USE OF A GERMICIDAL ULTRAVIOLET (UVC) LIGHT ON POROUS AND NON-POROUS TEXTILES TO REDUCE *STAPHYLOCOCCUS AUREUS* AND *ESCHERICHIA COLI* CONTAMINATION IN EMERGENCY MEDICAL SERVICE (EMS) VEHICLES

by

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As members of the Master's Committee, we certify that we have read the thesis prepared by: Veronica Lugo
titled: Use of a germicidal ultraviolet (UVC) light on porous and non-porous textiles to reduce *Staphylococcus aureus* and *Escherichia coli* contamination in emergency medical service (EMS) vehicles
and recommend that it be accepted as fulfilling the thesis requirement for the Master's Degree.

Kelly A Reynolds — Date: Aug 18, 2021

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Final approval and acceptance of this thesis is contingent upon the candidate's submission of the final copies of the thesis to the Graduate College.

I hereby certify that I have read this thesis prepared under my direction and recommend that it be accepted as fulfilling the Master's requirement.

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I want to acknowledge that all this work was conducted during the COVID-19 pandemic.

Dedication

Quiero dedicar esta tesis a mis padres, Pedro y Bertha Lugo. Gracias por apoyarme y darme la fuerza para completar este viaje. Fueron muchos sacrificios para llegar hasta aquí. Si no fuera por los dos, no estaría aquí. ¡Esto es para ustedes! Los amo.

English translation: I want to dedicate this thesis to my parents, Pedro, and Bertha Lugo. Thank you for supporting me and giving me the strength to complete this journey. It took many sacrifices to get me here. If it weren't for you both, I would not be here. This is for you! I love you.

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Abstract

Introduction: Pathogens rapidly spread throughout small, enclosed areas such as emergency medical service (EMS) vehicles; posing a higher infection risk for paramedics and increasing hospital-acquired infections (HAIs) among patients. New technology has been under development utilizing ultraviolet C (UVC) light on medical equipment for disinfection proposes. *Aim:* Evaluate a UVC light microbial log reduction efficacy using porous and non-porous textiles commonly found in EMS vehicles.

Methods: Six 5.08x5.08 cm textiles (stainless steel, cloth, vinyl, seatbelt, textured plastic, and acrylic materials) were inoculated with tryptic soy broth containing either vegetative *Staphylococcus aureus* or *Escherichia coli* and dried for 30 minutes. Each textile was positioned at a 45° angle facing the UVC light. The aim of the study was to evaluate time (30 seconds, 5 minutes, 10 minutes) and distance (12.7 cm, 50.0 cm, 100 cm) for UVC light disinfection efficacy on the six textile materials commonly found on EMS vehicles. Baseline samples were not exposed to UVC light for this study. Porous textiles were collected using digestive method and non-porous textiles were collected using swabbing method. Two separate one-way ANOVA with Bonferroni Correction tests were utilized to compare the significance of duration and distance on log reduction for both microorganisms to identify which duration and distance combinations had more efficacy on log reduction. A two-way ANOVA test was performed to analyze the significant difference of varying duration (30 seconds, 5 minutes, and 10 minutes) and distance (12.7 cm, 50.0 cm, and 100 cm) among the 5 varying textiles. A paired t-test was used to compare the mean log reductions among textile types to determine which textile material had larger log reductions.

Results: The greatest log reductions were at 12.7 cm (0.9-6.1) and 50.0 cm (0.7-5.6) distance. At time intervals of 5 and 10 minutes there was no significant log reduction (*p-value= 1.00*) for all textile types. Greater log reductions were seen within the acrylic (*S. aureus*: 1.4-4.5; *E. coli*: 1.1-5.6) and stainless-steel (*S. aureus*: 2.0-4.5; *E. coli*: 1.5-5.2) textile materials compared to the other non-porous textiles. When comparing acrylic and stainless steel textiles, they had similar log reductions (*p-value*: *S. aureus* = 0.39; *E. coli* = 0.63) for both microorganisms. Porous textile log reduction varied based on the textile material. Cloth (100% cotton; *S. aureus*: 0.8-6.1; *E. coli*: 1.1-5.8) had higher log reduction compared to seatbelt (polyester; *S. aureus*: 0.9-2.3; *E. coli*: 0.6-2.6) within the porous textiles.

Discussion and Conclusions: This research demonstrates that UVC light's impact on bacteria is affected by time, distance, and textile material. Shorter distances and time can significantly reduce bacterial log reductions. UVC light systems can be utilized to supplement traditional disinfection methods to minimize infection risk within EMS personnel and patients during the emergency call ride. More research should be conducted on the effects of UVC light exposure on porous textiles to capture the properties that contribute to greater log reduction and their role on causing infection risk on EMS personnel and patients in real-world use scenarios.

Introduction

Surface Decontamination

Human pathogen transmission relies on the behavior of healthcare professionals during check-ups and their hand hygiene compliance (Teter et al., 2015; Vikke et al., 2019; Bitely et al., 2019). In emergency departments, pathogens related to hospital-acquired infections (HAIs) have been found on surfaces rarely disinfected such as computer, keyboards, telephones, oxygen cylinders, door handle, patient compartment floor and door keypads (Su et al., 2020; Gibson, 2019). Pathogens are constantly being spread around in contained areas including medical facilities in the form of fomites. Fomites can be described as inanimate objects or materials that can transmit disease (Owen & Laird, 2020). When surfaces become contaminated by a pathogen, people can touch those surfaces and exercise hand-to-face contacts producing potential infection. Pathogen spread has been observed throughout a healthcare facility within only 4 hours of surface contamination (Sexton et al., 2018). Various studies have focused on the efficacy of disinfection methods and products on fomites to reduce microbial infection risk among healthcare providers (Lopez et al., 2014; Sassi et al., 2018; Bedrosian et al., 2021). A commonly used disinfection product within healthcare facilities are disinfectant wipes for counter tops or non-porous surfaces. Lopez et al. (2014) observed a log reduction of 3.5 to 4.0 for *E. coli* 15597 and a log reduction of 4.4 to 5.0 for *S. aureus* 25923. Other than disinfectant wipes, healthcare facilities have transitioned toward using other methods to improve fomite disinfection. Bedrosian et al. (2021) discovered that ultraviolet light, ethanol, hydrogen peroxide, and hypochlorite obtained a 99.9% log reduction with SARS-CoV-2 on surfaces. Sassi et al. (2018) tested four hospital grade disinfectants (chlorine bleach, hydrogen peroxide, quaternary ammonium, and

peracetic acid) where quaternary ammonium and peracetic acid had the greatest log reductions 2.22 and 3.43, respectively. In EMS vehicles, observed disinfectant products have been alcohol-based disinfectants, commercial disinfectant, and soap water combination (Goodman & Cone, 2001). Disinfection methods are constantly changing as technology and new products evolve.

Emergency Medical Service Vehicles Pathogen Contamination

First responders are in high-risk environments within the EMS vehicles because of proximity to infected patients in enclosed spaces; increasing pathogen transmission risks. Modes of transmission that could lead to high exposure to various pathogens from patient contact that can spread through fomites (surface contamination), airborne or droplet form (5-10 micrometer), coughing or sneezing, or direct contact (talking or direct person-to-person contact) depending on the patients viral shedding (Parini, 2003; Alidjinou et al., 2018; Yee et al., 2020; Li, Q et al., 2020). Within EMS personnel, it has been observed that 77% of providers have heavy bacterial loads on their hands after patient care with only 34% of providers performing hand hygiene (Teter et al., 2014). Additionally, 56.9% of EMS providers arrived wearing gloves to the scene and reusable equipment was disinfected 31.6% of opportunities (Bledsoe et al., 2014). In previous studies, microorganisms such as *Klebsiella* spp*., Escherichia coli, Citrobacter* spp*.,* and *Proteus* have been detected on surfaces within EMS vehicles (El-Mokhtar et al., 2018). Additionally, Methicillin-resistant *Staphylococcus aureus* (MRSA) has been one of the most concerning microorganisms to be prevalent within EMS vehicles and hospital surfaces (El-Mokhtar et al., 2018; Valdez et al., 2015; Liang et al., 2014; Alves et al., 2008). Currently, the novel SARS-CoV-2 (causative agent of COVID-19) has posed a major threat to the health of first responders and health care workers. A previous outbreak of SARS-CoV-1, resulted in a 0.6% incidence rate of infections to EMS personnel per patient transport (Ko et al., 2004).

Valdez et al. (2015) demonstrated viral spread to 56% (27/48) of surfaces within an EMS vehicle through a viral tracer study. High contact surfaces within EMS vehicles have tested positive for pathogen presence such as a flow meter knob, bench seat, communication radio microphone, driver's door, and cabinet base (Alves et al., 2008).

EMS Acquired Infections and EMS Personnel

EMS vehicles serve as the bridge between patients and healthcare facilities, and it is important to acknowledge the role of proper disinfection methods to prevent patients from contracting a hospital-acquired infections (HAIs) in this environment. For trauma related incidents, EMS vehicles are the primary mode of transportation for patients to reach medical attention. Within emergency medical providers, in the 2011 NFPA Injury Report there were 11,000 exposures to communicable diseases estimating to 1 exposure for every 1,500 EMS runs (International Association of Fire Fighters, 2021). With the ongoing SARS-CoV-2 pandemic, a study using a risk assessment model indicated that fomites within EMS vehicles contributed to 12% of infections when both first responders and patients did not wear masks or personal protective equipment (Wilson et al., 2021). Studies have demonstrated that 4.6% of EMS personnel and 22.5% of firefighters were colonized by MRSA (Stevenson, 2020; Roberts et al., 2011). In a previous study, MRSA had been found in the classroom space and within the couch of the fire department (10.6%) (Sexton & Reynolds, 2010). This study demonstrates how pathogens are not only a problem within the EMS vehicle, but EMS personnel can carry these pathogens out into the rest of the fire station exposing personnel not carrying for patients. With proper disinfection methods, surfaces in healthcare facilities and EMS vehicles can have a decrease of pathogen spread and less HAIs. There is limited data on EMS providers and occupational risk and outbreaks during emergency calls.

Functions of UVC light on bacteria

UV radiation contains wavelengths that range from 100 to 400 nm these electromagnetic irradiations can be split into four spectral light categories which include: Vacuum UV (100 – 200 nm); UVC (200 – 280 nm); UVB (280 – 315 nm) and UVA (315 – 400 nm) (*Figure* 1.) (Yin et al., 2013). Wavelengths greater than 400 nm can be visible to the human eye. UVC light is also referenced as a UVC germicidal light for the ability to cause damage to various microorganisms when exposed. UVC light has a wavelength of 200 to 280 nm, and it is not visible to the human eye. Many studies have indicated that UVC causes inactivation of MRSA and *E. coli* at 254 to 264 nm wavelength (Yin et al., 2013; Lindblad et al., 2020; Lindsley et al., 2017; Yang et al., 2017).

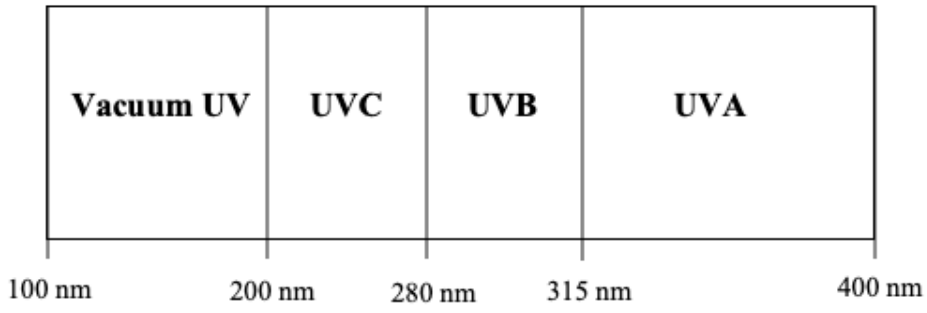


Figure 1. UV light irradiation spectrum for wavelength between 100 through 400 nanometers.

This wavelength is concerned to be a short wavelength compared to the other light wavelengths in the spectrum. At this short wavelength, UVC light can penetrate microorganisms causing damage to the cell membranes and DNA and RNA which interferes with cell replication (Lindblad et al., 2020). Studies have shifted into looking on the efficacy of UVC light technology as a passive, no touch system to assist in disinfection protocols within health care facilities (Yang et al., 2019; Mitchell et al., 2018; Lindblad et al., 2020; Katara et al., 2008; Byrns et al., 2017). UVC light positioning and duration of UVC light exposure have been the

two primary factors of interest. Multiple studies evaluating UVC light positioning (distance from textiles of interest) have resulted in shorter distances having the most optimal log reductions and for textiles to receive the highest dosage from the UVC light system (Lindblad et al., 2020; Yang et al., 2019; Byrns et al., 2017; Mitchell et al., 2018). Duration of UVC light exposure has also been a factor of interest for determining the efficacy of UVC lights as a passive disinfection method. Studies have discovered that exposing textiles for longer periods of time would result in the most optimal log reductions (Yang et al., 2019; Katara et al., 2008; Byrns et al., 2018). There have been many concerns about UVC light exposure on human skin and eyes and this topic will be further explored in the discussion portion of this paper. Chemical disinfectants have been the primary method for fighting pathogens in health care facilities, but this has led to exposures of various mixtures of substances that could be harmful to healthcare providers. It has been reported that up to 75% of products contain irritants, 64% are harmful, and 28% are corrosive (Gerster et al., 2014). Common routes of exposure from using chemical disinfectants are inhalation and dermal (Bello et al., 2009). Standard disinfection practices with combined utilization of UVC light technology can maximize surface disinfection and potentially reduce infection risk within healthcare providers, healthcare facilities and EMS vehicles.

Aims and Objectives of the Study

The aims of the study were to determine the antimicrobial efficacy of UVC light on two different bacteria (*Staphylococcus aureus* and *Escherichia coli*). These two bacteria were utilized to evaluate $\log_{10}$ reduction efficacy on textiles that are commonly found in EMS vehicles. The objectives of the study were to determine the antimicrobial efficacy regarding the duration and distance of the UVC light exposure among six different textiles.

Methods

Selection of Textile Type

Textile types were selected based on their commonality within emergency medical vehicles or in automotive vehicles. Six 5.08x5.08 cm textile material types were selected for the laboratory experiments which included stainless steel (Home Depot, Atlanta, GA), acrylic (Home Depot, Atlanta, GA), vinyl (Joann, Tucson, AZ), 100% cotton cloth (Joann, Tucson, AZ), seatbelt (obtained from a car), and textured plastic. Stainless steel simulated the counter tops inside the patient box and acrylic simulated medical equipment. Vinyl simulated stretcher material and the textured plastic simulated a dashboard. Cloth simulated linen or EMS personnel clothing.

Bacterial Inoculum Preparation

Staphylococcus aureus (ATCC 43300) and *Escherichia coli* (ATCC 25922) were obtained from the American Type Culture Collection (ATCC; Manassas, VA). These microorganisms were selected as proxies of human-pathogenic Gram-positive and Gram-negative bacteria. Tryptic soy broth (TSB; Criterion, Hardy Diagnostics, Santa Maria, CA) was inoculated with a culture of either of *S. aureus* or *E. coli* and left on the New Brunswick Scientific Excella E24 Incubator Shaker Series Model: Excella E24 (Edison, NJ) for an overnight growth. Tryptic soy agar (TSA; Difco, Becton, Dickinson and Company, Sparks, MD) was autoclaved and 15 - 20 mL were poured into periti dishes. TSA media was used for plate spreading for bacterial growth.

Non-porous Material Type Preparation

Non-porous material type textiles were disinfected with 70% ethanol solution, dried and then placed in a biosafety cabinet with a UVC light for 10 minutes. This disinfection process was conducted before and after each laboratory experiment.

Porous Material Type Preparation

Cloth textiles were autoclaved prior to usage. Cloth textile was only used once per experiment trial. For the seatbelt textile, 95% ethanol solution was used to soak the textile and then it was washed with detergent, dried, and then placed in a biosafety cabinet with a UVC light for 10 minutes.

Laboratory Experiments

All material type textiles were inoculated with 10, 10 µl drops of microbial suspension containing either vegetative *Staphylococcus aureus* or *Escherichia coli.* Each textile was dried for approximately 30 minutes after inoculation. 5.08x5.08 cm textiles were positioned at a 45° angle facing towards the UVC light. A 10-minute warmup of the UVC light was conducted before every laboratory experiment. A total of 162 textile samples were seeded, 81 were considered as baseline (no UVC light exposure) and 81 were intervention (exposed to UVC light). Initial surface swab and digestion samples were taken prior to UVC light exposure from the 5.08x5.08 cm textiles as a positive control (baseline = no UVC light exposure). The UVC light was positioned in three varying distances from the inoculated surfaces, 12.7, 50 and 100 centimeters (*Figure 2*). Duration (30 seconds, 5 minutes, and 10 minutes) of UVC light exposure was also explored for efficacy of the light. For porous textiles, wet swabs (3M, St. Paul, MN) containing 1 mL of Letheen Broth were used to collect samples from the surface of the textiles. For non-porous samples, a digestion method was performed with 5 mL of Phosphate Buffered

Saline (PBS) added to a Whirl-PAK baggie containing the seeded porous textile and then manually agitated to obtain the supernate. All samples were diluted using PBS and then spread plated onto TSA (Lopez et al., 2014). Plated samples were incubated overnight at 37°C. After incubation, plates were counted for bacterial growth. A digital ultraviolet radiometer (Solar Light Company, Inc, Glenside, PA) model 8.0 UVC with a range of 0 – 1999 $\mu W/cm^2$ and UV spectral response of 246 – 262 nm was used to capture the light density of the UVC light during each laboratory experiment.

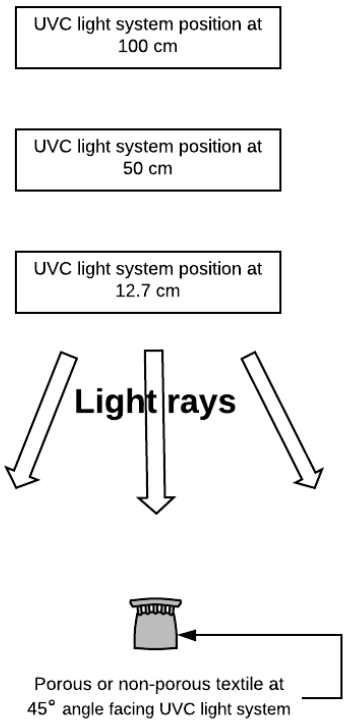


Figure 2. Positioning of the UVC light system for laboratory experiments.

Statistical analysis

Three internal and external experiments were conducted during the sampling period. Mean averages were calculated from the three internal and external experiments. Baseline samples were averaged within their internal experiments and then an external average was

calculated. Additionally, porous textile samples were multiplied by their final volume of supernate. Log reductions were calculated from the $\log_{10}$ of mean baseline (no UVC light exposure) and mean intervention (UVC light exposure) (*see equation 1*). (Note: Samples that could not be plate counted were excluded from the n=81). Only samples that did not contain water growth were counted as part of the analysis. A two-way ANOVA test was performed to analyze the significance difference on log reduction with combination of both duration and distance of the UVC light system among the six varying textiles. Two separate one-way ANOVA were utilized to compare the significance difference of duration and distance on log reduction for both microorganisms and to identify which duration and distance combinations were more efficient on log reduction. Additionally, two one-way ANOVA with Bonferroni Correction tests were explored to obtain the piece-wise combination comparisons. A paired t-test (time and distance factors were paired) was used to compare the log reduction among textile types. All statistical tests were evaluated at a p-value of <0.05 for significance level. All STATA code and output can be found in appendix A. All statistical analysis was conducted in STATA version 16 (StataCorp, College Station, TX).

$$(1)\ Log\ Reduction = log_{10}\left(Baseline\ Concentration / Intervention\ Concentration\right)$$

Results

For this study, both *S. aureus* and *E. coli* were sampled after a period of 30 seconds, 5 minutes, and 10 minutes light exposure with three different light positioning distances at 12.7, 50 and 100 cm. The mean log reductions for these laboratory experiments vary by organism type, UVC duration, and UVC distance (**Table 1**). Mean log reductions for both *S. aureus* and *E. coli*

ranged from 0.9-6.1 and 0.6-5.8, respectably. For the distance factor of 12.7, 50, and 100 cm, mean log reductions ranged from 0.9-6.1, 0.7-5.6 and 0.6-3.7, respectably. For the non-porous textile material type, stainless steel (*S. aureus*: 2.0-4.5; *E. coli*: 1.5-5.2) and acrylic (*S. aureus*: 1.4-5.4; *E. coli*: 1.1-5.6) had greater log reductions compared to the other non-porous textiles. For the porous textile material type, cloth (*S. aureus*: 0.8-6.1; *E. coli*: 1.1-5.8) had greater log reductions compared to seatbelt (*S. aureus*: 0.9-2.3; *E. coli*: 0.6-2.6). Tables for each microorganism can be found in appendix B & C. The experimentally measured minimum and maximum light densities were 878 μW/ cm^2 and 1856 μW/ cm^2, respectively. The UVC light density ranged from an average of 1182.4 μW/ cm^2 (±211) to 1304.1 μW/ cm^2 (±254) throughout the time intervals (**Table 2**).

Table 1. Laboratory experiments mean log reduction with standard deviation for both *S. aureus* and *E. coli.*

Organism Textile	*S. aureus* Stainless Steel	*S. aureus* Cloth	*S. aureus* Acrylic	*S. aureus* Vinyl	*S. aureus* Seatbelt	*S. aureus* Textured Plastic	*E. coli* Stainless Steel	*E. coli* Cloth	*E. coli* Acrylic	*E. coli* Vinyl	*E. coli* Seatbelt	*E. coli* Textured Plastic
	n=81	n=81	n=79	n=78	n=77	n=81	n=81	n=81	n=78	n=78	n=80	n=81
Distance (Time) 12.7 cm												
30 sec.	4.0 (±0.7)	4.8 (±0.6)	4.3 (±1.0)	3.5 (±1.3)	1.8 (±0.5)	3.1 (±0.6)	4.3 (±0.3)	5.6 (±0.5)	4.2 (±0.8)	3.4 (±1.0)	1.6 (±0.7)	2.7 (±0.4)
5 min.	4.3 (±1.3)	6.0 (±0.1)	5.3 (±0.8)	4.5 (±0.4)	1.6 (±0.7)	3.3 (±0.6)	5.1 (±0.9)	5.8 (±0.4)	5.4 (±0.7)	4.7 (±0.8)	0.9 (±0.9)	3.2 (±0.2)
10 min.	4.5 (±1.1)	6.1 (±0.3)	5.4 (±1.1)	4.4 (±0.8)	2.3 (±0.6)	4.6 (±0.9)	5.2 (±0.5)	5.8 (±0.2)	5.6 (±1.1)	5.3 (±1.0)	1.3 (±0.7)	4.1 (±1.1)
50.0 cm												
30 sec.	2.0 (±0.3)	2.8 (±0.6)	2.9 (±0.5)	2.3 (±0.4)	1.8 (±1.1)	2.6 (±0.6)	3.4 (±0.9)	4.5 (±0.2)	3.8 (±1.3)	2.8 (±0.7)	0.7 (±0.5)	2.3 (±0.2)
5 min.	4.6 (±1.2)	4.7 (±0.9)	4.6 (±0.5)	3.6 (±0.5)	2.1 (±0.4)	2.9 (±0.5)	5.0 (±0.8)	5.1 (±0.6)	5.1 (±1.2)	3.6 (±0.8)	2.6 (±0.6)	2.8 (±0.3)
10 min.	4.3 (±0.9)	4.7 (±0.8)	4.7 (±1.0)	3.7 (±0.5)	2.0 (±0.9)	4.1 (±0.8)	4.7 (±0.6)	5.6 (±0.4)	5.0 (±0.8)	4.0 (±0.6)	2.3 (±1.3)	4.1 (±0.7)
100 cm												
30 sec.	2.0 (±0.4)	0.8 (±0.5)	1.4 (±0.5)	1.4 (±0.3)	1.1 (±0.6)	1.9 (±0.3)	1.5 (±0.4)	1.1 (±0.7)	1.1 (±0.4)	1.2 (±0.3)	1.2 (±0.5)	2.7 (±0.6)
5 min.	2.7 (±0.4)	2.3 (±1.2)	2.3 (±0.6)	2.1 (±0.4)	0.9 (±0.5)	2.2 (±0.1)	2.6 (±0.2)	2.1 (±1.1)	2.5 (±0.2)	1.7 (±0.3)	0.6 (±0.4)	3.0 (±0.2)
10 min.	3.2 (±0.7)	2.3 (±0.9)	2.5 (±0.6)	2.5 (±0.3)	1.2 (±0.5)	3.0 (±0.6)	3.1 (±0.5)	2.1 (±0.7)	2.7 (±0.3)	1.8 (±0.5)	1.1 (±0.3)	3.7 (±0.9)

Table 2. Average and standard deviation of light density for each duration period n=18.

30 seconds	1182.4 μW/ cm^2 (±252.1)
5 minutes	1247.5 μW/ cm^2 (±291.7)
10 minutes	1304.1 μW/ cm^2 (±330.4)

Trends from the overall data: 12.7 cm had a larger log reduction compared to 50 cm and 100 cm for both *S. aureus* and *E. coli* (*Figure. 3 and 4*). 50 cm compared with 100 cm had a larger log reduction; as the distance increases, there is less light density reaching the surface area of the 5.08x5.08 cm textiles resulting in lower log reduction in the microorganisms. Yet, as the distance of the light position increases, the UVC light can cover more surface area that extends past the 5.08x5.08 cm textiles allowing for more UVC light exposure on other surfaces that surround the 5.08x5.08 cm textiles. From Figures 3 and 4, there is an upward trend as the function of time increases during every UVC light cycle run. The figures provide differences within each textile type.

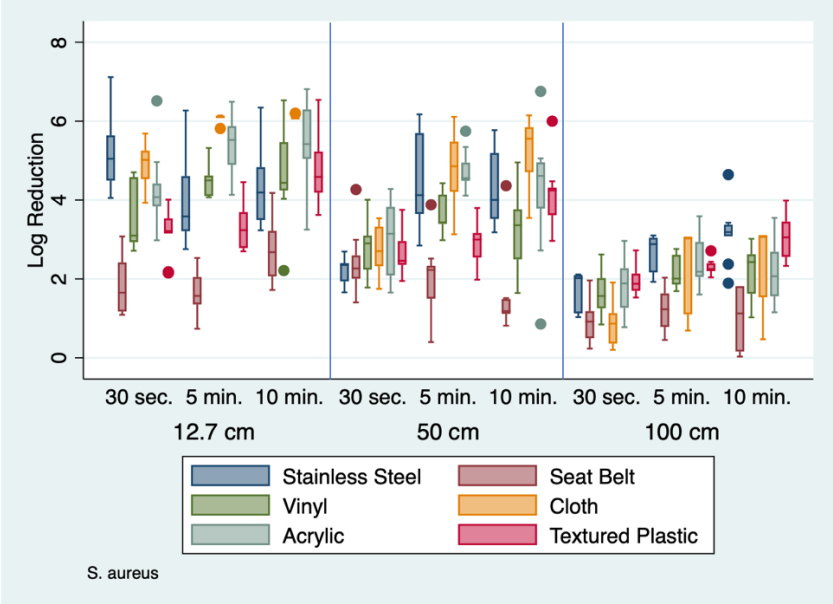


Figure 3. Box plots displaying six textile types of *S. aureus* log reduction over the function of time and distance. (Note: whiskers of box plots are lower and upper adjacent values from the box. The box represents 25th and 75th percentiles from log reductions. The middle line represents the median from the log reductions with dots representing outside values from our data.)

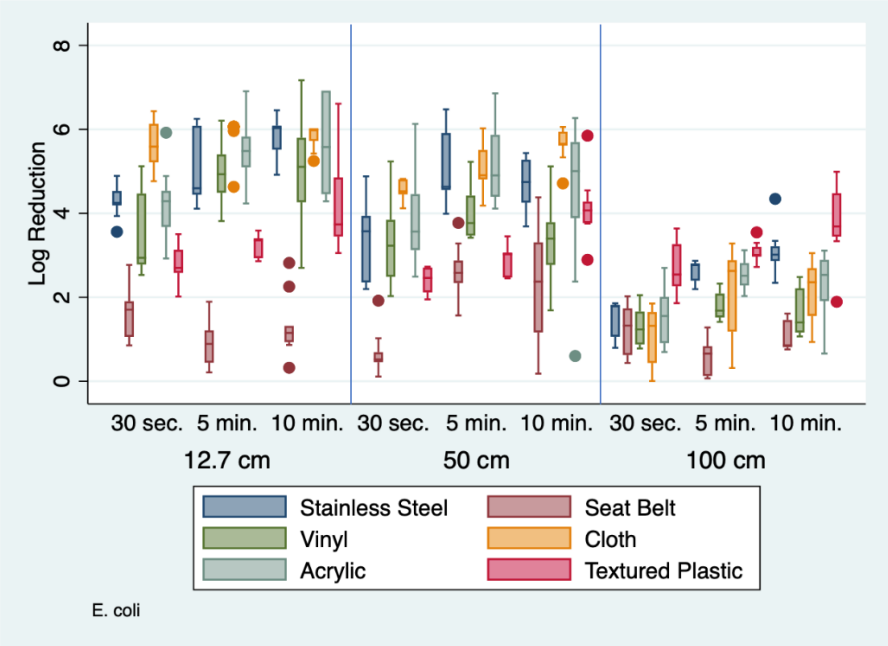


Figure 4. Box plots displaying six textile types of *E. coli* log reduction over the function of time and distance. (Note: whiskers of box plots are lower and upper adjacent values from the box. The box represents 25th and 75th percentiles from log reductions. The middle line represents the median from the log reductions with dots representing outside values from our data.)

Duration of UVC light exposure has an impact on the log reduction of both *S. aureus* and *E. coli* (*Figures 3 & 4*). A two-way ANOVA test was conducted to test the combined significant difference between distance and time of the UVC light and the log reductions of both *S. aureus* and *E. coli*. For both *S. aureus* and *E. coli* bacteria, time and distance factors were significantly different in log reduction were among stainless steel, vinyl, cloth, and acrylic (*p-value= <0.01*) (**Table 3**). Seatbelt did have significant difference in log reduction for light distance positioning for both microorganisms (p-value= <0.01) but did not have significant difference in the duration of light exposure for *S. aureus* (*p-value= 0.72*) and *E. coli* (*p-value= 0.29*) (**Table 3**). Consequently, textured plastic did not have a significant difference in log reduction for distance (*p-value = 0.30*) but did have a significant difference in duration of UVC light exposure.

Table 3. Results of two-way ANOVA test on porous and non-porous surfaces.

	Staphylococcus aureus			*Escherichia coli*		
	Model *p-value*	Distance *p-value*	Time *p-value*	Model *p-value*	Distance *p-value*	Time *p-value*
Stainless Steel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vinyl	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cloth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acrylic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Seatbelt	<0.01	<0.01	0.72*	<0.01	<0.01	0.29*
Textured Plastic	<0.01	<0.01	<0.01	<0.01	0.30*	<0.01

*Significance level above p-value of 0.05.

For the duration of light exposure, both 5 and 10 minutes had minimal to no difference in log reduction (**Table 1**). This created a maximum reduction threshold for light exposure on each of the textile types. A one-way ANOVA with Bonferroni Correction test was utilized to compare the significance between time intervals during UVC light exposure for both microorganisms. The Bonferroni Correction test provides piece wise comparisons of the factor of interest (for this

study time and distance). The results from the one-way ANOVA can be found in appendix D & E. For *S. aureus*, the time interval combination for 30 seconds and 5 minutes that have a significant difference in log reduction were among vinyl, cloth, and acrylic textiles (*p-value= <0.01*); textiles with no significant difference in log reduction were among stainless steel (*p-value= 0.16*), textured plastic (*p-value = 0.79*), and seatbelt (*p-value= 1.00*) (**Table 4**). The time interval combination between 30 seconds and 10 minutes that have a significant difference in log reduction were among stainless steel, vinyl, cloth, textured plastic, and acrylic textiles (*p-value= <0.01*); the only textile with no significant difference in log reduction was the seatbelt textile (*p-value= 1.00*). For *E. coli,* the time interval combination for thirty seconds and five minutes that have a significant difference in log reduction were among stainless steel, vinyl (*p-value= 0.02*), textured plastic (*p-value = 0.04*) and acrylic textiles (*p-value= <0.01*); textiles with no significant difference in log reduction were cloth (*p-value= 0.67*) and seatbelt (*p-value= 1.00*). The time interval combination between thirty seconds and ten minutes that have a significant difference in log reduction were among stainless steel, vinyl, textured plastic, and acrylic (*p-value= <0.01*); textiles with no significant difference in log reduction were cloth (*p-value= 0.67*) and seatbelt (*p-value= 0.44*) (**Table 4**). For both *S. aureus* and *E. coli*, the combination between five and ten minutes there was no significant difference within those two-time intervals and for porous and non-porous textile types (*p-value=1.00*) except for textured plastic (*p-value = <0.01*) (**Table 4**).

Table 4. Results of one-way ANOVA with Bonferroni Correction test comparing time intervals between six textile types.

Organism	*Staphylococcus aureus*		*Escherichia coli*	
Textile	30 sec. *p-value*	5 min. *p-value*	30 sec. *p-value*	5 min. *p-value*
Stainless Steel				
5 min.	0.16*		<0.01	
10 min.	0.05	1.00*	<0.01	1.00*
Vinyl				
5 min.	<0.01		0.02	
10 min.	<0.01	1.00*	0.01	1.00*
Cloth				
5 min.	<0.01		0.67*	
10 min.	<0.01	1.00*	0.38*	1.00*
Acrylic				
5 min.	0.01		0.01	
10 min.	<0.01	1.00*	<0.01	1.00*
Seatbelt				
5 min.	1.00*		1.00*	
10 min.	1.00*	1.00*	0.44*	1.00*
Textured Plastic				
5 min.	0.79*		0.04	
10 min.	<0.01	<0.01	<0.01	<0.01

*Significance level above p-value of 0.05.

Additionally, a one-way ANOVA with Bonferroni Correction test was conducted to compare the significant difference within distance combinations for each of the textile types. For *S. aureus*, all distance combinations were significantly different for stainless steel, vinyl, cloth, and acrylic textiles (*p-value= <0.01*) (**Table 5**). The textiles with no significant difference with the distance combination of 12.7 and 50 cm was seatbelt (*p-value= 0.65*) and textured plastic (*p-value = 0.11*) containing *S. aureus* as the microorganism of interest. For *E. coli*, all distance combinations were significantly different for stainless steel, vinyl, and cloth (*p-value= <0.01*). Acrylic (*p-value= 0.34*) and textured plastic (*p-value = 0.84*) had no significant difference for distance combination of 12.7 and 50 cm and between 50 and 100 cm (*p-value= 100*). Seatbelt (*p-*

value= 0.60) and textured plastic (*p-value= 1.00*) had no significant difference for distance combination of 12.7 and 100 cm (**Table 5**).

Table 5. Results of one-way ANOVA with Bonferroni Correction test comparing distance between six textile types.

Organism	*Staphylococcus aureus*		*Escherichia coli*	
Textile	12.7 cm *p-value*	50 cm *p-value*	12.7 cm *p-value*	50 cm *p-value*
Stainless Steel				
50 cm	0.03		0.02	
100 cm	<0.01	<0.01	<0.01	<0.01
Vinyl				
50 cm	<0.01		<0.01	
100 cm	<0.01	<0.01	<0.01	<0.01
Cloth				
50 cm	<0.01		<0.01	
100 cm	<0.01	<0.01	<0.01	<0.01
Acrylic				
50 cm	<0.01		0.34*	
100 cm	<0.01	<0.01	<0.01	1.00*
Seatbelt				
50 cm	0.65*		0.05	
100 cm	<0.01	<0.01	0.60*	<0.01
Textured Plastic				
50 cm	0.11*		0.84*	
100 cm	<0.01	<0.01	1.00*	1.00*

*Significance level above p-value of 0.05.

A paired t-test was used to compare the log reduction between each of the six textiles to one another to determine which textile material is most effective to use within EMS vehicles. For conducting this analysis, we paired both time and distance for each textile comparison. Textiles that did not have a significant difference in log reduction for *S. aureus,* was between stainless steel and acrylic (*p-value= 0.39*), vinyl and textured plastic (*p-value= 0.93*), and acrylic and cloth comparison (*p-value= 0.11*) (**Table 6**). These textile materials were similar in log reduction for *S. aureus* microorganism. All other surfaces were significantly different in log reduction in comparison of each other for S. aureus (*p-value= <0.01*). For E. coli, the only textiles that were not significantly different were between stainless steel and acrylic (*p-value= 0.63*), vinyl and

textured plastic (*p-value = 0.93*) materials. All other combinations of textile materials (vinyl, cloth, and seatbelt) were significantly different in log reduction (*p-value= <0.01*) (**Table 7**).

Table 6. *S. aureus* matrix table from paired t-test comparison of bacterial kill rate with other textile types.

	Stainless Steel *p-value*	Vinyl *p-value*	Cloth *p-value*	Acrylic *p-value*	Seatbelt *p-value*	Textured plastic *p-value*
Stainless Steel		<0.01	0.04	0.39*	<0.01	<0.01
Vinyl	<0.01		<0.01	<0.01	<0.01	0.93*
Cloth	0.04	<0.01		0.11*	<0.01	<0.01
Acrylic	0.39*	<0.01	0.11*		<0.01	<0.01
Seatbelt	<0.01	<0.01	<0.01	<0.01		<0.01
Textured Plastic	<0.01	0.93*	<0.01	<0.01	<0.01	

*Significance level above p-value of 0.05.

Table 7. *E. coli* matrix table from paired t-test comparison of bacterial kill rate with other textile types.

	Stainless Steel *p-value*	Vinyl *p-value*	Cloth *p-value*	Acrylic *p-value*	Seatbelt *p-value*	Textured plastic *p-value*
Stainless Steel		<0.01	0.04	0.63*	<0.01	<0.01
Vinyl	<0.01		<0.01	<0.01	<0.01	0.93*
Cloth	0.04	<0.01		0.04	<0.01	<0.01
Acrylic	0.63*	<0.01	0.04		<0.01	<0.01
Seatbelt	<0.01	<0.01	<0.01	<0.01		<0.01
Textured Plastic	<0.01	0.93*	<0.01	<0.01	<0.01	

*Significance level above p-value of 0.05.

Discussion

The present study demonstrates that UVC light used during controlled experimentation results in significant log reductions of vegetative *S. aureus* and *E. coli* bacteria and is likely to also be effective against human pathogenic strains including methicillin- resistant *Staphylococcus aureus* (MRSA) and *Escherichia coli* O157:H7 (Wallace et al., 2019; Murashita

et al., 2017; Yin et al., 2013). Increasing time and duration of light exposure influenced the effectiveness of the UVC light on reduction of bacteria on a certain surface. In our study, from the 30 second time interval, log reductions increased after UVC light exposure. There was a maximum reduction threshold reached when comparing combinations between five minutes and ten minutes. This has been observed in other studies using UVC light as a disinfection intervention (Byrns et al., 2017; Katara et al., 2008) a suggestion that has been discussed is to increase the time of exposure to increase the log reduction over decreasing the distance of the light positioning and the textile. From our study, the seatbelt textile did not have a significant difference in log reduction as a function of time which could be due to the thickness of the material that seatbelts are composed of. Compared to the one layer 100% cotton cloth, the seatbelt is made up of thicker material that bacteria can bind to preventing direct light penetration (Montanaro & Arciola, 2000). Regarding the distance positioning of the UVC light, all three distances (12.7, 50 and 100 cm) had a significant difference in log reduction meaning that bacterial inactivation will occur at any of those distances. Textured plastic was the only textile with no significant difference in log reduction as a function of distance which could be due to the larger ridges from the material type (Weir et al., 2016). Yet, 12.7 and 50 cm had larger log reductions compared to 100 cm but increasing the light duration could supplement for being further from the light. Textiles within the same material type category had similar log reductions when compared to each other. Comparison between textile material types, both acrylic and stainless steel did not have a significant difference among *S. aureus* (p-value= 0.39) and *E. coli* (p-value= 0.63). Similarly, vinyl and the textured plastic did not have a significant difference for both microorganism types (*p-value = 0.93*). In future studies, using either stainless steel or acrylic for non-porous textiles and using either vinyl or textured plastic for textured non-porous

textiles material types would be sufficient to capture the efficacy of the UVC light systems. For porous textiles, cloth and seatbelt had significant differences in log reduction meaning that for future studies both cloth and seatbelt should be used for further investigation. All other materials used in this study had varying properties that affected the UVC light efficacy. Vinyl and textured plastic did not have a smooth non-porous surface, it contained ridges that during the swabbing procedure could not pick up bacteria within those ridges. The cloth was a thin one-layer cotton material that could allow for efficient light penetration compared to the seatbelt material.

Benefits of UVC Light Usage

UVC light technology is vastly growing within the healthcare field. There is a need to optimize the time of the disinfection process and its effectiveness. Benefits to using UVC lights within EMS vehicles are:

1. Additional surface disinfection to surfaces already chemically disinfected (Memarzadeh et al., 2010).
2. Disinfection among porous textiles that are not commonly disinfected (i.e., seatbelt)
3. Fomite infection reduction among EMS personnel and patients.

Limitations of UVC Light Usage

Some of the limitations of UVC usage within EMS vehicles are:

1. Surfaces must be in the line of sight of the UVC light for exposure (Buchaklin et al., 2017).
2. Object overlap may not receive UVC light exposure C (Lindsley et al., 2017; Buchaklin et al., 2017).
3. Potential of degradation of medical equipment exposed to the UVC light particles see appendix F (Yousif & Haddad, 2013).

4. EMS personnel exposure to UVC light rays (Trevisan et al., 2006).
5. Adverse health effects (i.e., sunburns and eye irritations) (Fuller, 2020; Trevisan et al., 2006).

Recommendation for EMS Personal & Patient Protection of UVC Light Exposure

From our study, time factor increased from the 30 seconds time interval to the 5 and 10 minutes. Since a maximum reduction threshold was observed between 5 and 10 minutes, it would be recommended to use the UVC light for 5-minute exposure for significant log reduction. For the distance factor, proximity to the UVC increases the dose to the textiles. Placing the UVC light at 12.7 or 50 cm would result in significant log reductions. More research needs to be explored on the UVC light duration and distance for minimum and maximum for microorganism log reduction on various textiles. Additionally, more information is needed on the light positioning within an EMS vehicle to better optimize the variables of UVC light system positioning and microbial inactivation rates.

The American Conference of Governmental Industrial Hygienists has released threshold limit values (TLV) on the maximum exposure times allowed for workers to be exposed to various irradiance at 254 nm wavelength. The TLVs are as follows: 8hours – 0.2 μW/ cm^2; 4hours – 0.4 μW/ cm^2; 2hours – 0.8 μW/ cm^2; 1hour – 1.7 μW/ cm^2; 0.5hours – 3.3 μW/ cm^2; 0.25 – 6.7 μW/ cm^2 (Fuller, 2020). EMS personnel exposed to UVC light should be provided with personal protective equipment (PPE) (i.e., eyewear, hats, and sunscreen lotion) to limit their exposure (Fuller, 2020). Biotechnology Industries should create UVC light technology considering the TLV and limit the workers exposure. UVC lights should contain motion sensor technology to prevent EMS personnel and patients from the harmful UVC light irradiance. Additionally, EMS personnel should undergo training to learn about the usage of UVC light

disinfection and potential health outcomes. Fire departments should initiate proper protocols and install warning signs for when the UVC light is in use.

Conclusion

UVC light technology utilized in emergency medical service vehicles can aid in the reduction of pathogenic microbes and improve on standard disinfection protocols. Passive disinfection methods can decrease the incidence of human pathogenic microorganisms by 35% if combined with standard disinfection procedures (Anderson et al., 2018; Poster et al., 2018). UVC light technology should be used in adjunct with standard disinfectants to minimize both occupational and patient exposure. UVC light systems are capable of disinfecting non-porous and porous surfaces. Having passive, no touch technology can reduce pathogen spread among frequently touched surfaces that do not constantly undergo disinfection. Future studies should use this data to conduct studies on quantitative risk reductions accounting for the UVC light efficacy.

Appendices

Appendix A: STATA code and output

```
*############## two way anova with time = differences in time #################
. anova change_St_S distance_St_S time_St_S - Stainless steel staph

                          Number of obs =         81    R-squared     =  0.4139
                          Root MSE      =    1.08912    Adj R-squared =  0.3831

                 Source | Partial SS         df         MS        F    Prob>F
            ------------+----------------------------------------------------
                  Model |  63.665463          4   15.916366     13.42  0.0000
                        |
            distanc~t_S |  51.856108          2   25.928054     21.86  0.0000
              time_St_S |  11.809355          2   5.9046774      4.98  0.0093
                        |
               Residual |  90.149778         76   1.1861813
            ------------+----------------------------------------------------
                  Total |  153.81524         80   1.9226905

.
. anova change_St_E distance_St_E time_St_E- Stainless steel e.coli

                          Number of obs =         81    R-squared     =  0.7955
                          Root MSE      =    .680058    Adj R-squared =  0.7848

                 Source | Partial SS         df         MS        F    Prob>F
            ------------+----------------------------------------------------
                  Model |  136.75433          4   34.188584     73.92  0.0000
                        |
            distanc~t_E |  104.13131          2   52.065656    112.58  0.0000
              time_St_E |  32.623022          2   16.311511     35.27  0.0000
                        |
               Residual |  35.148442         76    .4624795
            ------------+----------------------------------------------------
                  Total |  171.90278         80   2.1487847

.
. anova change_Cs_S distance_Cs_S time_Cs_S- vinyl staph

                          Number of obs =         79    R-squared     =  0.7984
                          Root MSE      =    .562224    Adj R-squared =  0.7875

                 Source | Partial SS         df         MS        F    Prob>F
            ------------+----------------------------------------------------
                  Model |  92.626948          4   23.156737     73.26  0.0000
                        |
            distanc~s_S |  68.058331          2   34.029166    107.65  0.0000
              time_Cs_S |  25.048502          2   12.524251     39.62  0.0000
                        |
               Residual |  23.391132         74   .31609638
            ------------+----------------------------------------------------
                  Total |  116.01808         78   1.4874113

.
```

```
. anova change_Cs_E distance_Cs_E time_Cs_E - vinyl e.coli

                          Number of obs =         79    R-squared     =  0.7571
                          Root MSE      =    .770587    Adj R-squared =  0.7440

                 Source | Partial SS         df         MS        F     Prob>F
            ------------+----------------------------------------------------
                  Model |  136.99252          4   34.248129     57.68  0.0000
                        |
            distanc~s_E |  115.07699          2   57.538494     96.90  0.0000
              time_Cs_E |  21.815667          2   10.907833     18.37  0.0000
                        |
               Residual |  43.941486         74   .59380386
            ------------+----------------------------------------------------
                  Total |    180.934         78   2.3196667

.
. anova change_Cl_S distance_Cl_S time_Cl_S - cloth staph

                          Number of obs =         81    R-squared     =  0.8534
                          Root MSE      =    .758155    Adj R-squared =  0.8456

                 Source | Partial SS         df         MS        F     Prob>F
            ------------+----------------------------------------------------
                  Model |  254.21575          4   63.553938    110.57  0.0000
                        |
            distanc~l_S |  203.19208          2   101.59604    176.75  0.0000
              time_Cl_S |  51.023675          2   25.511837     44.38  0.0000
                        |
               Residual |  43.684684         76   .57479848
            ------------+----------------------------------------------------
                  Total |  297.90044         80   3.7237555

.
. anova change_Cl_E distance_Cl_E time_Cl_E- cloth e.coli

                          Number of obs =         81    R-squared     =  0.8874
                          Root MSE      =    .649888    Adj R-squared =  0.8815

                 Source | Partial SS         df         MS        F     Prob>F
            ------------+----------------------------------------------------
                  Model |   252.9976          4   63.249399    149.75  0.0000
                        |
            distanc~l_E |  243.72126          2   121.86063    288.53  0.0000
              time_Cl_E |  9.2763393          2   4.6381697     10.98  0.0001
                        |
               Residual |   32.09894         76   .42235447
            ------------+----------------------------------------------------
                  Total |  285.09654         80   3.5637067

.
. anova change_Ar_S distance_Ar_S time_Ar_S - acrylic staph

                          Number of obs =         80    R-squared     =  0.7354
                          Root MSE      =     .84643    Adj R-squared =  0.7213

                 Source | Partial SS         df         MS        F     Prob>F
            ------------+----------------------------------------------------
                  Model |  149.32635          4   37.331586     52.11  0.0000
                        |
            distanc~r_S |   119.4425          2   59.721251     83.36  0.0000
              time_Ar_S |   30.17491          2   15.087455     21.06  0.0000
                        |
```

```
    Residual |  53.733298         75   .71644398
-------------+------------------------------------------------------
       Total |  203.05964         79   2.5703752

.
. anova change_Ar_E distance_Ar_E time_Ar_E- acrylic e.coli

                          Number of obs =         79    R-squared     =  0.7465
                          Root MSE      =    .886294    Adj R-squared =  0.7328

       Source | Partial SS         df         MS        F    Prob>F
-------------+----------------------------------------------------
        Model |  171.15832          4   42.789579     54.47  0.0000
              |
  distanc~r_E |  138.34711          2   69.173557     88.06  0.0000
    time_Ar_E |  31.834906          2   15.917453     20.26  0.0000
              |
     Residual |  58.128257         74   .78551698
-------------+----------------------------------------------------
        Total |  229.28657         78   2.9395714

.
. anova change_Sb_S distance_Sb_S time_Sb_S - seat belt staph

                          Number of obs =         78    R-squared     =  0.3032
                          Root MSE      =    .814116    Adj R-squared =  0.2650

       Source | Partial SS         df         MS        F    Prob>F
-------------+----------------------------------------------------
        Model |  21.051593          4   5.2628983      7.94  0.0000
              |
  distanc~b_S |  20.603989          2   10.301994     15.54  0.0000
    time_Sb_S |   .4331115          2   .21655575      0.33  0.7223
              |
     Residual |  48.383307         73   .66278503
-------------+----------------------------------------------------
        Total |    69.4349         77   .90175195

.
. anova change_Sb_E distance_Sb_E time_Sb_E- seat belt e.coli

                          Number of obs =         81    R-squared     =  0.1827
                          Root MSE      =    .885595    Adj R-squared =  0.1397

       Source | Partial SS         df         MS        F    Prob>F
-------------+----------------------------------------------------
        Model |  13.323093          4   3.3307733      4.25  0.0037
              |
  distanc~b_E |   11.37881          2   5.6894052      7.25  0.0013
    time_Sb_E |   1.944283          2    .9721415      1.24  0.2953
              |
     Residual |  59.605183         76   .78427872
-------------+----------------------------------------------------
        Total |  72.928276         80   .91160346

   . anova change_Da_S distance_St_S time_St_S - textured plastic staph

                             Number of obs =         81    R-squared     =  0.6326
                             Root MSE      =    .626891    Adj R-squared =  0.6133

          Source | Partial SS         df         MS        F    Prob>F
-----------------+----------------------------------------------------
           Model |   51.42437          4   12.856093     32.71  0.0000
```

```
                    |
distanc~t_S |  22.897383          2   11.448691     29.13  0.0000
  time_St_S |  28.526987          2   14.263494     36.29  0.0000
            |
   Residual |  29.867416         76   .39299231
------------+-----------------------------------------------------
      Total |  81.291786         80   1.0161473
```

```
. anova change_Da_E distance_Da_E time_Da_E - textured plastic e.coli

                          Number of obs =         81    R-squared     =  0.4808
                          Root MSE      =    .641261    Adj R-squared =  0.4535

                     Source | Partial SS         df         MS        F    Prob>F
------------+-----------------------------------------------------
                      Model |  28.946357          4   7.2365892     17.60  0.0000
                            |
                distanc~a_E |  .99488884          2   .49744442      1.21  0.3040
                  time_Da_E |  27.951468          2   13.975734     33.99  0.0000
                            |
                   Residual |  31.252357         76   .41121523
------------+-----------------------------------------------------
                      Total |  60.198714         80   .75248392
```

```
. *############## One way anova with time = differences in time #################
. *#one-way anova with bonnferroni Stainless steel staph
. oneway change_St_S time_St_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      11.8093548      2   5.90467741      3.24     0.0444
 Within groups      142.005886     78   1.82058828
------------------------------------------------------------------------
    Total           153.815241     80   1.92269051

Bartlett's test for equal variances:  chi2(2) =   5.6339  Prob>chi2 = 0.060

                    Comparison of change_St_S by time_St_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .714262
         |      0.166
         |
       3 |    .880053    .165791
         |      0.057      1.000

.
. *#one-way anova with bonnferroni Stainless steel e.coli
. oneway change_St_E time_St_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      32.6230219      2    16.311511      9.13     0.0003
 Within groups      139.279754     78   1.78563788
------------------------------------------------------------------------
    Total           171.902776     80    2.1487847

Bartlett's test for equal variances:  chi2(2) =   0.1521  Prob>chi2 = 0.927
```

```
                Comparison of change_St_E by time_St_E
                             (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.19874
         |      0.004
         |
       3 |    1.45649    .257749
         |      0.000      1.000


. *#one-way anova with bonnferroni vinyl (cushion) staph
. oneway change_Cs_S time_Cs_S, bonferroni

                      Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      24.5686168      2   12.2843084     10.21     0.0001
 Within groups      91.4494638     76   1.20328242
------------------------------------------------------------------------
    Total           116.018081     78   1.48741129

Bartlett's test for equal variances:  chi2(2) =   0.1861  Prob>chi2 = 0.911

                Comparison of change_Cs_S by time_Cs_S
                             (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.07271
         |      0.002
         |
       3 |    1.25748    .184774
         |      0.000      1.000


. *#one-way anova with bonnferroni vinyl (cushion) e.coli
. oneway change_Cs_E time_Cs_E, bonferroni

                      Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      21.9155299      2    10.957765      5.24     0.0074
 Within groups      159.018473     76   2.09234833
------------------------------------------------------------------------
    Total           180.934003     78    2.3196667

Bartlett's test for equal variances:  chi2(2) =   1.9748  Prob>chi2 = 0.373

                Comparison of change_Cs_E by time_Cs_E
                             (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.10654
         |      0.020
         |
       3 |    1.11435    .007806
         |      0.019      1.000


.
```

```
. *#one-way anova with bonnferroni cloth staph
. oneway change_Cl_S time_Cl_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      51.0236749      2   25.5118375      8.06     0.0007
 Within groups      246.876761     78   3.16508668
------------------------------------------------------------------------
    Total           297.900436     80   3.72375545

Bartlett's test for equal variances:  chi2(2) =   0.0035  Prob>chi2 = 0.998

                   Comparison of change_Cl_S by time_Cl_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.58962
         |      0.005
         |
       3 |    1.76408    .174455
         |      0.001      1.000

.
. *#one-way anova with bonnferroni cloth e.coli
. oneway change_Cl_E time_Cl_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      9.27633931      2   4.63816965      1.31     0.2753
 Within groups      275.820198     78   3.53615639
------------------------------------------------------------------------
    Total           285.096537     80   3.56370672

Bartlett's test for equal variances:  chi2(2) =   0.4612  Prob>chi2 = 0.794

                   Comparison of change_Cl_E by time_Cl_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .624749
         |      0.678
         |
       3 |    .784199    .159451
         |      0.389      1.000

.
. *#one-way anova with bonnferroni acrylic staph
. oneway change_Ar_S time_Ar_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      29.8838437      2   14.9419218      6.64     0.0022
 Within groups        173.1758     77   2.24903636
------------------------------------------------------------------------
    Total           203.059644     79   2.57037524

Bartlett's test for equal variances:  chi2(2) =   0.0967  Prob>chi2 = 0.953
```

```
                  Comparison of change_Ar_S by time_Ar_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.23645
         |      0.011
         |
       3 |    1.34046    .104008
         |      0.005      1.000


. 
. *#one-way anova with bonnferroni acrylic e.coli
. oneway change_Ar_E time_Ar_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      32.8112021      2    16.405601      6.35     0.0028
 Within groups       196.47537     76   2.58520224
------------------------------------------------------------------------
    Total           229.286572     78   2.93957144

Bartlett's test for equal variances:  chi2(2) =   0.2625  Prob>chi2 = 0.877

                  Comparison of change_Ar_E by time_Ar_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    1.32935
         |      0.012
         |
       3 |    1.38441    .055065
         |      0.007      1.000


. 
. *#one-way anova with bonnferroni seat belt staph
. oneway change_Sb_S time_Sb_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .447604421      2   .223802211      0.24     0.7846
 Within groups      68.9872956     75   .919830609
------------------------------------------------------------------------
    Total           69.4349001     77   .901751949

Bartlett's test for equal variances:  chi2(2) =   1.2032  Prob>chi2 = 0.548

                  Comparison of change_Sb_S by time_Sb_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    -.05977
         |      1.000
         |
       3 |    .119299    .179068
         |      1.000      1.000


. 
. *#one-way anova with bonnferroni seat belt e.coli
```

```
. oneway change_Sb_E time_Sb_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups        1.944283      2   .972141502      1.07     0.3486
 Within groups      70.9839934     78   .910051198
------------------------------------------------------------------------
    Total           72.9282764     80   .911603455

Bartlett's test for equal variances:  chi2(2) =   5.0513  Prob>chi2 = 0.080

                   Comparison of change_Sb_E by time_Sb_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .207753
         |      1.000
         |
       3 |    .378912     .17116
         |      0.445      1.000

. . oneway change_Da_S time_Da_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      28.5269873      2   14.2634936     21.09     0.0000
 Within groups      52.7647985     78   .676471775
------------------------------------------------------------------------
    Total           81.2917857     80   1.01614732

Bartlett's test for equal variances:  chi2(2) =   5.8485  Prob>chi2 = 0.054

                   Comparison of change_Da_S by time_Da_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .252016
         |      0.791
         |
       3 |    1.36585    1.11383
         |      0.000      0.000



. oneway change_Da_E time_Da_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      27.9514679      2    13.975734     33.80     0.0000
 Within groups       32.247246     78   .413426231
------------------------------------------------------------------------
    Total           60.1987139     80   .752483924

Bartlett's test for equal variances:  chi2(2) =  27.8156  Prob>chi2 = 0.000

                   Comparison of change_Da_E by time_Da_E
                                (Bonferroni)
Row Mean-|
```

```
Col Mean |          1          2
---------+----------------------
       2 |    .441623
         |      0.041
         |
       3 |    1.40681    .965184
         |      0.000      0.000


. oneway change_Da_S time_Da_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      28.5269873      2   14.2634936     21.09     0.0000
 Within groups      52.7647985     78   .676471775
------------------------------------------------------------------------
    Total           81.2917857     80   1.01614732

Bartlett's test for equal variances:  chi2(2) =   5.8485  Prob>chi2 = 0.054

                    Comparison of change_Da_S by time_Da_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .252016
         |      0.791
         |
       3 |    1.36585    1.11383
         |      0.000      0.000
. oneway change_Da_E time_Da_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      27.9514679      2    13.975734     33.80     0.0000
 Within groups       32.247246     78   .413426231
------------------------------------------------------------------------
    Total           60.1987139     80   .752483924

Bartlett's test for equal variances:  chi2(2) =  27.8156  Prob>chi2 = 0.000

                    Comparison of change_Da_E by time_Da_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .441623
         |      0.041
         |
       3 |    1.40681    .965184
         |      0.000      0.000

.
. *############## One way anova with distance = diffences in distance ###########
. *#one-way anova with bonnferroni Stainless steel staph
. oneway change_St_S distance_St_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      51.8561078      2   25.9280539     19.84     0.0000
```

```
 Within groups      101.959133     78   1.30716837
------------------------------------------------------------------------------
    Total           153.815241     80   1.92269051

Bartlett's test for equal variances:  chi2(2) =   6.6762  Prob>chi2 = 0.036

                  Comparison of change_St_S by distance_St_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.799519
         |      0.036
         |
       3 |   -1.94943   -1.14991
         |      0.000      0.001


.
. *#one-way anova with bonnferroni Stainless steel e.coli
. oneway change_St_E distance_St_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      104.131313      2   52.0656563     59.92     0.0000
 Within groups      67.7714637     78   .868864919
------------------------------------------------------------------------
    Total           171.902776     80    2.1487847

Bartlett's test for equal variances:  chi2(2) =   2.1719  Prob>chi2 = 0.338

                 Comparison of change_St_E by distance_St_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.689488
         |      0.024
         |
       3 |   -2.67466   -1.98518
         |      0.000      0.000


.
. *#one-way anova with bonnferroni vinyl (cushion) staph
. oneway change_Cs_S distance_Cs_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      67.5784463      2   33.7892231     53.01     0.0000
 Within groups      48.4396343     76   .637363609
------------------------------------------------------------------------
    Total           116.018081     78   1.48741129

Bartlett's test for equal variances:  chi2(2) =   4.6022  Prob>chi2 = 0.100

                 Comparison of change_Cs_S by distance_Cs_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -1.05192
         |      0.000
```

```
          |
        3 |   -2.27772    -1.2258
          |      0.000      0.000

.
. *#one-way anova with bonnferroni vinyl (cushion) e.coli
. oneway change_Cs_E distance_Cs_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      115.176851      2   57.5884253     66.56     0.0000
 Within groups      65.7571522     76   .865225687
------------------------------------------------------------------------
    Total           180.934003     78    2.3196667

Bartlett's test for equal variances:  chi2(2) =  18.2961  Prob>chi2 = 0.000

                Comparison of change_Cs_E by distance_Cs_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.879019
         |      0.003
         |
       3 |   -2.90062    -2.0216
         |      0.000      0.000

.
. *#one-way anova with bonnferroni cloth staph
. oneway change_Cl_S distance_Cl_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      203.192077      2   101.596039     83.67     0.0000
 Within groups      94.7083591     78   1.21420973
------------------------------------------------------------------------
    Total           297.900436     80   3.72375545

Bartlett's test for equal variances:  chi2(2) =  11.0478  Prob>chi2 = 0.004

                Comparison of change_Cl_S by distance_Cl_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -1.44147
         |      0.000
         |
       3 |   -3.84004   -2.39857
         |      0.000      0.000

.
. *#one-way anova with bonnferroni cloth e.coli
. oneway change_Cl_E distance_Cl_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      243.721259      2   121.860629    229.73     0.0000
 Within groups      41.3752788     78   .530452292
```

```
------------------------------------------------------------------------------
    Total           285.096537     80   3.56370672

Bartlett's test for equal variances:  chi2(2) =  13.6639  Prob>chi2 = 0.001

                Comparison of change_Cl_E by distance_Cl_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.661401
         |      0.004
         |
       3 |   -3.96553   -3.30413
         |      0.000      0.000


. 
. *#one-way anova with bonnferroni acrylic staph
. oneway change_Ar_S distance_Ar_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      119.151435      2   59.5757177     54.67     0.0000
 Within groups      83.9082083     77   1.08971699
------------------------------------------------------------------------
    Total           203.059644     79   2.57037524

Bartlett's test for equal variances:  chi2(2) =   4.6130  Prob>chi2 = 0.100

                Comparison of change_Ar_S by distance_Ar_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.894635
         |      0.008
         |
       3 |   -2.90231   -2.00768
         |      0.000      0.000


. 
. *#one-way anova with bonnferroni acrylic e.coli
. oneway change_Ar_E distance_Ar_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      139.323409      2   69.6617047     58.85     0.0000
 Within groups      89.9631628     76   1.18372583
------------------------------------------------------------------------
    Total           229.286572     78   2.93957144

Bartlett's test for equal variances:  chi2(2) =   5.7559  Prob>chi2 = 0.056

                Comparison of change_Ar_E by distance_Ar_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.476042
         |      0.346
         |
```

```
       3 |   -3.02911   -2.55307
         |      0.000      0.000

.
. *#one-way anova with bonnferroni seat belt staph
. oneway change_Sb_S distance_Sb_S, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      20.6184815      2   10.3092408     15.84     0.0000
 Within groups      48.8164185     75    .65088558
------------------------------------------------------------------------
    Total           69.4349001     77   .901751949

Bartlett's test for equal variances:  chi2(2) =  10.5022  Prob>chi2 = 0.005

                Comparison of change_Sb_S by distance_Sb_S
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |     .28005
         |      0.659
         |
       3 |   -.906008   -1.18606
         |      0.000      0.000

.
. *#one-way anova with bonnferroni seat belt e.coli
. oneway change_Sb_E distance_Sb_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      11.3788103      2   5.68940517      7.21     0.0013
 Within groups      61.5494661     78   .789095719
------------------------------------------------------------------------
    Total           72.9282764     80   .911603455

Bartlett's test for equal variances:  chi2(2) =  18.7661  Prob>chi2 = 0.000

                Comparison of change_Sb_E by distance_Sb_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |    .591517
         |      0.050
         |
       3 |   -.312302   -.903818
         |      0.601      0.001

. oneway change_Da_S distance_Da_s, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      22.8973828      2   11.4486914     15.29     0.0000
 Within groups      58.3944029     78   .748646191
------------------------------------------------------------------------
    Total           81.2917857     80   1.01614732
```

```
Bartlett's test for equal variances:  chi2(2) =   5.9082  Prob>chi2 = 0.052

                  Comparison of change_Da_S by distance_Da_s
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.497636
         |      0.113
         |
       3 |    -1.2911   -.793461
         |      0.000      0.004



. oneway change_Da_E distance_Da_E, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .994888844      2   .497444422      0.66     0.5221
 Within groups       59.203825     78   .759023398
------------------------------------------------------------------------
    Total           60.1987139     80   .752483924

Bartlett's test for equal variances:  chi2(2) =   0.8481  Prob>chi2 = 0.654

                  Comparison of change_Da_E by distance_Da_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.257396
         |      0.843
         |
       3 |   -.203412    .053983
         |      1.000      1.000

. oneway change_Da_S distance_Da_s, bonferroni

                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      22.8973828      2   11.4486914     15.29     0.0000
 Within groups      58.3944029     78   .748646191
------------------------------------------------------------------------
    Total           81.2917857     80   1.01614732

Bartlett's test for equal variances:  chi2(2) =   5.9082  Prob>chi2 = 0.052

                  Comparison of change_Da_S by distance_Da_s
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.497636
         |      0.113
         |
       3 |    -1.2911   -.793461
         |      0.000      0.004

. oneway change_Da_E distance_Da_E, bonferroni
```

```
                        Analysis of Variance
    Source              SS         df      MS            F     Prob > F
------------------------------------------------------------------------
Between groups      .994888844      2   .497444422      0.66     0.5221
 Within groups       59.203825     78   .759023398
------------------------------------------------------------------------
    Total           60.1987139     80   .752483924

Bartlett's test for equal variances:  chi2(2) =   0.8481  Prob>chi2 = 0.654

                  Comparison of change_Da_E by distance_Da_E
                                (Bonferroni)
Row Mean-|
Col Mean |          1          2
---------+----------------------
       2 |   -.257396
         |      0.843
         |
       3 |   -.203412    .053983
         |      1.000      1.000


. *####################### Paired t-test = differences in log reduction between t
> extiles ######################
.
. ttest change_St_S==change_Cl_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_S |      81    3.561095    .1540679    1.386611     3.25449      3.8677
chan~l_S |      81    3.911911    .2144115    1.929703    3.485218    4.338603
---------+--------------------------------------------------------------------
    diff |      81   -.3508161    .1749094    1.574185    -.698897   -.0027353
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_S - change_Cl_S)                  t =  -2.0057
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0241         Pr(|T| > |t|) = 0.0483          Pr(T > t) = 0.9759

.
. ttest change_St_S==change_Ar_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_S |      80    3.575921    .1552819    1.388883    3.266841    3.885002
chan~r_S |      80    3.718975    .1792476    1.603239    3.362192    4.075759
---------+--------------------------------------------------------------------
    diff |      80   -.1430538    .1662561     1.48704   -.4739783    .1878707
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_S - change_Ar_S)                  t =  -0.8604
 Ho: mean(diff) = 0                               degrees of freedom =       79

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.1961         Pr(|T| > |t|) = 0.3921          Pr(T > t) = 0.8039

.
. ttest change_St_S==change_Cs_S
```

```
Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_S |      79    3.608135     .153839    1.367351    3.301865    3.914404
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
---------+--------------------------------------------------------------------
    diff |      79    .4388379    .1487088    1.321753    .1427814    .7348944
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_S - change_Cs_S)                 t =   2.9510
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9979         Pr(|T| > |t|) = 0.0042          Pr(T > t) = 0.0021

.
. ttest change_St_S==change_Sb_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_S |      78    3.599447    .1577645    1.393338    3.285298    3.913596
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
---------+--------------------------------------------------------------------
    diff |      78     1.87063    .1589087    1.403444    1.554202    2.187057
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_S - change_Sb_S)                 t =  11.7717
 Ho: mean(diff) = 0                               degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Cl_S==change_Sb_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_S |      78    3.943595      .22192    1.959944    3.501695    4.385494
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
---------+--------------------------------------------------------------------
    diff |      78    2.214777    .2109022    1.862638    1.794817    2.634737
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_S - change_Sb_S)                 t =  10.5014
 Ho: mean(diff) = 0                               degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Cl_S==change_St_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_S |      81    3.911911    .2144115    1.929703    3.485218    4.338603
chan~t_S |      81    3.561095    .1540679    1.386611     3.25449      3.8677
---------+--------------------------------------------------------------------
    diff |      81    .3508161    .1749094    1.574185    .0027353     .698897
------------------------------------------------------------------------------
```

```
     mean(diff) = mean(change_Cl_S - change_St_S)                 t =   2.0057
 Ho: mean(diff) = 0                                 degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9759         Pr(|T| > |t|) = 0.0483          Pr(T > t) = 0.0241

.
. ttest change_Cl_S==change_Ar_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_S |      80    3.922208    .2168581    1.939638    3.490563    4.353853
chan~r_S |      80    3.718975    .1792476    1.603239    3.362192    4.075759
---------+--------------------------------------------------------------------
    diff |      80    .2032329    .1269754    1.135703   -.0495053    .4559712
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_S - change_Ar_S)                 t =   1.6006
 Ho: mean(diff) = 0                                 degrees of freedom =       79

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9433         Pr(|T| > |t|) = 0.1135          Pr(T > t) = 0.0567

.
. ttest change_Cl_S==change_Cs_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_S |      79    3.964432    .2154175    1.914673    3.535568    4.393295
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
---------+--------------------------------------------------------------------
    diff |      79    .7951351    .1575539    1.400369    .4814694    1.108801
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_S - change_Cs_S)                 t =   5.0468
 Ho: mean(diff) = 0                                 degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Sb_S==change_Cl_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
chan~l_S |      78    3.943595      .22192    1.959944    3.501695    4.385494
---------+--------------------------------------------------------------------
    diff |      78   -2.214777    .2109022    1.862638   -2.634737   -1.794817
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_S - change_Cl_S)                 t = -10.5014
 Ho: mean(diff) = 0                                 degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Sb_S==change_St_S
```

```
Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
chan~t_S |      78    3.599447    .1577645    1.393338    3.285298    3.913596
---------+--------------------------------------------------------------------
    diff |      78    -1.87063    .1589087    1.403444   -2.187057   -1.554202
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_S - change_St_S)                 t = -11.7717
 Ho: mean(diff) = 0                               degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Sb_S==change_Ar_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
chan~r_S |      78    3.732025    .1835297    1.620891     3.36657    4.097479
---------+--------------------------------------------------------------------
    diff |      78   -2.003207    .1686954    1.489877   -2.339122   -1.667292
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_S - change_Ar_S)                 t = -11.8747
 Ho: mean(diff) = 0                               degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Sb_S==change_Cs_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_S |      77    1.725818    .1088849    .9554612    1.508955    1.942681
chan~s_S |      77     3.19153    .1397799    1.226564    2.913134    3.469926
---------+--------------------------------------------------------------------
    diff |      77   -1.465712    .1414251    1.241001   -1.747384   -1.184039
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_S - change_Cs_S)                 t = -10.3639
 Ho: mean(diff) = 0                               degrees of freedom =       76

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Ar_S==change_Cl_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_S |      80    3.718975    .1792476    1.603239    3.362192    4.075759
chan~l_S |      80    3.922208    .2168581    1.939638    3.490563    4.353853
---------+--------------------------------------------------------------------
    diff |      80   -.2032329    .1269754    1.135703   -.4559712    .0495053
------------------------------------------------------------------------------
```

```
     mean(diff) = mean(change_Ar_S - change_Cl_S)                 t =  -1.6006
 Ho: mean(diff) = 0                                degrees of freedom =       79

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0567         Pr(|T| > |t|) = 0.1135          Pr(T > t) = 0.9433

.
. ttest change_Ar_S==change_St_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_S |      80    3.718975    .1792476    1.603239    3.362192    4.075759
chan~t_S |      80    3.575921    .1552819    1.388883    3.266841    3.885002
---------+--------------------------------------------------------------------
    diff |      80    .1430538    .1662561     1.48704   -.1878707    .4739783
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_S - change_St_S)                 t =   0.8604
 Ho: mean(diff) = 0                                degrees of freedom =       79

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.8039         Pr(|T| > |t|) = 0.3921          Pr(T > t) = 0.1961

.
. ttest change_Ar_S==change_Sb_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_S |      78    3.732025    .1835297    1.620891     3.36657    4.097479
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
---------+--------------------------------------------------------------------
    diff |      78    2.003207    .1686954    1.489877    1.667292    2.339122
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_S - change_Sb_S)                 t =  11.8747
 Ho: mean(diff) = 0                                degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Ar_S==change_Cs_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_S |      79    3.728523    .1812733    1.611193    3.367636    4.089411
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
---------+--------------------------------------------------------------------
    diff |      79    .5592268    .1388271    1.233922    .2828432    .8356103
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_S - change_Cs_S)                 t =   4.0282
 Ho: mean(diff) = 0                                degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9999         Pr(|T| > |t|) = 0.0001          Pr(T > t) = 0.0001

.
. ttest change_Cs_S==change_Cl_S
```

```
Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
chan~l_S |      79    3.964432    .2154175    1.914673    3.535568    4.393295
---------+--------------------------------------------------------------------
    diff |      79   -.7951351    .1575539    1.400369   -1.108801   -.4814694
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_S - change_Cl_S)                  t =  -5.0468
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Cs_S==change_St_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
chan~t_S |      79    3.608135     .153839    1.367351    3.301865    3.914404
---------+--------------------------------------------------------------------
    diff |      79   -.4388379    .1487088    1.321753   -.7348944   -.1427814
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_S - change_St_S)                  t =  -2.9510
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0021         Pr(|T| > |t|) = 0.0042          Pr(T > t) = 0.9979

.
. ttest change_Cs_S==change_Sb_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_S |      77     3.19153    .1397799    1.226564    2.913134    3.469926
chan~b_S |      77    1.725818    .1088849    .9554612    1.508955    1.942681
---------+--------------------------------------------------------------------
    diff |      77    1.465712    .1414251    1.241001    1.184039    1.747384
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_S - change_Sb_S)                  t =  10.3639
 Ho: mean(diff) = 0                               degrees of freedom =       76

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. *#### e.coli ######
.
. ttest change_St_E==change_Cl_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_E |      81    3.962925    .1628748    1.465873    3.638794    4.287057
chan~l_E |      81    4.229988    .2097531    1.887778    3.812566     4.64741
---------+--------------------------------------------------------------------
```

```
    diff |      81   -.2670624    .1324455     1.19201   -.5306374   -.0034874
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_E - change_Cl_E)                 t =  -2.0164
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0236         Pr(|T| > |t|) = 0.0471          Pr(T > t) = 0.9764

.
. ttest change_St_E==change_Ar_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_E |      79    4.020143    .1614427    1.434934    3.698736    4.341551
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
---------+--------------------------------------------------------------------
    diff |      79    .0650685    .1362403     1.21093    -.206165    .3363021
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_E - change_Ar_E)                 t =   0.4776
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.6829         Pr(|T| > |t|) = 0.6343          Pr(T > t) = 0.3171

.
. ttest change_St_E==change_Cs_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_E |      79    4.020143    .1614427    1.434934    3.698736    4.341551
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
---------+--------------------------------------------------------------------
    diff |      79    .7680994    .1172004      1.0417    .5347713    1.001428
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_E - change_Cs_E)                 t =   6.5537
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_St_E==change_Sb_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~t_E |      81    3.962925    .1628748    1.465873    3.638794    4.287057
chan~b_E |      81     1.37776    .1060866    .9547793    1.166641    1.588879
---------+--------------------------------------------------------------------
    diff |      81    2.585166     .168429    1.515861    2.249981     2.92035
------------------------------------------------------------------------------
     mean(diff) = mean(change_St_E - change_Sb_E)                 t =  15.3487
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
```

```
. ttest change_Cl_E==change_Sb_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_E |      81    4.229988    .2097531    1.887778    3.812566     4.64741
chan~b_E |      81     1.37776    .1060866    .9547793    1.166641    1.588879
---------+--------------------------------------------------------------------
    diff |      81    2.852228    .2038134    1.834321    2.446626     3.25783
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_E - change_Sb_E)                  t =  13.9943
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Cl_E==change_St_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_E |      81    4.229988    .2097531    1.887778    3.812566     4.64741
chan~t_E |      81    3.962925    .1628748    1.465873    3.638794    4.287057
---------+--------------------------------------------------------------------
    diff |      81    .2670624    .1324455     1.19201    .0034874    .5306374
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_E - change_St_E)                  t =   2.0164
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9764         Pr(|T| > |t|) = 0.0471          Pr(T > t) = 0.0236

.
. ttest change_Cl_E==change_Ar_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_E |      79    4.282344    .2111552    1.876788    3.861966    4.702721
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
---------+--------------------------------------------------------------------
    diff |      79    .3272691    .1596839    1.419301    .0093629    .6451753
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_E - change_Ar_E)                  t =   2.0495
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9781         Pr(|T| > |t|) = 0.0438          Pr(T > t) = 0.0219

.
. ttest change_Cl_E==change_Cs_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~l_E |      79    4.282344    .2111552    1.876788    3.861966    4.702721
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
---------+--------------------------------------------------------------------
```

```
    diff |      79      1.0303    .1445359    1.284663    .7425512    1.318049
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cl_E - change_Cs_E)                 t =   7.1283
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
.
. ttest change_Sb_E==change_Cl_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_E |      81     1.37776    .1060866    .9547793    1.166641    1.588879
chan~l_E |      81    4.229988    .2097531    1.887778    3.812566     4.64741
---------+--------------------------------------------------------------------
    diff |      81   -2.852228    .2038134    1.834321    -3.25783   -2.446626
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_E - change_Cl_E)                 t = -13.9943
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Sb_E==change_St_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_E |      81     1.37776    .1060866    .9547793    1.166641    1.588879
chan~t_E |      81    3.962925    .1628748    1.465873    3.638794    4.287057
---------+--------------------------------------------------------------------
    diff |      81   -2.585166     .168429    1.515861    -2.92035   -2.249981
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_E - change_St_E)                 t = -15.3487
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Sb_E==change_Ar_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_E |      79    1.374074    .1087455    .9665509    1.157579     1.59057
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
---------+--------------------------------------------------------------------
    diff |      79      -2.581    .1986046    1.765236   -2.976392   -2.185609
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_E - change_Ar_E)                 t = -12.9957
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

```
.
. ttest change_Sb_E==change_Cs_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~b_E |      79    1.374074    .1087455    .9665509    1.157579     1.59057
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
---------+--------------------------------------------------------------------
    diff |      79   -1.877969    .1785941    1.587379   -2.233523   -1.522416
------------------------------------------------------------------------------
     mean(diff) = mean(change_Sb_E - change_Cs_E)                  t = -10.5153
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
.
. ttest change_Ar_E==change_Cl_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
chan~l_E |      79    4.282344    .2111552    1.876788    3.861966    4.702721
---------+--------------------------------------------------------------------
    diff |      79   -.3272691    .1596839    1.419301   -.6451753   -.0093629
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_E - change_Cl_E)                  t =  -2.0495
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0219         Pr(|T| > |t|) = 0.0438          Pr(T > t) = 0.9781

.
. ttest change_Ar_E==change_St_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
chan~t_E |      79    4.020143    .1614427    1.434934    3.698736    4.341551
---------+--------------------------------------------------------------------
    diff |      79   -.0650685    .1362403     1.21093   -.3363021     .206165
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_E - change_St_E)                  t =  -0.4776
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.3171         Pr(|T| > |t|) = 0.6343          Pr(T > t) = 0.6829

.
. ttest change_Ar_E==change_Sb_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
```

```
chan~b_E |      79    1.374074    .1087455    .9665509    1.157579     1.59057
---------+--------------------------------------------------------------------
    diff |      79       2.581    .1986046    1.765236    2.185609    2.976392
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_E - change_Sb_E)                 t =  12.9957
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Ar_E==change_Cs_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
---------+--------------------------------------------------------------------
    diff |      79    .7030309    .1497665    1.331154    .4048686    1.001193
------------------------------------------------------------------------------
     mean(diff) = mean(change_Ar_E - change_Cs_E)                 t =   4.6942
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Cs_E==change_Cl_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
chan~l_E |      79    4.282344    .2111552    1.876788    3.861966    4.702721
---------+--------------------------------------------------------------------
    diff |      79     -1.0303    .1445359    1.284663   -1.318049   -.7425512
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_E - change_Cl_E)                 t =  -7.1283
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

.
. ttest change_Cs_E==change_St_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
chan~t_E |      79    4.020143    .1614427    1.434934    3.698736    4.341551
---------+--------------------------------------------------------------------
    diff |      79   -.7680994    .1172004      1.0417   -1.001428   -.5347713
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_E - change_St_E)                 t =  -6.5537
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

```
.
. ttest change_Cs_E==change_Sb_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
chan~b_E |      79    1.374074    .1087455    .9665509    1.157579     1.59057
---------+--------------------------------------------------------------------
    diff |      79    1.877969    .1785941    1.587379    1.522416    2.233523
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_E - change_Sb_E)                t =  10.5153
 Ho: mean(diff) = 0                             degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

.
. ttest change_Cs_E==change_Ar_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
---------+--------------------------------------------------------------------
    diff |      79   -.7030309    .1497665    1.331154   -1.001193   -.4048686
------------------------------------------------------------------------------
     mean(diff) = mean(change_Cs_E - change_Ar_E)                t =  -4.6942
 Ho: mean(diff) = 0                             degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000


. ttest change_Da_S==change_Cl_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_S |      81    3.153048    .1120046    1.008041    2.930151    3.375944
chan~l_S |      81    3.911911    .2144115    1.929703    3.485218    4.338603
---------+--------------------------------------------------------------------
    diff |      81   -.7588634    .1725818    1.553236   -1.102312   -.4154147
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_S - change_Cl_S)                t =  -4.3971
 Ho: mean(diff) = 0                             degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest change_Da_S==change_Ar_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_S |      80    3.159118    .1132468     1.01291    2.933706     3.38453
chan~r_S |      80    3.718975    .1792476    1.603239    3.362192    4.075759
```

```
---------+--------------------------------------------------------------------
    diff |      80   -.5598573    .1623402    1.452015   -.8829874   -.2367271
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_S - change_Ar_S)                 t =  -3.4487
 Ho: mean(diff) = 0                               degrees of freedom =       79

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0005         Pr(|T| > |t|) = 0.0009          Pr(T > t) = 0.9995

. ttest change_Da_S==change_St_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_S |      81    3.153048    .1120046    1.008041    2.930151    3.375944
chan~t_S |      81    3.561095    .1540679    1.386611     3.25449      3.8677
---------+--------------------------------------------------------------------
    diff |      81   -.4080473    .1400419    1.260377   -.6867396   -.1293549
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_S - change_St_S)                 t =  -2.9138
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0023         Pr(|T| > |t|) = 0.0046          Pr(T > t) = 0.9977

. ttest change_Da_S==change_Sb_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_S |      78    3.177408    .1153995    1.019181    2.947618    3.407198
chan~b_S |      78    1.728818    .1075217    .9496062    1.514715    1.942921
---------+--------------------------------------------------------------------
    diff |      78     1.44859    .1272497    1.123839    1.195204    1.701977
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_S - change_Sb_S)                 t =  11.3838
 Ho: mean(diff) = 0                               degrees of freedom =       77

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

. ttest change_Da_S==change_Cs_S

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_S |      79    3.179742    .1127715    1.002335    2.955231    3.404253
chan~s_S |      79    3.169297    .1372151    1.219595    2.896122    3.442471
---------+--------------------------------------------------------------------
    diff |      79    .0104455    .1340874    1.191795    -.256502    .2773931
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_S - change_Cs_S)                 t =   0.0779
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.5309         Pr(|T| > |t|) = 0.9381          Pr(T > t) = 0.4691

. ttest change_Da_E==change_Cl_E

Paired t test
```

```
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_E |      81    3.253982    .0963843    .8674583    3.062172    3.445793
chan~l_E |      81    4.229988    .2097531    1.887778    3.812566     4.64741
---------+--------------------------------------------------------------------
    diff |      81   -.9760053    .2189851    1.970866     -1.4118    -.540211
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_E - change_Cl_E)                 t =  -4.4569
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest change_Da_E==change_St_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_E |      81    3.253982    .0963843    .8674583    3.062172    3.445793
chan~t_E |      81    3.962925    .1628748    1.465873    3.638794    4.287057
---------+--------------------------------------------------------------------
    diff |      81   -.7089429    .1617831    1.456048   -1.030901   -.3869844
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_E - change_St_E)                 t =  -4.3821
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. ttest change_Da_E==change_Sb_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_E |      81    3.253982    .0963843    .8674583    3.062172    3.445793
chan~b_E |      81     1.37776    .1060866    .9547793    1.166641    1.588879
---------+--------------------------------------------------------------------
    diff |      81    1.876223    .1373512    1.236161    1.602885     2.14956
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_E - change_Sb_E)                 t =  13.6600
 Ho: mean(diff) = 0                               degrees of freedom =       80

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

. ttest change_Da_E==change_Ar_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_E |      79    3.267867     .097147    .8634614    3.074462    3.461272
chan~r_E |      79    3.955075    .1928983    1.714518    3.571044    4.339106
---------+--------------------------------------------------------------------
    diff |      79   -.6872076    .1947732    1.731182   -1.074971    -.299444
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_E - change_Ar_E)                 t =  -3.5282
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
```

```
 Pr(T < t) = 0.0004         Pr(|T| > |t|) = 0.0007          Pr(T > t) = 0.9996

. ttest change_Da_E==change_Cs_E

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
chan~a_E |      79    3.267867     .097147    .8634614    3.074462    3.461272
chan~s_E |      79    3.252044     .171356    1.523045      2.9109    3.593187
---------+--------------------------------------------------------------------
    diff |      79    .0158232    .1874552    1.666138   -.3573714    .3890179
------------------------------------------------------------------------------
     mean(diff) = mean(change_Da_E - change_Cs_E)                  t =   0.0844
 Ho: mean(diff) = 0                               degrees of freedom =       78

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.5335         Pr(|T| > |t|) = 0.9329          Pr(T > t) = 0.4665
```

.

Appendix B: Laboratory experiments mean log reduction with standard deviation for *S. aureus*

Table 8. Laboratory experiments mean log reduction with standard deviation for *S. aureus*

Organism Textile	*S. aureus* Stainless Steel	*S. aureus* Cloth	*S. aureus* Acrylic	*S. aureus* Vinyl	*S. aureus* Seatbelt	*S. aureus* Textured Plastic
Distance (Time) 12.7 cm						
30 sec.	4.0 (±0.7)	4.8 (±0.6)	4.3 (±1.0)	3.5 (±1.3)	1.8 (±0.5)	3.1 (±0.6)
5 min.	4.3 (±1.3)	6.0 (±0.1)	5.3 (±0.8)	4.5 (±0.4)	1.6 (±0.7)	3.3 (±0.6)
10 min.	4.5 (±1.1)	6.1 (±0.3)	5.4 (±1.1)	4.4 (±0.8)	2.3 (±0.6)	4.6 (±0.9)
50.0 cm						
30 sec.	2.0 (±0.3)	2.8 (±0.6)	2.9 (±0.5)	2.3 (±0.4)	1.8 (±1.1)	2.6 (±0.6)
5 min.	4.6 (±1.2)	4.7 (±0.9)	4.6 (±0.5)	3.6 (±0.5)	2.1 (±0.4)	2.9 (±0.5)
10 min.	4.3 (±0.9)	4.7 (±0.8)	4.7 (±1.0)	3.7 (±0.5)	2.0 (±0.9)	4.1 (±0.8)
100 cm						
30 sec.	2.0 (±0.4)	0.8 (±0.5)	1.4 (±0.5)	1.4 (±0.3)	1.1 (±0.6)	1.9 (±0.3)
5 min.	2.7 (±0.4)	2.3 (±1.2)	2.3 (±0.6)	2.1 (±0.4)	0.9 (±0.5)	2.2 (±0.1)
10 min.	3.2 (±0.7)	2.3 (±0.9)	2.5 (±0.6)	2.5 (±0.3)	1.2 (±0.5)	3.0 (±0.6)

Appendix C: Laboratory experiments mean log reduction with standard deviation for *E. coli*

Table 9. Laboratory experiments mean log reduction with standard deviation for *E. coli.*

Organism Textile	*E. coli* Stainless Steel	*E. coli* Cloth	*E. coli* Acrylic	*E. coli* Vinyl	*E. coli* Seatbelt	*E. coli* Textured Plastic
Distance (Time) 12.7 cm						
30 sec.	4.3 (±0.3)	5.6 (±0.5)	4.2 (±0.8)	3.4 (±1.0)	1.6 (±0.7)	2.7 (±0.4)
5 min.	5.1 (±0.9)	5.8 (±0.4)	5.4 (±0.7)	4.7 (±0.8)	0.9 (±0.9)	3.2 (±0.2)
10 min.	5.2 (±0.5)	5.8 (±0.2)	5.6 (±1.1)	5.3 (±1.0)	1.3 (±0.7)	4.1 (±1.1)
50.0 cm						
30 sec.	3.4 (±0.9)	4.5 (±0.2)	3.8 (±1.3)	2.8 (±0.7)	0.7 (±0.5)	2.3 (±0.2)
5 min.	5.0 (±0.8)	5.1 (±0.6)	5.1 (±1.2)	3.6 (±0.8)	2.6 (±0.6)	2.8 (±0.3)
10 min.	4.7 (±0.6)	5.6 (±0.4)	5.0 (±0.8)	4.0 (±0.6)	2.3 (±1.3)	4.1 (±0.7)
100 cm						
30 sec.	1.5 (±0.4)	1.1 (±0.7)	1.1 (±0.4)	1.2 (±0.3)	1.2 (±0.5)	2.7 (±0.6)
5 min.	2.6 (±0.2)	2.1 (±1.1)	2.5 (±0.2)	1.7 (±0.3)	0.6 (±0.4)	3.0 (±0.2)
10 min.	3.1 (±0.5)	2.1 (±0.7)	2.7 (±0.3)	1.8 (±0.5)	1.1 (±0.3)	3.7 (±0.9)

Appendix D: Results from the one-way ANOVA test as function of time

A one-way ANOVA test was utilized to determine the significant difference in log reduction and time. For *S. aureus*, the textiles that have a significant difference were the stainless steel (*p-value= 0.04*), vinyl, cloth, textured plastic, and acrylic (*p-value= <0.01*); the only textile with no significant difference was the seatbelt (*p-value= 0.78*) (**Table 4**). For *E. coli,* the textiles that have a significant difference in log reduction were the stainless steel, vinyl, textured plastic, and acrylic (*p-value= <0.01*); textiles with no significant difference in log reduction were cloth (*p-value= 0.27*) and seatbelt (*p-value= 0.34*) (**Table 4**).

Table 8. Results of one-way ANOVA test as function of time on porous and non-porous surfaces.

	Staphylococcus aureus	*Escherichia coli*
	p-value	*p-value*
Stainless Steel	0.04	<0.01
Vinyl	<0.01	<0.01
Cloth	<0.01	0.27*
Acrylic	<0.01	<0.01
Seatbelt	0.78*	0.34*
Textured Plastic	<0.01	<0.01

*Significance level above p-value of 0.05.

Appendix E: Results from the one-way ANOVA test as function of distance

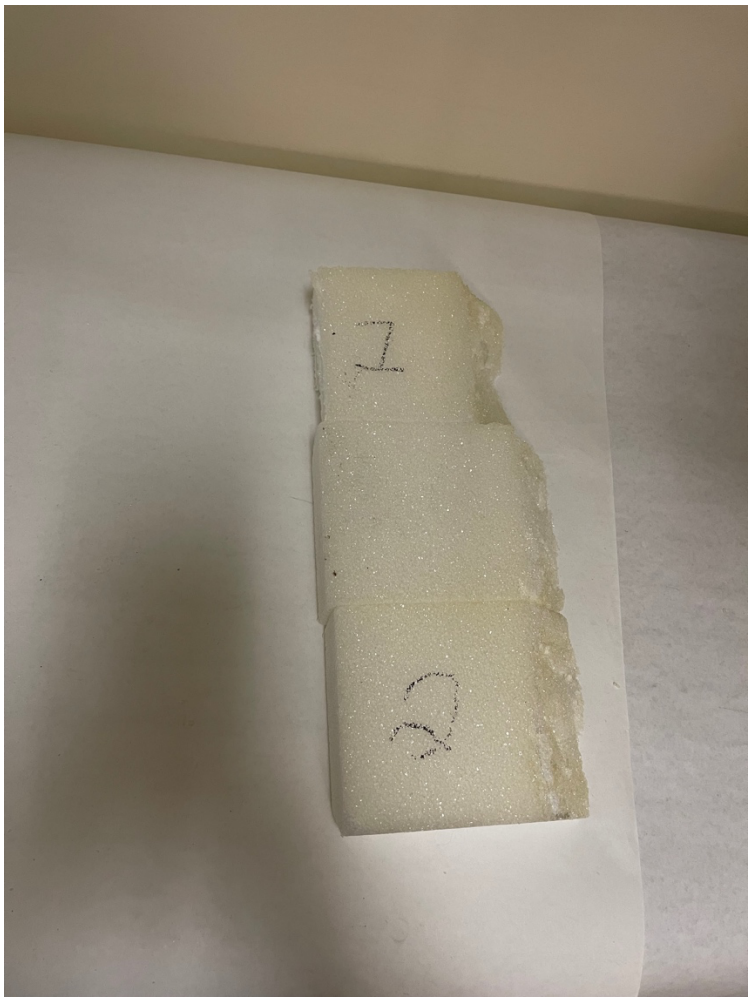
As much as duration of UVC light exposure affects the log reduction among *S. aureus* and *E. coli,* the positioning of the UVC light also makes an impact on the log reduction for both microorganisms. A one-way ANOVA test was utilized to determine the significant difference in log reduction and distance (position of UVC light). For both *S. aureus* and *E. coli*, all textile types (both porous and non-porous) were significantly different as a function of distance (*p-value = <0.01*) expect for textured plastic (*p-value = 0.52*) (**Table 6**).

Table 9. Results of one-way ANOVA test as function of distance on porous and non-porous surfaces.

	Staphylococcus aureus	*Escherichia coli*
	p-value	*p-value*
Stainless Steel	<0.01	<0.01
Vinyl	<0.01	<0.01
Cloth	<0.01	<0.01
Acrylic	<0.01	<0.01
Seatbelt	<0.01	<0.01
Textured Plastic	<0.01	0.52*

*Significance level above p-value of 0.05.

Appendix F: Picture of material degradation from UVC light exposure



References

Alves, D. W., & Bissell, R. A. (2008). Bacterial pathogens in ambulances: results of unannounced sample collection. *Prehospital emergency care: official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, *12*(2), 218–224.

Alidjinou, E. K., Sane, F., Firquet, S., Lobert, P. E., & Hober, D. (2018). Resistance of Enteric Viruses on Fomites. *Intervirology*, *61*(5), 205–213. https://doi.org/10.1159/000448807

Anderson, D. J., Chen, L. F., Weber, D. J., Moehring, R. W., Lewis, S. S., Triplett, P. F., Blocker, M., Becherer, P., Schwab, J. C., Knelson, L. P., Lokhnygina, Y., Rutala, W. A., Kanamori, H., Gergen, M. F., Sexton, D. J., & CDC Prevention Epicenters Program (2017). Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study. *Lancet (London, England)*, *389*(10071), 805–814. https://doi.org/10.1016/S0140-6736(16)31588-4

Bedrosian, N., Mitchell, E., Rohm, E., Rothe, M., Kelly, C., String, G., & Lantagne, D. (2021). A Systematic Review of Surface Contamination, Stability, and Disinfection Data on SARS-CoV-2 (Through July 10, 2020). *Environmental science & technology*, *55*(7), 4162–4173. https://doi.org/10.1021/acs.est.0c05651

Bello, A., Quinn, M. M., Perry, M. J., & Milton, D. K. (2009). Characterization of occupational exposures to cleaning products used for common cleaning tasks--a pilot study of hospital cleaners. *Environmental health: a global access science source*, *8*, 11. https://doi.org/10.1186/1476-069X-8-11

Bitely, C., Miller, B., & Glauser, J. (2019). EMS Disease Exposure, Transmission, and Prevention: a Review Article. *Current emergency and hospital medicine reports*, *7*(4), 135–140. https://doi.org/10.1007/s40138-019-00200-6

Bledsoe, B. E., Sweeney, R. J., Berkeley, R. P., Cole, K. T., Forred, W. J., & Johnson, L. D. (2014). EMS provider compliance with infection control recommendations is suboptimal. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, *18*(2), 290–294. https://doi.org/10.3109/10903127.2013.851311

Buchaklin A. (2017, December 7) Benefits and limits of UV-C Disinfection systems. https://www.reminetwork.com/articles/benefits-and-limits-of-uv-c-disinfection-systems/

Byrns, G., Barham, B., Yang, L., Webster, K., Rutherford, G., Steiner, G., Petras, D., & Scannell, M. (2017). The uses and limitations of a hand-held germicidal ultraviolet wand for surface disinfection. *Journal of occupational and environmental hygiene*, *14*(10), 749–757. https://doi.org/10.1080/15459624.2017.1328106

El-Mokhtar, M. A., & Hetta, H. F. (2018). Ambulance vehicles as a source of multidrug-resistant infections: a multicenter study in Assiut City, Egypt. *Infection and drug resistance*, *11*, 587–594. https://doi.org/10.2147/IDR.S151783

Fuller, T. (2020, July 3) *Occupational Safety and Health Guide for Surface Disinfection Practices using Germicidal Ultraviolet Radiation* [PowerPoint Slides] PDF. https://aiha-assets.sfo2.digitaloceanspaces.com/local/MetroNewYork/presentations/Fuller-UVC-Pres-NYC-073020.pdf

Gerster, F. M., Vernez, D., Wild, P. P., & Hopf, N. B. (2014). Hazardous substances in

frequently used professional cleaning products. *International journal of occupational and environmental health*, *20*(1), 46–60. https://doi.org/10.1179/2049396713Y.0000000052

Gibson C. V. (2019). Emergency medical services oxygen equipment: a fomite for transmission of MRSA? *Emergency medicine journal: EMJ*, *36*(2), 89–91. https://doi.org/10.1136/emermed-2018-207758

Goodman, C. S., & Cone, D. C. (2001). Emergency medical services equipment hygiene practices. *Prehospital emergency care: official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, *5*(2), 169–173. https://doi.org/10.1080/10903120190940074

International Association of Fire Fighters. (2021) *Infectious Disease.* https://www.iaff.org/infectious-disease/#diseases

Katara, G., Hemvani, N., Chitnis, S., Chitnis, V., & Chitnis, D. S. (2008). Surface disinfection by exposure to germicidal UV light. *Indian journal of medical microbiology*, *26*(3), 241–242. https://doi.org/10.4103/0255-0857.42034

Ko, P. C., Chen, W. J., Ma, M. H., Chiang, W. C., Su, C. P., Huang, C. H., Lu, T. C., Shih, F. Y., & Lin, F. Y. (2004). Emergency medical services utilization during an outbreak of severe acute respiratory syndrome (SARS) and the incidence of SARS-associated coronavirus infection among emergency medical technicians. *Academic emergency medicine: official journal of the Society for Academic Emergency Medicine*, *11*(9), 903–911. https://doi.org/10.1197/j.aem.2004.03.016

Liang, S. Y., Theodoro, D. L., Schuur, J. D., & Marschall, J. (2014). Infection prevention in the emergency department. *Annals of emergency medicine*, *64*(3), 299–313. https://doi.org/10.1016/j.annemergmed.2014.02.024

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K. S. M., Lau, E. H. Y., Wong, J. Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., … Feng, Z. (2020). Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *New England Journal of Medicine*, *382*(13), 1199–1207.

Lindblad, M., Tano, E., Lindahl, C., & Huss, F. (2020). Ultraviolet-C decontamination of a hospital room: Amount of UV light needed. *Burns: journal of the International Society for Burn Injuries*, *46*(4), 842–849. https://doi.org/10.1016/j.burns.2019.10.004

Lindsley, W. G., McClelland, T. L., Neu, D. T., Martin, S. B., Jr, Mead, K. R., Thewlis, R. E., & Noti, J. D. (2018). Ambulance disinfection using Ultraviolet Germicidal Irradiation (UVGI): Effects of fixture location and surface reflectivity. *Journal of occupational and environmental hygiene*, *15*(1), 1–12. https://doi.org/10.1080/15459624.2017.1376067

Lopez, G. U., Kitajima, M., Havas, A., Gerba, C. P., & Reynolds, K. A. (2014). Evaluation of a disinfectant wipe intervention on fomite-to-finger microbial transfer. *Applied and environmental microbiology*, *80*(10), 3113–3118. https://doi.org/10.1128/AEM.04235-13

Memarzadeh, F., Olmsted, R. N., & Bartley, J. M. (2010). Applications of ultraviolet germicidal irradiation disinfection in health care facilities: effective adjunct, but not stand-alone technology. *American journal of infection control*, *38*(5 Suppl 1), S13–S24. https://doi.org/10.1016/j.ajic.2010.04.208

Mitchell, J. B., Sifuentes, L. Y., Wissler, A., Abd-Elmaksoud, S., Lopez, G. U., & Gerba, C. P. (2019). Modelling of ultraviolet light inactivation kinetics of methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, *Clostridium difficile* spores and murine norovirus on fomite surfaces. *Journal of applied microbiology*, *126*(1), 58–67. https://doi.org/10.1111/jam.14103

Montanaro, L., & Arciola, C. R. (2000). Studying Bacterial Adhesion to Irregular or Porous Surfaces. In Y. H. An & R. J. Friedman (Eds.), *Handbook of Bacterial Adhesion: Principles, Methods, and Applications* (pp. 331–343). Humana Press. https://doi.org/10.1007/978-1-59259-224-1_21

Murashita, S., Kawamura, S., & Koseki, S. (2017). Inactivation of nonpathogenic *Escherichia coli*, *Escherichia coli* O157:H7, salmonella enterica typhimurium, and listeria monocytogenes in ice using a UVC light-emitting diode. *Journal of Food Protection, 80*(7), 1198-1203. doi:http://dx.doi.org.ezproxy3.library.arizona.edu/10.4315/0362-028XJFP-17-036

Owen, L., & Laird, K. (2020). The role of textiles as fomites in the healthcare environment: a review of the infection control risk. *PeerJ*, *8*, e9790. https://doi.org/10.7717/peerj.9790

Parini, S. (2003). Severe acute respiratory syndrome. *Nursing*, *33*(9), 96. https://doi.org/10.1097/00152193-200309000-00058

Poster, D. L., Miller, C. C., Obeng, Y., Postek, M. T., Cowan, T. E., & Martinello, R. A. (2018). Innovative Approaches to Combat Healthcare-Associated Infections Using Efficacy Standards Developed Through Industry and Federal Collaboration. *Proceedings of SPIE--the International Society for Optical Engineering*, *10730*, 10.1117/12.2500431. https://doi.org/10.1117/12.2500431

Roberts, M. C., Soge, O. O., No, D., Beck, N. K., & Meschke, J. S. (2011). Isolation and characterization of methicillin-resistant *Staphylococcus aureus* from fire stations in two northwest fire districts. *American Journal of Infection Control*, *39*(5), 382–389. https://doi.org/10.1016/j.ajic.2010.09.008

Sassi, H. P., Reynolds, K. A., Pepper, I. L., & Gerba, C. P. (2018). Evaluation of hospital-grade disinfectants on viral deposition on surfaces after toilet flushing. *American journal of infection control*, *46*(5), 507–511. https://doi.org/10.1016/j.ajic.2017.11.005

Sexton, J. D., Wilson, A. M., Sassi, H. P., & Reynolds, K. A. (2018). Tracking and controlling soft surface contamination in health care settings. *American journal of infection control*, *46*(1), 39–43. https://doi.org/10.1016/j.ajic.2017.08.002

Sexton, J. D., & Reynolds, K. A. (2010). Exposure of emergency medical responders to methicillin-resistant *Staphylococcus aureus*. *American journal of infection control*, *38*(5), 368–373. https://doi.org/10.1016/j.ajic.2010.01.004

Stevenson, K. B. (2010). MRSA colonization in EMS personnel and equipment as a risk factor for secondary injury in ohio trauma patients. *Ohio Division of EMS Injury Prevention Research Grant: Final Report*. http://www.publicsafety.ohio.gov/links/EMS_Stevenson_MRSA Project_Final Report_1.pdf

Su, L., Ma, X., Yu, H., Zhang, Z., Bian, P., Han, Y., Sun, J., Liu, Y., Yang, C., Geng, J., Zhang, Z., & Gai, Z. (2020). The different clinical characteristics of corona virus disease cases between children and their families in China - the character of children with COVID-19. *Emerging microbes & infections*, *9*(1), 707–713. https://doi.org/10.1080/22221751.2020.1744483

Teter, J., Millin, M. G., & Bissell, R. (2015). Hand hygiene in emergency medical services. *Prehospital emergency care: official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, *19*(2), 313–319. https://doi.org/10.3109/10903127.2014.967427

Trevisan, A., Piovesan, S., Leonardi, A., Bertocco, M., Nicolosi, P., Pelizzo, M. G., & Angelini, A. (2006). Unusual high exposure to ultraviolet-C radiation. *Photochemistry and photobiology*, *82*(4), 1077–1079. https://doi.org/10.1562/2005-10-27-ra-728

Valdez, M. K., Sexton, J. D., Lutz, E. A., & Reynolds, K. A. (2015). Spread of infectious microbes during emergency medical response. *American journal of infection control*, *43*(6), 606–611. https://doi.org/10.1016/j.ajic.2015.02.025

Vikke, H. S., Giebner, M., & Kolmos, H. J. (2017). 20 Hygiene in the emergency medical services (EMS) calls for attention. *BMJ Open, 7* doi:http://dx.doi.org/10.1136/bmjopen-2017-EMSabstracts.20

Wallace, R. L., Ouellette, M., & Jean, J. (2019). Effect of UV-C light or hydrogen peroxide wipes on the inactivation of methicillin-resistant *Staphylococcus aureus*, *Clostridium difficile* spores and norovirus surrogate. *Journal of applied microbiology*, *127*(2), 586–597. https://doi.org/10.1111/jam.14308

Weir, M. H., Shibata, T., Masago, Y., Cologgi, D. L., & Rose, J. B. (2016). Effect of Surface Sampling and Recovery of Viruses and Non-Spore-Forming Bacteria on a Quantitative Microbial Risk Assessment Model for Fomites. *Environmental science & technology*, *50*(11), 5945–5952. https://doi.org/10.1021/acs.est.5b06275

Wilson, A. M., Jones, R. M., Lugo Lerma, V., Abney, S. E., King, M. F., Weir, M. H., Sexton, J. D., Noakes, C. J., & Reynolds, K. A. (2021). Respirators, face masks, and their risk reductions via multiple transmission routes for first responders within an ambulance. *Journal of occupational and environmental hygiene*, *18*(7), 345–360. https://doi.org/10.1080/15459624.2021.1926468

Yang, J. H., Wu, U. I., Tai, H. M., & Sheng, W. H. (2019). Effectiveness of an ultraviolet-C

disinfection system for reduction of healthcare-associated pathogens. *Journal of microbiology, immunology, and infection = Wei mian yu gan ran za zhi*, *52*(3), 487–493. https://doi.org/10.1016/j.jmii.2017.08.017

Yee, J., Unger, L., Zadravecz, F., Cariello, P., Seibert, A., Johnson, M. A., & Fuller, M. J. (2020). Novel coronavirus 2019 (COVID-19): Emergence and implications for emergency care. *Journal of the American College of Emergency Physicians open*, *1*(2), 63–69. Advance online publication. https://doi.org/10.1002/emp2.12034

Yin, R., Dai, T., Avci, P., Jorge, A. E., de Melo, W. C., Vecchio, D., Huang, Y. Y., Gupta, A., & Hamblin, M. R. (2013). Light based anti-infectives: ultraviolet C irradiation, photodynamic therapy, blue light, and beyond. *Current opinion in pharmacology*, *13*(5), 731–762. https://doi.org/10.1016/j.coph.2013.08.009

Yousif, E., & Haddad, R. (2013). Photodegradation and photostabilization of polymers, especially polystyrene: review. *SpringerPlus*, *2*, 398. https://doi.org/10.1186/2193-1801-2-398