Perceptions of the Use of Synthetic Crewmembers in Aircrew Training: Instructor and Student Perspectives

Emily Anania, John Killilea, Beth Atkinson
Naval Air Warfare Center Training Systems Division
Orlando, FL
emily.c.anania1@navy.mil, john.killilea@navy.mil, beth.atkinson@navy.mil

Bill Schmermund
Aviation Systems Engineering Company
Jacksonville, FL
bill.schermund@ASEC-incorporated.com

Emma Burns
Zenetex, LLC
Orlando, FL
emma.burns.ctr@navy.mil

ABSTRACT

The use of synthetic crewmembers is aimed at solving a long-standing aircrew training challenge – how to train an individual to complete a mission that usually takes a team. The general purpose of synthetic crewmembers in training is to provide automated and realistic voice communications and behaviors to support trainee learning. However, prior to implementing this type of new technology into the current training environment, it is important to assess instructor and student perceptions, in order to gauge acceptance of new technologies and expectations of this new training environment. To this end, surveys were created for both instructors and students.

Participants included 38 instructors and 74 students from the U.S. Navy P-8A Poseidon maritime patrol community. Participants responded to survey questions regarding their trust in synthetic crewmembers, their expectations of synthetic crewmember behavior, and likely crewmember capabilities. Instructor questions were focused around instructor needs that synthetic crewmembers could support (e.g., role-playing different entities/agencies), while student questions were more focused on expected interaction types with these synthetic crewmembers. Overall results support that students and instructors are cautiously optimistic about the technologies, but have some trepidation regarding the likely issues in integrating new technologies into existing systems, as well as difficulties trusting synthetic crewmembers to perform adequately. Results will help prioritize verbal and behavioral actions that synthetic crewmembers should be able to perform prior to integration in training.

Overall, it is clear that synthetic crewmembers have the capability to alleviate instructor workload, allowing them to spend a training evolution providing instruction and feedback, rather than focusing on role-playing other crewmembers or entities needed in a given training environment. This paper will provide initial results that form a base from which to refine the technologies to better support the Fleet and to provide an initial look at ways to ease automated technology integration.

ABOUT THE AUTHORS

Dr. Emily C. Anania is a Research Psychologist at Naval Air Warfare Center Training Systems Division (NAWCTSD) in the Basic and Applied Training and Technology for Learning and Evaluation (BATTLE) Laboratory. Her PhD is in Human Factors from Embry-Riddle Aeronautical University (ERAU). Her research interests include human-automation interaction, human factors analyses of training systems, and aviation human factors.

Dr. John P. Killilea is a Research Psychologist at NAWCTSD in the BATTLE Laboratory. He holds a PhD in Modeling & Simulation (M&S), with a special focus on training, from the University of Central Florida. His research interests include training and interacting with synthetic agents, automated speech recognition, manned-unmanned teaming, and maritime training tactics and trend analysis.

Ms. Beth F. Wheeler Atkinson is a Senior Research Psychologist at NAWCTSD, a NAVAIR Associate Fellow, and the Lab Lead of the BATTLE Laboratory. She has led several research and development efforts devoted to investigating capability enhancements for training and operational environments, and has successfully transitioned a post-mission reporting and trend analysis tool that leverages automated performance measurement technology. Her

research interests include instructional technologies (e.g., performance measurement, post-mission reporting/review), Human Computer Interaction (HCI)/user interface design and analysis, and aviation safety training and operations. She holds an MA in Psychology, Applied Experimental Concentration, from the University of West Florida (UWF).

Mr. Bill Schmermund is a project manager and P-8A training systems tactical coordinator (TACCO) subject matter expert (SME) at Aviation Systems Engineering Company (ASEC). He supports the Maritime Patrol and Reconnaissance (MPR) community in core curriculum development, defining training requirements, and training systems support.

Ms. Emma Burns is a Research Psychologist Assistant with Zenetex, working at NAWCTSD in the BATTLE Laboratory. She hold a B.A. in Psychology from the University of Central Florida. Her research interests include applied behavior analysis, which she will be pursuing a M.S. in, as well as aviation psychology and training and simulation.

Perceptions of the Use of Synthetic Crewmembers in Aircrew Training: Instructor and Student Perspectives

Emily Anania, John Killilea, Beth Atkinson
Naval Air Warfare Center Training Systems Division
Orlando, FL
emily.c.anania1@navy.mil, john.killilea@navy.mil, beth.atkinson@navy.mil

Bill Schmermund
Aviation Systems Engineering Company
Jacksonville, FL
bill.schermund@ASEC-incorporated.com

Emma Burns
Zenetex, LLC
Orlando, FL
emma.burns.ctr@navy.mil

INTRODUCTION

This paper will address the benefits and potential barriers of acceptance to the use of synthetic agents in the military training community – specifically within an anti-submarine warfare (ASW) platform with the goal to train an individual in tasks that usually take an entire aircrew. Prior to implementing these technologies, it is vital to assess student and instructor perceptions of these technologies. Results of this paper can be useful not only for the ASW community in regard to training, but can also provide general recommendations for the use of synthetic crewmembers in military training situations.

Anti-Submarine Warfare Aircrew Training

One of the roles of the U.S. Navy is to patrol the world's oceans for surface and sub-surface forces. This responsibility largely falls on members of the Maritime Patrol community trained to: 1) conduct anti-submarine warfare first, 2) conduct intelligence, surveillance, and reconnaissance (ISR) always, and 3) conduct anti-surface warfare (SUW) if needed. They use a militarized version of the Boeing 737 multi-mission aircraft to accomplish these missions. The aircrew consists of both enlisted and officer personnel who operate a multitude of sensors. Using their training to employ multiple capabilities, their primary tasking includes searching, locating, and tracking submarines across the globe. The job is a difficult one and although the crew has a capable aircraft, they need to be proficient in their roles to achieve mission success. Crewmembers conduct training qualifications primarily in live flights, but maintain a strong reliance on various training devices and participation in synthetic training environments.

Although crew composition varies based on mission requirements, in general there are five core tactical positions aboard the aircraft in addition to the pilots. The Tactical Coordinator (TACCO) is responsible for synthesizing information from other crewmembers and deciding which tactics, techniques, and procedures to implement. The Co-Tactical Coordinator (COTAC) assists the TACCO with various tasks, but their principal roles are tactical communications of on and off board information and data management. COTACs eventually transition to the position of TACCO after completing additional training and acquiring more experience. Both are traditionally officers, while the traditionally enlisted Naval Aircrewman Operators (AWOs) operate various sensor equipment. These sensor operators include Acoustic Naval Aircrewman (AAWs) and Electronic Warfare Operators (EWOs). On a typical flight, there will be a senior AAW and a junior AAW, as well as a senior EWO, and a more junior EWO to provide apprentice-type experiences throughout the training continuum.

Aircrews qualify through the Air Combat Training Continuum (ACTC), which spans from ACTC Level 100 (novice) through ACTC Level 500 (highly qualified). ACTC is a training concept designed to provide infrastructure and support systems necessary for standardized and enhanced flight crew training across naval aviation. The goals of the program are to enhance war fighting capabilities while improving efficiency in the training process, and to standardize training to ensure interoperability of personnel. ACTC is a continuous progression of training, beginning with the basics and becoming more advanced as the flight crewmember acquires experience in various warfare areas. Each community will specify performance periods that satisfy community requirements, as well as qualification and designation titles associated with each ACTC level. Personnel at ACTC Level 100 comprise Fleet Replacement Squadron (FRS) graduates, which are junior personnel. Those at ACTC Level 200 are aircrew who are conditionally qualified, while those at ACTC Level 300 are mission/position qualified. ACTC Level 400 comprises advanced members who are positional instructors, while ACTC Level 500 are Weapons Tactics Instructors, who maintain the highest level of expertise. As such, the 500 level positions are exclusive and have a small number of billets each year. A practical example of the ACTC levels within an aircrew would be a COTAC that is level 200, while the TACCO is level 300. Similarly, the junior EWO and AAW members will be level 200, while the senior positions will be level 300.

To progress through the P-8A ACTC levels, aircrews work through a qualification syllabus comprised of verbal fundamentals, systems, tactics knowledge, discussion and quizzes, simulators, and flight events. Throughout their training continuum, they will use a variety of training devices and tools. However, they complete primary training on the Part-Task Trainers (PTT) or the Weapons Tactics Trainers and Weapons Systems Trainers (WTT/WST). The PTT system is an exact replica of the Mission Crew Workstation (MCW) for a single user. It is for training a single operator (which can be any role/position) on high-fidelity replicas of what they will use in the aircraft itself. An instructor will work with a few trainees conducting simultaneous PTT training events at a time. The WTT system is a high-fidelity replica of the entire aircrew's workstations. Essentially, this is a large cutout of the aircraft's fuselage, containing all the MCWs and other equipment that the crew would employ on the aircraft itself. This enables full crews to train together in an extremely high-fidelity environment. Multiple instructors observe the event through cameras inside the aircraft's fuselage and repeater displays showing what the crew inside is doing. Where the PTT allows individuals to gain competence in performing their own role, the WTT allows them to work together with the rest of their crew to practice mission performance. This requires significant communication and coordination with the rest of the crew. PTT and WTT training time is limited however and requires multiple instructors and contractors to run a single event.

Synthetic Crewmembers

Synthetic agents have been used in several different training-centered domains, including but not limited to aviation training (Bartolone et al., 2004), driver training (Çavuşoğlu & Kurnaz, 2011), and medical training (Damacharla et al., 2019). Synthetic agents are intelligent automated entities that complete specified actions, in order to help improve operator and team performance (Chen et al., 2018). Research has indicated that synthetic agents can help mitigate operator workload, as well as mediate interactions between the user and other technology (Chen, et. al., 2018). Synthetic agents are also used as a communicative tool between the operator, other teammates, and other software (Luck et al., 2005). In addition, synthetic agents have been shown to be beneficial for training an operator's attention and providing opportunities for students to learn by recognizing their own mistakes while training (Priest & Stader, 2012). In the domain of aviation training, synthetic agents have demonstrated an ability to work as fully-fledged teammates and can be used to provide constructive feedback for the user (Priest & Stader, 2012). Synthetic agents can also benefit aviation training by reducing the number of overall human teammates necessary while simultaneously observing, critiquing, and improving the team's behavior and situational awareness during training events (Myers, 2009). Synthetic agents in other domains can help with route planning and driving practice (Çavuşoğlu & Kurnaz, 2011), and provide monitoring and feedback to combat medics and first responders (Damacharla et al., 2019).

In order for synthetic agents to move past the development stage, and into a training environment, testing and assessing operator trust is critical (Gutzwiller et al., 2019). Specifically, optimal design and development concepts of agents for synthetic crewmembers should give the user a better sense of understanding and trust in the technology (Selkowitz et al., 2015). Operator trust in automation is based on a variety of factors, including human-related traits (e.g., attitudes, comfort), partner-related traits (e.g., reliability, mode of communication), and environment-related traits (e.g., amount of risk or uncertainty; Schaefer et al., 2016). It is important to understand these factors in relation to synthetic agents, as trust can cause users to disuse or misuse automated systems (Parasuraman & Riley, 1997). However, more research is required to determine key factors related to proper trust in automated synthetic agents. As training capabilities evolve, it is important to assess the effects of these technologies on operator performance and perceptions.

Application to ASW Aircrew Training

The P-8A Poseidon aircrew is composed of a variety of officers and enlisted operators. Given the high reliance on inter-crew communication for tactical decision-making and completion of associated tasking, these platforms can offer a valuable use case for synthetic agent exploration. While these use cases define scope based on the mission and the team, the dynamic nature of the tactical operations result in a plethora of technical challenges that require the state of the practice to evolve. As training scenarios increase in entity count and complexity, more robust training system capabilities and environments are required that can automate consistent student experiences that are not dependent on individual instructor contributions. Additionally, while crew collaboration accounts for a significant amount of individual communication, the need for external-to-aircraft radio calls adds another layer of interaction that requires training. Aircrew training addresses these communication skill requirements, but given scheduled limitations, there are few opportunities to enhance individual performance or offer remediation training outside of the current, formal training curriculum. Specific areas for new or increased attention identified by communities for consideration include practice of crew communication between individual part task training and complex aircrew training, as well as repetition of off-aircrew communication prior to multi-platform training, joint exercises, and deployment. As such, there have been on-going investigations into the use of synthetic agents that support teammate behavior modeling, automation of communications within and outside a platform. Over the last several years, efforts such as the Crew Role-player Enabled by Automated Technology Enhancements (CREATE) have sought to provide enhanced training at various levels of fidelity by leveraging automated technologies such as synthetic agents. To assist with transition of such technologies, an additional focus outside of technical maturity has emerged, focusing on perceptions and willingness to adopt these types of emergent technologies.

Assessing Perceptions of Emergent Technologies

When introducing emergent technology to any field it is important to assess variables that could affect how the user reacts to and handles the new technology (Wark, 2018). In a training context, perceptions of emergent technologies can provide information regarding: acceptance barriers (Blain-Moraes et al., 2012); pre-training to prepare instructors and students (Li et al., 2011); and expectations regarding the technology and how they can affect the design and development process (National Research Council, 2007). Examples of acceptance barriers include ease of use, subjective usefulness, and perceived threat (BenMessaoud, Kharrazi, & MacDorman, 2011; Brougham & Haar, 2018). Pre-training is an important factor when introducing emergent technology because it helps to prepare the users on how to use the technology and enhances understanding of the use of the technology (Li et al., 2011). Pre-training may also help remove some acceptance barriers. When developing technology, it is important to assess user's expectations of the technology design. It informs and advances the design and development process before it is complete, making the finalized technology more appealing to the user (National Research Council, 2007).

Current Study

The current study is aimed at assessing instructor and student perceptions of synthetic agent technology use for ASW aircrew training. Research questions include:

- Are instructors and student comfortable with synthetic agents replacing various aircrew positions in a training context?
- What behaviors and capabilities do instructors and students expect of synthetic agents?
- What role-playing needs do instructors have that synthetic agents may be able to support?

METHODS

In order to understand perceptions regarding the use of synthetic crewmembers (SC) in aircrew training for ASW, students and instructors were sampled. Because instructors and students have different roles in training, instructors and students received different surveys. Surveys were not time-dependent on a specific training event, and asked participants to draw on any/all training experiences to answer the questions. Surveys were sent via email in batches with no identifying information saved and they were retrieved in a manner that did not pair questionnaires to any particular individual.

Instructor Participants

A total of 38 instructors took this survey. Of the 38 instructors, 53% (n = 20) were officers and held the rank of Lieutenant (LT or O-3). Forty-seven percent of the instructors surveyed were enlisted Naval Aircrewman Operators. Of the enlisted instructors, 32% (n = 12) were First Class Petty Officers (AWO1 or E-6), 13% (n = 5) were Second Class Petty Officers (AWO2 or E-5), and 3% (n = 1) were Chief Petty Officers (AWOC or E-7). In addition, the sample was comprised of 53% (n = 20) TACCOs, 29% (n = 11) AAWs, and 18% (n = 7) EWOs. Instructor participants reported between 6 and 102 months instructing experience (*m* = 32, *SD* = 20). All instructor participants indicated that they had experience instructing in both PTT and WTT/WST training environments.

Student Participants

A total of 74 students took this survey. There was a large variation in student rank, and levels were comprised of ACTC 100 through ACTC 300/400 receiving refresher training at the Fleet Replacement Squadron. The sample was comprised of 46% (*n* = 34) student COTACs, 28% (*n* = 21) student AAWs, 20% (*n* = 15) student EWOs, and 5% (*n* = 4) student TACCOs. In regards to PTT simulator time, 42% (*n* = 30) reported having 10-25 hours in the PTT, 38% (*n* = 27) reported having over 25 hours, and 21% (*n* =15) reported having less than 10 hours. In regards to WTT/WST simulator time, 47% (*n* = 34) reported having over 25 hours in the WTT/WST, 28% (*n* = 20) reported having 10 - 25 hours, and 25% (*n* =18) reported having less than 10 hours. Two student participants declined to provide their PTT and WTT/WST time.

Instructor Survey

Participants filled out questions relating to the positions commonly role-played in WTT/WST events ("*During WTT/WST events, which of the roles listed below are the most commonly role-played? Check all that apply."* with answers including Other P-8A, Helo (MH-60R/S helicopter), Aircraft Control Unit (ACU) / Redcrown, Fighter, Intel Node, Tactical Operation Center (TOC) / Mobile Tactical Operations Center (MTOC), aircrew positions, Surface Blue Forces, Hostile Forces, Command and Control (C2) Assets, and Unmanned Aerial Systems (UAS)). They were also asked which of these positions were most difficult to play.

Regarding PTT events, participants were asked to list which aircrew position was most commonly role-played, and which other entities/agencies were most commonly role-played. For both PTT and WTT/WST, participants were instructed to indicate (in percentage format) how much time was spent role-playing as crewmembers, and how much time was spent role-playing as other entities/agencies. In addition, questions were asked how much time spent role-playing was typically devoted to voice communications, chat communications, and manipulating Next Generation Threat System (NGTS), the constructive simulation engine.

Participants were asked about their comfort with aircrew positions being replaced by SC in training (TACCO, COTAC, AAW, EWO, and FLIGHT). They were also asked to describe their expectations about whether a number of listed potential SC capabilities would be included as a synthetic crewmember characteristic, including verbal communication, chat-based communication, and behavioral actions (e.g., classifying contacts and providing fly-to-point steering to flight). Instructors were asked how effective they believed themselves to be at role-playing other aircrew members, as well as other agencies/entities. They were also asked whether or not they would employ synthetic aircrew members, friendly agencies/entities, and/or, hostile agencies/entities. Participants' predictions of their trust in potential SCs was collected.

Student Survey

Participants were asked about their comfort with aircrew positions being replaced by SC in training (TACCO, COTAC, AAW, EWO, and FLIGHT). They were also asked to describe their expectations of whether SCs would include verbal communication, chat-based communication, and behavioral actions (e.g., classifying contacts and providing fly-to-point steering to flight).

RESULTS

Instructor Role-playing

Instructors were asked to report the percentage of time spent on specific tasks while role-playing. Table 1 indicates the average percentages of time spent engaging in these tasks, while role-playing as aircrew, as well as role-playing as other entities/agencies.

Table 1. Means and Standard Deviations of Percentage of Time Spent on Different Tasks While Role-playing

	Percentage of Time Spent Role-playing as Aircrew		Percentage of Time Spent Role-playing as Other Entities/Agencies	
Activities	*M*	*SD*	*M*	*SD*
Voice Communications	44.78	33.18	32.95	22.99
Chat Communications	14.54	15.37	27.68	19.12
Manipulating NGTS	24.32	27.89	31.38	29.19
Other (list)	1.89	5.05	4.46	8.88

Participant responses also indicated that 84.21% (n = 32) felt that they were effective in role-playing other aircrew members, while 10.5% (n = 4) felt neutral, and 5.3% (n = 2) did not think they were effective. Regarding effectiveness of role-playing other entities/agencies, 60.53% (n = 23) felt that they were effective, 34.21% (n = 4) felt neutral, and 5.3% (n = 2) did not think they were effective.

WTT/WST Events

On average, instructors reported that they spent approximately 21.35% (SD = 21.11) of a WTT/WST evolution role-playing aircrew members, and approximately 34.06% (SD = 25.51) role-playing other friendly or hostile agencies and entities. When asked about the roles most commonly role-played during WTT/WST events by instructors, participants selected on average 5 of the 10 listed roles (m = 5.47, SD = 2.49). Helo was indicated as the most commonly role-played, 89% (n = 34) of participants indicated Helo; 71% (n = 27) selected Other P-8A, 68% (n = 26) selected ACU/Redcrown, 68% (n = 26) selected Hostile Force, 63% (n = 24) selected Other Surface Blue Force, 60% (n = 23) selected TOC/MTOC. Less than 50% of participants selected Fighter, Aircrew Position, Intel Node, C2 asset, or UAS.

When given the option to select the three most difficult roles to role-play in WTT/WST events, 55% (n = 21) of participants indicated Helo, 39% (n = 15) selected Fighter, 29% (n = 21) selected ACU/Redcrown, and 29% (n = 21) selected Hostile Force. Less than 25% of participants selected Other Surface Blue Force, Aircrew Position, Intel node, C2 asset, Other P-8A, TOC/MTOC, and UAS.

PTT Events

On average, instructors reported that they spent approximately 25.38% (SD = 21.28) of a PTT evolution role-playing aircrew members, and approximately 27.11% (SD = 26.3) role-playing other friendly or hostile agencies and entities. During PTT events, 55% (n = 21) indicated that the most common aircrew position role-played was TACCO, 13% (n = 5) selected FLIGHT, 10% (n = 4) selected AAW, 7% (n = 3) selected EWO, and 3% (n = 1) selected COTAC. In addition, 18% (n = 7) indicated that TOC/MTOC was the most common entity/agency to role-play, 18% (n = 7) selected Aircrew Positions, 13% (n = 5) selected Hostile Forces. Less than 10% of participants selected Other P-8A, ACU/Redcrown, Other Surface Blue Force, Helo, Fighter, C2 asset, UAS, or Intel node as the most common entity/agency to play in PTT events.

Instructor Perceptions of Synthetic Crewmembers

When asked about their expectation, most instructors believed SC should have various verbal, chat, and behavioral capabilities, including classifying contacts, and supporting ISR, SUW, and ASW phases (see Table 2 for more detail).

Table 2. Instructors Expectations of Synthetic Crewmembers

	Yes		No	
	n	%	*n*	%
Expectation				
Communicate verbally over internal comms	34	89.47	4	10.52
Communicate verbally over external comms	29	76.32	9	23.68
Communicate via chat	27	71.05	11	28.95
Make TOMS and TSD inputs	25	65.79	13	34.21

Verbal Communication Expectation				
Mission-relevant information, reports, and updates	35	92.11	3	7.89
Safety-of-flight information	30	78.95	8	21.05
Requests of information from other crewmembers	29	76.32	9	23.68
Requested tactical information	22	57.89	16	42.11
Unprompted mission-relevant information	17	44.74	21	55.26
Behavioral Capability Expectation				
Support all phases of ISR	29	76.32	9	23.68
Classify surface contacts	27	71.05	11	28.95
Support all phases of SUW	24	63.16	14	36.84
Support all phases of ASW	23	60.53	15	39.47
Safety-of-flight information	23	60.53	15	39.47
Classify air contacts	21	55.26	17	44.74
Classify subsurface contacts	20	52.63	18	47.37
Provide tactical assistance outside of normal duties	12	31.58	26	68.42

When asked about their comfort with various aircrew positions being automated during training, most participants were comfortable or neutral regarding FLIGHT and COTAC positions but had more mixed reactions regarding TACCO, AAW, and EWO positions (see Figure 1 for detail).

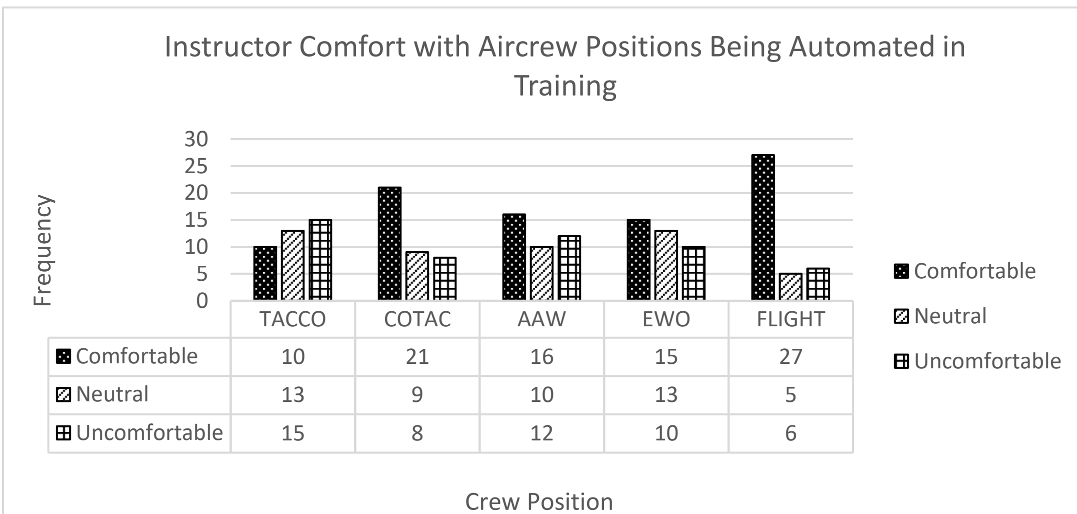

Figure 1. Instructor Comfort with Aircrew Positions being Automated during Training

When asked if they would use synthetic entities in training, 55% (*n* = 21) said they would employ synthetic aircrew members for training, 76% (*n* = 29) said they would employ synthetic friendly agencies/entities, and 68% (*n* = 26) said they would employ synthetic hostile agencies/entities. In addition, 55% (*n* = 21) of participants agreed that they would trust synthetic teammates to relieve instructor workload in a training environment, while 26% (*n* = 10) were neutral, and 18% (*n* = 7) disagreed.

Student Perceptions of Synthetic Crewmembers

When asked about their expectations, most trainees believed SC should have various verbal, chat, and behavioral capabilities, including classifying contacts, and supporting ISR, SUW, and ASW phases (see Table 3 for more detail).

Table 3. Student Expectations of Synthetic Crewmembers

	Yes		No	
	n	%	*n*	%
Expectation				
Communicate via chat	63	85.14	11	14.86

Make TOMS and TSD inputs	62	83.78	12	16.22
Communicate verbally over internal comms	56	75.68	18	24.32
Communicate verbally over external comms	53	71.62	21	28.38
Verbal Communication Expectation				
Mission-relevant information, reports, and updates	67	90.54	7	9.46
Safety-of-flight information	67	90.54	7	9.46
Requested tactical information	49	66.22	25	33.78
Unprompted mission-relevant information	47	63.51	27	36.49
Requests of information from other crewmembers	44	59.46	30	40.54
Behavioral Capability Expectation				
Classify surface contacts	69	93.24	5	6.76
Classify air contacts	61	82.43	13	17.57
Classify subsurface contacts	58	78.38	16	21.62
Safety-of-flight information	57	77.02	17	22.97
Support all phases of ISR	50	67.57	24	32.43
Support all phases of ASW	48	64.86	26	35.14
Support all phases of SUW	48	64.86	26	35.14
Provide tactical assistance outside of normal duties	35	47.30	39	52.70

When asked about their comfort with various aircrew positions being automated during training, responses were widely mixed depending on position (see Figure 2 for detail). Participants were more comfortable in general with the TACCO position being automated, and uncomfortable with the FLIGHT position being automated.

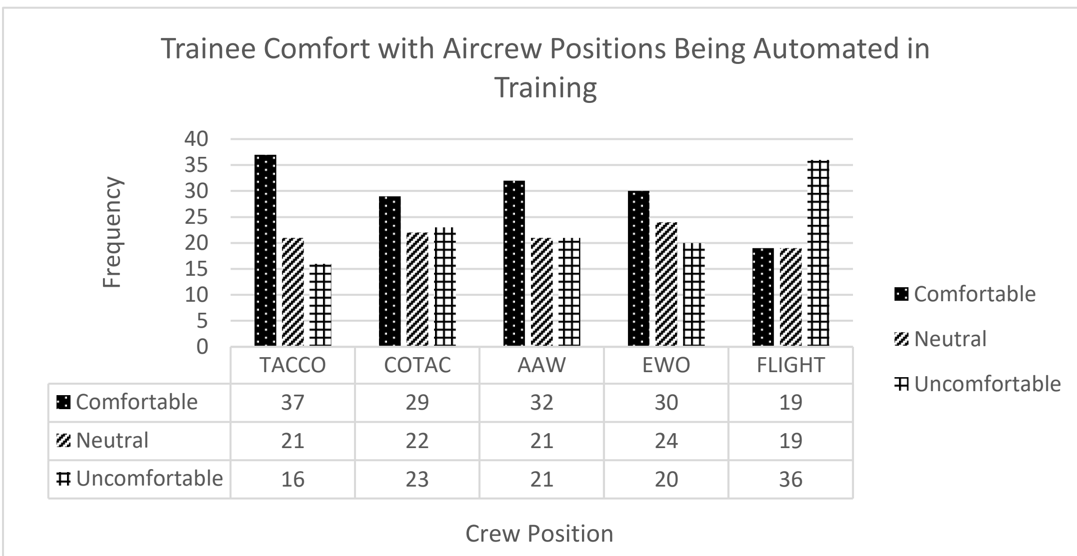

Figure 2. Student Comfort with Aircrew Positions being Automated during Training

DISCUSSION

The results provide important information regarding instructor and student perceptions of potential SC use in training events. Results were somewhat mixed, indicating that SC would be of value and accepted in certain situations, but not all. These results can be used to address any barriers to acceptance, pre-training needs, or further design and development or research that needs to be conducted prior to including SC in training events.

Instructor Perceptions

Based on the results, it is clear that role-playing as various entities is a key instructor task in PTT, WTT, and WST events, taking up a cumulative almost 50% of a WTT/WST or PTT training evolution. A typical PTT event lasts 2-3 hours, and a typical WTT/WST event lasts 3-4 hours. This is significant time spent by instructors that could be alleviated with the use of SC, freeing up instructors to provide more feedback, instruction, and observation time.

When role-playing as aircrew members, instructors indicated that voice-based communications took up the most time, but when role-playing as other friendly or hostile agencies/entities, manipulating NGTS took the most time. This entails micromanaging individual entities within the constructive simulation environment (e.g., increasing red force sub speed, performing a course change, and setting depth). The true difficulty for the instructor lies in managing the realistic representation of voice communications that accurately mirror the entity maneuvering the instructors are executing. In addition, while instructors seemed to believe in their effectiveness role-playing aircrew members, they were decidedly less confident in their effectiveness role-playing other agencies/entities. This is possibly due to the fact that instructors will likely have a greater depth of knowledge regarding the various aircrew positions, compared to their knowledge of outside agencies or entities. Furthermore, typically when instructors are required to role-play other entities and agencies many times it is within a complex coordinated operations environment that requires continuous instructor inputs shared amongst the instructor cadre for the event. Thus, due to the complexity of these multifaceted evolutions, instructors are less confident in their ability to execute them.

During WTT/WST events, the most commonly role-played entities were helicopters, P-8As, and the ACU/Redcrown. Helicopters and ACU/Redcrown were also listed as some of the most difficult entities to role-play. This is likely due to the coupled nature of ACU/Redcrown and helicopters. They usually occur together, and require coordinated inputs from the instructor to provide a constant flow of ordered communications that makes sense and is coordinated with realistic flight patterns of the helicopter(s). Simply put, role-playing as one of these entities means extra work role-playing voice communications of multiple entities, and providing specific inputs to the training system. Due to their incidence and difficulty, these entities are a prime opportunity for automation within the training system, in order to alleviate instructor workload.

Instructors largely expected the SC to be capable of verbal and chat communications, but less so making the required NGTS or TOMS/TSD (Tactical Open Mission Software/Tactical Situational Display), the crew's tactical mission software, inputs into the training system. This is possibly due to current instructor duties pertaining to controlling and monitoring NGTS during training – as instructors likely are used to this task and would expect to still be responsible for controlling various entities through NGTS. However, instructor expectations of SC behavioral capabilities were somewhat modest. Instructors have a better understanding of the domain, and perhaps a clear idea of which capabilities may be more difficult for an automated entity to handle (e.g., ASW is a more complicated domain than ISR). In addition, it is possible that instructors do not trust, or do not want to have the SC be capable of what they believe are more complex aircrew behaviors (e.g., classifying specific contacts or finding specific information).

In regards to comfort with automation of the various aircrew positions in a training context, instructors were the least comfortable with an automated TACCO position. This is likely due to the complexities of the TACCO role, and instructor familiarity with the intricacies of this role-playing experience. Instructors were the most comfortable with an automated FLIGHT position during training, potentially due to their understanding of the pilot's more limited involvement in tactics execution as compared to the rest of the crew, and the inputs necessary to accomplish this role's main duties (i.e., largely accomplished automatically through inputs by the crew using tactical mission software).

Overall, it seems that instructors are more likely to employ synthetic friendly or hostile agencies/entities than synthetic aircrew for on aircraft members. This is likely due to aforementioned reasons – instructors have more familiarity with aircrew positions, have an easier time role-playing these entities, and are more confident in their ability to be effective while doing so. However, instructors were hesitant to think that they could trust synthetic entities to lower their workload. One potential reason for this can be found in the qualitative comments provided. Instructors were repeatedly concerned that adding new technology to an already complex and issue-prone training system could cause more issues than the benefits it would provide. It is natural to be hesitant toward new technologies. However, the data resulting from the reported effort provides information of value to those designing and developing synthetic crewmembers for training (or operational) use.

Student Perceptions

Overall, students had high expectations of SC. They largely expected the SC to be able to communicate verbally and via chat, as well as handle NGTS and tactical mission software inputs. This is potentially due to their perspectives as students on how interact with various entities during training. They are focused on their most common interaction types, and so assume the SC will take on those roles. In regards to behavioral capabilities, students focused primarily on the SC's classification capabilities – for surface, air, and subsurface contacts (though instructors rated only surface contacts as a high expectation). This is perhaps because these are the capabilities that would most benefit students (i.e., part of the student's responsibilities). In addition, it may be due to limited familiarity with some mission sets that students did not have higher expectations for the SC in regards to supporting ISR, ASW, and SUW phases.

Students had some starkly different responses from instructors regarding their comfort with the various automated aircrew positions during training. Students were largely comfortable with the TACCO position being automated, but very uncomfortable with an automated FLIGHT position. This is potentially due to a lack of understanding regarding the complexities of the TACCO position, or just a general unfamiliarity with the duties. The lack of comfort regarding the FLIGHT automation may be due to safety-of-flight concerns and lack of knowledge regarding tactical mission software automation of flight management inputs and execution.

Overall, the instructor and student results did have some marked differences. This is likely due to their different perspectives – instructors and students experience training differently. Students may be viewing the SC through a slightly less experienced lens, and expecting the SC to take on some duties typically performed by the student. Instructors are more experienced, and will likely view the SC through the lens of not only what will alleviate instructor burden, but also what the appropriate level of SC capability would be in order to foster appropriate student training (i.e., SC should not be performing duties that a student is learning how to perform).

Summary Recommendations for Integration of Synthetic Crewmembers (SC) Into Training

- Target SC development for roles commonly used and/or roles that are typically difficult for instructors to mitigate workload and provide value to users.
- Address student and instructor expectations of SC, to include additional design/development, or clear pre-training regarding SC limitations.
- Consider root cause behind differences of instructor and student perceptions, in order to design optimal training capabilities for students.
- Perform further research in order to address likely user trust in SC, as this will affect usage.

CONCLUSION

Overall, it is clear that both instructors and students have some reservations regarding the use of SC in training situations, but they also see the potential of their use. Instructors and students seem largely in favor or neutral regarding the use of SC to replace some positions (namely COTAC, AAW, and EWO). A threefold approach to using information gained from this study is proposed. First, it provides input to design and development of synthetic crewmembers, in order to address students' and instructors' concerns and expectations. In order to provide value to the warfighter, this means focusing SC development on the entities that would be most beneficial to training. Second, for any SC-based systems being transitioned to the fleet, the data can provide context to aid in the design of pre-training to inform instructor and student expectations of the new capabilities. Third, this information can provide a military context to the current body of research focused on synthetic agents. It seems that synthetic agents have a strong potential for use in military training contexts, though further research and development is needed to successfully integrate them into an ASW training context.

ACKNOWLEDGEMENTS

The views expressed herein are those of the authors and do not necessarily reflect the official position of the DoD or its components. Sponsors for underlying research and development that have informed the design, development, and testing of synthetic crewmembers for ASW training have included the Naval Air Systems Command (NAVAIR) PMA-205 Air Warfare Training Development (AWTD) program and the Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR) program.

REFERENCES

Bartolone, A. P., Hughes, M. F., Wong, D. T., & Takallu, M. A. (2004). Symbology development for general aviation synthetic vision primary flight displays for the approach and missed-approach modes of flight. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 48*(1), 208–212. https://doi.org/10.1177/154193120404800145

BenMessaoud, C., Kharrazi, H., & MacDorman, K.F. (2011). Facilitators and barriers to adopting robotic-assisted surgery: Contextualizing the unified theory of acceptance and use of technology. *PLOS ONE 6*(1): e16395. https://doi.org/10.1371/journal.pone.0016395

Blain-Moraes, S., Schaff, R., Gruis, K. L., Huggins, J. E., & Wren, P. A. (2012). Barriers to and mediators of brain–computer interface user acceptance: Focus group findings. *Ergonomics*, *55*(5), 516-525. https://doi.org/10.1080/00140139.2012.661082

Brougham, D., & Haar, J. (2018). Smart technology, artificial intelligence, robotics, and algorithms (STARA): Employees' perceptions of our future workplace. *Journal of Management & Organization*, *24*(2), 239-257. doi:10.1017/jmo.2016.55

Çavuşoğlu, A., & Kurnaz, S. (2011). Developing a parameterized simulation platform with intelligent synthetic agents for training driver candidates. *Procedia Computer Science, 3*, 727–731. https://doi.org/10.1016/j.procs.2010.12.120

Chen, J. Y. C., Lakhmani, S. G., Stowers, K., Selkowitz, A. R., Wright, J. L., & Barnes, M. (2018). Situation awareness-based agent transparency and human-autonomy teaming effectiveness. *Theoretical Issues in Ergonomics Science, 19*(3), 259–282. https://doi.org/10.1080/1463922x.2017.1315750

Damacharla, P., Dhakal, P., Stumbo, S., Javaid, A. Y., Ganapathy, S., Malek, D. A., Hodge, D. C., & Devabhaktuni, V. (2018). Effects of voice-based synthetic assistant on performance of emergency care provider in training. *International Journal of Artificial Intelligence in Education*, *29*(1), 122–143. https://doi.org/10.1007/s40593-018-0166-3

Gutzwiller, R. S., Chiou, E. K., Craig, S. D., Lewis, C. M., Lematta, G. J., & Hsiung, C. P. (2019). Positive bias in the 'Trust in Automated Systems Survey'? An examination of the Jian et al. (2000) scale. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 217–221. https://doi.org/10.1177/1071181319631201

Li, Q., Ma, E. L., Liu, J., Fang, L. Q., & Xia, T. (2011). Pre-training evaluation and feedback improve medical students' skills in basic life support. *Medical Teacher*, *33*(10), 549-555. https://doi.org/10.3109/0142159X.2011.600360

Luck, M., McBurney, P., Shehory, O., Willmott, S., & the AgentLink Community. (2005). Agent Technology Roadmap: A Roadmap for Agent Based Computing. https://eprints.soton.ac.uk/261788/1/al3roadmap.pdf

Myers, C. W. (2009). Synthetic agents as full-fledged teammates. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 53*(12), 789–793. https://doi.org/10.1177/154193120905301206

National Research Council. (2007). Defining requirements and design. *Human-System Integration in the System Development Process: A New Look.* (pp. 190-252). The National Academies Press. https://doi.org/10.17226/11893.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 230-253.

Priest, H. A., & Stader, S. (2012). A framework for developing synthetic agents as pedagogical teammates: Applying what we already know. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*(1), 2552–2556. https://doi.org/10.1177/1071181312561530

Schaefer, K. E., Chen, J. Y., Szalma, J. L., & Hancock, P. A. (2016). A meta-analysis of factors influencing the development of trust in automation: Implications for understanding autonomy in future systems. *Human Factors, 58*(3), 377-400.

Selkowitz, A., Lakhmani, S., Chen, J. Y., & Boyce, M. (2015). The effects of agent transparency on human interaction with an autonomous robotic agent. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59*(1), 806–810. https://doi.org/10.1177/1541931215591246

Wark, N. (2018). *Shifting paradigms: A critical pragmatic evaluation of key factors affecting learner-empowered emergent technology integration*. [Unpublished doctoral dissertation]. Athabasca University.