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Human Centered Assistance Applications for the working environment of the future

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Abstract.
BACKGROUND: Social, technological, and legal changes imply new solutions to support the human worker in the industrial environment of the future.
OBJECTIVE: Optimizing working conditions by adapting collaborative assistance systems in terms of human acceptance and well-being. The Institute of Ergonomics at the Technische Universität München (TUM) follows this approach with three novel technical solutions: Exoskeletons (Lifting Aid), collaborative robots (Cobot), and orthosis (Assembly Glove).
METHODS: Fundamental scientific knowledge in cognition, anthropometrics, biomechanics, and physiology provide the basis for user-oriented designs and investigations via respiratory analysis, motion tracking, force measuring, and simulation.
CONCLUSIONS: The human, with its abilities, flexibility, and knowledge, will still be the key success factor in future working environments. Hence holistic approaches that support the human in a complementary way to raise overall performance have to be evolved to handle upcoming challenges like demographic change, a diverse workforce, and high stress jobs.

Keywords: Human Centered Assistance Applications, exoskeleton, collaborative robot, Cobot, orthosis, Human-Robot Interaction, Human-Robot Collaboration, factory of the future

1. The concept of Human Centered Assistance Applications (HCAA)

1.1. Facing future challenges requires action instead of reaction

Today, three prime innovation drivers require rethinking in novel working environments. In the first place, there is the main role of the society. Demographic changes and an increasing awareness of a diverse workforce unveil a certain call for action. Classic ergonomic solutions are no longer sufficient because of decreasing physical abilities and high stress jobs [1]. Hence, human resource development and management will be one of the biggest challenges in future working systems like production and logistic environments [2]. Decreasing physical abilities and increasing musculoskeletal disorders (MSDs) with age state reasons for ergonomic, age related, and health preserving work for every person. The Federal Institute for Occupational Safety and Health (BAUA) announced that over 7.6 million employees in Germany, which means 17.8% of the whole employed population (42.85 million people) with residence in Germany [3], have to handle heavy loads. Heavy loads are defined as higher than 10kg for women and higher than 20kg for men, respectively, in their daily work routine [4]. Especially in the age group of over 60 years, MSDs are one crucial type of illness that may result from repetitious handling of heavy

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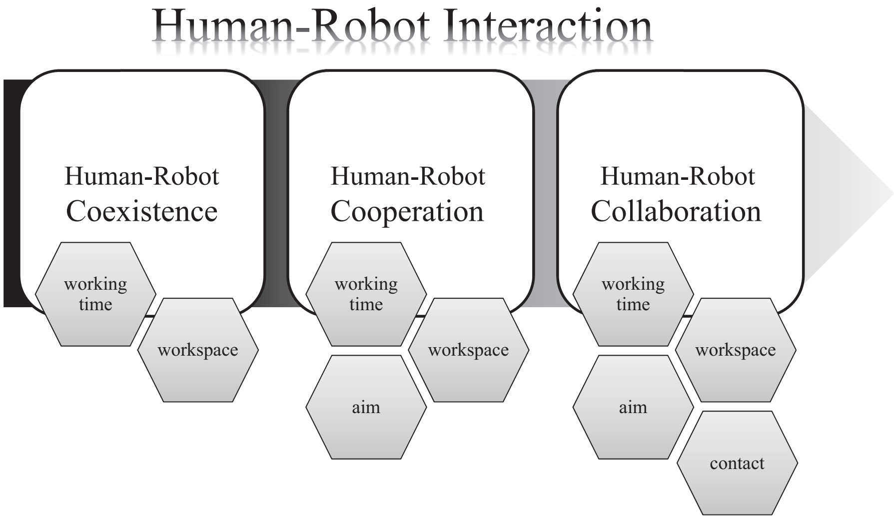


Fig. 1. Classification of Human-Robot Interaction in terms of working time, workspace, aim, and contact.

loads. The health insurance company DAK-Gesundheit published in 2013 that 30.1% of the main types of illness in the age group over 60 in Germany are MSDs, while in the group of 25–29 year old workers only 14.6% MSDs were recorded [5]. 25.2% of the total absenteeism of work is caused by MSDs [6] and correlates with an untimely entry into occupational disability [7]. One major reason for diseases of the musculoskeletal system is handling high physical loads in a repetitive manner [8]. Especially in automotive assembly, tasks are repetitive, monotonous, and still need high forces applied by the human [9] in combination with shorter cycle times and simplified tasks that inevitably lead to increasing effects of physical stress [10].

The second prime driver is represented by the industry. Nowadays decisive trends like mass customization [11] and the continuing trend of mechanization and automation [12] seem to be contrary. The first mentioned trend is characterized by a customer-orientated product and production planning. This can cause decreasing lot sizes and an increasing variety. In most situations modern automation cannot fulfill the required flexibility to this day and the presence of the human worker will still be necessary. Lotter and Wiendahl [13] propose a hybrid system, capable of the aforementioned flexible scope, where humans interact with automated systems (e.g. robotic assistance systems) to gain the expected flexibility and simultaneously productivity.

Last but not least, laws and standards like the DIN EN ISO 10218-2 [14] enable and promote a closer interaction between human and robotic systems.

1.2. Human-Robot Interaction the basis for novel assistance systems

In 2013, with an increase of 12% to 178,132 units per year, the highest number of industrial robots ever were sold [15]. Especially the automotive, chemical, rubber, plastics, and food industries participated in the purchases. This ongoing increase will strengthen the pursuit of new production systems with improved working conditions. The robotic partners will take heavy and repetitious actions of the shoulders of their human colleagues. In contrast to today's work systems, humans and robots respective automation will not only work side by side, but as dyads and teams. This future interaction, also referred to as Human-Robot Interaction (HRI, Fig. 1), began with a complete separation of human and robots.

Humans deployed and programmed the automated systems at a designated workplace. Fences, barriers, and other safety environments ensured that no human could get harmed and the robotic system could proceed with its predetermined tasks. But like every handy tool, robots also have undergone an evolution of functionality and are still gaining more capabilities in order to reach higher efficiency as well as safety.

This evolution now enables hybrid systems consisting of co-working humans and machines in the production branch as well. Human-Robot Interaction (HRI), as a general term for all forms of interaction between human and robot [16], can be seen as an umbrella term for this kind of hybrid system and subdivides itself into several subcategories (Fig. 1). The categorization follows the four criteria workspace, working time, aim, and contact in ascending order. Thiemermann [17,18] describes the overlapping space in the working range of human and robot as the common workspace. The working time is defined as the time the participant is working inside the workspace. Every entity of the interacting team has an aim that he, she, or it wants to achieve. This aim can, like working time and workspace, match or mismatch with the counterpart one. Consequently, if there is a common workspace for both entities and they act at the same time, the HRI can be labeled as a Human-Robot Coexistence (HRCoex) [16]. Human and robot do not necessarily have to have the same aim in HRCoex, as they can operate on very different tasks. In contrast, humans and robots are working on the very same aim in a Human-Robot Cooperation (HRCoop) and fulfill the requirements of time and space (HRCoex) at the same time. Should direct (e.g. physical respectively haptic or auditory) contact between humans and robots occur, the interaction can be labelled as a Human-Robot Collaboration (HRCollab).

1.3. Human Centered Assistance Applications offer physical and cognitive support

In relation to the Human-Robot Interaction model, the concept of *human centered assistance applications* (HCAA) for production, established at the Institute of Ergonomics at the Technische Universität München (TUM) [19], can be seen as part of a Human-Robot Collaboration because of the direct physical contact between the human and assistance system. Three approaches – Lifting Aid, Cobot and Assembly Glove – are consolidated within this common research focus. On the basis of cognition, anthropometrics, biomechanics, and physiology, the objective is to facilitate work by reducing time and strain while increasing efficiency of the task and effectiveness of the process in production environments and logistics. The human, with his needs and skills, is the center of the observations at all times.

1.3.1. Exoskeleton – Lifting Aid

The Hybrid Assistive Limb® (HAL) [20] is one of the most advanced exoskeleton assistance systems which has been developed in cooperation with the University of Tsukuba (Japan) and the Japanese company CYBERDYNE. Controlled by nerve signals, sensors attached to the skin forward the information to electric motors at the joints, which trigger an assisted movement of the muscles. The HAL is now tested in hospitals and will be applied to help in cases of emergencies or disaster [21,22]. The University of California-Berkeley (USA) researches in the field of exoskeletons in the military and health care sector (especially for disabled persons) [23,24]. Two representative exoskeleton systems for rehabilitation are the ReWalk® of Argo Medical Technologies Ltd. [25,26], a body-worn lightweight system, and the StringMan developed by Fraunhofer IPK in Berlin [27,28] which is a wire rope based non body-worn system. Gebhardt Logistic Solution GmbH, a German logistics company, developed an assistance system called EcoPick® to support lifting tasks which occur during the process of manual picking of pallets [29]. One disadvantage of the wire rope system is that it is mounted on ground conveyors and is, thus, restricted in its degree of freedom and movability. Strong Arm Technologies, Inc. tried to avoid these disadvantages and developed a body-worn vest that supports the upper body in particular, but did not consider an economic or anthropometric force application. Due to this fact, forces assisted by the Strong Arm Vest are initiated in the back of the wearer [30]. One crucial solution in the field of exoskeletons for an industrial use may be the Muscle Suit, presented by the Koba Lab of Tokyo University of Science [31,32]. Originally, the suit was developed to assist nurses in carrying heavy loads [33].

The above compiled list does not claim any completeness, but it indicates that the main research fields for exoskeletons involve areas like military, rehabilitation, healthcare, and, with an increasing portion nowadays, also the industrial sector. It can be admitted that numerous systems focus on the effects on the human body caused by repeated manual handling tasks and can be transferred from one area to another. However, today's systems for use in rehabilitation predominate the devolvement of exoskeletons and can be seen as pioneers. To optimize the working conditions by reduction of the forces acting on the human musculoskeletal system, two main research objectives have to be considered. First, it is imperative that the forces produced by the exoskeleton are introduced economically into the human body and minimized where it is possible; and, second, the validation of assistance by evaluating the reduced stress for the group of users caused by using the Lifting Aid.

1.3.2. Collaborative robot – Cobot

This part of HCAA is concerned with collaborative robots also called cobots or intelligent assist devices (IAD). They represent a class of handling systems most commonly used in automotive assembly. The word cobot was first introduced by Michael Peshkin and J. Edward Colgate at Northwestern University, USA. The main innovation that comes along with cobots is the combination of characteristics of industrial robots and handheld manipulators [34]. Cobots interact directly with their human counterpart handling a payload collaboratively [35]. That is possible because, unlike their industrial robot predecessors, they are not separated from humans because of safety issues. Via strength amplification, inertia masking, and guidance with virtual surfaces [36], they are able to improve ergonomic working conditions, product quality, and productivity [35]. In that way, cobots facilitate handling tasks by supporting the human not only physically, but also in a cognitive manner and, as a result, increase efficiency of the task and effectivity of the process itself.

While the human operator is in direct contact with the cobot, or the handled payload, the feedback experienced in the form of a reaction force is decisive for the performance of the handling process. According to that, the investigation of human characteristics while performing pushing and pulling tasks with power assisted and force amplified systems is one main research topic in the field of HCAA. It is crucial to design the haptic feedback like it is most natural for the human operator, ideally as if the worker performed the task manually [36]. Hence, the reaction force should not physically overexert the human operator but still not demand too little from the worker. Therefore, the overall goal is to enable a flexible operator centered adjustment of the Cobot to the physical abilities and needs of each individual in the field of sensomotorics as well as cognitive skills. Push and pull maneuvers can serve as basic movement patterns and should be investigated in terms of collaborative scenes, human dyads, and psychophysics.

1.3.3. Orthosis – Assembly Glove

Tasks in modern production environments are not always accomplished only by handling heavy payloads, but also by using the human's finest part for difficile assembly, packing or other fine-motor tasks: the hand. Of course safety of the human worker comes first in manual assembly, so protection is needed. Gloves should shield the hands in a variety of different task requirements; but only passive prevention from outside impacts, vibration or heat is not sufficient enough to prevent the human worker from injuries. Especially in areas like automotive assembly, the whole upper limb of the human body is stressed. In the case of the hand, the thumb, for example, used to push plugs into the bodywork of a car, is exposed to high physical strain. Special developed working gloves, divided into active and passive support systems for one or more fingers as well as the whole hand and arm system, can handle the aforementioned safety issues. It can prevent extreme wrist postures and musculoskeletal disorders of the upper limb while ensuring higher efficiency of the process itself.

Although Johansson et al. [37] and Bulthaup et al. [38] couldn't prove a decrease in muscle load wearing orthoses, the transmission of an acting force to less sensitive body points can bring relief with it for the human worker. With new technical approaches, like hand exoskeletons, an active support could increase the strength of fingers and hands. They are also able to semi-automate hand motions and assist the hand function by amplifying gripping strength [39]. Orthosis are lighter and sleeker than current hand exoskeletons which can be one major advantage in enabling assembly work. The Assembly Glove will improve tasks by transferring loads passively from fingers and wrists to more stable and tougher body parts. With semi-active parts, like pressure sensors, quality improvement of the whole assembly process could be tracked and reported, under consideration of data-protection of each user, back to the worker or production planer.

The research objective of the Assembly Glove concentrates on the physical support in manual operations by optimizing force progressions and feedback. By studying working actions, motions, and forces the support will be evaluated and used for modelling and simulation.

2. HCAA Interaction from the human factor perspective

2.1. HCAA Interaction model

Gordon Cheng [40], a pioneer in the development of body-worn exoskeletons, once said: "When we drive a car, the car becomes an extension of our body schema. When we eat, it's the knife, fork or chopsticks. It's the same with the exoskeleton." This extension relies on the optimal interaction of human and HCAA and is mainly influenced by the Human-Machine Interface (HMI). Rühmann and Bubb [41] postulated a Man-Machine System (MMS) that describes the interaction between human and technology as a control loop. The collaboration between human and HCAA picks up on this idea and proposes the HCAA Interaction Model – shown in Fig. 2. Starting with the task to fulfill a common goal, human and assistance system get in a close bi-lateral communication via a HMI. The produced outcome of this action will be looped back to the human and the machine as an input via several feedback channels (haptic, auditory, visual) on which the two partners will react to get to the desired results. The environment that, of course, represents one confounding variable will be out of consideration at that moment.

The research focus of HCAAs, represented as the developer in Fig. 2, focusses on decreasing operation times and stress while increasing the efficiency of the interaction process and is characterized by three operations. Via the fundamental sciences cognition, anthropometrics, biomechanics, and physiology, a huge database can be provided to describe human acceptance and well-being (Chapter 2.2) while interacting with novel assistance systems. In cases of HCAA, present and new knowledge will be gathered to design the HMI in a human-centered way. To ensure the above mentioned goals of time, stress, and efficiency, the performance of the technical side in the MMS will be influenced and optimized (Chapter 2.3).

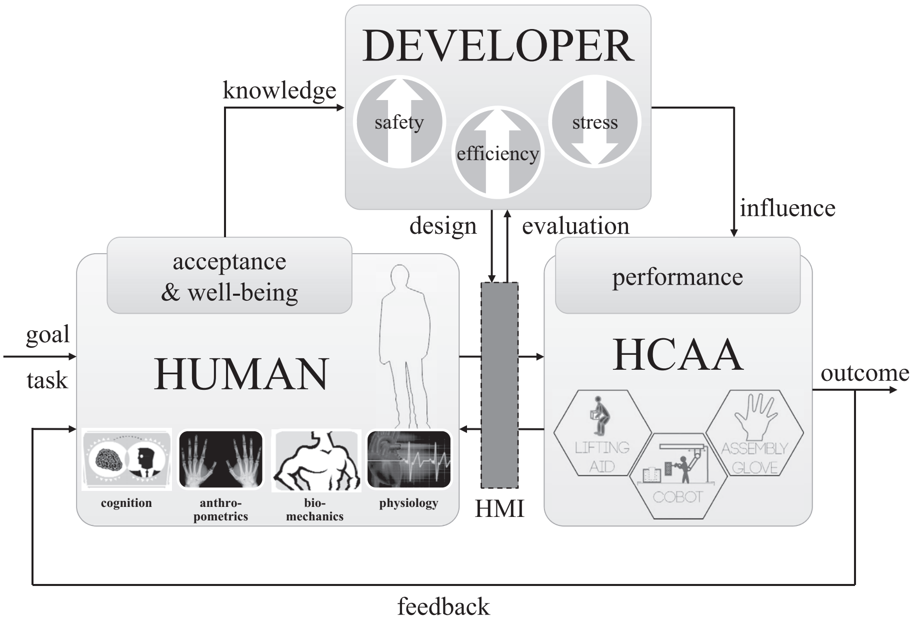


Fig. 2. Human – HCAA Interaction Model; adapted from [41].

2.2. Acceptance & well-being of novel assistance applications

Many existing assistance systems in production and logistics are ergonomic tools that enable the worker to perform a certain task easier and in an ergonomic way. However, one major problem with new working tools may be the acceptance to use them and realize that they help in a time and health manner. It has to be taken into account that high efficiency, acceptance, and well-being are strongly interconnected [42]. If the balance between capabilities and challenges (both physical, psychological, and social) shifts in a way that human well-being is lowered this will very likely result in lower performance. As a consequence, the performance influencing factors, describable by the aforementioned fundamental sciences, should be investigated that the experience of well-being can be influenced. In addition to that, the workers have to trust the assistance system to enable an efficient interaction [43]. Assuming the two factors' well-being and trust can be ensured by well-designed HMIs, it is crucial to gain knowledge about these points and describe their influencing parameters.

2.3. Performance influencing factors and methodological approaches

Bortot [16] provides a holistic overview of performance and well-being influencing factors in HRCoex scenarios in his dissertation. Bortot postulates a classification for depending factors based on, among others [44,45] in robot behavior (TCP-working height, robot trajectories, noise level), visual appearance (size, color, type), robot velocity, task & information, distance, and human demographic parameters (gender, age, anthropometrics, expertise). But these points do not exactly fit on HRCollab and HCAAs. As said before in the area of HRCollab, there is direct contact between the operator and assistance system, resulting in a sensible reaction force. Sensing the intention of the human operator and echoing the adapted feedback is of central importance. This feedback should be designed like it is most natural for the human operator and must not demand too little to still keep up an intuitive haptic, or in other words, kinesthetic feeling of the handling process. Furthermore, the resulting stress has to be evaluated and designed in an ergonomic, process-related, and situation-dependent way. As a third scope of performance influencing factors, free and restricted motion or motion guides (virtual walls or guidance) can be decisive for an ergonomic collaborative manipulation [46]. If there are constraints, provided that the human operator can apply forces in comfortable directions, guidance (with friction, or frictionless) can direct the load to the goal configuration. It is crucial to design the above-mentioned parameters in a particular way so that the operator is aware of the situation and the whole process and so that the worker accepts what is happening and, as a result, can perform at high levels.

2.3.1. Respiratory analysis

As part of the development of HCAA, it raises the question of how evidence of load reduction for manual handling of loads can be provided. First approaches show the use of cardiopulmonary exercise testing (CPET) for the analysis of lifting activities already in combination with support systems because lifting activities are not only musculoskeletal stressful, but also affect the cardiovascular system [47] and the ventilation in the human body [48]. CPET, which makes it possible to perform a respiratory gas analysis, has been used in different areas for quite some time. Medical science is concentrating, in particular, on the analysis of lung diseases [49,50]. Also, for studies in the field of sports, CPET is used to determine the personal performance of individuals [51–54]. In the field of occupational ergonomics Lehmann et al. [55] examined various professional fields with the Douglas Bag and the respiratory gas meter. In particular, for the application of an assistance system, the investigations of [56] and [57] are of major priority. Both examine lifting movements – supported by a passive assistance system – using the method of cardiopulmonary exercise testing.

As part of a study, the CPET-method was used at the Institute of Ergonomics to examine the influence of the type of a lifting motion on the workload. The study was performed at a replicated logistics workplace. By using a mobile breath-by-breath-CPET-system, the stress of the participants was determined while performing standardized lifting tasks. After a 10-minute adaptation phase, the respiratory parameters were measured while resting. Then the participants had to perform nine lifting movements that differed in the handling weight (0.375 kg (tare); 6.5 kg; 13 kg) and in the movement pattern in randomized order. The following movements had to be completed for each weight: Lifting a box from 0 cm to 150 cm (BS), lowering a box from 150 cm to 0 cm (SB) and carrying a box from 75 cm to 75 cm (NN). Three repetitions were summarized as a load phase per movement and weight. After each loading phase, an adequate regeneration-period followed while the Borg-RPE-scale was used to get subjective assessments of workload. 21 subjects with an age of M = 26.5 years (SD = 8.2) participated in the study. At 28.6% more than a quarter of women took part in the study.

As shown in Table 1, the above mentioned types of lifting motions at a constant weight show significant differences ($\alpha = 5$ %) in a one-way repeated-measures ANOVA in the stress, which is derived from the oxygen consumption based on the subjects body weight ($V'O_{2/kg}$). Post-hoc results according to Bonferroni are also visualized in Fig. 3. It can be summarized that the type of movement has significant influences on the stress. This is an important aspect that should be considered in a methodology for the evaluation of novel HCAA that should cover a reasonable set of test scenarios.

2.3.2. Force measuring

To enable an optimum interaction between human and collaborating system, the knowledge of applied forces during the working process are invaluable. Force measurement can be done with the help of several systems (direct or indirect force measurements) [58,59]. Once the external forces and movements

Table 1
Significant influence of different movement pattern on the stress measured by the V'$O_{2/kg}$

$V'O_{2/kg}$	F	df	p
0 kg	58.686	1.571, 31.417	0.000
6.5 kg	77.193	2, 40	0.000
13 kg	99.943	1.565, 31.297	0.000

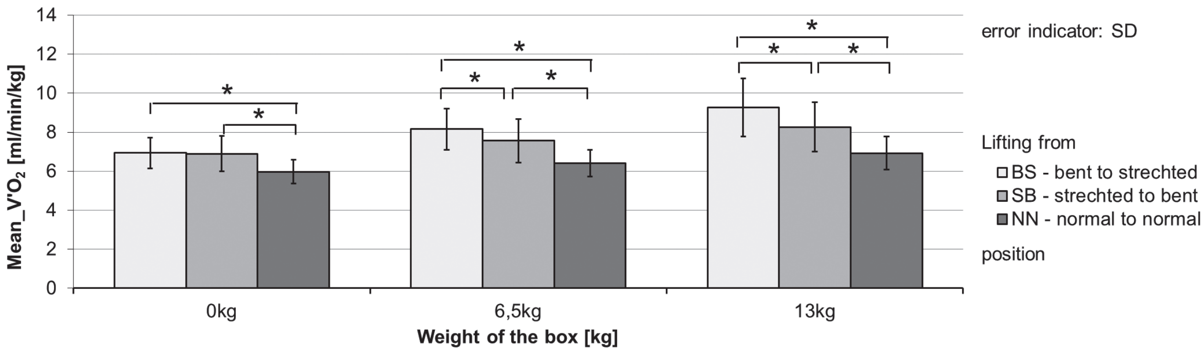


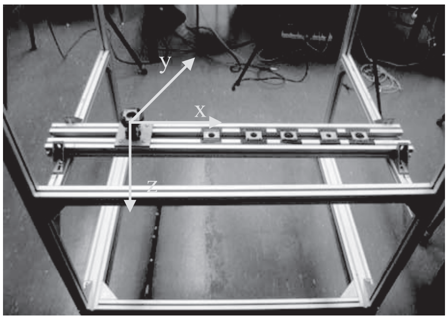
Fig. 3. Mean values of V'$O_{2/kg}$ in ml/min/kg while lifting boxes with the same weight and different types of movement.

are conducted, stresses and strains can be investigated with the help of detailed musculoskeletal models [60,61]. Results of the analysis help create a support that enables the worker to adapt the right amount of force in the process and, therefore, reduce physical loads, as the applied forces are often higher than required.

In an exploratory experiment the forces applied during manual assembly processes were investigated. Subjects were asked to perform a contact grip like it was proposed in [62]. In the conducted study the contact grip was applied on common plugs used for automobile bodyworks at a height of 70 cm and varying distances from the worker. The trial took place in a laboratory setting. Figure 4 shows the design of the test bench containing a three-component-load-cell (Type 9347 B).

Each subject performed 6 assemblies for any of three positions (proximal & straight, distal & straight, proximal & lateral) as well as five maximum thrust force trials in the proximal & straight position. Subjects could use either fingers, thenar or thumb for the plug installation. The participants were instructed that good quality of the connection plug to notch was valued higher than quickness. Force over time of the force components (x, y, z) and the resulting force as well as the peak of the resulting force (PF) were analyzed. The peaks of the 6 trials were averaged for each subject to a mean peak force (mPF) per subject. Standard deviations of mPF were analyzed as well to investigate individual differences in force application. The recorded forces were compared to recommendations from literature to allow conclusions about the difference between applied and recommended [63] as well as accepted force [64].

The results indicate that PF are varying strongly between subjects and positions. At this point results for the straight and proximal position only are presented. Figure 4 shows the mean peak forces (mPF) as well as the maximum pushing forces for each subject. The mPF ranged from 81 N for Subject 3 in the lowest up to 214 N for Subject 2 (M = 147.65 N; SD = 31.25 N). Furthermore the results show high variation of the peak forces not just between subjects but also for each subject within trials, indicated by high individual standard deviations (Fig. 4). Recommended and accepted forces from the literature vary due to repetitions as well as tasks. For highly repetitive motions, defined as 8 contact grips per minute, recommended forces are approximately 50 N [63]. The measured forces are 30–150 N higher



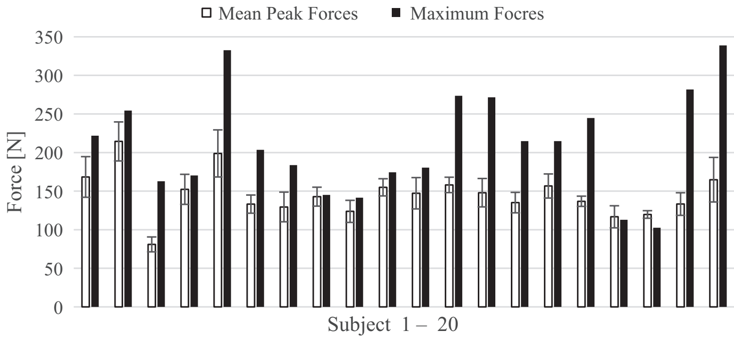


Fig. 4. Left: Design of the test bench for the subject trial; Right: Mean peak forces and maximum pushing forces for each subject in the proximal and straight position, error bars indicate the standard deviation.

compared to the assembly specific force atlas [63]. Potvin et al. [64] investigated maximal acceptable forces for manual insertions, of 50–60% of the maximum forces depending on the task frequency as well as the grip posture. Only one subject in the presented study is located within the range Potvin et al. [64] proposed. Subject 3 works with approximately 54% of the maximum force. The remaining subjects show vastly higher individual loads than recommended as acceptable [64]. Furthermore the results match the analysis of health statistics that show 4.5 times higher stresses for the thumb then the rest of the fingers for assembly workers.

The study shows that force measuring is one key aspect to analyze existing work situation to gain knowledge about the human side of the HCAA Interaction as well as preparing a test bed for validating new assistance systems although intraindividual and interindividual differences are remarkable.

2.3.3. Motion tracking

The identification and interpretation of human motion characteristics is an important point in understanding human needs and intentions to provide a transparent behavior and intuitive operation while experiencing physical support through novel assistance systems [19]. The study and design of human motion models, to individualize the collaborative systems through a flexible adaption to the operator and process properties, is critical for the success of the system.

Motion tracking systems that initially provide Cartesian coordinates [65] can be used to gather motion parameters like velocity v, acceleration a, and jolt j [66] to evaluate quality and performance of HRCollab. In addition to that, accuracy parameters, like mean lateral position MLP and standard deviation lateral position SDLP [67,68], can be adopted from the automotive realm. By researching these and new motion tracking parameters, it is possible to achieve more profound knowledge of how a comprehensive collaboration could look like and provide new evaluation techniques for haptic interactions.

In Schmidtler et al. [66] motion tracking was used to record data for velocity, acceleration, and jolt while maneuvering a trolley laden with three different object sizes (small – medium – large) and three invisible weights (0 kg – 20 kg – 60 kg) to induce a size-weight illusion [69]. Via the motion data it could have been shown that the humans' expectation about feedback is highly influenced by the size of the object they have to handle in pushing and pulling tasks using the whole body. The median values depicted in Fig. 5 for velocity, acceleration, and jolt are significantly influenced by the size-weight illusion (one-way ANOVA, Table 2). Post-hoc comparisons using Bonferroni indicated that the aforementioned motion parameters for the conditions 20 kg_medium and 60 kg_small were significantly higher from 0 kg_large ($p < 0.05$, one exception: acceleration 20 kg_medium, $p = 0.78$). For the two conditions

Table 2
Significant influence of a size-weight-illusion on v, a, and j while pushing and pulling a trolley [66]

	F	df	p	η_p^2
velocity	4.609	1.386,23.610	0.031	0.213
acceleration	4.041	1.386,23.561	0.044	0.192
jolt	4.516	1.430,24.310	0.032	0.210

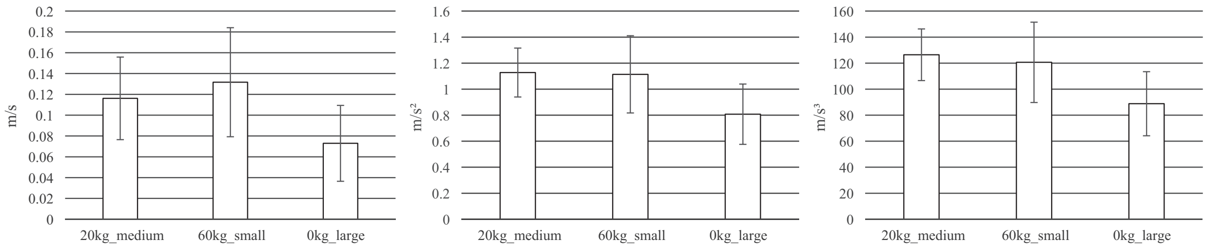


Fig. 5. Velocity v [m/s], acceleration a [m/s^2], and jolt j [m/s^3] for three loading conditions 20 kg_medium object, 60 kg_small object, and 0 kg_large object; error bars depict the 95% confidence interval [66].

20 kg_medium and 60 kg_small no significant difference could be found. In conclusion via motion tracking it could be shown that humans accelerate faster (jolt), higher (a), and get to higher velocities (v) when the trolley is laden or more specifically when a certain amount of force (higher than 30N in this study [66]) is necessary. If the system meet this requirement humans are liable to accelerate in a comparable way.

These results indicate that important principles for the design of novel HRCollab applications can be developed with the help of motion tracking. Further investigations will not only focus on the longitudinal but also on the transversal quality, like the above mentioned track quality (MLP, SDLP) of handling tasks. In that way it can get possible to describe human behavior in an appropriate way and design HCAA interfaces following these descriptions.

3. Conclusion

Today's challenges, like demographic change, a diverse workforce, mass customization, and automation, call for a rethinking in novel production and logistic facilities. Classic ergonomic solutions are no longer sufficient in handling heavy and repetitive tasks. Human Centered Assistance Applications should close this gap by supporting the human worker to reduce physical as well as cognitive stress. As the processes in future working environments will increase in their complexity, high flexibility could become a key success factor. In the context of a simple, natural, and intuitive operation, HCAAs focus on a comprehensive interaction of human and technology via different levels of dominance and task allocations. By implementing the presented proposal of assistance systems, a significant reduction of physical and cognitive stress can be achieved. Decreasing physical performance because of an older workforce will still be manageable. Handling tasks in difficult and varying situations can especially be performed by anybody and will include mental experiences that improve during a working life.

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