A USER-CENTERED ENGINEERING APPROACH TO STORAGE AND ACCESS IN HIGH PRIORITY SCENARIOS

by

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

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ABSTRACT

This thesis aims at introducing the importance of the application of user-centered ideologies to the redesign and organization of storage spaces in high priority/time-critical industries such as law enforcement and introducing a new area of study that we call "organizational engineering".

Throughout the thesis, the need for this new user-centered area of study was evaluated by carrying out experiments on six sworn officers in the miscellaneous equipment storage rooms at the Story County Sheriff's Office in Nevada, Iowa. This involved running the officers through a familiar scenario on the existing system design, redesigning and reorganizing the existing system using a combination of human-centered heuristics and quantitative data collected to develop an optimal design using a simulation software; SIMIO, running the officers on the new system and comparing the data obtained in both cases.

The analysis of both quantitative and qualitative data revealed that the new system was more intuitive to use and navigate through, easier to learn for new officers and enhanced greater visibility of the equipment in the room. The data also showed that the newly designed room was consistent with the design of the previous room and reduced the amount of wasted time by 74% and the associated cost by 63%. An ANOVA performed on the amount of wasted indicated a p-value of 0.00038 and a paired t-test of the indicated a one-tailed p-value of 0.01 suggesting the high possibility of a statistically significant difference between the two times. The data thus indicated that such user-centered redesigns could greatly reduce the amount of time devoted towards small duties that could greatly hinder the performance of more important tasks. The results obtained from this study indicate a potential to use this approach to storage systems in other high-priority/time-critical industries.

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CHAPTER 1. GENERAL INTRODUCTION

User-centered design is an area that has sparked the interest of researchers and companies alike. The idea of developing machines for use my humans goes back as far as the early 1940's (Yerkes, Robert. M, 1941). The late 1940's and early 1950's saw applications of human engineering to the design of human-operated systems (Chapanis et al., 1949; Birmingham et al., 1954). Further, the aviation sector adopted the human engineering approach in the development of air-navigation and air-traffic control systems to improve human performance in these scenarios (Fitts, Paul M. et al., 1951). By the year 1957, about 45 companies had human factors groups with average of ten personnel per group (Kraft, JA, 1957). This was around the time when human factors began to be considered important for the safety of people driving cars, owing to the large loss of manpower associated with vehicle accident injuries (Stapp, John et al., 1957). Although at that time the idea revolved around developing machines for use by humans, in due course of time, the idea evolved into the safety of operators of various systems.

As time passed, the concepts of human factors as well as the understanding of the physical and psychological limits and capabilities of human were used to develop systems that would require less physical and mental effort to enable the human to perform tasks better (Karat, John, 1997, Albayrak, Esra et al., 2004). A lot of studies began exploring the effects that workplace elements had on operator task performance (Bosch, T., Mathiassen et al., 2011). Correlations were drawn between the quality of the process/product produced as a result of human-related limitations (Drury, C.G, 2000). Around the 1970s, organizations like NIOSH and OSHA were developed with all this understanding in mind. These organizations had the sole purpose of ensuring worker safety at companies. Following this, human factors began to be applied towards making products and systems usable (Bannon, Liam J, 1995).

Literature has shown that workplace organization has been seen to increase productivity in manufacturing companies (Karwowski, Waldemar et al., 1998). Lean techniques like 5S and Visual Management have been used to manage various aspects of a production process and ensure that there is a place for every item. These techniques have been seen to have a strong correlation to the development of a company's business (Arvanitis, Spyros, 2005). Additionally, there have been studies that have shown that investing in human capital and workplace organization has contributed to the labor productivity in firms across Switzerland and Greece (Arvanitis, Spyros et al. 2009). Some studies have connected workplace organization to human injuries (Shahnavaz, H., 1987).

However, in all of the literature in the field of workplace organization and human factors, there doesn't seem to be a correlation between workplace organization and human factors. All the literature in the field of human factors has talked about safety, human-machine issues, human-centered design of systems and products for use by humans, organizational well-being of workers etc. While there are correlations between changing certain physical characteristics of a workplace and human performance. But nowhere does it mention reorganization of workplaces to enhance human performance, especially, in high-priority work settings. Even though the aviation sector has employed this idea of reorganization of flight instruments to enhance pilot task performance, such a concept has not been applied to a work setting like say a storage room. While techniques like 5S have been employed in storage rooms, there is no correlation between that and human factors. This thesis aims at establishing this link by not changing any variable but the layout of a workspace.

This paper aims to explain the importance of user-centered redesign of storage spaces in high-priority and time-critical scenarios by means of a detailed experimental study that was carried out at the Story County Sheriff's Office, Nevada, IA. The experimental study involved sworn officers with duties and responsibilities associated with the miscellaneous equipment storage room at the Sheriff's office. The study was comprised of three phases. First, the study was performed on the existing system and the time taken for each task and the time wasted on looking for items were recorded. The data obtained from this experiment, the user surveys, user-centered heuristics and a SIMIO model developed were used to redesign the storage room for the next phases of the study. The redesign was aimed at creating the most optimal storage room design that would not only enable the easy accomplishment of the tasks at hand, but also fit within the expectations and capabilities of the officers. After the redesign, there was a significant drop in the amount of time wasted looking for equipment in the storage room. The time wasted was translated to a cost associated with wasting time looking for items in the storage rooms. Both the qualitative and quantitative data thus obtained indicated that the redesign would not only make the room easier to navigate, but also would enable the officers to spend more time on actual Sheriff's office responsibilities by making the process of locating and retrieving items easier. Moreover, the cost associated with the wasted time could be used by the Sheriff's Office to purchase new equipment. The results indicated a very real need for such user-centered interventions in such time-critical scenarios to make tasks easier and quicker to perform and to support the capabilities and limitations of the humans involved in such systems, as has been shown time and again by time-critical industries like the aviation industry for instance. The data thus obtained indicated the need for organizational engineering of storage spaces in such environments.

In the upcoming chapter the journal paper associated with this thesis is discussed with the experiment carried out at the Sheriff's office along with the results obtained and inferences drawn. The last chapter concludes the findings inferred from the thesis.

CHAPTER 2. A USER-CENTERED ENGINEERING APPROACH TO STORAGE AND ACCESS IN HIGH PRIORITY SCENARIOS

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Abstract

This paper focuses on the organizational engineering of storage spaces to enable easy location and retrieval of equipment, thus supporting the time-critical nature of operations at a miscellaneous storage room at the Story County Sheriff's Office. The idea is to combine the concept of workplace organization with those of human-centered design to redesign the storage areas to better support the activities of the officers. In order to implement this idea, experiments were carried out on sworn officers with duties using a familiar scenario before and after the redesign of the storage room. After carrying out the first test (before redesign), using user-centered heuristics a SIMIO model was developed to optimize the redesign of the room to allow for the easiest access and retrieval of items from the room. The redesign was based on this model as well as participant surveys. As a result of the complete redesign, a significant reduction in the wasted time was observed as indicated by a statistical analysis performed. Further qualitative surveys indicated that 83% of the officers found the new system easier and more convenient to use. The use of labels and pictures to identify various shelves in the storage room was found to make the system easier to learn and more intuitive, based on the qualitative surveys. The wasted time calculated was then translated to a cost and the newly designed storage room was found to have reduced the cost by 63%, money that could be spent on actions that precluded the efficient accomplishment of tasks. The quantitative and qualitative results of the study indicate that there is a need for the industry to extend research towards this field that we name "organization engineering".

Introduction and Background

The research interest in of human factors and user-centered design goes back a long way in history. User-centered considerations began around the time of World War II when countries were developing airplanes that could go faster and higher than ever before. Designers began to realize that, in order to be successful in flying these faster aircraft, the pilots' physique needed to be considered during the design process. There was a need to design aircrafts according to the human flying it and to support the capabilities and understanding of the humans flying it. This was one of the first applications of human factors in high priority and time and safety-critical environments. The whole idea of fitting the workplace to the human became an important consideration (Wiener, E. L., & Nagel, D. C. 1988). The early origin and development of the concept of "user-centered design" began in the years following late 1980s during which time a lot of research was being done in this area. Some researchers through years of study and experimentation developed principles of user-centered design that seemed easy to understand and easily applicable to the design of day-to-day products. (Ben Shniederman, 1987; Norman, 1988; Nielsen, 1993, 2001). These principles highlighted the importance of intuitiveness in design.

Following this, many researchers and companies alike began exploring the advantages associated with the incorporating the concepts of human-centered design into the design of products and systems, thus giving their organizations a competitive edge over others in the market (Ahmad and Schroeder, 2003; Onyema, 2014). But there was still a lack of knowledge of human-centered approaches that seemed to have limited the application of human factors to industrial production (Dul and Neumann, 2009). This lack of understanding drove many laboratory experiments and tests in different industrial settings that aimed at providing the advantages of incorporating human

factors and ergonomic interventions into the design of everyday objects and process improvement. Many "usability studies" gained popularity during this period. These studies involved changing certain physical characteristics of the work environments, measuring the effect the change had on human performance and studying the overall improvement in the process and product quality (Chaffin, D.B., 2008).

More recently, studies have been done to identify how human-centered approaches can be used in the manufacturing of products and processes to reduce physical workload on employees. However, work related to the application of human-centered approaches to the organizational level is greatly limited. A few studies have incorporated this approach to better relationships between teams, to improve employee morale, to create a work environment that will favor learning and improve employee-management relationships (Leonard et al., 2004, Lank, E., 1997). For example, many companies have incorporated open. One study has touched upon activity-based work environment and its impact on satisfaction. Most studies have looked at human factors as a means of improving the quality products and processes, safety of users/operators performing their task or using the products and to increase their competitive edge over other companies.

Alongside this realization among industries that user-centered approaches were the key towards attracting customers and keeping them loyal and happy, the defense community began to embrace ideas of user-centered design for training personnel. For example, the developing virtual environments that would help train military personnel by providing a visualization of the battlefield (Hix, D et al., 1999) was an important application that the military was interested in. Law enforcement agencies were interested in the development of human-centered spatiotemporal

crime analysis tools (Roth, R et al., 2010, 2013) that could greatly help officers spend more of their time on law enforcement duties. User-centered design was also used to enhance situational awareness among officers (Razip, A et al., 2014).

For many decades, the design of exoskeletons (Schnieders, T. et al., 2014) seemed to interest a lot of researchers and defense communities. From design suits for army personnel to their use as prosthetics, extensive research has been performed to develop exoskeletons for various purposes. Most recently, exoskeletons were used in law enforcement for training officers in the use handguns to ensure accurate, precise, reliable and ergonomically safe postures (Schnieders, T. et al., 2019). The need for accuracy and precision in a fast-paces and high-priority/security environments of law enforcement agencies and defense departments seems to make user-centered design very important in such industries.

Theory

Most of literature talks about applying user-centered techniques to the design of products and systems that support human capability. Nowhere in the industry or in literature have there been specific studies that try to link the use of human-centered principles with optimal organization of workplaces. Similar to aviation where different flight controls and avionics need to be organized effectively, there is a real need to organize a workspace in a way that allows the user to spend more time on the task at hand rather than looking for items. This organization can be made based on functional or natural mapping, user evaluations and non-user evaluations. Even though literature has shown that human-centric design can improve the quality of a process, it does not tie the human-centric interventions directly to the performance of the human, there are usually a lot of variables.

This paper describes a Human Factors intervention that was carried out in a Story County Sheriff's office storage room with the aim of enhancing the performance of officers, with only one variable; the changing design of the room alone. In doing so, the hypothesis is that, re-organization of the workspace will enable the officers to locate and retrieve items quickly and efficiently and will enable the officers spend less time on the search and more time on their task at hand.

Methodology

Procedure

Following is a sequential set of actions that were performed throughout the process:



Figure 1: Process Involved in the Study

Participants

Six sworn officers with tasks specific to the miscellaneous equipment storage room participated in this study. They were selected based on the following criteria:

- 18 years or older,
- Employed by the Story County Sheriff's Office
- Able to legally give consent and

Independent variable

The independent variable in this experiment was the difference in organization between the existing storage room and that of the new storage room.

Dependent variables

The dependent variable in this experiment was the Time wasted on actions between finds. The reason for considering "Time Wasted" as a dependent variable was that the wasted time was identified to be the part of the time taken to perform the task that when extrapolated to other small tasks that form part of the Story County Sheriff's Office responsibilities could lead to major loss of time that could instead have been used by the Story County Sheriff's Office for more important duties such as serving the community or processing cases. It was believed that if this time could be reduced to the minimum, it would greatly benefit the Story County Sheriff's Office by allowing the officers to spend more time on important tasks at hand. Additionally, the time wasted was assigned a cost based on the time wasted by an officer on finding items and the average hourly salary of deputies at the Story County Sheriff's Office based on the Des Moines Register (2019).

User-Centered Heuristics

Following were the user-centered heuristics (based on the Nielsen–Shneiderman Heuristics) that were considered for the redesign of the storage room:

- Visibility: To ensure that users can see the status of the inventory while retrieving items. The existing system did not afford the officers with the ability to see whether a particular type of item was out or not.
- Consistency: To ensure that certain elements of the existing system were kept as is to avoid any confusions and support easier learnability of the new setup. If changes were such that the new system was too different, that would require the officers to support a longer learning curve and make task performance more difficult.
- Memory: To make location and retrieval quicker symbols and labels were provided. This way, the officers would not need to look for items.
- Flexibility: The new system was designed to enable easy location and retrieval of items for officers at different experience levels.

The study was divided into three phases; the control phase, the improvement phase and experimental phase. Following is a detailed description of the three phases:

Phase 1: Control Phase-Testing Participants on the existing arrangement of the storage rooms-Testing Scenario

The officers were run through a familiar testing scenario. They were asked to retrieve equipment pertaining to the testing scenario; "New hire scenario". This scenario was selected as it was a very common scenario faced by the Story County Sheriff's Office, owing to the large number of new hires being added to the team on a regular basis. Besides, it was a relatively easy scenario to test the hypothesis of the study in a clear and unambiguous way.

Testing scenario-New Hire: A scenario where the officers were tasked with giving a newly hired

officer essential equipment required for them to begin their duty. This scenario mimics a real-life scenario where a new hire is given equipment like uniforms etc. that is essential for them to be considered officers on duty. They were provided the same list of items that they would use to locate and retrieve equipment in a real scenario. The participants' actions were monitored on video for the time associated with the completion of the particular scenario assigned.

Phase 2: Improvement Phase-Updating the Storage Rooms

This phase involved:

- Gathering all the responses provided by the officers in the post study questionnaires
- Using the responses and the user-centered heuristics to develop an optimal room design model using SIMIO, a simulation software capable of supporting the optimization of resources and layouts of complex systems and scheduling processes: The user-centered heuristics along with the responses provided by officers in the post-study questionnaire were used while developing the model of the storage room using the SIMIO software; i.e., items were rearranged in the model in such a way that all of the equipment were visible at all times, the room's design was consistent with certain elements of the old design, specifically those called out in the questionnaires (officers called out elements that they liked about the existing system in the questionnaires), the design did not require officers to memorize the location of items and the new system could easily be navigated through by experienced and inexperienced officers alike. This was followed by creating various designs for the model using SIMIO (Version 10.174.16986). All storage shelves, cupboards or any stand that hold items to be retrieved at some point were modeled as 'Servers' as are the obstructions that the existing storage space setup provides to the

participants. One 'Source' and one 'Sink' were provided to serve as a point from where participants enter and exit the room, respectively. The model is explained it greater detail with images below.

By conducting simulations on various design iterations, an optimal design was selected such that it was in line with the user-centered heuristics and comments and such that it would minimize the time taken to follow the path pertaining to the new hire scenario, created using a list of items used by the Story County Sheriff's Office for the new hire equipment retrieval scenario.

• Reorganizing the storage room based on the most optimal design obtained from SIMIO: All the items were pulled out from the room and put back into the shelves once the room was reorganized. The items were organized into specific shelves on the basis of most used items, items used together in situations and items whose locations would not be changed based on recommendations by officers in the questionnaires

SIMIO Model

All the servers represent shelves/obstacles. In the model of the existing system Servers 1-10 represent shelves while the other represent obstacles that hindered the officers' ability to retrieve items. The different paths represent the specific path followed by officers as they go into the room to retrieve equipment pertaining to the scenario at hand; new hire. The simulation was run using an arrival rate of one per min, for a period of 24 hours. The various paths indicated represent the specific path that the officers were constrained by means of a list of equipment to follow to retrieve the equipment pertaining to the scenario at hand; in this case the scenario of giving a new hire all the equipment required for their first day. The time taken along each path

was recorded by SIMIO. Adding the times associated with following the paths indicated that the amount of time taken to move from one point to the other in the existing system was twice that of the time taken in the new system. For instance, moving from the source to server 1 required the officers to go through server 13 in case of the existing system while moving the same distance allowed officers to go direct to server 1. In such cases, the time taken was found to be the sum of the times taken along each path. This simulation provided an idea of the potential time wastage associated with the existing system and a need to redesign it to remove all the obstacles that seemed to get in the way of the officers' ability to accomplish the task at hand. Therefore considering the above attributes as well as the time taken, the new system was designed to keep certain elements of the existing system like the location of uniforms and grooming equipment as per participant surveys collected after the first experiment. In all, the time recorded, participant surveys and feedback, in addition to the human-centered attributes were used to develop the model of the new system.

In this model, the retrieval process follows a fixed path depending on the scenario assigned to the participant. The list of items to pick served as a means of providing for the path. The model is developed according to the task. For example, if a particular task requires a participant to retrieve items from shelf 2, 3, 5, 6 and then to exit the room, the model is developed in such a way that paths are drawn from the source to server 2, server 2 to server 3, server 3 to server 5, server 5 to server 6 and server 6 to the sink. The models were developed for the existing system and the total time taken to retrieve an item and the number of items processed are obtained by running a simulation of the model for 24 hours. Once this was done, an optimal process flow design was developed in such a way that it resulted in the least amount of system time and greatest number of processed items. Some human-centered concerns raised by the officers in the first questionnaire

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like keeping the grooming section the same as before were also incorporated into the design.

Existing System



Figure 2: SIMIO model of the room before user-centered redesign

New System



Figure 3: SIMIO model of the room after user-centered redesign

Phase 3: Experimental Phase-Testing Participants on the updated storage rooms

This phase is more or less the same as Phase 1 with the only exception being that the experiment was carried out on the new and updated process and then with labels and RFID cards on the

shelves. The participants were asked to fill a post-study questionnaire at the end of this phase. The same new hire scenario was employed.



Figure 4: Storage room before user-centered redesign



Figure 5: Storage room after user-centered redesign

Results

Hypothesis

• Null hypothesis: The mean of the time wasted before the redesign/reorganization equals that after the reorganization

 $\circ \quad \mu_{T_before} = \mu_{T_after}$

• Alternate hypothesis: Time wasted between finds before the new design is greater than the Time wasted between finds after the new design:

$$\circ \quad \mu_{T_before} > \mu_{T_after}$$

• Significance value selected: α =0.05

Quantitative

Table 1: Summary of Quantitative Data

Dependent variable	Before Change	After Change
Average time spent to complete	6.34 min	4.51 min
the task		
Time wasted on locating	3.05 min	0.78 min
equipment		
Estimated cost associated with	\$2699.62	\$693.34
the wasted time per officer		

Cost calculation: Percentage of time wasted x 8 hours a day x 5 days a week x 4 weeks x 12 months x \$27.66/hr. (approximate salary of deputy based on the Des Moines Register (2019)).

Table 2: Analysis of Variance

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	6	13.2348	2.205799	0.052426		
Column 2	6	9.955553	1.659259	0.012884		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.896119	1	0.896119	27.44212	0.00038	4.964603
Within Groups	0.326549	10	0.032655			
Total	1.222668	11				

Table 3: Paired t-test

t-Test: Paired Two Samples		
	Variable 1	Variable 2
Mean	2.205799265	1.659258844
Variance	0.052426159	0.012883622
Observations	6	6
Pearson Correlation	0.494019131	
Hypothesized Mean Difference	0	
df	5	
t Stat	6.724777568	
P(T<=t) one-tail	0.000550969	
t Critical one-tail	2.015048373	
P(T<=t) two-tail	0.001101938	
t Critical two-tail	2.570581836	

The data collected indicated a 74% reduction in the time wasted in between finds. Subsequently, there was a 63% drop in the cost associated with this wasted time as a result of the user-centered intervention. An ANOVA performed revealed a p-value of 0.00038. This indicates that the null hypothesis can be rejected and a paired t-test performed on these times indicated a p-value of 0.0005 one-tailed (very much less than the significance value of 0.005) indicating that there is a great possibility that there is a statistically significant difference between the time wasted in the older system compared to that of the new system.

Qualitative



Figure 6: Response collected from post-study questionnaire after the experimental phase

The graph depicts the opinions of the officers with regard to certain heuristics obtained from the post-study questionnaire. It indicates that most of the officers found the system organized, easy to use and issue-free. They even expressed that such interventions would greatly help with other operations at the Sheriff's office

Discussion

The results suggest that the re-organization of the storage room reduced the amount of time spent on looking for items, identifying them and navigating around items on the floor was reduced by 29%. The reason for the almost similar amount of time to complete the task can be owed to the lack of familiarity of the new system. The significantly lower amount of wasted time as evidenced by the ANOVA and paired t-test performed on the time wasted before and after the changes that indicated p-values of 0.00038 and 0.0005 respectively suggests that the two times are significantly different with the time wasted before the change being significantly larger than that of the time wasted after the redesign

Additionally, a 63% reduction in the cost associated with the wasted time was observed. The new design reduced the amount of time wasted in between finds significantly. This suggests that the Sheriff's office could spend the money saved by the new system for purposes that would help it serve the community better. Both the quantitative and qualitative data obtained suggested that the design of the system greatly supported the mental model of the participants. This was an important consideration during the redesign of the room that enabled easier learnability to support new and experienced officers alike and reduced confusion associated with the new system to an extent (Rouse, W.B et al., 1992).

Almost all of the officers who participated in the experiment reported to have found the system to be organized and intuitive to use. Many of them recommended the expansion of this area we call "organizational engineering" to other operations within the Story County Sheriff's Office as well as those in other high-priority work settings. Above all, the data obtained indicated a strong relation between human-centered design approaches and workplace design.

Unlike whatever was done earlier in literature (Karwowski, W et al. 1998), this study provided a direct link between human-centered principles and organization of workplaces. No variables but the design of the room was changed during the study.

Conclusion

Since the participant surveys indicated that the new system was easy to navigate and that it could be used even by officers who are new, this study serves as a baseline study for more research in this new area of "organization engineering".

Future work could involve performing such interventions in different storage and inventory spaces and can serve as a means of developing a model for developing a cost-benefit model that could justify such interventions.

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CHAPTER 3. General Conclusion

The quantitative data obtained indicated that the newly organized storage room reduced the amount of time wasted in between finds significantly, as evidenced by the ANOVA and paired t-test of the wasted time before and after the change that revealed p-values of 0.00038 and 0.0005 respectively for a significance value of 0.05. The cost associated with this wasted time was seen to have reduced by 63%. This suggests that adopting the new design would allow the Sheriff's officer to use the money that was once spent on the wasted time in the old system to purchase equipment that could aid the Sheriff's office in accomplishing its tasks and serving the community.

The qualitative data obtained indicated that the new system was more intuitive and easier to navigate through. The surveys indicated that most of the officers found the system more organized, easier to learn and consistent with certain elements of the older system that were preferred by the officers. Making the system consistent was seen as a means of supporting the mental model that the officers already had about the room and the location of various equipment. As a result, the officers did not spend a lot of time learning the new system. Thus, the organized rearrangement of the room, the labels and symbols provided on shelves and cupboards and the consistent design complete with careful mapping of the shelves to afford retrieval of the right items were seen to made the location and retrieval process easy and more intuitive.

The cost associated with the wasted tine was calculated over the whole work day to indicate that operations such as the location and retrieval of items could lead to a waste of time if it is not made as efficient as possible. This would potentially rob the Sheriff's office of precious time that could be used on more important tasks such as solving crimes and serving the community. As a result,

the data this obtained indicates that the area of "organizational engineering" needs to be expanded and applied to other such operations in time-critical settings like law enforcement to allow the agency to spend more time on matters requiring greater attention.

The results of the experiments indicate that using user inputs and user-centered heuristics to redesign a workplace setting is very effective in improving the productivity of the operation. Design the system around the user takes into account the capabilities and limitations of the humans using the system and as such helps the human to perform the tasks associated to the best of their capabilities and in turn improves productivity. The future work should focus on expanding this field to other time critical scenarios with law enforcement and beyond. Additionally, human-centered models can be created that can justify costs and benefits associated with the implementation of such interventions that can expand the adaptation of human-centered approaches to a variety of industry types.

APPENDIX A. Informed Consent Form

INFORMED CONSENT FORM	
Title of Study: An Engineering Approach to Storage and Access in High Prior Scenarios	rity
Investigators: Varun Ananthasivan Srikrishnan (PI- Principal Investigator), Dr. Richard Stone (Research Supervisor)	Τ.
Invitation to be Part of a Research Study	
You are invited to participate in a research study. This form has information to help you de whether or not you wish to participate—please review it carefully. Research studies include people who choose to take part—your participation is completely voluntary, and you can st any time.	cide e only top at
Please discuss any questions you have about the study or about this form with the project s before deciding to participate.	taff
Introduction and Purpose of the Study	
The purpose of this study is to improve the inventory control system in the Story County Sheriff's Office to enhance human performance by enabling easy access and location of cri equipment contained in some of the storage rooms. Through this intervention, this study, we prove how effective and economical human-centric process improvements can be to an organization, specifically high priority ones, in enhancing human performance and improve efficiency of their operations. This study will add a great deal of valuable knowledge to the of human-centered design and Macro-ergonomics and will provide a justification for its application in a variety of industries.	tical rill ing the area
The study is divided into four phases; the control phase, the improvement phase, the experimental phase and the RFID testing phase. The control phase and the experimental ph will further contain three testing scenarios. The participants will be subject to the 'within-subjects' experimental design methodology, i.e. each participant will be tested on all of the scenarios for Phase 1 and Phase 3. The same participants taking part in Phase 1 will be call Phase 3 once all the improvements have been done. Following is a detailed description of three phases:	ase three ed for the
<u>Phase 1: Control Phase-Testing Participants on the existing arrangement of the storage root</u> 1. You will be given one of the three scenarios mentioned below:	<u>ms</u>
 New Hire: A scenario where you will be tasked with giving a newly hired officer essential equipment required for them to begin their duty. This scenario mimics a rescenario where a new hire is given equipment like uniforms etc. that is essential for to be considered officers on duty. Critical, Rarely Seen: A rarely seen but critical scenario like a Riot, where you mus and retrieve all the essential equipment associated with that emergency. Random Search: A scenario where you will be asked to locate random items specifit the investigators of the study. 	al-life them t find ied by
IRB – Informed Consent Pa	tee 1 of 4

Phase 4: Testing the RFID system

This phase involves testing the RFID system by scanning some items and seeing if the count corresponding to the equipment scanned gets updated, identify potential issues, troubleshooting issues and make appropriate changes to the system. This will be followed by the development of a simple manual to help educate the officers in its use. This phase does not require your participation.

Eligibility to Participate

You are asked to participate in the study if you are:

- · 18 years or older,
- · Employed by the Story County Sheriff's Office
- · Able to legally give consent and
- Available to participate for Phase 1 and Phase 3 are asked to participate in the study.

Description of Study Procedures

If you agree to participate, you will be asked to,

- Fill out a pre-study questionnaire
- · Perform one of the three scenarios as specified by the PI and the supervisor
- Fill out post-study questionnaire at the end of phase 3

Expected Time or Duration of Participation:

Your participation will last for 30 minutes per phase. You will be separately invited for Phase 3 a month after Phase 1.

Risks or Discomforts

While performing this experiment, it is possible for you to feel discomfort from lifting and carrying items specified for the three scenarios. Please feel free to let us know if you feel any pain or discomfort during the study.

Benefits to You and to Others

It is hoped that the information gained in this study will convey the functional and economical benefit of incorporating human factors interventions in high priority industries that will enable its adoption in other industries, where designing products or processes on the basis of the capabilities and limitations of humans can greatly improve a organizations overall performance.

Your Rights as a Research Participant

Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences.

IRB – Informed Consent

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If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, <u>IRB@iastate.edu</u>, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Confidentiality

Research records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available without your permission. However, it is possible that other people and offices responsible for making sure research is done safely and responsibly will see your information. This includes auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) which may inspect and/or copy study records for quality assurance and data analysis. These records may contain private information.

To protect confidentiality of the study records and data, the following measures will be taken:

- All participants will be de-identified
- · All the data will be stored in a password protected hard disk
- · Information will be kept between the PI and the supervisor

The video will be in possession of the PI and the supervisor and will not be shared with anyone. Only the times will be used for the research.

Future Use of Your Information

De-identified information collected about you during this study may be shared with other researchers or used for future research studies. We will not obtain additional informed consent from you before sharing the de-identified data.

Questions

You are encouraged to ask questions at any time during this study. For further information *about* the study, contact

Varun Ananthasivan Srikrishnan-<u>vasrikri@iastate.edu</u> Dr. Richard T. Stone-<u>rstone@iastate.edu</u>

Your Consent

By signing this document, you are agreeing to participate in this study. Make sure you understand what the study involves before you sign. If you have any questions about the study after you agree to participate, you can contact the research team using the information provided above.

I agree to take part in this study.

Participant's Name (printed)

Participant's Signature

Date

IRB – Informed Consent

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APPENDIX B. Pre-Study Questionnaire

Pre-Study Questionnaire

- 1. How often do you use this room?
- 2. What circumstances, based on your experience have required you to access the equipment in this room?

- 3. Can you list some items that you take out most frequently?
- 4. Can you list some items that you take out least frequently?
- Have you ever experienced a shortage of equipment when you went to look for something? If so, what was your next course of action?
- 6. Do you see any issues with the existing system? If so, can you list some changes that you would like to see implemented?

APPENDIX C. Post-Study Questionnaire

Post-Study Questionnaire

- 1. What are your thoughts on the new system?
- On a scale of 1-10 (1 being very easy and 10 being very difficult), how easy or difficult did you find the new system?
- 3. Based on the new system, how likely on a scale from 1-5 (1 being least likely and 5 being most likely) are you to recommend such interventions for various operations at SCSO and other industries?

Are there any issues with the new system? If so, please list some things that could help us improve the system.