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Version 3.0.1

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## 1 Additional Information

### 1.1 Version Management

#### 1.1.1 Version Overview

<table>
<thead>
<tr>
<th>Version</th>
<th>Comments</th>
<th>Date</th>
<th>Responsible</th>
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<td>1.0</td>
<td>This version includes a description of the races and initial description of eligibility criteria for the pilots and the assistive devices.</td>
<td>02 Nov 2021</td>
<td>Lukas Jaeger</td>
<td>completed</td>
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<tr>
<td>2.0</td>
<td>This version includes the descriptions of the tasks in all disciplines.</td>
<td>05 Apr 2022</td>
<td>Lukas Jaeger</td>
<td>completed</td>
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<td>3.0</td>
<td>This version contains more detailed definitions of the tasks, including revised rules and specifications of task infrastructure. Any changes from version 2.0 are highlighted in orange.</td>
<td>31 Aug 2022</td>
<td>Lukas Jaeger</td>
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<tr>
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<td>Rule ROB-4 deleted since it was conflicting with rules ROB-5 to ROB-8. Otherwise, this version is identical with 3.0</td>
<td>5 Sep 2022</td>
<td>Lukas Jaeger</td>
<td>completed</td>
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Document versioning
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2 Preamble

With the aim to further stimulate the development of assistive devices that are tailored to the needs of the end users with respect to activities of daily living, CYBATHLON continues to challenge developers of assistive devices and the end-users of the devices (pilots) with adapted and new disciplines.

Based on version 2.0 of the Races & Rules for CYBATHLON 2024 (5 April 2022), the present version 3.0 includes more detailed specifications of the tasks in each competition discipline. Learnings from additional testing and feedback from the teams has been considered as much as possible.

In each discipline, the tasks are listed in the order which is currently planned for the competition in 2024. Changes to the current order are possible due to logistical reasons or to optimize race presentation in the stadium.
3 Introduction

Since the inaugural event in 2016, CYBATHLON has challenged pilots and device developers alike pushing the boundaries of assistive technology. The new project period sees the continuation of the original six competition disciplines and the addition of two new disciplines in the areas of assistance robots and vision assistance technologies.

While the competition tasks for CYBATHLON 2016 and 2020 were specified to a very high degree, tasks for CYBATHLON 2024 will be designed with task-specific uncertainty in most disciplines. Compared to previous competitions, this will require improved control, faster/advanced dynamics, increased functional flexibility of the assistive devices and more ad-hoc selection of the task solving strategy by the pilots as compared to previous competitions. The aim of adding variability to the competition tasks is to better account for daily life situations, where the exact circumstances of a given task are not always known, or constant over time and across different locations. For example, handrails can be located on the left or on the right of stairs, steps can vary in height and length, or items can sit in entirely different ways in a bag when they should be grasped.

The new and adapted competition tasks will build on the performances of the teams in the previous CYBATHLON competitions and recent technical developments in the field. Feedback from the teams, pilots, and other stakeholders on previous tasks is always considered when developing new competition tasks. At the same time, many of the basic principles of previous CYBATHLON competitions will continue to define the character and nature of upcoming events. For example, the competition tracks, divided into individual, independent tasks for most disciplines, proved to be a suitable approach to test and showcase specific functions of assistive technology. This set-up also proved valuable in exemplifying some of the pilots’ particular challenges in daily life to the audience in a tangible and approachable way. The scoring principle of prioritising assistive device function (task points) over execution speed (task time) was also confirmed to make sense from a daily life perspective.

Aspects such as the competition mode and the procedures to organise, govern, and run the competitions will be determined based on the learnings from past events and adapted to the aims and format of future editions of the CYBATHLON. Safety and fairness have the highest priority.
4 General definitions & rules

4.1 Definition of terms

- **Team**: An entity with the goal to develop an assistive device and to participate in a CYBATHLON competition.

- **Team official**: Accredited member of a team (e.g., pilot, team manager, support person) who contributes to the development of the assistive device or to the participation of the team in a CYBATHLON competition.

- **Team manager**: Team official who is responsible for the overall organisation and management of a team in a specific discipline.

- **Pilot**: Team official meeting the eligibility criteria and participating in the races of a specific discipline.

- **Backup pilot**: Team official meeting the eligibility criteria who takes the role of the pilot if the (primary) pilot drops out or withdraws from participation.

- **Support person**: Team official with specific expertise who supports the team in a specific area (e.g., technician, communication specialist, therapist).

- **Care person**: Team official who is a member of the pilot’s social network who helps with activities of daily living.

- **Assistive device**: A technical unit designed and developed to assist a person with a disability to perform specific tasks.

- **Technology provider**: Person or legal entity that provides the assistive device developed for and used in a specific discipline. The technology provider can be a research laboratory, a company, or a private individual. The technology provider is usually also the developer of the assistive device.

- **MedCheck**: A predefined process designed to systematically verify that pilots fulfil the general and discipline specific eligibility criteria and to ensure that participation is safe from a medical perspective. The MedCheck is conducted by neutral medical examiners appointed by the CYBATHLON organising committee who will keep the provided information confidential.

- **TecCheck**: A predefined process designed to systematically verify that an assistive device fulfils the general and discipline specific eligibility criteria, and to examine the risks for the pilots and their environment related to the use of the assistive device. The TecCheck is conducted by neutral technical examiners appointed by the CYBATHLON organising committee who will keep the provided information confidential.

- **Spotter**: A person accompanying the pilot during the race to prevent them from falling, to help them stand up or leave the track. A spotter is trained to only intervene in case of an imminent risk to the pilot or its environment.
• Referee: CYBATHLON official at a competition hub who is responsible for judging the behaviour of the pilot during task execution and enforcing the general and task specific rules during a race run.

• Timekeeper: CYBATHLON official at a competition hub who is responsible for measuring the time it takes the pilot to attempt the competition tasks during a race run.

• Competition task: Single stage of a racetrack reflecting a specific daily life challenge of a given discipline. Each task is defined by a set of infrastructure, a task space, and a set of rules. The rules define the criteria for successful completion or failure of task execution.

• Race run: A timed attempt of a single pilot to solve the entire set of competition tasks of a given discipline.

• Competition: The entirety of all races of a given discipline.

• Race direction: The most direct route between start and finish line.

• Task infrastructure: all elements defining a task

• Task objects: Parts of task infrastructure that must be manipulated by the pilot to solve a task.
### 4.2 Competition disciplines

The CYBATHLON competition consists of the following eight disciplines:

<table>
<thead>
<tr>
<th>Discipline Name</th>
<th>Discipline abbreviation</th>
<th>Discipline icon</th>
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<td>Brain-Computer Interface Race</td>
<td>BCI</td>
<td><img src="BCI.png" alt="BCI Icon" /></td>
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<td>Functional Electrical Stimulation Bike Race</td>
<td>FES</td>
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<td>Arm Prosthesis Race</td>
<td>ARM</td>
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<td>Exoskeleton Race</td>
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<td>Wheelchair Race</td>
<td>WHL</td>
<td><img src="WHL.png" alt="WHL Icon" /></td>
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<tr>
<td>Vision Assistance Race</td>
<td>VIS</td>
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</tr>
<tr>
<td>Assistance Robot Race</td>
<td>ROB</td>
<td><img src="ROB.png" alt="ROB Icon" /></td>
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</table>

Overview of CYBATHLON competition disciplines
4.3 General Rules

The following General Rules (GR) apply to all CYBATHLON disciplines:

GR-1 A team must consist of a technology provider and a pilot. Further team officials are allowed. Each team must be managed by a team manager.

Comment on GR-1: In exceptional cases, the team manager and the pilot can be the same person. The team manager and the technology provider can be the same person.

GR-2 A team and its team officials must meet the conditions outlined in the team registration section of the CYBATHLON website.

GR-3 A team can only participate in one discipline. Only one pilot can participate per team per discipline.

Comment on GR-3: To compete in several disciplines, the same institution can register more than one team.

GR-4 Teams shall provide their pilot(s) with sufficient training of the competition tasks prior to a competition to make sure that they are accustomed to the tasks.

4.4 General competition rules

GR-5 Pilots must use their dedicated assistive device for the entire duration of the competition. i.e., the assistive device may not be used by other pilots during the same competition.

GR-6 It is not allowed to exchange pilots (i.e., pilot and back-up pilot) between different race runs of the same competition.

GR-7 It is not allowed to exchange the assistive device (or components thereof) or to modify its function during the competition. Maintenance or repair using identical spare parts is allowed. Minor adjustments that do not affect the basic functions or safety of the assistive device (e.g., change the gearing of an FES bike) are allowed after the assistive device has passed the TecCheck – as long the parts used for these adjustments have been declared in and passed the TecCheck.

GR-8 Between race runs, any team official can maintain or replace components of the assistive device. If components are replaced, only identical replacement parts must be used.

GR-9 All components (e.g., batteries, control units, tools, spare parts) that are used during a race run must be carried by the pilots from the start to the
end of the race run. All components must be listed in the description of the assistive device handed in for the TecCheck.

GR-10 During a race run, only the pilots may maintain or replace components of their assistive device.

GR-11 During a race run, direct or remote control of the assistive device by any other person than the pilot is not allowed.

GR-12 Wireless communication between components of the assistive device is allowed. Wireless communication between the assistive device and computers beyond the race run (e.g., local computer, server or similar) is allowed provided that the communication is only used for data monitoring, recording or emergency shutdown of the assistive device.

GR-13 During a race run, the pilot must not be supported by another person or a service animal (e.g., a service dog) in solving tasks or parts thereof.

Comment on GR-13: Cases in which a pilot must be accompanied by another person or a service animal for medical reasons will be assessed by the organising committee individually.

GR-14 During a race run one team official can travel alongside the pilot on the competition field in a dedicated area (accompanying person). Unless otherwise specified in a rule of a specific discipline, the accompanying person can verbally interact with the pilot (e.g., for coaching). In case of any physical intervention of the accompanying person with the assistive device (e.g., in case of a technical defect or an emergency) the race run is terminated for that pilot. The pilot’s current score is then taken as the score for that race run (see also GR-38).

GR-15 Radio communication between the pilot and any team official or any other person is not allowed during a race run.

GR-16 In certain disciplines spotters must supplement the general safety precautions during the race run.

GR-17 Pilots must be ready for their race run at the time and location communicated by the CYBATHLON organising committee. If not, the pilot is not allowed to start the race run.

GR-18 Pilots must be prepared to start their race run when instructed to do so. Any undue delay results in the disqualification from the race run.
4.4.1 BCI

4.4.1.1 Scoring

GR-19 A race run is finished in any of the following instances:

(1) The pilot crosses the finish line of the last task.
(2) The time limit of the race period is reached.
(3) The maximum number of warnings is reached.
(4) A violation of a rule mandates termination of the race run.

The pilot’s score at the moment the race run is finished is considered for the final ranking.

GR-20 If a pilot is issued three warnings within the same race run, the race run is terminated for that pilot. The pilot’s current score is taken as the score for that race run. Each warning is communicated to the pilot and is indicated on the video screen.

4.4.2 FES

4.4.2.1 Scoring

GR-21 A race run is finished in any of the following instances:

(1) The time limit of the race period is reached.
(2) The pilot declares to end the race.
(3) The maximum number of warnings is reached.
(4) A violation of a rule mandates termination of the race run.

The pilot’s score at the moment the race run is finished is considered for the final ranking.

GR-22 If a pilot is issued three warnings within the same race run, the race run is terminated for that pilot. The pilot’s current score is taken as the score for that race run. Each warning is communicated verbally to the pilot.

4.4.3 ARM, LEG, EXO, WHL, VIS, ROB

4.4.3.1 Competition infrastructure

GR-23 The race runs take place on a racetrack that consist of discipline-specific tasks. The area of the task (task space) is defined by a start line, two side-lines and a finish line. These lines must be perpendicular to each other.

GR-24 The length of a task is 5.00 ± 0.005 m. The width of a task is 2.95 ± 0.005 m.
GR-25 The start and the finish line as well as the sidelines of a task must stand out clearly from the ground.

GR-26 At a given competition site, the elements of the competition tasks must be built up on an even and solid surface. Additional flooring may be used.

Comments

- If not stated otherwise, all dimensions are given in millimetres and weights in kilograms.
- Whenever possible, standard furniture and objects available at IKEA are used in the competition tasks.
- Furniture can be obtained from IKEA where available or built according to task drawings and (online) product specifications of the provider.
- For each task, a list of task infrastructure is provided, including links to external websites. CYBATHLON does not take any responsibility for the changes made by the providers to the linked products.
- Some of the surfaces of the obstacles can be coated to increase friction (e.g., ramps or stones). CYBATHLON applies a paint containing quartz sand. The mixing ratio is 1:0.13, and the grain size is 0.1 – 0.6 mm. Anti-slip tape (e.g., Grip Tape) may be used as an alternative.
- Appendix I gives detailed technical information about the task infrastructure (drawings, dimensions, screenshots, etc.)

4.4.3.2 Race procedures

GR-27 Each race run consists of a countdown period and race period.

GR-28 The start of a race period is valid only if the pilot crosses the start line after the countdown has ended. If the pilot crosses the start line before the countdown has ended the start is not valid, and the pilot will be disqualified from the race run.
4.4.3.3 Scoring

GR-29 Unless stated otherwise in the specific rules of a task, the pilot must cross each task obstacle once as they travel from the start to the finish line of the task.

GR-30 The tasks must be solved in their order of appearance on the racetrack.

GR-31 It is not allowed to retry a task after having passed the finish line of the task, after skipping the task, or after the task is failed.

GR-32 If a task is skipped, the task must be passed on the right-hand side (in race direction).

GR-33 The reference edges of the start, finish, and sidelines are defined below:

Definition of reference edges of the task lines.

GR-34 The start and finish line of a task are considered to be crossed once the following part of the pilot or the assistive device crosses the reference edge:

- ARM: torso of the pilot
- LEG: torso of the pilot
- EXO: torso of the pilot
- WHL: any part of a wheel, track, or leg of the wheelchair
- VIS: torso of the pilot
- ROB: any part of a wheel, track, or leg of the wheelchair or assistance robot

GR-35 A task starts once the pilot crosses the reference edge of the task start line for the first time in a race run.
GR-36 Once a task has been started, the pilot is allowed to cross the reference edge of the start line again as long as the following part of the pilot or the assistive device does not cross the reference edge in its entirety:

- **ARM**: torso of the pilot
- **LEG**: torso of the pilot
- **EXO**: torso of the pilot
- **WHL**: wheel, track of the wheelchair closest to the finish line
- **VIS**: torso of the pilot
- **ROB**: wheel, track, or leg of the wheelchair that is closest to the finish line. If two devices are used, one of the two devices must stay in its entirety within the task space at any time during task execution.

Comment on GR-36: This can become relevant if additional space is required for manoeuvring between the start line and the first obstacle or object of a task.

GR-37 Unless defined otherwise in the discipline specific race rules, a task ends when the pilot crosses the reference edge of the task finish line for the first time.

GR-38 A race run is finished in any of the following instances:

1. The pilot crosses the finish line of the last task.
2. The time limit of the race period is reached.
3. The number of maximum warnings is reached.
4. A violation of a rule mandates termination of the race run.

The pilot’s score at the moment the race run is finished is considered for the final ranking.

GR-39 If a pilot is issued three warnings within the same race run, the race run is terminated for that pilot. The pilot’s current score is taken as the score for that race run. Each warning is communicated verbally to the pilot.

GR-40 In case of race run termination, the pilot must proceed to the finish line of the task without any undue delay. If required, spotters may be asked to intervene and support the pilot to reach the finish line.

GR-41 A task is failed if the reference edge of any sideline of the task space is crossed by any part of the assistive device (including crutches if applicable) or the pilot’s body.
Comment on GR-41: For a sideline to be considered crossed it is not a require-
ment that the ground beyond the reference edge of the side-
line is touched by the pilot or the assistive device.

GR-42 A task is failed if any object of the task touches the ground beyond the ref-
erence edge of the sidelines or the start or finish line of the task space
caused by any action of the pilot.

GR-43 A task is failed if any task infrastructure is moved by the pilot that is not
explicitly asked to be moved by the task specific rules.

GR-44 A task is failed if a pilot touches a red object, enters, or exits a task, or
steps on or beyond the obstacles in a location that is red or that is col-
oured red in the task illustrations with any body part or the assistive de-
vice. In the Exoskeleton Race, the pilot’s crutches are exempt from this
rule.

GR-45 A task is failed if a pilot uses the handrails. This includes the use of hand-
rails to support movement or action or to keep balance by grasping, pull-
ing, pushing or similar, with any part of the body or the assistive device.
Handrails are provided for safety only.

GR-46 A task is failed if it is terminated prematurely by the pilot, by the referee
due to an infringement, or by a physical intervention from a third person,
i.e., a CYBATHLON official or a spotter.

GR-47 Task failure is indicated by a red flag and verbally communicated by the
referee to the pilot (“task fail!”)

GR-48 For each race run, the time to attempt each task is measured and points
are scored if the task is solved successfully.

4.4.4 Ranking

GR-49 Each pilot is ranked relative to the performance of all other pilots of the
same discipline, based on their score and time. To rank the pilots, the fol-
lowing rules are applied:

(1) sum of scored points/total distance reached

(2) time needed to score the points

(3) number of warnings received during the race run

GR-50 If two or more pilots achieve the same total score in the same total time
and the same number of warnings in their race run, they receive the same
final rank.
<table>
<thead>
<tr>
<th>Discipline</th>
<th>Race end</th>
<th>Ranking criteria</th>
<th>Final ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCI</td>
<td>1. Finish line of the last task is reached&lt;br&gt;2. Time limit reached&lt;br&gt;3. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td>pilots ranked relative to the performance of all other pilots in the same discipline</td>
</tr>
<tr>
<td>FES</td>
<td>1. Finish line of the final section is reached&lt;br&gt;2. Time limit reached&lt;br&gt;3. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Distance reached&lt;br&gt;2. Total time taken for distance reached&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>ARM</td>
<td>1. Finish line of last task reached&lt;br&gt;2. Time limit reached&lt;br&gt;3. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>LEG</td>
<td>1. Time limit reached&lt;br&gt;2. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>EXO</td>
<td>1. Time limit reached&lt;br&gt;2. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>WHL</td>
<td>1. Time limit reached&lt;br&gt;2. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>VIS</td>
<td>1. Time limit reached&lt;br&gt;2. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
<tr>
<td>ROB</td>
<td>1. Time limit reached&lt;br&gt;2. Three warnings received&lt;br&gt;4. A violation of a rule mandates termination of the race run</td>
<td>1. Points scored&lt;br&gt;2. Total time taken for scored points&lt;br&gt;3. Number of warnings</td>
<td></td>
</tr>
</tbody>
</table>

Summary of scoring and ranking criteria

GR-51 If a pilot does not agree with a referee’s decision during task execution, they must decide whether to continue or terminate the task. If the task is continued, the pilot must follow the procedures of an appeal against a referee’s decision during a race. If the pilot decides to terminate the task, no appeal can be filed.

4.4.5 Decision instances

GR-52 The CYBATHLON officials (i.e., timekeeper and referee) at the local hub act as the first decision instance, the CYBATHLON competition management acts as the second decision instance and may overrule the first decision instance.

GR-53 In case of any inconclusive occurrence or situation beyond a referee’s decision, rules or regulations, the Head of Competition acts as the final decision instance.
4.4.6 Communication rules

The verbal communication during the races shall be held in the following form:

From the referee to the pilot in the following situations:

- Task fail, e.g., after the violation of a task rule: “task fail”
- Warnings: “warning number X”
- Race stop, e.g., after the issue of three warnings: “race stop”
- Confirmation of correct execution of predefined subtasks: “Ok” (or “Not ok” if referee does not agree with the current execution when the pilot asks for confirmation).

From the pilot to the referee in the following situations:

- Pilot is stuck in a task and requires help by the spotters to do so: “help”
- A pilot suspects a refereeing error and wants to submit an appeal after the race run: “continue task”
- Emergency: “S.O.S” (leads to the stop of the race)

4.4.7 Appeals

GR-54 In case of an occurrence or decision which is considered as unfair by one of the teams, they have the possibility to file a written appeal to the competition management. The regulations and procedures related to the appeals are defined in Appendix II.

4.5 Competition eligibility

4.5.1 Pilot eligibility criteria

Pilots must fulfil the following criteria to be eligible for participation:

GR-55 A pilot must pass the MedCheck.

GR-56 Pilots must be at least 18 years of age on the first day of the competition.

GR-57 Pilots must have sufficient cognitive and communicative abilities to understand the Races & Rules and to follow the instructions of the competition staff.

GR-58 Pilots must meet the discipline-specific pilot eligibility criteria.

Comment on GR-58: Pilots who have more severe disabilities than those defined in the eligibility criteria are eligible to participate, although they
might have a disadvantage in comparison to those pilots who more closely match the eligibility criteria.

GR-59 Participation must be safe for the pilot at any time.

GR-60 If an assistive device (or (a) component(s) thereof) is implanted in the pilot’s body (e.g., electrodes, sensors, osseointegration), the implants must be medically stable for at least six months and free of complications (e.g., infections) prior to and at the time of the competition.

GR-61 If the implanted assistive device or parts thereof are research prototypes, the team must have an approval of the responsible regulatory body governing the institution of the participating team. At the time of the competition the approval must be valid, and it must cover all applications and activities connected with participation in a CYBATHLON competition (e.g., travelling, application outside the lab).

GR-62 Medical information must be submitted by the teams several months prior to the competition in accordance with registration and submission deadlines. If a team does not meet the deadlines, they will be removed from the starting list.

GR-63 Once a pilot has passed the MedCheck, any change to the pilot’s medical condition (affecting discipline eligibility or general health) must be communicated immediately to the CYBATHLON organising committee.

### 4.5.2 Technology eligibility criteria

It is allowed to use a commercial assistive device, a modified version of a commercial assistive device, prototypes, or research devices. In any case, assistive devices must fulfil all the following criteria to be eligible for participation:

GR-64 The assistive device must pass the TecCheck.

GR-65 The assistive device must be safe for the pilot and their environment at any time.

GR-66 Technical, functional, and safety information about the assistive device must be submitted by the teams several months prior to the competition in accordance with registration and submission deadlines. If a team does not meet the deadlines, they will be removed from the starting list.

GR-67 Assistive devices must meet the discipline-specific technology eligibility criteria to be allowed to participate in the competition.
GR-68 After all requirements of the TecCheck have been met, no further changes may be made to the assistive device that would alter its function or its safety.

GR-69 In addition to the predefined review during the TecCheck, additional reviews of a team’s assistive device can be carried out by the technical examiners at any time during the competition. Teams who refuse the review will be disqualified.

GR-70 Assistive devices (or (a) component(s) thereof) that are implanted in the pilot’s body (e.g., electrodes, sensors, osseointegration) are eligible to participate (see also GR-60 and GR-61).

GR-71 The pilot must be able to emergency stop the assistive device at any time during the competition.

GR-72 Combustion engines are not allowed.

Comment

- The assistive device can be operated in manual, semi-autonomous, or autonomous modes.
5 Brain-Computer Interface Race

Brain-computer interface race pilot playing BrainRunners during CYBATHLON 2016

5.1 Introduction

People with complete paralysis of nearly all voluntary muscles of the body (such as after a spinal cord injury at a high cervical level or in a locked-in syndrome) are not able to conduct many activities of daily living autonomously and they are therefore highly dependent on the assistance of care persons. In the case of a locked-in syndrome, the use of eye movements (e.g., blinking) is the only means of communicating with the outside world. Due to the inability to move any part of their body other than the eyes, even user interfaces such as sip-and-puff controllers, head joysticks or tongue drives are not feasible to control for example a wheelchair in the locked-in state. This severely impedes the use of assistive technology.

Brain-computer interfaces (BCI) are a technology that enables the direct communication between the brain and a computer. BCIs detect specific activation patterns of the brain and translate them into control signals suitable to interact with computer-based processes. A person with tetraplegia or a locked-in syndrome could use a BCI as an assistive technology for instance to autonomously steer a wheelchair, control a robotic manipulator, or to use a spelling device to communicate. BCI technology
bears the potential to improve the autonomy and social participation of people for whom current user interfaces are not usable.

## 5.2 Eligibility Criteria

In addition to the General Rules outlined in chapter 4.5, the following specific rules apply for the Brain-Computer Interface Race:

### 5.2.1 Pilots

The pilots must fulfil the following criteria to be eligible for participation in the BCI race:

- **BCI-PIL-1** The result of the pilot’s formal neurological examination using the American Spinal Injury Association (ASIA) International Standard for Neurological Classification of Spinal Cord Injury (ISNCSCI) must correspond to a neurological level of injury of C5 or above (i.e. a spinal cord injury with impairment at and below the neck) as well as an ASIA Impairment Scale (AIS) of A, B or C.

- **BCI-PIL-2** At least 3 out of 5 key muscles (as defined in the ISNCSCI form) in each extremity must have a muscle function grading below 3 (i.e., no antigravity muscle strength).

- **BCI-PIL-3** Pilots are not vulnerable to cyber-sickness, epilepsy, or similar conditions.

### 5.2.2 Technology

The assistive device must fulfil the following criteria to be eligible for participation in the BCI race:

- **BCI-TEC-1** Signal transmission must be unidirectional from the brain to the signal acquisition system. It is not allowed to provide any electric, magnetic, or other type of stimulation to the pilot’s nervous system. Visually evoked potentials (SSVEPs, P300, etc.) must not be used as the source of the input signal for the race unless they are elicited by the animated scenario provided by the organisers and not by an additional display.

- **BCI-TEC-2** Visual feedback is the only modality that is allowed to provide information to the pilot about the current state of the analysis or signal (e.g., how close the pilot is to sending a command at a given time). Any display used to provide the visual feedback must be mounted to the pilot’s wheelchair, not restrict the pilot’s mobility, and not exceed a screen diagonal of 0.18 m.
BCI-TEC-3  Ocular control, control by facial muscles or the use of any other volitional muscular activity is not allowed to generate control signals.

Comment on BCI-TEC-3: This includes attempted movements of partially paralysed and non-paralysed limbs, which result in some residual actual movement or activity of facial muscles, such as rolling the eyes, clenching the jaw, moving the tongue, swallowing, or frowning.

BCI-TEC-4  Artefact removal is mandatory. All teams must confirm in writing prior to the event that muscle, eye movement artefacts and other artefacts are removed or otherwise do not affect the command process, or that the classifier is blocked by artefact detection and not misused as commands to control the animated scenario. For example, the pilot should not be able to send commands by blinking with the eyes repeatedly but should also not be able to prevent commands from being sent by blinking repeatedly.

Comment on BCI-TEC-4: Before the event, teams are required to submit a description of the artefact removal procedure and examples of the signals to be checked by neutral technical examiners. Once artefacts are removed, any signal feature and classification procedure can be used in the BCI provided it primarily reflects volitional brain activity, and not automatic subconscious processes (e.g., alpha blockade). Teams must provide the description of the inference process to be checked by neutral technical examiners before the race.

BCI-TEC-5  Teams must implement and follow the regulations and protocols for communication between teams’ computers and the competition infrastructure provided by CYBATHLON organising committee.

Comment on BCI-TEC-5: Communication regulations and communication protocols between the teams’ computers and the competition infrastructure will be communicated at a later stage.

General comments on BCI technology:

- Any mobile technology that allows to measure brain activity is permitted for participation. Electroencephalography (EEG), electrocorticography (ECOG), microelectrode arrays, near infrared spectroscopy (fNIRS), or magnetoencephalography (MEG) are allowed, but also any other signal acquisition method provided it primarily measures brain activity.

- Sensors can be wired or wireless.
5.3 Specific race rules

BCI-1  It is not allowed to turn off the BCI system during the race.

BCI-2  Pilots are not allowed to intentionally use eye or muscle activity to control their BCI. Extensive or deliberate eye or muscle activity leads to a warning. See also BCI-TEC-3.

BCI-3  If a pilot is issued three warnings within the same race, the race is terminated for that pilot. The pilot’s current score is taken as the score for that race.

BCI-4  Pilots who are not able to connect with or send a command to the game in the preparation phase right before the start of the race are not allowed to participate in the race, i.e., the race is failed for these pilots.

BCI-5  One team official can accompany the pilot to the competition field. Once the race has started the support person is not allowed to interact with the pilot or the BCI system in any way (e.g., coaching is not allowed). In case of any intervention during the race (e.g., in case of coaching, a technical defect or an emergency), the race is terminated for that pilot. The pilot’s current score is taken as the score for that race.

5.4 Task set-up and description

BCIs have a wide range of potential applications in daily life, from operating a computer menu to communications and controlling an assistive device, such as a robotic arm or a wheelchair.

The BCI race takes place in a digital animated scenario (computer game) in which the BCI pilots have to guide avatars through a series of tasks. The behaviour of the avatars can be controlled by generating and sending the appropriate control commands at the right time.
5.4.1 General game structure

- The game consists of 10 tasks
  - A base task (navigating the avatar in two dimensions) and four supplementary tasks.
  - In some of the supplementary tasks, a specific extra function of the avatars must be activated by the BCI pilot by sending the appropriate command at the right time.
    - If the function is not activated or the wrong function is activated, the pilot is punished.
    - If the function is activated at the correct time/location, the pilot is rewarded.
- Total number of independent signals is 4 (2 continuous, 2 binary).
- The tasks are presented in a random order and each task is repeated twice (5x2).
- Each task contains specific fail criteria (e.g., navigating the avatar into a no-go zone). If a task is failed the pilot does not receive any points for this task and the pilot’s avatar is automatically transferred to the start line of the next task.
- The pilot can ask the referee to skip a task if they get stuck or want to abort a task. The pilot is then transferred to the start of the next task by the referee. If a task is skipped, no points are given for this task.

5.4.2 Tasks/functions

- Task type 1 (TT 1)
  - Base task (BT)
    - Navigate the avatar in two dimensions by actively controlling two independent continuous signals.
- Task types 2-5: BT and a supplementary task (ST)
  - Task type 2
    - BT
    - ST
      - Activate extra function 1 to change the state of the avatar.
      - Binary signal 1 activated (1) or deactivated (0) at the right time in the game.
o Task type 3
  ▪ BT
  ▪ ST
  • Activate extra function 2 to change the state of the avatar.
  • Binary signal 2 activated (1) or deactivated (0) at the right time in the game.

o Task type 4
  ▪ BT
  ▪ ST
  • Maintain idle state in a dedicated no-signal-zone or at a dedicated no-signal-time. The avatar must be maintained at a predefined location for a certain period without sending a signal.

o Task type 5
  ▪ BT
  ▪ ST
  • The pilot must react to a sudden change of the environment.

<table>
<thead>
<tr>
<th></th>
<th>Task type 1</th>
<th>Task type 2</th>
<th>Task type 3</th>
<th>Task type 4</th>
<th>Task type 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base task (BT)</td>
<td>The avatar must be navigated in two dimensions with two independent continuous signals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplementary task (ST)</td>
<td>-</td>
<td>Binary signal 1 activated (1) or deactivated (0) at the right time in the game</td>
<td>Binary signal 2 activated (1) or deactivated (0) at the right time in the game</td>
<td>Wait at a specific location or time until signal is given to continue</td>
<td>React to a sudden change of the environment.</td>
</tr>
<tr>
<td>No signal (idle)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>&quot;Skip task&quot;</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Overview of BCI game tasks and input types.

### 5.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 4 min
6 Functional Electrical Stimulation Bike Race

FES pilot during CYBATHLON 2020 Global Edition

6.1 Introduction

A spinal cord injury (SCI) resulting in the complete loss of lower limb motor control leads to the degradation of the musculoskeletal system of the lower limbs, including muscle atrophy and loss of bone mineral density.

Functional electrical stimulation (FES) is a technology that uses electrical pulses to excite skeletal muscles that are paralysed due to an injury to the central nervous system. Regular FES cycling exercise after SCI has been shown to lead to beneficial physiological adaptations such as improvements in bone density, an increase of muscle mass, and improved cardiovascular and respiratory fitness. Besides the application of FES cycling in rehabilitation, it can be of high recreational value to people with SCI. Furthermore, FES can be applied with other assistive technologies such as powered exoskeletons. This allows merging the movement control advantages of a robotic device with the physiological benefits provided by FES.

The use of FES hence bears the promising potential to counter some of the deleterious effects to the musculoskeletal system of the lower limbs after SCI.
6.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the FES Bike Race:

6.2.1 Pilots

In addition to the general pilot eligibility criteria set forth in chapter 4.5.1 pilots must fulfil the following criteria to be eligible for participation in the FES bike race:

FES-PIL-1 Pilots must have a spinal cord injury with paraplegia and a complete loss of motor function in the lower limbs (AIS A or B, http://www.sci-info-pages.com/levels.html).

FES-PIL-2 Pilots must have sufficient voluntary control of trunk, arms, and neck to control the bike and stabilise the upper body while riding.

Comment on FES-PIL-2: The eligibility of pilots with lesions affecting the control of trunk, arm and/or neck is evaluated on a case-by-case basis.

6.2.2 Technology

In addition to the general technology eligibility criteria set forth in Chapter 4.5.2 the assistive device must fulfil the following criteria to be eligible for participation in the FES bike race:

6.2.2.1 Stimulator

FES-TEC-1 Any technology that stimulates the neuromuscular structures of the lower limbs and/or the neural structures of the spinal cord is allowed for participation.

FES-TEC-2 The FES stimulator must fulfil the standard regulations for electrical safety, including the latest IEC standards 60601-1 and 60601-2-10 (or similar regulations applied in the country of development), which describe particular requirements for the basic safety and essential performance of transcutaneous nerve and muscle stimulators.

FES-TEC-3 Any equipment related to the FES stimulation required by the pilot to complete the race must be attached to the trike (e.g., FES stimulator, control units, batteries or similar). The FES stimulation set-up must allow for untethered, non-stationary cycling.
General comments on the stimulator

- The pilots may adjust the FES stimulation intensity and pattern during a race so that they can apply their own strategy to minimise effects of fatigue.
- The FES stimulators may apply closed-loop control strategies using sensors applied to the pilot or the bike. It is also allowed to manually trigger the stimulator.
- Any control strategy or stimulation pattern can be applied to stimulate single muscles or muscle groups of the lower extremities provided it is safe for the pilot.
- Any number of stimulation channels is allowed.

6.2.2.2 Bike

FES-TEC-4 Only bikes without actuation are allowed. The bike must only be actuated through the pilot’s legs.

FES-TEC-5 The bike must be fully functional for overground cycling. This will be tested as part of the TecCheck.

General comments on the bike

- The structure and function of the bike may be optimised for better mechanical efficiency.
- Any number and any size of wheels are allowed.

6.3 Specific race rules

FES-1 Each race run consists of a warm-up period and race period. At the end of the warm-up period the race period starts automatically. Acoustic and visual signals indicate the start of the warm-up period as well as the start and end of the race period.

FES-2 Pilots may start the pedalling movement at any point during the warm-up period.

(a) The movement of the legs during the first 20s of the warm-up period can be accomplished by the following means (or a combination thereof):

(i) the pilot’s arms,
(ii) FES to the pilot’s legs, or
(iii) a support person that moves the pilot’s legs.

(b) The movement of the legs during the final 10s of the warm-up period must be accomplished by FES to the pilot’s legs only.
Each race run consists of a warm-up period followed by the actual race period.

**FES-3**  
If the pilot is assisted when the last 10s of the warm-up period start, the transition is not valid, and the pilot will be disqualified from the race run.

**FES-4**  
If a pilot gets stuck at any point during the race run (e.g., due to fatigue or malfunction of the stimulator or the bike), the race is terminated for that pilot.

**FES-5**  
During the race, hands or arms are allowed to be used to push the legs to overcome pedalling dead points, but not to support on-going propulsion. Extensive use or any other misuse of hand or arm pushes leads to a warning. If a pilot is issued three warnings within the same race, the race is terminated for that pilot.

**FES-6**  
All participating teams use the same type of stationary bike trainer. They are not allowed to modify the provided stationary bike trainer.

### 6.4 Task set-up and description

The FES race is a stationary race in a virtual scenario in which several FES pilots compete against each other at the same time. The total race distance is divided into 10 sections with different gradients. A self-calibrating, controllable bike trainer will be used to render resistances according to the elevation profile of the virtual scenario and to measure the pilot’s performance (e.g., power, velocity, distance covered). The maximal race duration is 8 minutes. The pilot who reaches the finish line first, or travels the furthest within 8 minutes, wins the race.
• A minimum power output of 15 W (as measured by the bike trainer) will be required to set the avatar in motion.

• The elevation profile/resistance of the trainer be adapted such that the finish line can be reached within the maximal race duration with an average power output of 30 W (as measured by the bike trainer).

• Each of the 10 sections will be defined by a maximal gradient between -2 and 2%, e.g.,

<table>
<thead>
<tr>
<th>Section Nr.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max gradient [%]</td>
<td>-1</td>
<td>0</td>
<td>-2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>-1</td>
<td>-2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

• The sections will be presented in random order. During a competition round, the same order will be given to all teams.

• The avatar used in the virtual scenario will be a pilot on a recumbent bike. Steering of the avatar will not be required.

• The overall system weight (pilot and bike) will be considered in its physical representation in the virtual scenario.

### 6.4.1 Task infrastructure

<table>
<thead>
<tr>
<th>Object</th>
<th>Photo</th>
<th>Specification</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary bike trainer</td>
<td><img src="image" alt="Kickr 5" /></td>
<td>Kickr 5, self-calibrating and remote controlled</td>
<td>Wahoo</td>
</tr>
<tr>
<td>Virtual race scenario</td>
<td><img src="image" alt="Recumbent trike" /></td>
<td>Recumbent trike avatar taking system weight and road inclination into account</td>
<td>tbd</td>
</tr>
</tbody>
</table>
6.5 Competition mode and scoring

- Warm-up period: 0.5 min
- Total race duration: 8 min
- Total race distance: will be communicated at a later stage. The distance will be selected such that the finish line can be reached with the total race duration with an average power output of 30 W.
7 Arm Prosthesis Race

ARM pilot solving the Breakfast task during CYBATHLON 2016.

7.1 Introduction

A limb difference at the level of the forearm or above (e.g., due to an amputation above the hand or a congenital disorder) may lead to significant challenges when interacting with the physical environment. While many of the latest anthropomorphic hand prostheses provide a wide variety of grip patterns, their use and range of functions is often not fully satisfying for their users. The devices still lack some of the fundamental functionalities of a human hand such as wrist flexion and extension or the control of individual fingers. Missing degrees of freedom often result in non-physiological compensatory movements. Most devices do also not provide proprioceptive and haptic sensory information to their user which can lead to a lack of embodiment and acceptance of the prosthesis. Furthermore, the control of a hand prosthesis often requires significant cognitive and visual attention from their users. Due to these functional shortcomings many arm prosthesis users abandon their device in the long run.

Arm prostheses which fulfil the users’ expectations and needs have the potential to prevent device rejection. Additionally, prostheses that enable the functions of a human hand in a natural way may prevent secondary negative long-term effects due to non-physiological movements or anatomical asymmetry.
7.2 Eligibility criteria

In addition to the General Rules outlined in Chapter 4, the following specific rules apply for the Arm Prosthesis Race:

7.2.1 Pilots

In addition to the general pilot eligibility criteria set forth in Chapter 4.5.1 pilots must fulfill the following criteria to be eligible for participation in the ARM race:

ARM-PIL-1 Pilots must have a transradial or more proximal amputation or dysmelia of at least one arm.

7.2.2 Technology

There are no specific eligibility criteria in addition to the general technology eligibility criteria set forth in Chapter 4.5.2.

General comments on the prostheses

- Unpowered or powered (motor or body powered) prostheses are allowed.
- The prosthetic device may have any number of actively driven (powered) joints (e.g., for hand opening/closing or wrist pronation/supination). The prosthetic device can have several passive or mechanically coupled joints (e.g., at the fingers). Body powered (e.g., cable driven) systems are also allowed.
- If not otherwise specified in the task specific rules, any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- There is no weight limit for the prosthesis.

7.3 Specific race rules

ARM-1 Pilots are not allowed to use items such as trailers, backpacks, bags, pockets, ropes, or their clothes to carry objects of the racetrack (e.g., tools, plates, and bags of the tasks), but it is allowed to use such aids to carry components of the device (e.g., batteries, control units, tools, replacement equipment, etc.).

ARM-2 It is not allowed to touch the prosthesis while it is in direct contact with any competition infrastructure.

Comment on ARM-2: Non-robust control of prosthetic hand function during posture changes of the arm is an issue for many arm prostheses users. They oftentimes resort to turning off the device to maintain a secure grip while carrying objects. While
pragmatic and simple to implement, this is approach is not satisfying to many users. Rule ARM-2 aims to encourage teams to seek novel solutions to device design and control to maintain robust function during postural changes of the arm.

ARM-3  Unless stated otherwise in the specific rules of a task, any object on the racetrack that has blue parts is only allowed to be manipulated or touched with the prosthesis. If a pilot uses two prostheses, a blue object is only allowed to be manipulated or touched with one prosthesis at a time. Blue objects are only allowed to be manipulated or touched at the blue parts with the prosthetic hand (not including wrist, lower or upper arm).

ARM-4  It is allowed to grasp objects of the racetrack that are not blue or do not have blue parts with the prosthetic hand to manipulate blue objects (e.g., to use it as a tool), but not with the non-prosthetic hand.

ARM-5  If any task object or infrastructure that is not intended to touch the ground falls on the ground, the task is failed.

7.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in all following figures.
7.4.1 Bottles

7.4.1.1 Introduction

Forces that act on the prosthesis during the manipulation of heavy objects can cause a displacement of the prosthetic socket relative to the arm stump. In consequence the control signals recorded by traditional surface EMG can become unreliable leading to unsatisfactory function of the prosthesis.

In this task a series of bottles of different weights must be placed in a bottle crate and the crate must then be carried to a table. At the table, the bottles must be removed from the crate and placed on the table.

7.4.1.2 Task set-up & description

The pilot must carry the blue bottles using the blue bottle crate from the start area to the target area and then place the bottles on top of the table.
### 7.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Bottle (1.5l)</td>
<td>blue, partially filled with water (0l, 0.5l, 1l, 1.5l), bottle type subject to change</td>
<td>BOTTLESHOP</td>
</tr>
<tr>
<td>4</td>
<td>Bottle cap</td>
<td>blue</td>
<td>CZECH BREWERY SYSTEM</td>
</tr>
<tr>
<td>1</td>
<td>Bottle crate</td>
<td>blue</td>
<td>SIOS</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 7.4.1.4 Task rules

**ARM-BOT-1**  
The **blue** bottles must be carried to the table using the **blue** crate. The **blue** bottles must not be carried individually without the crate.

**ARM-BOT-2**  
The **blue** crate must not touch the ground between the start and the target area. The pilot is only allowed to lift up or set down the **blue** crate while both feet in their entirety are located in the start or target area.

**ARM-BOT-3**  
The **blue** crate is not allowed to be placed on top of the table.

**ARM-BOT-4**  
All **blue** bottles must be standing upright on the table at the time the pilot crosses the finish line of the task.

**ARM-BOT-5**  
If any of the **blue** bottles touches the ground again, after it has been lifted off the ground, the task is failed.

### 7.4.1.5 Comments

- Using other parts of the body (e.g., the legs) to proactively to stabilize the crate or the bottles when carrying the crate is considered a task fail.
7.4.2 Stacking

7.4.2.1 Introduction

Maintenance of a tight grip during postural changes of the arm (e.g., pronation and supination of the forearm, elbow flexion and extension) can be challenging for prosthetic hand users but is relevant in many situations in daily life such as when pouring liquids or turning objects.

In this task pilots sit in front of a table and must stack blue cups to a vertical pyramid.

7.4.2.2 Task set-up & description

The pilots must stack the cups to a pyramid and then dissemble them again. While manipulating the blue cups, the pilots must be sitting on the chair with their feet underneath the table and within the dashed lines indicated above.
Below left: initial position of the blue cups; bottom centre: blue cups stacked to a vertical pyramid; bottom right: blue cups stacked to a single pile.

### 7.4.2.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>10</td>
<td>Plastic cup</td>
<td>blue, Kalas, subject to change</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Chair</td>
<td>Adde</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 7.4.2.4 Task rules

**ARM-STACK-1** All blue cups must be stacked to a four-level vertical pyramid (4-3-2-1) on the table.

**ARM-STACK-2** In the vertically stacked pyramid, the opening of all blue cups must face downward.

**ARM-STACK-3** After stacking of the blue cups to a pyramid, the pilot must touch the table with both hands simultaneously. Thereafter the pyramid must be disassembled, and the blue cups must be stacked to a single pile of cups.

**ARM-STACK-4** The single pile of blue cups must be standing on the table when the pilot crosses the finish line of the task.

**ARM-STACK-5** If the lateral surface of any blue cup touches the table or floor (e.g., after it drops), the task is failed.

**ARM-STACK-6** The pilot must be sitting on the chair while stacking the blue cups. While sitting, the pilot’s feet must be placed behind the imaginary line connecting the two table legs facing the pilot.
7.4.2.5 Comments

- It is not considered a task fail if a **blue** cup drops on the table and by chance stops still on its opening or bottom without tipping over.
7.4.3 Do-it-yourself

7.4.3.1 Introduction

The dexterous use of hand tools requires a prosthetic hand and wrist that provide active motion about multiple axes (pronation/supination, palmar flexion/dorsal extension, and radial and ulnar abduction). Since hand tools are often used in confined space the active control of many degrees of freedom becomes even more important.

In this task, pilots must use a variety of hand tools in the context of do-it-yourself type work.

7.4.3.2 Task set-up & description

The following subtasks in the context of hand tool use must be solved:
• A nail must be driven into a piece of wood using a hammer and removed using pliers. The handles of both the hammer and the pliers are blue.

• A bolt must be screwed into a holder using a screwdriver. The handle of the screwdriver is blue.

• A blue light bulb must be screwed into a holder.

Below left: Initial location of the task objects. Below right: task objects after completion of all subtasks.

7.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 2x4, holders mounted</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Hammer</td>
<td>blue handle</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Nail</td>
<td>Art. No. 87.1001.35090, l: 90mm, d: 3.5mm</td>
<td>Hasler</td>
</tr>
<tr>
<td>1</td>
<td>Wooden plate</td>
<td>3mm through-hole, 4mm/10mm for insertion, notch for initial nail position</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Plate holder</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Pliers</td>
<td>blue</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Screwdriver (Torx)</td>
<td>blue</td>
<td>LUX</td>
</tr>
<tr>
<td>1</td>
<td>Bolt</td>
<td>Art. No. 83.1340.06030, M6, l: 30mm, Torx head</td>
<td>Hasler</td>
</tr>
<tr>
<td>2</td>
<td>Nut</td>
<td>Art. No. 83.2420.0060, M6</td>
<td>Hasler</td>
</tr>
<tr>
<td>1</td>
<td>Nut holder</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Lightbulb</td>
<td>blue, Star A Décor-Color</td>
<td>OSRAM</td>
</tr>
<tr>
<td>1</td>
<td>Bulb holder</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1 Bulb electronics set  The design of the electronics for this task will be communicated at a later stage.

7.4.3.4 Task rules

ARM-DOIT-1 The nail must be driven into the wood using the blue hammer until its tip breaks the bottom surface of the wood. Once the nail has broken the bottom surface of the wood, it must be fully removed from the wood using the provided tools.

Comment on ARM-DOIT-1: The referee will confirm the breaking of the tip through the bottom surface of the wood.

ARM-DOIT-2 The bolt must be screwed into the holder using the blue screw driver.

Comment on ARM-DOIT-2: The bolt must be turned 3 revolutions until the mark (a nut fixed on the bolt) contacts the holder. The referee will confirm the contact.

ARM-DOIT-3 The blue lightbulb must light up after it is screwed into the bulb holder. If the blue lightbulb breaks into pieces, the task is failed.

ARM-DOIT-4 It is allowed to use the non-prosthetic hand to support positioning the tools or the light bulb in the prosthetic hand while the pilot is in the ‘start area’ (between the start line of the task and the beginning of the workbench) with both feet.

Comment on ARM-DOIT-4: If the pilot needs to reposition a blue tool or the blue light bulb in the prosthetic hand, they must go back to the ‘start area’ to do this.

ARM-DOIT-5 All tools must be located on the top surface of the shelf at the moment the pilot crosses the finish line.
7.4.4 Laundry

7.4.4.1 Introduction

Handling laundry and putting on clothes requires a distinct set of fine motor skills, in particular in the fingers. Also, for an arm prosthesis to be practical for daily use it must be compatible with standard clothes.

In this task, the pilot must put on a hooded sweater and fully close the zipper. Then, the pilot must hang up the hooded sweater on the clothesline using a hanger. Finally, the pilot must hang up a t-shirt on the clothesline using blue clothespins.
7.4.4.2  Task set-up & description

Pilots must hang a t-shirt on the clothesline using blue clothespins, put on a hooded sweater, and hang the sweater on a coat hanger.

- Initially, the t-shirt and the hooded sweater are randomly placed in the hamper.
- The zipper of the hooded sweater is initially completely closed.
- The blue clothespins are initially located in a box.
- The height of the clothesline will be the pilot’s body height + 0.1 m.
### 7.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hamper</td>
<td>Torkis</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>T-shirt</td>
<td>subject to change</td>
<td>Neutral</td>
</tr>
<tr>
<td>1</td>
<td>Sweater</td>
<td>zipper: blue slider and pull tab</td>
<td>Neutral</td>
</tr>
<tr>
<td>1</td>
<td>Coat hanger</td>
<td>Bumerang</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Box for clothespins</td>
<td>Glis</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Clothespin</td>
<td>blue, Wenko Colorado</td>
<td>WENKO</td>
</tr>
</tbody>
</table>

---

### 7.4.4.4 Task rules

**ARM-LAUNDRY-1**  The hooded sweater must be taken from the hamper and put on correctly (both arms inserted into the sleeves). When wearing the hooded sweater, the blue zipper must be closed at least to the mark. When crossing the finish line of the task, the hooded sweater must hang on the clothesline using the hanger.

Comment on ARM-LAUNDRY-1:  The referee will confirm once the blue zipper is closed, and the pilot may continue.

**ARM-LAUNDRY-2**  The non-prosthetic hand is allowed to touch any part of the hooded sweater, but not the blue parts of the zipper.

**ARM-LAUNDRY-3**  The t-shirt must be hung on the clothesline and attached with two blue clothespins. If the t-shirt is not attached with both blue clothespins when the pilot crosses the finish line, the task is failed.

Comment on ARM-LAUNDRY-2:  It is permitted to hang the t-shirt over the line and then attach it with the blue clothespins.
7.4.5 Containers

7.4.5.1 Introduction

The ability to use kitchen utensils (e.g., cutlery, a can opener) is critical for independent living and involves countless tasks which are typically solved by dexterous bimanual interaction. Also, some objects in the kitchen are very delicate to handle and require a very precise control of grip force.

In this task, pilots must conduct a series of kitchen related bimanual tasks such as opening a bottle and pouring water into a glass, as well as opening a jam jar, and a tin can.

7.4.5.2 Task set-up & description

The pilots must open the bottle and pour water into a glass, open a jam jar and a tin can.
### 7.4.5.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Can opener</td>
<td>blue turning knob, one for left and one for right handed use will be provided, subject to change</td>
<td>Sieger</td>
</tr>
<tr>
<td>1</td>
<td>Can</td>
<td></td>
<td>Flaschenbauer</td>
</tr>
<tr>
<td>1</td>
<td>Disc</td>
<td>red</td>
<td>3D-printed</td>
</tr>
<tr>
<td>1</td>
<td>Bottle (0.5l)</td>
<td>blue, filled with 0.5l of red liquid (water-like viscosity)</td>
<td>bottleshop</td>
</tr>
<tr>
<td>1</td>
<td>Bottle cap</td>
<td></td>
<td>bottleshop</td>
</tr>
<tr>
<td>1</td>
<td>Glass</td>
<td>visual, non-haptic mark 1cm under brim</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Jar (230ml)</td>
<td>filled with expanded clay</td>
<td>Agrimarkt</td>
</tr>
<tr>
<td>1</td>
<td>Expanded clay</td>
<td>red, 78g, 4-8mm</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Lid</td>
<td>blue, subject to change</td>
<td>Agrimarkt</td>
</tr>
</tbody>
</table>

### 7.4.5.4 Task rules

**ARM-CONT-1** The top of the can must be completely removed from the can by using the can opener with the blue turning knob and the red disc must drop into the can. If the red disc drops off the top of the can at any point, the task is failed.

**ARM-CONT-2** The cap of the blue PET bottle must be removed, and the glass must be filled to the mark.

**ARM-CONT-3** It is allowed to touch the white cap of the of the blue PET bottle with the non-prosthetic hand.

**ARM-CONT-4** The blue lid must be separated from the jar. If any of the content of the jar is spilled, the task is failed.

**ARM-CONT-5** It is allowed to touch the jar with the non-prosthetic hand.
7.4.6 Hot Wire

7.4.6.1 Introduction

Maintenance of a tight grip during sustained postural changes of the arm (e.g., pronation and supination of the forearm, elbow flexion and extension) can be challenging for prosthetic hand users but is relevant in many situations in daily life (e.g., when picking up the phone or painting).

Pilots hold a conductive wire loop with a blue handle. A curved metal wire must be tracked without touching the wire with the loop by using the prosthetic hand only.

7.4.6.2 Task set-up & description

The metal loop with the blue handle must be moved around the bent wire to reach the target location. The blue handle is shown in the start position. The insert shows the blue handle with the metal loop.
### 7.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wire</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Handle with loop</td>
<td>blue</td>
<td>PB SWISS TOOLS</td>
</tr>
<tr>
<td></td>
<td>Set of electronics</td>
<td>The design of the electronics for this task will be communicated on a later stage.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Hot wire base</td>
<td></td>
<td>custom made</td>
</tr>
</tbody>
</table>

### 7.4.6.4 Task rules

**ARM-WIRE-1**  
The task must be started and finished in a designated region (start area and finish area), where pilots grasp and drop the loop respectively.

**ARM-WIRE-2**  
If there is any contact between the loop and the wire when the loop is located outside the start or finish area, the task is failed.

**ARM-WIRE-3**  
While the loop of the handle is in the designated area at the start of the wire, it is allowed to grasp the handle or loop with the non-prosthetic hand in order to support positioning the **blue** handle in the prosthetic hand.

### 7.4.6.5 Comments

- The **blue** handle of the wire loop is shaped to be gripped with a power grip (medium wrap), but any other grip is also allowed.
- The wire loop task can be accessed from either the right-hand or left-hand side, depending on pilot’s preference.
- It is not allowed to touch the silver part of the handle with the prosthesis. See examples below:

  ![Not allowed, since prosthetic hand is touching the silver part of the handle.](image1)

  Not allowed, since prosthetic hand is **touching** the silver part of the handle.

  The same grip type touching only the **blue** part of the handle is allowed.

  ![Allowed, since the prosthetic hand is not touching the silver part of the handle.](image2)

  Allowed, since the prosthetic hand is **not touching** the silver part of the handle.

  The same grip type touching the silver part of the handle would not be allowed.
### 7.4.7 Serving

#### 7.4.7.1 Introduction

Cooking often involves grasping and carrying objects (e.g., pans) of significant weight from one location to another while it must be made sure that none of the content is spilled.

In this task, a casserole dish and a frying pan must be carried from the stove to a predefined location on a table.

[Image source](image)

#### 7.4.7.2 Task set-up & description

Pilots must carry a casserole dish and a frying pan from the oven to the table.
• The handle of the frying pan and one of the handles of the casserole dish are blue.
• The casserole dish is initially placed in the oven (see insert above). The blue handle faces the pilot. The oven is initially closed.
• The frying pan is initially placed on the cooktop.
• The frying pan and the casserole dish both contain weights in the form of lacrosse balls (three in the frying pan and six in the casserole dish). The balls can move around freely in their containers.

### 7.4.7.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf, with front door</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wire basket</td>
<td>Utruska</td>
<td>IKEA</td>
</tr>
<tr>
<td>3</td>
<td>Cup hinge</td>
<td>OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Flap hinge left</td>
<td>OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Flap hinge right</td>
<td>OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Door handle</td>
<td>Bagganäs</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Frying pan</td>
<td>365+, 28cm. blue handle</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Casserole dish</td>
<td>Koncis, 1 blue handle</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>Trivet (round)</td>
<td>Heat</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Trivet (square)</td>
<td>Lämplig</td>
<td>IKEA</td>
</tr>
<tr>
<td>9</td>
<td>Lacrosse ball</td>
<td></td>
<td>CROSS EQUIP</td>
</tr>
</tbody>
</table>

### 7.4.7.4 Task rules

**ARM-SERV-1**  The frying pan must be placed on top of the circular trivet on the table.

**ARM-SERV-2**  The casserole dish must be placed on top of the rectangular trivet on the table.

Comment on ARM-SERV-1 and ARM-SERV-2: It’s ok if the frying pan or the casserole touch the table during manipulation at the target table.

**ARM-SERV-3**  It is allowed to touch the handle of the casserole which is not blue with the non-prosthetic hand.

**ARM-SERV-4**  It is only allowed to manipulate the casserole dish using the handles.

**ARM-SERV-5**  The oven must be closed when the pilot crosses the finish line.
7.4.8 Dishes

7.4.8.1 Introduction

Kitchen work oftentimes includes manipulating objects in confined space and at various heights, e.g., when grasping objects that are placed inside a cupboard.

In this task, typical kitchen objects must be grasped and stowed away at predefined target locations.

Image source

7.4.8.2 Task set-up & description

The blue objects on the table must be moved to their respective target locations in the shelf. The drawer will initially be closed, it is shown open for visualization only. Below left: frontal and side view of table, bottom right: frontal view of shelf.
### 7.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 1x4</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Cutlery tray</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Plate holder</td>
<td>Rinnig</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Cutlery stand</td>
<td>Ordning</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Plate</td>
<td>blue, 365+</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Mug</td>
<td>blue, Vardagen</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Set of fork, knife and spoon</td>
<td>blue, 365+</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Bowl</td>
<td>blue, 365+</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 7.4.8.4 Task rules

**ARM-DISH-1** The blue cutlery must be removed from the drying stand and stowed away in the cutlery tray in the top drawer. The drawer must be closed when the pilot crosses the finish line.

**ARM-DISH-2** The blue plate, the blue bowl and the blue cup must be removed from the drying stand and placed on their respective counterpart/target location on the shelf.
7.4.9 Haptic Bag

7.4.9.1 Introduction

The availability of sensory feedback from the terminal device improves a user’s control over the prosthesis and increases the acceptance and embodiment of the device.

In this task, pilot must recognise and retrieve objects of different shapes and compliance in the absence of visual feedback.

7.4.9.2 Task set-up & description

Two bags are presented to the pilots. Six different shapes are loosely and randomly placed in the two bags, three in each. The six shapes can be of high or low compliance.

Additionally, a subset of four of the six shapes is initially presented on the table (white objects). The pilot must retrieve these same shapes from the bags in the order in which they are initially presented (1-4, see below). The shapes on the table
are not indicative of the compliance of the shapes in the bags. Two objects from each bag must be retrieved.

Pilots must reach into the bags only with their prosthetic hand to explore the shapes that are placed inside but have no sight of their workspace during shape exploration and identification.

### 7.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (small) with holes for haptic bags</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Haptic bag - frame</td>
<td>blue, Standard strip brush, STL6001-494992, body: PVC deep black, fiber: PA6 signalblue 0 30, total length: 250mm, working length: 240mm, rows: 1, fiber height 100mm</td>
<td>custom made</td>
</tr>
<tr>
<td>4</td>
<td>Haptic bag - brush</td>
<td>blue, Brugnoli Roche jersey royalblau</td>
<td>MINK</td>
</tr>
<tr>
<td>2</td>
<td>Haptic bag - fabric</td>
<td>blue, Brugnoli Roche jersey royalblau</td>
<td>POMPON</td>
</tr>
</tbody>
</table>
### 7.4.9.4 Task rules

**ARM-HAPT-1**  The objects must be removed from the bags in the order in which they are initially presented on the table.

**ARM-HAPT-2**  Only the prosthetic hand must be inserted into the bags through the blue opening. The bags must not be touched with the other hand (prosthetic or non-prosthetic).

**ARM-HAPT-3**  Only one object must be removed from a bag at a time.

**ARM-HAPT-4**  Any object that has been removed from one of the bags must not be put back into the bag.

**ARM-HAPT-5**  Pilots are not allowed to obtain visual information from within the bag, (e.g., by looking into the bag or by feeding back images from inside the bag through cameras or other types of sensors).
7.4.10 Clean Sweep

7.4.10.1 Introduction

A vast variety of objects of different shape, size, compliance, texture, and weight must be grasped and manipulated in everyday life. The ability to cope with this diversity of requirements is challenged in this task.

In this task, pilots are asked to grasp and move blue objects individually with their prosthetic hand from their random, initial position on a table surface to a target position on a neighbouring table.

7.4.10.2 Task set-up & description

The blue objects that are initially located in the blue box on the table near the start line must be carried to and placed at their respective target position on the table near the finish line.
7.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Transparent box</td>
<td>Glis, blue</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Cube</td>
<td>With target locations</td>
<td>3D-printed</td>
</tr>
<tr>
<td>1</td>
<td>Key</td>
<td>blue, KABA 8</td>
<td>KABA</td>
</tr>
<tr>
<td>1</td>
<td>Credit Card</td>
<td>blue, w: 85 mm, l: 54 mm, h: 0.8 mm</td>
<td>ETH Print and Publish</td>
</tr>
<tr>
<td>1</td>
<td>Marble</td>
<td>blue, d: 15 mm</td>
<td>Jugglux</td>
</tr>
<tr>
<td>1</td>
<td>LEGO Block</td>
<td>blue, LEGO</td>
<td>KLICKBRICKS</td>
</tr>
</tbody>
</table>

7.4.10.4 Task rules

ARM-CLEAN-1 All blue objects must be moved from their random initial position in the blue box on the table near the start line to their designated target position on the table near the finish line. The order in which the objects are carried to and placed at their target location is not defined.

ARM-CLEAN-2 It is allowed to stabilize the target position on the table using the non-prosthetic hand, but it is not allowed to intentionally move or lift the target position off the table surface.

ARM-CLEAN-3 The vertical projection of the box must not leave the vertical projection of the table.
ARM-CLEAN-4  All blue objects must be located at their designated target position on the table near the finish line when passing the finish line of the task. Otherwise, the task is failed.

7.4.10.5 Comment

- According to rule ARM-3 it is not allowed to grasp the blue box on the table near the start line using the non-prosthetic hand.

7.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 8 min
8 Leg Prosthesis Race

A transfemoral limb difference above the knee (e.g., due to an amputation or a congenital disorder) may lead to significant challenges in personal mobility. Current micro-processor controlled transfemoral leg prostheses can control the mechanical properties of their joints (e.g., the stiffness of the knee) depending on the phase of the user’s gait cycle and adapt to different gait types. Nonetheless, the functionality of current devices does not always optimally support their users. Many prostheses are not actuated, i.e., they do not have a motor as part of the knee joint. As a result, they cannot adequately support a user when getting up from a chair, climbing stairs or walking uphill. This leads to asymmetric gait and increased energy expenditure by the user. The lack of actuation also means that the user cannot voluntarily control the angle of the knee (i.e., actively extend or bend the knee as needed). This function is for example required when getting into a car) or sitting down on a crowded bench (e.g., not hitting the people sitting already on the bench). The lack of actuation generally leads to compensatory movements which can have negative long-term effects on the user’s health such as musculoskeletal symptoms in the back or in the healthy leg. Furthermore, current devices lack the provision of proprioceptive and haptic sensory
feedback from the joints or the sole of the user’s foot. Consequently, their use can be strenuous, is not very intuitive, and requires a lot of attention and training from the user.

Leg prostheses which mimic and enable the natural function of the human legs bear the potential to optimally support their users. Leg prostheses that can be controlled intuitively and allow for symmetric gait lead to better device acceptance by increasing the satisfaction of their users.

### 8.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the Leg Prosthesis Race:

#### 8.2.1 Pilots

In addition to the general pilot eligibility criteria set forth in chapter 4.5.1 pilots must fulfil the following criteria to be eligible for participation in the LEG race:

- **LEG-PIL-1** Pilots must have a knee exarticulation or more proximal amputation of at least one leg.

#### 8.2.2 Technology

There are no specific eligibility criteria in addition to the general rules set forth in chapter 4.5.2.

General comments on the prosthesis

- Any kind of unpowered or powered prosthesis is allowed.
- The prosthesis can have any number of actively driven (i.e., powered) joints. The residual body parts can also be instrumented and electronically and/or mechanically connected to the prosthesis.
- Any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- There is no weight limit for the prosthesis.

### 8.3 Specific race rules

- **LEG-1** The use of any type of walking aid (e.g., crutches, canes, or similar) during the competition is not allowed.
- **LEG-2** Pilots are not allowed to use items such as trailers, backpacks, bags, pockets, ropes or their clothes to carry objects of the racetrack (e.g., tools, plates, and bags of the tasks), but it is allowed to use such aids to carry components of the device (e.g., batteries, control units, tools, replacement equipment).
LEG-3 Any object on the racetrack that is red is not allowed to be touched with any part of the assistive device or any other body part.

LEG-4 Any part of a task that is blue must be touched with the prosthetic leg (including the shoe) during task execution. Any part of a task that is blue must only be touched with the prosthesis during task execution.

LEG-5 It is not allowed to touch the prosthesis with the hands or any other body part to support movements.

8.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in the following figures.
8.4.1 Bench & table

8.4.1.1 Introduction

Often in daily life the angle of the knee must be controlled to make sure not to touch the environment with the leg, for example when getting into or out of a car, or when taking a seat between other people.

In this task, the pilot must take a seat at a bench that is placed very close to a table, similar to a picnic table.

8.4.1.2 Task set-up & description

Pilots must take a seat at the centre of the bench between the red poles and get up again.
### 8.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bench</td>
<td>Tjusig, stainless steel tubes not mounted</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (rectangular)</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Socle</td>
<td>red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>2</td>
<td>Pole</td>
<td>l: 800mm, red</td>
<td>Boje Sport</td>
</tr>
</tbody>
</table>

### 8.4.1.4 Task rules

**LEG-PICNIC-1** The pilot must take a seat on the bench and get up again.

**LEG-PICNIC-2** The pilot must place the non-prosthetic leg first underneath the table, i.e., the non-prosthetic leg must be the leading leg. Pilots with two (above-knee) prosthetic legs can choose their leading leg.

**LEG-PICNIC-3** While seated, the pilot must place both feet in the designated area on the floor underneath the table and both elbows on the table. If the pilot stands up again before the referee has verbally confirmed the correct sitting position, the task is failed.

**LEG-PICNIC-4** If any of the red poles is touched with any part of the body while sitting down or standing up, the task is failed.

### 8.4.1.5 Comments

- The referee verbally confirms the correct sitting position.
8.4.2 Stairs

8.4.2.1 Introduction

Stairs and steps are very common in daily life. To ascend or descend stairs, transfemoral prosthesis users must usually apply specific strategies and adapt their gait pattern to overcome the height difference of the single steps. The resulting movements are often non-physiological and asymmetric, can be exhausting, and may lead to secondary discomfort (e.g., back pain) in the long run.

Handrails are often used as an auxiliary mean. In addition, transfemoral prosthesis users usually rely on visual feedback to control the placement of their feet on the single steps of the stairs due to the lack of proprioceptive feedback from their knee and ankle joints.

In this task pilots must ascend and descend a flight of stairs multiple times while carrying objects.

8.4.2.2 Task set-up & description

The staircase must be crossed three times. The width of the staircase is limited to passageway at the centre of the steps.
### 8.4.2.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Stairs</td>
<td>wood, with checker plate edge protection</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>2 Handrail (1 for each side)</td>
<td>steel</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>Separation unit - holder</td>
<td>wood</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>Separation unit - pole</td>
<td>red</td>
<td>Boje Sport</td>
<td></td>
</tr>
<tr>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
<td></td>
</tr>
<tr>
<td>Saucer</td>
<td>365+</td>
<td>IKEA</td>
<td></td>
</tr>
<tr>
<td>Espresso cup</td>
<td>365+, red</td>
<td>IKEA</td>
<td></td>
</tr>
</tbody>
</table>

### 8.4.2.4 Task rules

**LEG-STAIRS-1** The pilot must cross the staircase three times:
- During the first crossing, the pilot must not carry any object.
- During the second crossing, the pilot must carry the red cup and saucer (2) from table 2 and place both items on table 1.
- During the third crossing, the pilot must carry the red cup and saucer (1) from table 1 and place both items on table 2.

**LEG-STAIRS-2** It is only allowed to carry one red cup and saucer at a time.

**LEG-STAIRS-3** It is only allowed to grasp the saucer, but not the red cup. It is only allowed to transport a red cup by balancing it on the saucer.

**LEG-STAIRS-4** If any of the red cups tip over or drop, the task is failed.

**LEG-STAIRS-5** It is only allowed to step on the staircase on the area between the red fences.

**LEG-STAIRS-6** The red fences must not be touched by the pilot. The red fence must not be crossed by the pilot while on the stairs.

**LEG-STAIRS-7** Each step must be stepped on by one foot only. The leading leg must alternate.

Comment on LEG-STAIRS-7: Pilots are not allowed to place two feet on one step. Pilots are not allowed to omit single steps or jump over steps.
8.4.3 Step-over

8.4.3.1 Introduction

Situations in outdoor locations often require the ability to lift the feet up high while accurately controlling the position of the feet, e.g., when walking in a forest (stepping over branches, roots, or stone blocks).

In this task, the pilots must stride through a group of wooden crates while carrying objects in their hands.

Image source

8.4.3.2 Task set-up & description

Pilots must step through a series of wooden crates. The crates are arranged in five pairs (rows 1-5). A red apple on a plate is initially placed in each crate of row 2 (see top view of crates in the insert).
8.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Crate</td>
<td>Knagglig, bottoms removed</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Saucer</td>
<td>365+</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Apple</td>
<td>red</td>
<td>Floristik24,</td>
</tr>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

8.4.3.4 Task rules

LEG-CRATES-1 While striding through the crates, pilots must step into each pair of crates.

LEG-CRATES-2 The red apples and plates must be located on the table when the pilot crosses the finish line.

LEG-CRATES-3 Only one red apple and plate must be carried at a time.

LEG-CRATES-4 It is only allowed to grasp the plates, but not the red apples. It is only allowed to transport the red apples by balancing them on the plate.

LEG-CRATES-5 If any of the red apples drops, the task is failed.

LEG-CRATES-6 Pilots are not allowed to touch the crates with their hands or any other body part to steady themselves.
8.4.4 Slopes

8.4.4.1 Introduction

Walking on surfaces that are tilted perpendicular to the walking direction is challenging when using a leg prosthesis because sufficient toe clearance must be guaranteed. Otherwise, the user may stumble and risk a fall.

In this task, pilots must carry a series of objects from one side of a slope to the other.

8.4.4.2 Task set-up & description

Pilots must place the six objects on their yellow target location that shows the respective shape of the object. Numbers are shown on the images above for the identification of objects only, they do not imply a predefined sequence of matching the objects.
The sequence of objects will be randomised. Three objects are placed on each side of the obstacle, their yellow target location showing the respective shape are placed on the other side of the obstacle.

### 8.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Ramp</td>
<td>wood</td>
<td>custom made</td>
</tr>
<tr>
<td>6</td>
<td>Object</td>
<td>different shapes</td>
<td>3D-printed</td>
</tr>
<tr>
<td>6</td>
<td>Target location</td>
<td>yellow, shapes corresponding to objects</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

### 8.4.4.4 Task rules

- **LEG-SLOPE-1**: Each of the six objects must be located on top of their respective yellow target location (showing the shape) when the pilot crosses the finish line of the task.
- **LEG-SLOPE-2**: Only one object must be carried at a time. The objects are not allowed to touch the slopes or the ground.
- **LEG-SLOPE-3**: The object must only be touched when both of the pilot's feet are in their entirety on the slopes of the obstacle.
- **LEG-SLOPE-4**: The target locations must not be moved by the pilot at any time.
- **LEG-SLOPE-5**: Once the pilot has stepped on the obstacle, they must not leave the obstacle until all objects have been placed at their target location.
- **LEG-SLOPE-6**: If the pilot touches the ground or the obstacle with any other part than with their knee, lower leg, or feet, the task is failed.

### 8.4.4.5 Comments

- The pilot is free to choose the order of transporting the objects.
8.4.5 Hurdles

8.4.5.1 Introduction

Sometimes, it is necessary to step over objects that are even higher than standard steps or to crouch to pass beneath objects, e.g., when walking in a forest, crossing a fence, or on a construction site.

In this task, the pilots have to pass a series of hurdles.

8.4.5.2 Task set-up & description

The pilots must pass once between each pair of poles without knocking down any of the poles or crossbars. When passing between the poles, the leading leg must alternate.
### 8.4.5.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Pole with socle</td>
<td>l: 1600mm, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>7</td>
<td>Crossbar</td>
<td>l: 800mm, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>14</td>
<td>Crossbar fixture</td>
<td>shortened</td>
<td>Boje Sport</td>
</tr>
</tbody>
</table>

### 8.4.5.4 Task rules

**LEG-HURD-1** The vertical poles that are connected by at least one crossbar are considered a pair. Pilots must pass once between each pair of poles.

**LEG-HURD-2** When passing between the pairs, the leading leg must alternate. I.e., if for the first pair, the left leg is leading, for the second pair, the right leg must be leading and so on.

**LEG-HURD-3** If the pilot knocks down a crossbar, either by hitting a pole or a crossbar, the task is failed.

**LEG-HURD-4** Pilots are not allowed to grasp any crossbar or pole with the hand or steady it with any other part of the body.
8.4.6 Wobbly Stones

8.4.6.1 Introduction

When walking outdoors, e.g., on a nature path the ground sometimes behaves in unexpected ways and the walking behaviour must be adapted to the ground immediately to keep balance.

In this task, the pilots are challenged to walk over series of wobbly stones.

8.4.6.2 Task set-up & description

The pilots must cross the series of wobbly stones (see insert) without touching the ground. The route of the wobbly stones can be mirrored between races.
8.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Circular plate with hemispheres</td>
<td>grey top surface, coated, hemispheres, positioned on O-ring seal</td>
<td>custom made</td>
</tr>
<tr>
<td>7</td>
<td>O-ring seal</td>
<td>positioned on friction layer</td>
<td>HUG</td>
</tr>
<tr>
<td>7</td>
<td>Friction layer</td>
<td></td>
<td>OBI</td>
</tr>
</tbody>
</table>

8.4.6.4 Task rules

LEG-WOBB-1 Pilots must alternate the leading leg to transition between two wobbly stones.

LEG-WOBB-2 Wobbly stones can be stepped on with both feet at a time.

LEG-WOBB-3 The task is failed if the pilot’s feet touch the ground before the target area.
8.4.7 Boxes

8.4.7.1 Introduction

Walking on surfaces that dictate irregular step lengths and heights can be required when walking in the nature or in cities. This is challenging since the position of the foot must be continuously controlled.

In this task, the pilot must negotiate a quasi-random sequence of wooden boxes that vary in height and length.

8.4.7.2 Task set-up & description

The pilots must step across the sequence of boxes.

- Three of the six boxes have a blue top surface
- The boxes are presented in random order, e.g., it is possible that all boxes with a blue surface are presented in direct sequence.
### 8.4.7.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Box</td>
<td>3 boxes with <strong>blue</strong> top surface</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Boxes fixation system</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>12</td>
<td>Pole</td>
<td>l: 800mm, <strong>red</strong></td>
<td>Boje Sport</td>
</tr>
</tbody>
</table>

### 8.4.7.4 Task rules

- **LEG-BOXES-1** Pilots must cross the sequence of boxes by passing between the **red** poles once in the direction of the race.
- **LEG-BOXES-2** The task is failed if any of the **red** poles is touched.
- **LEG-BOXES-3** The boxes that have a **blue** top surface must be stepped on by the prosthetic foot only. The boxes that do not have a **blue** top surface must be stepped on by the non-prosthetic foot only.
- **LEG-BOXES-4** Pilots are not allowed to place two feet on one box. Pilots are not allowed to omit single boxes or jump over boxes.
- **LEG-BOXES-5** The floor between the boxes must be touched with at least one foot.
8.4.8 Ladder

8.4.8.1 Introduction

Climbing and descending ladders with a transfemoral leg prosthesis is arduous and requires a lot of attention from the user.

In this task, pilots must climb up and down a stepladder by placing their feet only in pre-defined locations while balancing an apple on a plate.

The pilot must climb up the stepladder to pick up a plate with a red apple from the top of the shelf. The pilot then carries the plate and apple while climbing down from the stepladder and places it on the table.
### 8.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base plate</td>
<td>with mounting bracket for shelving unit</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Stepladder</td>
<td>all steps are reinforced with angle brackets, first step blue</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Shelving unit</td>
<td>Gnedby</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Saucer</td>
<td>365+</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Apple</td>
<td>red</td>
<td>Floristik24</td>
</tr>
</tbody>
</table>

### 8.4.8.4 Task rules

**LEG-LADDER-1** Each step must be stepped on when climbing and descending the stepladder.

Comment on LEG-LADDER-1: Pilots are not allowed to omit single steps or jump over steps of the stepladder.

**LEG-LADDER-2** Steps 1 and 2 must each be stepped on by one foot only. The leading leg must alternate.

**LEG-LADDER-3** Picking-up the plate is only allowed when standing on step 3 with both legs.

**LEG-LADDER-4** When crossing the finish line of the task, the red apple must be on the plate, the plate must be located on the table.

**LEG-LADDER-5** It is only allowed to grasp the plate, but not the red apple. It is only allowed to transport the red apples by balancing them on the plate.

**LEG-LADDER-6** If the red apple drops, the task is failed.
8.4.9 Stones

8.4.9.1 Introduction

In certain situations, it is required to accurately control the positioning of the foot, e.g., when entering an escalator or stepping on stones on a cross country path.

In this task, the pilots are challenged to walk over stones and place their feet only at predefined locations while keeping their balance.

8.4.9.2 Task set-up & description

Pilots must walk over the stone route. Along their way they must pick up the cubes and place them on the following yellow discs.

The stone route consists of four base plates (2-5), one start plate (1) and one end plate (6). On plates 2-5 the stones are arranged in different patterns. The order of the plates 2-5 is randomized.
### 8.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Base plate</td>
<td>wood, with fixtures for attachment and lateral reinforcement</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Base plate for start/finish zone</td>
<td>wood, with fixtures for attachment</td>
<td>custom made</td>
</tr>
<tr>
<td>10</td>
<td>Spacer</td>
<td>wood, with fixtures for attachment, maintaining constant space between base plates</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Half cylinder bar for start/finish zone</td>
<td>wood, grey, coated, l: 800 mm</td>
<td>custom made</td>
</tr>
<tr>
<td>8</td>
<td>Half cylinder bar short</td>
<td>wood, grey, coated, l: 250 mm</td>
<td>custom made</td>
</tr>
<tr>
<td>4</td>
<td>Half cylinder bar long</td>
<td>wood, grey, coated, l: 400 mm</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Cube</td>
<td>3D-printed</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Target position disc</td>
<td>yellow</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

### 8.4.9.4 Task rules

**LEG-STONE-1** The stone on plate 1 and the stone on plate 6 must be stepped on with both feet at the same time. Each of the stones on plates 2 to 5 must be stepped on with only one foot by using alternating steps.

**LEG-STONE-2** The cube initially located between plates 2 and 3 must be picked up, carried, and placed on the disc located between plates 3 and 4. The cube initially located between plates 4 and 5 must be picked up, carried, and placed on the disc located between plates 5 and 6.

**LEG-STONE-3** The objects must be picked up and placed on the discs while standing on the stones.
8.4.10 Balance Beam

8.4.10.1 Introduction

The ability to maintain dynamic body balance is critical in many situations in daily life, e.g., when climbing on a step or when walking on a very narrow path.

In this task, the pilots have to individually pick up and carry two buckets to a target area while walking across narrow wooden beams.

8.4.10.2 Task set-up & description

The pilot must start the task by stepping on the first beam from the start area. The pilot must then carry the buckets (one at a time) to the end of each beam and place it in the target area.
8.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Beam</td>
<td>blue marks at entry zone on two of the beams</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Bucket</td>
<td>PACKSTAR</td>
<td></td>
</tr>
</tbody>
</table>

8.4.10.4 Task rules

LEG-BEAM-1 Once a pilot's foot has left the start area, it must only touch the ground again in the target area and only when both buckets are located in the target area.

LEG-BEAM-2 One bucket must be carried to the end of the left beam and placed in the target area. One bucket must be carried to the end of the right beam and placed in the target area.

LEG-BEAM-3 It is only allowed to carry one bucket at a time.

LEG-BEAM-4 Once a bucket is picked up from its initial position, it must only touch the ground again in the target area.

LEG-BEAM-5 Pilots are only allowed to lift the buckets off the ground while they are standing on the first balancing beam.

LEG-BEAM-6 It is not allowed to hop with the non-prosthetic leg on the balance beam.

8.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 4 min
9 Exoskeleton Race


9.1 Introduction

Robotic exoskeletons are devices that enable paraplegic individuals to stand upright, walk, or to climb and descend stairs. Even though robotic exoskeletons for paraplegics have been in development since the late 1960's and early 1970's, the technology has not matured to a point where the devices are accepted by the end-users. The usability of current exoskeletons is attenuated by shortcomings such as a limited situational adaptability of their movement patterns (usually based on predefined motion profiles), the need for crutches, and time-consuming donning and doffing. Furthermore, the physical and cognitive load to the pilot combined with the need for crutches impedes the user from performing secondary tasks while walking. Therefore, current devices do not offer an actual alternative to the wheelchair yet. However, the prolonged use of a wheelchair can also be accompanied with challenges to the user’s general health such as musculoskeletal symptoms in the arms and shoulders due to overuse, impaired blood circulation, or osteoporosis in the lower limbs due to the lack of loading in the seated position.

Robotic exoskeletons enabling an upright posture and gait for paraplegic users bear the potential to address many of the above-mentioned shortcomings associated with
prolonged wheelchair use. The ability to communicate with peers on eye-level while standing is an often mentioned and welcome additional feature of exoskeleton use indicating that there is also a positive social impact of this technology.

### 9.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the EXO Race:

#### 9.2.1 Pilots

In addition to the general pilot eligibility criteria set forth in chapter 4.5.1 pilots must fulfil the following criteria to be eligible for participation in the EXO race:

EXO-PIL-1 Pilots must have a spinal cord injury with paraplegia and a complete loss of motor function in the lower limbs (AIS A or B, [http://www.sci-inforpages.com/levels.html](http://www.sci-inforpages.com/levels.html)).

EXO-PIL-2 Pilots must have sufficient voluntary control and strength of the upper body to control the exoskeleton.

General comments

- The eligibility of pilots with lesions affecting the control of trunk, arm and/or neck is evaluated on a case-by-case basis.
- Pilots can have a spastic or non-spastic lesion.

#### 9.2.2 Technology

The assistive device must fulfil the following criteria to be eligible for participation in the EXO race:

In addition to the general technology eligibility criteria set forth in Chapter 4.5.2, the assistive device must fulfil the following criteria to be eligible for participation in the EXO race:

EXO-TEC-1 Crutches or canes are allowed.

EXO-TEC-2 Load transfer to the ground via wheels or rolling contact is not allowed.

General comments

- Any kind of input device or automated gait intention detection strategy is allowed.
- Any type of joint actuation is allowed. Also, passive joints are allowed.
- Any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- Functional electrical stimulation can be added to assistive device.
9.3 Specific race rules

EXO-1  Wearing a helmet is mandatory. The teams are required to bring their own helmet.

EXO-2  If crutches or canes are used, they must be carried by the pilot during the entire race.

EXO-3  Pilots must walk such that during any point in time, at least one of their feet is in contact with the ground, i.e., swing-through gait patterns are not allowed.

9.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in all the following figures.
9.4.1 Carry

9.4.1.1 Introduction

For most devices, walking in an exoskeleton requires the use of crutches. As a result, it is difficult for a user to carry objects while walking. During in-home use, carrying objects while walking in an exoskeleton can be of high practical value.

In this task, pilots must carry a box to a target location while walking in their exoskeleton.

9.4.1.2 Task set-up & description

The cardboard box must be picked up from its initial location on the table and placed on the surface of the table near the finish line of the task. The box contains two full 0.5 l PET bottles.
### 9.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Box with lid</td>
<td>Pappis</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Bottle (0.5l)</td>
<td>filled with water</td>
<td>BOTTLESHOP</td>
</tr>
<tr>
<td>2</td>
<td>Bottle cap</td>
<td></td>
<td>BOTTLESHOP</td>
</tr>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 9.4.1.4 Task rules

**EXO-CARRY-1**  The parcel must be located on the table near the finish line of the task when the pilot crosses the finish line.

**EXO-CARRY-2**  The parcel must be in contact with one of the tables, the pilot, or the assistive device (including the crutches) at any time during task execution (i.e., the parcel must not be thrown).

**EXO-CARRY-3**  The bottles must not be removed from the parcel.

### 9.4.1.5 Comments

- The parcel may be carried using the hands or a tool which the pilot brings along, such as a bag.
9.4.2 Stairs

9.4.2.1 Introduction

Stairs are very common in daily life, both in the private and the public space. Stair climbing in powered exoskeletons is challenging since body balance must be always maintained while the exoskeleton must be very powerful to lift the user to the next step.

In this task, pilots must ascend and descend a flight of stairs without the use of a handrail.

9.4.2.2 Task set-up & description

Pilots must pass the stairs once in direction of the race.

The steeper side of the obstacle can face the start or the finish line.
### 9.4.2.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stairs</td>
<td>wood, with checker plate edge protection</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Handrail (1 for each side)</td>
<td>steel</td>
<td>custom made</td>
</tr>
</tbody>
</table>

### 9.4.2.4 Task rules

- **EXO-STAIR-1**  Pilots must cross the stairs once in race direction.
- **EXO-STAIR-2**  Pilots are allowed to place two feet on one step at the same time.
- **EXO-STAIR-3**  Pilots are not allowed to omit single steps or jump over steps. Thus, each step must be stepped on with at least one foot.
**9.4.3 Benches**

**9.4.3.1 Introduction**

Taking a seat and standing up are challenging when using an exoskeleton. Balance must be kept while substantial moments about the knee and hip joints must be generated and controlled.

In this task, pilots are challenged to take a seat on a bench and to get up again. Restricted space conditions, such as those found in a theatre or public transportation, make the task even more difficult.

[Image source](#)

**9.4.3.2 Task set-up & description**

Pilots must take a seat on one of the benches and get up again.
9.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Bench with backrest</td>
<td>Applarö</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Double-sided tape</td>
<td>to be specified</td>
<td></td>
</tr>
</tbody>
</table>

9.4.3.4 Task rules

EXO-BENCH-1 The pilots must sit down on and get up from one of the two benches.

9.4.3.5 Comments

- Pilots can approach the benches from the left or from the right and they are free to choose the bench on which they want to sit down.
9.4.4 Tilted path

9.4.4.1 Introduction

In daily life, some paths are tilted perpendicular to the direction of travel and walking surfaces may vary (e.g., when walking on nature paths, or when crossing a step road). Negotiating a tilted path in an exoskeleton is challenging as it requires abduction/adduction in the hip and pronation/supination in the ankle.

In this task, pilots must negotiate a tilted path.

9.4.4.2 Task set-up & description

Pilots must negotiate the tilted path once in the direction of the race.

The obstacle may be oriented to the left or to the right when facing the direction of the race (i.e., the tilted surface of the obstacle can point to the left or to the right).
9.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ramp (4m)</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Sidewall</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Backwall</td>
<td></td>
<td>custom made</td>
</tr>
</tbody>
</table>

9.4.4.4 Task rules

EXO-TILTED-1 Pilots must walk across the tilted path once in the direction of the race.
9.4.5 Free Walking

9.4.5.1 Introduction

Most current exoskeletons require the use of crutches to maintain balance during walking. Consequently, the arms are not free to be used for other tasks or gestures.

In this task pilot must walk a predefined distance without the use of their crutches.

9.4.5.2 Task set-up & description

Pilots must walk the distance between the start and the target area without using their walking aids to maintain balance.
9.4.5.3 Task infrastructure

No task infrastructure

9.4.5.4 Task rules

EXO-FREE-1 Walking aids are only allowed to touch the ground in the green start and target areas and only while the pilot’s feet are also in these areas. If the walking aids touch the ground between the green start and the target area, the task is failed.
9.4.6 Crowd

9.4.6.1 Introduction

Often in daily life, it is necessary to navigate around static or moving obstacles to reach a desired destination. When walking in dynamic crowds in particular, a constant control of direction and speed is required to avoid collisions.

In this task, pilots must pass between individual pieces of furniture. In addition, collisions with several robots that are roaming the task space must be avoided.

9.4.6.2 Task set-up & description

The pilot must pass between the tables without touching the orbiting robots.
• A full orbit for one robot takes appr. 40 s to 60 s. The velocity profile will be communicated at a later stage.
• The robots orbit counter-clockwise around the first table and clockwise around the second table.
• The two robots that orbit around a given table always have a phase shift of 180°.
• The robots that orbit around the first table have a phase shift of 90° as compared to the robots that orbit around the second table. The exact starting positions will be communicated at a later stage.
• The robots are set in motion the moment the pilot crosses the start line of the task.

### 9.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Table</td>
<td>Stensele</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Edge-following robot</td>
<td>e.g., Thymio from Mobsya. The final decision on what robot model will be used in the competitions will be communicated at a later stage.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Robot cover</td>
<td>red</td>
<td>3D-printed</td>
</tr>
<tr>
<td>4</td>
<td>Cover extension</td>
<td>red</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

### 9.4.6.4 Task rules

EXO-CROWD-1 The pilots must pass once between the two tables.

EXO-CROWD-2 The task is failed in case of any contact between the assistive device (including crutches), or any of the pilot's body parts with any part of the robots.

### 9.4.6.5 Comments

• The first piece of furniture can be passed on the left- or on the right-hand side.
9.4.7 Boxes

9.4.7.1 Introduction

Walking on surfaces that require irregular step lengths and heights is challenging since the position of the foot must be continuously controlled.

In this task, pilots must negotiate a quasi-random sequence of wooden boxes that vary in height and length.

9.4.7.2 Task set-up & description

The pilots must step across the sequence of three boxes.

The sequence of the boxes is randomized according to the following set of rules:

- The boxes will be installed in the following positions: 1, 3 or 4, 6 (see above).
• A subset of three of the six types of boxes will be presented (see below).

<table>
<thead>
<tr>
<th></th>
<th>Box 1</th>
<th>Box 2</th>
<th>Box 3</th>
<th>Box 4</th>
<th>Box 5</th>
<th>Box 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height [m]</td>
<td>0.18</td>
<td>0.20</td>
<td>0.22</td>
<td>0.24</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>Length [m]</td>
<td>0.30</td>
<td>0.27</td>
<td>0.29</td>
<td>0.31</td>
<td>0.33</td>
<td>0.25</td>
</tr>
</tbody>
</table>

9.4.7.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Box</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Boxes fixation system</td>
<td></td>
<td>custom made</td>
</tr>
</tbody>
</table>

9.4.7.4 Task rules

EXO-BOX-1  Pilots must cross the sequence of boxes once in the direction of the race.

EXO-BOX-2  Pilots are not allowed to omit single steps or jump over steps.
9.4.8 Doors

9.4.8.1 Introduction

Opening and closing doors is challenging as an exoskeleton user since the crutches must be carried and precise foot placement in changing directions in confined space (i.e., step backwards and sidewards) is required.

In this task, pilots must open and close multiple doors. One of the doors must be pulled to open while the other must be pushed.

9.4.8.2 Task set-up & description

The two doors must be opened, passed through, and closed. The first door is equipped with a door handle while the second door is equipped with a doorknob. Furthermore, the second door shuts automatically since it is equipped with a door closer.
9.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doorframe rack</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Doorframe</td>
<td>Pertura CPL white</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door left</td>
<td>Pertura Yori CPL white, right</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door right</td>
<td>Pertura Yori CPL white, left</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door handle</td>
<td>Pertura BB Vitur alu F1</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door knob</td>
<td></td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door closer</td>
<td></td>
<td>Hornbach</td>
</tr>
</tbody>
</table>

9.4.8.4 Task rules

EXO-DOOR-1 Each door must be opened, passed through, and fully closed (i.e., clicked shut) once. If the doors are not clicked shut when the pilot crosses the finish line of the task, the task is failed.
9.4.9 Stones

9.4.9.1 Introduction

In certain situations in daily life, it is required to accurately control the trajectory of the leg in order to accommodate for external circumstances, e.g., when entering an escalator or stepping over stones on a cross country path).

In this task, the pilot is challenged to walk over a series of stones. This tests the ability to place the feet in predefined location.

9.4.9.2 Task set-up & description

Pilots must walk across a series of steppingstones.
The route of steppingstones is randomized between races according to the following rules:

- There are 9 steppingstones (1-9) in total (i.e., 8 steps to be taken)
- Steppingstones 1 and 9 are always placed at the locations as shown above
- The location of steppingstones 2 to 8 is random considering the following conditions:
  - The step from steppingstone 1 to 2 can be to the left or to the right.
  - Alternating steps (left-right-left or vice-versa) must be taken.
  - There are 2 steps lengths and 2 step widths.

### 9.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Base plate</td>
<td>wood, with fixtures for attachment and lateral reinforcement</td>
<td>custom made</td>
</tr>
<tr>
<td>9</td>
<td>Stone</td>
<td>grey</td>
<td>custom made</td>
</tr>
</tbody>
</table>

### 9.4.9.4 Task rules

EXO-STONES-1 Each of the nine steppingstones must be stepped on with one foot at least once.
9.4.10  Kitchen

9.4.10.1  Introduction

For exoskeletons to be practical for everyday use, they must allow their user to perform auxiliary tasks that go beyond the basic walking functions. Such auxiliary tasks are then usually performed with the upper extremities and can involve manipulation of objects at various levels above the ground.

In this task, pilots must conduct several upper extremity tasks while standing in a kitchen environment in their exoskeleton.

9.4.10.2  Task set-up & description

The bread and the basket must be taken from the shelf and carried to the table. On the table, a slice of ‘bread’ must be cut off and placed in the basket. The shelf and drawer will be initially closed, they are shown open above for clarity only.
### 9.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 1x4</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Basket</td>
<td>Saluding (small)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Bread surrogate foam</td>
<td>RG80</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Butcher’s block</td>
<td>Aptitlig</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Bread knife</td>
<td>Vardagen</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 9.4.10.4 Task rules

**EXO-KITCHEN-1**
A cuboid slice of approximately 20 mm width must be cut off the foam on the breadboard, using the breadknife. The slice must be clearly separated from the rest of the foam by cutting and then placed in the breadbasket.

**EXO-KITCHEN-2**
The breadbasket (containing the cut slice of foam), the knife, the foam, and the breadboard must be located on the table (no specific target location) when the pilot crosses the finish line of the task.

**EXO-KITCHEN-3**
The door of the cupboard and the drawers must be closed when the pilot crosses the finish line of the task.

### 9.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 10 min
10 Wheelchair Race

WHL pilot solving the Stairs task during CYBATHLON 2020 Global Edition

10.1 Introduction

People with a severe walking disability who use a powered wheelchair for personal mobility are often confronted with challenges when interacting with their physical environment. Single steps (e.g., a curb), flights of stairs, or uneven terrain can pose significant obstacles. Depending on a user’s function of the trunk and arms it can also be very arduous to open/close a door or to pick up an object from the ground. Users often must rely on the help of a third person to overcome such situations.

Recently, technologies such as stair climbing mechanisms or robotic manipulators have been developed to provide support in some of the abovementioned situations. However, these technologies are often developed for specific tasks only and thus they do not perform well in varying scenarios. Their use is not versatile, often not intuitive, and therefore unsatisfying and frustrating for the user.

The addition of technologies to powered wheelchairs, such as stair climbing mechanisms or robotic manipulators, bear the potential to improve the autonomy in personal mobility of people with a severe walking disability in daily life.
10.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the Wheelchair Race:

10.2.1 Pilots

In addition to the general pilot eligibility criteria set forth in chapter 4.5.1 pilots must fulfil the following criteria to be eligible for participation in the WHL race:

WHL-PIL-1 Pilots must have a severe walking disability due to any kind of central nervous system disease or injury, any systemic neural or muscular disease or bilateral above knee amputation.

WHL-PIL-2 Pilots must be able to control their wheelchair. Thus, the pilots must have sufficient voluntary control of head, shoulder, hand, finger, tongue and/or voice to operate an input device.

10.2.2 Technology

In addition to the general technology eligibility criteria set forth in Chapter 4.5.2 the assistive device must fulfil the following criteria to be eligible for participation in the WHL race:

WHL-TEC-1 Both powered wheelchairs and manual wheelchairs that are powered by an external device are allowed, provided the power is solely produced by the device and not by the pilot.

WHL-TEC-2 Chest, shoulder, leg, foot, and head restraints or any other type of restraint are allowed provided they are required to secure the pilot in the device.

WHL-TEC-3 Backpacks, bags, or similar can be attached to the powered wheelchairs during the race provided they do not pose a hazard to the pilot and the environment.

General comments

- Input (control) devices can include any standard or novel technology such as a hand joystick, head joystick, a sip & puff controller, a tongue drive, headrest switches, a touchpad, a tiller, a BCI, speech processing methods or any other technology.
- Load transfer to the ground can occur using wheels, tracks, or other means. Legged or wheeled-legged robots are also allowed.
- Any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- Any type of active actuation (other than combustion) is allowed.
• It is recommended that the width of the wheelchair does not exceed 900 mm (otherwise, it cannot pass many of the obstacles).

### 10.3 Specific race rules

**WHL-1**  
Wearing a helmet is mandatory. The teams are required to bring their own helmet.

**WHL-2**  
If any handrails are used to support movement or action or used to keep balance by grasping, pulling, pushing or similar, with any part of the body, the task is failed. Handrails are provided for safety reasons only.

**WHL-3**  
Any object coloured **blue** in any of the following drawings must only be touched and manipulated using the robotic manipulator.

**WHL-4**  
Pilots are only allowed to operate the robotic manipulator while they are attempting the respective task. During completion of all other tasks, the robotic manipulator must be in a safe state such that it cannot present an impending hazard to the pilot or to bystanders.

Comment re. WHL-4: The safe state for a given robotic manipulator is subject to agreement between the head of discipline and the team.

**WHL-5**  
The end effector of the robotic manipulator may be exchanged during the race. The process must be fully externally powered and not require any manipulation by the pilot other than operating the input device.

Comment re. WHL-5: Pilots with good motor function of their upper extremities (e.g., low lesion level) would have an advantage over pilots with more severely impaired motor function of their upper extremities (e.g., high lesion level) if manual exchange of the end effector was allowed.

**WHL-6**  
The energy required for actuating the robotic manipulator (e.g., positioning, actuate door handle, open/close door in the Doors task) must not be provided by the pilot.

### 10.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in all the following figures.
10.4.1 Restaurant

10.4.1.1 Introduction

Powered wheelchairs are often too bulky to fit under a standard table, yet this is critical for social interaction (i.e., in a restaurant, at home, at work). Pilots should be able to drive close to a table in such a way that the thighs of the pilot fit below the tabletop.

In this task the pilots have to navigate their wheelchair so that half of their thighs are placed under a table without moving any furniture.

10.4.1.2 Task set-up & description

The pilot must approach tables 1 and 2. At both tables half of the pilot's thigh must be covered by the tabletop. The tables must be approached on the long sides that are marked with a yellow line. The task set-up can set up as shown above (table 1 right, table 2 left) or reversed (table 1 left, table 2 right).
### 10.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Table</td>
<td>IKEA Lerhamn (rectangular)</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Table</td>
<td>IKEA Lerhamn (square)</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 10.4.1.4 Task rules

- **WHL-REST-1**  The pilot must approach the two tables at the side marked with a yellow line until both knees and half of the thighs are covered by the long side of the table.
- **WHL-REST-2**  The pilots are not allowed to remove their feet from the footrest as they approach the target table.

### 10.4.1.5 Comment

- The referee verbally confirms correct execution at each table.
10.4.2 Stairs

10.4.2.1 Introduction

Stairs are very common in daily life, both in the private and public space.

In this task, pilots have to ascend and descend a straight staircase twice. Pilots have to bring their wheelchair to a standstill while on the descent from the stairs to show that they are able to stop at any time.

Image source

10.4.2.2 Task set-up & description

The staircase must be ascended and descended once. The slope of the stairs is not equal on both sides. The step depth on one side is 350 mm (gentle slope), on the other side 280 mm (steep slope). The steep slope can face the start or the finish line of the task.
10.4.2.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stairs</td>
<td>wood, with checker plate edge protection</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Handrail (1 for each side)</td>
<td>steel</td>
<td>custom made</td>
</tr>
</tbody>
</table>

10.4.2.4 Task rules

WHL-STAIR-1  The pilot must ascend and descend the stairs once in the direction of the race (i.e., once up, once down).

WHL-STAIR-2  When descending the stairs, pilots must bring their wheelchair to a full standstill while the foremost part of the wheelchair is in contact with the last step and does not touch the ground. If the ground is touched before the full standstill of the wheelchair, the task is failed.

10.4.2.5 Comments

- The last step of the staircase will be highlighted for better visibility.
- The referee will verbally confirm the full standstill of the wheelchair.
10.4.3 Pick-up

10.4.3.1 Introduction

Small items that are randomly lying around (e.g., a child’s toys) can obstruct a wheelchair user’s path. He or she might want to pick up the objects to either use them or to stow them away.

In this task, the pilots must pick up a bottle from the floor and place it on a table.

The blue bottle that blocks the pilot’s way must be picked up and placed on the yellow target location on the table.

The bottle will initially be placed in any of the 8 (1-8) orientations shown above.
10.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottle (0.5l)</td>
<td>blue</td>
<td>bottleshop</td>
</tr>
<tr>
<td>1</td>
<td>Bottle cap</td>
<td>blue</td>
<td>CZECH BREWERY SYSTEM</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Target disk</td>
<td>yellow</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

10.4.3.4 Task rules

WHL-PICK-1 The blue bottle must be standing upright on the yellow target location on the table when the pilot crosses the finish line of the task.
10.4.4 Tilted Path

10.4.4.1 Introduction

Driving on a path that is tilted perpendicular to the direction of travel can be very challenging for wheelchair users. Continuous steering is required to prevent the wheelchair from turning into the direction of the tilt. Such tilts can occur on sidewalks, but also when on a nature path.

In this task, pilots must negotiate tilted path.

Image source

10.4.4.2 Task set-up & description

Pilots must negotiate the tilted path once in direction of the race.
The obstacle may be oriented to the left or to the right when facing the direction of the race (i.e., the inclined surfaces of the obstacle can point to the left or to the right).

10.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ramp (4m)</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Sidewall</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Backwall</td>
<td></td>
<td>custom made</td>
</tr>
</tbody>
</table>

10.4.4.4 Task rules

WHL-TILT-1 Pilots must navigate their wheelchair across the tilted path once in direction of the race.
10.4.5  **Uplift**

10.4.5.1  **Introduction**

Many challenging situations arise in daily life for wheelchair users due to their seated position. For example, it is impossible to reach for objects that are located on the top shelves in a store, it is difficult to interact with staff at a standard counter, or to look someone in the eyes when having a conversation.

In this task, pilots and their assistive devices are challenged to reach an object above the level of sitting height.  

**Image source**

10.4.5.2  **Task set-up**
Pilots must pass between each pair of poles. While they are not allowed to touch the 1st and the 3rd red crossbar, they must touch with their head the yellow curtain hanging from the 2nd yellow crossbar.

### 10.4.5.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Pole with socle</td>
<td>l: 1600mm, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>2</td>
<td>Crossbar</td>
<td>l: 1200mm, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>1</td>
<td>Crossbar</td>
<td>l: 1200mm, yellow</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>6</td>
<td>Crossbar fixture</td>
<td>shortenend</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>1</td>
<td>Curtain</td>
<td>yellow</td>
<td></td>
</tr>
</tbody>
</table>

### 10.4.5.4 Task rules

**WHL-LIFT-1** The pilot must pass between each pair of poles once.

**WHL-LIFT-2** The red crossbar of the 1st and 3rd pair of poles must not be touched by any part of the pilot or the assistive device.

**WHL-LIFT-3** The heights of the 1st and 3rd red crossbar are identical, the height of yellow curtain hanging from the 2nd crossbar is 30 cm higher than the height of the 1st and 3rd red crossbar.

**WHL-LIFT-4** The yellow curtain hanging from crossbar of the 2nd pair must be touched with the head.

**WHL-LIFT-5** The robotic arm must not be used to touch the yellow curtain hanging from the 2nd crossbar.

**WHL-LIFT-6** The pilot is not allowed to actively move towards or away from the crossbar to contribute to task solving (i.e., the pilot’s posture must be the same throughout the task).

### 10.4.5.5 Comments

- The team can define the height of the 1st crossbar in steps of 5 cm, the heights of the 2nd and 3rd crossbar will be set up accordingly.

- If a pilot’s headrest extends above the head, the highest part of the headrest may be used as a reference for touching the poles and curtain. In this case, the headrest is the reference for all the poles and the headrest must not move relative to the head during the entire task.
10.4.6 Crowd

10.4.6.1 Introduction

Often in daily life, it is necessary to navigate around static or moving obstacles to reach a desired destination. When moving in dynamic crowds in particular, a constant control of direction and speed is required to avoid collisions.

In this task, pilots must pass between individual pieces of furniture. In addition, collisions with several robots that are roaming the task space must be avoided.

10.4.6.2 Task set-up & description

The pilot must pass between the tables without touching the orbiting robots.

- A full orbit for one robot takes appr. 40 s to 60 s. The velocity profile will be communicated at a later stage.
• The robots orbit counter-clockwise around the first table and clockwise around the second table.
• The two robots that orbit around a given table always have a phase shift of 180°.
• The robots that orbit around the first table have a phase shift of 90° as compared to the robots that orbit around the second table. The exact starting positions will be communicated at a later stage.
• The robots are set in motion the moment the pilot crosses the start line of the task.

10.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Table</td>
<td>Stensele</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Edge-following robot</td>
<td>e.g., Thymio from Mobsya. The final decision on what robot model will be used in the competitions will be communicated at a later stage.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Robot cover</td>
<td>red</td>
<td>3D-printed</td>
</tr>
<tr>
<td>4</td>
<td>Cover extension</td>
<td>red</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

10.4.6.4 Task rules

WHL-CROWD-1  The pilots must pass once between the two tables.
WHL-CROWD-2  The task is failed in case of any contact between wheelchair, or any of the pilot's body parts with any of the robots.

10.4.6.5 Comments

• The first piece of furniture can be passed on the left- or on the right-hand side.
10.4.7 Doorstep

10.4.7.1 Introduction

Crossing the doorstep is usually the first step when entering a building. They come in many different sizes, and it is often decided at the doorstep if a wheelchair user can enter or leave a building at all. Powered wheelchairs should therefore be able to negotiate a big variety of doorsteps.

In this task, pilots and their devices are challenged to negotiate different types of doorsteps.

10.4.7.2 Task set-up

The obstacle must be crossed once in the direction of the race.
10.4.7.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doorstep obstacle</td>
<td></td>
<td>custom made</td>
</tr>
</tbody>
</table>

10.4.7.4 Task rules

WHL-STEP-1  The obstacle must be crossed once in the direction of the race.
10.4.8 Doors

10.4.8.1 Introduction

Opening and closing doors is challenging as a wheelchair user. Oftentimes, the available space in front of a door is confined. Furthermore, not all doors require the same amount of force to push or pull them open.

In this task, pilots must open and close multiple doors using an external robotic manipulator. One of the doors must be pulled to open while the other must be pushed.

10.4.8.2 Task set-up & description

The two doors must be opened, passed through, and closed. The first door is equipped with a door handle while the second door is equipped with a doorknob.
Furthermore, the second door shuts automatically since it is equipped with a door closer.

### 10.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doorframe rack</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Doorframe</td>
<td>Pertura CPL white</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door left</td>
<td>Pertura Yori CPL white, right</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door right</td>
<td>Pertura Yori CPL white, left</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door handle</td>
<td>Pertura BB Vitur alu F1</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door knob</td>
<td></td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door closer</td>
<td></td>
<td>Hornbach</td>
</tr>
</tbody>
</table>

### 10.4.8.4 Task rules

WHL-DOOR-1 Each door must be opened, passed through, and fully closed (i.e., clicked shut) once. If the doors are not clicked shut when the pilot crosses the finish line of the task, the task is failed.

WHL-DOOR-2 The blue doorhandle and blue doorknob must be manipulated using a robotic manipulator (e.g., a robotic arm).
10.4.9 Stony Path

10.4.9.1 Introduction

Paths in nature are often uneven and rough. Powered wheelchairs must be able to cope with such terrain such that their users have are not restricted during recreational outdoor activities.

In this task, pilots and their assistive devices are challenged to navigate a stony path with their wheelchair.

10.4.9.2 Task set-up & description

![Image source](Image source)

Pilots must cross the stony path once in direction of the race. The obstacle consists of four base plates (1-4). On each of the baseplates the stones are set up in a different layout. The order of the baseplates will be randomized.
### 10.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Base plate</td>
<td>wood, with fixtures for attachment and lateral reinforcement</td>
<td>custom made</td>
</tr>
<tr>
<td>16</td>
<td>Half cylinder bar (long, for placement across to race direction)</td>
<td>wood, grey, coated, l: 400 mm</td>
<td>custom made</td>
</tr>
<tr>
<td>12</td>
<td>Half cylinder bar (long, for angled placement)</td>
<td>wood, grey, coated, l: 400 mm</td>
<td>custom made</td>
</tr>
<tr>
<td>12</td>
<td>Half cylinder bar (short, along race direction)</td>
<td>wood, grey, coated, l: 250 mm</td>
<td>custom made</td>
</tr>
</tbody>
</table>

### 10.4.9.4 Task rules

- **WHL-STONE-1** Pilots must cross the stony path once in direction of the race.
- **WHL-STONE-2** The pilot must bring the wheelchair to a full standstill in the second half of the obstacle, i.e., when the wheelchair is located on plates 3 and 4. If the wheelchair touches the ground after the stony path before it has reached full standstill, the task is failed.
- **WHL-STONE-3** Crossing the boundaries of the stony path on the side is not allowed (i.e., the pilot can only exit at the start and end of the obstacle).

### 10.4.9.5 Comments

- The referee will verbally confirm full standstill of the wheelchair.
10.4.10 Winding stairs

10.4.10.1 Introduction

Winding stairs can be found both in the private and public space. They pose a particular challenge to stair climbing mechanisms of wheelchairs since the slope of the stairs depends on the selected path and varies between the sides of the wheelchair.

In this task, pilots have to climb and descend a flight of winding stairs.

Image source

10.4.10.2 Task set-up & description

The flight of winding stairs must be climbed and descended once in the direction of the race.
10.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stairs</td>
<td>wood, with checker plate edge protection</td>
<td>custom made</td>
</tr>
</tbody>
</table>

10.4.10.4 Task rules

WHL-WIND-1 Pilots must ascend and descend the flight of winding stairs once in the direction of the race (once up, once down).

10.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 8 min
11 Assistance Robot Race

11.1 Introduction

People with severe motor impairments or missing limbs to both the upper and the lower extremities have limited autonomy when interacting with their physical environment resulting from their disability. Tasks such as shopping for groceries independently, eating and drinking, personal hygiene, or dishwashing are just a few examples in which these people might depend on a care person.

Assistance robots are a relatively new category of assistive devices which can accompany a user with limited motor control in daily life. They can assist and take over some of the tasks which are otherwise managed by a care person. To become a fully accepted technology these devices must be seamlessly integrated and capable to meaningfully contribute to the manifold domains of daily life. Their use must be effortless and reliable while providing diverse functions such as the dexterous manipulation of delicate objects or the autonomous avoidance of obstacles.

Assistance robots bear potential to increase the autonomy of people who have very little to no voluntary motor control of their limbs due to their disability.
11.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the Assistance Robot Race:

11.2.1 Pilots

Pilots must fulfill the following criteria to be eligible for participation in the ROB race:

ROB-PIL-1 Pilots must be wheelchair users in daily life and have a severe impairment of both upper limbs due to pathologies such as any kind of central nervous system disease or injury, any systemic neural or muscular disease, a bilateral shoulder disarticulation, or phocomelia.

Comment re. ROB-PIL-1: In case of doubt whether a pilot candidate meets this feasibility criterion, please get in touch with the CYBATHLON organizing committee.

ROB-PIL-2 Pilots must have sufficient ability to control their wheelchair as well as their personal assistance robot at any time.

11.2.2 Technology

The envisioned technology approach is a robotic manipulator mounted to a mobile platform. The mobile platform can be the pilot’s own wheelchair or an auxiliary device. Exemplary approaches are given in the table below. In the first envisioned approach, the combination of the robotic manipulator and the pilot’s wheelchair is considered the personal assistance robot. In the second envisioned approach, the robotic manipulator and its mobile base are considered the personal assistance robot.

Exemplary approaches

Envisioned approach 1: A robotic manipulator mounted to a powered wheelchair.

Envisioned approach 2: A person in a powered wheelchair and a robotic manipulator mounted to an auxiliary mobile platform. Image source
The assistive device must fulfil the following criteria to be eligible for participation in the ROB race:

ROB-TEC-1  The mobile base and the wheelchair used by the pilot must fulfil the technology eligibility criteria for the WHL race (see chapter 10, page 112).

ROB-TEC-2  Only actively driven robotic manipulators are eligible.

General comments

- The personal assistance robot should be designed in compliance with ISO 13482:2014 (or similar regulations applied in the country of development).
- Input (control) devices can include any standard or novel technology such as a hand joystick, head joystick, a sip & puff controller, a tongue drive, headrest switches, a touchpad, a tiller, a BCI, speech processing methods or any other technology.
- Any type of actuation is allowed.
- Any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- Multiple robotic manipulators mounted to the same mobile platform can be used.
- Load transfer to the ground can occur using wheels, tracks, or other means. Legged or wheeled-legged robots are also allowed.

11.3 Specific race rules

ROB-1  The end effector of the robotic manipulator may be exchanged during the race. The process must be fully externally powered and not require any manipulation by the pilot other than operating the input device.

ROB-2  The energy required to manipulate the task objects must come entirely from the robot and not from the pilot.

Comment on ROB-2: The operation of the robot by the pilot is excluded from this rule.

ROB-3  Pilots are not allowed to actively touch or carry any objects of the tasks (e.g., grasping, holding in the hands or between the teeth, pinching between shoulder and head or in the arm pit). If any objects must be transported as part of a task, the object must be carried by the assistance robot.

Comment on ROB-3: This rule intends to reduce the impact of the pilot’s residual motor function on task difficulty. The assistance robot may however place an object on the pilot’s lap.
ROB-4 If the pilot uses a separate assistance robot, a task must only be solved, i.e., any of the task material must only be touched, if both the pilot’s wheelchair and the assistance robot are in their entirety on the respective task space.

ROB-5 Any object coloured blue in any of the following drawings must only be touched and manipulated using the robotic manipulator.

In case a pilot uses an auxiliary mobile platform as the assistance robot the following additional rules apply:

ROB-6 Two referees judge the race. One referee observes the pilot, and one referee observes the assistance robot.

ROB-7 Task timing is based on the location of the pilot. The task time is started and stopped when the pilot crosses the start-/finish line.

ROB-8 Task completion is based on the location of pilot and assistance robot. A task is considered completed when the task is solved, and both (pilot and assistance robot) have left the task space. Once a task is completed, neither the pilot nor the assistance robot is allowed to go back to this task.

Comment on ROB-8: This means that the pilot and the assistance robot do not have to be located on the same task at a given time. For example, the pilot, located on task 2, can send the assistance robot ahead to start completing task 3.

11.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in all the following figures.
11.4.1 Mailbox

11.4.1.1 Introduction

Grasping objects from within confined space can be of particular challenge to robotic grippers. Such tasks are further exacerbated if the object has a smooth surface and offers little to no opportunity to be gripped (e.g., due to size or the lack of a handle).

In this task, the pilot must remove a parcel from a mailbox and transport it to a target location.

11.4.1.2 Task set-up & description

The parcel must be removed from the mailbox and placed on the table. The hatch of the mailbox is initially closed.
The task can be set up as shown above or mirrored (i.e., mailbox located at the right task side line). In any case, the opening of the mailbox always faces the opposite sideline of the task.

### 11.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mailbox</td>
<td></td>
<td>BURG WÄCHTER</td>
</tr>
<tr>
<td>1</td>
<td>Mailbox pole</td>
<td>steel</td>
<td>BURG WÄCHTER</td>
</tr>
<tr>
<td>1</td>
<td>Mailbox base</td>
<td>wood</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Parcel</td>
<td>foam (RG80)</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

### 11.4.1.4 Task rules

ROB-MAIL-1 The parcel must be located on the table when the pilot crosses the finish line of the task.

ROB-MAIL-2 The hatch of the mailbox must be closed when the pilot crosses the finish line of the task.
11.4.2 Toothbrush

11.4.2.1 Introduction

Many powered wheelchair users require the help of a care giver to complete tasks of personal hygiene. For assistance robots such situations pose a particular challenge. On the one hand, because the involved objects have heterogenic properties (e.g., shape, compliance, texture), on the other hand due the required interaction between the device and the pilot during which safety must be guaranteed at any time.

In this task, the pilot must use a toothbrush.

11.4.2.2 Task set-up & description

The pilot must 'brush' the teeth using the assistance robot.
11.4.2.3  **Task infrastructure**

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Mirror</td>
<td>Lilltjärn</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Mirror feet</td>
<td>wood</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Plastic cup</td>
<td>Kalas</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Toothbrush</td>
<td>Thoothbrush Special Care</td>
<td>TEPE</td>
</tr>
</tbody>
</table>

11.4.2.4  **Task rules**

ROB-TOOTH-1  The brush of the blue toothbrush must be brought in contact with the pilot’s teeth.

ROB-TOOTH-2  The blue toothbrush must be located in the upright standing cup when the pilot crosses the finish line of the task.

ROB-TOOTH-3  The pilots are not allowed to actively move towards the blue toothbrush, respectively with their trunk or head as the device approaches the pilot.

11.4.2.5  **Comments**

- The referee confirms correct task execution.
11.4.3 Pick-up

11.4.3.1 Introduction

Small items that are randomly lying around (e.g., a child’s toys) can obstruct a wheelchair user’s path. He or she might want to pick up the objects to either use them or to stow them away.

In this task, the pilots must pick up a bottle from the floor and place it on a table.

11.4.3.2 Task set-up & description

The blue bottle that blocks the pilot’s way must be picked up and placed on the yellow target location on the table.

The bottle will initially be placed in any of the 8 (1-8) orientations shown above.
11.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottle (0.5l)</td>
<td>blue</td>
<td>bottleshop</td>
</tr>
<tr>
<td>1</td>
<td>Bottle cap</td>
<td>blue</td>
<td>CZECH BREWERY SYSTEM</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Target disk</td>
<td>yellow</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

11.4.3.4 Task rules

ROB-PICK-1 The blue bottle must be standing upright on the yellow target location on the table when the pilot crosses the finish line of the task.
11.4.4 Laundry

11.4.4.1 Introduction

Assistance robots must be able to carry out a multitude of manipulation tasks of a wide range of objects when carrying out household work. Soft objects such as cloth can be difficult to manipulate in particular.

In this task, the pilot must hang a t-shirt on a clothesline using two clothespins with the help of the assistance robot.

The blue t-shirt must be taken from the clothesline and put into the clothes hamper. The blue clothespin must be grasped and moved to a designated box mounted to the stand of the clothesline. The height of the clothesline is 1.30 m above the ground.
### 11.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hamper</td>
<td>Torkis</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>T-shirt</td>
<td>subject to change</td>
<td>Neutral</td>
</tr>
<tr>
<td>1</td>
<td>Clothesline</td>
<td>custom made</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Box for clothespins</td>
<td>Gis, yellow</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Clothespin</td>
<td>blue</td>
<td>WENKO</td>
</tr>
</tbody>
</table>

### 11.4.4.4 Task rules

**ROB-LAUNDRY-1**  
The t-shirt must be located inside the clothes hamper when the pilot crosses the finish line of the task. If the t-shirt touches the ground at any point, the task is failed.

**ROB-LAUNDRY-2**  
The clothes pin must be located in the designated box when the pilot crosses the finish line of the task.
11.4.5 Eating

11.4.5.1 Introduction

Eating and drinking are situations in which an assistance robot can be of great help to a user. However, such situations pose a particular challenge to the control of the assistance robot. On the one hand, because the involved objects have heterogenic properties (e.g., shape, compliance, texture), on the other hand due the required interaction between the device and the pilot during which safety must be guaranteed at any time.

In this task, pilots must use their assistance robot to eat an apple.

11.4.5.2 Task set-up & description

One of the blue apples must be brought in contact with the pilot’s mouth.
11.4.5.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coffee table</td>
<td>Vittsjö</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Plate</td>
<td>365+</td>
<td>IKEA</td>
</tr>
<tr>
<td>3</td>
<td>Apple</td>
<td>blue</td>
<td>Floristik24</td>
</tr>
</tbody>
</table>

11.4.5.4 Task rules

ROB-EAT-1  The pilots must grasp any of the blue apples from the bowl and bring it to their mouth, i.e., they must make contact between their lips and the apple.

ROB-EAT-2  After making contact between the blue apple and the pilot’s mouth, the blue apple must be placed on the plate or on the table. If any of the blue apples touch the table before it was in contact with the pilot’s mouth, the task is failed.

ROB-EAT-3  The pilots are not allowed to actively move towards the apple with their trunk or head as the device approaches the pilot.

11.4.5.5 Comments

- The referee confirms correct task execution.
11.4.6 Crowd

11.4.6.1 Introduction

Often in daily life, it is necessary to navigate around static or moving obstacles to reach a desired destination. When navigating in dynamic crowds in particular, a constant control of direction and speed is required to avoid collisions.

In this task, pilots must pass between individual pieces of furniture. In addition, collisions with several robots that are roaming the task space must be avoided.

11.4.6.2 Task set-up & description

The pilot and the assistance robot must pass between the tables without touching the orbiting robots.
• A full orbit for one robot takes appr. 40 s to 60 s. The velocity profile will be communicated at a later stage.
• The robots orbit counter-clockwise around the first table and clockwise around the second table.
• The two robots that orbit around a given table always have a phase shift of 180°.
• The robots that orbit around the first table have a phase shift of 90° compared to the robots that orbit around the second table. The exact starting positions will be communicated at a later stage.
• The robots are set in motion the moment the pilot crosses the start line of the task.

### 11.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Table</td>
<td>Stensele</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Edge-following robot</td>
<td>e.g., Thymio from Mobsya. The final decision on what robot model will be used in the competitions will be communicated at a later stage.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Robot cover</td>
<td>red</td>
<td>3D-printed</td>
</tr>
<tr>
<td>4</td>
<td>Cover extension</td>
<td>red</td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

### 11.4.6.4 Task rules

**ROB-CROWD-1** The pilot and the assistance robot must pass once between the two tables.

**ROB-CROWD-2** The task is failed in case of any contact between the assistance robot, the wheelchair, or any of the pilot’s body parts and any of the orbiting robots.

### 11.4.6.5 Comments

• The first piece of furniture can be passed on the left- or on the right-hand side.
11.4.7 Dishwasher

11.4.7.1 Introduction

Emptying a dishwasher of clean tableware is a great challenge to an assistance robot since space for grasping objects is limited and because there are many ways to put the tableware in the dishwasher initially.

In this task, pilot have to empty a dishwasher.

11.4.7.2 Task set-up & description

The blue plate initially located in the dishwasher must be removed and placed on the table that is located opposite the dishwasher. Insert: View of half-opened dishwasher as seen from the table.
### 11.4.7.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf, with front door</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wire basket</td>
<td>Utrusta IKEA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cup hinge</td>
<td>BLUM CLIP top BLUMOTION OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Flap hinge left</td>
<td>OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Flap hinge right</td>
<td>OPO</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Door handle</td>
<td>Bagganäs IKEA</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Plate holder</td>
<td>Rinnig IKEA</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Plate</td>
<td>365+ IKEA</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square) IKEA</td>
<td></td>
</tr>
</tbody>
</table>

### 11.4.7.4 Task rules

- **ROB-DISH-1** The blue plate must be located on the table when the pilot crosses the finish line of the task.
- **ROB-DISH-2** If the blue plate drops on the ground, the task is failed.
- **ROB-DISH-3** If the blue plate breaks into pieces, the task is failed.
- **ROB-DISH-4** The dishwasher door must be closed when the pilot crosses the finish line of the task.
11.4.8 Doors

11.4.8.1 Introduction

Opening and closing doors is challenging as a wheelchair user. Often-times, the available space in front of a door is confined. Furthermore, not all doors require the same amount of force to push or pull them open.

In this task, pilots must open and close multiple doors using their assistance robot. One of the doors must be pulled to open while the other must be pushed.

11.4.8.2 Task set-up & description

The two doors must be opened and passed through. The first door is equipped with a door handle while the second door is equipped with a doorknob. Furthermore, the second door shuts automatically since it is equipped with a door closer.
### 11.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doorframe rack</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Doorframe</td>
<td>Pertura CPL white</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door left</td>
<td>Pertura Yori CPL white, right</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door right</td>
<td>Pertura Yori CPL white, left</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door handle</td>
<td>Pertura BB Vitur alu F1</td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door knob</td>
<td></td>
<td>Hornbach</td>
</tr>
<tr>
<td>1</td>
<td>Door closer</td>
<td></td>
<td>Hornbach</td>
</tr>
</tbody>
</table>

### 11.4.8.4 Task rules

**ROB-DOOR-1**  Each door must be opened, passed through, and closed once.

**ROB-DOOR-2**  The blue doorhandle and blue doorknob must be manipulated using a robotic manipulator (e.g., a robotic arm).
11.4.9 Touch Screen

11.4.9.1 Introduction

Many user interfaces are nowadays based on touch screens (e.g., vending machines, the menu in restaurants). Their use is primarily based on visual perception and some motor dexterity is required to use them.

In this task, pilots have to navigate a touchscreen and order a predefined item from a variety of foods and drinks.

11.4.9.2 Task set-up & description

The pilots must select a food or a drink on a touchscreen. The food or drink to be selected is displayed on the touch screen at the beginning of the task. Further details about the app for the touchscreen will be communicated at a later stage.
11.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 1x4</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Tablet fixation</td>
<td>The design of the custom made smart pad fixation will be provided on a later stage.</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Tablet</td>
<td>11&quot; display size, Android</td>
<td>e.g. Lenovo</td>
</tr>
</tbody>
</table>

11.4.9.4 Task rules

ROB-SCREEN-1 If any food or drink other than the one specified is selected, the task is failed.
11.4.10 Clean Up

11.4.10.1 Introduction

Stowing away objects is a task in which assistance robots can be of significant help to their user. However, the vast variety of objects, their orientation and target locations make this type of task a challenge.

In this task, pilots must clean up a table from several objects and stow them in predefined locations.

11.4.10.2 Task set-up & description

Initially, four objects are randomly placed on the table and each object is covered by a non-transparent box (1-4).

The same four objects are also randomly placed in the shelf, one object in each of the four compartments (see below). The referee lifts the first box, and the corresponding object must be moved from its compartment to the top of the shelf. Thereafter the referee lifts the second box and so forth.
Left: Initially, the four blue objects are randomly allocated to the four compartments of the shelf. Right: at the end of the task, the four blue objects must be located on top of the shelf.

### 11.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 2x2 IKEA</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Box</td>
<td>Kugis</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Cylinder (long, narrow)</td>
<td></td>
<td>3D-printed</td>
</tr>
<tr>
<td>1</td>
<td>Die</td>
<td></td>
<td>3D-printed</td>
</tr>
<tr>
<td>1</td>
<td>Disc</td>
<td></td>
<td>3D-printed</td>
</tr>
<tr>
<td>1</td>
<td>Cube</td>
<td></td>
<td>3D-printed</td>
</tr>
</tbody>
</table>

### 11.4.10.4 Task rules

**ROB-CLEAN-1** The blue objects must be moved from their initial location in the shelf onto the top surface of the shelf in the order in which they are revealed by the referee.

**ROB-CLEAN-2** All blue objects must be located on the top surface of the shelf when the pilot and the assistance robot cross the finish line of the task.

**ROB-CLEAN-3** The objects on the table are only revealed by the referee when the pilot’s wheelchair, in its entirety, is located in the start area and the previous blue object has been placed on top of the shelf.

### 11.5 Competition mode and scoring

- Points per task: 10
- Total race duration: 10 min
12 Vision Assistance Race

A blind person using an intelligent white cane (Image source: Stefan Schneller, RELab, ETH Zürich, ZHdK)

12.1 Introduction

People with a severe impairment or complete loss of vision lack environmental information compromising their autonomy in completing many activities of daily living across multiple domains. According to the World Health Organisation (WHO), a vision impairment not only impacts quality of life but also leads to lower rates of workforce participation and higher risk of falls. Simple situations such as selecting colour matching clothes or identifying a desired product in the supermarket can become a challenge. Unexpected road work on the daily commute can lead to perilous situations. Generally, unfamiliar, or dynamic environments are challenging to people with a severe impairment or complete loss of vision.

Assistive devices such as smart vision assistants (e.g., an intelligent white cane) are designed to provide information about the environment by rendering the information to other available senses, such as touch or hearing. While there is a wide range of vision aids available on the market using a variety of approaches (e.g., computer vision, artificial intelligence), their functions are usually restricted to specific domains (e.g., reading a text aloud, identifying a colour) or are unpractical to use and therefore do not satisfy the user’s needs.

Smart vision assistants that provide an intuitive, comprehensive, and reliable substitute to vision bear the potential to improve the quality of live and autonomy of people with a severe impairment or complete loss of vision.
12.2 Eligibility criteria

In addition to the General Rules outlined in chapter 4, the following specific rules apply for the Vision Assistance Race:

12.2.1 Pilots

Pilots must fulfil the following criteria to be eligible for participation in the VIS race:

VIS-PIL-1  Pilots must be blind according to the definition of ICD-11, i.e., category 4 or worse in their better eye. This corresponds to pilots presenting with a visual acuity of worse than 20/400 (0.05).

12.2.2 Technology

The assistive device must fulfil the following criteria to be eligible for participation in the VIS race:

There are no specific eligibility criteria in addition to the general rules set forth in chapter 4.

General comments

- Input (control) devices can include any standard or novel technology such as but not limited to BCIs, speech processing methods or any other technology.
- Any technical modality (and their combination) to collect information about the environment is eligible (e.g., LIDAR, vision, ultrasound).
- Any type of feedback modality (e.g., sound, voice, vibro-tactile, electric stimulation) is eligible provided it is safe for the pilot and the environment.

12.3 Specific race rules

VIS-1  All Pilots will be completely blindfolded during the competition. The blindfold must be applied according to the guidelines provided by the CYBATHLON organising committee.

VIS-2  A team official can accompany the pilot to the competition field. Once the race has started the support person is not allowed to interact with the pilot or the assistive device in any way (i.e., coaching is not allowed). In case of any intervention during the race (e.g., in case of coaching, a technical defect or an emergency) the race is terminated for that pilot. The pilot’s current score is then taken as the score for that race.

VIS-3  If a pilot requires help from a referee or the accompanying team official to orient him- or herself on a task, the task is failed. After a task fail, pilots can ask for assistance to be guided to the start line of the next task.
Comment re. VIS-3: Guidance lines will be installed along the sidelines and at the start and finish line of the task to support orientation on the racetrack.

12.4 Task definitions

Each task is described in the following sections. If not otherwise stated, the direction of the race is (bottom) left to (top) right in all the following figures.
12.4.1 Front Door

12.4.1.1 Introduction

Finding the right entrance to a house and identifying the location and correct name on a panel of doorbells is often very challenging for blind people ("last mile problem").

In this task, pilots have to locate the entrance to a house, find the panel of doorbells and ring the pre-specified bell.
12.4.1.2 Task set-up & description

The pilots must locate the entrance and ring the correct doorbell. The target doorbell to be rang will be written on a A4 sheet located on the table at the start line of the task.

- The position of the entrance will be varied between the left and the right task side lines between races.
- The location of the doorbell panel will be varied between races (the four possible locations are shown below left).
- The order of the individual names and doorbells on the doorbell panel will be varied between races (the doorbell panel is shown below right).
### 12.4.1.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Card with name</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Wardrobe frame</td>
<td>Pax</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Sidewall</td>
<td></td>
<td>custom made</td>
</tr>
<tr>
<td>8</td>
<td>Doorbell unit hooks</td>
<td>two each for mounting of the doorbell unit</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Doorbell unit</td>
<td>magnets for mounting of subunits</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Buttons subunit</td>
<td>the full button subunit will be provided to CYBATHLON hubs, 8 buttons: C&amp;K</td>
<td>custom made</td>
</tr>
<tr>
<td>2</td>
<td>Names subunit</td>
<td>with 4 names each, to be mounted on doorbell unit with magnets</td>
<td>custom made</td>
</tr>
<tr>
<td>20</td>
<td>Name plate</td>
<td>detailed specification and mounting procedure will be provided on a later stage</td>
<td>laser cut</td>
</tr>
</tbody>
</table>

### 12.4.1.4 Task rules

- **VIS-DOOR-1** If the pilot rings the wrong doorbell, the task is failed.
- **VIS-DOOR-2** Pilots are not allowed to pass the entrance to the left or the right.
12.4.2 Colours

12.4.2.1 Introduction

Without assistance, identifying colours is not possible for blind people. However, this is important in many situations in daily life (e.g., when selecting colour matching clothes).

In this task, pilots must identify sets of different colours and sort them according to their brightness.

12.4.2.2 Task set-up & description

Pilots must take the colours from the clothesline on the left and hang them on the clothesline on the right. At the end of the task the colours must be sorted by base colour and within each base colour by brightness.
- A subset of two base colours from a pool of five base colours, each in four different levels of brightness will be presented in each race.

- The clothes hangers will initially be placed at predefined locations (evenly spaced) on the clothesline.

12.4.2.3 **Task infrastructure**

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Clothes rack</td>
<td>Turbo</td>
<td>IKEA</td>
</tr>
<tr>
<td>8</td>
<td>Hanger</td>
<td>Bumerang</td>
<td>IKEA</td>
</tr>
<tr>
<td>16</td>
<td>PVC foam board</td>
<td>DIN A3 size, different colours, mounted to hangers</td>
<td>custom made</td>
</tr>
</tbody>
</table>

12.4.2.4 **Task rules**

VIS-COLOUR-1 If the colours are not sorted by base colour and within colour by brightness when the pilot crosses the finish line, the task is failed.

Comment on VIS-COLOUR-1: Pilots are free to choose if they sort the brightness of the base colours from left to right or from right to left.
12.4.3 Road Work

12.4.3.1 Introduction

Objects that are located at chest height or above are (e.g., a truck’s hydraulic ramp that is left open or certain road signs, a branch of a tree) are difficult to be detected by blind people but bear a high potential for collisions and injury.

In this task, pilots must navigate through a maze of obstacles which are located at head height.

12.4.3.2 Task set-up & description

Pilots must find the openings to navigate through the maze.

- **Red** crossbars at 1.3 m height block the pilots’ way.
- The path of the maze will be alternated between races. In each row there will be one opening.
- The **red** poles and crossbars are very light to avoid injury in case of a collision.
12.4.3.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Pole</td>
<td>1600mm slalom poles, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>6</td>
<td>Socle</td>
<td>custom made</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Crossbar</td>
<td>800mm, red</td>
<td>Boje Sport</td>
</tr>
<tr>
<td>6</td>
<td>Crossbar elbow connector</td>
<td>3D-printed</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Rope guiding ring screw</td>
<td>-</td>
<td>Jumbo</td>
</tr>
<tr>
<td>6</td>
<td>Crossbar connector</td>
<td>3D-printed</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Tensioning rope</td>
<td>red</td>
<td>Berger</td>
</tr>
</tbody>
</table>

12.4.3.4 Task rules

VIS-ROAD-1 If the pilot hits a red pole or a red crossbar, the task is failed.

VIS-ROAD-2 Pilots are not allowed to grasp any red crossbar or red pole with the hand or steady it with any part of the body.

VIS-ROAD-3 The pilot’s head is not allowed to pass underneath the red crossbars.
12.4.4 Grocery

12.4.4.1 Introduction

Shopping for groceries is extremely challenging and time consuming for blind people. They usually ask other shoppers or shop staff for assistance when searching for specific products or group of products.

In this task, pilots must fill a shopping basket with items according to a shopping list.

12.4.4.2 Task set-up & description

Specific products must be collected from the shelves and added to a shopping basket.
• There are three groups of products placed in the shelf: cardboard boxes, cans and bottles. One specific item from each group must be shopped.

• The initial order of the product groups in the shelf varies between races.

• A shopping list will initially be placed in the basket. The names of the items are printed in English as a list on a card (postcard size).

• Each product in the shelf will have a generic label that contains the following information: name of product, picture of content

12.4.4.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basket</td>
<td>Risatorp</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Card with shopping list</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Heijne</td>
<td>IKEA</td>
</tr>
<tr>
<td>20</td>
<td>Can</td>
<td></td>
<td>Flaschenbauer</td>
</tr>
<tr>
<td>20</td>
<td>Box</td>
<td>Flaschenbauer</td>
<td>AliExpress</td>
</tr>
<tr>
<td>20</td>
<td>Bottle (0.5l)</td>
<td></td>
<td>bottleshop</td>
</tr>
<tr>
<td>20</td>
<td>Bottle cap</td>
<td></td>
<td>bottleshop</td>
</tr>
<tr>
<td>60</td>
<td>Label</td>
<td>custom made, data (training set) for creation of labels will be provided</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Side table</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

12.4.4.4 Task rules

VIS-GROCERY-1 The predefined items must be placed in the shopping basket. The shopping basket must be located on table when the pilot crosses the finish line of the task.

VIS-GROCERY-2 The task is failed if a wrong product is in the basket when the pilot crosses the finish line.

VIS-GROCERY-3 The items that are not listed on the shopping list must be located in any of the shelves when crossing the finish line of the task.

VIS-GROCERY-4 If any of the items drops on the ground, the task is failed.
12.4.5 Sidewalk

12.4.5.1 Introduction

When walking in a public space, blind people are often confronted with physical obstacles (e.g., an e-scooter that is carelessly left on a sidewalk, a tree branch lying on the ground). This may lead to collisions and falls.

In this task, pilots must negotiate a set of obstacles obstructing their path.

12.4.5.2 Task set-up & description

Pilots must negotiate a set of obstacles that obstruct their path. The objects are randomly placed on the task space.
The obstacles are placed according to the following rules:

- The task space is divided into a virtual grid of 9 (1-9) columns and 6 rows (A-F).
- Up to ten (5x2) objects (see below) are randomly placed on the grid on the task space. The same subset will be used for all races of a given round.
- All objects are placed upright.
- The objects can be placed in four orientations: facing left or right sideline, facing start or finish line of the task.

<table>
<thead>
<tr>
<th>Chair</th>
<th>PET bottle</th>
<th>Scooter</th>
<th>Waste bin</th>
<th>Customer stopper</th>
</tr>
</thead>
</table>

12.4.5.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Chair</td>
<td>Adde</td>
<td>IKEA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottle (0.5l)</td>
<td>filled 0.3l, with water</td>
<td>bottleshop</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottle cap</td>
<td></td>
<td>bottleshop</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Scooter</td>
<td></td>
<td>AREBOS</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Waste bin</td>
<td>Knodd</td>
<td>IKEA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Customer stopper</td>
<td></td>
<td>DEUBA-XXL</td>
<td></td>
</tr>
</tbody>
</table>

12.4.5.4 Task rules

- VIS-SIDE-1: The pilot must walk from the start to the finish line of the task.
- VIS-SIDE-2: If any of the objects is touched, the task is failed. This includes touching of the objects with a white cane or any other assistive device.

12.4.5.5 Comments

- Pilots are free to choose their path from the start to the finish line.
- It is allowed but not necessary to step over objects to reach the finish line.
12.4.6 Finder

12.4.6.1 Introduction

Finding misplaced objects is a big challenge for blind people. Therefore, they usually keep their own apartment very tidy. However, this is not always possible, e.g., with kids.

In this task pilots have to locate and grasp a specific object from a group of other objects.

12.4.6.2 Task set-up & description

One of the six boxes on the table near the start line of the task must be opened by the pilot to determine the target object. Thereafter, the identical object must be located on the task space, picked up, and placed on the small table near the finish line of the task.

- Initially, the six objects are randomly placed inside the six boxes on the table and
- The six objects are randomly allocated to six predefined locations on the ground.

<table>
<thead>
<tr>
<th>Coffee mug</th>
<th>Toothbrush, yellow</th>
<th>Cell phone black</th>
<th>Apple, green</th>
<th>Banana, yellow</th>
<th>PET bottle, clear with green content or green with clear content</th>
</tr>
</thead>
</table>

The objects that are randomly placed in the six boxes on the table and allocated to one of the six initial object positions on the floor.

### 12.4.6.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (rectangular)</td>
<td>IKEA</td>
</tr>
<tr>
<td>6</td>
<td>Box</td>
<td>Tjena</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Coffee mug</td>
<td>Backig</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Toothbrush</td>
<td>Thoothbrush Special Care</td>
<td>TEPE</td>
</tr>
<tr>
<td>2</td>
<td>Smart phone replica</td>
<td></td>
<td>AMAZON</td>
</tr>
<tr>
<td>2</td>
<td>Apple</td>
<td>Floristik24</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Banana</td>
<td>Festfabrik</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottle (0.5l)</td>
<td>bottleshop</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottle cap</td>
<td>bottleshop</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Lack</td>
<td>Lack</td>
<td>IKEA</td>
</tr>
</tbody>
</table>
12.4.6.4 Task rules

VIS-FIND-1  The pilot must open only one of the six boxes on the table located near the start line of the task to determine and identify the target object.

Comment on VIS-FIND-1: After identifying the target object, the pilot shall verbally communicate the name of the object to the referee to make sure that there is a mutual understanding between the pilot and the referee about the target object.

VIS-FIND-2  The target object must be located and placed on the table near the finish line.

VIS-FIND-3  If the pilot or any assistive device (including the white cane) touches any of the non-target objects, the task is failed.
12.4.7 Path

12.4.7.1 Introduction

Blind people use a white cane to detect changes in terrain, such as the boundary between a paved path and the lawn on the side. However, the cane can get stuck on protruding roots, stones or potholes which is unpleasant for the user.

In this task, pilots have to follow a path without touching the ground on the side.

12.4.7.2 Task set-up & description

Pilots must follow the path without touching the ground to the left and to the right.

- The path is made of six hexagonal plates.
- The hexagonal plates have different lengths but equal width.
• The path varies between races. The first plate is always placed on the midline of the task. Each of the following plates is offset either to the left or to the right.

• The plates are tightly attached to each other.

**12.4.7.3 Task infrastructure**

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Hexagon</td>
<td>different lengths, the hexagons can be joined in any order to form a path</td>
<td>custom made</td>
</tr>
</tbody>
</table>

**12.4.7.4 Task rules**

VIS-PATH-1 The pilot must walk from the start to the finish line of the task without touching the ground to left or to the right of the path.

VIS-PATH-2 It is not allowed to haptically explore the edge of the path by using the feet or an assistive device (including a white cane).
12.4.8 Serving

12.4.8.1 Introduction

Serving food is a challenge for blind people since plates and glasses must be kept horizontal to make sure that contents are not spilled while walking.

In this task, pilots must serve food and place it at table.

Image source

12.4.8.2 Task set-up & description

The pilots have to place a drink and a soup plate at the correct location at the table near the finish line.

The target locations for the glass and the soup plate can face the left or the right side of the track.
12.4.8.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (square)</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Tray</td>
<td>Klack</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Bottle (0.5l)</td>
<td>filled with 0.5dl of <strong>red</strong> liquid (water-like viscosity)</td>
<td>bottleshop</td>
</tr>
<tr>
<td>1</td>
<td>Bottle cap</td>
<td></td>
<td>bottleshop</td>
</tr>
<tr>
<td>2</td>
<td>Drinking glass</td>
<td>365+, visual, non-haptic mark 1cm under the brim</td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Fork</td>
<td>365+, <strong>red</strong></td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Knife</td>
<td>365+, <strong>red</strong></td>
<td>IKEA</td>
</tr>
<tr>
<td>2</td>
<td>Deep plate</td>
<td>Oftast, filled with <strong>red</strong> liquid (water-like viscosity) up to 1cm under the brim</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Table</td>
<td>Lerhamn (rectangular)</td>
<td>IKEA</td>
</tr>
</tbody>
</table>

12.4.8.4 Task rules

**VIS-SERVE-1**  The glass must be filled **at least** to the mark. If the filling of the glass is below the mark when passing the finish line, the task is failed.

**VIS-SERVE-2**  The **red** content of the glass and the soup plate must not be touched.

**VIS-SERVE-3**  The filled glass and the soup plate must be carried to the table using the tray and by touching the tray only. **Neither the glass nor the soup plate must be touched while carrying the tray.**

**VIS-SERVE-4**  The filled glass and the soup plate must be located at their target location when the pilot crosses the finish line of the task.

**VIS-SERVE-5**  If any of the **red** content of the glass or the soup plate is spilled, the task is failed.

**VIS-SERVE-6**  The **red** tableware and cutlery that are initially placed on the table must not be touched or moved by the pilot.
12.4.9 Touch Screen

12.4.9.1 Introduction

Many user interfaces are nowadays based on touch screens (e.g., vending machines, the menu in restaurants). Their use is primarily based on visual perception, and they rarely provide the necessary accessibility for the blind.

In this task, pilots have to navigate a touchscreen and order a predefined item from a variety of foods and drinks.

12.4.9.2 Task set-up & description

The pilots must select a food or a drink on a touchscreen. The food or drink to be selected is displayed on the touch screen at the beginning of the task. Further details about the app for the touchscreen will be communicated at a later stage.
12.4.9.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shelf</td>
<td>Kallax 1x4</td>
<td>IKEA</td>
</tr>
<tr>
<td>1</td>
<td>Tablet fixation</td>
<td>The design of the custom made smart pad fixation will be provided on a later stage.</td>
<td>custom made</td>
</tr>
<tr>
<td>1</td>
<td>Tablet</td>
<td>11” display size, Android</td>
<td>e.g. Lenovo</td>
</tr>
</tbody>
</table>

12.4.9.4 Task rules

VIS-SCREEN-1 If any food or drink other than the one specified is selected, the task is failed.
12.4.10 Empty Seats

12.4.10.1 Introduction

Finding an empty seat (e.g., when traveling in a train or visiting a theatre) is a challenge for blind people.

In this task, pilots have to identify for several rows of seats if there are empty seats.

12.4.10.2 Task set-up & description

Some or all the seats in each row are occupied by persons or backpacks. For each row, the pilot must indicate the location of the empty seat.
• Pilots indicate the empty seat using the display located at the right sideline of the task. They must place the cylinder in the recess that corresponds to location of the empty seat on the left side of the task (left, middle, right). If there is no empty seat, the pilot leaves the cylinder at the default position.

• For each row no more than one seat is empty.

• The backpacks are initially placed against the backrest of the chairs with the straps around the backrest.

### 12.4.10.3 Task infrastructure

<table>
<thead>
<tr>
<th>Units</th>
<th>Object description</th>
<th>Details / Model</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Chairs</td>
<td>Adde</td>
<td>IKEA</td>
</tr>
<tr>
<td>8</td>
<td>Backpacks</td>
<td>Pivring</td>
<td>IKEA</td>
</tr>
<tr>
<td>8</td>
<td>People</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Filling of backpacks</td>
<td>Närsen</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Shelf</td>
<td>Vesken</td>
<td>IKEA</td>
</tr>
<tr>
<td>4</td>
<td>Frame (1x3)</td>
<td>for presentation of target and selected objects</td>
<td>custom made</td>
</tr>
</tbody>
</table>

### 12.4.10.4 Task rules

**VIS-SEAT-1** All empty seats must be indicated correctly when the pilot crosses the finish line.

**VIS-SEAT-2** The task is failed if any of the task infrastructure on the left side of the task (i.e., people, chairs, backpacks) is touched by the pilot or their assistive device (including a white cane).

### 12.5 Competition mode and scoring

• Points per task: 10

• Total race duration: 8 min
Appendix I: Infrastructure Guideline
Appendix II: Appeals

This section will be added at a later stage.