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The effect of AR guidance on locating maintenance items: A use case

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NAVAL POSTGRADUATE SCHOOL

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The effect of AR guidance on locating maintenance items: A use case

by

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ABSTRACT

Efficient maintenance is critical for the U.S. Navy to sustain surface fleet operational readiness, capability, and capacity. Efficient maintenance relies on the ability to quickly locate needed maintenance items. The current process to locate critical maintenance items relies on the written description of a work order, which offers little description and ambiguity of the exact physical location of the maintenance item, creating inefficiencies in repairs, and cost and schedule delays. Augmented Reality (AR) has been shown to improve maintenance efficiency in the private sector; we provide empirical evidence to suggest the U.S. Navy should consider AR adoption for maintenance for certain use cases. We conducted an experiment in which 20 subjects were randomly assigned to locate visible unobstructed objects in two rooms that represented shipboard compartments using either the current maintenance process or with AR guided assistance. Performance was measured by time to locate items, accuracy, and the confidence in having identified the proper item. Results indicated that use of AR guidance led to considerably better performance on all measures, in terms of both statistical significance and practical importance. This research shows evidence that AR can potentially close the capability gap existing within the current process.

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LIST OF ACRONYMS AND ABBREVIATIONS

AR	Augmented reality
CNO	Chief of Naval Operations
CSMP	Current ship’s maintenance project
GAO	Government accountability office
OMMS-NG	Organization maintenance management system – next generation
SWO	Surface warfare officer
IRB	Institutional review board

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I. INTRODUCTION

Maintenance of surface ships within the Navy is a multi-billion-dollar industry. In 2016, the Navy delivered a five-year contract of $1.3 billion to San Diego shipyards for repairs of warships; San Diego is only one of many U.S. Navy support facilities (Robbins 2016). The ship maintenance industry has a direct tie to the readiness, capability and capacity of the U.S. Navy Fleet and its efficiency is integral. However, this billion-dollar industry experiences a variety of schedule delays that result in increased costs and decreased fleet readiness. One of many examples is that of the USS *Stout* (DDG 55), which experienced a 23% cost growth of $4.3 million and a 35% schedule growth of 56 days during its 2018 Chief of Naval Operations (CNO) Maintenance Availability (Government Accountability Office [GAO] 2020).

This research focuses on a contributing factor of these delays: the inability to identify maintenance items accurately and efficiently. This problem is commonplace throughout the different levels of maintenance, from actions performed on the ship by sailors to when the ship is in an intensive maintenance period in which the maintenance/repair is being completed by outside contracted civilians or Navy personnel. The current process involves an input by ships' force into a computerized list of maintenance discrepancies called the Current Ship's Maintenance Project (CSMP). Using the shipboard computer program Organization Maintenance Management System—Next Generation (OMMS-NG), the sailor describes the location of the discrepancy. The maintenance item is then analyzed by the repair party, either civilian or sailor, who reads the description and must first find the physical location of the maintenance that needs to be performed. In the current process, the location of the maintenance item can at times be unclear. It is up to the author of the work order to be descriptive enough for the repair party to correctly interpret the description and then locate and identify the specific maintenance item. This potential lack of clarity can become time consuming and very vulnerable to human error. Furthermore, if the repair item cannot be found or is not easily recognizable, no repair will be executed, and the ship's material readiness goes unchanged, and over time, deteriorates.

AR technology has the potential to bridge this capability gap, removing the current processes' ambiguity and in turn, potentially reducing scheduling delays experienced during USN ship's maintenance intensive periods. AR is becoming more commonplace within big industries, such as Boeing and GE Aviation (a subsidiary of General Electric), and shows potential to increase maintenance efficiency by decreasing execution time and human error (Robertson et al, 2017; Wang et al, 2020). For example, in examining the impact of AR on jet assembly, GE Aviation's performance reports stated that use of AR improved mechanics' efficiency by 8 – 11% and that it could save the company millions of dollars over a decade (Kloberdanz 2017). Another study by Boeing (Boeing 2018) found that use of AR dramatically improved technicians' ability to install electrical wiring throughout the KC-46 aircraft fuselage, with a 90% improvement in accuracy and a 30% decrease in time.

Based on such findings, we examined whether use of AR would show similar positive effects on correctly locating and identifying a maintenance item. To our knowledge, this is the first project to apply AR to this process. Therefore, ***the purpose of this project was to address two knowledge gaps: 1) how often do shipboard maintenance item identification delays occur and 2) whether AR can improve the efficiency of the identification process***. Accordingly, this project entailed two parts: We first conducted a survey of Surface Warfare Officers (SWOs) to gather their maintenance experiences and gauge their opinions on using AR. Second, we conducted an experiment in which subjects must locate items using either current method or with AR guidance. This project was approved by the NPS IRB. This project is one of several ongoing efforts to understand for whom and under what circumstances use of AR guidance could benefit the Navy in terms of time and cost savings.

II. KEY FINDINGS FROM THE PROJECT (BLUF)

Below, we summarize the central findings from the survey of SWOs and the experiment. An important result from the survey was that SWOs reported experiencing maintenance delays frequently, at least four times per month. This finding confirms that a portion of new growth costs and delays are due to the inability to correctly locate and identify maintenance items. To our knowledge, this is the first survey to capture the frequency of maintenance delays and some of the consequences of those delays.

Experiment results indicated that the use of AR guidance led to faster, more accurate, and more confident item identifications than the current location description method. The accuracy results, in particular, emphasize limitations with the current method. Whereas the AR group had 100% accuracy, the control group found item identification in the more complex space challenging, making a total of 13 errors. These errors show that current process can elicit due to the ambiguity of the interpretation of the written location descriptions for the desired maintenance item subject's accuracy is compromised, particularly when the item to be found is of the same shape, size, color, and in the same vicinity of other items. These items can be representative of components within a complex shipboard space such as an engine room where multiple valves, pipes, power panels, etc. may all be within the same vicinity.

Somewhat surprisingly, SWOs were responsible for eight of the 13 errors committed by the control group throughout the more complex space. Of the six SWOs within the control group, they accounted for 25.5 years of experience involved in military maintenance, which made them the most military maintenance experienced demographic throughout the control group. Although this group had the most military maintenance experience, four of six SWOs identified items incorrectly. This result indicates that regardless of the amount of maintenance experience a person has, they are still capable of inaccurately identifying maintenance items through the current process and contributing to the problem of which this study was focused. Post task survey results reiterated this point in that control subjects reported that the location descriptions added ambiguity and difficulty to the task.

III. IMPLICATIONS OF RESULTS

The lack of efficiency in the identification of shipboard maintenance items is a contributing factor of the U.S. Navy's problem of new work. This new work is experienced during intensive maintenance periods at the intermediate and depot level and is the result of the current process' lack of efficiency. The inability of repair party personnel to identify shipboard maintenance items is a cause of this new work. This research focused on leveraging the proven benefits of AR technology demonstrated in the private sector to address this problem.

This study addressed the current process' lack of efficiency in maintenance item identification by comparing it to a process in which the individual was guided by AR. This comparison was conducted in two spaces, a less and more complex space. Complexity, in this case, was defined by the amount of "stuff" in the room that the participants would be able to see (difference between an empty classroom and a full laboratory). It was hypothesized that with AR technology, there would be a decrease in time required to identify objects, an increase in identification accuracy, and an increase in the subject's confidence in identifying the correct items. An experiment consisting of a random sample of 24 active-duty military subjects (12 control, 12 AR) showed that the use of AR was statistically more efficient in terms of time, accuracy and confidence. In terms of overall completion time, the AR notably outperformed the current process in both the less and more complex space with a percent difference of 81.64% and 103.24% respectively. In terms of accuracy throughout testing, AR proved 100% accurate regardless of an increase in space complexity whereas the current process was 93.56% accurate. Of the items inaccurately identified by the current process, more than half of them were from active-duty SWOs involved in the experiment. These officers were the most familiar with the current process, and inadvertently demonstrated its ambiguity. AR's better performance also continued to show in the confidence of each subject, showing a high level of confidence 93.94% throughout the entire experiment compared to that of the current process having a high level of confidence of 85.6%. In conclusion, AR's ability to identify maintenance items within a space is more efficient, faster and more accurate.

Based on the GAO report GAO-20-370 new work comprised of approximately $1.5B in repair from the years FY03 to FY15. Although it is unclear how much the inefficiencies in maintenance item identification contribute to new work, if it accounted for only 2% of its total dollar amount in FY03-15 approximately $30M could have been saved. With AR's proven successes in this research in terms of time and accuracy its long-term cost benefits would be invaluable.

IV. DESCRIPTION OF METHODS AND RESULTS

A. SURVEY

Purpose: The purpose of the survey was to gather information from SWOs on their maintenance location and identification experiences, and on their opinions regarding whether or not AR could be a potential solution in bridging the capability gap between ship's force and outside maintenance personnel. To our knowledge, this is the first survey to query SWOs on these topics. See appendix for full survey questions.

Questions: Survey questions covered: 1) subjects' experience with maintenance, specifically with any delays or identification issues; 2) subjects' opinions regarding the potential impact of AR technology use on maintenance identification, effectiveness, and accountability, See Appendix A for a list of the specific questions.

Results: Thirty-one SWOs at the Naval Postgraduate School with an average of 8.5 years of surface warfare experience ($s = 4.33$) and an average of 5.48 years of military maintenance experience ($s = 1.72$) completed the online survey. Approximately 84% subjects reported experiencing maintenance delays throughout their careers, with more than half of subjects indicating that delays happened at least 4 times a month. Almost 60% believed that use of AR could save 6 – 10 work hours a week. Not surprisingly, those who experienced high frequency of maintenance delays believed AR could save a greater number of work hours per week (see Figure 1). In terms of who would benefit from AR use in maintenance, subjects thought that Khaki leadership (CPOs, Junior Officers, Department Heads) and Enlisted Sailors (LPOs, Workcenter Supervisors, Maintenance Persons) would most benefit. Finally, most subjects thought that use of AR could help improve sailors' identification, effectiveness, and accountability in completing maintenance (see Figure 2).

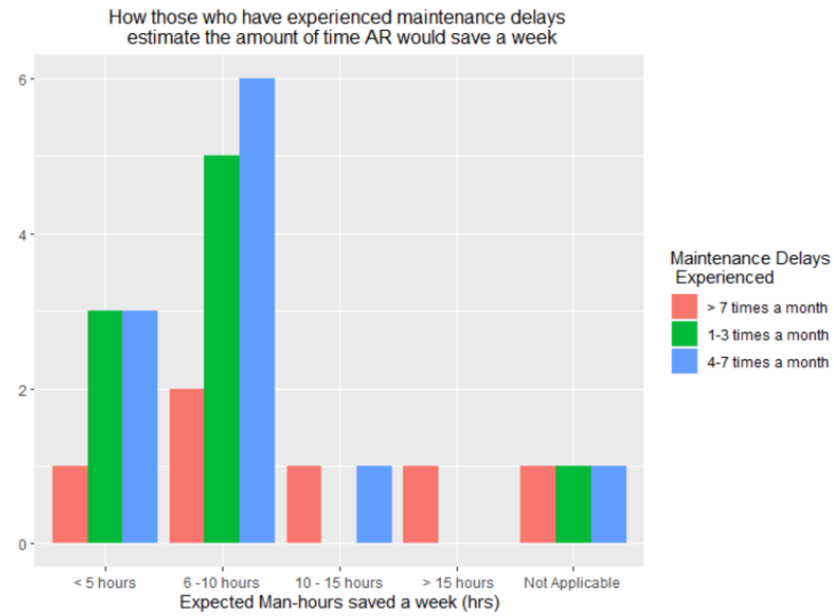


Figure 1. Maintenance delays and estimated work hours saved by implementing AR into the maintenance process. Adapted from Wiltshire (2021).

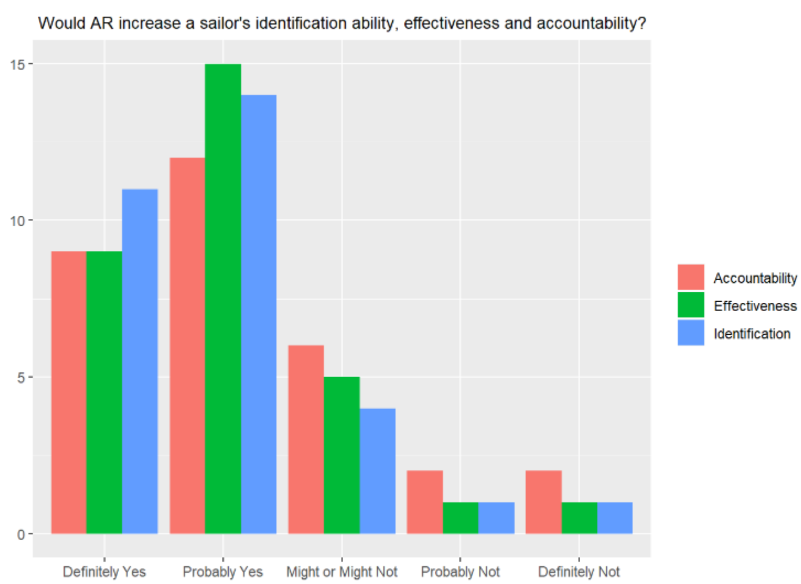


Figure 2. Subjects' responses regarding whether or not use of AR in maintenance could increase identification, effectiveness, and accountability. Adapted from Wiltshire (2021).

B. EXPERIMENT

1. Study design

We conducted a 2 (guidance method) x 2(space complexity) experiment. Subjects were randomly assigned to locate and identify several items guided either by the current process to replicate a JSN on a U.S. Navy ship or by AR. All subjects had to locate items in both a simple space and in a complex space.

2. Hypotheses

We hypothesized that the AR guided method would lead to faster identification times, more accurate identifications, and greater confidence than the current process.

3. Methodology

a. Control condition

The control condition mimicked the current shipboard process of identifying maintenance items throughout a ship, in which the research team served as the maintenance item originating party who wrote the item description. Figure 3 provides an example of such a description.

Find the Following Items:

Item Name: Classroom Thermostat

Location Description:

This classroom thermostat is approximately 3" by 2" in size. Located on the left bulkhead of the classroom upon entry and near the secondary exit of the space. It is labeled "VAV-203".

Figure 3. Example of a maintenance item location description used in the control condition. Adapted from Wilthshire (2021).

b. AR condition

Subjects wore an AR headset to guide them in locating and identifying the items. The headset provided subjects with blue directional arrows and highlighted the item in a white three-dimensional reticle (see Figure 4). Subjects in the AR condition did not receive any item descriptions other than its name (see Figure 5).

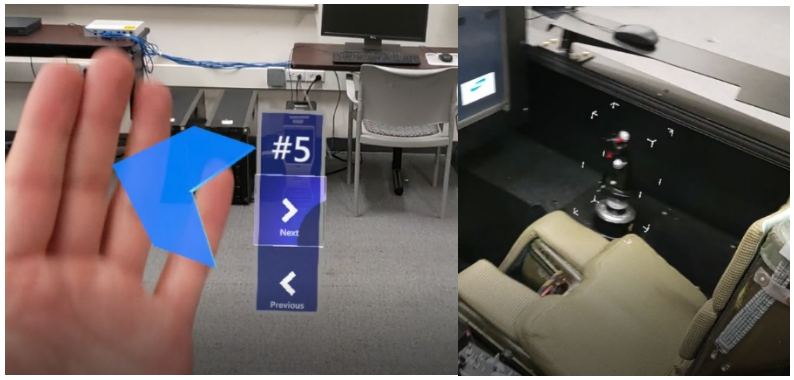


Figure 4. AR point of view, illustrating the blue directional arrows in the left image and the white 3-D reticule highlighting the item to be located; in this case a joystick. Adapted from Wilthshire (2021)

Find the Following Items:
<u>Item 1:</u> Classroom Thermostat

Figure 5. Example of item information provided in the AR condition. Adapted from Wilthshire (2021).

c. Space complexity

There were two levels of space complexity, determined by the number of different components and material within the space as well as the amount of maneuvering a subject must make to locate the components to be identified for the experiment. These spaces were selected to represent the difference in complexity between shipboard compartments. See Figures 6 and 7 for photos of the simple and complex spaces.

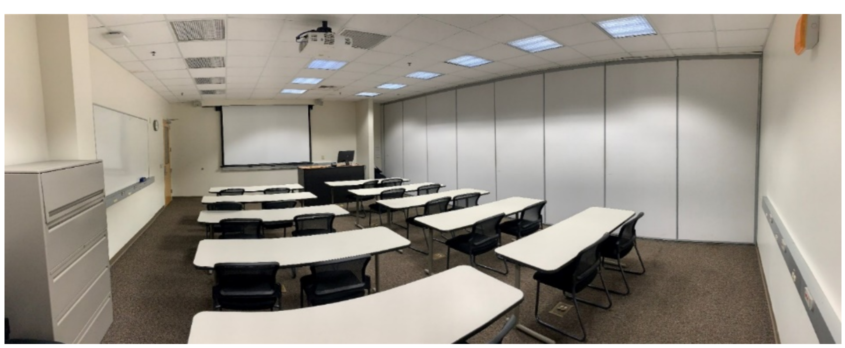


Figure 6. Simple space. Adapted from Wiltshire (2021)

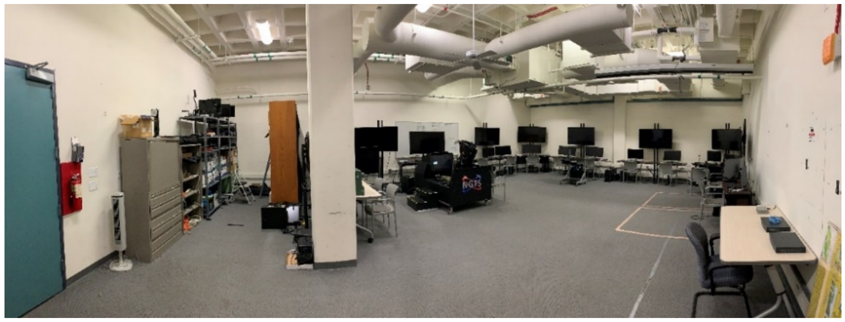


Figure 7. Complex space. Adapted from Wiltshire (2021).

d. Items

Subjects had to find the following ten items in the simple space: thermostat, light switch, overhead sprinkler head, projector screen up/down switch, fire alarm, wall panel, computer monitor, ceiling tile, presentation speaker, and floor outlet; and the following 12 items in the more complex space: overhead junction box, flight simulator joystick, overhead sprinkler head, fan coil assembly, damper solenoid, large computer monitor, wall outlet, power pane. HTG hot water return piping, floor stain, toolbox drawer, flight simulator TV monitor. The research team placed identification numbers on each item. To make the task more realistic, identification numbers also were placed on similar items in the near proximity of the item to be located.

e. Performance measures

Overall time, individual item location time, accuracy (correct/incorrect), and level of confidence (low, medium, high) were the main measures of performance. The researcher used a stopwatch to capture overall time and individual item location time and recorded subject's accuracy in identifying each item at the time of identification.

f. Surveys

Two surveys were administered, a demographics survey and a post-experiment survey. The demographics survey included information regarding subjects' military maintenance experience and any previous AR experience. The post-experiment survey asked subjects' opinions regarding difficulty of task, least and most difficult items to find. Subjects in the AR condition completed additional questions regarding use of the AR headset.

g. Hardware and software

The Microsoft HoloLens 2 was used for the AR headset. The NPS Future Tech team used Unity to create and view persistent location tags in 3D space in the HoloLens 2.

h. Procedures

One subject completed the experiment at a time. After having the opportunity to provide informed consent, the subject completed the demographic survey. They were randomly assigned to either the control or AR condition. The researcher then instructed the subject as to what they would do and how their performance would be assessed. Subjects in the AR condition completed AR environment training in which they received an introduction to how to use the AR headset. All subjects then completed a practice run by identifying three items in a non-experiment room; control subjects using written descriptions; AR subjects using the AR headset guidance. Next, subjects were tasked with locating and identifying 10 items in the simple space and 12 items in the complex space. In all cases, each item was surrounded by decoy items that also had component ID numbers. The sequence of items was the same for all subjects. Once a subject believed they had located the required item, they would state the associated component ID number. They also would indicate their level of confidence in accurately identifying the correct item.

4. Results

a. Subject demographics

Twenty-four active duty U.S. military members at NPS completed the experiment. Table 1 below depicts descriptive statistics for general and military experience demographics, as well as previous use with AR. Although there were more subjects in the AR group with virtual reality experience, this difference was not statistically significant (χ^2 (1) = 1.527, p = 0.2165). Half of the control subjects turned out to be SWOs, which is why job required to ID maintenance items has a larger frequency in the control group than the AR group.

Table 1. Descriptive statistics of subjects' demographic information.

		Control	AR
Age	Min	27	25
	Mean	30.25	31.9
	Max	39	44
Sex (%)	Male	92%	92%
	Female	8%	8%
Dominant Hand (%)	Left	8%	17%
	Right	92%	83%
Branch of Service (%)	USA	0%	17%
	USAF	0%	0%
	USMC	8%	8%
	USN	92%	75%
Years of Active Duty Service	Min	4.5	3.5
	Mean	7.8	9.5
	Max	16.25	17
Highest Rank (%)	O3	75%	67%
	O4	25%	17%
	O5	0%	8%
Job required to ID maintenance items (%)	Yes	83%	58%
	No	17%	42%
Years involved with military maintenance	Min	0	0
	Mean	5.1	5.4
	Max	12	17
Experienced Virtual Environment (%)	Yes	42%	67%
	No	58%	33%

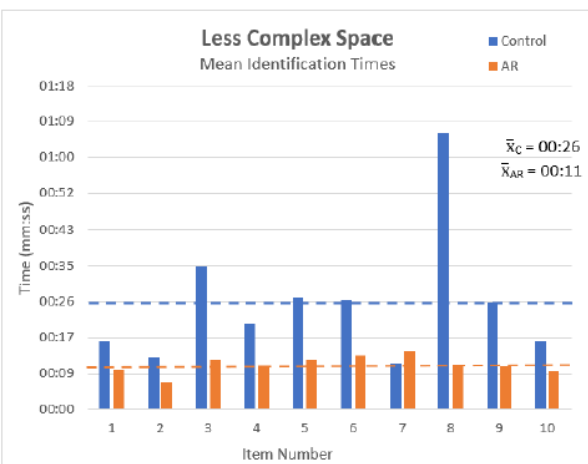
b. Time

Our hypothesis regarding item identification time was supported. The Wilcoxon rank-sum test indicated that the control group had significantly longer average overall completion time for both the simple and complex spaces than the AR group (Z = 4.12805, $p < 0.0001$) (see Table 2). Regression analyses revealed a space complexity x group interaction effect (b_1 =2.06, $SE(b_1)$ = 0.59, t = 3.50, p =.0005), such that AR overall completion time was unaffected by space complexity, but the control group was negatively impacted by the increase in space complexity.

Table 2. Descriptive statistics of overall completion times by room complexity and group.

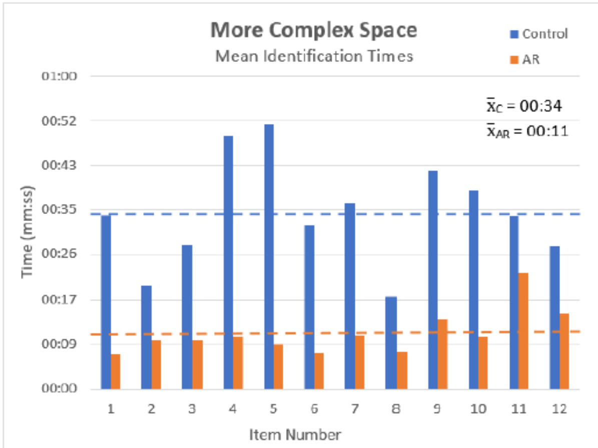
Overall Completion Time (mm:ss)			
	Mean	Max	Min
Simple space			
Control	04:17.2	06:03.0	03:15.1
AR	01:48.3	02:31.6	01:16.3
Complex space			
Control	06:47.4	10:16.1	03:31.3
AR	02:10.0	02:52.9	01:39.4

Figures 8 and 9 illustrate the time benefit of AR for all items except two (computer monitor in the simple space and the power panel in the more complex space).



Legend: Simple Space Items	
1	Thermostat
2	Light Switch
3	Overhead Sprinkler
4	Projector Up/Down Switch
5	Fire Alarm
6	Wall Panel
7	Computer Monitor
8	Ceiling Tile
9	Presentation Speaker
10	Floor Outlet

Figure 8. Mean time to locate and identify items in the simple space. Adapted from Wiltshire (2021)



Legend: Complex Space Items	
1	Overhead Junction Box
2	Flight Simulator Joystick
3	Overhead Sprinkler
4	Fan Coil Assembly
5	Damper Solenoid
6	Large Computer Monitor
7	Wall Outlet
8	Power Panel
9	HTG Hot Water Return Piping
10	Floor Stain
11	Toolbox Drawer
12	Flight Simulator TV Monitor

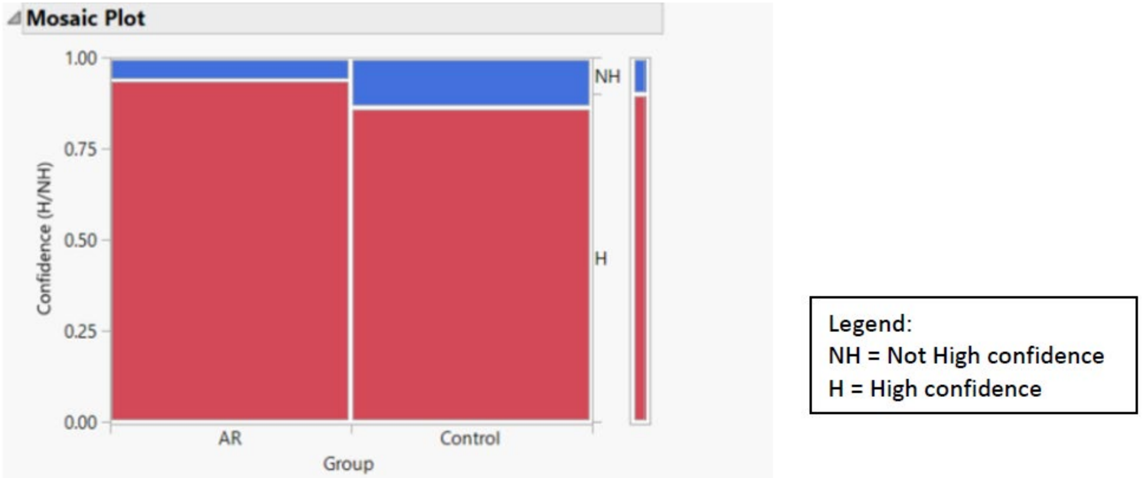
Figure 9. Mean time to locate and identify items in the complex space. Adapted from Wiltshire (2021).

c. Accuracy

Our hypothesis regarding accuracy was supported. The control group had significantly lower mean accuracy in identifying items than the AR group (Wilcoxon test, Z = -2.99, p = .0028). Again, regression analyses revealed an interaction such that the AR group's mean accuracy was unaffected by space complexity (100% accuracy in both spaces), while the control group's accuracy decreased from 100% in the simple space to 90% in the complex space. Of note, exploratory analyses revealed that of the 13 errors made by the control group in the more complex space, the SWOs made eight of those errors. Inaccuracies tended to occur when the item to be found is of similar shape, size, color, and in the same vicinity of other items.

d. Confidence

Our final hypothesis also was supported. A chi-square test of homogeneity indicated that the control group reported significantly lower frequency in having high confidence in correctly identifying items than the AR group ($\chi^2(1) = 8.375$, $p = 0.0031$) (see Figure 10). Because the AR group reported less than 5 instances of low confidence, ratings of low and medium confidence were combined into a "Not High Confidence" category. As expected, confidence rates correlated with accuracy performance (Wilcoxon test; $Z = 6.088$, $p < .0001$).



Tests

N	DF	-LogLike	RSquare (U)
528	1	4.3673731	0.0257

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	8.735	0.0031*
Pearson	8.533	0.0035*

Fisher's Exact Test	Prob	Alternative Hypothesis
Left	0.9990	Prob(Confidence (H/NH)=NH) is greater for Group=AR than Control
Right	0.0026*	Prob(Confidence (H/NH)=NH) is greater for Group=Control than AR
2-Tail	0.0051*	Prob(Confidence (H/NH)=NH) is different across Group

Figure 10. The control group reported fewer high confidence and more not high confidence (low and medium confidence combined) than the AR group. Adapted from Wiltshire (2021).

e. Post task survey

All AR subject reported that they could see all virtual images clearly and experienced no discomfort while wearing the AR headset. Half of the control group indicated that they found the task moderately difficult (2 subjects) to average difficulty (4 subjects), whereas the AR subjects reported it was very easy (10 subjects) or easy (two subjects). That a large portion of the control group found the task at least of average difficulty was due to the item location descriptions. Two thirds of the control group found the location descriptions at least average in difficulty. Of the four subjects that found it moderately difficult, they expanded on why they experienced difficulty through additional statements:

> *"The location descriptions became difficult, especially when there existed multiple items similar to the item being found."*
> *"The location descriptions are subjective to the writer's perception of the space."*
> *"After I found each item, I was disoriented about what part of the room was the front or back when reading the item location descriptions."*

> *"Some descriptions can be subjective or easily miss-interpreted. I experienced difficulty whenever there were multiple items of the same type, or I was required to count from a certain point to find the item."*

These comments emphasize the ambiguity of the current process, and how easily a misinterpretation of a maintenance item can occur even if the description of a maintenance item is written in accordance with the appropriate references.

APPENDIX. ONLINE SURVEY

AGREEMENT OF CONSENT TO PARTICIPATE

Introduction. You are invited to participate in a research study entitled *AR Technology effect on efficiency of locating items throughout a compartment* . The purpose of the research is determine the Surface Navy's first practical use of Augmented Reality Technology.

1) Participation is voluntary
2) This survey will take approximately 5–10 minutes
3) The purpose of this research is determine the initial reaction of Surface Warfare Officers about the use of Augmented Reality technology for shipboard use, in specifically locating maintenance items throughout the ship.
4) This survey will help determine possible benefits of Augmented Reality for the Surface Navy's first practical use of this technology

Procedures. Answer the following questions to the best of your ability. There is no time limit. Completed surveys will be collected until maximum sample size is reached. Desired sample range is 10 to 50 completed surveys.

Location. This is an online survey and can be taken by using your PC, laptop, mobile phone or any online enabled device.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential. The research team will collect as many surveys as possible until maximum sample size is reached, no personal information will be associated with the answered questions.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, *Dr. Quinn Kennedy* mqkenned@*nps.edu.* Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Chair, Dr. Larry Shattuck, 831–656-2473, lgshattu@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

- ◯ I consent to participate in the research (1)
- ◯ I do not consent to participate in the research (2)

---

1) Where would you be on this scale?

- ◯ Just entered the service (1)
- ◯ First Tour (2)
- ◯ Second Tour (3)
- ◯ Multiple Tours (4)
- ◯ End of Career (5)

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2) How many years of maintenance experience do you have total?

- ◯ < 3 years (1)
- ◯ 3 - 6 years (2)
- ◯ > 6 years (3)

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3) How often during your time on-board was the identification of the maintenance or corrective maintenance repair not completed in a timely fashion?

- ☐ 0 times a month (1)
- ☐ 1-3 times a month (2)
- ☐ 4-7 times a month (3)
- ☐ Greater than 7 times a month (4)
- ☐ Not sure (5)

If your answer to the previous Question was anything greater than 0, do you have an example you would like to share?

- ○ Yes (1) ____
- ○ No (2)

---

4) If AR technology was available to sailors, do you believe they would be more effective in identifying components throughout a ship's compartment: valve numbers, junction boxes, transformers, stocked inventory, maintenance items etc. ?

- ○ Definitely yes (1)
- ○ Probably yes (2)
- ○ Might or might not (3)
- ○ Probably not (4)
- ○ Definitely not (5)

---

5) If anyone, who would benefit from this technology?

- ☐ Senior Leadership (XO, CO) (1)
- ☐ Khaki Leadership (CPO's, Junior Officers, Department Heads (2)
- ☐ Enlisted Sailors (LPO's, Workcenter Supervisors, Maintenance Persons) (3)
- ☐ Other (4) ____
- ☐ None (5)

---

6) Augmented Reality has shown proven benefits in the private industry such as increasing efficiency for GE Aviation mechanics. Do you believe this technology would increase a sailor's effectiveness?

- ☐ Definitely yes (14)
- ☐ Probably yes (15)
- ☐ Might or might not (16)
- ☐ Probably not (17)
- ☐ Definitely not (18)

---

7) If you answered the previous question with a degree of "yes," how many hours a week would you estimate it would save?

- < 5 hours (1)
- 6 -10 hours (2)
- 10 - 15 hours (3)
- > 15 hours (4)
- Not Applicable (5)

---

8) What type of effect would the added AR capability of virtually tagging equipment, maintenance items, and repairs have on your Current Ship's Maintenance Project (CSMP)?

- Increase the size of the CSMP (1)
- CSMP size would stay the same (2)
- Decrease the size of the CSMP (3)

---

9) Do you think with the addition of AR and its relationship with the CSMP, accountability in making sure these maintenance items are completed would be increased?

- Definitely yes (1)
- Probably yes (2)
- Might or might not (3)
- Probably not (4)
- Definitely not (5)

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10) During your ship's Continuous Maintenance Availabilities (CMAV's) would you expect more or less work to be completed with the assistance of AR? Contracted workers or Navy Regional Maintenance personnel would be able to identify the repair required not solely based on a work order description but with the work order description and supplemental information supplied by the AR technology.

- Much more (1)
- Moderately more (2)
- Slightly more (3)
- About the same (4)
- Slightly less (5)
- Moderately less (6)
- Much less (7)

---

11) Does implementing AR technology give you any reason for concern? If so, please explain

- Definitely yes (1)
- Probably yes (2)
- Might or might not (3)
- Probably not (4)
- Definitely not (5)

If yes, please explain (not required): (6)

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