Improving Safety of Human-Robot Interaction

OMB Control No. 0920-xxxx

NEW

Supporting Statement Part A –

Justification

Project Officer: Justin Haney, Ph.D.
Title: Associate Service Fellow
Phone: 304-285-6179
Email: poe5@cdc.gov
Fax: 304-285-5866

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Part A. Justification

Goal of the study: Determine how physical characteristics of robots (e.g. size and speed) impact human movement behavior, perceived workload, and trust, when working together in a shared workspace.

Intended use of the resulting data: Findings from this study will be useful in refining voluntary consensus standards for industrial robot systems by improving the design and modeling of robots to reduce human-robot collisions.

Methods to be used to collect: The data collection will take place in the CDC Virtual Reality Research Laboratory, using a virtual reality simulator.

Subpopulation to be studied: Adults who have previously worked or currently work in the manufacturing industry and live in Morgantown, Pittsburgh, or the surrounding areas, with varying job experiences. This study will utilize 78 research participants. Additional participants, up to 33, will be recruited if needed to replace dropouts due to simulator sickness.

How data will be analyzed: Repeated measures analyses of variance will be used to examine effects of robot size, movement speed, and movement trajectory on human behaviors, task performance, and self-reported safety measures, mental workload, and trust. Tables and figures will be generated to illustrate the differences between the conditions and any interaction effects.

The Centers for Disease Control and Prevention (CDC) requests OMB approval of a new research project for the National Institute for Occupational Safety and Health (NIOSH) for a three-year period.

A.1. Circumstances Making the Collection of Information Necessary

This is a new information collection request (ICR) from the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). The request is for three years to complete data collection. This data collection is authorized by Occupational Safety and Health Act of 1970 and the Federal Mine Safety and Health Act of 1977 (Attachment A). The 60-day Federal Register Notice was published on 08/26/2020 (Attachment B) and is further discussed in Section A.8.

The manufacturing industry is the largest market for industrial robots [IFR 2017]. U.S. manufacturing workers, who numbered approximately 15 million in 2015, may be put at risk of injury if/when their workplaces introduce robots. Safety concerns associated with industrial robots are expected to increase, as more small and medium-sized manufacturing companies will use an increasing number of robots in the near future. The guidelines on physical barriers that have protected human workers from potential injuries resulting from unintended contacts with traditional caged robots are no longer applicable to many new robots. There is an increasing need for adequate safety measures to prevent unintended contacts between human workers and robots [Murashov et al. 2016; Robotics VO 2016; Sheridan 2016]. Manufacturing workplaces adopting emerging technologies may expose workers to higher risks of injuries due to unfamiliarity with emerging technologies or relevant safety practices. Similarly, mobile robots (or sometimes called autonomous mobile robots), initially used in warehousing, have been introduced to various work settings. Mobile robots are designed to operate alongside human coworkers, sharing walkways and aisles, and maneuvering around working machinery and operators.

While there has been a proliferation of robotics research, most attention has been given to technological advances (e.g., robot sensor and control technology) and limited research has specifically addressed the safety of humans working with robots. Given the rapid growth in the use of collaborative and mobile robots, it is of interest to improve safety of human-robot collaborative operations. Current standards and guidelines for industrial robot safety do not consider human movement. These knowledge gaps need to be addressed because human behaviors during collision or near-collision situations may intensify or lessen collision risks or impact forces [HSE 2012]. For instance, movements of humans relative to the robot may increase collision likelihood or raise forces to levels which cause greater injuries. To address these knowledge gaps, NIOSH has initiated a laboratory simulation study on effects of robot

size, speed, and movement trajectory on human behavior, perceived safety, workload, and trust.

A.2. Purpose and Use of the Information Collection

The outputs from the study will be science-based information on the effects of individual features of robots on human behaviors and perceptions. The empirical data generated by the successful completion of the proposed study will improve our understanding of the factors that critically influence human-robot interactions in a collaborative work environment. Specifically, we will determine certain robot sizes, movement speeds, and trajectories, that increase trust and perceived safety, and decrease mental workload. These data could be useful in design and modeling of robots and robot functions to reduce human-robot collisions as a result of improved robot navigation and movement, enhanced human-robot interfaces, reduced human workers' workload, and increased trust. The study findings will be useful for refining voluntary consensus standards for industrial robot systems, including ANSI/RIA R15.06 (safety requirements for industrial robots and robot systems), ISO/TS 15066 (technical specification for collaborative robots), and ANSI/RIA R15.08 (in development, safety standards for industrial mobile robots).

A.3. Use of Improved Information Technology and Burden Reduction

The data collection involves the use of a virtual reality simulator. The virtual testing environment can simulate task scenarios performed in manufacturing operations involving mobile and collaborative robots within the work areas, as well as, robots with varying physical characteristics and robot movements. Conducting the experiment in virtual reality will reduce data collection time and thus decrease the burden to the respondents. Also, the simulator-based data collection can obtain realistic data without exposing participants to physical harm, which reduces injury risk of study participants.

A.4. Efforts to Identify Duplication and Use of Similar Information

We conducted a literature search in 2017 on challenges involving safety in human-robot interaction. Recent advancements in robotics have been far more significant than in the past three decades. There is a need for research to ensure adequate protection of workers from the safety risks associated with new and emerging types of robots. Current standards and guidelines for industrial robot safety do not consider human movement. These knowledge gaps need to be addressed because human behaviors during collision or near-collision situations may intensify or lessen collision risks or impact forces. Additionally, this study addresses stakeholders' need for research on safe and effective human-robot interaction. The Advanced Robotics for Manufacturing (ARM) Institute explicitly includes human-robot interaction as one of the technology gaps in their 2017 Project Call.

A.5. Impact on Small Businesses or Other Small Entities

No small business will be involved in this data collection.

A.6. Consequences of Collecting the Information Less Frequently

This is a one-time data collection.

A.7. Special Circumstances Relating to the Guidelines of 5 CFR 1320.5

This request fully complies with the regulation 5 CFR 1320.5.

A.8. Comments in Response to the Federal Register Notice and Efforts to Consult Outside the Agency

A. A 60-day Federal Register notice was published in the Federal Register on 08/26/2020 Vol. 85, No. 166, pp. 52604-52606 (Attachment B). No comments were received in response to this notice.

B. In 2017, the NIOSH research team consulted with members from academia and industry to assist in the concept and design of this study including, Dr. David B. Kaber, Distinguished Professor and Research Director of the Ergonomics Center at North Carolina State University and Dr. Bob Grabowski, Deputy Chief Technology Office for The Advanced Robotics for Manufacturing (ARM) Institute.

A.9. Explanation of Any Payment or Gift to Respondents

Respondents will be compensated a gift card of $30 value per hour for the study. Gift cards will be furnished at the end of the study visit. It will take approximately 6 hours for a participant to complete the study using the virtual reality simulator to complete the manufacturing task scenarios. If respondents withdraw their participation during the study, they will receive partial compensation at the rate of $30 per hour in gift cards. The use of incentives is necessarily for two main reasons. First, data collection will occur in the NIOSH Morgantown facility. The study population will be people who currently work or had worked in the manufacturing industry, with varying job experiences. Participants are to travel to the data collection site to participate in the study. In addition, manufacturing workers are considered a hard-to-reach study population for their work schedule and maintaining a stratified sampling plan is critical to the scientific validity of the study. Use of incentives in this study is warranted.

A.10. Protection of the Privacy and Confidentiality of Information Provided by Respondents

The NIOSH Information Systems Security Officer reviewed this submission and determined that the Privacy Act does not apply. Potential participants will be informed that their participation is voluntary, and they may withdraw their consent and participation in this study at any time. Participants who decide to participate in the data collection for the study will be required to sign an Informed Consent Form. Participants do not need to reveal their names, except for signing the consent form. The personal information that is collected for the study is limited to birth date, gender, motion sickness level, whether they're pregnant, and previous job experience, which are used to verify the eligibility for participation. The data collected is assigned to a subject number for identification. Only the project officer and lab technical lead will have the key to the random number assignments. All participant data and personal identifiers in the study will be managed in accordance with the Privacy Act and the NIOSH IRB informed consent procedures. All forms and computer data will be coded with a randomly assigned number to ensure privacy. The link between the identifiers (in the consent form) and the assigned random numbers will be kept in the NIOSH Virtual Reality Research Lab (an access-controlled room) in a locked cabinet for 3 years and will then be shredded. The project officer and lab technical leader will be the only persons with access to the random subject number assignments that link to the consent form. They will be responsible for the secured transfer of custody of the data to a different project officer in the event of a change in job assignment. The consent forms and the "key" of random number assignments will be destroyed 3 years after the study is completed.

The results of the study may be disseminated to robot developers, manufacturers utilizing industrial robots, trade associations, safety professionals, and academia through fact sheets,

recommendations, and guidance for robot and robot interface designs. Summary results will be reported in peer-reviewed journals and other robotic safety forums.

A.11. Institutional Review Board (IRB) and Justification for Sensitive Questions

- IRB Approval
  - The proposed data collection was reviewed and approved by the NIOSH Institutional Review Board (Attachment C).
- Sensitive Questions
  - The study does not contain sensitive questions. The personal information that is collected for the study is limited to name [for participation consent], gender, motion sickness level, whether they're pregnant, and previous jobs experience, which are used to verify the eligibility for participation. The data collected is assigned to a subject number for identification. Only the project officer and lab technical lead will have the key to the random number assignments.

A.12. Estimates of Annualized Burden Hours and Costs

The data collection for the two experiments will take three years in total. Informed consent and the data collection are expected to take 6 hours (total) to complete Experiments 1 and 2 for each participant. The total estimated annualized burden hours are 216. There are no costs to the respondents other than their time.

Estimated Annualized Burden Hours

Type of Respondents	Form Name	Number of Respondents	Number of Responses per Respondent	Average Burden per Response (in hours)	Total Burden (in hours)
Manufacturing Workers	Simulator Sickness Susceptibility Questionnaire	37	1	1/60	1
	Consent Form	37	1	10/60	6
	Participant Data Collection Form	37	1	1/60	1
	Virtual Reality Sickness	37	2	1/60	1

	Questionnaire				
	Robot Experience Questionnaire	37	1	6/60	4
	Actual Experiment 1 – Mobile Robot	37	1	1.16	43
	Actual Experiment 2 – Collaborative Robot	37	1	1.16	43
	NASA Task Load Index	37	63	1/60	39
	Perceived Safety Questionnaire	37	63	1/60	39
	Robot Trust Questionnaire	37	63	1/60	39
Total					216

The estimated total cost for the three years of this information collection is $18,370.80*.

Estimated Annualized Burden Costs

Type of Respondent	Total Burden Hours	Hourly Wage Rate	Total Respondent Costs
Manufacturing Workers	216	$28.35	$6,123.60
Total	216		$6,123.60

* The value assigned for the hourly wage rate is based on the average U.S. hourly wage rate for Manufacturing Workers available in the following information: Bureau of Labor Statistics, U.S. Department of Labor, https://www.bls.gov/iag/tgs/iag31-33.htm

A.13. Estimates of Other Total Annual Cost Burden to Respondents and Record Keepers

No other cost burden to respondents or record keepers

A.14. Annualized Cost to the Federal Government

The NIOSH project team consists of a project manager at $36.76/hour Personnel Salary and Benefits (PS&B) and three technicians averaging at $44.90/hour PS&B.

Annual PS&B for this collection is in the following table.

	Rate Yr 1	Year 1 Hours	YR 1 PS&B	Rate Yr 2	Year 2 Hours	YR 2 PS&B	Rate Yr 3	Year 3 Hours	YR 3 PS&B
Project Manager	$36.76	1560	$57,346	$37.50	1560	$58,500	$38.25	1560	$59,670
Technician 1	$44.90	1040	$46,696	$45.80	1040	$47,632	$46.71	1040	$48,578
Technician 2	$44.90	520	$23,348	$45.80	520	$23,816	$46.71	520	$24,289
Technician 3	$44.90	520	$23,348	$45.80	520	$23,816	$46.71	520	$24,289
Technician 4	$44.90	520	$23,348	$45.80	520	$23,816	$46.71	520	$24,289
	Annual totals		$174,086			$177,580			$181,115
	Grand Total		$532,781						

The total cost to the government for this data collection is expected to be $532,781. Annualized over the 3 year data collection is $177,593.67.

A.15. Explanation for Program Changes or Adjustments

This is a new data collection.

A.16. Plans for Tabulation and Publication and Project Time Schedule

Project Time Schedule	
Recruiting of respondents for Experiment 1 & 2	1-9 months after OMB approval
Information/Data collection for Experiment 1 & 2	3-24 months after OMB approval
Analyses for Experiment 1 & 2	16-35 months after OMB approval
Prepare report for publication	36 months after OMB approval

A.17. Reason(s) Display of OMB Expiration Date is Inappropriate

Not applicable. The OMB expiration date will be displayed

A.18. Exceptions to Certification for Paperwork Reduction Act Submissions

There are no exceptions to the certification.

References

HSE [2012]. Collision and injury criteria when working with collaborative robots. Buxton, Derbyshire: U.K. Health and Safety Executive, Health and Safety Laboratory, RR906

IFR [2017]. Executive summary world robotics 2017 industrial robots. Frankfurt, Germany: International Federation of Robotics, https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf. Date accessed: February 5, 2018.

Murashov V, Hearl F, Howard J [2016]. Working safely with robot workers: Recommendations for the new workplace. Journal of occupational and environmental hygiene 13(3):D61-71.

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Sheridan TB [2016]. Human–robot interaction: status and challenges. Human factors, 58(4):525-32.