (“alarm fatigue”)

						<p>reducing L2 SA discrimination between true and false alarms</p> <ul style="list-style-type: none"> • Interface design that groups related information effectively and dynamically gives visual prioritization to important information can improve L1 SA perception • AI-enabled interfaces could improve comprehension (L2 SA) and aid forecasting (L3 SA)
Rees et al. (2017)	Evaluation research	Mixed methods	Primary care (2178)	Individual SA	Patient safety review of incidents involving sick children in primary care, including national telephone triage service (telephone)	<ul style="list-style-type: none"> • Over-reliance on CDS^f protocols at the expense of critical thinking interpreted as poor SA on the part of telephone triage providers
Santomauro et al. (2024)	Evaluation research	Qualitative research	Critical care specialists; MDTc in rural / remote hospital ER (10)	Individual SA; Team SA	Hybrid team with regional critical care coordinators providing on-demand virtual support to rural/remote ER (videoconference, telephone)	<ul style="list-style-type: none"> • Lack of background information about patient case, on-site staff skill sets, and local facility context diminish individual SA for remote specialist • Supporting multiple remote sites concurrently divides coordinators' attention and diminishes SA • Aspects of video imaging (fixed viewpoints, lack of stereoscopic depth perception) make L1/L2 SA more difficult • Remote operators provide increased SA to local team as observers not engaged in manual tasks; reduced cognitive load for the local team through shared mental model and distributed decision-making • Not all conversations are suitable when videoconference is accessible to whole team and/or family, e.g., if local provider needs to express uncertainty/inexperience with a procedure • VC systems unsuitable for team debrief when hardwired installation in trauma bays (psychologically safe environment)

Skinner et al. (2017)	Opinion paper	Text and opinion	Neurosurgical operative team	Team SA	Hybrid team with IONM ^d provided by remote neurophysiologist OR team for patients undergoing neurosurgery (RPM ^e , videoconference, telephone)	<ul style="list-style-type: none"> • Inadequate communication channel bandwidth for remotely situated IONM^d professional to achieve and maintain adequate SA • Burden of supervising multiple cases diminishes SA • Communication technology implemented in IONM^d insufficient for effective collaboration with OR team
Skinner and Holdefer (2020)	Opinion paper	Text and opinion	Neurosurgical operative team	Team SA	Hybrid team with IONM ^d provided by remote neurophysiologist OR team for patients undergoing neurosurgery (RPM ^e , videoconference, telephone)	<ul style="list-style-type: none"> • IONM^d requires situationally aware analysis of incoming RPM^e data stream (L2 SA) and proactive feedback to the operative team of risk probability (L3 SA) • Remote telepresence with dedicated videoconference connection may improve SA and effectiveness of team communications
Stirling and Maclean (2016)	Solution proposal	Cross-sectional study	Occupational therapists (8)	Individual SA	Provision of virtual rehabilitation services to patients in-home by remote occupational therapist) RPM ^e , video ^g)	<ul style="list-style-type: none"> • Cognitive task analysis of occupational therapists in-clinic to inform requirements for VC system to afford L1 SA remote observation and measurement of patients and L2 comprehension within context of patients' situations. • Metrics and presentation of information in VC system must align to clinicians' existing mental models for ease of integration (L2 SA)

^a derived from (Wieringa et al., 2006).

^b Given the variety of methodologies among included studies, there is no consistent unit of measure for the count (N) of sample representing the population of study. E.g., for case series, (N) represents the number of cases in the series; for systematic reviews, the number of included studies; for qualitative interviews it is the number of participants. For narrative review and opinion papers the concept of (N) is not meaningful, and no value is reported.

^c multidisciplinary team

^d intra-operative neurophysiological monitoring

^e remote patient monitoring

^f clinical decision support

⁹ Authors propose use of video for functional assessment, but do not specify if store-and-forward or live interactive videoconferencing is envisioned.

Most reviewed studies (17/31, 55%) make explicit reference to SA concepts without SA itself being the subject of inquiry (Table 5). The largest group comprises studies on field care of patients in prehospital triage and transport (Boyle et al., 2021; Morgan & Muskett, 2020; Söderholm & Sonnenwald, 2010; Zhang et al., 2022), inter-hospital critical care transport (Jackson et al., 2018), and while in military deployment (Morgan et al., 2009; Powell et al., 2016; Sandhu et al., 2023) with a virtual care component (i.e., hybrid care models). For the most part these authors report on patient care delivered by hybrid teams of providers situated in the field connecting via interactive or asynchronous VC to centralized experts, making comment on shared (Jackson et al., 2018; Morgan et al., 2009; Powell et al., 2016; Sandhu et al., 2023; Zhang et al., 2022) or distributed (Boyle et al., 2021; Söderholm & Sonnenwald, 2010) team SA. The sole exception is the paper by Morgan and Muskett (2020), which is primarily a critique of the conclusions of Rees et al. (2017) in their finding of individual SA failure as a root cause of patient safety events in telephone triage. Two studies examine virtual provider support of rural and remote emergency care: Aston and Powell (2025) report specialist consultation to small outlying hospital emergency room teams; (Morian, 2025) addresses virtual general physician support to nurse-led 'cottage hospital' outposts. One paper looks specifically at video RPM for behaviourally disturbed pediatric patients in the emergency department (De M. Goulart et al., 2025). Pulosof et al. (2021) consider the relationship of VC use and hospital unit physical design layout to SA for operational leaders. The narrative review of Elendu et al. (2024) which spans inpatient and community-based care settings is structured as an argument advocating for 5G network communications infrastructure deployment to enable 'smart hospital' digital health technologies that include VC. Enhanced SA in disaster response scenarios is an envisioned benefit to accrue from 5G enabled smart hospitals, but the authors do not link SA concepts directly to VC. Two studies that focus on outpatient primary care settings incorporating VC make mention of SA, the experience paper of van Bockxmeer (2022) reporting on HC team huddles, and the systematic scoping review of Leonardsen et al. (2023) focusing on person-centred digital primary care. Three of the 12 studies included by the latter in its synthesis identified digitalization in primary care as having an effect on SA of providers or patients, one of which (Kim et al., 2020) also met criteria for inclusion in the present study (discussed below).

Four papers discussed SA as a component feature of a higher-order construct: person-centeredness (Leonardsen et al., 2023), inter-professional handoff (Lieng et al., 2019), trust in robotic systems (Louca et al., 2023), and non-technical communications skills (Morian, 2025).

Table 5: Summary of studies with SA not a focus of investigation

Reference	Report type ^a	Design	Population (N ^b)	SA Concept	Context (modality)	Findings
Aston and Powell (2025)	Experience paper	Case report	Critical care specialist; MDT ^c in rural / remote hospital ER	Distributed SA; Shared mental model	Hybrid team with regional critical care coordinator providing on-demand virtual support to rural/remote ER (videoconference, telephone)	<ul style="list-style-type: none"> • Remote medical consultant provided overall task SA to the on-site staff by providing of patient vital signs on the monitor while local staff acutely focused on mechanics of completing interventional procedure • Shared mental model was pivotal for prompt team performance and capacity to troubleshoot and revise plans during procedure
Boyle et al. (2021)	Evaluation research	Cross sectional study	Paramedics in-field; Hospital based medical consultants	Distributed SA	Hybrid team delivering prehospital emergency pediatric care (asynchronous messaging, store-and-forward images/data, videoconference)	<ul style="list-style-type: none"> • Survey study of paramedics' perceptions of VC • Expected VC to increase SA of hospital providers regarding incoming patients
De M. Goulart et al. (2025)	Evaluation research	Qualitative research	MDT ^c in hospital ER	Distributed SA	Hybrid team providing care to behaviourally disturbed pediatric patients using constant remote video observation (RPM ^d)	<ul style="list-style-type: none"> • Remote video observation enables concurrent monitoring of multiple patients by a single staff member • Concerns from staff that remote observation does not afford the same speed and ease of communication for observer to alert clinicians to patient status changes • Virtual monitoring recommended as a complementary resource to constant direct observation
Elendu et al. (2024)	Review paper	Text and opinion	Hospital and community health care providers	Individual SA	Envisioned enhancements to providers enabled by 5G connectivity, including remote monitoring of	<ul style="list-style-type: none"> • Principal argument is for acceleration of 5G networking infrastructure for 'smart hospitals', with improved provider SA asserted as a downstream benefit of

					community patients and augmented reality for remote-assisted operative procedures (RPM ^d , augmented reality, telerobotics)	digital health technologies including VC using 5G connectivity. <ul style="list-style-type: none"> Improved SA in disaster response scenarios is implied to arise from envisioned technologies but not specifically linked to VC.
Jackson et al. (2018)	Experience paper	Case series	Pediatric critical care transport team; tertiary pediatric neurosurgical team	Team SA	Hybrid team; transport team supported virtually at sending site and in transit by central tertiary specialists (videoconference, store-and-forward images/data)	<ul style="list-style-type: none"> Early pediatric neurosurgical subspecialist involvement led to shared mental models among providers across multiple specialties and institutions, expediting time to definitive care
Leonardsen et al. (2023)	Systematic review	Scoping review	Primary care providers	SA as component of patient-centredness	Systematic scoping review of person-centredness and digital primary health care (asynchronous messaging, telephone, videoconference)	<ul style="list-style-type: none"> SA is one of four themes emerging from synthesis of 12 reviewed studies on person-centredness and digitalization in primary care (others are accessibility, self-management, and digitalization at odds with patient centredness) Three of 12 included studies address SA concepts
Lieng et al. (2019)	Experience paper	Cross sectional study	Hospital ED and inpatient nursing staff	SA as component of interprofessional handoff	Nurses providing handoff reports at time of interfacility transfer of pediatric patients to tertiary care centre (videoconference, telephone)	<ul style="list-style-type: none"> Comparison of telephone to videoconference for nurse to nurse handoff at time of interfacility patient transfer favours VC, based on completeness of I-PASS^e documentation SA is only mentioned as a component of I-PASS^e, not addressed as a concept in its own right Related concepts of shared mental model, perception, and preparedness/unanticipated needs are present
Louca et al. (2023)	Solution proposal	Qualitative research	Surgeons performing	SA as component of	Telerobotic system operators from 4 industries [robot-	<ul style="list-style-type: none"> One mandatory and two high-priority of 9 trustworthiness requirements identified relate to SA

			robot-assisted procedures	trust in robotic systems	assisted surgery, nuclear reactor maintenance, underwater exploration, bomb disposal] perceptions on developing trust in robotic systems (telerobotics)	<ul style="list-style-type: none"> • Operator understanding of systems', tools' and support teams' capabilities and limitations (mandatory) • Affordance of multiple camera views from fixed and movable viewpoints adequate to see all necessary details (high priority) • System health status monitoring and warning systems for operators with visual and audio feedback, documentation and explanation of cause and effect of error states (high-priority)
Morgan et al. (2009)	Experience paper	Case series	Infectious disease specialists; deployed military medical providers	Command and control SA	Review of consecutive consults to remote infectious disease specialists from providers deployed in military theaters of operation (asynchronous messaging, store-and-forward images/data)	<ul style="list-style-type: none"> • Command and control SA of problems encountered in the combat theater is improved • Infectious disease specialists can better influence policies for managing identified problems
Morgan and Muskett (2020)	Evaluation research	Qualitative research	Telephone triage call handlers	Distributed SA	Conversation analysis of recorded calls to national telephone triage service examining interactions between system components (telephone)	<ul style="list-style-type: none"> • Study is a response to Rees et al. (2017) • Recommend a shift in focus from individual components to system interactions for safety improvement • Distributed SA is a more suitable construct than individual SA perspective of Rees et al. (2017)
Morian (2025)	Experience paper	Mixed methods research	Nurses in rural outpost 'cottage hospitals'; remotely located general physicians	SA as a component of non-technical skills	Hybrid team with nurses providing direct care in rural settings with remote GP support (videoconference)	<ul style="list-style-type: none"> • Uses TEAM instrument (Cooper et al., 2010) to assess distributed hybrid team performance, of which one item addresses L1 SA (perception) and one item L3 SA (projection) • Nurses perform tasks in the ER that would typically be performed by the GP if physically present

						<ul style="list-style-type: none"> • GPs rely on role of RN trusting professional training before familiarity with personal ability or experience could develop
Pilosof et al. (2021)	Experience paper	Qualitative research	Hospital inpatient MDT; Telemedicine experts; Architecture design team	SA for management of operations	Hybrid teams co-located in the same hospital units, segmented into contaminated [patient care] and clean [VC provider] partitions (videoconference)	<ul style="list-style-type: none"> • Unit design influences SA for medical director and impacts dimension of staff safety; direct vision through window to open unobstructed space increases SA affording 'whole-unit' view not attainable from individual patient camera displays; lines of sight limited by L-shaped unit design decrease SA but is partly mitigated by VC
Powell et al. (2016)	Experience paper	Text and opinion	SOF ^f military medics; Critical care specialists	Individual and shared SA for critical care specialists; Command and control SA for SOF ^e medical leaders	Hybrid care with prolonged in-field patient care delivered by SOF ^e military medics supported by virtual critical care specialist consultation (asynchronous messaging, telephone, store-and-forward images/data)	<ul style="list-style-type: none"> • Prolonged field care is classified as pre-hospital care not requiring EMR documentation so no PII⁹ included in store-and-forward communications allowing for use of simpler / more rapidly deployed systems • Use of automatic distribution lists for incoming messages to consultant providers and leaders contributed to shared SA • Scripted communication formats assisted inexperienced callers to consistently convey information in a compressed, high-yield format • 'capabilities' section of script increases consultant SA of austerity and limitations of operational field environment
Sandhu et al. (2023)	Experience paper	Case report	Military medical officers; CMTs ^h	Shared SA	Hybrid team with deployed CMTs ^h providing in-field patient care supported by virtual physician medical officers (videoconference,	<ul style="list-style-type: none"> • Use of group messaging application increased shared SA among military medical officers • Observed improvement in continuity of care at provider handoff attributed to overall impact of VC, not specifically to effects on SA

					asynchronous messaging, store-and-forward images/data)	
Söderholm and Sonnenwald (2010)	Solution proposal	Qualitative research	MDT ^c in hospital ER; EMS ^f managers; hospital IT support	Distributed SA ⁱ	Hybrid team of paramedics providing direct patient care in-field with VC support from hospital ER staff (videoconference)	<ul style="list-style-type: none"> • Qualitative participatory design study to identify potential benefits and disadvantages of VC proposed technology solution • Participants from different frames identified common and unique advantages, supporting the concepts of distributed cognition and distributed SA
van Bockxmeer (2022)	Experience paper	Text and opinion	MDT ^c in outpatient primary care	Team SA	Hybrid MDT ^c delivering clinic-based services with remote providers working from home joining care team huddles via VC (videoconference)	<ul style="list-style-type: none"> • Daily visual huddles enabled by VC increased team L1 SA (perception) and L2 SA (understanding) of shifting clinic priority goals during COVID
Zhang et al. (2022)	Validation research	Qualitative research	Paramedics in-field; Hospital ER providers	Distributed SA; joint decision-making	Hybrid team with pre-hospital paramedic providers using VC for consultation with hospital-based ER providers (augmented reality)	<ul style="list-style-type: none"> • Specific focus on field use of AR^k technology to support SA and joint decision-making in distributed team. • Contant display of patient vital signs in AR^k display increases paramedic SA • Video feed from field ER provider SA of patient environment

^a derived from (Wieringa et al., 2006).

^b Given the variety of methodologies among included studies, there is no consistent unit of measure for the count (N) of sample representing the population of study. E.g., for case series, (N) represents the number of cases in the series; for systematic reviews, the number of included studies; for qualitative interviews it is the number of participants. For narrative review and opinion papers the concept of (N) is not meaningful, and no value is reported.

^c multidisciplinary team

^d remote patient monitoring

^e I-PASS is a mnemonic for standardized patient handoff between providers, standing for Illness severity, Patient summary, Action list, Situation awareness and contingency planning, and Synthesis by receiver (Starmer et al., 2012)

^f Special Operation Forces

^g personally identifiable information – includes direct and indirect identifiers (IBM, 2022)

^h combat medical technicians

ⁱ The authors' concept is *interwoven SA* which is considered here to map interchangeably with the concept *distributed SA* that has superseded it in the literature.

^j emergency medical services

^k augmented reality

Five of 31 studies (16%) did not specifically include mention of SA in the bodies of the reports, but employed closely related concepts: distributed team coordination, contextual awareness (Ali et al., 2020); guided patient self-examination (Björndell & Premberg, 2021); situational understanding (Kim et al., 2020); mutual understanding (Melanie et al., 2025); and shared mental model (Powell & Gibbs, 2025). Features of these studies are summarized in Table 6.

Table 6: Summary of studies without explicit reference to SA

Reference	Report type ^a	Design	Population (N ^b)	SA-related concept	Context (modality)	Findings
Ali et al. (2020)	Review paper	Text and opinion	Hospital MDT ^c ; Stroke medicine specialists	Contextual awareness; Distributed team coordination	Hybrid care with on-site MDT ^c providing acute stroke patient management with VC support of remote stroke specialists (videoconference)	<ul style="list-style-type: none"> • AI^d systems could facilitate distributed team coordination through contextual awareness of patient location and status, staff schedules, timing of patient clinical events, team member roles • Such AI^d systems can predict patient outcomes, which would have effect of increasing L3 SA (projection)
Björndell and Premberg (2021)	Experience paper	Qualitative research	General physicians in public virtual primary care clinic	Guided patient self-examination	Booked patient direct consultation with primary practitioner care for episodic care via VC (videoconference)	<ul style="list-style-type: none"> • Providers guide patients remotely to perform self-palpation examinations and report observations to mitigate loss of tactile perception by VC provider (mitigation of diminished L1 SA) • Referrals to VC service from other health centres are problematic when physical examination required and unable to be delivered via VC, which implies absence of distributed SA: health centres not having comprehension (L2) of VC providers' capacity/limitations lose SA and ability to project (L3) outcome of referral to VC
Kim et al. (2020)	Experience paper	Qualitative research	Health/lifestyle coaches for CDM ^e in diabetes	Situational understanding	Lifestyle intervention program with coaching delivered via mobile health [mHealth] application (asynchronous messaging)	<ul style="list-style-type: none"> • Situational understanding (maps to L2 SA comprehension) built through constantly repeated contact with users and availability of information from electronic health records archived in application platform • Enhanced understanding helps individual tailoring of interventions while maintaining alignment to broad program goals

Melanie et al. (2025)	Evaluation research	Qualitative research	Community nurses delivering home health care	Mutual understanding	Nurses with experience in both traditional physical homecare visits and telehomecare (videoconference)	<ul style="list-style-type: none"> • Participants comment on diminished perception due to inability to use all senses over VC (implies reduction in L1 SA) • Social aspect of sociotechnical VC system enhanced mutual understanding between nurses and patients due to increased frequency of contact and continuity with providers (implies increase in shared L2 SA)
Powell and Gibbs (2025)	Experience paper	Case report	Critical care specialist; MDT ^c in rural / remote hospital ER	Shared mental model	Hybrid team with regional critical care coordinator providing on-demand virtual support to rural/remote ER (videoconference, RPM)	<ul style="list-style-type: none"> • Success of limb-saving procedure facilitated by VC mediated rich conversation between remote supervising specialist and local staff to build shared mental models re: anesthetic experience, foreseeable potential side effects of sedation, and contingency management plans that would be compatible with VC support (implies L2 SA comprehension and L3 SA projection shared among distributed team) • Vital sign monitoring task allocated to remote clinical nurse (implies distributed SA)
^a derived from (Wieringa et al., 2006).						
^b Given the variety of methodologies among included studies, there is no consistent unit of measure for the count (N) of sample representing the population of study. E.g., for case series, (N) represents the number of cases in the series; for systematic reviews, the number of included studies; for qualitative interviews it is the number of participants. For narrative review and opinion papers the concept of (N) is not meaningful, and no value is reported.						
^c multidisciplinary team						
^d artificial intelligence						
^e chronic disease management						

3.4 Results of individual studies

3.4.1 Narrative synthesis

All 31 studies selected for review were included in narrative synthesis. In the service of formulating an answer to the main research question, “What is known from the existing literature about situation awareness in virtual and hybrid virtual/in-person care contexts?” (RQ1, discussed in the following chapter), narrative synthesis for each of the sub-questions RQ2 – RQ7 is presented in the remainder of this section.

3.4.2 Theoretical foundations and definitions

The first two sub-questions in this review are: How is SA defined in research into VC and HC? (RQ2). What theoretical models have been developed and applied to SA in VC/HC? (RQ3). Most studies that explicitly mention SA did so without defining the term in the body of the work or citation of a literature reference (16/26, 62%). Ten papers included definitions of SA, and all but one referenced previous work in support of the definition (Table 7). The dominant definition authors refer to is that of Endsley (1995c, 2015). Three articles cite this model directly (Dixit et al., 2020; Korentsides et al., 2025; Stirling & Maclean, 2016), and two articles refer to it indirectly via citations that in turn cite Endsley (DeBruyn et al., 2024; Rees et al., 2017). One additional paper (Morgan & Muskett, 2020) begins with consideration of Endsley’s model as manifest in Rees et al. (2017), then present an argument for it to be supplanted by the theory of distributed SA by Stanton et al. (2017) which extends Endsley’s original framework for individual SA. Söderholm and Sonnenwald (2010) cite Sonnenwald’s own earlier work on what they termed *interwoven* SA (Sonnenwald & Pierce, 2000), which built upon individual SA concepts proposed by Vidulich et al. (1994) that are isomorphic to Endsley (1995c)*. All considered, of the nine articles identifying a theory upon which SA is grounded, seven papers (78%) align to Endsley’s framework in its original form, or as extended by others. The two articles authored by Skinner (Skinner et al., 2017; Skinner & Holdefer, 2020) are the outliers, anchored in the work of Leonard et al. (2004). Leonard’s model is framed within a healthcare-specific context, and is not as richly articulated as Endsley and its subsequent elaborations (Salmon & Plant, 2022).

Five studies treat SA as a component in a superordinate concept, with the related theoretical framework organized at the level of abstraction of the higher-order constructs.

* This should in no way be surprising, as Vidulich and colleagues cite Endsley’s earlier 1989 conference presentation of her SA model that subsequently became popularized (Endsley, 1990).

The synthesis presented in the systematic review by Leonardsen et al. (2023) identifies SA as one of four themes that emerged in the domain of person-centeredness and digital primary health care. The work of Lieng et al. (2019) utilizes the I-PASS mnemonic (Starmer et al., 2012) in which SA is set out as one component element of the structured data template for interprofessional patient handoff that bears the same name, without further theoretical grounding. Qualitative inquiry by Louca et al. (2023) included surgeons performing robot-assisted surgery as well as telerobotics operators from fields outside of healthcare, with findings that operator SA was one of four requirements identified for building trustworthiness in telerobotic systems. Work by Morian (2025) draws on a theoretical framework of non-technical skills supporting function and performance of healthcare teams, within which SA is framed as one of several acquirable skills (Flin et al., 2008). Finally, the paper by Korentsides et al. (2025) presents a novel framework to conceptualize operator capacities required for effective telemetry monitoring of patients, within which SA is one of five identified concepts.

Table 7: Study theories and definitions of SA

Reference	SA definition	Citation
De M. Goulart et al. (2025)	"the ability of the observer to be constantly aware of the patient and context and to act in a timely fashion if the patient engages in risky behavior" (p. 6)	N/A
DeBruyn et al. (2024)	"the perception of the elements in the environment, comprehension of their meaning and projection of future events" (p. 62)	Walshe et al. (2019) ^a
Dixit et al. (2020)	"Level 1, perception, is ... the ability to perceive the current state and monitor specific data elements in the environment ... Level 2, comprehension, is the ability to integrate and synthesize different data elements, Level 3, projection, is the ability to forecast or predict future states." (p. 1457)	Endsley (1995c)
Korentsides et al. (2025)	"the ability to perceive, comprehend, and anticipate changes in patient conditions based on real-time data from telemetry monitoring" (p. 4)	Hazlehurst et al. (2008); Endsley and Garland (2000)
Morgan and Muskett (2020)	<i>Lack</i> of SA defined as "insensitivity to operations or failing to "know what is going on" (p. 5)	Rees et al. (2017); Stanton et al. (2017)

Rees et al. (2017)	"sensitivity to operations or "knowing what is going on" (p. 16)	Brady et al. (2014) ^a ; Weick and Sutcliffe (2015)
Skinner et al. (2017)	"dialogue, which keeps members of the team up to date with what is happening and how they will respond if the situation changes" (p. 479)	Leonard et al. (2004)
Skinner and Holdefer (2020)	"dialogue, which keeps members of the team up to date with what is happening and how they will respond if the situation changes" plus "ongoing situationally aware knowledge of pertinent in-room and in-wound events by all members of the monitoring effort" (p. 932)	Leonard et al. (2004); Skinner (2013)
Söderholm and Sonnenwald (2010)	"interwoven situational awareness posits that to collaborate effectively actors need not have identical understanding of the situation but rather have common and unique understandings that enable them to apply their own expertise while working together" (p. 1819)	Sonnenwald and Pierce (2000)
Stirling and Maclean (2016)	"decomposition of SA into three levels (perception of the elements, comprehension of the current situation, and projection of future status)" (p. 571)	Endsley (1995c)
^a uses definition in Endsley (1995c)		

The majority of the reviewed papers (26/31, 84%) are atheoretical studies, describing observations, measurements, and/or patterns without formal hypothesis testing that characterizes theory-driven research. The studies by Jackson et al. (2018), Lieng et al. (2019), and Morian (2025) all report results of empirical tests of theory-derived hypotheses. Each of these papers sets VC as an input with SA as mediator for their respective outputs of interest. Only Jackson et al. (2018) consider SA as a unitary mediating concept, though the term is utilized without explicit definition. The others treat SA as a constituent component of a higher-order concept: Morian (2025) conceptualizes SA as a component factor in the composite construct of non-technical skills (NTS) where NTS mediates the process of team performance (output). Lieng et al. (2019) uses the I-PASS tool as a measure of handoff quality (output), where SA is a sub-component of the I-PASS (Starmer et al., 2012). Reports of iterative user-centered design studies (Bavare et al., 2021; Dixit et al., 2020) can also be considered theory-driven, since the method entails presentation of candidate designs as hypotheses that are tested against user feedback,

the results of which are fed back into refining subsequent hypothetical designs (Kushniruk & Nøhr, 2016).

The paucity of theory-driven research on SA and clinical delivery of VC is not necessarily problematic, as "...careful observation, rigorous pattern-finding and targeted problem solving can be valuable forms of research" (Miller, 2007, p. 184). Whereas theory-driven research revolves around hypothesis testing, exploratory atheoretical work may be hypothesis-generating as conjectures emerge from systematic observations and provide grist for the workings of inductive reasoning from which theories and paradigms are milled (Glaser & Strauss, 2017). Setting aside opinion papers (DeBruyn et al., 2024; Elendu et al., 2024; Skinner et al., 2017; Skinner & Holdefer, 2020), the remaining reviewed atheoretical studies are evenly divided between the purely descriptive (Aston & Powell, 2025; Boyle et al., 2021; De M. Goulart et al., 2025; Leonardsen et al., 2023; Melanie et al., 2025; Morgan et al., 2009; Powell & Gibbs, 2025; Powell et al., 2016; Sandhu et al., 2023; Santomauro et al., 2024; van Bockxmeer, 2022) and those generating conjectures or hypotheses (Ali et al., 2020; Björndell & Premberg, 2021; Kim et al., 2020; Korentsides et al., 2025; Louca et al., 2023; Morgan & Muskett, 2020; Pilosof et al., 2021; Rees et al., 2017; Söderholm & Sonnenwald, 2010; Stirling & Maclean, 2016; Zhang et al., 2022).

Hybrid in-person and virtual care

Most studies (19/31, 61%) reported on systems of care that blended together patient services delivered by in-person providers along with those delivered by remotely situated professionals using VC enabling technologies. However, only two papers (Bavare et al., 2021; van Bockxmeer, 2022) explicitly describe their teams as 'hybrid' in this sense.

3.4.3 Measurement and outcomes

Research questions RQ4 and RQ 5 ask: What methods are used to measure or assess SA in VC and HC? What outcomes have been reported for studies evaluating SA in VC/HC? None of the studies selected for inclusion in this review reported direct or indirect measures of SA. Hence, no light is able to be shed on the questions of measures or metrics for SA in applied VC or HC settings, a gap that is discussed below.

The final two research questions ask: What factors influence SA in VC and HC delivery? (RQ6) What are the reported consequences of high or low SA in these settings? (RQ7) The dearth of literature addressing measures and metrics notwithstanding, the studies included in this review do offer some insights into factors affecting SA in VC and HC. SA influences were reported in 21 studies (68%) with outcomes attributable to SA reported in 10 (32%).

Thematic analysis revealed 28 influencing factors clustering into 8 over-arching concepts, listed in Table 8. Fewer studies (10/31, 32%) discussed outcomes attributable to high or

low SA (i.e., presence or loss of SA). The heterogeneity of study designs in the papers selected for review made identification of common themes related to reported outcomes challenging to ascertain. Positive patient outcomes in single-case reports (Aston & Powell, 2025; Powell & Gibbs, 2025) are difficult to combine with retrospective analysis of serial adverse patient safety events (Rees et al., 2017) when the populations and sociotechnical systems of study vary widely between studies. Given these limitations, outcomes were able to be grouped at a high level according to one of three frames: patient-related outcomes (9 studies), provider-related outcomes (3 studies), or system-related outcomes (1 study). Four studies (13%) related positive outcomes (Aston & Powell, 2025; Jackson et al., 2018; Kim et al., 2020; Powell & Gibbs, 2025), all describing actual observed outcomes. A larger number of studies (6/31, 19%) discussed adverse SA-related outcomes but only two-thirds were considering actual observed outcomes (Björndell & Premberg, 2021; Morgan & Muskett, 2020; Morian, 2025; Rees et al., 2017). The others presented cautionary discussion in abstract regarding adverse outcomes that could arise with deterioration of SA (De M. Goulart et al., 2025; Korentsides et al., 2025).

Table 8: Factors influencing SA in VC and HC

Influence	Examples	Valence ^a	Studies reporting
Available information	Capabilities and limitations of remote site (staff/resources/environment);	+	3 (Morian, 2025; Powell et al., 2016; Santomauro et al., 2024)
	Real-time and historical vital signs	+	2 (Bavare et al., 2021; Zhang et al., 2022)
	EHR ^b records, archived images	+	2 (Kim et al., 2020; Santomauro et al., 2024)
	Multiple measures available to monitor	+	1 (Stirling & Maclean, 2016)
	Visual image of remote scene	+	1 (Boyle et al., 2021)
	Documentation explaining the cause and effect of system error states	+	1 (Louca et al., 2023)
	Technology capabilities / performance	Video image quality / multiple camera views	+
Communication network bandwidth		+	2 (DeBruyn et al., 2024; Skinner et al., 2017)
System status monitoring with visual and audio feedback		+	1 (Louca et al., 2023)
Automatic group message distribution		+	1 (Powell et al., 2016)
Remote patient monitoring		+	1 (Santomauro et al., 2024)
AI-powered prediction/forecasting		+	1 (Korentsides et al., 2025)
Individual cognitive/sensory		Divided attention	-
	Prior knowledge / experience	+	2 (Björndell & Premberg, 2021; DeBruyn et al., 2024)
	Working memory saturation	-	1 (Korentsides et al., 2025)
	Inability to use all senses	-	1 (Melanie et al., 2025)

Teamwork	Effective communication / persuasive communication	+	3 (Aston & Powell, 2025; Powell & Gibbs, 2025; Skinner & Holdefer, 2020)
	Shared mental model	+	1 (Aston & Powell, 2025)
	Trust	+	1 (Björndell & Premberg, 2021)
	Appreciation of other team members' perspectives	+	1 (DeBruyn et al., 2024)
Workflow	Frequency of patient contact	+	2 (Kim et al., 2020; Melanie et al., 2025)
	Sequence and timing of video call initiation	+/-	1 (Santomauro et al., 2024)
	Delay in communication with team members	-	1 (De M. Goulart et al., 2025)
User interface	Alignment of metrics and interface metaphors to users' existing mental models	+	2 (Korentsides et al., 2025; Stirling & Maclean, 2016)
	Dynamic interface	+	1 (Korentsides et al., 2025)
	Non-actionable alarms	-	1 (Korentsides et al., 2025)
Education/training	Script for consistent transfer of information in compressed, high-yield format	+	1 (Powell et al., 2016)
Policy	Pre-hospital care does not require EMR documentation/transfer of PII ^c enabling simpler, more easily deployable systems	+	1 (Powell et al., 2016)
^a Positive valence indicates a beneficial effect on SA when present and/or an adverse effect on SA when absent. Negative valence indicates adverse effect when present and beneficial effect when absent.			
^b electronic health record			
^c personally identifiable information			

Chapter 4 Discussion

4.1 Overview

This work undertakes to systematically survey the landscape of VC professional literature that incorporates concepts drawn from discourses in human factors and ergonomics on SA for individuals and teams working in complex dynamic environments. Despite there being extensive discourses that have been established in the domains of teamwork, situation awareness, and telehealth, little has emerged from the literature at the intersection of these domains. VC is fundamentally concerned with telesensing and telecommunication between patients and providers, sense-making (diagnosis by the professional, patients understanding explanations), and prescriptive intervention to improve anticipated outcomes — functions that map directly to the three levels of perception, comprehension, and projection in Endsley's model of SA. When VC is expanded beyond a patient-provider dyadic interaction to HC involving care teams whose members are distributed across distances, then the theories and principles of teamwork generally and distributed teamwork specifically become germane.

In the development of the bibliographic search strategy used for this study a notable contrast between the VC and SA domains became apparent: The clinically oriented bibliographic databases being searched did not have any controlled vocabulary concepts related to SA. The included studies all had a primary focus on healthcare-at-a-distance of some kind, with SA coming in as a more or less explicitly established supporting concept.

It is also noteworthy that there are no controlled vocabulary terms for HC, and that while most studies had hybrid systems of care under consideration it was rare for hybridity to be explicitly addressed in the papers. This implicit treatment of hybridity presents a challenge for identifying HC discourses in the literature absent any systematic subject tagging metadata.

At the broadest level of analysis, the studies included in this review fall into two categories: those explicitly making reference to SA in some fashion, and those which do not but nevertheless are considering ideas that are components of SA or are closely related concepts. Of those directly mentioning SA, studies subgroup further into those in which a definition of SA is offered (the minority), and those using the term without an anchoring definition. Most of the works reviewed (22/31 articles) incorporate SA as an idea that is not central to their topic focus, and formal definitions may be judged unnecessary to support the thesis under consideration. However, even among the nine studies that had SA as focus (Table 4) formal definitions were not always offered (Bavare et al., 2021; Santomauro et al., 2024). This presents a fundamental challenge to attempts at integrating and synthesizing findings from across the literature, as the pragmatic meanings of terms as-used are not necessarily harmonious.

Two reciprocally related perspectives emerge from the present synthesis, with corresponding reflective questions: (1) How does the use of VC affect practitioner and/or

team acquisition and maintenance of SA? (2) What is the influence of SA (or lack thereof) upon VC processes and outcomes? Viewed from an input-process-output frame (IPO, or IMO: input-mediator-output; Ilgen et al., 2005), these two questions approach VC and SA differently with respect to their respective “places” within the system of analysis: The former views VC as an upstream input or process mediator with SA as an output, which we shall refer to as SA-output (SA_O). The latter views SA as a mediator of the processes and outcomes of VC, which we will call SA-process (SA_P). The SA_P and SA_O views are complementary, not mutually exclusive: They represent different perspectives from which to approach the same underlying complex dynamic systems which entail causal loop feedback as a defining characteristic — as such, labelling elements of loops as ‘inputs’ and ‘outputs’ becomes somewhat arbitrary and a matter of convenience to support a given analytic exercise (Ilgen et al., 2005). Accepting the validity of heterogeneous framings, however, inevitably broadens diversity in the discourses which we see reflected in the literature at the intersection of SA and VC. The mapping for VC and SA according to IPO for each study is given in Table 9. In total, 14 studies adopt SA_P and 17 studies use the SA_O frame.

Table 9: Input-Process Mediator-Output framing for VC and SA in selected studies

Study	Input	Mediator	Output
Ali et al. (2020)	VC	AI ¹	SA
Aston and Powell (2025)	VC	SA	patient outcome
Bavare et al. (2021)	VC	dashboards	SA
Björndell and Premberg (2021)	VC	SA	provider experience
Boyle et al. (2021)	VC	attitudes	SA
De M. Goulart et al. (2025)	constant observation	VC	SA
DeBruyn et al. (2024)	teamwork	VC	SA
Dixit et al. (2020)	dashboards	design	SA
Elendu et al. (2024)	5G ICT ²	VC	SA
Jackson et al. (2018)	VC	SA	time to definitive care
Kim et al. (2020)	VC	SA	self-management
Korentsides et al. (2025)	cardiac monitoring	VC	SA
Leonardsen et al. (2023)	VC	SA	person-centeredness
Lieng et al. (2019)	VC	SA	handoff quality
Louca et al. (2023)	VC	SA	trustworthiness
Melanie et al. (2025)	VC	SA	sustainability

Morgan et al. (2009)	military deployment	VC	SA
Morgan and Muskett (2020)	VC	SA	latent system risk
Morian (2025)	VC	SA	team performance
Pilosof et al. (2021)	hospital design	VC	SA
Powell et al. (2016)	military deployment	VC	SA
Powell and Gibbs (2025)	VC	SA	patient outcome
Rees et al. (2017)	VC	SA	patient outcome
Sandhu et al. (2023)	military deployment	VC	SA
Santomauro et al. (2024)	VC	SA	patient outcome
Skinner et al. (2017)	IONM ³	VC	SA
Skinner and Holdefer (2020)	IONM ³	VC	SA
Söderholm and Sonnenwald (2010)	VC	SA	teamwork
Stirling and Maclean (2016)	VC	CTA ⁴	SA
van Bockxmeer (2022)	clinical huddle	VC	SA
Zhang et al. (2022)	EMS ⁵	VC	SA
¹ artificial intelligence			
² 5 th generation wireless information communication technology			
³ intra-operative neurophysiological monitoring			
⁴ cognitive task analysis			
⁵ emergency medical services			

Of the nine studies with SA as a topic focus, two take a SA_P perspective. Rees et al. (2017) treat SA as a mediator where input is teletriage (VC) and the output is patient safety events. Santomauro et al. (2024) similarly take VC as an input where patient outcomes are outputs with SA as a mediating factor. The remaining seven adopt SA_O perspectives. The paper by Bavare et al. (2021) describes dashboard displays as a mediator with VC as input and SA as output. The study of Stirling and Maclean (2016) is concerned with designing for SA as an output, taking VC as an input and having cognitive task analysis (CTA) as process mediator. Four studies place VC as a mediator in the production of SA as an output in different patient monitoring input contexts: cardiac monitoring (Korentsides et al., 2025), and IONM (DeBruyn et al., 2024; Skinner et al., 2017; Skinner & Holdefer, 2020).

The paper by Dixit et al. (2020) is unique among the studies reviewed in that it considers health system leaders and operations management of VC services as its population of

interest, and addresses SA at that system level rather than from the perspective of practitioners utilizing VC in patient care. While the Dixit paper addresses SA more directly than any of the other included studies, paradoxically it is not concerned with the interplay between SA and VC at all: These authors frame the performance of their institution's VC infrastructure as the situation about which awareness needs to be acquired and maintained, i.e., VC is neither input, mediator, nor output, but merely context. Their focus is on how design (mediator) of system dashboards (input) can increase SA for leadership and operations (output) — the fact of VC infrastructure as context is incidental to the discussion, and their arguments would be equally valid if applied in some other infrastructure context.

Considering the set of studies that adopt SA_o perspective, it is notable that the bulk of reviewed studies that focus on SA (7/9, 78%) fall into this group. However, SA_o also includes all four opinion papers, three of which are numbered among the SA-focused studies. Setting aside the opinion articles (DeBruyn et al., 2024; Elendu et al., 2024; Skinner et al., 2017; Skinner & Holdefer, 2020), there are four SA_o studies that give a definition of SA (De M. Goulart et al., 2025; Dixit et al., 2020; Korentsides et al., 2025; Stirling & Maclean, 2016), all of which use the construct of individual SA.

None of the four SA_o studies that give SA definitions utilize measures of SA, however. In Stirling and Maclean (2016) design requirements for occupational therapist SA in VC are developed through in-clinic observations and cognitive task analysis and while the study lays ground work for potential future objective measurement of SA as a function of their design specifications, no such measures are possible at the stage of research being reported. Korentsides et al. (2025) present work which is hypothesis-generating with specific conjectures that particular interface refinements, AI-powered predictive analytics, simulation-based training, and organizational policy adjustments will strengthen the SA of clinicians. Discussion of methods to ascertain and measure SA was outside the scope of their narrative review and would need to be addressed in any subsequent consideration of their conjectures. In the paper of Dixit et al. (2020) a user-centered design process is described for iterative dashboard development to support SA among leadership and operations management. Based on user satisfaction feedback they infer the suggestion that visualizations improved SA without making any attempt at direct measurements, something we will discuss further below. Finally, the paper by De M. Goulart et al. (2025) offers a definition of SA but since SA is not the focus of their research there is no rationale for it to be further operationalized or measured within the scope of the work they report. Bavare et al. (2021) report their experiences in user-centered design for hybrid in-person and virtual ICU rounding where effects on team SA are noted to be an observed output, though SA is neither defined nor measured in the study.

Among the 14 studies with an SA_p frame, only three offer a definition of SA and none operationalize it in a measurable way. This tranche of papers includes four of the five studies that entail SA-related concepts without explicitly using the term SA, as well as all four of the papers where SA is specified as a constituent of a higher order conceptual

construct without SA (as a component) being defined. From the studies of SA as a process mediator the theme emerges of SA being viewed as a factor in various outcomes of interest, but just how, and by how much, remain open questions. A total of six atheoretical SA_p papers offer conjectures that could be subjects of further investigation. One further conjecture arises from Jackson and colleagues' (2018) theory-driven testing of the hypothesis that compared to usual care VC use would improve time-to-care for critically ill pediatric neurosurgery patients: They offered post hoc speculation that SA (not further defined) was a mediator of the observed intervention effect—a testable proposition.

The pair of papers by Rees et al. (2017) and Morgan and Muskett (2020) are of interest to consider together, since they represent research progress with advance in understanding of SA concepts in the context of teletriage. These are the only studies for which SA is a topic focus that adopt the SA_p frame. Rees et al. (2017) produced the proposition that individual operator SA could be improved with training and better CDS tools. Even though this is readily stated as a testable experimental hypothesis, in the subsequent work of Morgan and Muskett (2020) the proposition was challenged as not being the right question to ask based upon their own atheoretical approach yielding alternate conjectures emphasizing distributed system SA over individual SA.

Conspicuously absent from the literature reviewed was any study reporting measures of SA in VC or HC clinical settings. Considering that measures of SA are well established in the human factors and ergonomics literature (see, e.g., Endsley & Garland, 2000; Fracker, 2011; Salas et al., 2011; Salmon, Stanton, & Jenkins, 2009) and that SA is recognized as a critical factor in performance and safety of health systems (Feller et al., 2023; Green et al., 2017; Weller et al., 2024), this gap warrants deeper examination. Regarding aircraft flight crews, Prince and Salas remarked, "There are several explanations for the lack of research on SA as it is evidenced in a [flight] crew. These include: access to crews, complexity in both the task and the environment, and complexity of the construct. ... to study crew SA, one must study people in their work environment. However, access to crew members as they work on their jobs (particularly when working space is limited as it is in a cockpit) is difficult to obtain" (2000, p. 299). These comments apply equally well to bedside delivery of healthcare, and the complexity is compounded when needing to assess SA across a widely distributed group of team members.

Logistical challenges and complexity notwithstanding, some progress has been made in the assessment of SA over the quarter century since the publication of Prince and Salas' comments (Endsley, 2021; Gawron, 2019). The intrinsic difficulty with SA when it comes to evaluation and measurement is that it is at its root a fundamentally private mental phenomenon of mental models and how they change over time: With no way of directly observing the SA of an individual or team, investigators must either infer SA from directly observable behaviors or rely upon subjects' verbal report of their inner experiences. Behaviors are multidetermined and context-dependent (Wickens, 2000), limiting the strength of inference that is possible especially in complex, dynamic situations that are by

definition the essence of SA and hence objective measures of SA that rely on operator report have become dominant (Endsley, 2021).

Eliciting reports of mental states is not without issue though, as it entails interruption of the task at hand in order to do so and places task performance at risk through dividing attention and/or introducing delays in the sequences of task activities. The Situation Awareness Global Assessment Technique (SAGAT, Endsley, 1995a), one of the most widely used measures of SA, is specifically designed for use in simulation scenarios where activities can be paused and “frozen” at arbitrary points in time in order to afford investigators the opportunity to query participants about their current states of perception, comprehension, and perception without task interference. Real-time probe measures have also been developed, such as the Situation Present Assessment Method (SPAM, Durso et al., 1999) where subjects are probed with verbal questions while carrying out the operational tasks. While this potentially allows for use in non-simulation settings, the intrusive nature of the probing becomes particularly problematic in a healthcare setting as it interferes not only with the operators’ cognitive task performance but will also disrupt the active processes of communication and rapport-building between the patient and provider. Retrospective post-event self-rating techniques have also been developed, but correlate poorly with SAGAT and performance measures, calling their validity into question (Salmon, Stanton, Walker, et al., 2009).

The net of all this is that there are no readily usable SA measures that are suitable to be employed in settings where the actual care of real patients is involved: It is not possible to implement a SAGAT-type freeze-probe technique in anything other than a controlled simulation environment. Real-time probing techniques such as SPAM would be too disruptive of clinical care to be acceptable, and even unprompted techniques such as “think aloud” methods (Kushniruk & Patel, 2004) would significantly disrupt the flow of communication within clinical teams, and between teams and the patients being served. The recent review of SA measures in healthcare providers by Ghaderi et al. (2023) using COSMIN methodology found that while promise was shown, none could be recommended. To the extent that team SA is a composite construct which include the individual SA of each team member plus team processes (Salas et al., 2011), measuring team SA in real-life healthcare settings also inherits all the same challenges intrinsic to evaluating individual SA. Unsurprisingly then, the state of affairs for team SA measures is no better than that for individual SA*. Studies that report direct measures of SA will

* Indeed, the view of distributed SA as an emergent property of systems-of-systems rather than a mental representational model (Salmon & Plant, 2022) complicates the appraisal of distributed SA further still, as it shifts from intuitively familiar constructs of perception, comprehension, and projection to system-level abstractions about network nodes and patterns of connectivity. The distributed SA measure anchored in this theoretical framework, Event Analysis of Systemic Teamwork (EAST, Stanton et al., 2018), was not intended to provide a quantitative

necessarily have been conducted in simulated environments and field exercises tolerant to the freeze and probe techniques being used. The absence of any such studies in the present review is a direct consequence of the *a priori* decision to limit this study's scope to real-world use of VC in patient care delivery and exclude papers focused on training or education.

Even without studies reporting SA measures in clinical practice settings, the reviewed body of work does offer some insights into the ways in which SA that is supported and enhanced by VC use within distributed HC teams might address the healthcare system quintuple aims of improved patient experience, better outcomes, lower costs, clinician wellbeing, and health equity (Itchhaporia, 2021). Consistent with Picot's "...plea for abandoning the pilot study in favour of the case study..." (1999, p. 27) to foster development and adoption of best practices in VC, some of the most compelling reports among the reviewed studies were the experience papers of Aston and Powell (2025), Morian (2025), and Powell and Gibbs (2025), as well as the evaluation research of Santomauro et al. (2024). Detailed descriptions of the distributed sociotechnical systems in real-world use highlight how SA is acquired and maintained by both on-site clinicians and remote VC providers and demonstrate how outcomes, experiences, costs, and equity can all be improved. Narrative reviews (Ali et al., 2020; Elendu et al., 2024; Korentsides et al., 2025) and opinion papers (DeBruyn et al., 2024; Skinner et al., 2017; Skinner & Holdefer, 2020) asserting authors' beliefs about potential benefits to be realized are by comparison less persuasive.

The concept of hybrid care — combined VC and in-person face to face care (F2F)— is demonstrated to exist in the literature, with the majority of reviewed papers describing healthcare delivery combining both modalities in some manner. However, explicit identification of these models as HC was rare. The recent rapid review of HC by Vélez et al. (2023) similarly found that most literature examining virtual and in-person care focused on comparisons between the two with very few studies explicitly describing the implementation of hybrid models. They also found that models of HC varied widely in terms of VC and F2F being placed in series (e.g., teletriage for routing to appropriate F2F), arranged as parallel service channels (e.g., virtual counselling or monitoring alongside F2F services), or blended in synchronous multidisciplinary team care, yet that many reports

evaluation of the 'quality' of distributed SA (such as the SAGAT does for individual SA) but rather aims "...to describe which agents are using what information and what SA transactions occur..." among them (Salmon & Plant, 2022, p. 3).

did not provide detailed explanations of just how virtual and in-person care services were integrated.

To be able to investigate SA in HC more deeply will require clarity in the definitions and descriptions of HC models and the distributed teamwork being entailed. Fundamental to Endsley's (1995c) foundational formulation of SA is that it is comprised of perception, comprehension, and projection of salient environmental elements *within a volume of time and space*. What is salient and where the boundaries lie for the relevant volume of time and space, i.e., the 'situation' for which awareness is to be acquired and maintained, will be task-defined. There is considerable difference between the volume of space and time that concerns the trauma resuscitation team (trauma bay, minutes) and that for a hospital's ICU team (entire site, inclusive of the trauma bay and operating rooms, plus outlying sources of transfers, over a scale of hours to days). This range of times and distances needs to be accounted for in research on SA in different HC settings, as findings from a study of a virtual MRP program such as the limited overnight coverage model described by Blacklaws et al. (2025) may not generalize to a continuous virtual MRP model of care (Kuperman et al., 2018). Development of consensus around how to best describe and categorize HC sociotechnical systems will be needed in order to understand the commonalities and differences among the various use cases. In particular, having a clearly articulated conception of the time scope across which SA must be achieved and sustained for a given HC implementation will be valuable in system design and evaluation. The temporality of a given context is known to affect the ways in which SA is manifested (Samimian-Darash, 2025). Systems with longer time constant (τ) change more slowly in response to stepped inputs (i.e., have greater lag, or latency), so in a HC setting with sufficiently large τ it can become feasible to do certain kinds of probe studies for direct measurement of provider SA, provided that the time needed for responding to probes is small relative to the time scale over which environmental elements are expected to change and oblige the clinician to update their SA. While it may never be possible to access the mental models of providers whilst they are engaged in rapid-sequence time-sensitive activities such as a trauma resuscitation, a slower rate of evolution for environmental elements on a virtual hospitalist service should allow for SAGAT or SPAM type measurement techniques with the caveat that these would need to be timed in such a manner that probe questions occur between engagements with individual patients, and would be oriented to case-, ward-, or service-level SA rather than immediate in-call SA.

4.2 Study strengths

This study has several key strengths. First is its use of a systematic review and mapping methodology following the accepted PRISMA-ScR framework for best practices in scoping reviews. This ensures rigor and transparency in the process of literature identification, selection, and synthesis. Searching multiple bibliographic databases as well as grey literature served to maximize coverage of the literature and reduce publication bias. It employs the PCC (Population, Concept, Context) framework to organize and focus eligibility criteria for study inclusion, ensuring that there is relevance and consistency in the literature selected for review. Inclusion of detailed documentation of search strategy logic, selection criteria, and data management processes support the transparency and reproducibility of this study.

A second strength is the study's focus on real-world clinical practice. Intentional exclusion of purely technical, educational, or simulation-based research to instead focus on investigations of SA in clinically deployed virtual and hybrid care delivery settings makes the findings more applicable and relevant to current healthcare system challenges. As will be discussed below, however, this tight clinical focus also brings its limitations.

The study employs rich thematic analysis with synthesis of findings across multiple dimensions including definitions, theoretical models, influencing factors, and outcomes related to SA in VC and HC. This allowed for identification of 28 influencing factors, clustering into 8 overarching concepts. The interdisciplinary perspective employed draws from literature in human factors, teamwork, and health informatics which broadens the relevance and applicability of the study findings.

4.3 Knowledge contribution

4.3.1 Patterns

This work presents the first attempt at description and synthesis of the existing literature at the intersection of human factors research into situation awareness and discourses on healthcare services provided by distributed teams via use of digital virtual care technologies arising out of both the clinical and the medical informatics domains. As a response to the global COVID-19 pandemic many healthcare organizations saw dramatic growth in VC adoption and use, such that VC quickly became a salient element of the environments within which clinicians and providers had to acquire and maintain effective situational awareness. Intuitive notions of SA without explicit definition appear most frequently in the reviewed literature that is largely atheoretical and descriptive. Opinions and conjectures regarding the benefits VC for individual and team SA are offered by some

authors, but not with a sufficiently articulated theoretical undergirding to be stated as formally testable hypotheses. The same is true for the speculations that are offered regarding both influences of VC effects on SA and the influences of SA on the outcomes of VC and HC service. This literature is largely characterized by a general air of enthusiasm for the ability of VC to improve SA of healthcare teams and individual providers. However, evaluation studies with measures of SA that could refute or support those conjectures have yet to be done in the context of VC or HC.

4.3.2 Advances

The high proportion of atheoretical descriptive research suggests that the intersection of VC and SA is still a nascent area of pretheoretical scientific investigation. The studies included in this review examining patient safety within the UK National Health Service telephone triage service represent advancement in the level of sophistication in application of SA theory to the topic area over the interval of years between studies. The earlier work of Rees et al. (2017) that invokes fairly basic notions of individual SA in its discussion of findings is contrasted by the more nuanced treatment afforded by Morgan and Muskett (2020) whose interactionist approach identifies distributed (system) SA as a theoretical frame that was better suited to the subject matter.

4.3.3 Gaps

This study cannot speak to the state of the science for measures and evaluation of SA in VC and HC contexts, except to say that any such work is not being reported and conducted in actual clinical care settings where real patients are being treated. Studies of simulation and field exercises where direct measures of SA are most feasible were excluded from this review based on the way research questions had been formulated at inception, and subsequently how inclusion/exclusion criteria were specified.

While it has not been feasible to employ accepted direct measures of SA in real-time health care settings to date, the resultant gap in evidence may becoming possible to start to address: As noted in the discussion, the diffusion of HC models into clinical service lines that have differing temporalities compared to those domains such as operative anesthesia and critical care medicine where application of SA within healthcare was pioneered may begin to afford opportunities for existing measures of SA to be applied in clinical settings without unacceptable disruption of tasks.

A more fundamental gap in the source literature may have been identified in the absence of bibliographic controlled vocabulary concepts for notions of SA and HC. Controlled vocabularies will reflect the lexicon of contemporary professional and scholarly endeavors

as the semantics and pragmatics of language evolve with use over time. Hence, the lack of relevant terms in the controlled vocabularies almost certainly results from the ideas and concepts related to SA and HC most commonly being used informally, with reliance on intuitive understanding of the terms rather than theory-linked explicit definitions. Since SA has well developed theoretical treatment in the human factors and ergonomics literature, and so it can be considered a deficiency in the domain boundary definitions that bibliographers do not consider this work to properly belong in the biomedical literature. Such cannot be said for the concept of hybrid care, as this notion is situated squarely within the scope of healthcare literature. The absence of an acknowledged and accepted definition of hybrid care in the academic literature despite its growing use in Canadian healthcare policy discourse (Abacus Data & Canadian Medical Association (CMA), 2020; Canada Health Infoway, 2024a, 2024b; Real-Time Virtual Support Learning Health System, 2024; Virtual Care Task Force, 2022) is a gap that will need to be addressed if aspirations to evidence-based practices and learning health systems are to be attained.

4.3.4 Evidence for practice

This synthesis does not distill down to any specific evidence-based recommendations for clinical practice, other than exercising caution in transferring findings reported in experience papers to another context since the lack of theory-grounded definitions and reliance on implicit, intuitive understandings for terms limits generalizability. Evidence for informatics professionals would be the need for more attention to the formal description and definition of HC when reporting on design, implementation, or evaluation of these sociotechnical systems. The absence of controlled vocabulary content coverage for SA and HC is important for informatics professionals to appreciate, and to reflect upon as possible changes to submit for consideration by the authorities overseeing the controlled vocabulary.

4.3.5 Research recommendations

With the learnings from this study about how the evidence base for direct measures of SA in clinical care is not rooted in real-world patient care scenarios, a clear next step should be to extend the scope of this review to include reports investigating SA in clinical simulation, field exercises, and training scenarios. A replication study with suitably modified inclusion/exclusion criteria and that specifies a multi-reviewer protocol, per Arksey and O'Malley (2005), would add rigor and therefore confidence in the findings and would be the favored approach for following up this study.

Advancing research at the intersection of situation awareness in virtual care and hybrid team-based care combining in-person and virtual components will benefit from methodological innovation, theoretical clarity, and consideration of the individual and collective aspects of SA within the evolving landscape of contemporary healthcare systems. Research would ideally benefit from development of a valid, practical, non-disruptive tool for direct measurement of SA in real-world VC and HC settings, but this is likely to remain elusive given the practical challenges for accessing private mental representational states of clinicians who are otherwise engaged. Existing tools that entail an obligate burden of task interruption might be suitable for adapted use in certain HC systems that differ in temporality from highly dynamic settings (e.g., anesthesia, trauma resuscitation) where no interruptions can safely be afforded, and this would be a valuable area for focused inquiry.

Future investigations into the interplay of VC and SA should be encouraged to include explicit definitions of SA and make clear how SA is conceptualized and operationalized in their work. Similarly, there is a need for consensus on how hybrid models of care are defined and described as sociotechnical systems. Future studies should include detailed accounts of how in-person and virtual care modalities are integrated, including team structure and composition, workflows, and distribution of responsibilities, in addition to specification of the enabling technologies and interfaces used. Such work should incorporate knowledge from human factors and sociotechnical systems research to better explicate how technology, workflow, and organizational factors interact to influence SA in VC and HC.

4.4 Limitations

This study has limitations arising out of the methodology employed, and from the contents of the studies on which the review is based. The study is limited by its organization as single-investigator protocol, which deviates from best practice for scoping reviews that calls for at least two reviewers to independently apply the inclusion and exclusion criteria for study selection, with clear procedures for resolving disagreements and with reporting of concordance between reviewers (Arksey & O'Malley, 2005). This introduces risk of bias in study selection that cannot be completely mitigated. Despite efforts to include grey literature in the review, there is risk of additional selection bias introduction as not all relevant studies or reports may be discoverable or accessible through available indices and search engines.

Another limitation arises from the initial parameters set out for this review, which entailed the strategic decision to exclude training and simulation-based studies and focus solely on

research done in actual patient care settings. While the value of this decision has been touched on above in the consideration of study strengths, it had the unforeseen consequence of all studies reporting direct measures of SA being screened out since technical constraints of those measurement techniques preclude their use outside of field exercises and simulator studies. What appears as a gap in the literature regarding measures of SA in VC more likely reflects weakness revealed in this study's search strategy to identify pertinent research rather than non-existence of any such research, and this has important implications for future investigations in this area.

Limits on the strength of the study's findings also arises from the nature of the reviewed studies themselves. There is broad heterogeneity of study designs and contexts, with reports drawing from a range of clinical settings, team structures, modalities of VC employed, and research methods utilized. This wide range of variation among the included studies limited the potential for synthesis of findings and the ability to identify common themes related to SA in VC and HC. There was limited theoretical grounding within the reviewed work, with only a minority of studies offering clear definitions or referencing established models of SA. HC was not well described or defined either, with only two papers using the term explicitly despite the majority of studies describing service delivery that entailed components of both in-person and virtual care modalities. Considering that the controlled terminology sets for the bibliographic databases search vocabularies did not include any concept coverage for SA or HC, the lack of clarity in definitions and descriptions in the reviewed studies may reflect more broadly the state of discourses at the intersection of virtual care, distributed teamwork, and situational awareness. The absence of controlled vocabulary terms for situation awareness and hybrid care makes systematic searching and identification of pertinent literature more difficult to undertake.

Conclusion

The rapid expansion of VC during the COVID-19 pandemic has fundamentally reshaped clinical practice, introducing new ongoing complexities for individuals and teams tasked with maintaining SA across physical and virtual boundaries, especially when being implemented in new models that attempt to mitigate contingencies of a widespread HHR crisis. This systematic review provides the first comprehensive mapping of the literature at the intersection of situation awareness (SA) and virtual/hybrid care (VC/HC) in healthcare delivery, setting out to answer the main research question (RQ1), "What is known from the existing literature about situation awareness in virtual and hybrid virtual/in-person care contexts?" While SA is widely recognized as critical for safe and effective decision-making in dynamic environments, including healthcare, this review reveals that its

conceptualization, measurement, and operationalization in VC/HC contexts remain poorly defined and underexplored.

The sub-questions, “How is SA defined in research into VC and HC?” (RQ2) and, “What theoretical models have been developed and applied to SA in VC/HC?” (RQ3) posed in this study were addressed by the findings that most studies in the reviewed literature reference SA intuitively, without explicit definition or theoretical grounding, and predominantly employ descriptive, atheoretical approaches. The dominant theoretical model cited is Endsley’s three-level framework of perception, comprehension, and projection, though distributed and system-level perspectives are increasingly acknowledged. Despite the recognized importance of SA, none of the included studies reported direct or indirect measures of SA in real-world VC/HC clinical settings, leaving the questions, “What methods are used to measure or assess SA in VC and HC?” (RQ4) and, “What outcomes have been reported for studies evaluating SA in VC/HC?” (RQ5) unanswered at present. While this highlights a significant gap in the understanding emerging from this synthesis, it would be premature to consider this to be evidence of a major gap in the underlying evidence base as it most likely arises as a consequence of the review’s inclusion/exclusion criteria that de-scoped simulation studies where established measures of SA (e.g., SAGAT, SPAM) would typically be used.

This study identifies 28 factors influencing SA in VC and HC (RQ6), clustering into eight overarching concepts of available information, technology capabilities / performance, individual cognitive / sensory, teamwork, workflow, user interface, education / training, and policy. Outcomes attributable to SA are only reported in a minority of studies. Positive effects of VC on SA are often asserted, particularly in hybrid distributed teams, but these claims lack robust empirical support (RQ7).

The absence of controlled vocabulary terms for SA and HC concepts in bibliographic databases adds complexity to the systematic identification and selection of relevant literature for review and synthesis. To advance scholarship and clinical practice in this emerging field, future research should (1) explicitly define and operationalize SA in VC/HC contexts; (2) seek consensus on definitions and descriptions of hybrid care models and distributed teamwork that are enabled by VC technologies; and (3) incorporate insights from human factors, sociotechnical systems, and teamwork theory in order to explicate the interplay among technological, workflow, and organizational factors as they influence acquisition and maintenance of individual, team, and system SA. Ultimately, a deeper understanding of SA in VC and HC is essential for attaining the quintuple aims of healthcare in an increasingly digital and distributed ecosystem.

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Appendices

Appendix A

Literature Search Specification Details

Database queries are included for each of the bibliographic resources utilized in this study. Each presents the platform-specific syntax implementation of the general search logic specification (Table 3) and includes the number of items returned for the date on which the query was run.

MEDLINE (Ovid)

Ovid MEDLINE(R) ALL <1946 to September 03, 2025>		
Thu Sep 11 2025 12:09 (Pacific Daylight Time)		
1	telehomecare.mp.	101
2	telementor*.mp.	653
3	telemonitor*.mp.	3097
4	Telemetry/ or telemetry.mp.	16315
5	1 or 2 or 3 or 4	19842
6	(virtual* adj2 care).mp.	2767
7	(virtual* adj2 medic*).mp.	974
8	(virtual* adj2 health*).mp.	2365
9	(virtual* adj2 visit*).mp.	1452
10	Telemedicine/ or telemedicine.mp.	61226
11	((video* adj2 visit*) or Videoconferenc*).mp. or *Videoconferencing/	7211
12	telepsychiatry.mp.	1274
13	teleneurology.mp.	291
14	telemental health.mp. or Distance Counseling/ or Mental Health Teletherapy/	654
15	telehealth.mp.	19542
16	teleconsultation.mp.	2027
17	telenursing.mp. or Telenursing/	578
18	(remote* adj2 consult*).mp. or exp Remote Consultation/	7578
19	(remote* adj2 care).mp.	2319
20	Monitoring, Ambulatory/ or Remote Patient Monitoring/ or (remote* adj2 patient* adj2 monitor*).mp.	10437
21	(digital* adj2 consult*).mp.	225
22	((virtual* adj2 triag*) or telephone triage).mp.	823

23	teleICU.mp.	14
24	(virtual* adj2 MRP).mp.	1
25	(virtual* adj2 hospitalist*).mp.	7
26	hybrid* N2 care.mp.	0
27	("mixed model*" adj2 care).mp.	30
28	((combin* adj5 virtual) and (virtual* adj3 in-person)).mp.	74
29	(situation* adj3 aware*).mp.	3172
30	("context*" adj3 "aware*").mp.	2112
31	(operat* adj3 aware*).mp.	770
32	(environment* adj3 aware*).mp.	2639
33	("organization*" adj3 "aware*").mp.	501
34	29 or 30 or 31 or 32 or 33	8967
35	5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28	107459
36	34 and 35	161

CINAHL (EBSCOhost)

EBSCOhost CINAHL Complete		Thu, September 11, 2025 11:17:55 AM	
#	Query	Limiters/Expanders	Results
S34	S32 AND S33	Search modes - Proximity	57
S33	S28 OR S30	Search modes - Proximity	60,868
S32	S5 OR S31	Search modes - Proximity	5,803
S31	"organization*" N3 "aware*"	Search modes - Proximity	364
S30	(MH "Telemetry") OR "telemetry" OR "telehomecare" OR "telementor*" OR "telemonitor*"	Search modes - Proximity	4,650
S29	S5 AND S28	Search modes - Proximity	50
S28	S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27	Search modes - Proximity	57,491
S27	(combin* N5 virtual*) AND (virtual* N3 in-person)	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	182

S26	"mixed model*" N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	75
S25	hybrid* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	580
S24	(virtual* N2 hospitalist*) OR (virtual* N2 "MRP")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	16
S23	telenursing OR (MH "telenursing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	3,185
S22	tele-icu OR teleICU	Expanders - Apply related words; Also search within the full text of the articles; Apply equivalent subjects Search modes - Proximity	462
S21	virtual* N2 triag* OR (MH "Telephone Triage Nursing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	188
S20	digital N2 consult*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	593
S19	(MH "Remote Patient Monitoring") OR remote* N2 patient* N2 monitor*	Search modes - Proximity	842
S18	remote* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	4,306
S17	remote* N2 consult* OR (MH "Remote Consultation")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	5,316
S16	teleconsultation	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1,668

S15	telehealth OR (MH "telehealth")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	36,470
S14	telemedicine OR (MH "telemedicine")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	36,400
S13	"telemental health" OR (MH "Mental Health Teletherapy")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	855
S12	teleneurology	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	137
S11	(MH "Telepsychiatry") OR "telepsychiatry" OR (MH "Mental Health Teletherapy")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	2,125
S10	(video* N2 visit*) OR (MH "Videoconferencing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	6,461
S9	virtual* N2 health*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	8,437
S8	virtual* N2 visit*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	2,910
S7	virtual* N2 medic*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	2,943
S6	virtual* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	5,274
S5	S1 OR S2 OR S3 OR S4	Search modes - Proximity	5,451

S4	environment* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	4,627
S3	operat* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1,387
S2	context* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	2,834
S1	(situation* N3 aware*) OR (MH "Reality Orientation (Iowa NIC)") OR (MH Problem Identification) OR (MH Intuition) OR (MH "Anticipatory Guidance (Iowa NIC)")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	8,633

Embase (Ovid)

Embase <1974 to 2025 September 10>		
Thu Sep 11 2025 14:39 (Pacific Daylight Time)		
1	(virtual* adj2 care).mp. or telecare/	4797
2	(virtual* adj2 medic*).mp.	1392
3	(virtual* adj2 health*).mp.	2839
4	(virtual* adj2 visit*).mp.	2721
5	exp telemedicine/ or telemedicine.mp.	98636
6	((video* adj2 visit*) or Videoconferenc*).mp. or *Videoconferencing/	16323
7	telepsychiatry.mp.	2294
8	teleneurology.mp.	481
9	telemental health.mp. or e-counseling/ or teletherapy/	2409
10	telehealth.mp. or telehealth/	41761
11	teleconsultation.mp. or exp teleconsultation/	19591
12	telenursing.mp. or Telenursing/	745
13	(remote* adj2 consult*).mp. or video consultation/	3969
14	(remote* adj2 care).mp.	3167
15	(remote* adj2 patient* adj2 monitor*).mp. or home monitoring/	9503
16	telehomecare.mp.	137
17	telementor*.mp.	869

18	telemonitor*.mp. or telemonitoring/	9655
19	telemetry.mp. or (*telemetry/ or *telephone telemetry/)	27313
20	(digital* adj2 consult*).mp.	305
21	((virtual* adj2 triag*) or telephone triage).mp.	1226
22	teleICU.mp.	37
23	(virtual* adj2 MRP).mp.	0
24	(virtual* adj2 hospitalist*).mp.	10
25	hybrid* N2 care.mp.	0
26	("mixed model*" adj2 care).mp.	44
27	((combin* adj5 virtual) and (virtual* adj3 in-person)).mp.	115
28	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	178094
29	(situation* adj3 aware*).mp.	4175
30	("context*" adj3 "aware*").mp.	2323
31	(operat* adj3 aware*).mp.	1088
32	(environment* adj3 aware*).mp.	3035
33	("organization*" adj3 "aware*").mp.	634
34	29 or 30 or 31 or 32 or 33	10991
35	28 and 34	203

APA PsycINFO (EBSCOhost)

Thu, September 11, 2025 12:43:02 PM			
#	Query	Limiters/Expanders	Results
S34	S32 AND S33	Search modes - Proximity	21
S33	S28 OR S30	Search modes - Proximity	20,573
S32	S5 OR S31	Search modes - Proximity	7,116
S31	"organization*" N3 "aware*"	Search modes - Proximity	857
S30	(MH "Telemetry") OR "telemetry" OR "telehomecare" OR "telementor*" OR "telemonitor*"	Search modes - Proximity	1,821
S29	S5 AND S28	Search modes - Proximity	17

S28	S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27	Search modes - Proximity	19,071
S27	(combin* N5 virtual*) AND (virtual* N3 in-person)	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	15
S26	"mixed model*" N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	14
S25	hybrid* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	90
S24	(virtual* N2 hospitalist*) OR (virtual* N2 "MRP")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1
S23	telenursing OR (MH "telenursing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	137
S22	tele-icu OR teleICU	Expanders - Apply related words; Also search within the full text of the articles; Apply equivalent subjects Search modes - Proximity	15
S21	virtual* N2 triag* OR (MH "Telephone Triage Nursing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	5

S20	digital N2 consult*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	57
S19	(MH "Remote Patient Monitoring") OR remote* N2 patient* N2 monitor*	Search modes - Proximity	139
S18	remote* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	478
S17	remote* N2 consult* OR (MH "Remote Consultation")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	953
S16	teleconsultation	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	427
S15	telehealth OR (MH "telehealth")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	6,339
S14	telemedicine OR (MH "telemedicine")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	14,738
S13	"telemental health" OR (MH "Mental Health Teletherapy")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	708
S12	teleneurology	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	80

S11	(MH "Telepsychiatry") OR "telepsychiatry" OR (MH "Mental Health Teletherapy")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1,116
S10	(video* N2 visit*) OR (MH "Videoconferencing")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	415
S9	virtual* N2 health*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	742
S8	virtual* N2 visit*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	325
S7	virtual* N2 medic*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	3,331
S6	virtual* N2 care	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	596
S5	S1 OR S2 OR S3 OR S4	Search modes - Proximity	6,301
S4	environment* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1,852
S3	operat* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	526

S2	context* N3 aware*	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	1,616
S1	(situation* N3 aware*) OR (MH "Reality Orientation (Iowa NIC)") OR (MH Problem Identification) OR (MH Intuition) OR (MH "Anticipatory Guidance (Iowa NIC)")	Expanders - Apply related words; Also search within the full text of the articles Search modes - Proximity	2,685

Scopus (Elsevier)

date	Thu, September 11, 2025 13:53:02 PM	
	search string	results
44	((TITLE-ABS-KEY (telemetry)) OR (TITLE-ABS-KEY (telemonitor*)) OR (TITLE-ABS-KEY (telemotor*)) OR (TITLE-ABS-KEY (telehomecare)) OR (TITLE-ABS-KEY (combin* W/5 virtual*) AND (virtual* W/3 "in-person"))) OR (TITLE-ABS-KEY ("mixed model" W/2 care)) OR (TITLE-ABS-KEY (hybrid* W/2 care)) OR (TITLE-ABS-KEY (virtual* W/2 hospitalist*)) OR (TITLE-ABS-KEY (virtual* W/2 "MRP")) OR (TITLE-ABS-KEY (teleICU)) OR (TITLE-ABS-KEY (virtual* W/2 triag*)) OR (TITLE-ABS-KEY (digital W/2 consult*)) OR (TITLE-ABS-KEY (remote* W/2 patient* W/2 monitor*)) OR (TITLE-ABS-KEY (remote* W/2 care)) OR (TITLE-ABS-KEY (remote* W/2 consult*)) OR (TITLE-ABS-KEY (teleconsultation)) OR (TITLE-ABS-KEY (telenursing)) OR (TITLE-ABS-KEY (telehealth)) OR (TITLE-ABS-KEY (telemedicine)) OR (TITLE-ABS-KEY ("telemental health")) OR (TITLE-ABS-KEY (teleneurology)) OR (TITLE-ABS-KEY (telepsychiatry)) OR (TITLE-ABS-KEY (videoconferenc*)) OR (TITLE-ABS-KEY (video* W/2 visit*)) OR (TITLE-ABS-KEY (virtual* W/2 visit*)) OR (TITLE-ABS-KEY (virtual* W/2 medic*)) OR (TITLE-ABS-KEY (virtual* W/2 care)) OR (TITLE-ABS-KEY (virtual* W/2 health*))) AND ((TITLE-ABS-KEY (situation* W/3 aware*)) OR (TITLE-ABS-KEY (context* W/3 aware*)) OR (TITLE-ABS-KEY (operat* W/3 aware*)) OR (TITLE-ABS-KEY (environment* W/3 aware*)) OR (TITLE-ABS-KEY (organization* W/3 aware*))))	686
43	(TITLE-ABS-KEY (situation* W/3 aware*)) OR (TITLE-ABS-KEY (context* W/3 aware*)) OR (TITLE-ABS-KEY (operat* W/3 aware*)) OR (TITLE-ABS-KEY (environment* W/3 aware*)) OR (TITLE-ABS-KEY (organization* W/3 aware*))	104698

42	TITLE-ABS-KEY (organization* W/3 aware*)	4268
41	TITLE-ABS-KEY (environment* W/3 aware*)	30086
40	TITLE-ABS-KEY (operat* W/3 aware*)	6357
39	TITLE-ABS-KEY (context* W/3 aware*)	39894
38	TITLE-ABS-KEY (situation* W/3 aware*)	29844
37	(TITLE-ABS-KEY (telemetry)) OR (TITLE-ABS-KEY (telemonitor*)) OR (TITLE-ABS-KEY (telementor*)) OR (TITLE-ABS-KEY (telehomecare)) OR (TITLE-ABS-KEY ((combin* W/5 virtual*) AND (virtual* W/3 "in-person"))) OR (TITLE-ABS-KEY ("mixed model" W/2 care)) OR (TITLE-ABS-KEY (hybrid* W/2 care)) OR (TITLE-ABS-KEY (virtual* W/2 hospitalist*)) OR (TITLE-ABS-KEY (virtual* W/2 "MRP")) OR (TITLE-ABS-KEY (teleICU)) OR (TITLE-ABS-KEY (virtual* W/2 triag*)) OR (TITLE-ABS-KEY (digital W/2 consult*)) OR (TITLE-ABS-KEY (remote* W/2 patient* W/2 monitor*)) OR (TITLE-ABS-KEY (remote* W/2 care)) OR (TITLE-ABS-KEY (remote* W/2 consult*)) OR (TITLE-ABS-KEY (teleconsultation)) OR (TITLE-ABS-KEY (telenursing)) OR (TITLE-ABS-KEY (telehealth)) OR (TITLE-ABS-KEY (telemedicine)) OR (TITLE-ABS-KEY ("telemental health")) OR (TITLE-ABS-KEY (teleneurology)) OR (TITLE-ABS-KEY (telepsychiatry)) OR (TITLE-ABS-KEY (videoconferenc*)) OR (TITLE-ABS-KEY (video* W/2 visit*)) OR (TITLE-ABS-KEY (virtual* W/2 visit*)) OR (TITLE-ABS-KEY (virtual* W/2 medic*)) OR (TITLE-ABS-KEY (virtual* W/2 care)) OR (TITLE-ABS-KEY (virtual* W/2 health*))	207703
36	TITLE-ABS-KEY (telemetry)	57737
35	TITLE-ABS-KEY (telemonitor*)	8392
34	TITLE-ABS-KEY (telementor*)	911
33	TITLE-ABS-KEY (telehomecare)	208
32	TITLE-ABS-KEY ((combin* W/5 virtual*) AND (virtual* W/3 "in-person"))	115
31	TITLE-ABS-KEY ("mixed model" W/2 care)	80
30	TITLE-ABS-KEY (hybrid* W/2 care)	594
29	TITLE-ABS-KEY (virtual* W/2 hospitalist*)	8
28	TITLE-ABS-KEY (virtual* W/2 "MRP")	3
27	TITLE-ABS-KEY (teleICU)	19
26	TITLE-ABS-KEY (virtual* W/2 triag*)	119
25	TITLE-ABS-KEY (digital W/2 consult*)	667
24	TITLE-ABS-KEY (remote* W/2 patient* W/2 monitor*)	7117
23	TITLE-ABS-KEY (remote* W/2 care)	4907
22	TITLE-ABS-KEY (remote* W/2 consult*)	7935
21	TITLE-ABS-KEY (teleconsultation)	16430

20	TITLE-ABS-KEY (telenursing)	894
19	TITLE-ABS-KEY (telehealth)	35760
18	TITLE-ABS-KEY (telemedicine)	86164
17	TITLE-ABS-KEY ("telemental health")	772
16	TITLE-ABS-KEY (teleneurology)	378
15	TITLE-ABS-KEY (telepsychiatry)	2253
14	TITLE-ABS-KEY (videoconferenc*)	17133
13	TITLE-ABS-KEY (video* W/2 visit*)	1693
12	TITLE-ABS-KEY (virtual* W/2 visit*)	2618
10	TITLE-ABS-KEY (virtual* W/2 medic*)	3192
7	TITLE-ABS-KEY (virtual* W/2 care)	3873
5	TITLE-ABS-KEY (virtual* W/2 health*)	5394

Web of Science (Clarivate)

Thu Sep 11 2025 11:43:22 GMT-0700 (Pacific Daylight Time)		
#	Search Query	Results
1	virtual* NEAR/2 care (Topic)	3481
2	TS=(virtual* NEAR/2 medic*)	2252
3	TS=(virtual* NEAR/2 visit*)	2310
4	TS=(virtual* NEAR/2 health*)	4019
5	TS=(video* NEAR/2 visit*)	1599
6	TS=(videoconferenc*)	8689
7	TS=(telepsychiatry)	2049
8	TS=(teleneurology)	423
9	TS=(telemental health)	1036
10	TS=(telemedicine)	46378
11	TS=(telehealth)	26018
12	TS=(telenursing)	504
13	TS=(teleconsultation)	2459
14	TS=(remote* NEAR/2 consult*)	2410
15	TS=(remote* NEAR/2 care)	3863
16	TS=(remote* NEAR/2 patient* NEAR/2 monitor*)	3629
17	TS=(digital NEAR/2 consult*)	456
18	TS=(virtual* NEAR/2 triag*)	110
19	TS=(teleICU)	20
20	TS=(virtual* NEAR/2 "MRP")	1
21	TS=(virtual* NEAR/2 hospitalist*)	8
22	TS=(hybrid* NEAR/2 care)	560

23	TS=("mixed model" NEAR/2 care)	43
24	TS=((combin* NEAR/5 virtual*) AND (virtual* NEAR/3 "in-person"))	106
25	TS=(telehomecare)	175
26	TS=(telementor*)	784
27	TS=(telemonitor*) OR TS=(telemetry)	37676
28	#27 OR #26 OR #25 OR #24 OR #23 OR #22 OR #21 OR #20 OR #19 OR #18 OR #17 OR #16 OR #15 OR #14 OR #13 OR #12 OR #11 OR #10 OR #9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1	122845
29	TS=(situation* NEAR/3 aware*)	20371
30	TS=(context* NEAR/3 aware*)	26122
31	TS=(operat* NEAR/3 aware*)	4133
32	TS=(environment* NEAR/3 aware*)	20469
33	TS=(organization* NEAR/3 aware*)	2239
34	#29 OR #30 OR #31 OR #32 OR #33	69637
35	#28 AND #34	344

ProQuest Dissertations & Theses Citation Index (Clarivate)

ProQuest™ Dissertations & Theses Citation Index		
Thu Sep 11 2025 12:50:48 GMT-0700 (Pacific Daylight Time)		
#	Search Query	Results
1	TS=(virtual* NEAR/2 care)	148
2	TS=(virtual* NEAR/2 medic*)	204
3	TS=(virtual* NEAR/2 visit*)	164
4	TS=(virtual* NEAR/2 health*)	257
5	TS=(video* NEAR/2 visit*)	116
6	TS=(videoconferenc*)	985
7	TS=(telepsychiatry)	37
8	TS=(teleneurology)	2
9	TS=(telemental health)	57
10	TS=(telemedicine)	1914
11	TS=(telehealth)	1206
12	TS=(telenursing)	11
13	TS=(teleconsultation)	87
14	TS=(remote* NEAR/2 consult*)	100
15	TS=(remote* NEAR/2 care)	184

16	TS=(remote* NEAR/2 patient* NEAR/2 monitor*)	189
17	TS=(digital NEAR/2 consult*)	59
18	TS=(virtual*NEAR/2 triag*)	0
19	TS=(teleICU)	3
20	TS=(virtual* NEAR/2 "MRP")	0
21	TS=(virtual* NEAR/2 hospitalist*)	0
22	TS=(hybrid* NEAR/2 care)	25
23	TS=("mixed model" NEAR/2 care)	0
24	TS=((combin* NEAR/5 virtual*) AND (virtual* NEAR/3 "in-person"))	2
25	TS=(telehomecare)	11
26	TS=(telementor*)	31
27	TS=(telemonitor*)	176
28	TS=(telemetry)	3502
29	#28 OR #27 OR #26 OR #25 OR #24 OR #23 OR #22 OR #21 OR #20 OR #19 OR #18 OR #17 OR #16 OR #15 OR #14 OR #13 OR #12 OR #11 OR #10 OR #9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1	8640
30	TS=(situation* NEAR/3 aware*)	2331
31	TS=(context* NEAR/3 aware*)	2361
32	TS=(operat* NEAR/3 aware*)	597
33	TS=(environment* NEAR/3 aware*)	4255
34	TS=(organization* NEAR/3 aware*)	1028
35	#30 OR #31 OR #32 OR #33 OR #34	10095
36	#35 AND #29	33

Google Scholar

https://scholar.google.com			
Date	String	Results	Scanned
20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" -simulation	~1250	250
20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.edu	135	135
20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.gc.ca	1	1
20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.bc.ca	0	
20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.ca	31	31

20-Sep	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.org	~523	250
15-Nov	telemedicine OR telehealth OR "virtual care" "situation awareness" site:.gov	48	48
	TOTAL		715

Appendix B

Inclusion and Exclusion Criteria

	Exclusion criteria	Inclusion criteria
Population	Educators; Students; Non-professionals; Healthcare professionals, teams, or systems providing in-person care without VC component;	Health care providers from any professional discipline providing VC; Health care teams utilizing VC; Health care systems delivering VC;
Concept	Studies of cognitive constructs without explicit linkage to SA;	SA Level 1 perception; SA Level 2 comprehension; SA Level 3 projection; Shared SA; Team SA; Distributed SA; Interwoven SA; Organizational SA;
Context	Studies not involving healthcare delivery; Studies focused on training, education, or simulation; Non-clinical technical/engineering studies;	Implemented clinical VC services (remote patient monitoring, synchronous real-time patient-provider or provider-provider interaction, asynchronous store-and-forward); Hybrid services with VC and in-person components;

Appendix C

Data Extraction Template

The data collection template used for this study was implemented within Covidence. Table presents a list of data fields grouped under headings as organized in the Covidence user interface.

General Information	
	<i>Title</i>
	<i>Author</i>
	<i>Year</i>
	<i>DOI</i>
	<i>Paper type</i>
	<i>Country in which study conducted</i>
	<i>Funding source</i>
	<i>Conflict of interest</i>
	<i>Notes</i>
Characteristics of included studies	
	<i>Methods</i>
	<i>Aim of study</i>
	<i>Study design</i>
	<i>Start date</i>
	<i>End date</i>
	<i>Notes</i>
Setting/Context	
	<i>Description</i>
	<i>VC Modalities</i>
	<i>Patient locations</i>
	<i>Provider locations</i>
	<i>Care description</i>
Participants	
	<i>Population description</i>
	<i>Inclusion criteria</i>
	<i>Exclusion criteria</i>
	<i>Total number of participants</i>
	<i>Notes</i>
	<i>Concept</i>
	<i>SA is explicit construct</i>
	<i>SA is focus of paper</i>

	<i>Levels of SA</i>
	<i>Who embodies SA?</i>
	<i>Extended SA Constructs</i>
	<i>Notes</i>
Outcomes/Key Findings	
	<i>Primary Outcome</i>
	<i>Secondary Outcome(s)</i>
	<i>Measures Used</i>
	<i>Main Findings</i>
	<i>Authors' Conclusions</i>
	<i>Notes/Reviewer comments</i>
Relevance to Scoping Review	
	<i>RQ(s) Addressed</i>
	<i>Evidence type</i>
	<i>Thematic codes</i>