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Testing CareDEX: SAGAT methodology deployed for a disaster drill at a senior living community

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Abstract

The NSF-funded CareDEX Team, in conjunction with a partner Senior Living Community (SLC) and several local first responder agencies, conducted a disaster response tabletop exercise and experiment. The research methodology utilized at this event was the SAGAT methodology. The exercise scenario consisted of a wildfire in Anaheim Hills California with concomitant smoke and poor air quality. A quantitative analysis of the SAGAT data is presented. The results of the experiment indicate the CareDEX technology does provide situational awareness to first responders and this disruptive technology impacts decision-making in all experimental groups while maintaining residents' privacy and data security.

Keywords: Resiliency, Disaster Response, CareDEX, Seniors, Cybersecurity, SAGAT

Introduction

On 22 MAR 2022, the CareDEX researchers performed a tabletop exercise at a Senior Living Community (SLC) in Anaheim California. In attendance were local first responder agencies as well as Community Emergency Response Team (CERT) and Operations representatives. The choice of a tabletop exercise was deliberate to minimize staff and resident burden and exposure risk during the devastating COVID-19 pandemic in California. The researchers utilized Mica Endsley's (1988) Situational Awareness Global Assessment Technique (SAGAT) methodology in assessing situational awareness information provided by the CareDEX technology for disaster response as well as a qualitative analysis (participants/users) on feedback related to the CareDEX technology. SAGAT is a methodology originally designed for the military in gauging pilot Situational Awareness (SA) during combat flight operations. After its initial development for the military, the SAGAT methodology is utilized in a number of other situational awareness contexts (Hunter et al., 2019) including disaster response technology evaluation as well as in medical/healthcare domains. More recent work in fighter pilot SA utilizing the SAGAT methodology involves the impact of emotions caused by accidents and other serious incidents as it relates to their situational awareness (Lu et al., 2023).

In this SAGAT experiment, the situational awareness contributions of CareDEX were evaluated in the context of an emergency situation at a senior assisted living community campus. Participants in the tabletop included first responders (firefighters, community emergency response team members, police officers, emergency response managers, and EMTs) and facility operations personnel (caregivers, medical staff, facility operations staff). The drill scenario included a wildfire with deteriorating air quality conditions, ash debris, smoke, and a facility assembly with subsequent evacuation.

The purpose of this study is to provide a quantitative analysis of CareDEX's impact on decision-making. The CareDEX technology provides information (i.e., situational awareness) to users in real-time as the situation and events change and unfold. The methodology used to assess the decision-making and situational awareness is the SAGAT methodology. Additionally, the users of CareDEX provided qualitative feedback on the technology and that feedback was coded and analyzed, incorporated into the next generation CareDEX. However, only the quantitative data is reported here in this research study.

Stop points were utilized in order to compare the effects of CareDEX on decision-making versus decision-making without the technology. A stop point in a SAGAT exercise (often referred to as a *freeze point*) is where the scenario is halted and the referee will allow time for the participants to reflect on their decision-making and fill in any forms (see Figure 1). Participants were asked if the information provided by CareDEX impacted their decision-making and if so, in what way.

Background and Literature Review

In this section, the authors will define and explain research specific terminology as well as provide a literature review. Additionally, the CareDEX technology along with the SAGAT methodology is explained.

SAGAT and Situational Awareness

The Situation Awareness Global Assessment Technique (SAGAT) is a method of objectively and directly measuring SA during a team simulation using *freezes* at predetermined points in time with participants reporting on *what is going on* from their perspective on the situation. This method was originally created for the military (combat flight operations) by Mica Endsley but is used extensively in disaster response technology evaluation (Gonçalves et al., 2017) and even, more recently, measuring situational awareness of forklift drivers in relation to accident prevention (Kang et al., 2022).

Endsley (1998) defined situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p. 792). Endsley's first work around situational awareness was the development of a methodology that would help pilots be more conscious about the current situation and the possible movement of threats and allies in the vicinity, and therefore, react accordingly.

The proposed methodology was named Situation Awareness Global Assessment Technique (SAGAT) and consisted in halting combat simulations midway, to assess the pilot's situational awareness (Endsley, 1998). In a simulation exercise, pilots would run a combat simulation, then they were randomly stopped and asked a series of questions regarding the situational awareness they perceived from the simulation. Collected answers were analyzed by subject experts, other pilots, and finally run through the SAGAT evaluation system to determine a pilot's SA score (Endsley, 1988). Endsley's conclusion about the SAGAT technique was that it had a great potential to be used "as a measure of pilot situation awareness" (1988, p. 795). Further and more recent expansion of SAGAT measurement research on combat aviators include fighter pilot workload and distraction analysis (Li et al., 2023), quantifying the impact of multitasking on pilot situational awareness (Pan et al, 2023), and measuring team situational awareness similarity within the context of air combat (Mansikka et al., 2023).

The use of SAGAT as a measurement technique, includes three levels of SA perception measured from operators: (Level 1) perception of data, (Level 2) comprehension of meaning, (Level 3) projection of the near future components (Endsley & Garland, 2000). Ensley tested SAGAT's validity by determining that "fighter pilots who were able to report on an enemy aircraft's existence via SAGAT were three times more likely to later kill that target in the simulation" (Endsley & Garland, 2000, p.161).

After Endsley first introduced SAGAT for military use, this technique was applied to assess SA in many fields including human-robot interaction, transportation, automation, machine learning, first response systems, and paramedicine. Endsley's studies also proved that there is a link between human error and their lack of SA, which can be evidenced in different fields like medical training (Gardner et. al., 2017), aviation, oil-drilling, and emergency dispatch (Hunter & Williams, 2019).

Related to the medical field, Hunter and Williams (2019) point out that even though initial research has shown the potential benefits of SA in this field, few empirical studies have been conducted on such a topic within the domain. To emphasize SA measurement techniques' potential in the medical field, Hunter and Williams (2019) mention that:

> "Paramedics, emergency medical technicians (EMTs), and other out-of-hospital emergency providers are routinely placed in unpredictable situations where they must recognize an event, interpret what the event means, predict what the outcome will be, and then make a decision"(p.27). In the above-mentioned situations, the applications of SA measurement techniques could lead to better-informed decisions, improved patient care, and potentially reduce medical errors (Hunter & Williams, 2019).

The study performed by Hunter and Williams found three potential impacts of SA in the paramedicine field being: " i) overall general scene safety, ii) shared SA, and iii) SA directly related to field paramedics and patients" (2019, p.30). Conclusions drawn from such a study prove that there is still not enough empirical data to quantify the impact SA measurement techniques could have in the paramedical field. However, initial findings are encouraging, and further studies applying SA simulation technologies could result in a breakthrough for the field.

A 2022 study by Hunter et al. found that implementing a targeted educational approach, based on Crew Resource Management (CRM) ideas like the sterile cockpit rule and quick references, can improve SA in paramedics during 9-1-1 calls. This study was implemented in three phases to match the three levels of Endsley's framework, phase one (recognition) included 60-second stop points during active 911 calls, phase two (interpretation) included 60-second stop points after an educational module and quiz on CRM topics and phase three (prediction) included the same 60-second stop points. In phase two, paramedics were educated on the sterile cockpit rule, which in the healthcare space, limits nonessential communication or interaction between individuals until the transfer of care is complete (Hunter et al., 2022). After this education module was completed, paramedics were given a quick reference tool called *RIP It!* that aided in guiding focus during an overall emergency. Implementing this educational module with a focus on situational awareness as it relates to CRM topics proved to increase the SA of 8 out of 9 paramedics, with overall SA jumping from 62% to 86% (Hunter et al., 2022). This study proves that although research is ongoing, the implementation of educational modules in relation to SA in high-dynamic environments like paramedicine is beneficial.

As researchers continue to investigate the potential impacts of SA, Hunter et al. (2020) discuss the need for a paramedicine-centered framework for situational awareness stating that "Endsley's framework (the three-level framework) is the most appropriate framework to focus on for further research in paramedicine" (2020, p.4). As Endsley's framework separates the product from the process, researchers will be able to identify medical errors early on while attempting to improve early intervention and time-sensitive care (Hunter et al., 2020). While this framework focuses on individual situational awareness that can then be brought back to a team, group awareness has also become a topic of interest.

When looking at group awareness, Lauria et al. (2019) note the distinction between active systems of SA and passive systems of SA stating that active systems pertain to behaviors or cognitive processes that focus on environmental cues prior to incidents. In contrast, passive systems of SA are described as equipment or alarm based, that alert when the incident occurs (Lauria et al., 2019). Applying this distinction to group awareness as a whole, teams should use both active and passive systems of SA.

Another study developed by Pogrebnyakov and Maldonado (2018) also emphasizes the importance of SA in first responding teams during emergency situations. According to their study, and building on the initial findings from Endsley, "firefighters and military personnel depend on their SA to make decisions" (Pogrebnyakov & Maldonado, 2018, p. 3). During emergency response situations, it is important for each individual to develop their own SA, but it is as important to develop SA as a group to respond efficiently to the situation. (Pogrebnyakov & Maldonado, 2018).

Pogrebnyakov and Maldonado (2018) mention that in the context of emergency response, first responders like police officers, medical responders and firefighters will perform different tasks, meaning that each of those groups needs to have a different sense of SA, while also developing a shared SA to avoid obstruction between each group's performance. According to their findings, it is not uncommon for first responders to hamper each other's SA due to a lack of communication and a different understanding of concepts by different actors (Pogrebnyakov & Maldonado, 2018). In order to address these problems, the use of several Information Technology tools have been proven useful to develop an increase in SA for first respondents and avoid obstruction when attending an emergency (Pogrebnyakov & Maldonado, 2018). Building upon these research findings, the CareDEX team involved first responders (e.g., firefighters, EMTs, police officers, CERT personnel), users, scientists and all stakeholders in the development from beginning to end. Additionally, multiple testing exercises (including this SAGAT exercise) were performed that included all of the stakeholders.

Other research pertaining to the use of Information Technology tools for SA improvement has been developed by Ferreira et al. (2017). This study examined the performance of indoor positioning systems (IPS) as a means of responding to emergencies. Ferreira et al. (2017) analyzed several existing IPS and determined that some of them have limitations due to a “lack of cooperation between the IPS development teams and the emergency responders” (p. 2861).

These findings suggest that most of the IPS currently in place cannot adapt to the dynamic situations encountered during an emergency situation due to the above-mentioned lack of cooperation, which results in poor performance systems that lack accuracy and precision (Ferreira et al., 2017). In spite of the poor accuracy of existing IPS systems, Ferreira et al. (2017) are confident that the application of properly developed IPS or other Information Technology tools that are “…capable of, simultaneous positioning and tracking emergency responders on the field is of utmost importance as it allows: 1) increasing the situational awareness of both, the emergency responders and the incident commander 2) supporting the decision-making process and the mission planning; and 3) generating escape routes and assisted navigation” (p. 2867) that will greatly improve emergency response. The SAGAT methodology is an ideal candidate for initial testing and evaluation of these IPS tools.

A recent meta-analysis by SAGAT pioneer Mica Endsley (2021) explored “evidence of sensitivity, predictiveness, and methodological concerns regarding direct, objective measures of situation awareness” (p.124). This study compared SAGAT to different SA measurement techniques such as The Situation Present Assessment Method (SPAM), and evaluated the preciseness both techniques have to improve and predict situational awareness. Endsley’s analyzed over 240 studies concluded that SAGAT has a sensitivity close to 95%, without the need of being overly memory reliant nor being as intrusive as other techniques for participants. From the CareDEX perspective, this lack of intrusiveness is particularly appealing when working with seniors and aging populations.

Endsley’s (2021) meta-analysis determined that SAGAT is truly “a predictive measure of SA that is useful across a wide variety of domains and experimental settings” (p.124). Finally, Endsley’s study determined that SAGAT usage improves shared SA amongst teams, which supports its application for research, diagnostics, and design in several fields and study objectives. In the partner SLC where the tabletop and SAGAT exercise was conducted, there are teams of residents (Earthquake Committee - CERT) as well as staff and first responders that require a shared SA, as highlighted by Endsley (2021).

SAGAT provides a cost-effective and straightforward tool to assess the SA benefits of technologies without the added overhead of a large exercise. Often, these larger-scale exercises are costly in terms of resources and time. However, larger exercises, with appropriate participant levels, can effectively stress test systems beyond just a tabletop.

In a SLC, the potential disruption caused by a large-scale response exercise is a unique and important consideration. These facilities often have strict medication and care schedules as well as memory-care residents’ routines that are prioritized for older adult populations. Any disruptions, such as a technology testing drill, can have a deleterious impact on residents and staff. The recent COVID-19 pandemic disproportionately impacted SLCs with high morbidity and mortality for residents and staff. The challenges of the pandemic continue to be felt in these communities with strict infection control measures and severe nursing and care workforce shortages. A carefully choreographed tabletop and SAGAT exercise can provide excellent SA assessment with a small investment of time and personnel with minimal risks to the facility and residents. This is in contrast to actual drills and evacuation practices that can result in injury, infection exposure, and staff challenges.

CareDEX Architecture: Privacy and Cybersecurity

The CareDEX (Enabling Disaster Resilience in Aging Communities via a Secure Data Exchange) project aims to enhance and transform the resilience of older adults in our communities during disasters. This population group is often severely impacted during large events due to the lack of effective triage, comfort, and care. Through the use of a smart-space platform, this effort enables the assimilation and exchange of customized care information rapidly between first responders, caregivers in senior housing facilities, and older adults in a secure manner.

CareDEX, empowers organizations to readily assimilate, ingest, store and exchange information, both apriori and in real-time, with response agencies to protect and care for the elderly in extreme events. Using CareDEX, SLC workers and residents are able to share information about changing health conditions, personalized needs and identify those in need of specialized triage and critical care. Given the sensitive nature of personal information (e.g., health profiles, ability status, medications) and the cybersecurity implications of data sharing, CareDEX incorporates techniques to balance the need for individual privacy with authorized release of information to responders when needed. CareDEX addresses user data privacy and cybersecurity by virtue of its underlying middleware platform. CareDEX is an application that is engineered on top of the Testbed for IoT-based Privacy-Preserving PERvasive Spaces (TIPPERS) architecture. TIPPERS is an award-winning sensor and data management system with support for mechanisms such as Function Secret-Sharing (FSS), Differential Privacy (DP), cryptography, and policy-based access to ensure information privacy and cybersecurity (Mehrotra et al., 2019). TIPPERS is deployed in several organizations including universities and the US Navy.

Given the sensitive nature of personal information (e.g., health-profiles and other sensitive data), CareDEX can enable policy-based information sharing mechanisms that balance needs for individual privacy with authorized information release. CareDEX enables data to be securely stored on-premises (at the SLC) for providing access to responders and temporary caregivers. Ongoing work in the CAREDEX team aims to support a hybrid cloud architecture to enable resiliency. Relocation of older adults requires regional information (e.g. road-conditions, facility status), so CareDEX integrates GIS tools to provide first-responders with up to date region-level situational awareness for dynamic decision-support.

The situational awareness information is provided to authorized and authenticated users by virtue of a dashboard. The dashboard contains two components: a local view and a regional view. The local view contains facility information such as blueprints, hazmat storage, and resident information. The regional view provides information on mutual aid facilities (e.g., number of beds, services, operational status) as well as road and route conditions.

The dashboard supports semantic queries by virtue of the underlying substrate of TIPPERS (Archer et al., 2020). An example of a local view semantic query would be " display residents who are not ambulatory" and the geo-located residents would be displayed on the dashboard. Similarly, a regional view semantic query would be "display damage assessment of local roadways and bridges" and the information would be displayed in the regional view dashboard. These queries assist in casualty location and casualty evacuation route planning while still preserving privacy and security with encryption (SSL) and policy-based release (opt-in and opt-out) .

The CareDEX team consists of academic partners (UCI Computer Science, UCI School of Medicine, UCI School of Nursing, Natural Hazards Center at CU Boulder, Ball State University's Center for Information and Communication Sciences), and civic partners with expertise in senior health and disaster resilience

(National Fire Protection Association (NFPA) / /Fire Protection Research Foundation (FPRF), Front Porch Senior Living, ImageCat Inc., national and local first response partners).

The CareDEX project is funded through the National Science Foundation (NSF) CIVIC Innovation Challenge award #213391 (David Corman, Program Manager). The project began in October 2021 and will continue through March 2024. The CIVIC Innovation Challenge is a collaboration with the Department of Energy, Department of Homeland Security Science and Technology Directorate, Federal Emergency Management Agency (FEMA), and the National Science Foundation.

CareDEX IRB and Human Subjects Protection

The human subjects research performed by the CareDEX team is covered under IRB Protocol Number 1005. The research protocol was granted *Exempt* status (approved: 18 MAR 22) as no personal identification information will be collected or used as part of the CareDEX research.

Methodology

Participant subjects were assembled at the SLC at 0900 hours. Subjects were divided into three groups representing their roles: First Responders, Facility Operations, and Community Emergency Response Team (CERT). Participants were seated together, by their respective group, in an L-shaped conference room with two projectors. One projector displayed the CareDEX Regional View (Orange County California and the surrounding area) that provided information on the fire, smoke, air quality as well as information regarding local mutual-aid facilities such as hospitals and other care facilities. The second projector displayed the local view of the situation which included each floor of the SLC as well as occupancy and resident information (mocked-up, e.g., synthetic data, for privacy preservation but based on a representative sample population of SLCs).

The Regional information was based on a previous real fire incident (Silverado Canyon Fire). Fire spread perimeter was obtained from National Interagency Fire Center (NFIC), smoke covered area and density from NOAA's Hazard Mapping System Fire and Smoke Product, and air quality information from AirNOW.gov. The wind direction was simulated in order to create a threat to the SLC partner facility in which the SAGAT exercise was conducted.

The occupant information was based on the partner SLC providing realistic non-identifiable information about a number of visitors, staffing, residents as well as some general, base-line healthcare information for populating the resident table in CareDEX. The CareDEX medical team then injected synthetic medical data for each resident, based on a representative population of SLCs. First, demographics including age and gender distribution formed the background for the profiles. Then, health conditions and chronic diseases most commonly found in this population were added. Functional and physical limitations were assigned to the digital residents based on prevalence within this population. Two board-certified geriatricians were consulted and confirmed that realistic medical data was created for each resident based on representative conditions for residents living in the SLC. One geriatrician specializes in SLC-based medical care and was instrumental in this review. Random names were generated from a database and then anonymized so as not to have any real personal identification information in the system. From that anonymized starting point, the CareDEX team ran simulations of activities, movements, and medical needs then populated the local view of the tabletop scenario with this synthetic data.

Each participant of the exercise was given an IRB briefing and then provided verbal consent to collect anonymous data, the scenario script, and a Technology Evaluation form. All participants were given 15 minutes to discuss any IRB concerns, understand that participation and answering surveys were voluntary and participants were free to opt out of the exercise at any time.

To begin the exercise, the participants were reminded that the scenario is a Wildfire, poor air quality, and high winds (commonly referred to as *Santa Anas*) blowing toward the facility causing First Responder ordered Evacuation (simulated) to a Mutual Aid Facility. Then the following was read to all participants:|

> DAY 1, 1 PM: As a result of a severe drought and high Santa Ana winds, a wildfire has started in Silverado Canyon and is moving west. The facility has not had interruption of water or power. Within 5 minutes of calling (Step 2), first responders arrive and the emergency response plan is activated to address the situation. Facility should implement the first phase of the emergency plan and complete the following steps in the plan.

There are nine steps to the Disaster Response plan. As prescribed in SAGAT methodology, there are Stop Points embedded in the plan to introduce the CareDEX technology and assess decision-making. These stop points followed steps one, three, six, eight, and nine (see Figure 1). At each stop point, the participants were asked to annotate whether or not their decision changed based on the information provided by CareDEX. In addition, the participants were asked to provide comments on the technology.

Steps to Plan	**Actions Taken**	**Est. Time**	**Who Completed**	**Comments**
1. Assess immediate threat to residents.				
Stop 1. Show CareDEX Technology				
2. Call any necessary emergency services (simulated)				
3. Assemble, move and secure residents and staff as necessary (simulated)				
Stop 2. Show CareDEX Technology				
4. Once assembly is complete, drill participants meet in the designated assembly area.				
5. Take emergency supply box to local assembly area				
6. Take emergency resident information.				
Stop 3. Show CareDEX Technology				

7. Notify facility management of the situation.				
8. Communicate facility status with residents and their families.				
Stop 4. Show CareDEX Technology				
9. Inform physicians of facility status as well as resident conditions. Follow their instructions on resident follow up.				
Stop 5. Show CareDEX Technology				

Figure 1: Drill Scenario

Results

Overall analysis of the decision-making data and the feedback indicates that CareDEX does impact decision-making in all groups (CERT, First Responders, and Operations staff). The First Responder group was the most impacted by the CareDEX technology with 75% of their decisions changed by the situational awareness information provided by the technology. See discussion below for further details.

SAGAT Quantitative Analysis

In this section, the decision-change data will be displayed and discussed at an aggregate (all participants) and then further analyzed by group membership. Finally individual decision-change data as well as individual Stop Point data will be presented and discussed.

At each Stop Point, the exercise was halted and the participants were shown the CareDEX technology. The five stop points were chosen as particular areas of impact for CareDEX. The participants walked through each step of the exercise (nine steps in total) and they would write down their decisions (actions taken), estimated time to completion, who completed the actions and any additional comments. At each Stop Point, the participants were asked to write down if their decision had changed and what actions would now be taken, time to complete, who completed and any additional comments. It is important to note that only Stop Points 2 and 3 are relevant to the First Responder group as those two points deal with evacuation and situational awareness of potential casualties. At the other Stop Points, either the First Responders are not on-site yet or the information is only pertinent to Operations and CERT.

The following is an explanation of each stop point. Stop Point 1 shows CareDEX Technology in both the regional view and the local view. The CareDEX regional view displays the air quality (poor and deteriorating) as well as fire and impacted facilities. The local view displays localized occupancy information. Stop Point 2 displays the same information but with an emphasis on anyone left in the building or missing. At Stop Point 3, CareDEX provides information regarding the residents such as names, any medical conditions (e.g., needing dialysis) , any *good to know* information (e.g., has a particular fondness for a pair of red slippers or is a retired police officer) along with other self-disclosed demographics. Stop Point 4 displays the CareDEX contact information for each resident. Finally, at Stop Point 5, the CareDEX technology will display physician contact information and follow up care instructions after the evacuation. Additionally, the regional information is updated, and the most current local conditions of the fire and air quality are displayed. It is important to note that all data is synthetic and modeled, and no personal identifiable information is used.

At all Stop Points, overall decision change analysis reveals that approximately 50% of the decisions by all participants were changed by CareDEX (see Figure 2 and Table 1). This would indicate that CareDEX has a considerable impact on decisions throughout the entire disaster response.

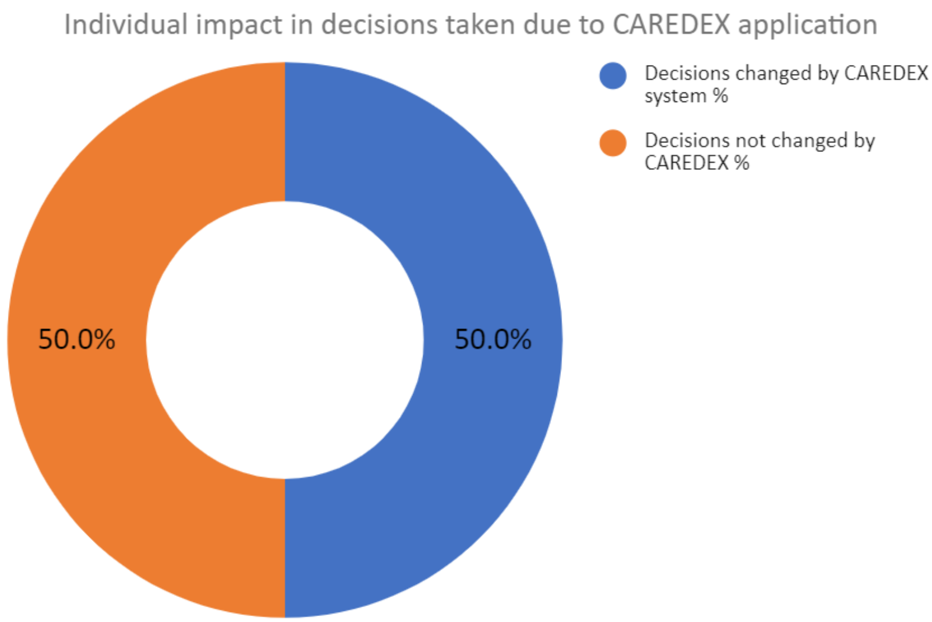

Figure 2: Overall Decision Change

There were three groups participating in the SAGAT exercise: First Responders, Operations personnel, and CERT personnel. The First Responder group had the highest percentage of decision-change at 75%, followed by CERT at 50% and finally Operations Personnel at 46% (see Figure 3 and Table 1).

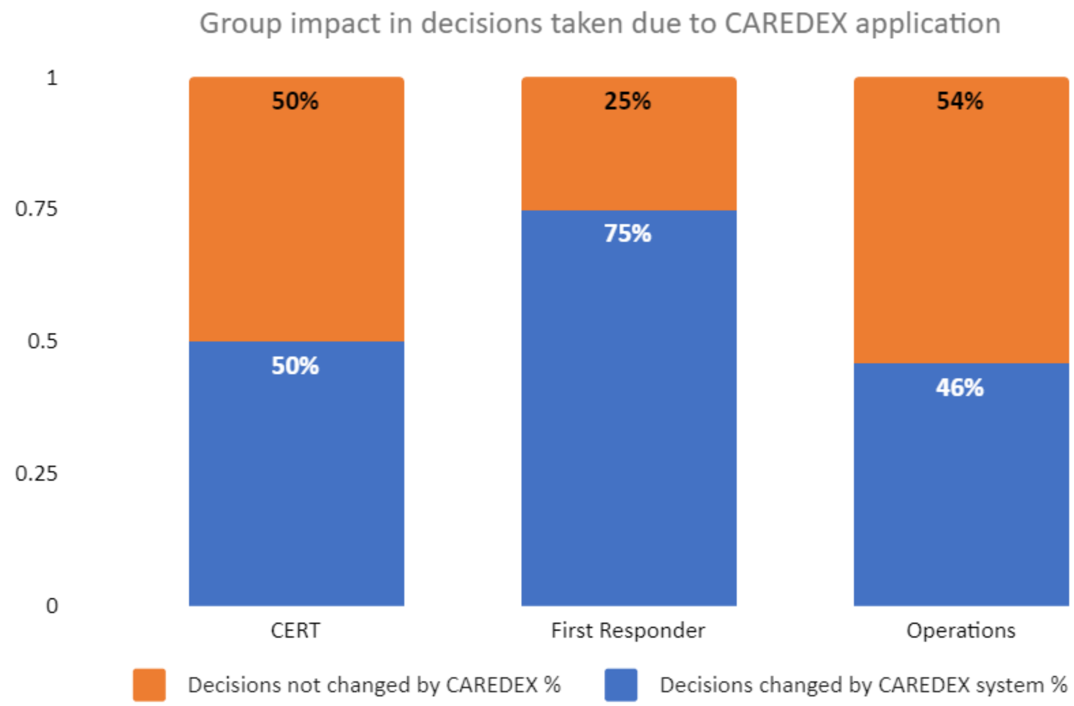

Figure 3: Group Decision Change

Table 1:Number of Decision Changes by Group Membership

Group	Decisions taken sum of all stops	Decisions changed by CAREDEX system	Decisions not changed by CAREDEX
CERT	10	5	5
First Responder	8	6	2
Operations	50	23	27
Grand Total	68	34	34

At the individual level, Stop Point 2 showed an extraordinary impact on decision change. All but one participant indicated that CareDEX information changed their decision. In parsing the comments, it appears that standard SOP requires evacuation assembly outside and that was changed to inside by virtue of the air quality information provided by CareDEX. Additionally, Stop Points 1, 2, and 3 showed a majority of participants would change their decision but not at Stop Points 4 and 5. See Figure 4 for more information on individual decision-change by Stop Point.

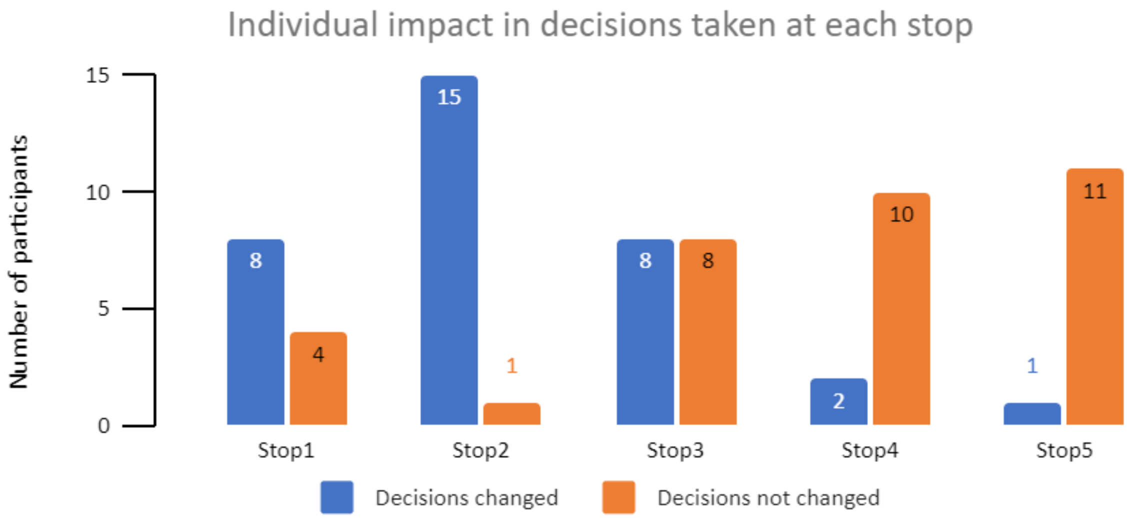

Figure 4: Decision Change at each Stop Point

Discussion

Efficacy of CareDEX

After analysis of the findings the authors concluded that the utilization of CareDEX increased situational awareness for all groups involved. Notably, the First Responder group experienced the most pronounced impact, with 75% of their decisions being modified based on the additional information provided by CareDEX. Furthermore, Operations, and the Community Emergency Response Teams, had about 50% of their decisions affected by CareDEX. Based on the findings presented here (which are congruent with the research by Pogrebnyakov and Maldonado (2018) on group-based situational awareness), CareDEX would appear to be an effective tool in providing group-based situational awareness information.

Analysis of the resultant data further revealed that the situational awareness information delivered by CareDEX had the greatest impact at the initial stages of the exercise. This is evidenced by the higher number of decision changes observed during that period. However, as the exercise progressed, the frequency of decision changes gradually decreased across all three participant groups.

According to Endsley & Garland (2000), Level 3 of situational awareness is projection. That is the ability to formulate directions and courses of action based on the understanding and awareness of situational factors. Endsley terms this forecasting and states that it is the highest level of understanding of a situation. Furthermore, Endsley states that projection is the "mark of a skilled expert" (2000, p.7). Accurate and timely information is the cornerstone of projection.

In this experiment, CareDEX provided both timely and accurate information as evidenced by the number of decisions changed, especially in the early stages of the exercise. Stop Points 2 and 3 were the crux of the exercise and involved outside First Responder agencies. These points were the initial response and local facility evacuation portions of the experiment. These are the time sensitive areas where lives are lost due to inaccurate information or no information at all. In high-stress operations that are dynamic and complex, achieving accurate situational awareness is difficult (Strater et al., 2001). It would appear that CareDEX was successful in providing both timely and accurate information to all experimental groups.

Policy and Privacy

his field experiment provided a useful test of the residents' data privacy and security. The privacy and security of resident data is provided by the underlying TIPPERS technology upon which CareDEX resides. TIPPERS supports contextually aware privacy as well as authentication and authorization-based data access. In the context of a disaster, data privacy rules are implemented in a pre-arranged manner. An example of this would be that resident's *opt-in* to the sharing of their information with first responders and possibly alternative facilities in the event of a disaster situation (e.g., Jane Smith must have her anticoagulant medication every day at noon). This information is vital both at the initial first responder/resident point of contact as well as during an evacuation where the resident could be evacuated to a mutual aid facility. It is important to note that while the patient data was simulated, it was based on actual resident information, anonymized and then further reworked by the CareDEX team of medical doctors and healthcare professionals. The goal was to make the data as real-world as possible but still be synthetic and avoid any real personal information or data sharing of resident health information.

Secure and privacy-preserving location-based resident data is an important feature of CareDEX. The system will show residents' location and vital information on the *dashboard* of the system. Authorized users can drill down into the varying views (room, floor, etc.) to see real-time location information as the residents evacuate. Residents experiencing mobility issues are flagged for needing assistance from staff or first responders. While the building evacuation and assembly was simulated as is the case in a tabletop exercise, the location information of the synthetic residents was quite useful to all groups and informed decisions at the stop points. During this SAGAT exercise, the resident evacuation was modeled and led by the Resident Earthquake Committee. The geo-location of the residents was displayed on the dashboard for the participants to base their decisions on this data.

In the normal course of events (i.e., the default CareDEX policy), human location-based data is not provided. However, a change in situation (i.e., a CareDEX policy change event) such as an earthquake would trigger the location streaming from TIPPERS to the CareDEX system if the resident has opted into sharing this data with the appropriate persons. In this experiment, CareDEX functioned as expected on the synthetic resident data. The dashboard information regarding the route-based information (i.e., the regional view) was modeled on the 2020 Silverado Canyon fire. This fire was quite close to the SLC in which this SAGAT experiment took place and that fire was exacerbated by exceedingly strong Santa Ana winds. As the scenario unfolded, the road and route information were displayed on the dashboards. While there was no off-facility evacuation executed (only demonstrated) or evaluated with SAGAT as part of this exercise, some residents could choose to self-relocate and that information would be available to them. The road conditions and mutual-aid facility status was shown to the participants and qualitative feedback was provided by the groups.

Conclusions

This research article presents a comprehensive discussion of a SAGAT-style tabletop exercise conducted to evaluate the effectiveness of CareDEX technology. The primary objective was to assess the impact of CareDEX on decision-making within the context of a disaster response scenario. The results demonstrate efficacy in assisting decision-making among all participants, including First Responders, Operations personnel, and CERT personnel.

In the research literature, the use of SAGAT as a SA measurement technique has demonstrated its validity, reliability and relevance; showing a link between SA and decision-making effectiveness in various domains, including aviation, emergency response, and paramedicine (Endsley & Garland, 2000; Gardner et al., 2017; Hunter & Williams, 2019; Pogrebnyakov & Maldonado, 2018). The results of the study indicate that the CareDEX system provides SA information that increased decision-making effectiveness to the three experimental groups. As such, CareDEX could lead to improved decision-making, casualty care, and reduced errors as called for in the emergency response domain research literature (Hunter & Williams, 2019).

CareDEX technology significantly affected decision-making with the highest percentage of decision change observed among First Responders (75%). The analysis showed that approximately 50% of all the participants' decisions were changed by CareDEX across different Stop Points. The technology provided timely and accurate information, most effectively in the initial stages of the exercise, which provided enhanced situational awareness. Location-based resident data proved valuable in informing decisions, and CareDEX successfully preserved privacy and shared data according to policy.

These findings tend to make the case for the application of CareDEX technology in various emergency and disaster response scenarios. The enhanced situational awareness offered by CareDEX can help support and influence decision-making, particularly at the initial stages of an incident when critical and time-sensitive choices are often made (Hunter & Williams, 2019). By providing real-time and evolving information, CareDEX equips responders and operations personnel with the tools necessary to respond effectively to changing circumstances. Furthermore, the insights gained from this study can guide future development and refinement of CareDEX technology for emergency response applications. The identification of the varying impact on decision-making among different participant groups highlights the importance of tailoring the technology to meet the specific needs based on the roles of each stakeholder involved in emergency situations.

In sum, this research underscores the significant benefits of incorporating CareDEX technology into emergency response protocols in the area of situational awareness (Pogrebnyakov & Maldonado, 2018). By leveraging its capabilities to enhance situational awareness and facilitate informed decision-making, CareDEX has the potential to improve response effectiveness, minimize risks, and enhance the safety and well-being of individuals and communities during critical incidents.

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