Technology Innovation: A Study of Wireless, Visual Information Communication Technology on Situational Awareness for Tactical Police Commanders

By

Frank X. Hartle III

M.S., Master of Science in Criminal Justice Administration, Point Park University, 2009

B.S. Bachelor of Science in Computer Systems Technology, Duquesne University, 2002

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Under the Supervision of Fredrick G. Kohun, Ph.D.

Daniel R. Rota, Ph.D.

Robert J. Skovira, Ph.D.

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Dedication

To my God from whom all good things come.

To the love of my life, my wife Cari

To my family.

I love you.

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Abstract and Key Words

Technology innovations in visual, wireless communications have yet to be leveraged by law enforcement. These technologies have a future in law enforcement. This limited study has provided evidence that the addition of visual, wireless communication for tactical police commanders enhances situational awareness and speeds decision making. In addition, this study has established that the technology would be accepted for use by police tactical officers once utility is demonstrated. Several issues remain that may delay its widespread adoption. These include unfamiliarity, a police centric design that is rugged, reliable and without impaired vision, and liability and cost. In addition, there is not a current wireless, broadband backbone that can transmit the signals over a large distance. Once these limitations have been overcome this technology has the potential to revolutionize policing and tactical law enforcement.

Keywords: Situational Awareness, Visual two-way Communication, Information Communication Technology

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Chapter 1: Introduction to the Study

1.1 Introduction

A Scenario: You are a shift police lieutenant listening to one of your officers responding to a call. You hear your officer call out that she has arrived and is awaiting her backup. Suddenly the radio is filled with chaos and confusion. Gun shots, screams and incomprehensible panicked requests can be heard in the background. Between the eerily silent breaks in the transmission, the officer frantically requests backup. What started out as a routine call has erupted into a violent confrontation. Seconds seem like hours as you and your fellow officers rush to the scene. As officers arrive they start to relay the situation as they encounter it. There is a wounded officer and two injured suspects. Only later does the wounded officer recover enough to reveal that there were three attackers. Anyone who has suffered a similar situation can attest to the feeling of helplessness and confusion that responding officers' experience and the paralysis of effective decision making that can occur while a leader awaits more information in order to manage the situation.

This is the essence of police communication. Starting in the1930's police officers and their leaders have relied on two-way radio communication to dispatch officers and to transmit information back to decision makers (Poli, 1942). With the development of wearable devices and the advancements of wireless information communication technology (ICT) is there a better way for police to communicate? Could the addition of real-time, wearable video cameras allow for better situational awareness for police leaders?

Scenario 2: The responding officer had been wearing a wireless video camera when she was attacked. Would the lieutenant have made faster or different decisions as the incident unfolded if he had been able to see it from the officer's vantage point? Would he have deployed

his officers differently? Would the third suspect been identified sooner and apprehended? Would the medical teams have a better understanding of the officer's medical needs while en route? Endsley (1988) defined situational awareness (SA) 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." The ability to correctly perceive or identify key elements during a situation, comprehend these elements and project what is likely to soon occur is key to improving decision making and performance (Endsley, Holder, Leibrecht, Garland, Wampler, & Matthews, 2000). The addition of wireless, visual ICT devices may shorten the time it takes for first responders and police leaders to identify what's going on, reach incident comprehension and predict solutions by presenting information both audibly and visually; hastening situational awareness.

Throughout history police officers have endeavored to communicate effectively with each other and with the public (Leonard, 1938; Poli, 1942). Innovations in effective communication were cobbled together out of necessity, borrowed from the military or forced upon the profession by society (Leonard, 1938; Poli, 1942). The struggle to achieve awareness by the patrol domain is as old as the beat patrol officer checking in each hour with the sergeant of the rounds (Leonard, 1938). Criminals too have innovated, becoming more technological, less geographically based and more violent (Wollman, Wilke, & Lai, 2011). In most cases, criminals are the first to employ new technologies in their attempt to circumvent law enforcement (Wollman, Wilke, & Lai, 2011). To prevent them from succeeding, law enforcement professionals are always looking for new and innovative technologies. Once in a while a new technology emerges whereupon law enforcement professionals and the companies that provide technology and equipment to them, instantly recognize its potential utility. This was the case for

the automobile, for the radio and currently for wireless, visual ICT (Bryant, 2013; Estes, 2013; Leonard, 1938). To study examines the effect of this new technology in expanding situational awareness (SA) for law enforcement.

1.2 Visual Communication

The introduction of new information communication technologies (ICT), such as Google Glass[1], that gives users the ability to wear functional ICT without being overt or noticeable, has caused a stir over privacy issues and has led to conversations about how to limit the new technology (Pogue, 2013). Each new technological advance brings naysayers and critics until its utility is discovered and accepted (Rogers, 2003). Perceived usefulness as theorized by Davis (1989) may play a part in great technological advances being ridiculed and discarded because the technological utility was misperceived early on and the technology's reputation never recovered. Visual ICT devices like Google Glass may, if perceived early on to be non-utilitarian, face a similar fate. Since Google Glass was introduced, media and public comments have been mixed creating the potential for the product to fade into obscurity (Pace 2013). Pace (2013) makes the case that innovators view consumers as rational and cultural agents in determining consumer practices. Innovative concepts must be accepted culturally and innovative features must be accepted as functional and rational. Recognizing this, Google has since stopped manufacturing it's product for consumers instead moving it to an enterprise product (Hoge, P, 2015). This study attempts to determine if wireless, visual ICT products such as Google Glass enhances law enforcement's abilities by focusing on one segment of policing; tactical law enforcement officers and their leaders. Utility is tested quantitatively and qualitatively to measure situational awareness.

[1] Google Glass is a wearable computer (eyeglass) with an optical display that enables two way visual communication.

1.3 S.W.A.T.

Because of increasing violence and technological advances, special law enforcement teams were developed starting in the 1960's to combat heavily armed or barricaded criminals (California Department of Justice, 2002). Routine law enforcement can be fraught with unpredictability and danger. In large part it is monotonous with police officers conducting regular patrols and taking reports and detectives interviewing victims and perpetrators (Vila, Morrison, & Kenney, 2002). Because of this daily unpredictability, it would be near impossible to replicate an exact exercise scenario for testing and measuring wireless, visual ICT. Tactical law enforcement officers were chosen because they employ repetitive, exercised, tactical actions and train as a cohesive team. They deal with high risk, potentially violent situations and as specially trained officers; they are dispatched to incidents requiring paramilitary-like weapons and tactics (California Department of Justice, 2002; Kraska, 1999). Tactical law enforcement teams are more commonly referred to as Special Weapons and Tactics or SWAT teams (California Department of Justice, 2002). For the purposes of this paper the researcher focuses on these specially trained teams and refers to them and their members as tactical law enforcement.

1.4 The Concept of Situational Awareness

Situational Awareness (SA) is critical for efficient decision making and performance in systems that are complex and where the environment is dynamic (Harrald, & Jefferson, 2007). The early concept of situational awareness is attributed to Oswald Bölcke a German, World War I ace pilot (Spick, 1988). While Bölcke never used the term SA, he does highlight in his war journaling the necessity of gaining awareness first by sound and/or observation in order to achieve the upper hand in air warfare (Bölcke, & Hirsch, 1917). Bölcke was an early expert on

air battles and as such authored air combat lessons as well as mentoring other German ace pilots such as Manfred von Richthofen; otherwise known as the Red Baron. Based on German successes, it is no surprise that this concept was adopted and improved upon by air forces around the world and integrated into the military lexicon and flight training manuals. The first use of this term was in the US Air Force around the time of the Korean War (Watts, 1996).

To say that military leaders throughout history did not recognize the necessity and advantage of SA would be disingenuous. Situational awareness, as a concept, could be applied to any military event where one leader uses the advantage of observing a situation and whereupon the advantage to attack is comprehended; an action is forecasted and acted on before the enemy can do the same (Boyd, 1987). Clausewitz (1909) asserts that the "fog of war" is the inability to see the battlefield as one imagined. In the passage below he speaks of SA and maintains that this incomplete understanding is one of the elements of "friction." Experienced leaders with a realistic view of what is planned, what is happening, and what may happen reduce friction.

> What is required of an officer is a certain power of discrimination, which only knowledge of men and things and good judgment can give. The law of probability must be his guide. This is not a trifling difficulty even in respect of the first plans, which can be formed in the chamber outside the real sphere of War, but it is enormously increased when in the thick of War itself one report follows hard upon the heels of another; it is then fortunate if these reports in contradicting each other show a certain balance of probability, and thus themselves call forth a scrutiny (p.198).

This early SA concept theorized by Clausewitz also foregrounds the importance of surprise. In fact, he dedicates an entire chapter to it. He says:

> From the subject of the foregoing chapter, the general endeavour to attain a relative superiority, there follows another endeavour which must consequently be just as general in its nature: this is the surprise of the enemy. It lies more or less at the foundation of all undertakings, for without it the preponderance at the decisive point is not properly conceivable.
>
> The surprise is, therefore, not only the means to the attainment of numerical superiority; but it is also to be regarded as a substantive principle in itself, on account of its moral effect. When it is successful in a high degree, confusion and broken courage in the enemy's ranks are the consequences; and of the degree to which these multiply a success, there are examples enough, great and small. We are not now speaking of the particular surprise which belongs to the attack, but of the endeavour by measures generally, and especially by the distribution of forces, to surprise the enemy, which can be imagined just as well in the defensive, and which in the tactical defence particularly is a chief point (p.199).

When the enemy force's SA is poor, only then is the surprise possible (Fracker, 1991).

Tactical strategy and advantage notwithstanding, the invention and employment of the airplane and its tactical use necessitated faster tactical decisions and actions than the previous slower moving land battles. Though both are complex battle systems, the time and space needed to make tactical decisions decreased with the speed of the machinery. The aircraft compressed space and time thus compelling military strategists and pilots to study ways to advantage faster decision making for victory. In the 1950's John Boyd, a US Air Force pilot during the Korean War and later a Pentagon strategist, conceived the Decision Cycle or the Observe-Orient-Decide-Act Cycle later named the OODA Loop (Breton, & Rousseau, 2005). Boyd proposed that

fundamental to victory is the capability to create conditions where one can make good, tactical decisions faster than one's opponent (Boyd, 1987). The OODA loop was originally devised by Boyd to understand why U.S. F-86 fighter pilots were winning battles in the skies over Korea during the war (Brehmer, 2005; Angerman, 2004). Boyd's study revealed that although the Korean MiG-15s were superior to the U.S. aircraft, a single design feature and a single mechanical feature enabled pilots to gain the advantage. The 360° canopy and the powered hydraulics enhanced pilots SA by enhancing their observation and orientation abilities while also allowing them to gain decisive tactical advantages with faster maneuvering (Angerman, 2004). The OODA loop was quickly adopted by all U.S. military services and applied strategically for use offensively (to overcome the fog of war and achieve the element of surprise) and defensively with the goal of shrinking your OODA loop to regain the advantage over an attacking enemy (Schechtman, 1996; Angerman, 2004). It is from the Observe-Orient portion of the Boyd's theory that the study of SA derives.

The bulk of the study in SA was done by the military until the late 1980's when human factor scientists and the aviation industry began to study methods to improve, test, and, measure SA due to the increasing complexity of flight systems; these included the aircraft and the airspace controls systems (Endsley, 2000; Stanton, Chambers, & Piggott, 2001). Numerous definitions and theories of SA were developed and closely associated with the aviation domain (Endsley, 2000). Dominguez (1994) highlights the controversial issue of the competing definitions while presenting the various definitions in Table 1-1.

Table 1-1 Dominguez (1994) Situational Awareness Definitions

Conscious awareness of actions within two mutually embedded four-dimensional envelopes.	Beringer and Hancock (1989)
A pilot's continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission and the ability to forecast, then execute tasks based on that perception.	Carroll (1992)
The ability to extract, integrate, assess, and act upon task- relevant information is a skilled behavior known as 'situational awareness.'	Companion, Corso, Kass, & Herschler (1990)
The accurate perception of the factors and conditions that affect an aircraft and its flight crew.	Edens (1991); Schwartz (1993) uses this definition with "during a defined period of time" at the end.
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.	Endsley(1995)
The knowledge that results when attention is allocated to a zone of interest at a level of abstraction.	Fracker(1990)
The pilot's overall appreciation of his current 'world.'	Gibson and Garrett (1990)
One's ability to remain aware of everything that is happening at the same time and to integrate that sense of awareness into what one is doing at the moment.	Haines & Flateau (1992)
Where refers to spatial awareness.. . what characterizes identity awareness, or the pilot's knowledge of the presence of threats and their objectives, [as well as] engine status and flight performance parameters. Who is associated with responsibility, or automation awareness; that is knowledge of 'who's in charge.' Finally, when signifies temporal awareness and addresses knowledge of events as the mission evolves.	Harwood, Barnett, & Wickens (1988)
The ability to envision the current and near-term disposition of both friendly and enemy forces."	Masters, McTaggart, & Green (1986)
Awareness of conditions and threats in the immediate surroundings.	Morishige & Retelle (1985)
The ability to maintain an accurate perception of the surrounding environment, both internal and external to the aircraft as well as to identify problems and/or potential problems, recognize a need for action, note deviations in the mission, and maintain awareness of tasks performed.	Salas, E., Prince, C., Baker, D. P., & Shrestha, L. (1995).
[Situational awareness] means that the pilot has an integrated understanding of factors that will contribute to the safe flying of the aircraft under normal or non-normal conditions.	Regal, Rogers, & Boucek (1988)
Situation awareness refers to the ability to rapidly bring to consciousness those characteristics that *evolve* during flight.	Wickens (1992)
The pilot's knowledge about his surroundings in light of his mission's goals.	Whittaker & Klein (1988)
Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events.	Dominguez, C. (1994).

The most generally accepted definition of SA, which has been found to be the most applicable across many research areas, is Endsley's (1995) definition (Figure 1-1):

> "The perception of 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.36).

Endsley's definition best fits multiple research domains and is utilized in multiple SA measurement tools. This definition best describes "knowing what is going on" (Endsley, 2000) and Perception and Comprehension in Endsley's first two levels relate most closely to the OODA processes of Observe and Orient from where the study of SA derives (Grant, 2005). Furthermore dividing SA into measurable levels allows each level to be quantified and examined. For this reason SA is defined as such in this study.

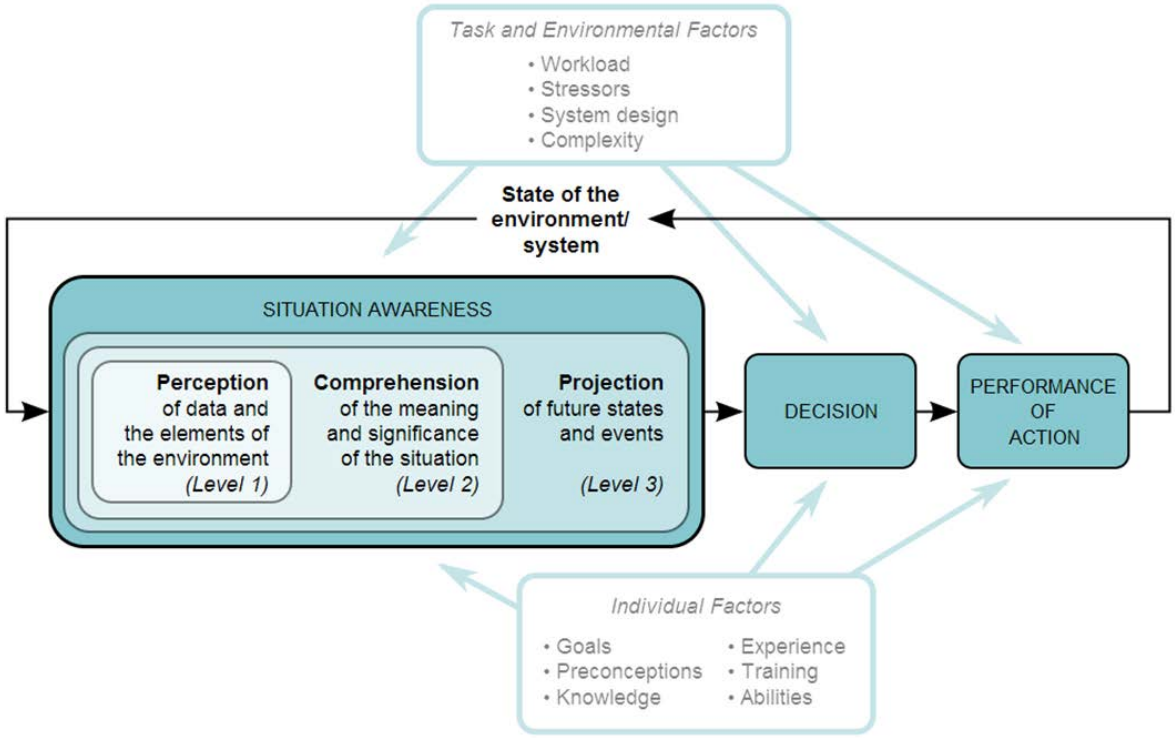

Figure 1-1 Theoretical Model of Situational Awareness (Endsley, 1995)

1.5 Statement of the Problem

Law enforcement and most of what we refer to as first responders (police, fire, EMS, and rescue) have employed the traditional Shannon Weaver model of communication by utilizing two-way radios since the late 1930's. This technology, developed in the 1890's[2], is still utilized for most first responder incident communications. This communication system is limited in that only one person can communicate at a time. Even though the communication is from one to many, only one person can respond at a time. Furthermore a single frequency channel is often used by many responders to carry multiple disjointed conversations at the same time (Timmons, 2006). The receivers must determine whether a particular message was intended for them or for others on the channel. Therefore, perceiving, comprehending and predicting takes longer for responders who have not arrived on the scene, or remain in separate locations and cannot see the entire extent of the situation (Timmons, 2006). When a violent crisis situation happens, it must be relayed to responding decision makers in person or via two-way radio. Trying to decipher and direct an ongoing violent incident with only the use of a two-way radio is impractical at best (Timmons, 2006). Crosstalk, background noise, and decision demands can further complicate communication over these devices. First person accounts of the incident can also be skewed by victims, law enforcement, and rescue personnel who perceive risk and crises differently, therefore adding confusion as to what is really happening (Timmons, 2006; Wester, 2009). The collective radio "noise" of disjointed communication is something first responders have learned to overcome with experience, great concentration, and time on scene; all of which are required before basic incident comprehension can be achieved. The addition of wireless, visual ICT devices may shorten the time it takes for first responders and emergency management leaders to

[2] The year Guglielmo Marconi patented his wireless invention.

reach incident comprehension by presenting information both audibly and visually; potentially from a distance.

History shows us that the addition of new communication technology, like the telegraph, telephone, and radio, incrementally increase law enforcement's SA (Leonard, 1938; Poli, 1942). Timmons (2006) reports that the addition of a well-designed, visual display during highly dynamic and stressful situations enhanced SA for navy decision makers. Other studies by military researchers have substantiated these findings. The majority of these studies were conducted on large command and control systems utilized to comprehend large troop movements. What has not been well studied is the use of wireless, visual ICT devices and its effect on SA of a tactical team leader during a dynamic, small tactical team, law enforcement event.

1.6 Purpose of the Study

Literature shows that when graphical and visual information is added to voice communications for incident leaders, SA is enhanced. Additionally, it shows that if multiple streams of data are added to the communication, information overload may occur. The researcher took Jones's (2011) findings a step further and researched how simultaneous video and audio communication could exponentially increase SA for the incident commander and in turn the tactical team in a simulated tactical operation. There is limited research in the area of small coordinated teams utilizing wireless, visual ICT and its effect on SA. This study examines whether or not wireless, visual ICT enhances incident understanding and SA for tactical commanders and identifies correlations between the technology, SA and information overload.

1.7 Aims and Objectives

The objective of this study is to add to the current body of knowledge of Situational Awareness (SA), to demonstrate the current standard of communication currently used for law enforcement and to discover if adding visual capabilities would enhance or speed incident and domain awareness for incident leaders. Moreover this study is intended to highlight the need for future research, development and improvement of wearable, wireless communication devices.

1.8 Research Question

This research aims to study one cutting edge technology and to determine if it enhances incident situational awareness. The research question is:

RQ. *Does wireless, visual ICT enhance incident SA for incident commanders during a tactical law enforcement event?*

Chapter 2: Literature Review

2.1 A Brief History of Police Communication and Quest for Greater Situational Awareness

Situational awareness (SA) as defined by Endsley (1995) is "the perception of 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." With the development of communication technology throughout history, and the adoption of that technology by law enforcement, the task of perceiving what is happening, interpreting why it is happening, deciding what needs to be done, are being accomplished exponentially faster at farther distances.

The attainment of SA for the law enforcement officer is an integral part of his or her job. Since the beginning of organized law enforcement, officers have been using tools to alert others to crime or danger and to request help (Leonard, 1938; Wadman, & Allison, 2004). Starting in the 1600's night watchmen used large wooden rattles to alarm other watchmen and citizens to danger (Wadman, & Allison, 2004). Rattles remained in use up into the late 1800's and were phased out in favor of the lighter and smaller whistles which could be heard up to a mile away (Wadman, & Allison, 2004). As officers only had two ways to travel, either by foot or horse, they often utilized their voices, whistles or a baton smacked on the sidewalk to summon other officers (Leonard, 1938). This one way communication was a signal that help was needed and upon hearing it, officers rushed to the location of the sound. This was a partial SA communicator in that officers knew help was needed but nothing more until they arrived.

Starting around the 1850's police departments starting using the telegraph to communicate with each other. They shared information about outlaws and other pertinent information related to law enforcement (Leonard, 1938; Wadman, & Allison, 2004). Soon larger departments were outfitting boxes along the streets so that officers could check in once an hour

and if needed, summon help from a central location. These boxes evolved from single check in apparatuses requiring a key, to sophisticated boxes where an officer could spin a dial and select the level of help he required (Leonard, 1938; Wadman, & Allison, 2004). The telegraph expanded the officers' ability to reach help, both spatially and temporally, thus expanding SA to more officers faster. The system was limited by the fact that it remained one way communication.

The telephone was the next great leap for police communication with limited use starting in the 1880's and rapid use by 1890's (Leonard, 1938; Wadman, & Allison, 2004). The telephone was the officers' first real two way communication technology (Leonard, 1938). Since the telegraph boxes had already been established, many cities started to place telephones in the boxes. These early phones ran directly to the station but it soon became apparent that switchboards would be required (Leonard, 1938). These boxes were utilized in the same way the telegraph was in that officers would check in with the desk sergeant hourly or when they needed assistance (Leonard, 1938). Soon, a new system of signaling was developed to notify the beat officer that he had a call from headquarters and varied from city to city. These consisted of semaphores, lights and bells and that would ring or flash depending on the urgency of the call (Leonard, 1938). The telephone enabled the officers and headquarters to communicate in plain language with instructions completely explained and questions asked and addressed in the course of one conversation. This expanded SA for the officers and headquarters allowing leaders, for the first time, the ability to formulate plans and instructions remotely and to communicate them without the need to physically be present.

The next revolution in police communications was the invention of wireless telegraphy (Poli, 1942). The use and adoption of radio by law enforcement was a slow and arduous process

(Poli, 1942). Starting in 1920, police leaders started to see the utility of adopting radio as a communication tool (Leonard, 1938). As police departments began to deploy officers in vehicles, they needed a better way to communicate with them. In the 1920's the Detroit police department began to experiment with radios in police cars and thought so much of its potential that in 1923 it secured a license from the Federal Radio Commission to broadcast from its own radio station (Poli, 1942). It would take five more years but in 1928 the station began to dispatch to vehicles over the radio, a first in the United States (IEEE Global History Network, n.d.). Patrol officers listened to a car radio station that by federal rules had to play music. The music would be interrupted and calls would be dispatched city wide to whatever vehicle was closest (Poli, 1942). Since the radio transmission was over a car radio, officers had to drive to a call box to telephone back the results of the call. Until the call was received from the car, headquarters did not know what vehicles responded nor the outcome of the call (Poli, 1942). The advent and deployment of the two-way radio, independent from a broadcast radio station came in the early 1930's along with the implementation of dispatch centers usually run from the police sergeant's desk (Poli, 1942). This was the beginning of two-way radio communication between officers in the field and leaders at every level. Unlike the telephone, officers could now communicate at the scene giving real-time updates and descriptions to other units and headquarters while at the same time receiving instructions from superiors. Starting in the early-1940's individual, hand held radios were being developed for foot patrol officers (Poli, 1942). Two-way radios have seen dramatic advances since then. Vacuumed tube radios gave way to crystal radios, which were supplanted by today's software microprocessor radios (Seaskate, 1998). Even with today's ultra-computerized radios, communication is limited in that multiple disjointed conversations may occur at the same time and only one person may speak at a time while all other radio traffic is

blocked during the transmission (Timmons, 2006).

Communication technology innovation for law enforcement came to a virtual halt during World War II and lasted until the 1960's (Wadman, & Allison, 2004). In 1968, 9-1-1 was established as a national emergency number giving police officers a central location to receive calls and report information that could be combined with other information obtained by fire, rescue and civilian reports (Seaskate, 1998). This central location enabled a collection point for information and allowed emergency dispatchers and police leaders the ability to construct a better understanding of what was going on by receiving comprehensive reporting from varied sources. This further expanded the SA of police officers as more data was available and could be reported to the officers as they responded. Finally in the late 1990's police departments started to outfit computer-aided dispatching (CAD) into police vehicles (Seaskate, 1998). CAD systems reduced routine radio traffic and allowed the officer to query information about subjects and vehicles. These systems now allow for recording of video and voice and for officers, GPS, instant reports from many databases, the ability to complete reports and upload them for approval without having to go back to the station (Moore, 2012). As modern as in-vehicle computing has become common place, it is of little value when the officer is outside his vehicle as he or she must rely once again on the two-way radio (Manning, 1988).

Technology has evolved to the point where mass diffused ICT like smartphones and off the shelf technology like Google Glass, along with high bandwidth connectivity can be the next step forward in police communications and further push the envelope of situational awareness for law enforcement.

2.2 Situational Awareness as a Science

As stated earlier, situational awareness (SA) as defined by Endsley (1995) is "the perception

of 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.36).

The study of SA is ongoing and many models have been developed to test SA in a variety of ways and for a variety of purposes (Salmon, Stanton, Walker, & Green, 2006; Dominguez, 1994). This includes shared SA where individual SA is studied within shared SA. There are many divergent opinions about how to measure SA and what techniques best memorialize the experience for documentation and there is no accepted "one way". There are several views on how to measure SA. These include knowledge-based techniques also referred to as objective measures that seek to tie SA to knowledge structure by using freeze probing, memory retrieving, and probing during task simulation (Endsley, 1995; Gorman, Cooke, & Winner, 2006; Sohn, & Doane, 2004). Performance based techniques are another way to measure SA and involve using implicit performance and behavior based measurements that assumes that if the task was performed well or poorly is an indication of the operator's SA at the time (Gorman, Cooke, & Winner, 2006). Subjective measurements assess SA by having participants rate their feelings of SA after performing a task. Subjective measurement tools can also be made by observers and rated without participant input; however, subject matter experts are required (Taylor, 1990, 1995; Jones, 2000). In addition, there are SA measurement tools that utilize process indices that include analyzing eye tracking, text and verbal communication plotting (Endsley & Jones, 1997). One of these tools uses verbal data converted into textual data by applying artificial neural networks (ANN) to plot clusters of concepts for plotting and analysis (Chen et al, 2010). Of these SA measurements the most validated and widely used technique is the Situational Awareness Global Assessment Technique (SAGAT) (Jones and Kaber, 2004; Endsley, 2000; Collier and Folleso, 1995).

In addition to Endsley's (1995) definition, Rahman (2011) presents a model for SA, denoted to as Somatic Situation Awareness (SSA). The author makes a case that SA does not have to be developed in the conscience mind. He asserts that "unconscious informs the conscious mind" in time compressed, dangerous situations.

2.2.1 Situational Awareness and Task Performance

Jones (2011) studied the ecologic aspects of human-computer interface (HCI) where the interactions are conducted predominantly via voice communication. The research explores the communicational relationship between the incident commander or the Emergency Operations Center (EOC) and the emergency responder. While the EOC utilizes data technologies during normal conditions it must relay the digital information verbally to the field. Conversely, during period of intense activity, digital data is replaced with two-way radio and telephonic messages between the emergency responders and the EOC. Jones argues that computer automation of this process is currently beyond practicality and therefore HCI needs to be developed to support both normal and extreme conditions. SA was evaluated by utilizing the Situational Awareness Global Assessment Technique (SAGAT) pioneered by Endsley (1988). The findings indicate several interesting but not surprising results. The interface, when changed to include graphics, allowed for better SA and less errors under both normal and extreme conditions. However, when secondary data was introduced, to corroborate the original data, errors in reporting were recorded only during the extreme conditions. This was, it is theorized, due to information overload. This may cause sensory overload or informational overload. Hwang & Lin's (1999) study showed how information overload can affect decision quality.

Matthews, Beal, & Pleban (2002) conducted a study utilizing the mission awareness rating scale (MARS) in which they tested night vision goggles and their effects on SA. This

study's focus was whether the MARS would distinguish improved SA among different simulating night vision goggle perspectives. The resulting data showed that MARS did detect differences both in the SA content and SA workload. It also served as a blueprint for this study presenting visual ICT in place of the night vision goggles.

Salmon, Stanton, Walker, & Green's (2006) paper proposes that all current SA measurement methods fail to adequately assess C4i (command, control, communication, computers and intelligence) environments. C4i systems are systems that consist of both human and technological entities designed to assemble information and enable communication of information between multiple entities dispersed geographically. C4i is described as "complex, dynamic and information rich" (p. 11) and examples include police and military operations. The researchers opine that reliability and validity issues remain and maintains that there is little evidence that SA measurement methods actually work. The study looked at seven common categories of SA measurement. The authors concluded that each SA measurement lacked something in one category or another and when attempting to measure "team or shared" SA all of the measurements fell short. The available SA measurement techniques could not assess individual or teams across geographically dispersed locations for the same task and also assess SA in real time (p. 31). The authors recommended two solutions to the SA measurement problem. The first is to develop a new SA measurement technique. This was not a consideration nor expanded on in this dissertation. The second recommendation was to combine the most successful SA measurement techniques into a "toolkit". This approach was championed by the authors as the only way to reliably collect valid data while crosschecking and validating data across categories.

2.3 Literature Synthesis

Jones (2011) makes the case that the inclusion of graphical information into the incident command process enables more SA for the incident commander. The incident commander is then in a better position to relay accurate and timely information to the first responders in the field. This research takes that theory a step further and examines how simultaneous video and audio communication could increase SA for the incident commander and in turn the tactical team. Jones (2011) found that too much data can create information overload for the incident commander, especially under extreme conditions. While Jones, (2011) utilized the Situational Awareness Global Assessment Technique (SAGAT) pioneered by Endsley (1988), the literature review reveals that there are a multitude of SA measurement techniques. As such, this researcher noticed that each SA technique presented and examined seemed to measure only a part of what was necessary for this study. Salmon, et al (2006) compared and contrasted 17 situational awareness (SA) measurement techniques against C4i (command, control, communication, computers and intelligence). They found that none of the accepted SA measurements were adequate alone and none measured "team or shared SA". C4i compares nicely with police tactical teams and was used as an example in Salmon et al. (2006). The results of Salmon et al. (2006) review of the applicability of SA measurement techniques for C4i environments concluded that a multi-measurement system should be utilized to ensure reliability and validity of the data.

Based on a study of the literature, the researcher concluded that a combination of objective and subjective SA measurement tools should be utilized to fully understand and evaluate SA for police leaders in a dynamic law enforcement environment.

Chapter 3: Research Method

3.1 Overview

This study has highlighted law enforcement's evolution in communication, the ongoing study of human factors theory including the most accepted definition for situational awareness and presented, through the literature, a multi-measurement process recommended to test situational awareness. Upon examining the extensive SA literature and speaking to leading researchers in the field, the researcher concluded that a mixed method approach would best measure SA of tactical SWAT commanders (Matthews, M. D. personal communication, January 22, 2014; Endsley, M. R. February 4, 2014). All testing and interviews were conducted at a location of the participants choosing. The testing and interviews were conducted consecutively and averaged 40 minutes per participant. Most testing and interviews were conducted at the participant's workplace.

3.1.1 Problem Statement

History shows us that the addition of new communication technology, like the telegraph, telephone, and radio, incrementally increase law enforcement's SA (Leonard, 1938; Poli, 1942). The literature review revealed that although police ICT equipment has evolved, the basic and main communication device currently utilized by law enforcement is the two-way radio (Manning, 1988). Furthermore the literature has shown that, for the military, the addition of a well-designed visual display during highly dynamic and stressful situations enhanced SA for decision makers. The majority of these studies were conducted on large command and control systems utilized to comprehend large troop movements. Although many studies exist testing SA for aviation and the military, little has been done in the area of law enforcement. What has not

been studied is the use of wireless, visual ICT devices and its effect on SA of a tactical team commanders during a dynamic, small tactical team, law enforcement event.

3.1.2 Purpose of the Study

Literature shows that when graphical and visual information is added to voice communications for incident leaders, SA is enhanced. Additionally, it shows that if multiple streams of data are added to the communication, information overload may occur. The researcher examined how simultaneous video and audio communication could increase SA for the incident commander and in turn the tactical team in a simulated tactical operation. There is limited research in the area of small coordinated law enforcement teams utilizing wireless, visual ICT and its effect on SA. This study examines if wireless, visual ICT enhances incident understanding and SA for tactical teams and to identify correlations between the technology, SA and information overload.

3.1.3 Research Question

This research aims to study one cutting edge technology (visual, wireless ICT) and to determine if it enhances incident situational awareness. The research question is:

RQ. Does wireless, visual ICT enhance incident SA for incident commanders during a tactical law enforcement event?

3.2 Research Design

This is a concurrent mixed method experimental study. Creswell (2013) defines a concurrent mixed method study where a researcher merges quantitative and qualitative methods to provide a comprehensive analysis of the research problem (pp. 14-15). This mixed-method

research design assesses if wearable, two-way visual IT, enhances an incident commander's situational awareness.

A rehearsed tactical law enforcement scenario was recorded, both audibly and visually, from the perspective of the SWAT team leader who leads his/her SWAT team into the tactical course. Using a GoPro hi-definition camera strapped to the helmet of the team leader, the researcher simulated wireless, visual ICT.

Working with the National Tactical Officers Association (NTOA) the researcher identified 12 SWAT incident commanders to conduct the study. Incident commanders are on scene during SWAT events, stationed at a short distance from the incident and manage over a radio (SWAT Standard for Law Enforcement Agencies, 2011). The experiment consists of two validated self-rating tests, one validated objective rating technique that utilizes probing question during the event, and a semi-structured interview afterwards. Six commanders heard only the scenario, simulating the current two-way radio technology; while the other six both heard and saw the scenario, simulating Google glass or similar visual ICT product. Probing questions were asked during the incident and consisted of questions such as, "Where is your team now?" and "Has the approach gone without compromise? ?" These questions were developed with a NTOA subject matter expert so that they mimic actual questions the participants would be asked at the time. These questions are used to objectively measure situational awareness. The probing questions are derived from goal- directed task analysis (GDTA) where the information requirements for SA are determined by focusing on goals to accomplish the task (Endsley, 2012). This is a form of Cognitive Task Analysis. Goals are defined by the subject matter expert (NTOA) and the researcher (Figure 3-1.). From these goals, dynamic information requirements are identified which become our SA requirements. According to Endsley (2012), GDTA focuses

on information that is relevant to a particular profession and is utilized to determine information needs that change dynamically throughout the course of the task (p.63).

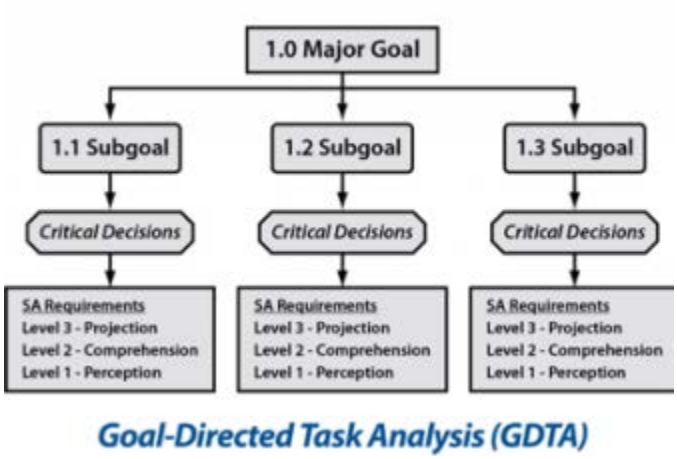

Figure 3-1 Goal-Decision-SA requirements

Probing questions are then developed based on the SA requirements identified in the GDTA. The question is scored as correct or incorrect and given values as 2 and 1. The overall score is based on the answers by the participant. This SA assessment technique is done using a method based on the Situational Awareness Global Assessment Technique (SAGAT). Unlike the SAGAT, probing questions are asked without freezing the simulation. Due to the dynamic and fluid work environment of tactical law enforcement situations and based on the literature, the SAGAT was modified for use with real-time probes as developed from the GDTA. Salmon, Neville, Stanton, Ladva, Jenkins, Walker, & Rafferty (2007) offer the following critique of freeze probes,

> "Freeze probe techniques are, however, flawed in a number of ways. Firstly, the extent to which probe responses reflect participant SA is questionable. By probing participants, these approaches could be directing them towards the required answer, thus deriving an

> artificial measure of the participant's awareness at the time of the freeze. The freezing of tasks is also problematic (Salmon et al., 2006). Freezing a 'real' scenario (with multiple information sources) and administering SA queries to multiple agents across different geographical locations appears to be almost impossible. This limitation alone poses serious questions regarding the use of freeze probe techniques in such environments. Secondly, the intrusion upon primary task performance caused by the task freezes is problematic (pp. 14-15).

For dynamic law enforcement situations, answering questions while still continuing to monitor the situation is a reality whereas stopping the scenario or task to contemplate an answer is not. Situational awareness testing has to take this multi-task approach into account in order to accurately measure success. It may be counterproductive to remove reality or freeze the action, for even one minute, as police officers often operate in all three levels of Endsley's (1995) SA model, perception, comprehension and projection, at the same time. Rahman, M. (2011) maintains that Situational Awareness (SA) is obtained in the non-conscious mind as well as the conscious mind. He articulates that in situations with severely compressed time, that are non-typical and highly volatile that situation awareness can only be obtained somatically calling it somatic situational awareness (SSA). Rahman calls this study High Velocity Human Factors (HVHF) with SSA serving as a paradigm where the unconscious informs the conscious mind. This process model for SSA has been developed as part of the Rahman's effort to help with informing systems design for first responders. Rahman maintains that the underlying process of SSA is unconscious; the participant may not be able to verbally explain on how he/she achieved SSA. The study makes the point that it is a conflict of terms to say that SA is achieved without

awareness in the conscious. Freeze probes may hinder SSA and therefore affect the outcome of the SA measurement.

After the scenario each participant was administered two self-rating tests, the MARS (a subjective measure of SA) and the NASA TLX (a subjective measure of task overload). The test took approximately 20 minutes to complete. The participant was then interviewed and had the ability to look at and use the Google Glass technology. These semi-structured interview questions related to usability, acceptance and issues and opinions of the technology. The participants were able to discuss their opinions on the value of the technology, the future of wearable technology and any issues they see related to it. The objective test (SAGAT) is followed by the two subjective SA tests. This is followed by an oral debrief where semi-

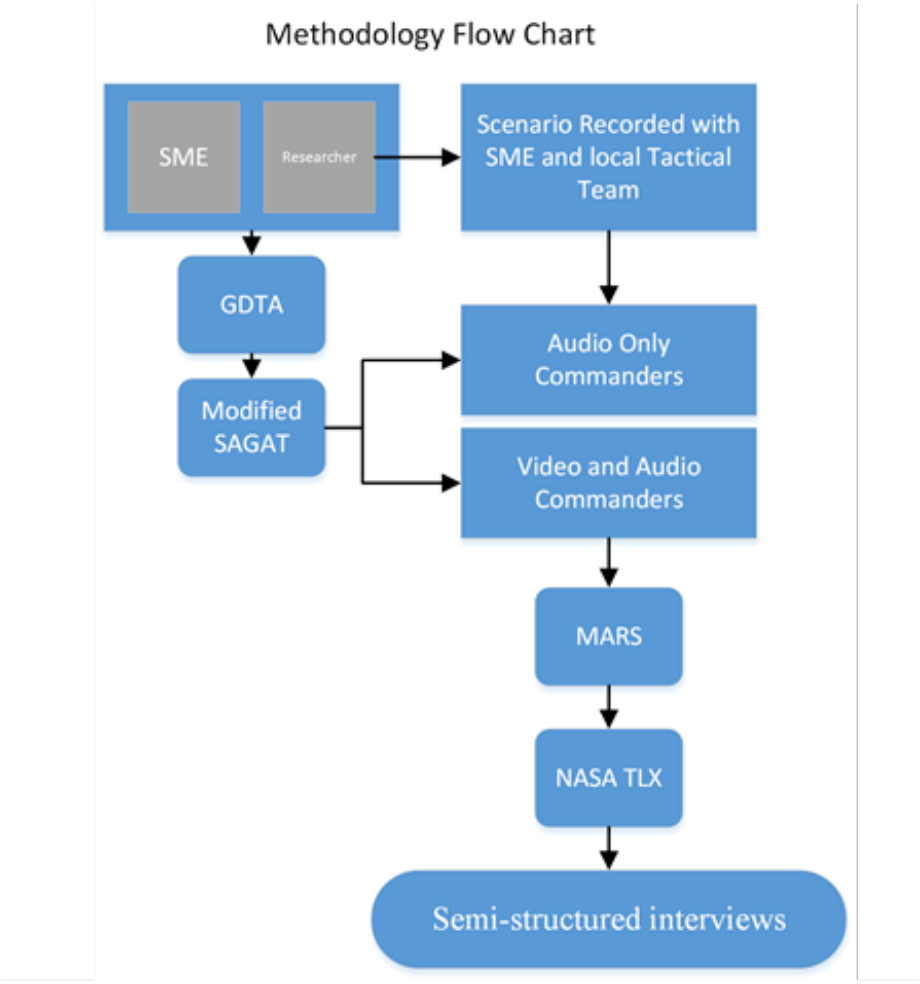

Figure 3-2 Methodology Flow Chart

structured interview questions were asked.

3.3 Data Collection

Data collection was accomplished utilizing multiple collection methods. Four were quantitative and one was qualitative. The quantitative instruments consisted of one objective measurement of SA (SAGAT), two subjective measurements of SA (MARS & NASA TLX) and lastly spatial and temporal information from the scenario. The quantitative data collection method consisted of semi-structured interviews. Data collection began on May 16, 2014 and concluded on August, 30, 2014.

3.3.1 Situational Awareness Global Assessment Technique SAGAT

The most validated and widely used technique for measuring situational awareness is the Situational Awareness Global Assessment Technique (SAGAT) (Jones and Kaber, 2004; Endsley, 2000; Collier and Folleso, 1995). This technique utilizes probing questions during scenarios to measure all SA requirements objectively. Questions or probes are developed using a Goal Directed Task Analysis (GDTA). Information requirements for SA are determined by focusing on goals to accomplish the task (Endsley, 2012). This GDTA narrows overall goals into specific sequence of tasks and then into information that is needed to complete each task. The *information need* is then broken down into questions that are scored as correct or incorrect based on input from subject matter experts. From these GDTA questions, a simulation or scenario is constructed for testing (Endsley, 1988).

The development of the GDTA began when the researcher examined the tactical law enforcement domain to better understand the profession, its culture and its tactical requirements. Several documents were utilized including Klinger & Rojek‘s 2008 multi-method study and the NTOA’s 2011 SWAT Standards. Next the researcher then identified subject matter experts

(SMEs) from the National Tactical Officers Association. Several semi-formal consultations were conducted over a four month period. These meetings involved 15 SMEs who were tactical commanders and members of the National Tactical Officers Association (NTOA). The researcher communicated with the SMEs in person, over the phone and via email; explaining the research project, its purpose and solicited their expertise in the development of a tactical GDTA. The initial meeting was with an influential member of the association who introduced the researcher to the group. During this initial meeting a preliminary overall goal and goal structure was discussed and a rough outline developed. The overall SWAT goals were developed with NTOA's tactics in mind and had to be representative of all critical SWAT incidents. This allowed the researcher and SMEs to identify the goals and task that must be competed in most critical incidents, relieving the GDTA developers of undertaking an expanded task structure with potentially infinite scenarios. The initial SWAT overall Goals and SWAT GDTA was communicated to the group for comment. Upon receiving feedback on the SWAT GDTA the overall goals and final structure was agreed upon (Figure 3-3).

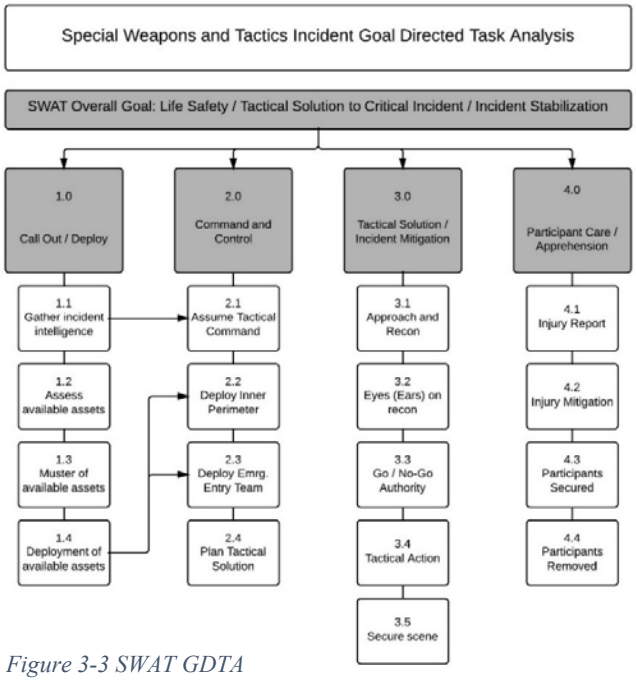

Figure 3-3 SWAT GDTA

The SWAT GDTA represents the main tasks that need to be completed during most tactical operations. The SMEs agreed that the goals, sub-goals, and task represented what must be completed in most critical incidents however they stipulated that the order of the tasks depended on the individual critical incident and the potential for multiple variables. In other words the content was correct regardless of what order the tasks were to be completed

The next step in the development of the GDTA was focus on a sub-goal that allowed for testing within a reasonable period of time. The SWAT GDTA identified four sub-goals for most SWAT incidents. These include Call Out/Deploy, Command and Control, Tactical Solution/Incident Mitigation, and Participant Care/Apprehension. Since the goal of the GDTA was to develop a scenario for testing SA, it was determined that three sub-goals were not appropriate for use. The sub-goals Call Out/Deploy, Command and Control and Participant Care/Apprehension were determined to be too lengthy of a process and/or too complicated for inclusion in SAGAT testing or not dynamic enough to adequately test SA and workload. Taken as whole, the SWAT GDTA would ebb and flow dynamically. This would be problematic when analyzing the subjective measurements as too much time would pass between the start of the scenario and its conclusion. The subjective measurements could not be adequately timed and administered with the most dynamic and time compressed portions of the extended scenario. Finally the SMEs agreed that the time needed to test the entire scenario would exceed most participants' ability and deter willingness to volunteer. The sub-goal Tactical Solution/Incident Mitigation was selected for testing as it can be tested in a shorter period of time, has the potential for the development of a dynamic and time compressed scenario and can be utilized with the SAGAT measurement tool. As an example, a rough outline of task 2.4 illustrates the complexity of including the entire SWAT GDTA into the scenario (Figure 3-4).

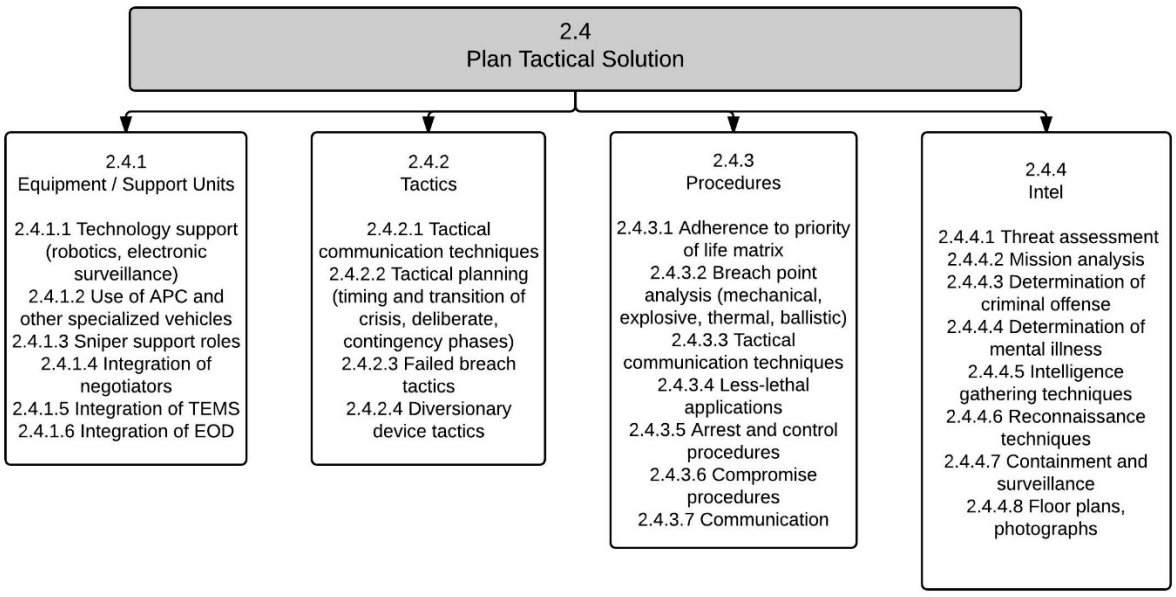

Figure 3-4 GTDA 2.4 Example

The Tactical Solution/Incident Mitigation sub-goal structure was expanded and a rough outline was communicated via email and survey to the larger group of SMEs. This included narrowing the tasks to information requirements and the solicitation and agreement of decisions for each. There was little disagreement among the SMEs about the information requirements as they had been decided in the overall SWAT GDTA. The task decisions were relatively agreed upon however there was one insistence that negotiation (police negotiation) be added. This was also mentioned in the larger SWAT GDTA however the main objective of this GDTA is to create a task analysis that is representative of all critical SWAT incidents. The police negotiator has a part in some incidents and could encompass the sub-goals and tasks in Call Out/Deploy, Command and Control, and Tactical Solution/Incident Mitigation depending on the critical situation. For this reason it is assumed that the police negotiator is included in several tasks across several sub-goals; however, it was not formally included in the final Tactical

Solution/Incident Mitigation GDTA because it was incident dependent and it had the potential to prolong the scenario. Upon receiving feedback on the Tactical Solution/Incident Mitigation GDTA the information requirements and task decisions were agreed upon (Figure 3-5).

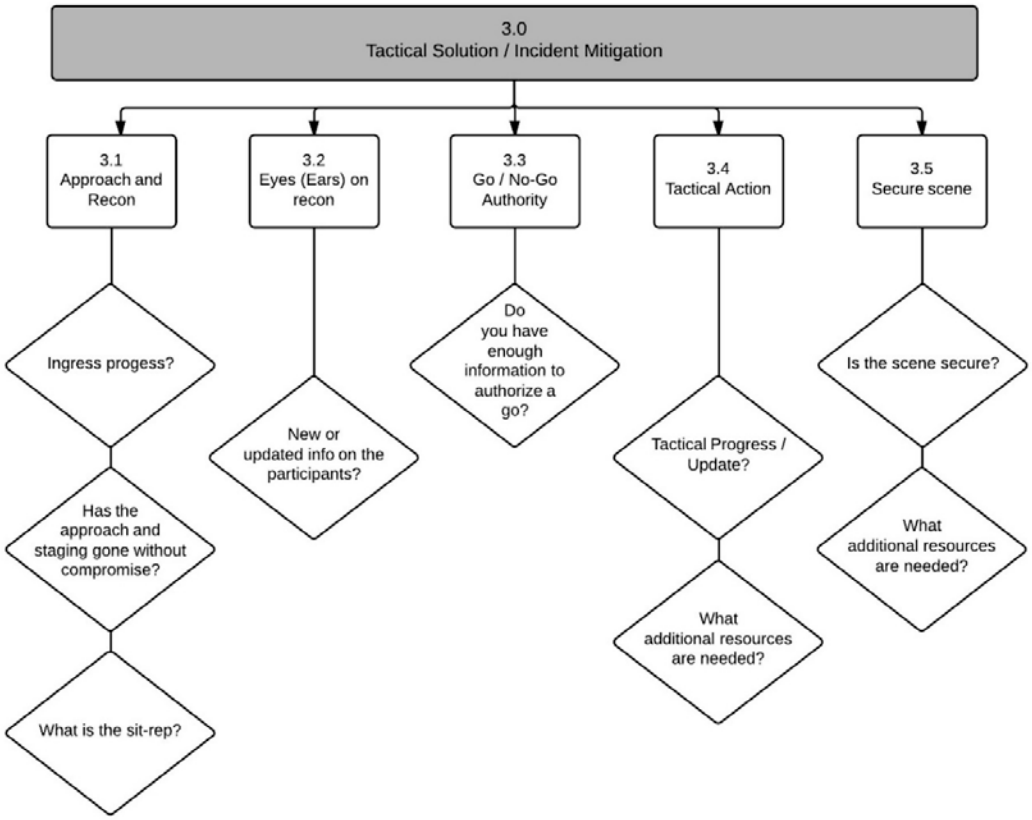

Figure 3-5 Tactical Solution/Incident Mitigation GDTA

Once the GDTA was complete the researcher worked with an SME to design an appropriate scenario where the GDTA could be utilized to test SA using the SAGAT, MARS and NASA TLX protocols. Since tactical officers' tasks vary and there are multiple potential variables prior to, during and after an actual tactical event; the constructed scenario was restricted to only tasks that any tactical officer, in the same situation, would have to perform. Therefore the scenario was narrowed in scope to restrict options outside of the Tactical Solution/Incident Mitigation GDTA. For this reason police negotiation, and sniper assets were

not available in this scenario, limiting the participant's options to a *tactical resolve* utilizing an emergency entry team. This necessitated the use of the entry team and provided a controlled scenario whereupon the SAGAT probes could be utilized uniformly regardless of the technology being used. In addition, the recorded scenario was bounded to tasks 3.1 Approach and Recon through 3.4 Tactical Action eliminating task 3.5 Secure Scene for testing purposes. Again the researcher wanted to utilize the subjective measurements immediately after the dynamic and time compressed portion of the GDTA. Task 3.5 Secure Scene, would wind down the dynamics of the scenario prolonging the play.

The scenario was finished and agreed upon by an SME and the researcher (Appendix A). Utilizing a NTOA trained SWAT team, not part of the research participant pool, the researcher and SMEs spent four days recording the scenario using the above mentioned script. The script and subsequent recording was produced in order to employ the SAGAT probes derived from the GDTA. The 8 minute 29 second scenario was recorded both on video and audibly. The scenario was recorded from the perspective of the tactical team leader and the participant plays the role of the tactical commander. Each participant was briefed on the scenario and given additional information about the suspect and victim, the layout of the building, and limitations such as lack of view in the building and the suspect's rejection of negotiation (Appendix B1-B4). In addition the scenario adds exigent circumstances that compel the use of the emergency entry team. A participant SAGAT scoring sheet was made to be used with both the video and audio recording and marks the exact time the probes should be asked to the participant and the answers given. The SAGAT sheet also records the time to answer and if the correct answer was given (Appendix C).

3.3.2 Mission Awareness Rating Scale MARS

Matthews, Beal, & Pleban (2002) conducted a study utilizing the mission awareness rating scale (MARS) in which they tested night vision goggles and their effects on SA. This study's focus was whether the MARS would distinguish improved SA among different simulating night vision goggle perspectives. The resulting data showed that MARS did detect differences both in the SA content and SA workload. It also served as a blueprint for this study presenting visual ICT in place of the night vision goggles. The MARS rating scale was based on the Crew Awareness Rating Scale developed by McGuinness & Foy (2000) and modified to be more consistent with infantry tasks and functions (Matthews, Beal, & Pleban, 2002). The MARS scale was used as it best fits the infantry like tactics and function also performed by SWAT teams.

The MARS was completed by the participant immediately following the completion of the scenario and followed the NASA TLX (Appendix D).

3.3.3 NASA Task Load Index (TLX)

The NASA TLX instrument was developed by NASA to subjectively measure mental workload. Hart and Staveland (1988) developed, tested and validated the NASA TLX instrument to determine workload using a weighted combination of factors that provide a sensitive indicator of the overall workload between different tasks and among different levels of each task (p.39). The weights and the magnitude of the ratings of the individual scales provide important diagnostic information about the specific source of loading within the task (p.39). A desktop application was utilized to capture the NASA TLX (Appendix E). It was developed by Sharek, (2011) and was downloaded at www.playgraph.com/nasatlx.

The NASA TLX was completed by the participant immediately following the completion of the scenario and preceded the MARS.

3.3.4 Interviews

The semi-structured interviews were conducted following the completion of the subjective SA measurements. These semi-structured interview questions (Appendix F) related to usability, acceptance and issues and opinions. Creswell (2012) reports the mixing of qualitative methodology with quantitative data creates an opportunity for a comprehensive analysis of the research data.

The participants were shown the visual ICT device (Google Glass) and a short demonstration on how to use the device was completed. The device was then worn and used by the participant while the interview questions were asked. The participants were able to discuss their opinions on the value of the technology, the future of wearable technology and any issues related to it. No time limit was placed on the interviews. These interviews were recorded using a RCA VR6320 note recorder as well as recorded with the Google Glass during the interview. Permissions were obtained prior to the start of the experiment.

3.3.4.1 Interview Questions

The interview questions were developed as triangulation and complementary justifications for the mixed method research. Green et al. (1998) described triangulation as the convergence of different methods to find corroboration in the data and complementary as the elaboration of the data from one method with the results of the other (p. 259). While the research question and quantitative tests were designed to demonstrate if the technology enhanced SA, the interview questions were developed to ascertain if the technology would be accepted and utilized. For this reason the interview questions may or may not link to the research question

Table 3-1). The data from the interviews relating to the perceived usefulness were compared with participants who viewed the scenario to those participants who only heard the scenario. Differences (if any) between the groups were discussed and compared with the overall data collected.

Table 3-1 Interview Questions

Interview Questions	Purpose
1. Describe how you feel this technology could be useful for law enforcement. 2. What features are useful? 3. What features are not useful? Why?	Usability Links to RQ if enhancement of SA is perceived.
1. Would this technology be accepted by police officers? Why? Why not? 2. Give me some reasons this technology might succeed? 3. Give me some reason this technology might fail? 4. What could be done to make this technology acceptable in the LE culture?	Acceptance Links to the RQ if workload issues are perceived.
1. What is your overall opinion of this technology for this application? 2. Are there design issues with the current technology? 3. What would you change? 4. How would you utilize this technology?	Issues, Opinions and Comments

3.3.5 Other Data

The author collected and noted spatially, the location of the aggressor in the scenario in relation to the victim and which way he was facing when the participant called for action. This was plotted on a schematic of the floor plan (Appendix G). The researcher also noted the time it took participant to call for action. (Appendix C). Although not part of any of the above protocols, the researcher believes it will add to the data as the position of the aggressor from the

victim and the direction the aggressor is facing is of extreme importance when completing the tactical task.

3.4 Permissions

This was a human subject research study. This study was reviewed and approved by the Robert Morris University Institutional Research Board on May 16th, 2014 (Appendix H). Assistance and approval was requested from the National Tactical Officers Association (NTOA) on April 27, 2014. Final approval to recruit and utilize NTOA members as participants was obtained on May 13, 2014. This was obtained from the Executive Director (Appendix I).

Prior to the start of each experiment the participant was briefed on the study. This discussion included a description of the study, the procedure of the experiment, potential risks, confidentiality, and withdrawals. Each participant was then asked to read and sign an Informed Consent Agreement (Appendix J).

3.5 Research Sample

Tactical law enforcement officers were chosen because they employ repetitive, exercised, tactical actions and train as a cohesive team. Tactical officers deal with high risk, potentially violent situations and as specially trained officers; they are dispatched to incidents requiring paramilitary-like weapons and tactics (California Department of Justice, 2002; Kraska, 1999). This repetitive and standardized training allows for the creation of a testable scenario that enables predicable outcomes that can be utilized with the SAGAT protocol to objectively test SA. It also allows for the inclusion of subjective measures recommended in the literature.

This study consists of 12 tactical commanders. The sampling for this study was purposeful and convenient based on criteria (tactical commanders) and convenient (based on

participant willingness). Each commander serves as a commander on a SWAT team. All participants had extensive experience in conducting dynamic forced entries. The sample represents a large number of SWAT commanders for the entire western half of an eastern state. All participants were white males between the age of 30 and 50 years of age.

3.6 Participants

Participants were identified through gaps in the literature as this technology had not been tested in this way on law enforcement officers. The participants were further narrowed to only tactical command officers. Tactical team commanders who are members of the National Tactical Officers Association (NTOA) and who work in a northeastern state were chosen for this study. The NTOA members train according to a national standard that requires each member to utilize similar training, tactics, and vernacular and who adhere to a common set of standards (NTOA 2011 SWAT Standards).

Recruitment of the participants began on July, 10, 2014, when, upon the request of the author, an influential member of NTOA sent an email to 23 NTOA members introducing the researcher, describing the study and inviting NTOA SWAT commanders to consider taking part in the study (Appendix K).

From a contact list provided by the above influential member, the author contacted the 23 potential participants via email and followed up contact with a phone call upon positive email affirmation that they were interested in participating. The author stopped soliciting participants when reaching 12 positive responses. The 12 participants were SWAT commanders dispersed widely across the western part of a northeastern state. During testing, Participant 6 failed to understand and follow the instructions while completing the SAGAT. Upon completion of

viewing the scenario the participant admitted that he misunderstood the instructions and thought he was to watch the entire scenario before the test. The scenario could not be viewed again by the participant without skewing the results. This participant's results was eliminated from the study and another participant was identified. Participant 13 was contacted utilizing the potential participant list mentioned above and agreed to be tested.

3.6.1 Ethical Consideration (Human Subject Protections)

Because the participants are volunteers and do not and have not worked for the researcher, there is no power differential issues. Each participant was asked to sign an informed consent and advised as to the purpose of the study, the nature of the research and its anticipated length (Appendix J).

Research protocols such as confidentiality, anticipated risks, compensation and/or benefits were discussed and employed. The participants were advised that they are free to discontinue the study at any time without penalty. This study was administered under the approval of the Robert Morris University Institutional Review Board (Appendix H).

3.7 Data Analysis and Validity

Data analysis was conducted by using previously validated quantitative instrumentation and tools found in the literature and by adhering to their established data analysis processes. Corroboration and elaboration of the quantitative data was achieved by comparing the quantitative data results from each instrument/tool and by incorporating a qualitative method, namely interviews. According to Greene, Caracelli, & Graham (1989) validity is achieved through triangulation in mixed methodology when, "the quantitative and qualitative methods be different from one another with respect to their inherent strengths and limitations/biases and that both method types be used to assess the same phenomenon" (p. 266).

3.7.1 SAGAT

This SA assessment technique is done using a method based on the Situational Awareness Global Assessment Technique (SAGAT). Probing questions were developed with a subject matter expert so that they mimic actual question the participants would be asked at the time. These questions are used to objectively measure situational awareness. The probing questions are derived from goal- directed task analysis (GDTA) where the information requirements for SA are determined by focusing on goals to accomplish the task (Endsley, 2012). This is a form of Cognitive Task Analysis. Goals are defined by the subject matter expert and the researcher. From these goals, dynamic information requirements are identified which become our SA requirements. According to Endsley (2012), GDTA focuses on information that is relevant to a particular profession and is utilized to determine information needs that change dynamically throughout the course of the task (p.63).

The probing questions were scored as correct or incorrect and given values as 2 and 1. The overall score was based on the answers by the participant. This test was modified by replacing freeze probe questions with real time probes. Using SPSS, the data was analyzed using chi-square and descriptive data. (Endsley, 2012, p 18). Each query was evaluated separately.

3.7.2 Mission Awareness Rating Scale (MARS)

The Dependent variables are SA and Workload. The instrument utilized to test for SA is the Mission Awareness Rating Scale. Situational awareness is measured by the participant's response to 8 questions of SA grouped into 2 subsets. One subset assesses SA and the other assesses workload. There are four questions in each subset that address SA: Identification, Comprehension, Prediction and Achieve.

A four point rating scale is used for each of the 8 SA questions with interval data from low (1) to high (4).

Utilizing SPSS, the researcher ran a means and standard deviation for the 8 MARS questions by position, then several ANOVAs.

3.7.3 NASA Task Load Index (NASA-TLX)

The Dependent variable was mental workload (MW) and the instrument utilized to test for MW was the NASA-TLX (Hart, & Staveland, 1988). The NASA-TLX is a two part instrument that first rates six subscale tasks from Very Low (0) to Very High (100) creating interval data. The output is combined and each task receives a load index. The second part of the instrument has the participant weigh each category of the six subscales pairwise whereupon the participant chooses which tasks are more relevant to workload. The number of times the task is chosen creates the weighted score. The weighted score for each subscale is multiplied by the load index from the first part of the instrument. This is then divided by 15 to achieve a score from 0 to 100. The MW dependent variables (subscales) are mental demand, physical demand, temporal demand, own performance, and effort frustration.

Utilizing SPSS, the researcher ran a means and standard deviation. Correlations were run across the subscales to find relationships.

3.7.4 Interview Questions

Each interview was audibly recorded. These recordings were listened to several times and significant points, idea, words and phrases were noted for each question. Reviewing the raw data allowed the researcher to develop knowledge and recognize patterns. Similarities were noted and the researcher attempted to make sense of the relationships. A list of categories were made and the data was coded into themes. The results were reexamined looking for similarities

and redundancy. The codes were then represented graphically with the best representation from each theme presented verbatim for descriptive elaboration. The quantitative findings were compared to the qualitative themes that emerged so that a comprehensive analysis of the research data could be accomplished (Creswell, 2013).

3.7.5 Temporal and Spatial Data

Time and space data was collected during the SAGAT scenario. The author collected and noted spatially, the location of the aggressor in the scenario in relation to the victim and which way the aggressor was facing when the participant called for action. The researcher also noted the time it took participants to call for action. This data was compared to the data analyzed from the other methods and compared graphically.

3.8 Data Security

All physical data collected resides in a locked safe. This includes all recordings, signed forms, personally identifiable information (PII), instrumentation score sheets and handouts. Any data removed for data analysis is free from PII. Each participant was assigned a code starting with P1 through P13. The linking document that matches the participants to each code is also locked in a safe. All computer data, videos, audio, and scanned forms, including the above mention data, has been scanned and resides on a secure cloud backup system called Carbonite. All Carbonite data is encrypted using 128 bit encryption and transmitted using a secure socket layer (www.carbonite.com). The author is the only person with access to the data.

3.9 Paradigm

As a lifelong criminal investigator, the researcher's theoretical perspective has been formed by his profession. The researcher believes that a good investigation should be pragmatic

in its process and reflective on its results. Good research combines pragmatism with the ability to observe the reasoning of the participant/s. What is happening and what is thought to be happening. They could be the same or vastly opposite. A justifiable homicide is a homicide none the less. It needs to be investigated methodically as any other homicide. What was going on in the killers mind is important as it informs to the facts. The effects on cognitive actions like situational awareness can be tested at the individual and small group level and aggregated to a larger population that would evidence a similar positive or negative influence on SA.

3.10 Bias

As a law enforcement professional, the researcher holds certain bias as it relates to police tactics, training, and the usefulness of certain technologies in the profession. As such, the researcher will utilize in -member checking, clarify his bias from the outset and add reflectivity to the findings to ensure that all bias and assumptions are understood and employ external audits for coding and analysis.

Chapter 4 Data Analysis

4.1 Overview and Objectives

The objective of this mixed-method study is to assess if wearable, two-way visual ICT, enhances an incident commander's situational awareness. This concurrent mixed method experimental study merges quantitative and qualitative methods to provide a comprehensive analysis of the research problem. Furthermore the researcher concluded, based on a study of the literature, that a combination of objective and subjective SA measurement tools should be utilized to fully understand and evaluate SA for police leaders in a dynamic law enforcement environment.

The Situational Awareness Global Assessment Technique was used to objectively measure situational awareness (SA). This included identifying goals and tasks then narrowing the tasks to information requirements. These dynamic information requirements were used to produce a scenario for testing. Probing questions were created and matched to the information requirements that related to perception, comprehension and projection as outlined previously (Table 4-1). The SAGAT scenario consisted of four probing questions that were scored as correct or incorrect; each based on the answer to the dynamic information requirement that the researcher and the SMEs identified. The overall score was based on the answers given by the participant. The scenario was administered to 12 participants. Six participants heard only the scenario, simulating the current two-way radio technology; while the other six both heard and saw the scenario, simulating Google Glass or similar visual ICT. This test was modified by replacing freeze probe questions with real time probes.

Table 4-1 SA Levels and Probes.

Information Needs / Probes / SA Elements		
3.1 Approach and Recon	Probe 1	Perceive
3.1 Approach and Recon	Probe 2	Comprehension 1
3.2 Eyes (Ears) on recon	Probe 3	Comprehension 2
3.3 Go / No-Go Authority	Probe 4	Projection

The Mission Awareness Rating Scale (MARS) instrument was utilized to subjectively test SA. Situational awareness was measured by the participant's responses to 8 questions of SA grouped into 2 subsets. One subset assesses SA and the other assesses workload. There are four questions in each subset that address SA: Identification, Comprehension, Prediction and Achieve.

A four point rating scale is used for each of the 8 SA questions with interval data from low (1) to high (4). This test was administered immediately after the SAGAT and the NASA TLX.

The NASA-Task Load Index was utilized to subjectively measure mental workload Hart and Staveland (1988) developed, tested and validated the NASA TLX instrument to determine workload using a weighted combination of factors that provide a sensitive indicator of the overall workload between different tasks and among different levels of each task (p. 39).

Finally, semi-structured interviews were conducted following the completion of the subjective SA measurements. These semi-structured interview questions related to usability, acceptance as well as issues and opinions of the technology.

4.2 SAGAT Results

The SAGAT scenario consisted of four probing question that were scored as correct or incorrect each based on the answer to the dynamic information requirement that the researcher and the SMEs identified. The overall score was based on the answers given by the participant.

Table 4-2 SAGAT Coding

Coding		No	Yes
Q1	Perception	1	2
Q2	Comprehension		
Q3	Comprehension		
Q4	Projection		

4.2.1 SAGAT Data Analysis

Probe 1. Perception

Where is your team now? (Progress of ingress) 3.1

Table 4-3 SAGAT Probe 1 Perception Scores

Perception: Probe 1 * Communications Type Crosstabulation

		Communications Type		
		Audio	Visual	Total
Perception	No	6	0	6
	Yes	0	6	6
Total		6	6	12

Table 4-4 SAGAT Probe 1 Audio Group

Audio Group Perception

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	6	100.0	100.0	100.0

Table 4-5 SAGAT Probe 1 Visual Group

Visual Group Perception

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100.0	100.0	100.0

Table 4-6 SAGAT Probe 1 Chi-Square

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	12.000[a]	1	.001		
Continuity Correction[b]	8.333	1	.004		
Likelihood Ratio	16.636	1	.000		
Fisher's Exact Test				.002	.001
Linear-by-Linear Association	11.000	1	.001		
N of Valid Cases	12				

a. 4 cells (100.0%) have expected count less than 5. The minimum expected count is 3.00.

b. Computed only for a 2x2 table

The initial crosstabs for Probe 1 indicates a substantial difference in the ability to perceive what was going on during the scenario with the visual group able to correctly answer the probe 100% of the time and the audio only group displaying the reverse. A significance of .001 was found using the Chi-Squared test.

Probe 2. Comprehension

Has the approach gone without compromise? 3.1

Table 4-7 SAGAT Probe 2 Comprehension Scores

Comprehension 1: Probe 2 * Communications Type Crosstabulation

Count

		Communications Type		
		Audio	Visual	Total
Comprehension 1	No	1	0	1
	Yes	5	6	11
Total		6	6	12

Table 4-8 SAGAT Probe 2 Audio Group

Audio Group Comprehension 1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	16.7	16.7	16.7
	Yes	5	83.3	83.3	100.0
	Total	6	100.0	100.0	

Table 4-9 SAGAT Probe 2 Visual Group

Visual Group Comprehension 1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100.0	100.0	100.0

The initial crosstabs and frequencies for probe 2 show that the audio and visual group scored 100% while the audio only group scored 83.3% with one participant incorrectly answering the probe. There was no significant finding using the Chi-Squared test. This probe required the participant to comprehend information about the location of the entry team and their success in moving to the staging location.

Probe 3. Comprehension

Is there any new or updated information? 3.2

Table 4-10 SAGAT Probe 3 Comprehension Scores

Comprehension 2 * Communications Type Crosstabulation

Count

		Communications Type		
		Audio	Visual	Total
Comprehension 2	No	4	2	6
	Yes	2	4	6
Total		6	6	12

Table 4-11 SAGAT Probe 3 Audio Group

Audio Group Comprehension 2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	4	66.7	66.7	66.7
	Yes	2	33.3	33.3	100.0
	Total	6	100.0	100.0	

Table 4-12 SAGAT Probe 3 Visual Group

Visual Group Comprehension 2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	2	33.3	33.3	33.3
	Yes	4	66.7	66.7	100.0
	Total	6	100.0	100.0	

The initial crosstabs and frequencies for probe 3 shows that the audio and visual group scored 66.7% while the audio only group scored 33.3% with four audio only participants incorrectly answering the probe compared to two participants in the audio and visual group. The probe

required the participants to correctly update the situation. Missed cues included an update of the description and location of the scenario suspect.

Probe 4. Projection:

You have compromised authority for tactical resolve when you have appropriate separation. Call out "go" to initiate. 3.3

Table 4-13 SAGAT Probe 4 Projection Scores

Crosstab

Count

		Communications Type		
		Audio	Visual	Total
Projection	Yes	6	6	12
Total		6	6	12

Table 4-14 SAGAT Probe 4 Audio Group

Audio Only Group Projection

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100.0	100.0	100.0

Table 4-15 SAGAT Probe 4 Visual Group

Audio and Visual Group Projection

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100.0	100.0	100.0

Both groups correctly answered the probe and initiated the team for entry. The location of the suspect in relation to the suspect was used to score this probe.

4.2.2 SAGAT Data Interpretation

Probe 1 revealed a substantial difference in situational awareness as it related to perception. The participants were briefed as to the location of the staging area on the second floor prior to the start of the scenario. Initial briefings indicated that a winding staircase with a landing needed to be ascended between the floors and that once the team was on the second floor they would notify the incident commander. Correct answers could vary from "ascending stairs to the second floor" to "in the stairwell" or any mention of stairs. Incorrect answers were any answer where the participant indicated they did not know where the team was.

Probes 2 revealed that the both audio and visual cues were sufficient to allow the participants to gain comprehension of the team's successful movement to the staging area. One audio only participant could not verify that the team was in place since he missed the audio cue. Probe 3 revealed that updated descriptions and suspect location was missed more frequently by the audio only group 66.7% compared to the visual group 33%.

4.3 MARS Results

The Mission Awareness Rating Scale (MARS) was coded from 1 to 4 as follows:

Table 4-16 MARS Coding

	Very Easy	Fairly Easy	Somewhat Difficult	Very Difficult
Code	1	2	3	4

The first four questions deal with the participant's ability to detect and understand important cues present during the mission. These questions related to Situational Awareness Identification, Comprehension, Prediction and Achievement. The last four questions ask how difficult it was

for the participant to detect and understand important cues present during the mission. These questions related to Workload Identification, Comprehension, Prediction and Achievement.

4.3.1 MARS Data Analysis

Situational Awareness: Identify

Question 1: Please rate your ability to identify mission-critical cues in this mission.

Table 4-17 MARS Question 1 Scores

Situational Awareness: Identify

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
SA Identify	Very Easy	1	1	2
	Fairly Easy	3	5	8
	Somewhat Difficult	1	0	1
	Very Difficult	1	0	1
Total		6	6	12

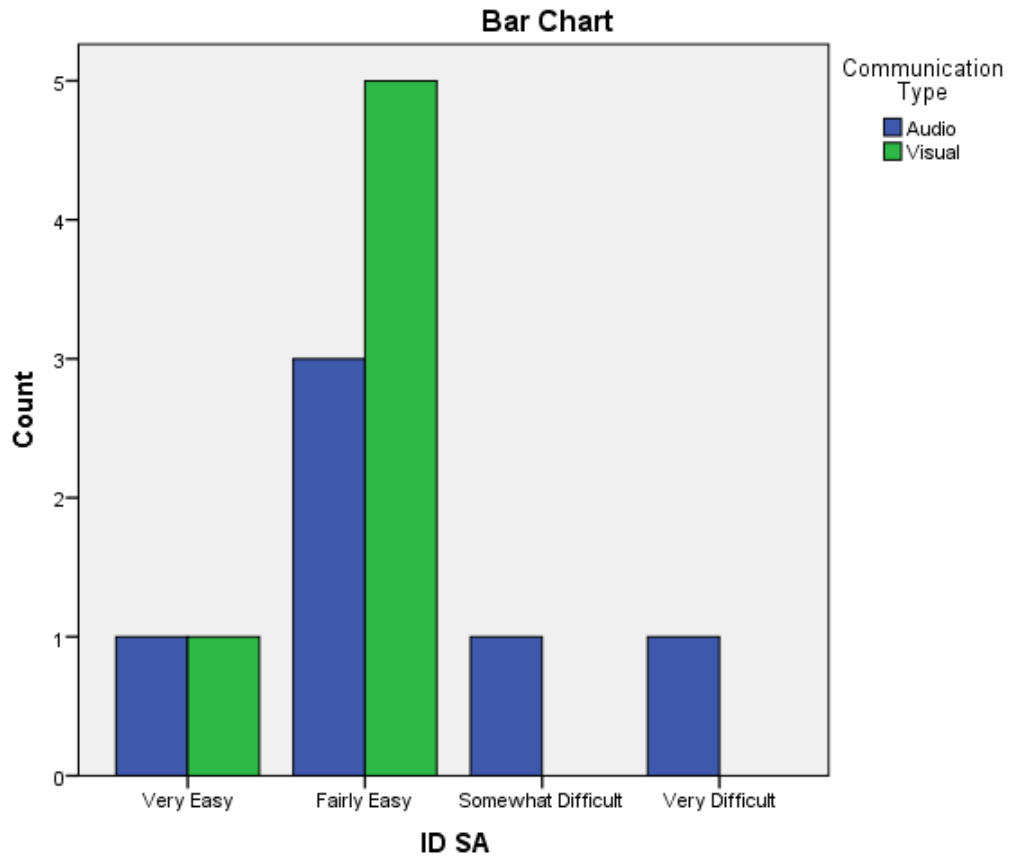

Figure 4-1 MARS Situational Awareness: Identify

The cross tabulation and the corresponding bar chart reveal that the visual group had a larger and more consistent positive result identifying mission-critical cues in the scenario. A third (2) of the audio group found it Somewhat Difficult or Very Difficult to identify mission-critical cues in the scenario while all (6) of the video group found it Very Easy or Fairly Easy. As expected, due to the small testing population an ANOVA test revealed no significant results.

Situational Awareness: Identify

Communication Type Mean and Standard Deviation

Table 4-18 MARS Mean and SD Question 1

Communication Type		ID SA
Audio	Mean	2.33
	N	6
	Std. Deviation	1.033
Audio and Visual	Mean	1.83
	N	6
	Std. Deviation	.408
Total	Mean	2.08
	N	12
	Std. Deviation	.793

The visual group's score on this question was more consistent than the audio only group with a SD .4 compared to a SD of 1. As noted above the visual group's score is less distributed.

Situational Awareness: Understand

Question 2: How well did you understand what was going on during the mission?

Table 4-19 MARS Question 2 Scores

Situational Awareness: Understand

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
SA Understand	Very Easy	1	3	4
	Fairly Easy	5	3	8
Total		6	6	12

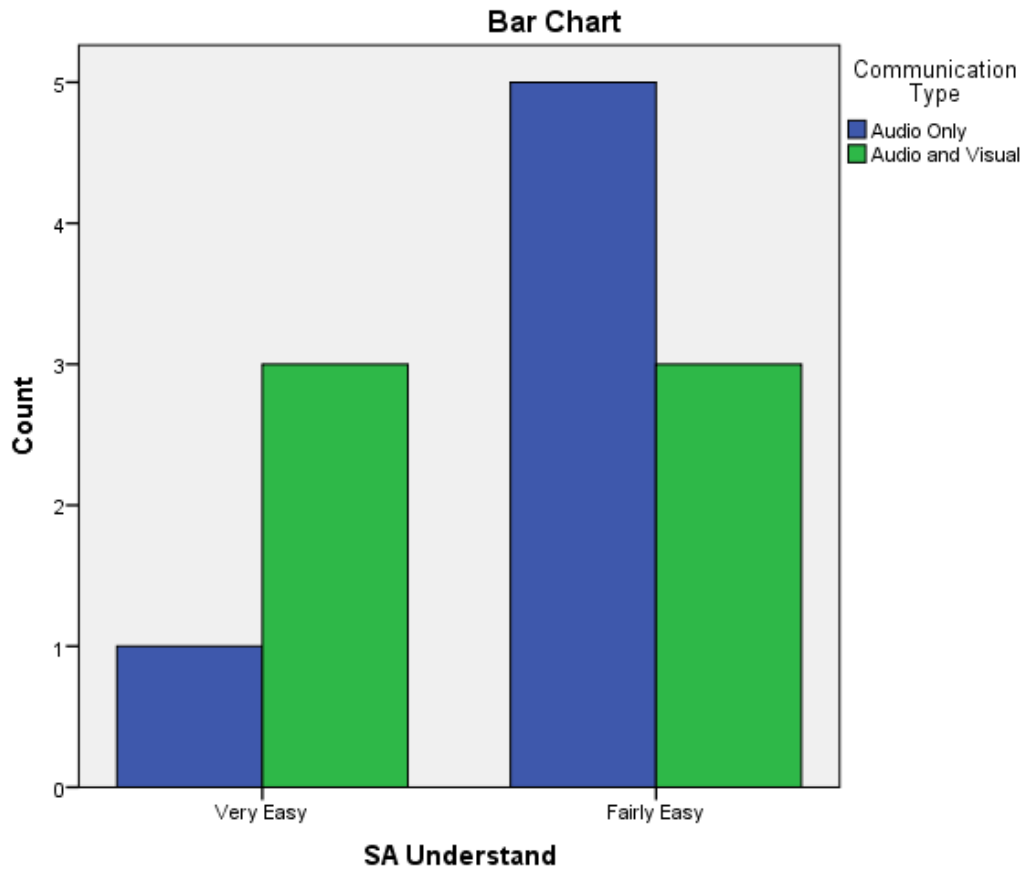

Figure 4-2 MARS Situational Awareness: Understand

The cross tabulation and the corresponding bar chart reveal that neither group scored themselves negatively in their ability to understand what was going on during the mission. The visual group rated themselves evenly with 50% in the Very Easy category (3) and 50% in the Fairly Easy category (3) while the audio group split 17% Very Easy (1) and 83% Fairly Easy. As expected, due to the small testing population an ANOVA test revealed no significant results.

Situational Awareness: Predict

Question 3: How well could you predict what was about to occur next in the mission?

Table 4-20 MARS Question 3 Scores

Situational Awareness: Predict

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
SA Predict	Fairly Easy	4	6	10
	Somewhat Difficult	2	0	2
Total		6	6	12

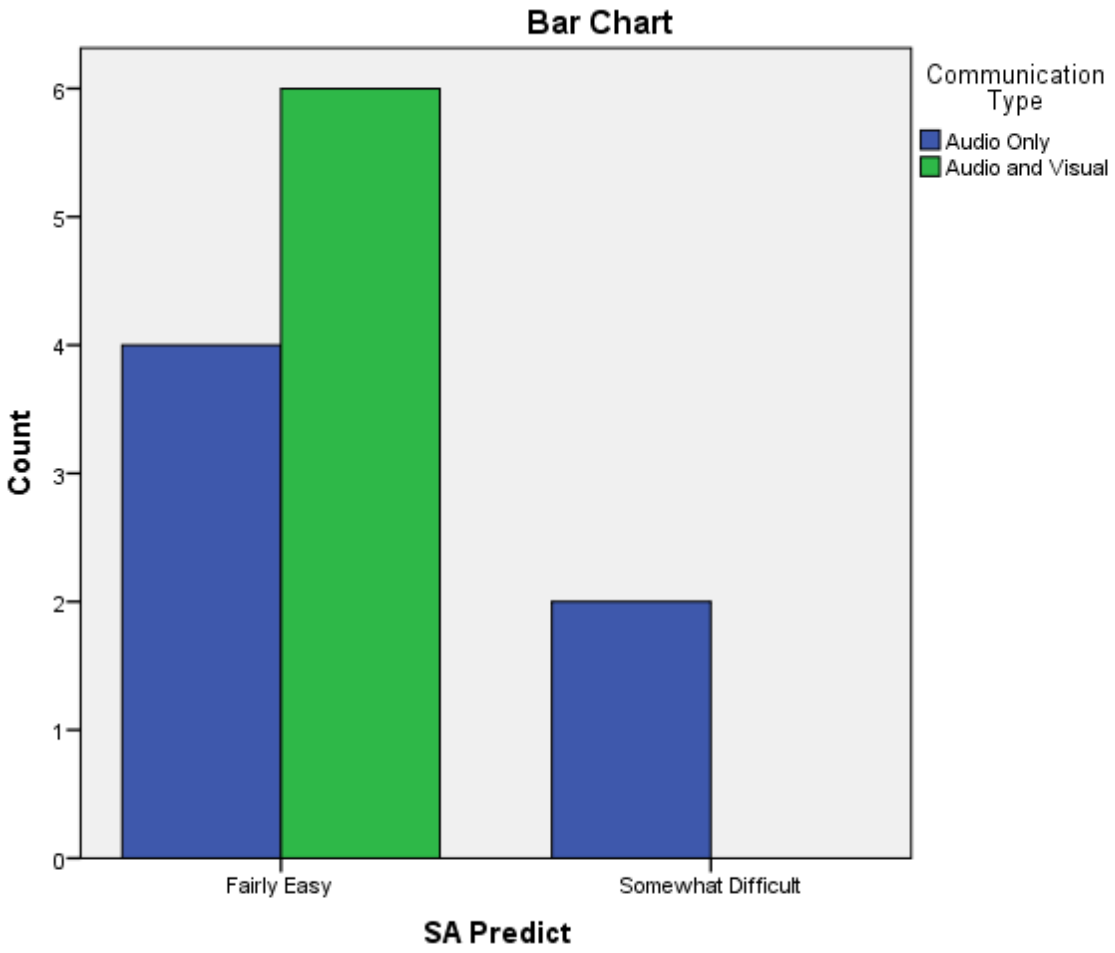

Figure 4-3 MARS Situational Awareness: Predict

The cross tabulation and the corresponding bar chart reveal that 83% of all participants scored themselves positively in their ability to predict what was about to occur next in the mission. The visual group rated themselves at 100% for Fairly Easy. The audio group split their ratings at 66% Fairly Easy and 33% Somewhat Difficult. As expected, due to the small testing population an ANOVA test revealed no significant results.

Situational Awareness: Achieve

Question 4: How aware were you of how to best achieve your goals during this mission?

Table 4-21 MARS Question 4 Scores

Situational Awareness: Achieve

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
SA Achieve	Vary Easy	2	2	4
	Fairly Easy	4	4	8
Total		6	6	12

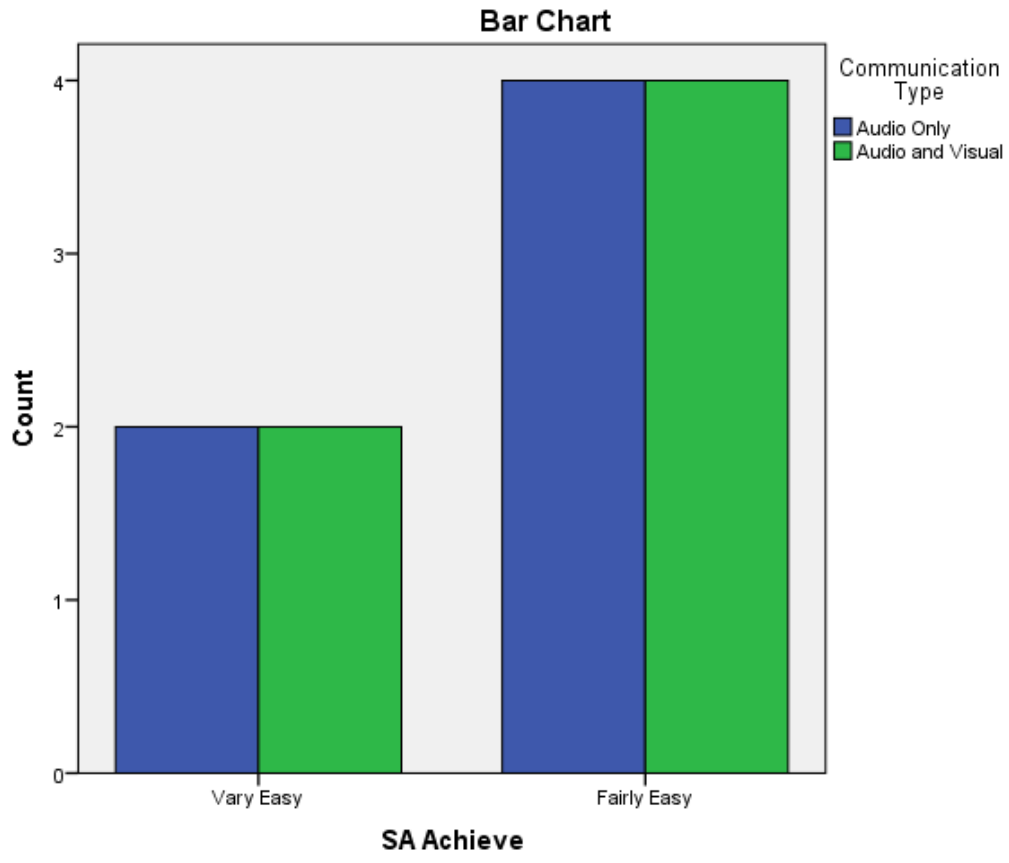

Figure 4-4 MARS Situational Awareness: Achieve

The cross tabulation and the corresponding bar chart reveal that there were no differences in how the participants rated their ability to achieve their goal during this mission with both groups rating themselves 33% for Very Easy and 66% Fairly Easy.

Workload: Identify

Question 5. How difficult – in terms of mental effort required - was it for you to identify or detect mission-critical cues in the mission?

Table 4-22 MARS Question 5 Scores

Workload: Identify

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
Workload Identify	Vary Easy	1	2	3
	Fairly Easy	3	3	6
	Somewhat Difficult	2	1	3
Total		6	6	12

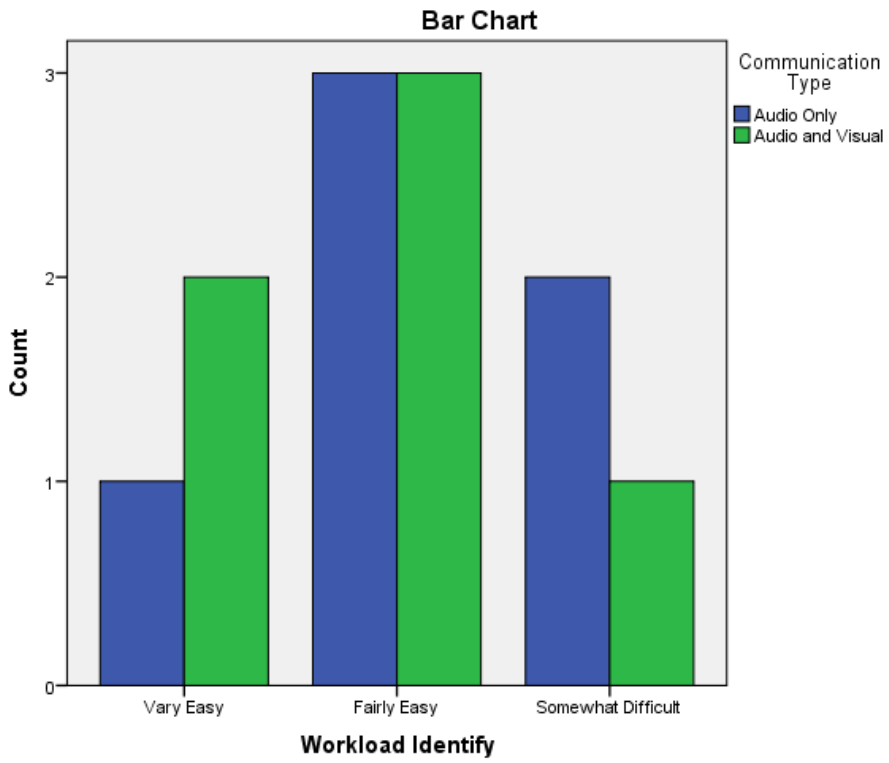

Figure 4-5 MARS Situational Awareness: Workload Identify

The cross tabulation and the corresponding bar chart reveal that 50% of the video and audio participants rated themselves Fairly Easy on their ability to best achieve their goals. The video group rated themselves 33%Very Easy to the audio groups 17%. Conversely 17% of the video group rated themselves Somewhat Difficult compared to the audio only group at 33% rating the task as Somewhat Difficult.

Workload: Understand

Question 6: How difficult in terms of mental effort was it to understand what was going on during the mission?

Table 4-23 MARS Question 6 Scores

Workload: Understand

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
Workload Understand	Very Easy	2	2	4
	Fairly Easy	3	4	7
	Somewhat Difficult	1	0	1
Total		6	6	12

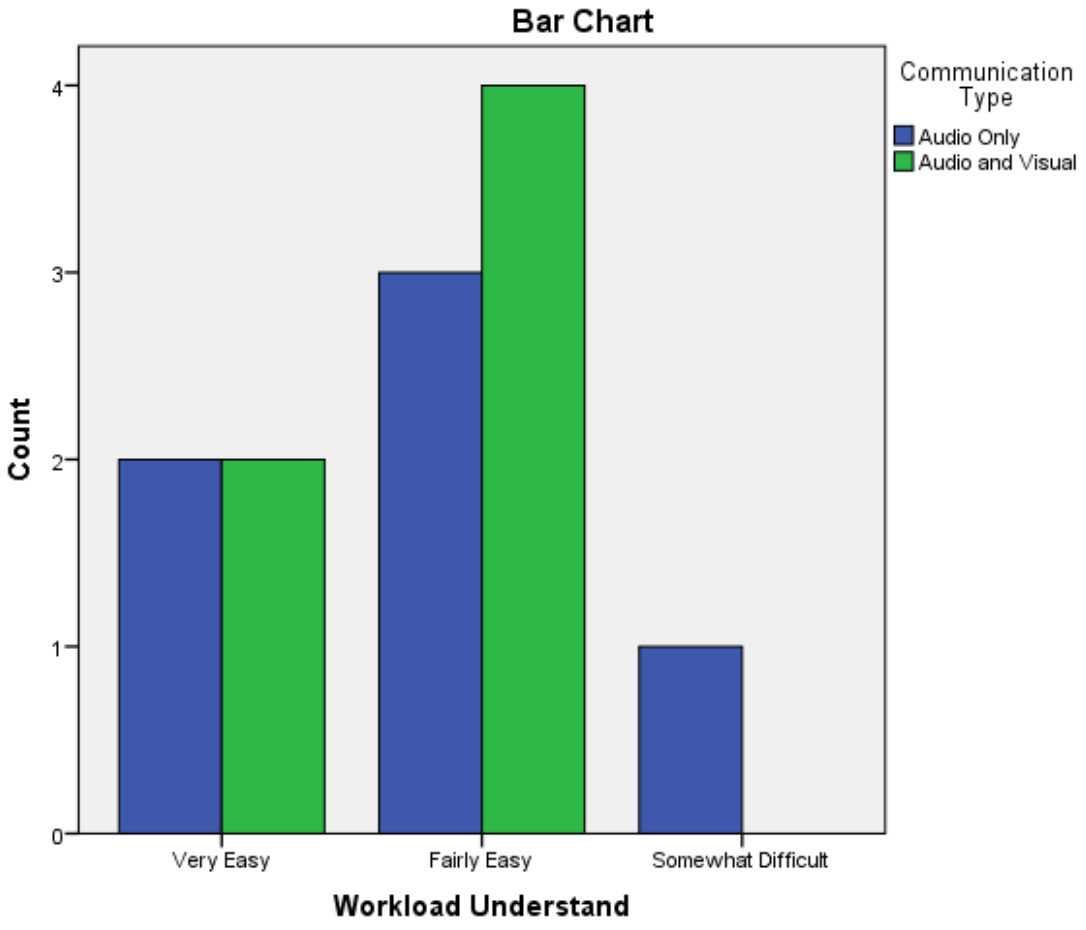

Figure 4-6 MARS Situational Awareness: Workload Understand

The cross tabulation and the corresponding bar chart reveal little differences in how the participants rated their level of difficulty, in terms of mental effort, to understand what was going during the mission.

Workload: Predict

Question 7: How difficult in terms of mental effort was it to predict what was about to happen during the mission?

Table 4-24 MARS Question 7Scores

Workload: Predict

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
Workload Predict	Fairly Easy	4	4	8
	Somewhat Difficult	2	2	4
Total		6	6	12

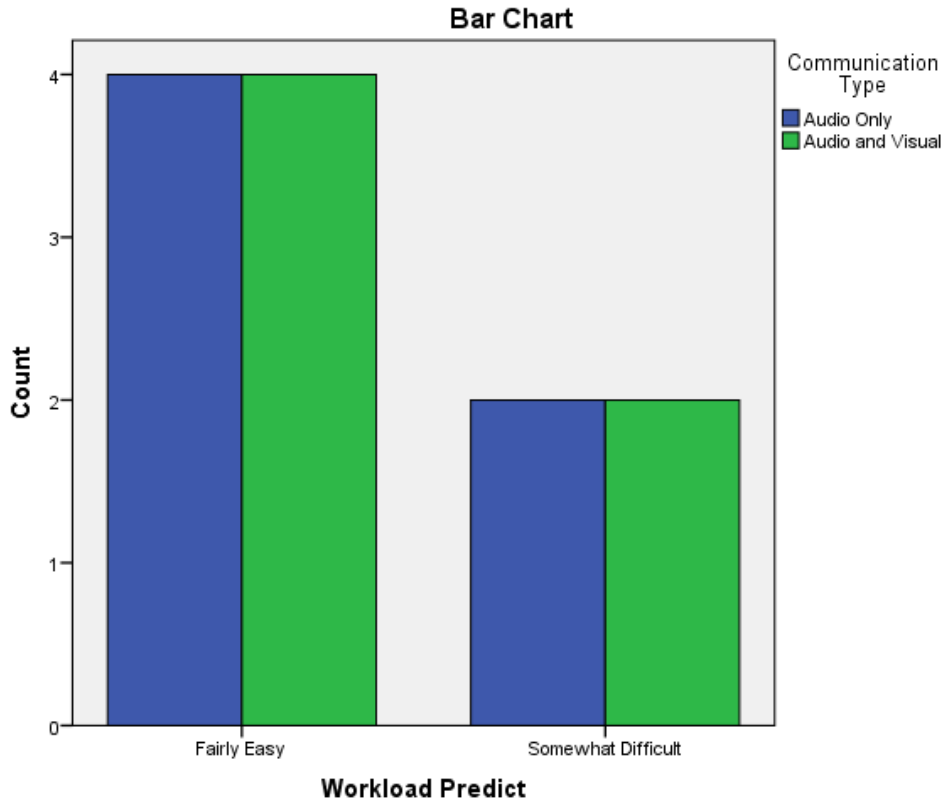

Figure 4-7 MARS Situational Awareness: Workload Predict

The cross tabulation and the corresponding bar chart reveal that there were no differences in how the participants rated their level of difficulty, in terms of mental effort, to predict what was about to happen during this mission with both groups rating themselves 66% for Fairly Easy and 33% Somewhat Difficult.

Workload: Achieve

Question 8: How difficult in terms of mental effort was it to decide on how to best achieve mission goals during this mission?

Table 4-25 MARS Question 8 Scores

Workload: Achieve

Communication Type Crosstabulation

Count

		Communication Type		
		Audio Only	Audio and Visual	Total
Workload Achieve	Fairly Easy	5	6	11
	Somewhat Difficult	1	0	1
Total		6	6	12

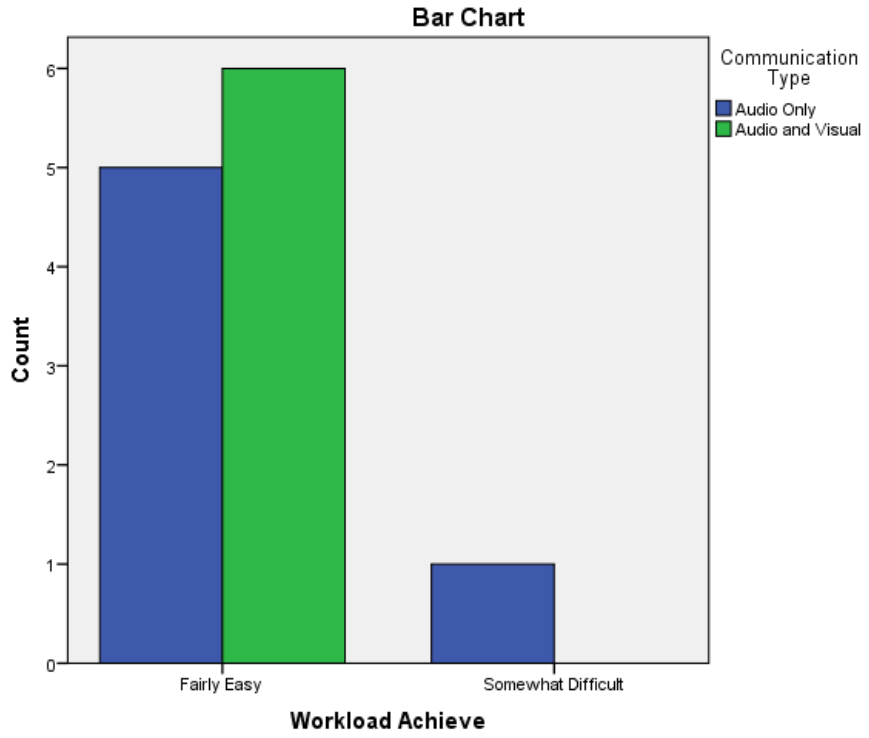

Figure 4-8 MARS Situational Awareness: Workload Achieve

The cross tabulation and the corresponding bar chart reveal little differences in how the participants rated their level of difficulty, in terms of mental effort, to decide on how best to achieve mission goals during the mission.

4.3.2 MARS Data Interpretation

The MARS SA results suggest that the audio group rated themselves less able to identify the mission critical cues during the scenario. This measure of situational awareness, identity, correlates to the first level of SA, perception. The visual and audio groups determined that they were able to understand what was going on during the scenario. This measure of situational awareness, understand, correlates to the second level of SA, comprehension. In terms of prediction, the audio group rated themselves mixed. On question three the audio group rated themselves less able to predict what was about to occur in the scenario. However, on question four the audio and video group both rated their awareness in how to best achieve their goals positively. These two measures, predict and best achieve, mirror the third level of SA, projection.

The MARS workload results suggest that the audio group rated that more mental effort was required than the visual group. The visual and audio group determined that the level of effort it took to understand the scenario varied little. In terms of metal effort and prediction the two groups were even. Lastly, there was little difference in the level of mental effort and decision between the groups.

4.4 NASA TLX Results

The NASA-TLX is a two part instrument that first rates six subscale tasks from Very Low (0) to Very High (100) creating interval data. The output is combined and each task receives a load index. The second part of the instrument has the participant weigh each category of the six subscales pairwise whereupon the participant chooses which tasks are more relevant to workload. The number of times each task is chosen over another creates the weighted score. The weighted score for each subscale is multiplied by the load index from the first part of the

instrument. This is then divided by 15 to achieve a score from 0 to 100. Each of the six subscales are defined below (Table 4-26). The score for each subscale is an indication of the amount of *mental workload*, *physical workload*, *temporal workload, effort and frustration* the participant felt. These subscales are scored low to high with higher scores indicating greater participant workload. The subscale *performance* is scored high to low with lower scores indicating greater participant satisfaction with their individual performance in accomplishing the goals of the scenario.

Table 4-26 NASA TLX Rating Scale Definitions

RATING SCALE DEFINITIONS		
Title	Endpoints	Descriptions
MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*Low/High*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	*Low/High*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	*Low/High*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
PERFORMANCE	*Good/Poor*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	*Low/High*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Hart, S. G., & Staveland, L. E. (1988)

4.4.1 NASA TLX Data Analysis

The overall NASA TLX scores revealed that there was little difference between the audio group and the visual group participants as it relates to overall workload during the task. The visual group had a lower overall score indicating a slight decrease in task effect on overall workload. The combined mean was 46.91. The audio group had a mean score of 48.48 with the Visual group scoring a mean of 45.35.

Table 4-27 NASA TLX Mean and Standard Deviation

Mean NASA TLX Scores	Audio and Visual	Audio	Difference	Combined Mean	Std Dev
NASA Task Load Score	45.35	48.48	-3.13	46.91	11.29
MENTAL DEMAND	59.17	60.83	-1.66	60	14.89
PHYSICAL DEMAND	20.50	15.33	+5.17	17.92	15.62
TEMPORAL DEMAND	57.50	54.83	+2.67	56.17	12.23
PERFORMANCE	18.50	30.83	-12.33	24.67	15
EFFORT	42.83	39.67	+3.16	41.25	14.64
FRUSTRATION LEVEL	34.33	47.50	-13.17	40.92	23.77

Mental Demand

The NASA TLX mean scores revealed that there was little difference between the audio group and the visual group participants. The combined scores were on the high side of the NASA TLX scale indicating that more perceptual and mental activity was required to complete the tasks. The audio group had a mean score of 60.83 whereas the visual group had a mean score of 59.17. The combined mean was 60.

Physical Demand

The NASA TLX mean scores revealed that there was little difference between the audio group and the visual group participants. The combined scores were on the low side of the NASA

TLX scale indicating that the less physical activity was required to complete the tasks. The audio group had a mean score of 15.33 whereas the visual group had a mean score of 20.5. The combined Mean was 17.92. It is interesting to note that the visual group found it more physical demanding to complete the tasks than the audio group.

Temporal Demand

The NASA TLX mean scores revealed that there was little difference between the audio group and the visual group participants. The combined scores were on the high side of the NASA TLX scale indicating that task had an effect on the amount of pressure the participants felt due to the pace that the tasks occurred in the scenario. The audio group had a mean score of 54.83 whereas the visual group had a mean score of 57.50. The combined mean was 56.17. The visual group felt more time pressure while accomplishing the task than the audio group.

Performance

The NASA TLX mean scores revealed that there was large difference between the audio group and the visual group participants. The combined scores were on the low side of the NASA TLX scale indicating that the participants thought they performed well during the task. In this subscale a smaller number indicates better performance. The audio group had a mean score of 30.83 whereas the visual group had a mean score of 18.50. The combined mean was 24.67. The visual group felt more confident that they performed well while accomplishing the task than the audio group.

Effort

The NASA TLX mean scores revealed that there was little difference between the audio group and the visual group participants. The combined scores were mid-range of the NASA TLX scale indicating there was some level of effort to accomplish the task. The audio group had a mean score of 39.67 whereas the visual group had a mean score of 42.83. The combined mean was 41.25. Like the Physical and Temporal subscales the visual group found it took more effort to complete the tasks than the audio group.

Frustration

The NASA TLX mean scores revealed that there was large difference between the audio group and the visual group participants. The combined scores were mid-range of the NASA TLX scale indicating that the participants felt some level of stress or frustration while completing the task. The audio group had a mean score of 34.33 whereas the visual group had a mean score of 47.50. The combined mean was 40.92. The visual group felt less frustration while accomplishing the task than the audio group.

4.4.2 NASA TLX Interpretation

The NASA TLX revealed that the visual group had a slight decrease in task effect on overall workload. This indicates that overall the visual group felt less workload stress than the audio group. However, when each category is examined individually the visual group showed a higher degree of workload in the areas of physical demand, temporal demand, and effort. These may be linked to the addition of another sense while of viewing the scenario. Conversely the audio group had a higher degree of workload for mental demand, performance, and frustration level. This may be due to the lack of the visual sense. The largest difference in overall scoring

was found in the frustration subscale. This indicated that the audio group had a high level of frustration while conducting the task possibly due to the inability to visualize the evolving event and/or the inability to gather enough fact to make a correct decision. Another subset with a large scoring difference was the performance subscale. This indicated that the visual group felt most confident in how they performed on the task. This may be due to the ability to see the position of the suspect and the victim at the time. The weighted subscales revealed that of the six subscales, mental demand and temporal demand were more relevant to overall workload. This was consistent for both groups.

4.5 Interviews

The qualitative data collected for this study was semi-structured interviews. Each interview was recorded. These recordings were listened to several times and significant points, idea, words and phrases were noted for each question. Reviewing the raw data allowed the researcher to develop knowledge and recognize patterns. Similarities were noted and the researcher attempted to make sense of the relationships. A list of categories was generated and the data was coded into themes. The results were reexamined looking for similarities and redundancy. The researcher utilized two independent coders who reviewed the interview data. The initial feedback had a 50% agreement. After additional rounds and discussions an 80% intercoder agreement was reached that included 14 themes. A spreadsheet was created for each question and the emerging themes were analyzed for frequency (Appendix N). The themes are represented graphically below with the best representation from each theme presented verbatim for descriptive elaboration. The quantitative findings were compared to the qualitative themes that emerged so that a comprehensive analysis of the research data could be accomplished (Creswell, 2013).

The participants were shown the visual ICT device (Google Glass) and a short demonstration on how to use the device was completed. The device was then worn and used by the participant while the interview questions were asked. The participants were able to discuss their opinions on the value of the technology, the future of wearable technology and any issues they see related to it. No time limit was placed on the interviews. These interviews were recorded using a RCA VR6320 note recorder as well as recorded with the Google Glass during the interview. Permissions was obtained prior to the start of the experiment.

4.5.1 Interview Data Analysis

The data from the interviews relating to the perceived usefulness were compared with participants who viewed the scenario to those participants who only heard the scenario. No significant differences emerged between the groups. The interview questions (Table 4-28) were grouped into three sections; usability, acceptance and overall opinion.

Table 4-28 Interview Questions

Interview Questions	
Usefulness	
1.	Describe how you feel this technology could be useful for law enforcement.
2.	What features are useful?
3.	What features are not useful? Why?
Acceptance	
1.	Would this technology be accepted by police officers? Why? Why not?
2.	Give me some reasons this technology might succeed?
3.	Give me some reason this technology might fail?
4.	What could be done to make this technology acceptable in the LE culture?
Issues, Opinions and Comments	
1.	What is your overall opinion of this technology for this application?
2.	Are there design issues with the current technology?
3.	What would you change?
4.	How would you utilize this technology?

Fourteen themes emerged without any expressive differences in views between visual and audio groups on usability, acceptance or overall opinion of the technology (Table 4-29). This may be in part to the fact that both groups were able to use the technology.

Table 4-29 Interview Themes

Theme 1	A positive response to the usefulness of the technology
Theme 2	Seeing what the team sees (visual)
Theme 3	Information to command
Theme 4	Memorializing the moment
Theme 5	Fit
Theme 6	Ruggedness
Theme 7	Loss of vision
Theme 8	A positive response to the acceptance of the technology
Theme 9	Generational acceptance
Theme 10	Liability Issues
Theme 11	Technology Failure
Theme 12	Cost
Theme 13	Access to the technology
Theme 14	Positive overall opinion

The themes represented in table 4-30 correspond to the questions in each category. The number of times each theme was mentioned was recorded across the question categories revealing the thematic frequency. The thematic frequency was analyzed revealing the overall major themes and themes for each of the question categories.

Table 4-30 Thematic Frequency

Question	Usability			Acceptance				Issues / Opinions				Thematic Frequency
Theme	1	2	3	4	5	6	7	8	9	10	11	
1	66.7											8
2	50	75			33.3			8.3			33.3	24
3	41.7	25			41.7			16.6			33.3	19
4	8.3	16.7		16.7	16.7		16.7				25	12
5			25				8.3	8.3	25	8.3		9
6			25			25	8.3		33.3			11
7	8.3		33.3	8.3			8.3	8.3	58.3	8.3		16
8				83.3								10
9				25								3
10				33.3		33.3	16.7				8.3	11
11						33.3						4
12						16.7	8.3					3
13							41.7					5
14								75				9

The major themes were analyzed and divided into two groups, positive and negative themes. This was repeated throughout the question categories below. The themes in table 4-31 represent the overall frequency of the themes throughout the transcripts. The two top themes are *Seeing what the team sees* and *Information to command*. The third theme is *Loss of vision*. Three of the top themes in the interviews deal with the attainment, transfer or loss of situational awareness.

Table 4-31 Major Themes

Major Themes	
Positive	**Negative**
Seeing what the Team sees (24)	Loss of Vision (16)
Information to Command (19)	Ruggedness (11)
Memorializing the moment (12)	Liability (11)

The answers to questions relating to usefulness mimicked the major themes in table 4-31 being *Seeing what the team sees* on the positive side and *Loss of vision* on the negative side (Table 4-32). These two themes deal with the attainment and loss of SA. Other themes relate to the transfer of SA (*Information to command*), the positive response to the technology as far as usefulness us concerned.

Table 4-32 Usefulness Themes

Usefulness	
Positive	**Negative**
Seeing what the Team sees (15)	Loss of Vision (5)
Positive response to the usefulness (8)	Ruggedness (3)
Information to Command (8)	Fit (3)

The dominant theme for the Usefulness category was, *Seeing what the Team sees* and *Loss of Vision*. The following quotes best represent the themes as conveyed in the interviews.

Seeing what the Team Sees

"Real time information is always critical to decision making. I was thinking about that when I was doing the test. If I hadn't see that video as the whole thing was going on, the whole decision making process would be a lot more difficult. I'd have been asking for more information from the recon team. Right. So I could see what they were seeing at that time, so it was easier for me to make a call than if I was just hearing the information over the radio.." P8; Q1

Loss of Vision

"Having it over one of your eyes. I don't know how, would you shoot with this on." P3; Q3

The answers to the questions relating to acceptance differed from the major overall themes. The answers related to the acceptance of the technology for law enforcement was positive and became one of the dominant themes for the questions on acceptance. Equally mentioned was liability, and was more frequently discussed in the negative. (Table 4-33). Acceptance was also associated with *memorializing the moment*, *information to command* and

seeing what the team sees on the positive side. On the negative side acceptance was also related to *access to the technology*, *technology failures* and *ruggedness*.

Table 4-33 Acceptance Themes

Acceptance	
Positive	**Negative**
Positive response to acceptance (10)	Liability (10)
Memorializing the moment (6)	Access To the technology (5)
Information to Command (5)	Technology failure (4)
Seeing what the Team sees (4)	Ruggedness (4)

The dominant theme for the Acceptance category was *positive response to acceptance* and *liability*. The following quotes best represent the themes as conveyed in the interviews.

Positive response to acceptance and memorializing the moment

"I believe it should be. I would certainly welcome it. I mean it really covers you well. It covers you to what your perspective and your viewpoint was at that time which is one thing to be able to look at something, somebody outside given the ability to look and have someone look thereafter on what your viewpoint was and why you made the decisions you made." P9; Q4

Information to Command

"Again, I think just we already discussed as far as the ability to visually communicate with other team members, team leaders, incident command. I think you would have more of an overall picture of the incident and how it was going." P11; Q5

Liability

"I guess it could hurt you in that everything is visually recorded and if something - people, whether it be the public, the media, perceive things a little differently sometimes - because they don't see the whole situation. They don't understand the perception that the officer has when something happens." P4; Q6

Access to the Technology

"I would think that really just putting it out there that this technology is available and having the opportunity for officers to use this, test this; have agencies play with it, use this and test this and see for themselves what are the capabilities it provides." P9: Q7

The answers to the questions relating to technology issues and overall opinions revealed that *positive overall opinion* of the technology and *loss of vision* were the two dominate themes. Other themes included *information to command* and *seeing what the team sees* on the positive side. Negative themes were the technology's ability to fit with the current equipment utilized by SWAT as well as the technologies ability to withstand the rigors of the task (Table 4-34).

Table 4-34 Issues and Opinions Themes

Issue and Opinions	
Positive	**Negative**
Positive overall opinion (9)	Loss of Vision (9)
Information to Command (6)	Fit (5)
Seeing what the Team sees (5)	Ruggedness (4)

The dominant theme for the Issues and Opinions category was, *positive overall opinion* to the technology and *loss of vision*. The following quotes best represent the themes as conveyed in the interviews.

Positive overall opinion / Information to Command / Seeing what the Team sees

"I think it's really good. I think it's great. Again, I've been on both sides and sometimes its frustrating at command - somebody's trying to tell you something, what this is and its frustrating not being able to really have a clear picture of it. I think this would alleviate too a lot of, for example the difference sides. We say, 'One, Two Three, Four', for whatever reason, in my head I'm like, 'One, Two', so I go the wrong way and that could throw everything off. So I think it would alleviate a lot of miscommunication between command and other teams." P4; Q8

Loss of Vision

"I think, maybe if this piece would swivel so that you can move it out of the way and have the use of both eyes. I think that would be great. If you could swivel it out of the way, have use of both eyes, get back to it when you need it, or when you have information incoming through it you can use it." P7; Q9

Seeing what the Teams Sees

"Well definitely your entry team would have at least your point man would be wearing something like this. He could actually watch what's going on. Me personally right now, and 90% of our stuff is high risk drug warrant stuff, but I like to have my eyes on the operation from a distance, just so I can get a better - and that's because I like to have that visual feedback of what's going on. This would allow me to be further back in a command center." P8: Q11

4.5.2 Interview Interpretation

The interviews revealed that there is a positive response to the use of the technology, the acceptance of the technology and the overall opinions of the technology. Concerns remain over the liability exposure for some participants however the many thought that memorializing the moments would better protect against litigation. The participants appeared to want to use the technology but with some modifications. These included an eyepiece that swiveled out if the way, use with gas masks and helmets and a rugged system that works without many failures.

The dominate themes that emerged were related to situational awareness and workload. The two top themes were, Seeing what the team sees and Information to command. The third theme is Loss of vision. Three of the top themes in the interviews deal with the attainment, transfer or loss of situational awareness. These themes were also associated to workload by the participants who often claimed it meant they could stay in the incident command and that it made communication and decision making easier.

4.6 Temporal and Spatial Analysis

During the scenario the researchers noted the time the tactical commander authorized the team to enter, the distance between the victim and the suspect and whether the suspect was facing the entry location. This data was collected to compare the audio and visual groups to observe any advantages that emerged relating to communication type.

4.6.1 Response Time

This scenario was either viewed or listen to by the participants. During the scenario the researcher noted the time each participant authorized a tactical resolution, meaning the team was to enter the room and rescue the victim. The average response time for the audio group was five minutes and nineteen seconds. The average response time for the visual group was four minutes and forty three seconds. The visual group authorized the tactical team entry thirty six seconds faster, on average, than the audio group (Table 4-35).

Table 4-35 Average Response Time

Average Response time	
Audio	Visual
0:05:30	0:04:23
0:05:24	0:05:29
0:04:33	0:04:30
0:05:30	0:04:13
0:05:32	0:05:30
0:05:24	0:04:12
0:05:19	0:04:43
Difference: 00:36	

4.6.2 Distance from the Victim

During the development and filming of the scenario the researcher choreographed four instances where the suspect would distance himself from the victim. The suspect varied his distance moving towards and away from the victim four times stopping at 2,6,10 and 14 feet. During testing, the researcher recorded whether the suspect was facing the victim. Figure 4-9 shows the timeline and distances of the suspect overlapped with the time each group called for the tactical team to enter along with the times when the suspect was looking away from the victim.

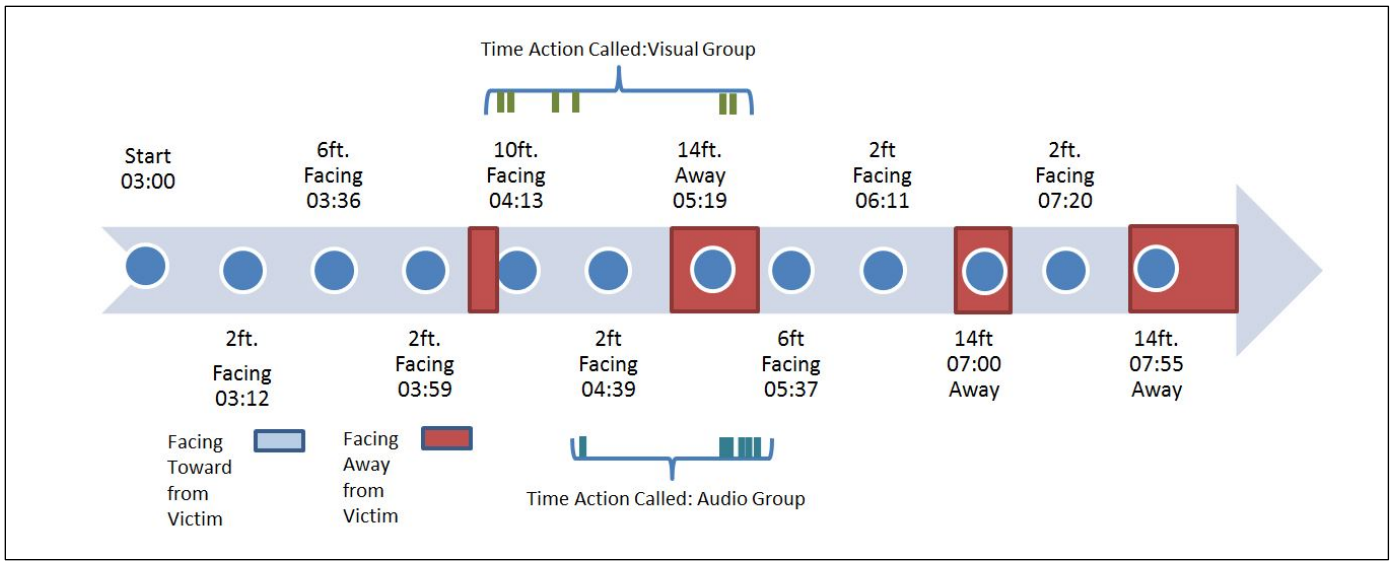

Figure 4-9 Scenario Timeline

The visual group called for action or a tactical resolution 33% of the time when the suspect was facing away from the victim. The audio group called for action 66% of the time when the suspect was facing away (Table 4-36).

Table 4-36 Suspect / Victim Position

Audio				Visual and Audio			
Participants	Response Time	Facing	Distance	Participants	Response Time	Facing	Distance
P1	5:30	away	14	P2	4:23	towards	10
P3	5:24	away	14	P4	5:29	away	14
P5	4:33	towards	10	P8	4:30	towards	10
P7	5:30	away	14	P9	4:13	towards	10
P10	5:32	away	14	P12	5:30	away	14
P11	5:24	away	14	P13	4:12	towards	10

Visual and audio cues may have played a part in the participant's decision to call for entry of the team. During the scenario the team leader called out the actions and location of the suspect. Each Participant had a layout of the room. Tables 4-37 through 4-41 show the type of communication used by the participant, the location of the suspect in the room and any associated verbal cues given by the team leader to the participant.

Table 4-37 Screen Shot

04:12 "Be advised the hostage taker looks like he looking out the 3 side."	04:13 Participant 9 04:12 Participant 13	Visual Visual

Participant 9 and 13 are both viewing and hearing the scenario. Watching the suspect and hearing the team leader indicate that the suspect may be looking out the "three side" may have prompted these participants to authorize an entry. The suspect in the video does not look out the window (three side) but the suspect remains at the appropriate distance, 10 feet, for entry. The team leader is not specific about the distance but refers to the schematic map used in the briefing the participants prior to the mission. No audio participants authorized an entry at this stage in the scenario (Table 4-37).

Table 4-38 Screen Shot

<table>
<tr><td colspan="3">  </td></tr>
<tr><td>04:23 "Has a gun in his hand." Having some type of conversation with the hostage."</td><td>04:23 Participant 2</td><td>Visual</td></tr>
</table>

Participant 2 authorizes an entry after hearing and seeing that the suspect is at the appropriate distance, mentioned 11 seconds prior, and upon the verbal mention of the weapon. No audio participants authorized an entry at this stage in the scenario (Table 4-38).

Table 4-39 Screen Shot

04:30 "The distance from hostage to hostage taker is 10ft."	04:30 Participant 8 04:33 Participant 5	Visual Audio

Participants 8 and 5 authorize an entry upon hearing the team leader mention the distance from the victim. The team leader is more specific and calls the distance at 10 feet. This is the first participant that authorizes an entry for the audio group. At this point 67% of the visual group has authorized entry. The combination of visual and audio communication allowed the visual participants to determine the appropriate entry distance without relying on the briefing schematics. The visual participants did not take into account which way the suspect was facing when authorizing the entry (Table 4-39).

Table 4-40 Screen Shot

05:17 “Still pointing the gun at him, looks like he’s walking towards the window.”	05:24 Participant 3 05:24 Participant 11	Audio Audio

Participants 3 and 11 authorize the entry after hearing the team leader indicate that the suspect was walking towards the window. The team leader is more specific and mentions the window rather than calling it the “3” side. The team leader mentions that the gun is pointing at the victim. The participants may have considered the mentioning of the weapon pointed at the victim in combination of the suspect’s movement away from the victim as an appropriate time to enter (Table 4-40).

Table 4-41 Screen Shot

<table>
<tr><td colspan="3">  </td></tr>
<tr><td>05:28 “Be advised he’s at the window.”</td><td>05:29 Participant 4
05:30 Participant 12
05:30 Participant 1
05:30 Participant 7
05:32 Participant 10</td><td>Visual
Visual
Audio
Audio
Audio</td></tr>
</table>

The last group of participants (4, 12, 1, 7 and 10) authorize the entry upon hearing the team leader state that the suspect is at the window. The remaining participants authorized the entry within 3 seconds of each other. Once again the visual participants (4 and 12) call the action based on the distance of the suspect and not which way he was facing (Table 4-41).

4.7 Comparing the Data

The data from the quantitative and qualitative test were compared to see if there were correlations among the tests and to show and discuss differences in the subjective and objective measures.

4.7.1 Synthesis Analysis

Comparing the SAGAT with the MARS results allows the researcher to compare differences in situational awareness using objective and subjective means. To compare the groups the MARS scores were recoded to match the SAGAT coding. The Very Easy and Fairly Easy answers on the scale were codes as a correct whereas the Somewhat Difficult and Very Difficult were coded as incorrect. The scores where recoded then given a percentage based on the number of correct answers in each group.

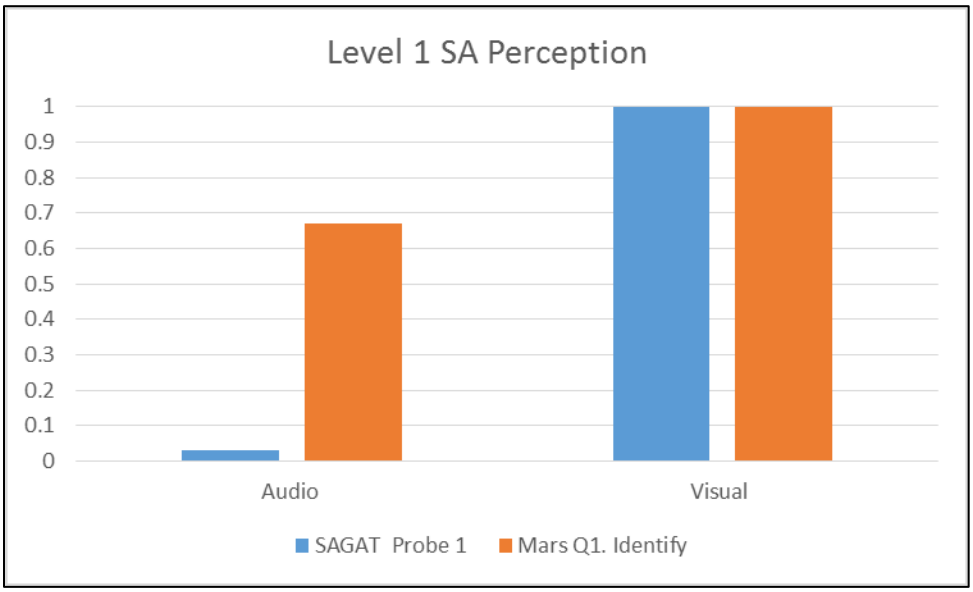

Figure 4-10 SAGAT / MARS Identify

Figure 4-10 illustrates a significant difference in the MARS self-rating test and the objective SAGAT scores. The audio group failed the perception test when queried about the

location of the team. However, 67% of the audio group rated themselves correctly when compared to the SAGAT. The visual group's MARS scores correlated correctly with the SAGAT scores. The difference in the MARS audio scores may have to do with the participants not being bounded to the first part of the scenario as was probe 1 during the SAGAT.

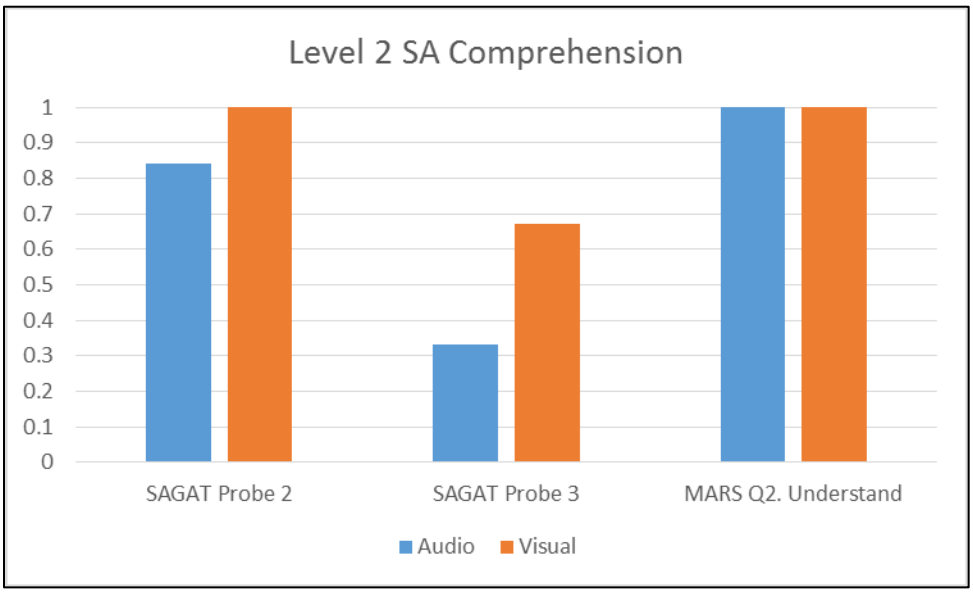

Figure 4-11 SAGAT / MARS Understand

The SAGAT score in probes two and three illustrate the specific information request that were required during the test and at specific points during the scenario. The MARS score is a subjective overall score of how the participants felt they understood what was going on during the entire scenario (Figure 4-11). The SAGAT revealed that the visual group had a slightly better understanding or comprehension of what was going on during the mission. This was confirmed with the temporal and spatial analysis. The first audio participant authorized the entry at 04:30 min upon hearing the team leader say "The distance from hostage to hostage taker is 10ft." At this point 67% of the visual group had authorized a team entry. Temporal and spatial data revealed that the majority of audio group hesitated significantly longer than the visual group to authorize the entry as they needed more time to understand what was going on. There were no

Level 1 SAGAT probes this far into the scenario to compare with the temporal and spatial as the scenario was too short in duration.

The need to understand correlates with the dominate themes that emerged during the interviews. The majority of the participants from both groups emphasized the necessity to see what the team sees and get information to command. The participants felt that if the visual data could get to command and they could see what the team is seeing they could perceive, understand and decide faster.

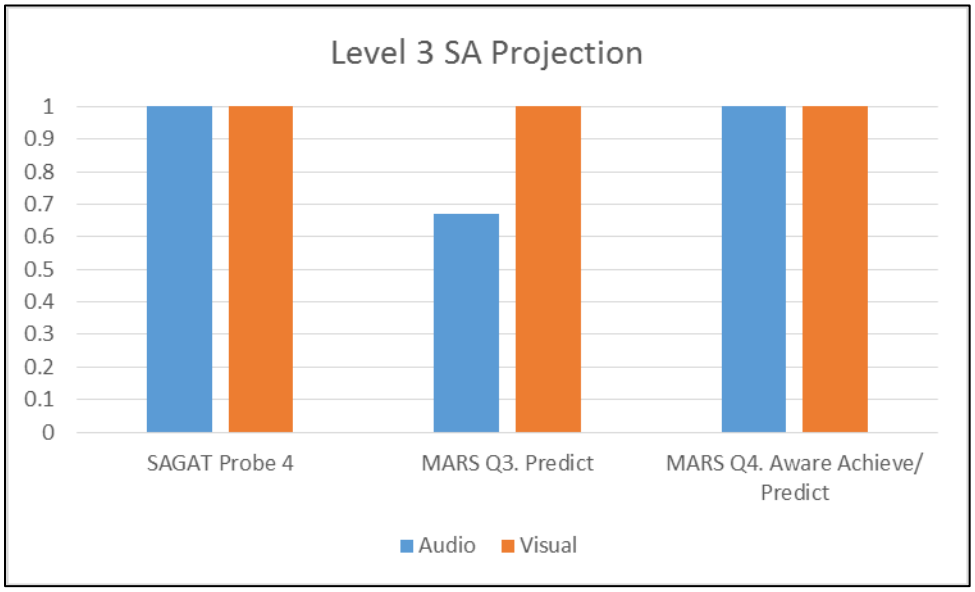

Figure 4-12 SAGAT / MARS Predict

The visual and audio group were able to correctly predict when to send the entry team. The entry times differed based on the confidence levels of each participant (Figure 4-12). The distance was correct in every instance. Interestingly the audio group felt less confident about their ability to predict as they rated themselves lower when conducting the MARS Q3.

Workload

Workload was measured by the second part of the MARS and the NASA TLX. The MARS workload measurements were more specific to each task whereas the NASA TLX was the participants overall feeling of task load. In every instance except for Predict Workload the audio group felt more workload demand than the visual group. In terms of overall work load this correlates with the NASA TLX that showed a slight increase in overall workload for the audio group.

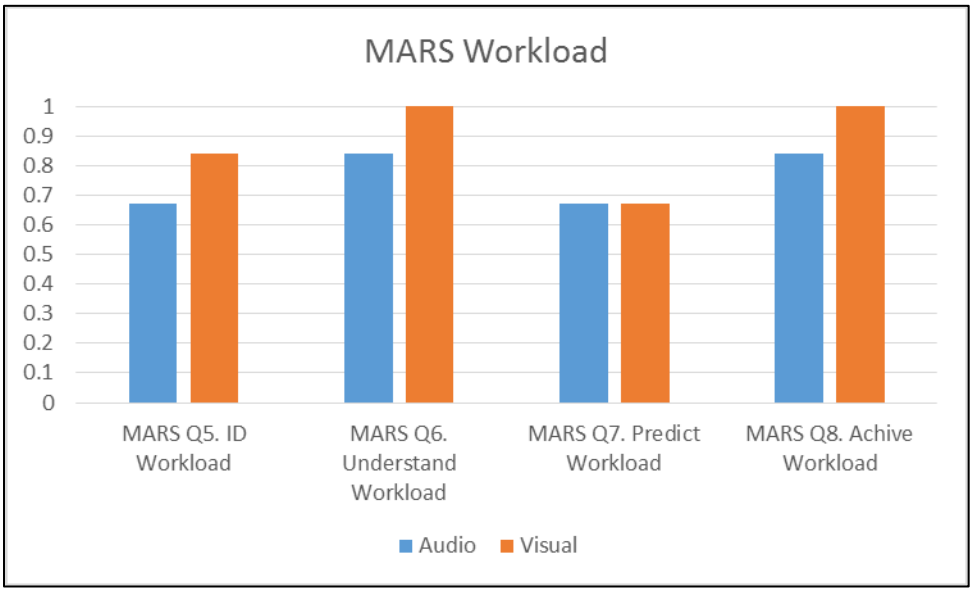

Figure 4-13 SAGAT / MARS Achieve

The NASA TLX score differs from the MARS in that the higher the score the more demand the participant felt. Again physical, temporal and effort were more demanding for the visual group. No participant in either group mentioned task overload. Participants, regardless of group, suggested that the visual ICT technology may lower overall task load. This contradict the NASA TLX findings (Figure 4-14).

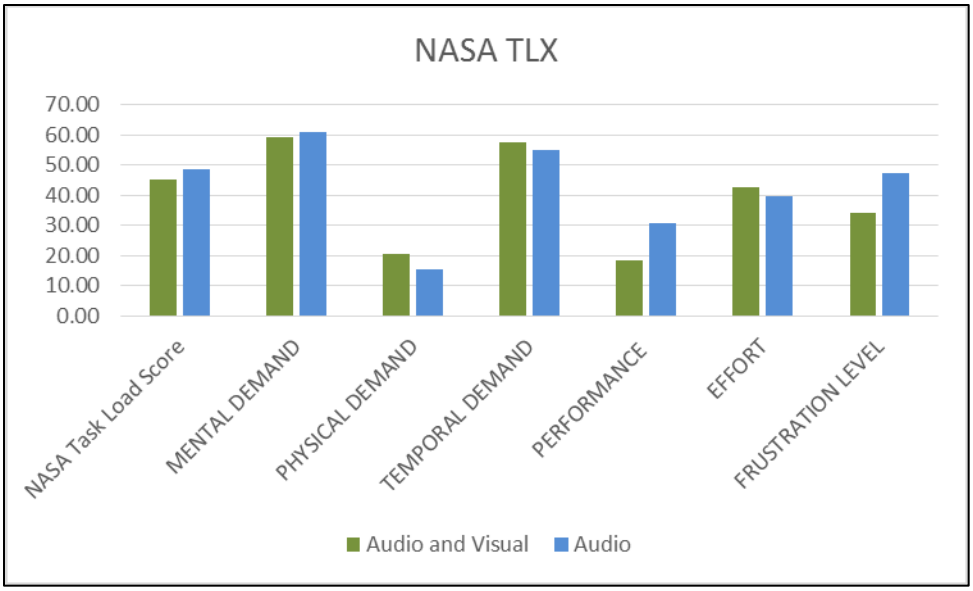

Figure 4-14 NASA TLX

4.7.2 Synthesis Interpretation

The collective SAGAT, MARS and Temporal and Spatial data seems to suggest that the visual group perceived, comprehended and predicted faster than the audio group. While the differences were not large, in highly dynamic and potentially violent situations time and accuracy is off the essence. The greatest difference between the groups was in Level I SA Perception. The audio group failed to recall briefed data and missed audio cues during the first probe. The speed of comprehension was the second difference among the groups with the visual group comprehending and projecting faster than the audio group. Lastly, there was little difference for Level 3 SA. Despite the visual groups ability to quickly predict when to send the entry team the audio group showed equal accuracy; which was the aim of this probe. However, if time and accuracy were counted as measures for projection the visual group would have outscored the audio group significantly.

In addition, the audio and visual group felt demand and workload differences. These were at times contradictory as visual participants felt increased workload in the areas of effort,

temporal demand and physical demand on the NASA TLX while during the interviews most participants indicated that the technology would decrease their physical and decision making effort. The audio group showed consistently more workload demand on the MARS and the overall NASA TLX score. The audio group's frustration level was greater than the visual group and many of audio group participants stated that had they viewed the scenario with the technology they would have performed better. Overall participant performance or success was consistent between the NASA TLX (subjective) the SAGAT (objective) and the Temporal and Spatial (objective) data.

Chapter 5 Discussion

5.1 Summary

The objective of this study was to determine if wireless, visual information communication technology (ICT) enhanced incident situational awareness (SA) for incident commanders during a tactical law enforcement event. The intention of the experiment was to test visual communication against standard communication practices and measure situational awareness. The individual factors such as overall goals, preconceptions and knowledge were controlled by giving all participants the same pre-mission briefing. Experience, training and abilities were controlled by selecting participants who operate under a standard operating procedure (NTOA) and who held similar positions with similar training requirements.

Multiple measurement tools were utilized to collect subjective and objective measures of situational awareness and workload. In addition, participants were interviewed to gauge usability, acceptance and overall opinions of the technology. Once collected and analyzed, the data presented some interesting discoveries. Wireless, visual (ICT) provides law enforcement leaders better Level 1 and Level 2 situational awareness allowing for faster perception, comprehension and prediction of events. Level 3 situational awareness was similar when using accuracy as the only factor. If taking time and accuracy into account, Level 3 situational awareness for the audio only group is significantly slower than the visual group.

Workload measurements revealed that the audio and visual group felt demand and workload differences. These were at times contradictory as visual participants felt increased workload in the areas of effort, temporal demand and physical demand on the NASA TLX while during the interviews most participants indicated that the technology would decrease their physical and decision making effort. The audio group showed consistently more workload

demand on the MARS and the overall NASA TLX score. The audio group's frustration level was greater than the visual group and many of audio group participants stated that had they viewed the scenario with the technology they would have performed better. Overall participant performance or success was consistent between the NASA TLX (subjective) the SAGAT (objective) and the Temporal and Spatial (objective) data.

Finally, the interviews revealed that tactical commanders overwhelmingly embraced the technology as positive for their profession. The participants relayed their concerns about liability, ruggedness and vision impairment however they felt that if these issues could be rectified the technology would greatly improve their ability to lead tactical missions.

5.1.1 Situational Awareness

Situational awareness is perceiving what's going on, comprehending its meaning and projecting future events (Endsley, 1988). In time compressed, violent situations those who achieve SA sooner usually win the day. This limited study demonstrates that enabling tactical commanders to see what their team leader sees speeds SA. In this study the visual group of tactical commanders not only perceived faster and more accurately but comprehended the significance of the situation sooner allowing for a faster and accurate prediction of when to send the entry team into the room. While the audio group of tactical commanders scored relatively well overall, they felt less confident about what they knew and the decisions they made.

Police have been using audio communication since the 1930's. It is evident that its long continued use has honed the tactical commanders' skill at perceiving, comprehending and predicting without the luxury of seeing the incident unfold firsthand. The visual group did not have the luxury of years of training. They utilized the simulated wireless, visual ICT cold and managed to outscore the audio group who had years of experience and use conducting actual

incidents using only the radio. Since both groups heard the same scenario, the faster and more accurate scores for the visual group seemed to indicate an advantage in SA attainment. The future and continued use and training with wireless, visual ICT for SWAT team commanders may further improve SA.

Although human generations are not homogenous units, each subsequent generation has a more integrated experience with technology (Prensky, 2001; Bennett, Maton, & Kervin, 2008). From the telegraph to the radio to wireless visual communication, the acceptance and continued use of iterative information communication technologies has a positive effect on situational awareness for command and control leaders.

The research question addressed is: does wireless, visual ICT enhance incident SA for incident commanders during a tactical law enforcement event? Although the sample was small and the scenario limited, this narrow study indicates that wireless, visual ICT does enhance incident situational awareness. Limitations of this study will be address later in the chapter.

5.1.2 Workload

Testing situational awareness requires real world task and environmental factors. The formation of the tactical scenario required a time compressed, realistic incident with the potential for violence. These elements are necessary for collecting accurate data on SA. Workload is a task factor that effects SA. In this experiment the scenario remained the same for both the visual group and the audio group. The differentiating influence on the groups was the type of technology they used to communicate with the team leader. The NASA TLX allowed the measuring of demand, frustration, performance and effort of the scenario tasks. Utilizing the MARS the researcher was able to collect workload data on the levels of SA.

The workload tests discovered that the audio and visual group felt demand and workload differences. These were at times contradictory as visual participants felt increased workload in the areas of effort, temporal demand and physical demand on the NASA TLX while during the interviews most participants indicated that the technology would decrease their physical and decision making effort. The increased effort demand can be attributed to the extra sensory activity involved in watching the scenario. However, the researcher was surprised at the outcome as having to construct the scene in one's mind (audio only) while listening to a complex scenario would seem to require more mental effort. The physical workload effects are also interesting in that most commanders stated that they move around while on SWAT incidents and that this technology could limit that. However, the physical demand increase for visual user is more likely attributed to the actual physical act of watching the scenario than movement in and around the incident. The visual group also felt more temporal demand. This may be due to the constant sensory involvement during the event. Between reports from the team leader the audio group had breaks of silence that lasted for several seconds. This may have lessened the temporal demand as they could not view the scenario. The audio group was projecting and predicting on what they last heard whereas the visual group was constantly reevaluating the situation visually and updating their predictions as the action played out in front of them. The visual group, viewing every action by the suspect in real time, may have projected or anticipated future events throughout the scenario. Each time the suspect moved, waved or turned the visual group was attempting to predict a future action. The audio group did not have this issue as they had to wait on audio cues from the team leader. This extra work more than likely accounted for the higher scores for effort, time and physicality for the visual group.

The audio group showed consistently more workload demand on the MARS and the overall NASA TLX score. The audio group's frustration level was greater than the visual group and many of audio group participants stated that had they viewed the scenario with the technology they would have performed better. Overall participant performance or success was consistent between the NASA TLX (subjective) the SAGAT (objective) and the Temporal and Spatial (objective) data. The visual group felt more confident about how they performed than the audio group.

5.1.3 Usability and Acceptance

The participants had an overwhelmingly positive response to the technology after wearing Google Glass. Most surprisingly, to the researcher, was the immediate response from the participants of how this technology could be used for a myriad of law enforcement purposes. Each participant put the device on and after a short tutorial began to conceive of different ways Google Glass could be implemented. Both utility and acceptance can be concluded from these statements.

The overall major theme of the semi-structured interviews related to "seeing what the team sees". Both the audio and visual groups commented that being able to see the scenario as it happened would allow them to better make decisions. Many in the audio group felt that they would have scored better having had the ability to see as well as hear. This was a major positive for both groups.

The second theme was related to getting the visual information back to command. The participants felt that this technology could help the leaders above them participate in the decision making process by providing a better understanding of the environment and circumstances.

The third most frequent theme conveyed had to do with the design features of the Google Glass. Many of the participants spoke from the position of once being team leaders. The importance of no obstructions and clear vision in their dominate eye was popular among the group. Many did not want anything in their vision while they were tactical. However, the participants stated that it would be helpful to have a flip down screen so they could see information from command or from another team in a different location. Other design issues were discussed such as ruggedness and fit of the technology. Tactical officers want technology that will not break. They move, shoot and fight in many different environments and felt that the technology in its current state would be too fragile. In addition, they felt that the current technology would not integrate with their helmet systems and would not work with gas masks.

Liability and memorializing the moment were two other themes that emerged during the interviews. Some participants felt that the technology might cause hesitation from tactical officers because all their actions would be recorded. This fear of future lawsuits may cause hesitation and impair officer safety. Others felt that memorializing the actions would benefit the police both in court and in training. While most participants believed the recording of the tactical events would ultimately benefit them, they conveyed concern that officers' actions would be played out in the media where proper tactics and use of force is little understood. There was an interesting dichotomy in a few participants who mentioned both the need to record incidents for use and later the potential for litigation because the incidents were recorded. It seems that participants were comfortable having the incidents recorded if they were shared among training, police administration, and the courts but not to the general public. Not because they had anything to hide but mostly due to the public inexperience with how police are trained to react to deadly force incidents. The overwhelming sentiment was that the video was better to have than

not where there might be questions about police actions. These findings were consistent with Jennings, Fridell, & Lynch's 2014 study on police acceptance of cameras.

5.2 Limitations

5.2.1 Live Video

This was a study of how wireless, visual ICT effects situational awareness for incident commanders. This study does not look at shared awareness directly and does not measure the effectiveness of live, two-way visual communication via ICT. A basic understanding of how SA effects law enforcement was undertaken to test effectiveness so that a foundation for utility, if proven, can be built upon. The simulated "live video" allowed the researcher to control the scenario and maintained a similar experience for each participant. The scenario was recorded four times. In each instance there were various visual obstructions. In consultation with the subject matter experts it was decided that the first take of the video would be used as it best represented what would actually happen, that is, multiple minor obstructions and an imperfect view. Future studies should involve live, two-way visual communication.

5.2.2 Small Participant Pool

This was a limited study with 12 participants. The pool of participants was small however, the researcher traveled the entire western half of a northeastern state to reach this number. The participants are a well-trained but a limited group. Because of the low participant number many statistic formulas could not be used. This study should be expanded to include a greater number of similarly trained participants in different geographic locations.

5.2.3 Bounded GDTA

A Goal Directed Task Analysis was prepared for this study. This GDTA was created to represent the entire SWAT process and consisted of four goals. Under each goal were sub-goals for each action. This study was narrowed to the goal Tactical Solution/Incident Mitigation and further bounded to sub-goals 3.1 Approach and Recon through 3.4 Tactical Action for testing purposes. Because of the narrowing of the GDTA to one goal, an in depth GDTA was not completed for each goal. Although not a limiting factor in this study, a complete GDTA with detailed sub goals, noting the decisions and information needs, should be completed and is a future objective for the researcher.

5.2.4 Limited SAGAT Probes

The scenario was developed by the researcher and National Tactical Officers Association subject matter experts. The eight minute scenario included four basic SAGAT probes. These probes were limited due to the length of the scenario and the researcher's use of real time probes. Each probe solicited a response from the participants that measured a level of situational awareness and was associated with an information need. Future experiments should attempt to elongate the scenario and incorporate more probes. This allows for better corroboration and measurement. In addition, this experiment could be replicated utilized using freeze probes. This would allow for insertion of additional probes. The overall scores could be compared against real-time probes to find measurement differences.

5.2.5 The Hawthorne Effect

While the author does not believe the Hawthorne Effect was a limiting factor due to the participants' extensive and repetitive training, it cannot be ruled out. The participants may have exhibited uncharacteristically high levels of performance due to the fact they were aware

that they were being studied. Despite this possibility both the audio and visual group scored and rated similarly through the study within each group.

5.3 Recommendations for Future Research

This research study demonstrated that wireless, visual ICT improves situational awareness (SA) for tactical commanders during a simulated crisis event. It exposed that although the technology improves SA for visual users, it requires more physical effort and the users felt more time pressure. However, overall workload was less evident with visual communication than just audio. It also revealed that police leaders find the technology useful and would accept the technology with improvements. The identification of future research was derived from the findings of this research, the research limitations identified in this study, and the state of the current technology used for law enforcement.

5.3.1 Updated and Future Technology

Google Glass is not manufactured for use with tactical policing or general policing for that matter. Google Glass was used to demonstrate the technology of two way, visual communication. Google has since stopped manufacturing it's product for consumers instead moving it to an enterprise product manufactured for specific professions (Hoge, P, 2015). This study has demonstrated that Google Glass like products would be accepted once proven durable and dependable for field use. Similar devices, manufactured for law enforcement, do exist for recording interactions of police and the public but few offer continuous, live two-way communication. This study should be used by manufacturers to develop products based on practical and tactical needs. Future research should include testing of an updated wireless, visual ICT device using the recommendations outlined here by the tactical commanders.

As discussed in the literature review, technology for policing has historically been borrowed and retrofitted from military or civilian products. New wearable camera devices are being sold to law enforcement agencies around the United States without the benefit of empirical testing. This study could be used to test new products and their ability to enhance SA for commanders and team leaders alike. In addition, the usability and acceptance issues could be identified prior to purchase.

5.3.2 Live, Continuous, Two-Way Visual Communication

This experiment utilized simulated two-way visual communication. Its aim was to measure SA differences between visual and audio communication. It required little technological training and experience by the participants. Expanding on this study, research should include the use of live, continuous, two-way communication. An expanded live scenario would be best measured using the SAGAT with real time probes. A live iteration of this study would take considerably more time considering the participants would have to be trained on the technology to an acceptable level for testing. However, a longer, more drawn out scenario would enable the researcher to incorporate more or all of the GDTA goals. In addition, many more SAGAT probes could be inserted. A longer scenario would require the use of more researchers and subject matter experts to collect SAGAT data.

An expanded scenario with live, continuous, two-way communication could also be utilized to test shared SA from command post participants, team SA from tactical team participants and information overload from all the participants. This would include the addition of multiple live cameras on multiple teams.

5.3.2 Expanded Populations

This study looked at a narrow, well trained segment of law enforcement. Due to the limited participant pool, the participants were not screened on the basis of age or technological experience. This research should be expanded to test visual two-way communication on a larger population of law enforcement. Widening this study to include new and younger police and police recruits, as well as more experienced and older patrol officers would allow SA comparisons between participants with varied work experiences, generational differences and non-technical backgrounds.

5.3.3 Gameplay and Augmented Reality vs. Experience and Training

An equally interesting question for research is if non-law enforcement participants' are able to use this technology with similar situational awareness. More specifically, people Prensky (2001) called digital natives and participants who self-identify as gamers. McGonigal (2011) posits that people who play games purposely tackle unnecessary problems making the player better and faster by playing at the edge of their skill level. The Army and Marines use video games to facilitate training and team tactics (Herr & Allen, 2014). Tootell, Freeman, & Freeman, (2014) advance the idea of the gamification of learning and how new generations are motivated through technology. Highly technical participants outside law enforcement, such as self-proclaimed gamers, can be tested and compared with skilled law enforcement participants to explore experience and training vs. participants who dwell and train in the virtual. Implications for recruiting gamers and training skilled law enforcement using augmented reality should be explored.

5.3.4 Infrastructure

The future implications of adopting this technology have not been well studied. As the means of communication becomes less proprietary and more IP based, research into the areas of networking current and future high data technologies with command structures and the prevalent 9-1-1 system should be undertaken. The infrastructure requirements of large bandwidth devices for daily law enforcement use as well as big data issues such as storage and retrieval, including for evidentiary purposes, remains unstudied.

5.3.5 The Technology Officer

With each advancement in law enforcement technology, agencies were required to hire or train officers to collect, analyze and store new types of evidence. This includes fingerprinting and DNA, crime scene reconstruction, blood stain analysis, firearm tracing, physical and digital evidence. With the potential proliferation of wearable technology including wireless, visual ICT devices, the collection of a multitude of disparate digital evidence from public and private surveillance systems the addition of robots and drones; recruiting, hiring, training and retaining highly skilled technology officers will be needed in the near future. These technology officers will implement, administer and maintain future systems. Research should be extended into this area.

5.4 Assumptions

During this research several assumptions were made. These include that the participants were honest in their responses and that they genuinely reflected their awareness at the time. At the time of testing, instructions were given to the participants that this was not a test of their ability rather a measurement of the technology; it is assumed that they were genuine in their answers. In addition, it is assumed that the data collected was reflective of the population

intended for testing, i.e. tactical commanders, and that the analysis of these individuals can be aggregated to a larger population of professionals.

5.5 Conclusion

Technology innovations in visual, wireless communications have yet to be leveraged by law enforcement. These technologies have a future in law enforcement. This limited study has provided evidence that the addition of visual, wireless communication for tactical police commanders enhances situational awareness and speeds decision making. In addition, this study has established that the technology would be accepted for use by police tactical officers once utility is demonstrated. Several issues remain that may delay its widespread adoption. These include unfamiliarity, the potential of the technology (usefulness), a police centric design that is rugged, reliable and without impaired vision, liability and cost. In addition, there is not a current wireless, broadband backbone that could transmit the signals over a large distance. Once these limitations have been overcome this technology has the potential to revolutionize policing and tactical law enforcement. What is mostly unknown or misunderstood about policing and police tactics will be collected and potentially viewed by anyone. A Kuhnian paradigm shift (Kuhn, 1996) in police recruiting, training, thought, research and societal relations will have to take place.

Visual, wireless ICT has the potential to save lives. A Special Weapons and Tactics teams overarching goal is life safety. The reduction of time it takes for police leaders to make accurate decisions deceases the time violent actors have to do harm. Although the participant pool was small and the study limited, the addition of visual ICT enabled tactical commanders to make accurate decisions on average thirty six seconds faster that their audio counterparts.

Equally important, they also perceived what was happening, comprehended the situation and projected future events more accurately.

Finally, this study only scratched the surface of future implications of this technology on policing. The adaptation of current technologies with new and evolving ones as well as the merging generational skill sets of tactically proficient, seasoned officers with younger technological natives who have honed augmented reality and gaming skills has yet to be explored.

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Appendices

Appendix A

You have arrived on the scene of a hostage crisis situation. The actor is a well-known violent offender who has a current arrest warrant for threating to murder the victim. He is also in violation of his parole for aggravated assault and attempted murder for which he served 10 years. He has made statements to the victim and associates that he will not go back to jail.

The actor is believed to be holed up in an art co-op building were the victim works. A 9-1-1 call was received from the victim stating that he was being held by the actor at this location. The victim mentioned a gun prior to the line going dead. The call taker heard the words "You're a dead man".

Negotiators have been unable to contact the actor. There is one exterior window in the structure however it is blocked by thick vine vegetation and an overgrown tree. Spotters and snipers are not able to view inside the structure.

Neighbors and fellow artists say that there are several studios inside the building with separate doors and windows. They describe a dim stairway where there are several private segmented studios each with an internal window looking into a hallway and a door for each studio. The victim's studio is on the 2nd floor of a 4 story building.

An Emergency Entry Team has assembled outside the main exterior door. These officers are SWAT team members who were the first to arrive. There are no windows for the actor to see the team on that side of the building. The Incident Commander is on scene and you have assumed tactical command of the situation. The site perimeter has been secured by uniformed officers.

Due to the exigent circumstance including the actor's prior statements about wanting to murder the victim, his admission that he will not go back to jail and his knowledge of police presence combined with his criminal history of violence along with the victim's 9-1-1 report, it has been determined that the EET will proceed into the building. The team will attempt to gain an uncompromised, superior location for tactical resolve. The IC has authorized tactical resolve when there is an opportunity. The EET will report what they see and await your command for tactical resolve (a "g"o) based on their reports back.

Tactical Scenario

Appendix B1

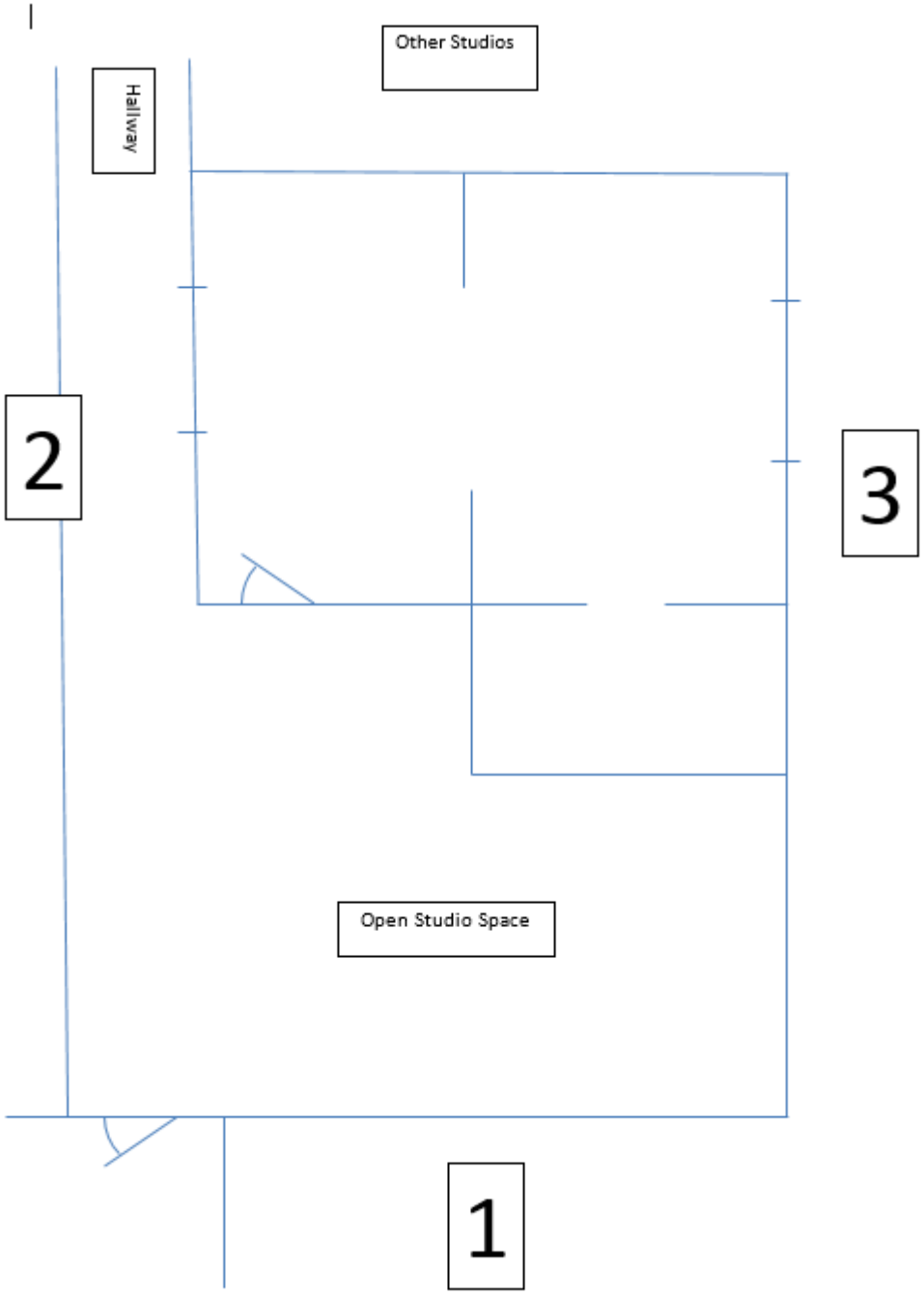
Building Information

Appendix B2

Building Information

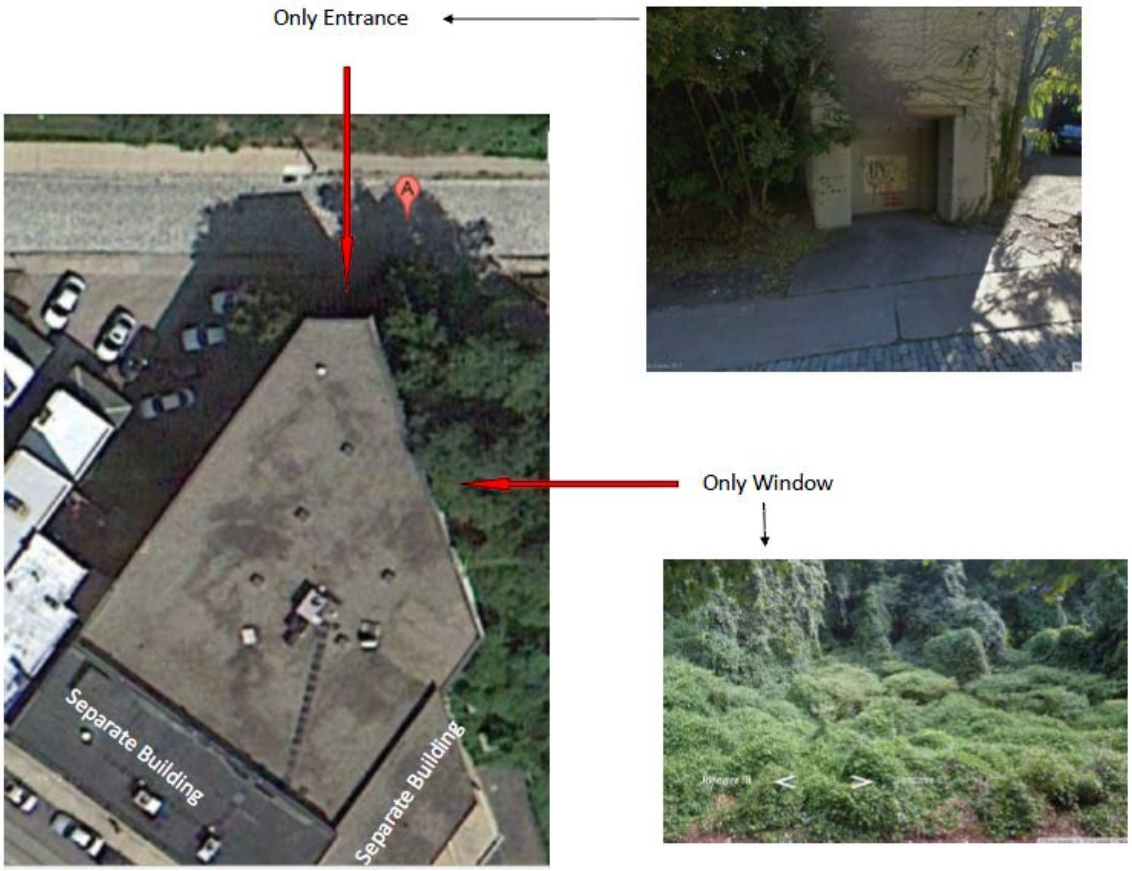
Appendix B3

Building Layout



Appendix B4

Ingress and Aerial View



Appendix C

SAGAT TEST: ICT AND LAW ENFORCEMENT

PARTICIPANT____ | RESEARCHER _____ | DATE_____ | TIME_____ | VISUAL / AUDIBLE

TASK	STATEMENT/QUESTION TIME	YES	NO	TIME ANSWERED
Where is your team now? (progress of ingress) 3.1	1:20	☐	☐	
Comment:				
Has the approach gone without compromise? 3.1	3:42	☐	☐	
Comment:				
Is there any new or updated information? 3.2	3:42	☐	☐	
Comment:				
You have compromised authority for tactical resolve when you have appropriate separation. Call out "go" to initiate. 3.3	4:08 Start Timer	☐	☐	
Notes:				
Is there any new or updated information? 3.2	6:18	☐	☐	
Comment:				
Tactical Resolve Initiated	[redacted]	☐	☐	
Notes:				
Finish Time:				

Appendix D

Mission Awareness Rating Scale (MARS)

Participant: ___
Date:_____

Mission Awareness Rating Scale (MARS)

Instructions. Please answer the following questions about the mission you just completed. Your answers to these questions are important in helping us evaluate the effectiveness of this training exercise. Check the response that best applies to your experience.

The first four questions deal with your ability *to detect and understand important cues present during the mission.*

1. Please rate your ability to ***identify*** mission-critical cues in this mission.

___ very easy – able to identity all cues
___ fairly easy – could identify most cues
___ somewhat difficult – many cues hard to identify
___ very difficult – had substantial problems identifying most cues

2. How well did you ***understand*** what was going on during the mission?

___ very well – fully understood the situation as it unfolded
___ fairly well - understood most aspects of the situation
___ somewhat poorly – had difficulty understanding much of the situation
___ very poorly – the situation did not make sense to me

3. How well could you ***predict*** what was about to occur next in the mission?

___ very well – could predict with accuracy what was about to occur
___ fairly well – could make accurate predictions most of the time
___ somewhat poor – misunderstood the situation much of the time
___ very poor – unable to predict what was about to occur

Mission Awareness Rating Scale (MARS) Page 2

4. How aware were you of ***how to best achieve*** your goals during this mission?

___ very aware – knew how to achieve goals at all times
___ fairly aware – knew most of the time how to achieve mission goals
____ somewhat unaware was not aware of how to achieve some goals
___ very unaware - generally unaware of how to achieve goals

The last four questions ask how *difficult* it was for you to detect and understand important cues present during the mission.

5. How difficult – in terms of mental effort required - was it for you to *identify* or detect mission-critical cues in the mission?

___ very easy – could identify relevant cues with little effort
___ fairly easy – could identify relevant cues, but some effort required
___ somewhat difficult - some effort was required to identify most cues
___ very difficult – substantial effort required to identify relevant cues

6. How difficult – in terms of mental effort – was it to *understand* what was going on during the mission?

___ very easy – understood what was going on with little effort
___ fairly easy – understood events with only moderate effort
___ somewhat difficult – hard to comprehend some aspects of situation
___ very difficult – hard to understand most or all aspects of situation

7. How difficult – in terms of mental effort – was it to *predict* what was about to happen during the mission?

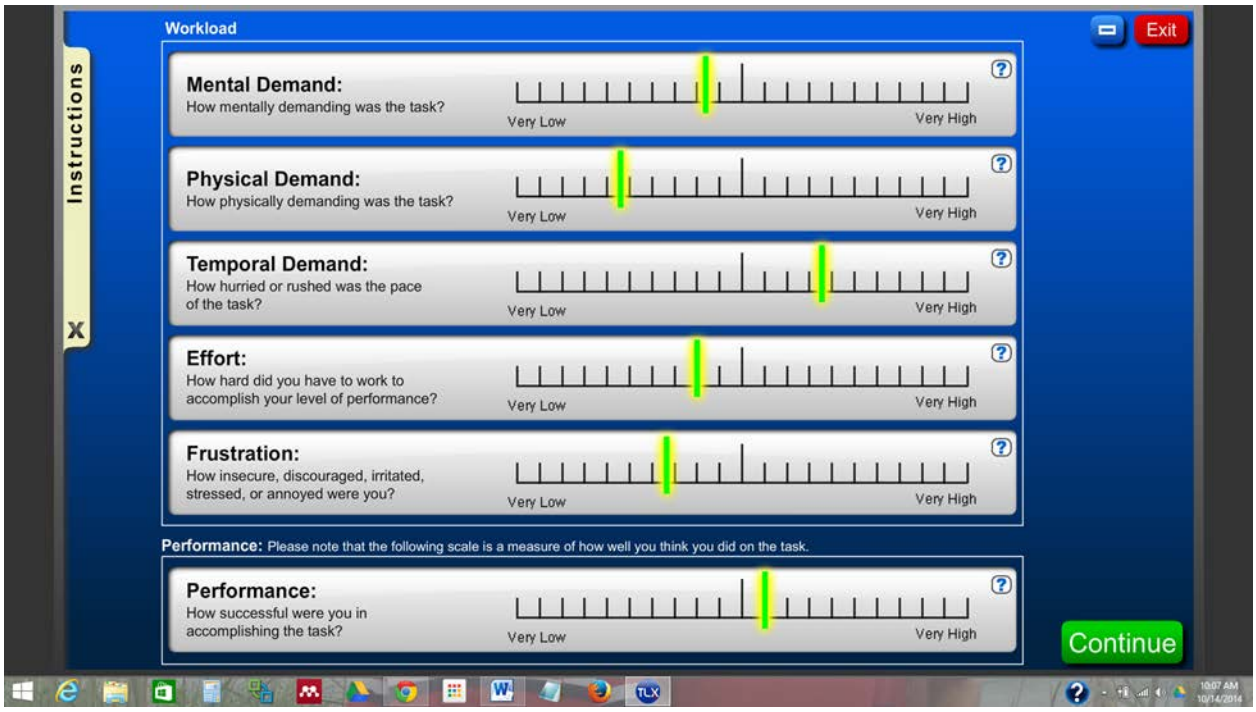
___ very easy – little or no effort needed
___ fairly easy – moderate effort required
___ somewhat difficult - many projections required substantial effort
___ very difficult – substantial effort required on most or all projections

8. How difficult – in terms of mental effort – was it to decide on *how to best achieve* mission goals during this mission?

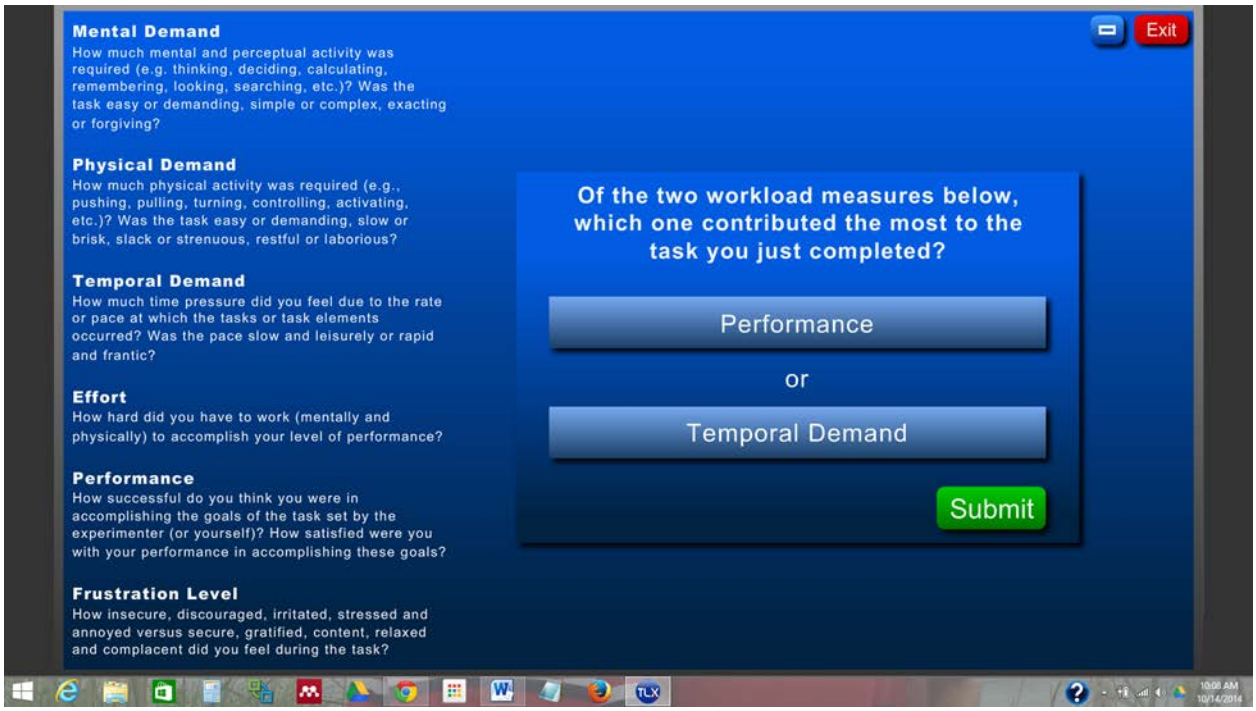
___ very easy – little or no effort needed
___ fairly easy – moderate effort required
___ somewhat difficult - substantial effort needed on some decisions
___ very difficult - most or all decisions required substantial effort

Appendix E

NASA TLX



Appendix E Continued



NASA TLX

Appendix F

Interview Protocol

Interview Protocol Participant:_____

1. Ask the background questions listed below.
2. The participant will be interviewed and have the ability to look at and use the Glass technology. These semi-structured interview questions will relate to usability and acceptance. The participants will be able to discuss their opinions on the value of the technology, the future of wearable technology and any issues they see related to it. It is estimated that the conversation will take about 20 – 30 minutes.
3. Take 10 minutes to summarize the top three themes interviewee identified in the discussion

Conclusion:

1. Ask if I could contact the officer again if I want to validate findings.
2. Thank the officer for lending their professional insight and devoting time to this project.

BACKGROUND QUESTIONS:

1. What is your age? (optional)_____
2. How long have you been an incident commander? _____
3. How long have you been at your current rank? _____
4. What are the main responsibilities of your current position?_____
5. Do you have prior law enforcement experience prior to this department?_____
6. Do you have prior military experience? _____
7. Have you ever used a device like Google Glass prior to this? _____
8.. How would you rate your exp with technology? Basic/ PC / video games or more advanced?_____

MAIN INTERVIEW QUESTIONS:

Topic 1

Topic #1: Usability

1. To begin, please describe how you feel this technology could be useful for law enforcement.
   - PROBE:
   - PROBE:
2. What features are useful?
3. What features are not useful? Why?

Topic 2

Appendix F Continued

Interview Protocol Page 2.

Topic #2: Acceptance

Now, I'd like to discuss how you feel this technology would be accepted in the law enforcement community.

4. Would this technology be accepted by police officers? Why? Why not?
5. Give me some reasons this technology might succeed?
6. Give me some reason this technology might fail?
7. What could be done to make this technology more/less acceptable in the LE culture?

Topic 3

(15 minutes)

Topic #3: Issues, Opinions and Comments

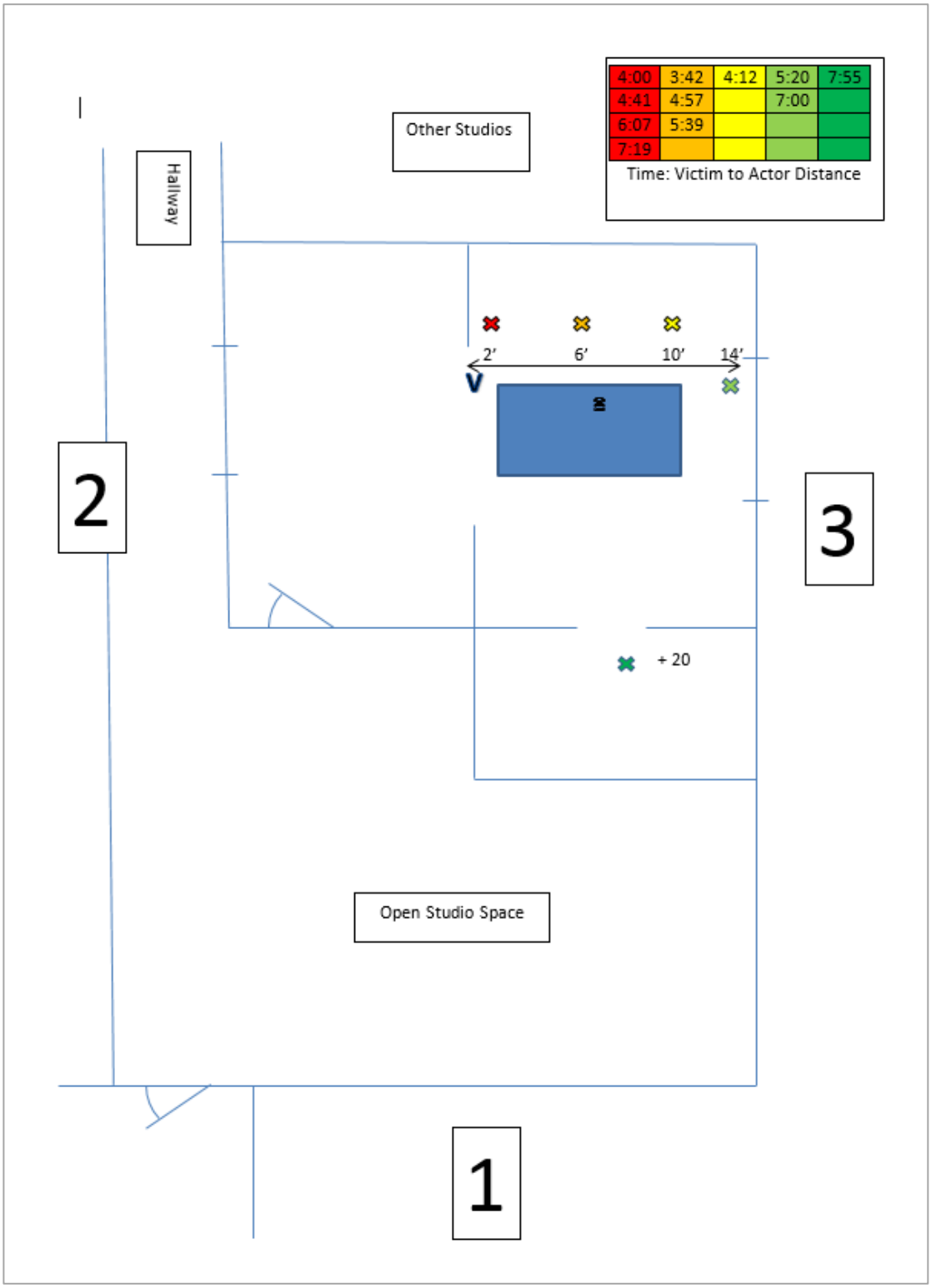
The last thing that I'd like to discuss with you are any potential issues with the technology.

8. What is your overall opinion of this technology for this application?
9. Are there design issues with the current technology?
10. What would you change?
11. How would you utilize this technology?

Final thoughts?

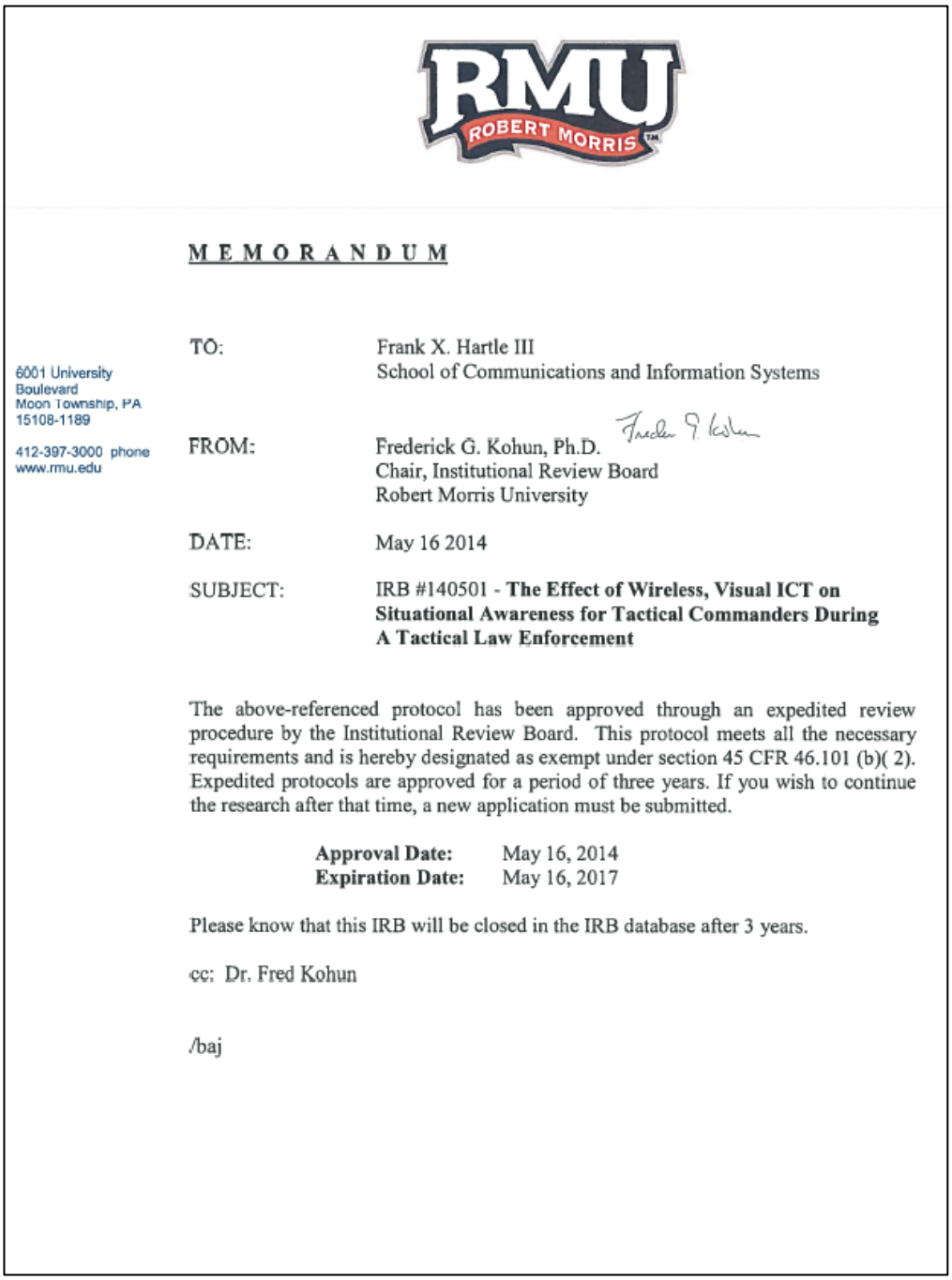
Appendix G

Spatial and Temporal Plotting



Appendix H

Robert Morris IRB Approval



RMU
ROBERT MORRIS

MEMORANDUM

6001 University Boulevard
Moon Township, PA
15108-1189

412-397-3000 phone
www.rmu.edu

TO: Frank X. Hartle III
School of Communications and Information Systems

FROM: Frederick G. Kohun, Ph.D.
Chair, Institutional Review Board
Robert Morris University

DATE: May 16 2014

SUBJECT: IRB #140501 - **The Effect of Wireless, Visual ICT on Situational Awareness for Tactical Commanders During A Tactical Law Enforcement**

The above-referenced protocol has been approved through an expedited review procedure by the Institutional Review Board. This protocol meets all the necessary requirements and is hereby designated as exempt under section 45 CFR 46.101 (b)(2). Expedited protocols are approved for a period of three years. If you wish to continue the research after that time, a new application must be submitted.

Approval Date: May 16, 2014
Expiration Date: May 16, 2017

Please know that this IRB will be closed in the IRB database after 3 years.

cc: Dr. Fred Kohun

/baj

Appendix I

NTOA Approval

-----Original Message-----

From: Frank Hartle <frank.hartle@[redacted]

To: [redacted]@aol.com>

Sent: Sun, Apr 27, 2014 10:23 pm

Subject: Research

[redacted]

Attached is a summary of my research proposal. I hope it makes sense. Thank again for the help.

Stay safe,

Frank

[redacted]@aol.com Tue, May 13, 2014 at 1:36 PM

To: frank.hartle@gmail.com, [redacted]

Mark,

Here is the information we discussed concerning the research project that [redacted] SWAT will be involved with and neighboring teams. The request from Mr. Hartle is to have NTOA "interest and backing on the project" please see attached documentation. Mr Hartle is currently a [redacted] in [redacted]

Thanks

[redacted]@ntoa.org> Tue, May 13, 2014 at 1:57 PM

To: [redacted]@aol.com, frank.hartle@[redacted]

Hi Steve,

This project looks very interesting. Please keep me informed of the progress. Let me know if you need any additional NTOA assets.

Thanks,

[redacted]

Executive Director

National Tactical Officers Association

Appendix J

Informed Consent Agreement

Informed Consent Agreement

TITLE OF RESEARCH: The Effect of Wireless, Visual ICT on Situational Awareness for Tactical Commanders during a Tactical Law Enforcement Event

INVESTIGATOR: Frank X. Hartle III

SPONSOR: This research project has been approved by the Institutional Review Board of Robert Morris University

DESCRIPTION: The researcher is seeking SWAT commanders to test if visual communication devices enhance your ability to understand what is going on during a simulated event. You have been asked to participate in this study due to your unique skill as an SWAT incident commander. This is not a test of your ability rather it is a test of how current and new technology affect situational awareness. The name of this s study is: The Effect of Wireless, Visual ICT on Situational Awareness for Tactical Commanders during a Tactical Law Enforcement Event. This study is designed to test the utility of visual communication technology like Google Glass in the law enforcement environment. Although this technology is being adopted by numerous law enforcement departments, to date, there is no experiential study proving the benefits of this technology for law enforcement. There is no compensation provided to you to take part in this study.

PROCEDURE:

If you agree to participate, a tactical law enforcement scenario will be presented to you. You will act as though you are the commander on scene and the researcher is an inquisitive superior. The researcher will ask you questions during the scenario relating to your perception of events, comprehension of what is happening and your projection of what to do. A score will be recorded based on your response. This is not a score of your ability rather it is a measurement of awareness. After this scenario you will be asked to take two self-rating tests. These measure situational awareness and workload. Each test takes about 5 minutes each. As above, this is not a test of your ability. After the self-rating test, a short semi-structured interview will be conducted with you. You will be presented a pair of Google Glass to try. At the conclusion of the interview, responses will be summarized and you will be asked to comment on any emerging themes related to this technology.

POTENTIAL RISKS:

There are no known risks. Concerns of public disclosure of sensitive or competitive information can be a participant concern. This study was structured to allow police commanders to provide personal opinions and not opinions sanctioned by their employers. Individual one-on-one interviews safeguard against confidential or competitive information from being shared publically by assuring participants that all information is de-identified to remove references to individual by name, employer or related affiliation.

Appendix J Continued

Informed Consent Agreement page 2.

CONFIDENTIALITY:

Published results, presentations or discussions regarding this study will not reveal any personal information about the participant's name, employer or affiliation. Field notes and audio tapes will be used for thematic analysis only. All field notes will be kept confidential and stored in locked box and all electronic information will be password protected.

WITHDRAWAL:

If you choose to participate, you can withdraw your consent and discontinue your participation at any time. You are not waiving any legal rights because of participation in this study. If you have questions about your rights as a study participant, concerns or complaints about the research, please call the RMU IRB office at 412-397-6227 during the hours of 8:00 a.m. – 5:00 p.m. ET or email IRB@rmu.edu.

OFFER TO ANSWER QUESTIONS:

If at any time during the study you have questions, please contact Frank Hartle at fxhst270@mail.rmu.edu or 412-953-5026.

SIGNATURES:

All of the above has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research during the course of this study and that such future questions will be answered by the researchers listed on the front page of this form.

Your signature below indicates that you agree to participate in this study. You will receive a copy of this signed document.

Signature of Participant: _____ Date: _____

Signature of Principal Investigator: _____ Date: _____

Appendix K

Gentlemen,

Please see the below request from Frank Hartle, who is ----------..

Starting in July through August, a friend and former Pittsburgh Police officer will be asking us to help him collect data to finish his doctorate. Frank Hartle is an ---------- who spent 10 years with the PD before moving to the ----------. He is getting his Doctorate at RMU. His main theory and overall experiment is to see if there is utility for visual communication for tactical officers. He is asking for 20 minutes of your time to test situational awareness. You have been asked to participate in this study due to your unique skill as a SWAT Tactical/Commander/ Incident Commander.

This is not a test of your ability rather it is a test of how current and new technology affects situational awareness.

The name of this s study is: The Effect of Wireless, Visual ICT on Situational Awareness for Tactical Commanders during a Tactical Law Enforcement Event.

This study is designed to test the utility of visual communication technology like Google Glass in the law enforcement environment. Published results, presentations or discussions regarding this study will not reveal any personal information about the participant's name, employer or affiliation. Frank will come to you (anywhere) and the process will take no more than 20 min of your time.

Again, he will travel to you and at your convenience. If you get a call from him please consider taking part as this research has implications for our profession and how we use future technology.

Appendix L

Question	Participant	Acceptance Quotes	Word-Count	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6	Theme 7	Theme 8	Theme 9	Theme 10	Theme 11	Theme 12	Theme 13	Theme 14
6	1	I could see the things like, what's the word I'm looking for, how robust it would be or what have you. It's going to fill up the rigors of law enforcement especially SWAT runs. I mean, I know I got a bunch of gorillas, so I...	46						1								
6	2	As before, if it is not a rugged piece of equipment and we have military grade communications equipment that fails all the time. This seems a little fragile but if they rugged it out, it may something that is effective in any tactical environment, it would be successful and the other reason is just, that people not accepting it as a piece of their gear.	65						1								
6	3	The downside is that I think people get too reliant on technology and they think it's a magic answer to everything and as we are seeing when I was in homicide we had an in car video, yeah the prosecutors were mad because the in-car video didn't have the exact angle that they were looking for. It just doesn't work that way sometimes. I think they will still have to do what they do. You just can't become totally reliant upon it.	82											1			
6	4	I guess it could hurt you in that everything is visually recorded and if something - people, whether it be the public, the media, perceive things a little differently sometimes - because they don't see the whole situation. They don't understand the perception that the officer has when something happens, so yes.	52										1				
6	5	If the technology doesn't keep up with the...right now, it seems like the technology is there but yet really if think if there is SWAT technology, for example if you are not getting a good signal or you're wasting too much time adjusting things where you just go and turn it on and it works.	55											1			
6	7	Expense. I can't image what it would cost the department to invest in something like this	16												1		
6	8	The only failure I could see, especially in that building where the scenario was set up, you may have difficulty with wireless transmissions through that structure. If you become too dependent on receiving information through a device like this that could actually be a tripping point for you. That you hesitate to make a decision because you're so used to getting an accurate up to date information. I don't know how this operates - strictly wireless or by cell? . I could see that being - some structures don't lend themselves a lot, or terrain doesn't lend itself well to wireless transmission, so that could be a shortcoming. Less acceptable would probably be the ruggedness of the equipment. If it breaks easily guys aren't going to bother using it. Reliability. If you're driving through town and you can't receive a transmission because of structure interference or electrical interference from different power substations or whatever, guys will just give up on it and not use it. I've seen that. Anything that's frustrating to use or unreliable just gets discarded, no matter how much it cost or...	185						1					1			
6	9	I think that there are some times that officers instinctively, due to just our nature, would have a sense of being guarded of how we do our job and things like that but I don't really a reason why it would fail.	42										1				
6	10	Just on overall general acceptance, I guess some guys in recording day-to-day, I'm looking on the administrative side, the fear of guys thinking they're going to get jammed up with their actions or something they say or something they do being recorded.	42										1				
6	11	Just the same with any technology, it's prone to failure, Anytime it fails, batteries go dead, In the event that it would fail physically in the middle of what you're trying to do.	33											1			
6	12	one good lawsuits will ruin it for everybody.	8										1				
6	13	Failures be probably the price. These aren't cheap and budgets aren't where they should be but I could see it being useful I guess	24												1		