A NOVEL INTERVENTION METHOD TO PROMOTE WORKERS' SAFETY AWARENESS AND MENTAL HEALTH DURING HUMAN-ROBOT COLLABORATION

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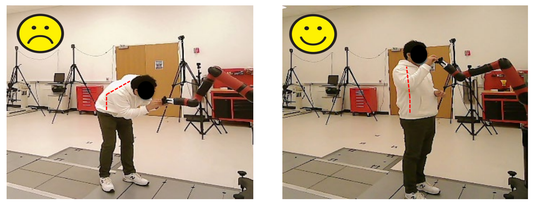
Introduction

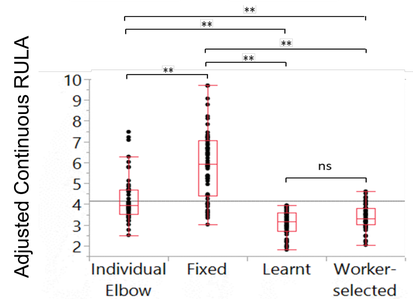
- **Human-robot collaboration (HRC)** is an emerging area that has gained tremendous research interest. Compared to traditional industrial robots, collaborative robots (co-robots) need to be designed with consideration of workers' safety. Particularly, both physical safety and psychological safety of workers should be considered.
- **Research Topic 1**
- Due to the great inter-individual anthropometric variability, co-robots need to be adaptive to workers anthropometric dimension during a collaborative task. We proposed a method that integrates computer-vision and reinforcement learning to allow a co-robot to choose a working location where workers can adopt a body posture that can minimize the risk of developing musculoskeletal disorders.
- **Research Topic 2**
- An HRC task may alter workers' mental states. Therefore, we investigated the mental stress caused by human-robot handover activities using galvanic skin response (GSR) as an objective measurement and task load index (TLX) as a subjective assessment. Several robot-related factors that may lead to mental stress were experimentally examined.

Research topic 1



- We have developed a reinforcement learning algorithm which optimizes worker's posture by changing the end-effector to an optimal location.
- We adopted the ergonomics tool Rapid Upper Limb Assessment (RULA) to evaluate worker's risk.

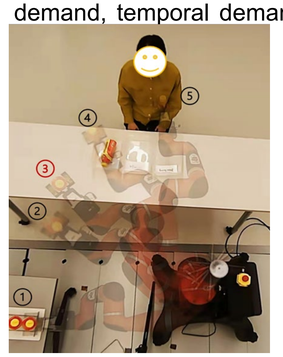
Algorithm

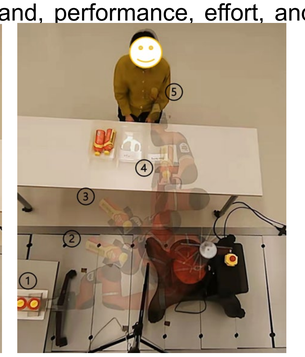


- The proposed method (shown as "learnt" in the figure above) can lead to a significantly lower RULA score compared to the condition where workers work at a fixed height or at individual elbow height.
- The RULA score of the proposed method is similar to that of the self-selected working height.

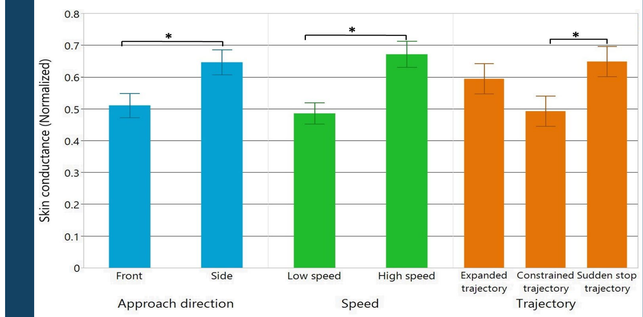
Research topic 2

- During the experiment, the robot end effector picked up a bottle from a ramp and then approached a participant by turning 90° about the vertical axis of its pedestal and handed the bottle to the participant.
- The **independent variables** include
- 1) End effector **approaching direction** toward the participants **(from Front / Side)**;
- 2) End effector **approaching speed** towards the participants **(fast / slow)**;
- 3) End effector **motion trajectory** to hand over the bottle (3 types as shown in the figures below):
- **Expanded trajectory**: (left figure), the end effector moved directly from the bottle storage area to the participant without any retraction. **Constrained trajectory** (right figure): after picking up a bottle, the end effector first retracted back to a location close to the robot pedestal before bringing the bottle to the participants. **Sudden stop trajectory** is similar to the expanded trajectory, but the end effector stopped for 2 seconds in the middle of the moving path (marked as point 3 in left figure).
- **Dependent variables** include **GSR and NASA-TLX**. GSR measures emotional sweat when a human gets nervous by detecting the change of skin conductance. NASA-TLX uses six dimensions to assess subjective workload: mental demand, physical demand, temporal demand, performance, effort, and





- **Skin conductance response**

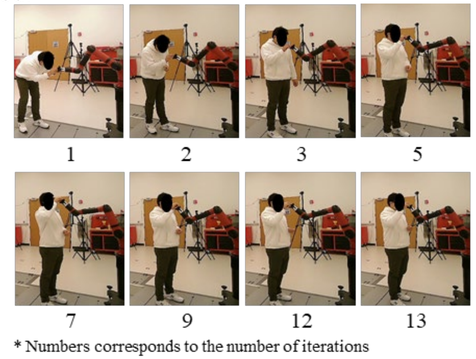


- Significantly increased skin conductance was observed when the end effector approached participants from the side, at high speed, or in an unpredictable trajectory, implying that the mental stress levels were significantly higher under these conditions.
- **NASA-TLX**
- There was no significant difference in NASA-TLX results. One possible reason is that the sample size (n=8) is relatively small at this point. Another possible reason is that the levels of independent variables are too close to lead to a subjectively distinguishable mental stress difference.

Future works

- For research topic 1, a more efficient reinforcement learning algorithm needs to be further investigated. A robot needs 10 to 15 iterations to reach a steady location with the current algorithm. In addition, implementation of customized rewards in the reinforcement learning algorithms should be examined.

Optimized locations over iteration



* Numbers corresponds to the number of iterations

- For research topic 2, additional physiological signals, such as EMG, ECG, EEG, could be further investigated to evaluate mental stress.

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