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Workload of rehabilitation healthcare personnel when assisted by a robot

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The current study investigated how a human-like robot, EVE, can be applied in healthcare services to support personnel in their daily tasks. The focus of the current study was staff workload, since high workload may have adverse impacts on patient safety, job satisfaction and turnover. We conducted a small-scale study with eight participants in a rehabilitation hospital in Norway. The participants were asked to perform professional tasks and pick-up tasks in a simulated setting. In one condition they were assisted by EVE for the pick-up tasks, and in the other condition they performed the pick-up tasks themselves. The findings indicated that when assisted by EVE, the healthcare personnel experienced reduced workload and improved performance. They also reported less time pressure and a possibility to perform tasks with less interruptions and better quality when assisted by the robot. When the healthcare personnel did not have support from the robot, they spent a considerable amount of time outside the patient room, as they needed to fetch the necessary equipment themselves. In the current study, minimal interaction between healthcare workers and the robot was required. Future studies may expand interaction tasks or make them more complex to investigate safe interaction and user acceptance including both staff and patients.

Keywords: NASA-TLX, robotics, nurses, physiotherapists, occupational therapists, rehabilitation hospital.

1. Introduction

A significant increase in the demand for long-term treatment and care is expected in the next couple of decades, especially for rehabilitative and municipality healthcare services. Predictions point to a shortage of healthcare personnel to manage the increased demand. The World Health Organization has estimated that globally, an additional 18 million healthcare workers will be needed by 2030 (WHO, 2016).

A major challenge in the years to come is the high turnover rate. Statistics Norway has reported that after ten years, as many as 20% are no longer employed as a nurse (Skjøstad et al., 2017). Contributing reasons stated for ending their practice as a nurse are high workload and time pressure, understaffing, inconvenient working hours, and low pay (ibid.). Similar findings have been reported in a survey distributed to 6,000 nurses in Norway: When asked about reasons for wanting to quit or change jobs, 69% expressed that the staffing is insufficient, 59% reported high mental workload and 57% reported high physical workload (Sykepleien, 2021). A recent study found that increased focus on professional tasks enabled by robot assistance in non-professional tasks was positively related to overall job satisfaction and thereby reducing turnover intentions (Chang, Huang, Wong, Ho, Wy, Teng, 2021). Healthcare professionals in rehabilitation units have been identified as a potentially high-risk occupational category for job stress and dissatisfaction (Crose, 1999; Elliott et al., 1996; Koerner, 2011) which may have negative consequences for patients and staff. In rehabilitation, multidisciplinary teams are needed to provide complex treatment and care for patients with serious and long-term disabilities and diseases. High responsibilities towards severe suffering patients and associated emotional burden may induce high workload and psychological distress, which increases the risk of errors and burnout (Weissman et al., 2007; West et al., 2018). Thus, measures to reduce workload appear particularly important for healthcare professionals in rehabilitation to maintain patient safety, support job satisfaction and performance.

Assistance from new technology and robotics can constitute one opportunity to alleviate high workload among healthcare personnel. Yet, there are few, if any, robots capable of supporting a variety of tasks and disciplines as presented in a rehabilitation hospital. The current study investigated whether a robot could support nurses, physiotherapists, and occupational therapists in daily tasks such as fetching equipment and bringing patients to appointments. Their acceptance and trust in the robot are discussed in another paper (Kaarstad et al., 2023). The research question for the current study was: How does assistance from a human-like robot, EVE, impact workload of healthcare personnel in a rehabilitation hospital? A brief introduction to workload and robotics in healthcare will be provided below.

2. Related research

2.1. *Socially assistive robots*

Robot technology has been piloted in the health care domain and shown promising results for improving patients' autonomy and for offloading healthcare workers (Vysocky & Novak, 2016; Miseikis et al., 2020; Fernandes et al., 2021). Socially assistive robots (SARs) can support humans through social interaction and include service robots, companion robots, or a combination of these (Bedaf et al., 2015). Some of the robots have human-like features. SARs may support both patients and staff, contributing to better quality of the healthcare services. Previous studies have shown that if implemented correctly and sensibly, users experience these robots as enjoyable and safe to use, which is crucial for successful adoption (Papadopoulos et al., 2020). While many studies are focused on the patient experiences and interaction with robots, impacts on workload and performance among healthcare professionals are less understood, with mixed results being reported. This motivated the ongoing study, providing early insights on tasks that may be performed by a robot to assist health care personnel at a rehabilitation hospital in their daily work.

2.2. *Cognitive workload*

Mental or cognitive workload is a complex and multifaceted concept, for which no commonly agreed definition exists. Cognitive workload can be understood as the margin between the mental efforts needed to perform a task and the resources available, i.e., the ratio between demand and capacity (Young et al., 2015). The ratio depends on personal characteristics (age, experience etc.), and environmental factors, such as complexity and time constraints. Workload in the healthcare context can be conceptualized in terms of staff competence and experience; the complexity and intensity of treatment and care activities; the illness severity and patient's dependency on care; and the time available and time needed to carry out the work (Morris et al., 2007).

The NASA Task Load Index (NASA-TLX) scale (Hart & Staveland, 1988) is a validated and widely used self-report measure of workload applied in several domains. A meta-analysis of 87 studies in healthcare showed a mean TLX of 63% for nurses and 40% for physicians in real-life settings, while mean TLX in laboratory settings were 48% and 42% respectively (Hertzum, 2021). The main contributors to workload in health care settings were typically mental demand, temporal demand, and effort. The mean TLX reported from real-life healthcare settings is comparable to other domains, but some studies reported a mean TLX of 70% or more for hospital nurses (Herzum, 2021).

Introducing new technologies such as robotics may alleviate the workload of healthcare professionals. However, in a recent study of neurorehabilitation, physiotherapists reported significantly higher workload with support of robotic-assisted therapy compared to traditional therapy (Gilardi et al., 2020). Studies of robot assisted surgery have reported lower workload for surgeons, but increased workload for other team members (see Catchpole et al., 2019 for a review). The mixed results could possibly be explained by the degree of interaction with the robot and its ease of use. Sometimes new technologies are introduced with the best intentions, but if they are cumbersome to use, they may just add additional workload to the user, especially in the early adoption phase.

3. Method

3.1. *Participants*

Eight employees, five women and three men, at a rehabilitation hospital participated in the study. The sample included four nurses, two occupational therapists, and two physiotherapists. Their average age was 40 years (min 31, max 52), and their average work experience within the health sector was 16,5 years (min 7, max 28). The participants´ average experience at the rehabilitation hospital was 9,3 years, and their experience in the current role ranged from 1 to 21 years.

3.2. *The robot EVE*

The human-like robot EVE, developed by 1X, was applied in the current study (see Fig.1).

Fig.1: The robot EVE. Picture from 1X.

It is a flexible platform that has a head with a face (eyes and mouth), movable arms, and can move on three wheels. The robot is approximately human-size (180 cm tall) and has humanlike manipulation capabilities through its arms and a selection of hands. It can be remotely operated using manual controls or virtual reality (VR) controls. In the current study, the robot was controlled remotely by use of virtual reality from a separate room close to the location where the study was conducted.

3.3. *Scenarios*

Prior to this study, interviews with nurses identified frequent, non-medical tasks a robot could perform to assist healthcare personnel in their daily work. Fetching equipment and bringing patients were identified as tasks requiring a lot of time that would alleviate staff workload if being performed by a robot.

Due to staff being very busy during their workday, we planned a data collection that would not keep them away from work for more than one hour in total. We created scenarios lasting for 10 minutes, representing a snapshot of their working day.

All participants were exposed to one scenario in two conditions, with and without the robot. Each condition included two pickup tasks. In the first condition, without the robot, the participants were supposed to perform the pickup tasks themselves, while in the second condition, the participants were supposed to get the robot to perform these tasks. In addition, the participants were given some primary tasks, as displayed in Table 1, that they had to carry out within the 10 minutes duration. The participants were instructed to perform secondary tasks if they had time. These were approximately the same for all staff and included: patient examination; follow-up and planning; tidying; take notes; and talk with the patient.

Table 1. Tasks for the participants.

Participants	Pickup tasks	Primary tasks
Nurses	Blood pressure monitor New patient	Measure and document blood pressure Assist with meal
Occupational therapists	Stocking pullers and grippers Notes/PC	Supervise dressing Give water
Physio-therapists	Transfer board and slide Notes/PC	Supervise chair transfer Give water

The order of conditions was the same for all participants, i.e., having the robot available in the second condition. This enabled observations of their current way of working prior to introducing assistance from a robot. The scenarios were video recorded.

3.4. *Procedure*

The study was conducted in a training apartment (patient room with kitchen and bathroom) in a secluded area within the facilities of the hospital. Each participant was introduced to the researchers, the robot EVE, the purpose of the study and data to be collected prior to signing an informed consent. They were told that the robot is not yet autonomous, but for this study controlled by an operator through VR technology.

Before the scenario started, the participants were informed about the physical and medical status of their patient, a spinal cord injured woman with incomplete tetraplegia (C7 AIS-C). Since the study was focused solely on healthcare personnel, two members of the research team alternated to play the patient. They were familiar with the spinal cord injury and conducted dry-runs prior to the study to ensure that the patient behaved as realistic and consistent as possible.

The participants were informed about the tasks they were expected to complete within the ten-minute scenario, as displayed in Table 1. During the scenario, the participants could monitor the time in a stopwatch placed visibly in the room. The research team announced the start and stop of each condition and ensured the same task duration for the pickup tasks for all participants. The study was designed in such a way that when the participants performed the pickup tasks themselves, they did not have to walk the actual distance, but waited outside the training apartment for a predefined time based on actual walking durations (2 mins for picking up equipment, 4 mins for picking up patient or notes/PC).

In the second scenario condition, the participants called the robot, which spent the same time to perform the pickup tasks as the health personnel. A short introduction on how to call the robot was provided prior to the condition. The participants called the robot through a touch interface, with the predefined tasks displayed. When one of the tasks were selected, the operator controlling the robot was notified and ensured that the robot provided what the participant asked for.

The robot did not use speech communication or facial expressions during the study but raised the right hand if greeted by the participant. The robot pressed an actuator button to open the door; placed the equipment on a table inside the training apartment and left the room. The next patient was brought to the door opening, sitting in a wheelchair. Thus, there were no actual interaction between the staff and the robot in this study.

After each condition, the participants were asked to fill in questionnaires. When both conditions and questionnaires were completed, semi-structured interviews lasting for about 20 minutes were conducted.

3.5. *Data collection and analysis approach*

3.5.1. *Self-report workload*

NASA-TLX (Hart & Staveland, 1988) was administrated after completion of each scenario run, i.e., two times for each participant. It consists of six items: mental demand; physical demand; temporal demand; performance; effort; and frustration. In the current study, the items were rated by pen and paper in ten steps, ranging from 1 to 10. Raw scores were converted to percentage prior to statistical analyses.

3.5.2. *Video analysis of task duration*

Scenarios were recorded by use of a GoPro HERO 10 black camera mounted on a tripod, capturing the patient and staff present in the training apartment used in the study. Videos of scenarios, with and without the robot available, were analyzed using the free and open-source Behavioral Observation Research Interactive Software, BORIS (Friard & Gamba, 2016). In total, 30 annotation codes were specified in an ethogram to capture behaviors by the staff, patient, and the robot. Some codes were created as 'point events' referring to behaviors with short durations (1-3 seconds), for which the purpose was to capture the frequency of events, e.g., patient requests for assistance. Most codes were 'state events', for which the start and stop of the behavior was annotated, e.g., measuring blood pressure; conversation between patient and staff; and treatment activities. Often, several behaviors occurred in parallel. The frequency and durations of annotated events were exported in tabular format to Excel and Statistica for statistical analyses.

3.5.3. *Interviews*

The interview focused on the participants' experience and perception of advantages and disadvantages when carrying out the tasks with and without support from the robot. The data from the interviews were used to support the interpretation of results from the workload questionnaire and the videos. The interview analyses followed a similar approach as the directed qualitative content analysis (Hsieh & Shannon, 2005). The interviews were transcribed, and statements related to workload were highlighted and categorized into themes corresponding to the six items in the NASA-TLX questionnaire. For example, expressions related to stress/internal stress were categorized as mental demand, whereas time pressure and hectic workdays were categorized as temporal demand. Statements related to experiences in the study itself and statements related to their real everyday working life were included in the analysis.

4. Results

4.1. *NASA-TLX*

An unweighted average of the six items in NASA-TLX were calculated for all participants and compared for the two conditions 'no robot' (M = 38.5%, SD = 13.8%) and 'robot' (M = 25.4%, SD = 6.5%), A repeated measures ANOVA indicated significantly higher workload when the staff did not have the robot available ($F(1,14)=5.963$, $p=.028$). The robot impacted temporal demand ($F(1,14)=15.33$, $p=.002$) and performance ($F(1,14)=6.222$, $p=.026$), while remaining workload dimensions revealed smaller differences between conditions (n.s.). The health care staff reported higher temporal demand when not having the robot available, and better performance with access to the robot, see Fig.2.

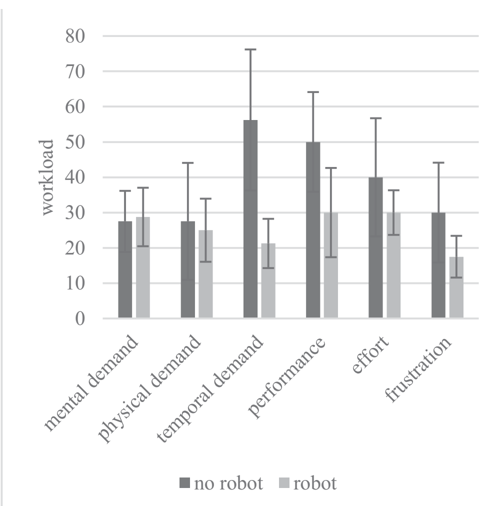

Fig.2: NASA-TLX dimensions in two conditions, with no robot (dark grey) and robot (light grey) available. Error bars denote 0,95 confidential intervals.

4.2. *Task completion times*

Video analyses showed that nurses spent approximately the same amount of time (about 2 minutes) on their primary tasks while being assisted by the robot. The physiotherapists and occupational therapists utilized their extra time available to conduct more training together with the patient. Fig.3 shows that the time spent on treatment was almost doubled in conditions with the robot available for these participants. Nurses, on the other hand, spent more time on talking with the patient when having the robot available, see Fig. 4.

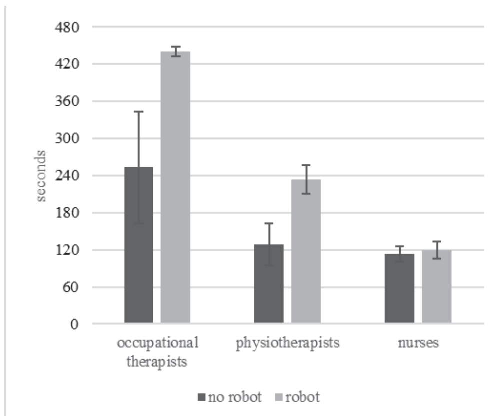

Fig.3: Duration of primary tasks for occupational therapists (supervise dressing), physiotherapists (supervise chair transfer), and nurses (assist with meal and measure blood pressure). Error bars denote standard deviation.

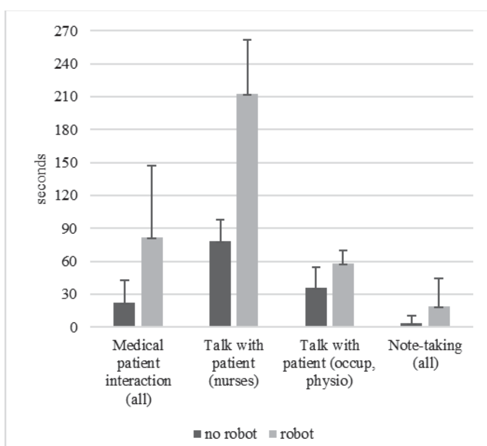

Fig. 4: Examples of secondary task durations.

For nurses, talking with the patient included how the patient handled the injury, and discussion of nursing needs when the patient moves home. For the other health care professionals, talking with the patient included conversations between staff and patient beyond the performance of care and treatment tasks. Medical patient interaction (see

Fig. 4) included patient examination and follow-up planning. Note-taking included staff making handwritten notes of observations, decisions, and future actions. Error bars denote standard deviation.

Although results indicate individual variation, medical interaction, and documentation (notetaking) appeared to have longer durations with the robot available for all participants. Since the sample size is small and tasks may not be fully comparable for nurses, occupational therapists and physiotherapists, inferential statistical analyses were not conducted on task durations.

4.3. *Interviews*

From the individual interviews with eight participants, 76 statements concerning workload were identified, see Table 2.

Table 2. Workload (WL) statements

WL category	Frequency	Percent
Mental demand	6	8
Physical demand	14	18
Temporal demand	22	29
Performance	19	25
Effort	6	8
Frustration	9	12
Total	76	100

Regarding mental demand (6 statements), most participants mentioned that they often feel internal stress, and believed they would feel less stressed with support of a robot. All participants mentioned considerable physical demand (14 statements) as nurses, occupational therapists and physiotherapists spend much of their working time traversing long distances in the hospital to e.g., pick up equipment, meet new patients, and accompany patients to different appointments. Concerning effort (6 statements), participants mentioned that they often are drawn in all directions and feel like they must run back and forth all the time. Some also expressed frustration (9 statements), particularly in situations when they need assistance from a colleague, and the colleague then must leave his/her patient to help out.

Most of the input from the interview concerned aspects related to temporal demand (22 statements) and performance (19 statements). In the scenarios with support of EVE, the personnel expressed that they had better performance, as they could spend more time interacting with the patient. The therapists mentioned that they often need to interrupt training with patients to pick up equipment during their daily work. This breaks the concentration in the treatment sessions. With support of a robot, they felt that they could perform their intended patient-related tasks with better quality, less interruptions, and reduced workload.

5. Discussion

The purpose of the current study was to investigate whether a robot could support healthcare professionals in daily tasks at a rehabilitation hospital. The NASA-TLX showed reduced workload, i.e., lower temporal demands and better performance, with assistance from the robot EVE compared to a similar situation in which the staff had to perform all tasks themselves. The interviews support this finding, as the participants felt less time pressure and a possibility to perform their tasks with less interruptions and better quality. In both conditions, the unweighted mean of the six NASA-TLX dimensions was quite low compared to previous studies (below 40%, compared to 48% and upwards reported by Hertzum, 2021). The condition in which participants performed all tasks themselves was not fully realistic in terms of physical demands, as participants did not have to walk several minutes to fetch equipment and patients but waited outside the appartement. Walking the actual distances may have been reflected in higher ratings of physical demands, and thereby workload. Nevertheless, the results suggest higher workload compared to getting assistance from a robot performing these tasks. Furthermore, the duration of both scenario conditions may have been too short to induce workload comparable to what healthcare personnel experience in their daily work. The scenarios and data collection were also decoupled from the normal work. Thus, any accumulated workload throughout the working day would probably not contribute to the load experienced during the study.

All participants appeared to have more time to perform their primary and secondary tasks, when they had the robot available for the pickup tasks. This is not surprising, as the actual time spent within the room together with the patient was much longer in the condition with the robot. When the healthcare personnel did not have support from the robot, they spent a large proportion of the scenario time outside the apartment, picking up equipment. The participants appeared to regulate their efforts and mental demands in terms of adapting tasks to the time available. The fixed order of conditions, in which all participants were exposed to the condition without the robot prior to having the robot available, may have introduced a learning effect in terms of better understanding of resource demands and the time available when performing tasks the second time, supported by the robot. However, the nurses seemed to have sufficient time to perform their primary task in both conditions, while the occupational therapists and physiotherapists adapted the primary task execution to the time available.

Previous studies report mixed results regarding workload and performance in the healthcare sector when introducing robotic technologies, (e.g., Gilardi et al., 2020; Catchpole et al., 2019). The mixed results may have several explanations such as technological maturity and the extent to which users need to continuously interact with or operate the robots. The pickup tasks used in the current study may relieve employees in a busy working day but could also have been carried out by other means. Thus, the actual human-robot-interaction was not targeted, but rather the effect of being assisted in certain pickup tasks that otherwise take a lot of time and effort to perform. Therefore, we do not know at this point, whether comparable workload reductions could be achieved by other technological or organizational measures.

However, human-like robots, as the one being tested, provide advantages in complex environments developed for humans and human work processes. Their human-like capabilities and characteristics may enable more flexible and diverse deployment areas compared to robots that are developed for specific tasks, for example within logistics, cleaning, and telemedicine. Thus, a single robot may assist staff and patients in a wide variety of tasks and situations. From the workload data, the video analyses, and the interviews, we found that the employees benefit from and appreciate robot assistance. Our findings support that having a robot available for pickup tasks may have a positive effect on workload, especially regarding performance and temporal demands. It appears that by receiving such assistance, the healthcare personnel report reduced workload, which in the long run also might positively affect their wellbeing, job satisfaction and performance (Chang et al., 2021). Thus, it is reasonable to suggest that robot assistance has the potential to enhance patient safety and improve the quality of patient care.

6. Conclusion and further work

The current study investigated the impacts of a human-like robot, EVE, on the workload of healthcare professionals in a rehabilitation context. Results of our study must be interpreted with caution due to the small sample size and abovementioned limitations. Still, the self-report workload scores and feedback in interviews indicated that participants experienced support from the robot and improved performance while using it. Follow-up studies should consider longer scenarios and include physical demands such as walking to fetch equipment or move between patients. The scenarios may also include more complex and simultaneous tasks such as alternating between several patients, and repeatedly requesting the robot for support. Future studies could also compare assistance from a human-like robot with other types of robots, alternative technological or organizational measures. Finally, counterbalancing test conditions would reduce carryover effects.

In the current study, the robot performed fetching tasks that required minimal interaction between healthcare workers and the robot. Future studies on human-robot interaction may expand these tasks or create situations that imply more coordination and communication between the robot and its end-users, e.g., investigating acceptance and workload impacts of the robot failing in some way, such as providing the wrong object or getting lost. In addition, the robot may move around in the hospital to fetch equipment and hand it over to patients and staff. This will require further research into user acceptance, and how the robot can safely interact with physically and cognitively impaired patients. Tasks involving sustained interaction or co-presence with end-users enable in-depth analyses of human-robot interaction, situational trust, ease of use and usefulness, as well as longer-term impacts on work processes, job performance and satisfaction. Our study suggests that robots can support healthcare personnel in non-professional tasks, and thus alleviate workload. However, more research is needed to identify requirements for successful human-robot interaction in healthcare involving both staff and patients.

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