CYBATHLON
ETH zürich

CYBATHLON 2021 - 2024

RACES & RULES

Date 30 June 2024

Version 5.3

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1 Additional Information

1.1 Version Management

1.1.1 Version Overview

Version	Comments	Date	Responsible	Status
1.0	This version includes a description of the races and initial description of eligibility criteria for the pilots and the assistive devices.	02 Nov 2021	Lukas Jaeger	completed
2.0	This version includes the descriptions of the tasks in all disciplines.	05 Apr 2022	Lukas Jaeger	completed
3.0	This version contains more detailed definitions of the tasks, including revised rules and specifications of task infrastructure. Any changes from version 2.0 were highlighted in orange.	31 Aug 2022	Lukas Jaeger	completed
3.0.1	Rule ROB-4 deleted since it was conflicting with rules ROB-5 to ROB-8. Otherwise, this version is identical with 3.0	5 Sep 2022	Lukas Jaeger	completed
3.0.2	Task Infrastructure tables moved to Appendix I “Competition Infrastructure”	30 Sep 2022	Lukas Jaeger	completed
3.0.3	Typos corrected. Rules clarified. Missing information added. Redundant rules deleted. Some task names changed. Special note: WHL-STAIR Comment deleted: The last step of the staircase will be highlighted for better visibility.	20 Jan 2022	Roland Sigrist	completed

4.0	Update of 4. General definitions & rules, 5 BCI and 12 VIS, including new illustrations of the task set-up. Changes in the chapters 4, 5 and 12 are marked in blue. This includes also existing paragraphs that have been moved to another sections. The chapters 5.4.2-5.4.6 are newly added, here only the title is marked blue.	20 June 2023	Marionna Münger	Completed
4.1	Update of 6 FES, 9 EXO, 10 WHL and 11 ROB, including new illustrations of the task set-up. Additionally in ROB the task order changed. In 4.4.4 the competition mode was added. Minor changes in 4. General definitions & rules, 5 BCI, and 12 VIS.	25 July 2023	Marionna Münger	Completed
4.2	Changes are marked in blue. Update of 7 ARM and 8 LEG, including new illustrations of the task set-up. Minor changes in 6 FES, 10 WHL, 11 ROB and 12 VIS.	28 August 2023	Marionna Münger	Completed
5.0	Change in task order in ARM, LEG, EXO, WHL & VIS. Changes in the illustrations of the task set-up in all disciplines. Minor specification of rules in all disciplines. Moved rules and moved part of rules are not marked in blue.	30 November 2023	Marionna Münger	Completed
5.1	Update in FES, ARM & WHL. Changes in illustrations in ARM & ROB. Updated screenshots in BCI.	16 January 2024	Marionna Münger	Completed

5.2	Minor changes in the illustrations across all track disciplines and screenshots in BCI & FES. BCI: New task order. Available in the Download Centre: - BCI: New version of the BCI game & manual and a configuration file for the competition - VIS & ROB: New Touchscreen application. - Examples of randomization for all disciplines.	30 April 2024	Marionna Münger	Completed
5.3	Changes in the text are marked in blue. Formatting changes are not marked. Minor changes in the illustration following updates in the Appendix 1 and in the rules, specifying open points in all disciplines.	30 June 2024	Marionna Münger	Completed

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.

The new version of the Races and Rules, V 5.3 includes minor changes in the general rules and in all disciplines.

The *Appendix I: Competition Infrastructure* was updated to cover the changes in the Races & Rules and required updates in the competition infrastructure.

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

Accompanying team official:	Team member which is standing (BCI and FES) or walking (other disciplines) besides the pilot in dedicated areas.
Assistive device:	A technical unit designed and developed to assist a person with a disability to perform specific tasks.
Backup pilot:	Team official meeting the pilot eligibility criteria who may take the role of the pilot if the (primary) pilot drops out or withdraws from participation.
Call room:	Room or defined space where pilots and accompanying team official wait before going to the start line of the race. In some disciplines and competitions, the sight from the call room to the racetrack may be required to be blocked.
Care person:	Team official who is a member of the pilot's social network who helps with activities of daily living.
Competition:	The entirety of all races of a given discipline.
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.
Disqualification:	The team's passed race runs of the competition become invalid. The team is not allowed to attend to any upcoming race runs of this competition.
Hub:	Site where the competition takes place. There is a Zurich hub in the area of Zurich and there are local hubs all over the world, e.g., organised by the participating teams or their institutions.
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.
Pilot:	Team official meeting the pilot eligibility criteria and participating in the races of a specific discipline.
Race direction:	The most direct route between start and finish line.

Race run:	A timed attempt of a single pilot to solve the entire set of competition tasks of a given discipline.
Race termination:	The current (not yet completed) task is failed, and the race run is terminated for the pilot. The pilot's current score is then taken as the score for that race run.
Racetrack:	The area on which the competition takes place, i.e., the sum of all task spaces.
Referee:	CYBATHLON official at a hub who is responsible for judging the behaviour of the pilot during task execution and enforcing the general, discipline and task-specific rules during a race run.
Scorer:	CYBATHLON official at a hub who is responsible for scoring the task (according to the decision of the referee) and measuring the time it takes the pilot to attempt the competition tasks during a race run with the results system mobile app.
Spotter:	A team official to prevent the pilot from falling, to help them to move or leave the track during the race in certain disciplines. A spotter is trained to only intervene in case of an imminent risk to the pilots or their environment.
Support person:	Team official with specific expertise who supports the team in a specific area (e.g., technician, communication specialist, therapist).
Task infrastructure:	All elements on the task space that must not be manipulated by the pilot to solve a task.
Task objects:	All elements on the task space that must be manipulated by the pilot to solve a task.
Task space:	The space for one task, defined by a start line, two sidelines, and a finish line.
Team:	An entity with the goal to develop an assistive device and to participate in a CYBATHLON competition.
Team manager:	Team official who is responsible for the overall organisation and management of a team in a specific discipline.
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.
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.

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.

Time for passed tasks:
Total time of all completed tasks, which is decisive for the ranking.

Time limit: Available number of minutes to solve all tasks, i.e., maximal race duration.

Track disciplines: ARM, LEG, WHL, EXO, VIS and ROB

4.2 Competition disciplines

The CYBATHLON competition consists of the following eight disciplines:

Discipline Name	Discipline abbreviation	Discipline icon
Brain-Computer Interface Race	BCI	
Functional Electrical Stimulation Bike Race	FES	
Arm Prosthesis Race	ARM	
Leg Prosthesis Race	LEG	
Exoskeleton Race	EXO	
Wheelchair Race	WHL	
Vision Assistance Race	VIS	
Assistance Robot Race	ROB	

Overview of CYBATHLON competition disciplines

4.3 General team 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: 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 receives one starting place for one discipline. This means 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. The assistive device may not be exchanged between race runs. Violation of this rule leads to disqualification.

GR-6 It is not allowed to exchange pilots (pilot and back-up pilot) between different race runs. Violation of this rule leads to disqualification.

GR-7 It is allowed to maintain or repair the device between the race runs. The minor adjustments are not allowed to affect the basic functions or safety of the assistive device. Violation of this rule leads to disqualification.

Comment on GR-7: All parts used for these adjustments must have been declared in the TecCheck.

GR-8 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. If any part is left behind on a task space, the race is terminated at the finish line of this task.

Comment on GR-8: Residual adhesives and tyre wear particles are allowed to be left on the racetrack.

GR-9 During a race run, only the pilots may maintain or replace components of their assistive device. Violation of this rule leads to race termination.

GR-10 During a race run, direct or remote control of the assistive device by the pilot is allowed.

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

GR-12 Wireless communication between different components of the assistive device on the racetrack is allowed.

GR-13 Wireless communication between the components of the assistive device and computers beyond the race track (e.g., local computer, server, or similar) is only allowed for data monitoring, recording, or emergency shutdown of the assistive device.

Comment on GR-13: A hub does not guarantee the possibility to place a computer or similar near the racetrack .

GR-14 Wireless communication between components of the assistive device and publicly available online services is allowed. All services must be listed in the description of the assistive device handed in for the TecCheck.

Comment on GR-14: A hub does not guarantee stable internet connection. Finding access to the internet is a matter for the teams.

GR-15 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. Violation of this rule leads to race termination.

Comment on GR-15: Cases in which a pilot must be accompanied by another person or a service animal for medical reasons will be assessed by the CYBATHLON organising committee individually.

GR-16 During a race run one accompanying team official can travel beside the track in the track disciplines or stand alongside the station (BCI, FES). The team official must be out of the way for any other person involved (e.g., scorer, referee, camera person, spotter). In case that the accompanying team official walks on the racetrack (ARM, LEG, WHL, EXO, ROB & VIS), the task is failed.

GR-17 If the accompanying official interacts with the pilot physically, the task is failed. As soon as the accompanying team official is off the task space, the pilot can continue with the next task.

Comment on GR-17: This may be necessary, in an unforeseen and unfortunate situation, e.g., to putting back on the glasses or putting back the feet on the footrest of the wheelchair. Unless otherwise specified in a rule of a specific discipline, the accompanying team official can verbally interact with the pilot (e.g., for coaching). No other team official is allowed to do coaching.

GR-18 In case of any physical intervention of the accompanying team official with the assistive device (e.g., in case of a technical defect or an emergency), the race run is terminated for that pilot.

GR-19 Radio communication between the pilot and any team official or any other person is not allowed during a race run. Violation of this rule leads to race termination.

GR-20 In certain disciplines, spotters must (EXO, WHL) or can (ROB, LEG) supplement the general safety precautions during the race run. Spotters are allowed to touch the pilots or devices, but not to physically support the pilots or devices. The task is failed if a spotter physically supports or coaches a pilot or a device.

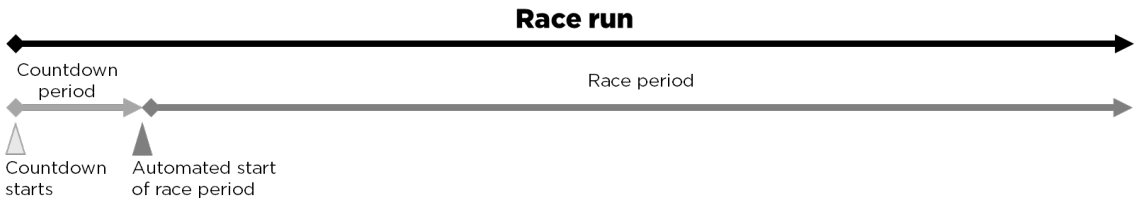
Comment on GR-20: The spotters are not allowed to coach (see GR-16). The task is failed if a spotter coaches the pilot.

GR-21 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. The pilot scores 0 points in this race run (see also race termination).

4.4.1 Race procedures

GR-22 Each race run consists of a countdown period and race period.

GR-23 The race period starts when the countdown ends. The task time of the first task starts with the end of the countdown. If the pilot crosses the start line before the countdown has ended the pilot scores 0 points for this race run (see also race termination).



Overview of race procedures

4.4.1.1 Scoring, race termination, and disqualification

GR-24 The tasks must be solved in their order of appearance on the racetrack.

GR-25 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-26 If a task is skipped, the task is scored as "task failed". The pilot must proceed to the start line of the next task across the task space, and thereby bypass on the right-hand side of the obstacles (in race direction), if possible.

Comment on GR-26: In some tasks, the right-hand side is blocked by competition obstacles, hindering a proper re-entry on the track to reach the start line of the next task. In these cases, it is allowed to pass the obstacle on left-hand side.

GR-27 The start line and finish line of a task are considered crossed once the following part of the pilot or the assistive device crosses the reference edge (including its vertical projection):

- 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

  - any wheel, track, or leg of a robot

GR-28 A task starts once the pilot crosses the reference edge of the task start line for the first time in a race run.

GR-29 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, or leg 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

  - wheel, track, or leg of the robot that is closest to the finish line.

If the listed part crosses the reference edge in its entirety, the task is failed.

Comment on GR-29: 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-30 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-31 In case of race run termination, the pilot must proceed to the finish line of the task without any undue delay. If required, spotters and the accompanying team official may be asked to intervene and support the pilot to reach the finish line.

GR-32 A task is failed if the sideline of the task space is touched (touching the sideline) or crossed (touching the ground beyond the sideline) by any part of the assistive device (including crutches if applicable) or the pilot's body. Exceptions of this rule are traditional white canes in the VIS race.

Comment on GR-32: If a task is completed and passed, it is allowed to cross the reference edge of the sidelines of this passed task (e.g., to skip the subsequent task). The completed task remains scored as passed.

GR-33 A task is failed if any object of the task touches the ground beyond the reference edge of the sidelines or the start or finish line of the task space caused by any action of the pilot.

GR-34 A task is failed if any task infrastructure is moved by the pilot or a spotter that is not explicitly asked to be moved by the task specific rules.

GR-35 A task is failed if a pilot touches a red object, area or liquid. This rule applies to any part of the pilot's body, device, and crutches. A task is failed if a spotter touches a red object or liquid. Spotters are allowed to step on red areas to ensure the safety of the pilot.

GR-36 A task is failed if any task object touches the ground, which, according to the task specific rules, does not have to touch the ground to solve the task. Unless otherwise specified, this applies also to objects which are initially on the ground and are lifted once.

Comment on GR-36: The ground includes the floor, as well as obstacles which the pilot negotiate (e.g., stairs, baseplates, slopes, etc.)

GR-37 A task is failed if any task infrastructure or task object is damaged by any action of the pilot or spotters.

GR-38 A task is failed if a pilot uses the handrails. This includes the use of handrails to support movement or action or to keep balance by grasping, pulling, pushing or similar, with any part of the body or the assistive device. Handrails are provided for safety only.

GR-39 Task failure is indicated by a red flag and verbally communicated by the referee to the pilot ("task fail!"). Task passing is indicated by a green flag and verbally communicated by the referee to the pilot ("task pass!") at the finish line of the task.

GR-40 For each race run, the time to attempt each task is measured and points are scored if the task is solved successfully.

GR-41 The following practices, previous, during, and after the race runs, result in the disqualification of the team from the competition.

1) Change or modification of the device after the TecCheck. For Details see GR-7, GR-8, and GR-9.

2) Severe and intentional failing to comply with the instructions of CYBATHLON officials.

3) Serious unsporting behaviour or other serious disturbance.

4) Abusive, threatening, or violent behaviour to any person.

5) Sabotage of another team or their equipment.

4.4.2 BCI & FES

4.4.2.1 Scoring

GR-42 A race run is finished in any of the following instances:

(1) The pilot crosses the finish line of the virtual racetrack (FES) or completes the last task (BCI).

(2) The time limit of the race period is reached.

(3) Three yellow cards are issued.

(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-43 Use of obscene or abusive language or unsporting behaviour of a relatively minor nature by the pilot or accompanying team official, for example assaulting the referee or any other person attending the competition, is issued by a yellow card.

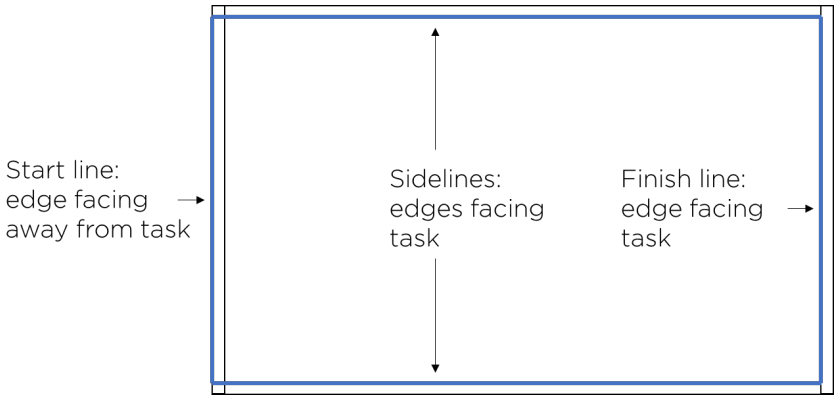
GR-44 If a pilot is issued three yellow cards within the same race run, the race run is terminated for that pilot.

GR-45 Each yellow card is communicated verbally to the pilot.

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

4.4.3.1 Competition infrastructure

GR-46 The race runs take place on a racetrack that consist of discipline-specific tasks. The task space is defined by a start line, two sidelines, and a finish line. These lines must be perpendicular to each other. The reference edges of the start, finish, and sidelines are defined below.



Definition of reference edges of the task lines.

GR-47 The length of a task is 5 m. The width of a tasks is 3 m.

Comment on GR-47 The task space needs to be represented even if a team at a local hub decides to skip a task. The obstacles do not need to be built or set up if the task is skipped. At the Zurich hub, all task spaces and obstacles are set up.

GR-48 The start line and the finish line as well as the sidelines of a task must stand out clearly from the ground.

Comment on GR-48: Guidance lines with a height of 2-3 mm are installed along the sidelines and at the start and finish line of the task to support orientation on the racetrack in the VIS. If the same base track is used for other disciplines than VIS as well, the guidance lines remain.

GR-49 At a given hub, the elements of the competition tasks must be built up on an even and solid surface. Additional flooring may be used.

Comments Competition Infrastructure
For details please see *Appendix I: Competition Infrastructure*

- If not defined 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 and objects is provided, including links to external websites. CYBATHLON does not take any responsibility for the changes made by the providers to the linked products.
- *Appendix I: Competition Infrastructure* gives detailed technical information about the competition infrastructure (drawings, dimensions, screenshots, etc.).

4.4.3.2 Scoring

GR-50 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) Three warnings received.

(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-51 Use of obscene or abusive language or unsporting behaviour of a relatively minor nature by the pilot or accompanying team official, for example assaulting the referee or any other person attending the competition, is issued by a warning. The third warning results in race termination.

4.4.4 Mode & Ranking

GR-52 In the BCI, ARM, LEG, WHL, EXO, VIS and ROB discipline, the four race runs of a heat start with a time shift of 1 minute.

Comment on GR-52: The countdown lasts: 30 s on track 1, 90s on track 2, 150s on track 3 and 210 s on track 4.

GR-53 In the FES discipline all four race runs of a heat start at the same time.

GR-54 The time for passed tasks is measured to the second.

GR-55 In ARM, LEG, EXO, WHL, VIS, ROB and BCI each pilot competes in one or two race runs in the qualification round (to be defined). In case of two race runs, the better race run counts for the qualification ranking.

GR-56 In FES each pilot competes in one race run in the qualification round.

GR-57 Each pilot is ranked relative to the performance of all other pilots of the same discipline. To rank the pilots, the following rules are applied:

Discipline	Race end	Ranking criteria
BCI	1. Finish line of the last task is reached. 2. Time limit reached. 3. Three yellow cards issued. 4. A violation of a rule mandates termination of the race run.	1. Points scored 2. Time for passed tasks 3. Number of yellow cards
FES	1. Finish line of the track is reached. 2. Time limit reached. 3. Three yellow cards issued. 4. A violation of a rule mandates termination of the race run.	1. Points scored. 2. Total time taken for points scored. 3. Number of yellow cards
ARM	1. Finish line of last task reached. 2. Time limit reached. 3. Three warnings received. 4. A violation of a rule mandates termination of the race run.	1. Points scored. 2. Time for passed tasks.
LEG		
EXO		
WHL		
VIS		
ROB		

Summary of scoring and ranking criteria

GR-58 In case that the better run of two pilots is equivalent (according to the ranking criteria defined in GR-57) the two pilots receive the same rank.

GR-59 In each discipline, the four pilots ranked best after the qualification round will proceed to the final. In the final, one race is conducted by each pilot.

GR-60 In the qualification round, the assignment of the teams to the tracks 1 to 4 is random. A team starts on the same track in the first and second attempt.

Comment on GR-60: For FES, the position of the team's bike in indieVelo is random and may differs from the assigned track.

GR-61 In the finals, the assignment of the teams to the tracks 1 to 4 is based on the ranking in the qualification. The best team from the qualification starts on track 4, the second on track 3 and so on.

Comment on GR-59: For FES, the position of the team's bike in indieVelo is random and may differs from the assigned track.

4.4.4.1 Second pilot

GR-62 A team can register a second pilot starting with the same device. The parts which are allowed to be customized to the two pilots (e.g. socket in LEG & ARM) are specified in GR-65.

GR-63 All aspects of the assistive device which are customized for the two pilots must be mentioned in the TecCheck.

GR-64 The teams must be able to switch the device between pilots within the following time restrictions:

- ARM, LEG, VIS: 5 min
- EXO, WHL, ROB, BCI, FES: 20 min

GR-65 The following aspects of the assistive device can be customized to each pilot:

Discipline	Aspects allowed to be customized
All	1. Adjustment of software parameters 2. Attachment of the device to the pilot's body (e.g., cushions, straps, etc)
BCI	1. Electrode cap (it must be the same type of electrode cap, but separate units can be used) or electrode array

	2. Mental strategies to send commands
FES	1. Electrodes (it must be the same type of electrodes, but separate units can be used)
ARM	1. Socket
LEG	1. Socket
EXO	1. Input device (e.g., joystick and touchscreen)
WHL	1. Input device (e.g., joystick and touchscreen)
ROB	1. Input device (e.g., joystick and touchscreen)

GR-66 Only one pilot per team can reach the final. The pilot ranked better reaches the finals.

4.4.5 Hub setting

- A team can start at a local hub or at the Zurich hub (Kloten, Schluefweg)
- At the hub, there might be applause, cheering, or other sound sources. The noise level may vary within and between different races.
- Zurich hub:
    - Track disciplines: There is a large LED wall set up after the finish line, showing live images of the pilot competing on this track. The distance from the finish line to the LED wall is at least 4m.
    - BCI/FES: The FES & BCI stations are in front of a large LED wall showing live images of the pilot competing. The distance from the station to the LED wall is at least 4m.

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”.
    - Yellow cards: “yellow card number X” (BCI, FES).
    - Warning: “warning number X (ARM, LEG, EXO, WHL, ROB, VIS)”.
    - Race termination, e.g., after the issue of three yellow cards or warnings: “race termination”.
    - Confirmation of correct execution of predefined subtasks: “Okay go”.
    - If the referee does not agree with the current execution when the pilot asks for confirmation: “not yet”.
- From the pilot to the referee in the following situations:
    - If the pilot is not sure whether the subtask is executed correctly, the pilot may ask for confirmation.
    - A pilot suspects a refereeing error and wants to submit an appeal after the race run: “continue task”.
    - If the pilot wants to terminate the race: “race termination“

- General
    - Pilot is stuck in a task and requires help by the spotters: “help”.
    - Emergency: “S.O.S” (leads to the stop of the race).

4.4.7 Decision instances

GR-67 The CYBATHLON officials (i.e., referee and scorer) 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-68 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.

GR-69 If a pilot does not agree with a referee's decision during task execution, the pilot must decide whether to continue or terminate the task. If the task is continued, the pilot can 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. See also GR-70.

4.4.8 Appeals

GR-70 In case of an occurrence or decision which is considered as incorrect in the own race, the team has the possibility to file a written appeal to the competition management. The regulations and procedures related to the appeals are defined in *Appendix II: Appeals*.

4.5 Competition eligibility

4.5.1 Pilot eligibility criteria

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

GR-71 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-72 Pilots must pass the MedCheck.

GR-73 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.

GR-74 Pilots must reach the legal age in their home country on the first day of the competition.

GR-75 Pilots must have sufficient cognitive and communicative abilities to understand the *Races & Rules* and to follow the instructions of the competition staff.

GR-76 Pilots must meet the discipline-specific pilot eligibility criteria.

Comment on GR-76: 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-77 Participation must be safe for the pilot at any time.

GR-78 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-79 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).

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-80 The assistive device must be safe for the pilot and their environment at any time.

GR-81 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-82 The assistive device must pass the TecCheck. In the TecCheck all parts of the device and items, which will be carried by the pilot to the racetrack must be listed.

GR-83 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. Violation of this rule leads to disqualification.

GR-84 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-85 Assistive devices must meet the discipline-specific technology eligibility criteria to be allowed to participate in the competition.

GR-86 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-78 and GR-79).

GR-87 The pilot must be able to emergency stop the assistive device at any time during the competition. Exception from this rule are pilots in the BCI race.

Comment on GR-87: In ROB, if the pilot is not able to emergency stop the device, the team must provide a concept how to stop the device(s) in an emergency (e.g., a team official follows the robot on the track and activates the emergency stop if necessary.).

GR-88 Combustion engines are not allowed.

5 Brain-Computer Interface Race

Brain-computer interface race pilot playing the CYBATHLON BCI game “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 mean 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 (input signals from the pilot are further referred as commands). 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. Violation of this rule leads to disqualification.

BCI-TEC-2 Visually evoked potentials (SSVEPs, P300, etc.) or auditory evoked potentials are not allowed as a source for commands unless they are elicited by the animated scenario provided by the organisers and not by an additional display. Violation of this rule leads to disqualification.

BCI-TEC-3 Noice cancelling, including white noise, is allowed.

Comment on BCI-TEC-3 The headphones and white noise provided to the pilot must be added in the TecCheck.

BCI-TEC-4 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). The screen must not exceed a screen diagonal of 0.18 m. The team may fix the screen to the pilot's wheelchair.

Comment on BCI-TEC-4: The organisational committee does not guarantee a specific set-up at the hub to place the additional screen (e.g., distance between table and wheelchair).

BCI-TEC-5 Ocular control, control by facial muscles or the use of any other volitional muscular activity is not allowed to generate control commands.

Comment on BCI-TEC-5: 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-6 Information from additional systems, e.g., eye-tracking or cameras, are not allowed.

BCI-TEC-7 Artefact removal is mandatory, or it needs to be stated explicitly how it is prevented that artefacts are affecting the decoding procedure.

Comment 1 on BCI-TEC-7: During the TecCheck (prior to the event), all teams are required to submit a description of the artefact removal procedure and/or a rationale how artefacts are not affecting game control. The teams may provide examples of the signals to be checked by the technical examiners.

Comment 2 on BCI-TEC-7: During the TecCheck (prior to the event), all teams must confirm 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.

BCI-TEC-8 After the artifact removal, any signal feature and classification procedure can be used in the BCI provided it primarily reflects volitional brain

activity evoked by mental strategies, and not automatic subconscious processes which can be elicited by movement of the eye (e.g., alpha blocking).

BCI-TEC-9 Error potentials are allowed to be used.

BCI-TEC-10 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-10: The communication regulations and communication protocols are defined in the *BCI-game user guide*. Registered teams find the document in the *Download Centre*, linked on the dashboard.

BCI-TEC-11 It is allowed to turn off specific commands which are not used in a specific task.

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 intentionally use eye or muscle activity to control the BCI. Extensive or deliberate eye or muscle activity leads to a yellow card. See also BCI-TEC-5.

BCI-2 Once the race has started the accompanying team official is not allowed to coach the pilot. In case of any coaching, the race run is terminated.

BCI-3 Task pass and fail decisions are given by the game.

BCI-4 The game configurations are given by the published configuration file (e.g., C24_config_VXX.json). Registered teams find the configuration file in the *Download Centre*, linked on the dashboard. In the competition we use a different randomization for each race. Load the configuration file and press "random seed" to get a new randomization for each new race.

BCI-5 The *Disable Game Log Output over UDP* and *Disable Keyboard Input* will be checked.

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 the BCI game, i.e., a digital animated scenario (computer game) in which the BCI pilots must solve tasks by sending the appropriate commands at the right time.

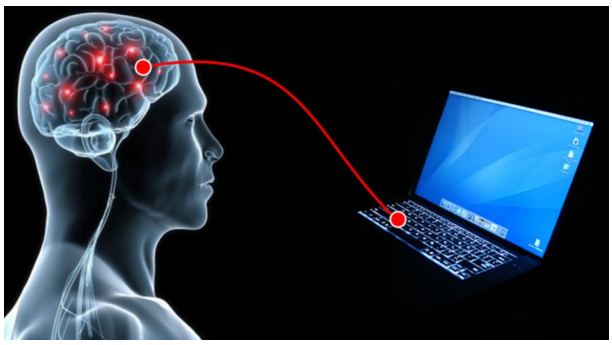


Image source

5.4.1 General game structure

- The BCI game consists of ten tasks. Three different devices (wheelchair, robotic arm, and cursor) are used in the ten tasks: In one task, only one device type is used.
- There are five task types. The task types are presented in a fixed order. Each task type is repeated twice (5x2).

- The total number of independent commands that can be applied in the game is 4 (2 continuous, 2 binary).
    - 2 independent continuous commands to control navigation.

      Comment: This can be solved by using two signals (forward movement and one rotation) or four signals (forward/backwards movement and rotation clock- and counterclockwise) signals.
    - 2 binary commands ("A", "B") with differing effects depending on the task.
- Certain tasks contain specific fail criteria (e.g., navigating the wheelchair into a vacuum cleaner). If a task is failed, the pilot is automatically transferred to the next task.
- The pilots can ask the team official to skip a task if they get stuck or want to abort a task. The team official can also skip a task without interaction with the pilot (e.g., the teams decided beforehand to skip a specific task). The task skipping is conducted by a button press of the accompanying team official of the pilot's own team. The pilot is then automatically transferred to the next task.
- Overview task types, with device and commands:

	Task type 1	**Task type 2**	**Task type 3**	**Task type 4**	**Task type 5**
	Furniture	Ice Machine	Computer Screen	Key Lock	Vacuum Cleaner
Device (avatar)	**Wheelchair**	**Robotic Arm**	**Cursor**	**Robotic Arm**	**Robotic Arm**
Commands	**Two continuous**	**Two continuous**	**Two continuous and A or B**	**Two continuous and A or B**	**Two continuous**

Overview of BCI game tasks and command types.

5.4.2 Task type 1: Furniture (Device: Wheelchair)

5.4.2.1 Introduction

In daily life, spaces can be full of obstacles which need to be avoided to reach a destination safely, e.g., when using an electric wheelchair.

Pilots must negotiate a set of furniture obstructing their path to cross a virtual room by controlling a wheelchair avatar.

Image source

5.4.2.2 Task set-up & description

Pilots must negotiate a set of furniture that obstruct their path. Different objects such as tables or plants are randomly placed on the task space.

The commands in this task are:

- 2 independent continuous commands control the navigation of the wheelchair in two dimensions.

5.4.2.3 Task rules

BCI-FURN-1 If the wheelchair collides with a table or the wall, there is a time punishment. During this time, the wheelchair cannot be controlled.

Comment on BCI-FURN-1: The furniture can be moved through pushes by the wheelchair. The objects on the table may fall if the wheelchair collides with the table. These objects can be moved by the wheelchair (without time punishment).

BCI-FURN-2 The task is passed if the door (target area) on the other side of the room is reached.

BCI-FURN-3 The plants (including its pots) must not be touched by the wheelchair. If the wheelchair collides with a plant, the task is failed.

5.4.2.4 Comments

- The level of difficulty increases in the second series of the task with the placement of the obstacles. A plant is only included as an obstacle in the second series.
- The position of the tables and plants are randomised.

5.4.3 Task type 2: Ice Machine (Device: Robotic Arm)

5.4.3.1 Introduction

For certain situations in everyday life, it is important to be able to hold a position for some time and wait, such as filling a glass of water without spilling it or not or not moving with the wheelchair in a confined space such as in a crowded elevator.

The pilot must position a glass under the ice machine and hold the glass still to catch all the falling ice cubes, i.e., not sending a command during this period.

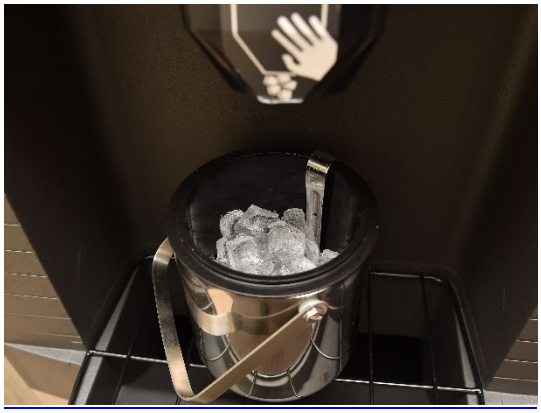
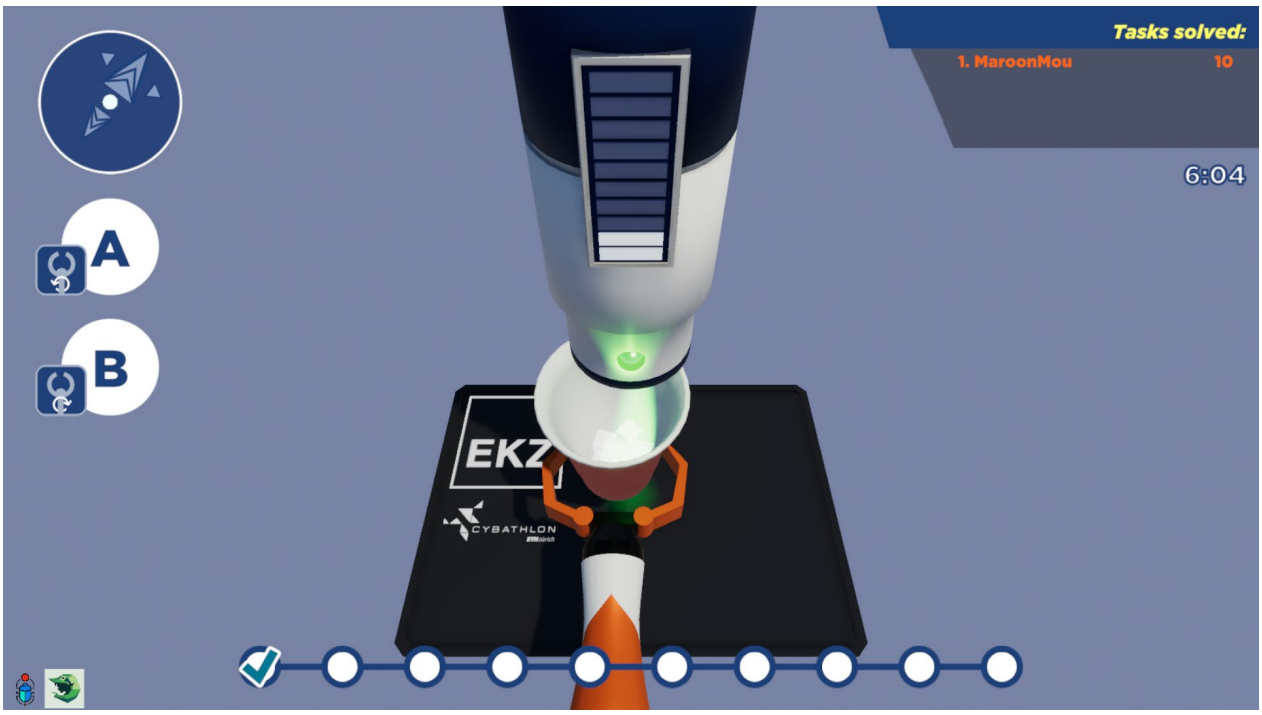


Image source

5.4.3.2 Task set-up & description



Pilots need to position the glass under the ice machine and catch all the falling ice cubes.

- If the glass is at the dedicated position, the green light switches on.
- The remaining number of the ice cubes is indicated on the ice machine. Each bar represents an ice cube.

The commands in this task are:

- 2 independent continuous commands control the movement of the robotic arm in two dimensions.
- 2 binary commands control the orientation of the robotic arm (tilt of the glass).

5.4.3.3 Task rules

BCI-ICE-1 The pilot must catch all the ice cubes with the glass. If an ice cube falls beside the cup, there is a time punishment.

5.4.3.4 Comments

- The starting position of the gripper of the robotic arm is randomised.
- The level of difficulty differs for the two series of the task. In the second series, the glass size is smaller making it more difficult to position the glass correctly.

5.4.4 Task type 3: Computer Screen (Device: Cursor)

5.4.4.1 Introduction

Many tasks in daily life, either privately or professionally, are done on computers. Thereby, it is often very helpful or even necessary to be able to control a cursor on the screen.

The pilots must navigate a cursor on the screen and click on the target icon.

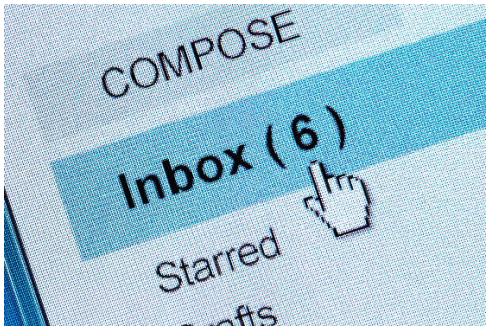
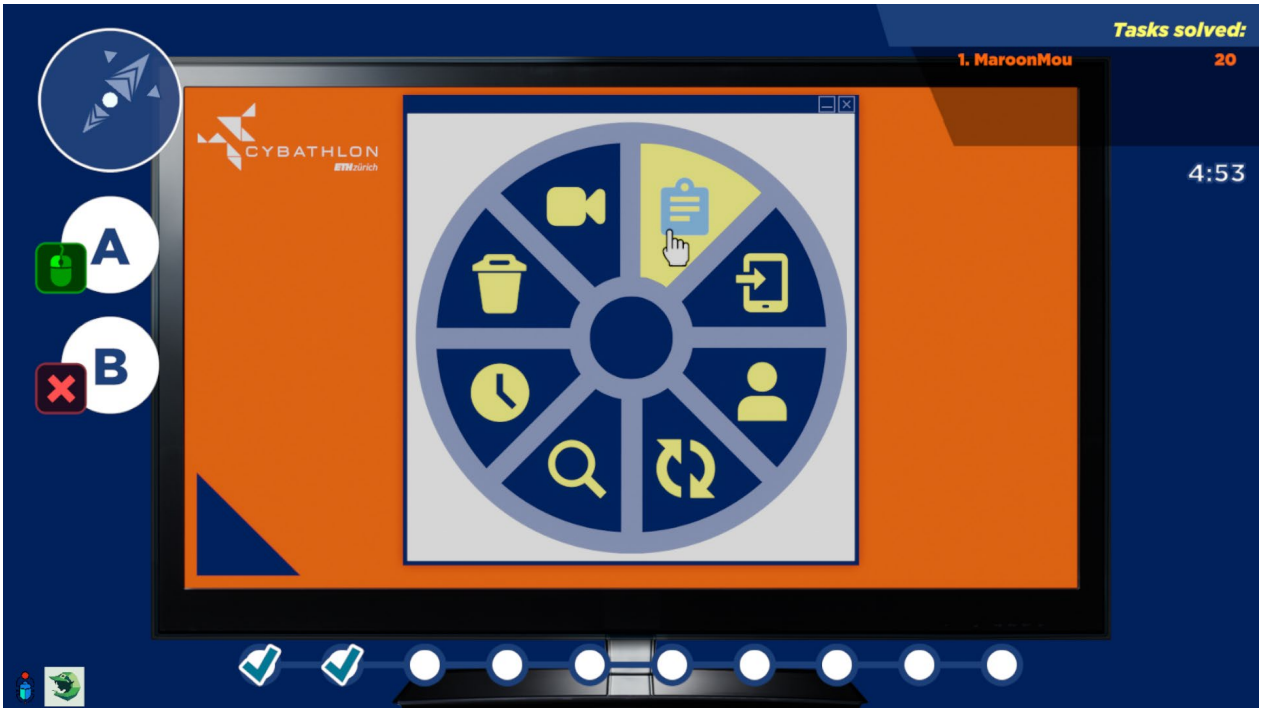


Image source

5.4.4.2 Task set-up & description



Pilots need to position the cursor on the target icon and click the indicated button.

The commands in this task are:

- 2 independent continuous commands control the navigation of the mouse in two dimensions.
- 2 binary commands corresponding to a right click and left click.

5.4.4.3 Task rules

BCI-COMP-1 If the wrong binary command is sent on the target icon or if a binary command is sent outside of the target icon, there is a time punishment. During this time the cursor cannot be controlled.

BCI-COMP-2 The task is passed if the target icon is clicked with the correct command.

5.4.4.4 Comments

- The correct binary command to click on the target icon is randomised. The required binary command is visually indicated at the beginning of the task.
- The target icon is randomised. The target icon is visually indicated.

5.4.5 Task type 4: Key Lock (Device: Robotic Arm)

5.4.5.1 Introduction

Manipulating of small objects is essential to solve many tasks in daily life.

The pilots must navigate a key to the lock and turn the key to open or close the door.

Image source

5.4.5.2 Task set-up & description

Pilots need to position the key into the lock and turn the key in the indicated direction.

The commands in this task are:

- 2 independent continuous commands control the navigation of the robotic arm in two dimensions.
- 2 binary commands control the turning of the key.

5.4.5.3 Task rules

BCI-KEY-1 If the pilot turns the key in the wrong direction while it is in the key lock, the task is failed.

Comment on BCI-KEY-1: Turning the key in any direction before it is inserted in the key lock has no consequences.

BCI-KEY-2 The task is passed if the pilot inserts the key into the key lock and turn it in the correct direction to open the door.

5.4.5.4 Comments

- It is randomised in which direction the key must be turned. The required direction is visually indicated at the beginning of the task.
- The starting position of the key is randomised.

5.4.6 Task type 5: Vacuum cleaner (Device: Wheelchair)

5.4.6.1 Introduction

In daily life, it is often necessary to navigate around moving persons, animals, objects, or devices. In such situations it is important to be able to adapt and react.

Pilots must cross the room while avoiding the moving vacuum cleaner(s).

Image source

5.4.6.2 Task set-up & description

Pilots must navigate around the moving vacuum cleaner(s).

The commands in this task are:

- 2 independent continuous commands control the navigation of the wheelchair in two dimensions.

5.4.6.3 Task rules

BCI-VAC-1	The vacuum cleaners must not be touched by the wheelchair. If the wheelchair collides with a vacuum cleaner, the task is failed.
BCI-VAC-2	The plants (including its pots) must not be touched by the wheelchair. If the wheelchair collides with a plant, the task is failed.
BCI-VAC-3	If the pilot collides with the wall, there is time punishment. During this time the wheelchair cannot be controlled.
BCI-VAC-4	The task is passed if the door (target area) on the other side of the room is reached.

5.4.6.4 Comments

- The positions of the plants and the starting positions of the vacuum cleaners are randomised.
- The level of difficulty increases in the second series when a second moving vacuum cleaner is added.

5.5 Competition mode and scoring

Points per task: 10

Time limit: 8 min

5.5.1.1 Comment

- The loading time for each task is 3 seconds. Hence the total time to solve all ten task is reduced by 10 x 3 seconds.
- The icons “A” and “B” are shown for 2.5 seconds in the Furniture, Ice Machine and Key Lock tasks. Henc the total time to solve all ten task is reduced by 6 x 2.5 seconds.

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).

Comment on FES-PIL-1: Pilot must fulfil the eligibility criteria at the time of the MedCheck. If there is an improvement of their motor function in the lower limbs due to therapy after they passed the MedCheck, the pilots are still allowed to participate in the FES bike race.

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 structure of the spinal cord is allowed for participation.

FES-TEC-2 The FES stimulator must fulfil the standard regulations for electrical safety. The IEC standards 60601-1 and 60601-2-10 (or similar regulations applied in the country of development), describe particular requirements for the basic safety and essential performance of transcutaneous nerve and muscle stimulators provide a helpful guideline to manufacture a safe stimulator. Compliance with 60601-1 and 60601-2-10 (or similar

regulations applied in the country of development) is recommended for prototypes.

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 It is allowed to modify the bike (i.e. change of the shifting system), this will be assessed as part of the TecCheck.

FES-TEC-6 The bike must be fully functional for overground cycling. This will be assessed as part of the TecCheck.

6.3 Specific race rules

FES-1 The race condition is given by the game and its physical rendering on the smart trainer. The game settings are defined by the CYBATHLON organising committees.

FES-2 Each race consists of a warm-up period and race period. At the end of the warm-up period the race period starts automatically.

FES-3 Pilots may start the pedalling movement at any time.

(a) Until 10 seconds before the end of the countdown (start of the race run) movement of the legs 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 countdown must be accomplished by FES to the pilot's legs only.

FES-4 If the pilot is assisted when the last 10s of the warm-up period started, the pilot scores 0 points in this race run (see also race termination).

FES-5 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-6 During the race, hands or arms are allowed to be used to push the legs to overcome pedalling dead points sporadically, but not to support on-going propulsion. Extensive use or any other misuse of hand or arm pushes to overcome pedalling dead points leads to a yellow card.

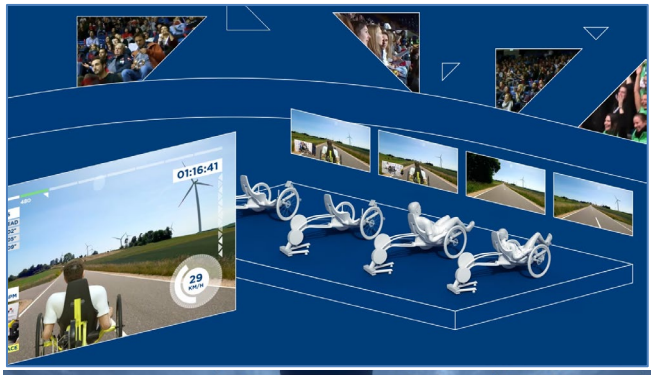
FES-7 Any misuse of hand or arm pushes to support on-going propulsion leads to a yellow card.

FES-8 All participating teams use the same type of stationary bike trainer sent to all registered teams. It is not allowed to modify the provided stationary bike trainer except for the cassette/cogset and the axle/quick release.

FES-9 All participating teams must use the dual-sided powermeter pedals *Wahoo Powerlink Zero sensors* sent to all registered team as the input source for "powermeter" and "cadence" in indieVelo.

6.4 Task set-up and description

Find an informational video here



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 ten sections. A self-calibrating, controllable bike trainer will be used to render the virtual scenario and to measure the pilot's performance (e.g., velocity, distance covered).

- IndieVelo is used to set-up the racetrack. Find more information on the webpage indieVelo.
- A minimum power output according to the sensor specific threshold will be required to set the avatar in motion.
- The race distance is 1960 m.
- The track is flat.
- The race distance with its resistance profile of the trainer can be covered within the time limit of 8 min with an average output of around 30 W.
- The pilot will be given 10 points for each section. The section number 1-9 are each 200 m, the section number 10 is 160 m.

- The track used for the competition is Forest Velodrome on indieVelo.
- The avatar used in the virtual scenario is a pilot on a trike. Steering of the trike is not required.
- The weight of the pilot will be considered in its physical representation in the virtual scenario. The weight of the frame will not be considered.
- All teams use the smart trainer Wahoo KICKR V6 and the dual-sided powermeter pedals *Wahoo Powerlink Zero*. The smart trainer and the pedals will be shipped to registered teams for free. All smart trainers are validated prior to shipping by the CYBATHLON organising committee together with an expert company.

6.5 Competition mode and scoring

Warm-up period:	30s
Total race distance:	1960 m
Points per section	10
Time limit:	8 min

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 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 prostheses users abandon their device in the long run.

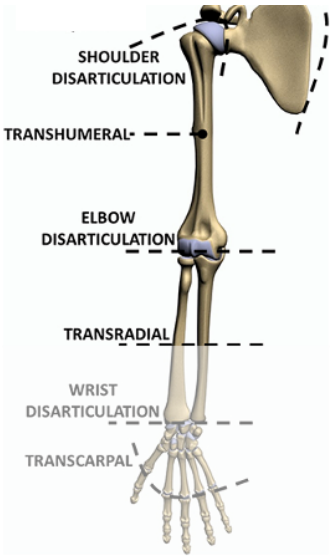
Arm prostheses which fulfil the users' expectations and needs have the potential to prevent device rejection. Additionally, prostheses that enable the functions of a human hand in a natural way may prevent secondary negative long-term effects due to non-physiological movements or anatomical asymmetry.

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 fulfil 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.

Comment 1 on ARM-PIL-1: The pilot should not have any residual function in the wrist.

Comment 2 on ARM-PIL-1: Please mind the following x-rays to check if your pilot candidate is eligible for the competition.

Eligible for the competition:
Transradial or more proximal amputation.

Not eligible for the competition:
Residual wrist structure and function.

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 It is 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, replacement equipment, etc.).

ARM-2 It is not allowed to touch, i.e., get in contact with, any part of theprosthesis , while it is in direct contact with any blue part of an object.

Comment 1 on ARM-2: Part of the prosthesis includes any wired or wireless interfaces which can be used to control the function of the prosthetic arm (e.g., buttons, remote control units, user interface).

Comment 2 on ARM-2: Non-robust control of prosthetic hand function during postural 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 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 Blue parts are only allowed to be manipulated or touched with the prosthetic hand (not including wrist, lower or upper arm).

ARM-4 It is allowed to touch several blue objects at a time.

ARM-5 If a pilot uses two prostheses, only one prosthesis is allowed to touch blue objects at a time.

Comment on ARM-5: If a pilot uses two prostheses, the pilot can decide for each manipulation which of the two prosthesis acts as the “prosthetic hand” and which one as their “non-prosthetic hand”. Note that handing a blue object from one prosthetic hand to another prosthetic hand is not allowed.

7.4 Task definitions

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

7.4.1 Carry Bottles

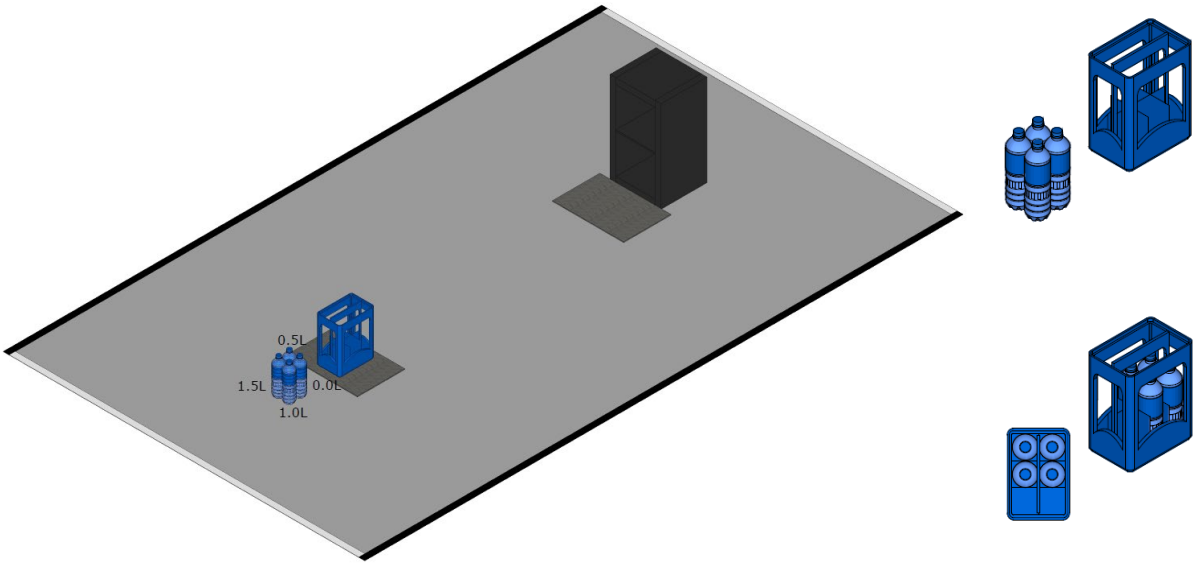
7.4.1.1 Introduction

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 shelf, removed from the crate and placed on top of it.

Image source

7.4.1.2 Task set-up & description



Pilots must carry the blue bottles using the blue bottle crate and then place the bottles on top of the shelf. The initial position of the 1.5 L PET bottles with the different fillings (1.5 L, 1.0 L, 0.5 L, 0 L water) is defined as in the illustration.

7.4.1.3 Task rules

ARM-BOT-1 The blue bottles must be carried to the shelf using the blue crate. If the blue bottles are carried without the crate, the task is failed.

Comment on ARM-BOT-1: The order of placing the bottles in the crate is free.

ARM-BOT-2 Each time the blue crate is put down on a mat, the crate must be placed on the mat in its entirety. If the crate is placed on the shelf or on the floor (next to the mats), the task is failed.

ARM-BOT-3 All blue bottles must be standing upright on the shelf and the blue crate must be standing on the mat closer to the finish line, when the pilot crosses the finish line of the task.

ARM-BOT-4 If any of the blue bottle touches the ground (floor or mat) again, after it has been lifted off the ground, the task is failed.

ARM-BOT-5 If any blue bottle tips over and touches the ground (floor or mat), the task is failed.

ARM-BOT-6 It is allowed that the crate slightly touches the side of the leg or hip while the pilots carry the crate with the prosthetic hand. If any part of the body (e.g., the legs or torso) is used to proactively stabilize the crate or the bottles when carrying the crate, the task is failed.

7.4.2 Serving Food

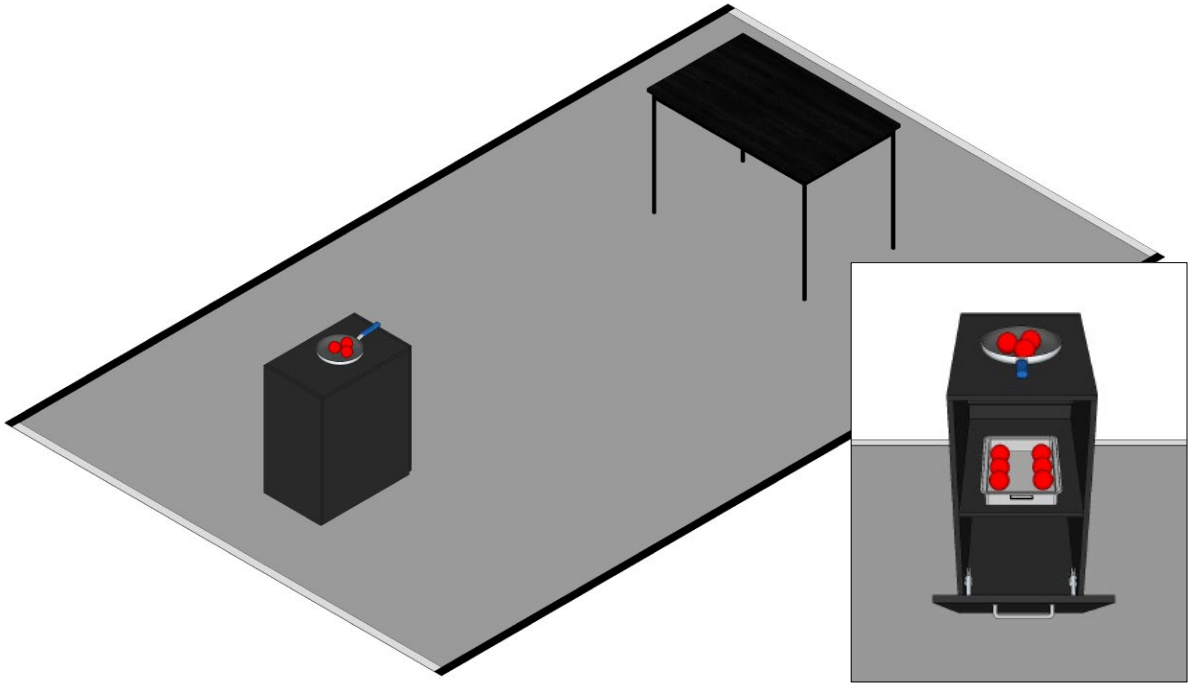
7.4.2.1 Introduction

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

7.4.2.2 Task set-up & description



Pilots must carry a casserole dish and a frying pan from the oven to the table.

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. The handles of the casserole dish are lifted all the way to the stop.
Insert: The casserole dish is initially placed in the oven. The oven is initially closed, the open oven is shown for illustration only. The handle of the oven is silver and can be opened with either hand.

7.4.2.3 Task rules

ARM-SERV-1	The frying pan and the casserole dish must be placed on top of the table.
ARM-SERV-2	The handle of the frying pan is blue. The rest of the frying pan is not allowed to be touched with the prosthetic or non-prosthetic hand.
ARM-SERV-3	The casserole dish must be held and carried at both handles when the casserole dish leaves the oven, i.e. the posterior handle crosses the front edge of the shelf.
ARM-SERV-4	If a lacrosse ball falls out of the frying pan or the casserole dish, the task is failed.

7.4.3 Storing Dishes

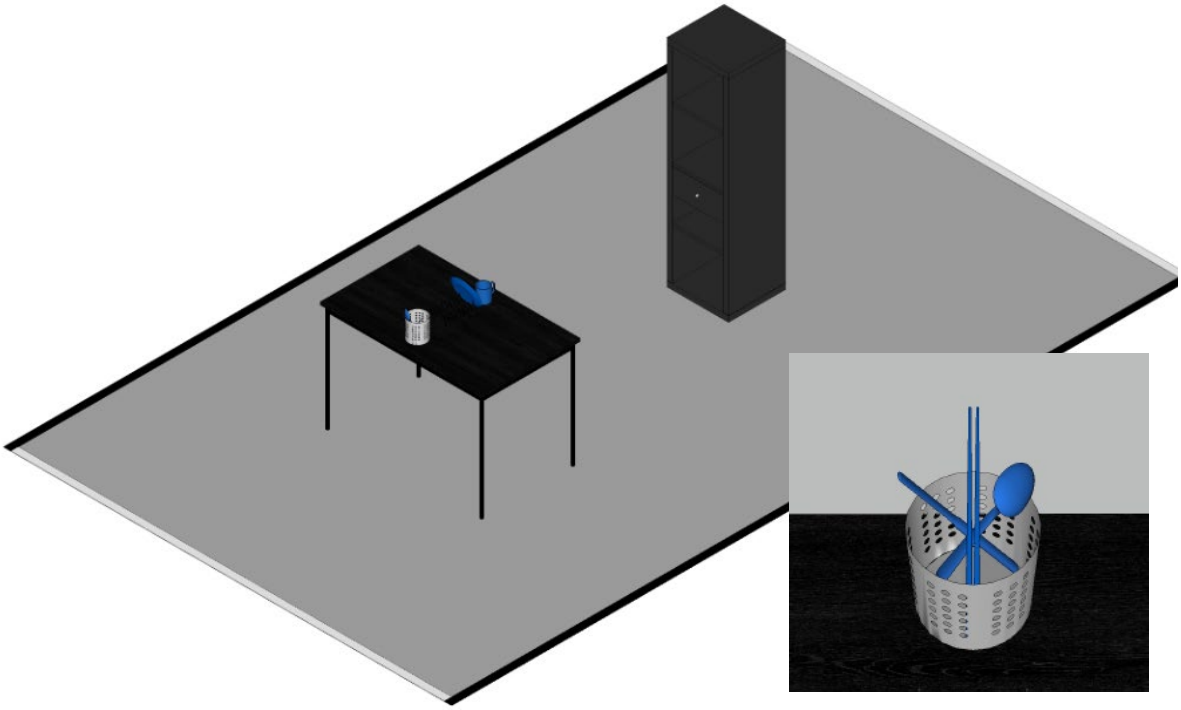
7.4.3.1 Introduction

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

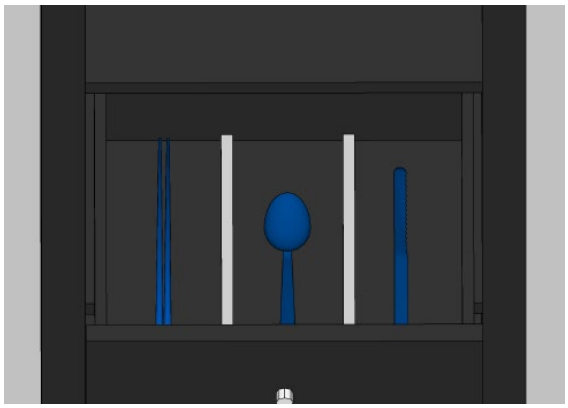
7.4.3.2 Task set-up & description



Pilots must move the blue dishes and blue cutlery from the table to their respective target locations in the shelf. Target locations are marked with dashed outlines. Close-up: Positioning of the cutlery in the tray in the drying stand.

Below left: frontal view of the shelf with all items at their target location

Below right: top view of the open drawer with all items at their target location.



7.4.3.3 Task rules

ARM-DISH-1	The blue cutlery must be removed from the cutlery stand and stowed away in the corresponding cutlery tray compartment in the shelf.
ARM-DISH-2	The blue plate must be removed from the plate holder and placed on the top shelf.
ARM-DISH-3	The blue cup must be placed on the middle shelf.
ARM-DISH-4	The plate holder and the cutlery stand can be moved around on the table. If either of them is lifted off the table, the task is failed.

7.4.4 Hanging Laundry

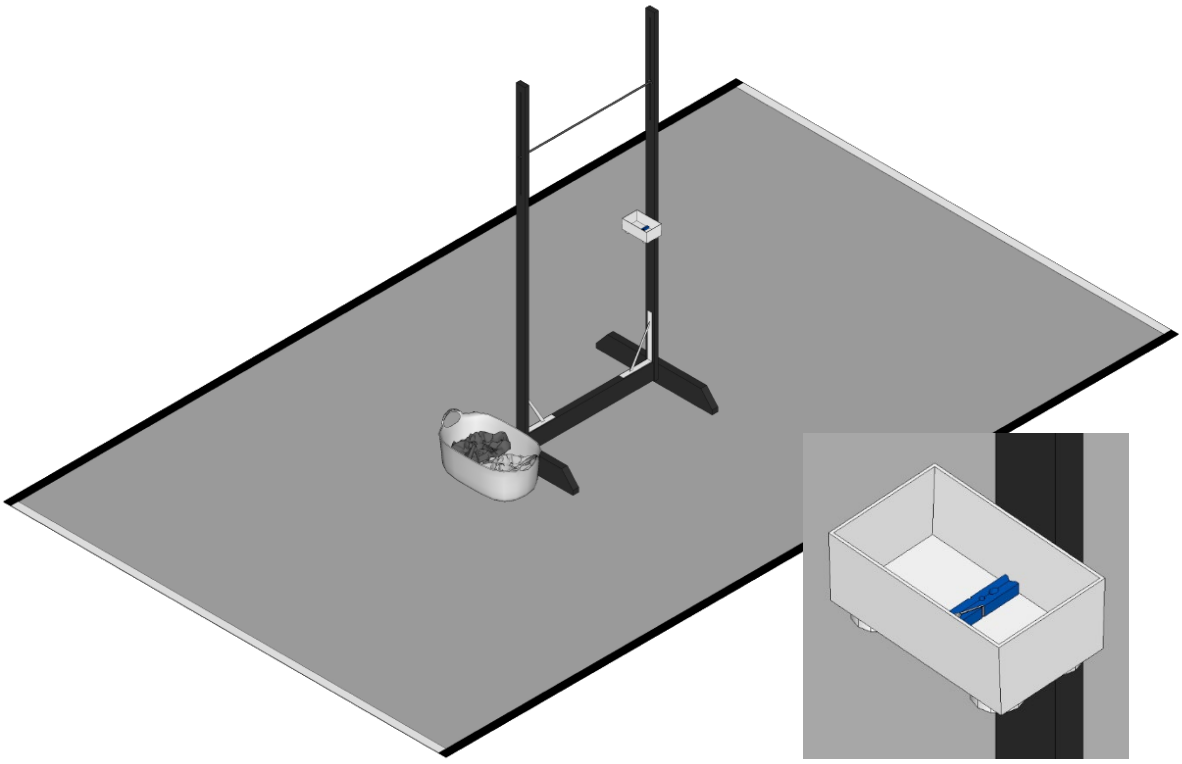
7.4.4.1 Introduction

Handling laundry and putting on clothes requires a distinct set of fine motor skills, in particular with the fingers. Furthermore, 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, fully close the zipper, take it off and hang it over the clothesline. Finally, the pilot must hang up a t-shirt on the clothesline using a blue clothespin.

Image source

7.4.4.2 Task set-up & description



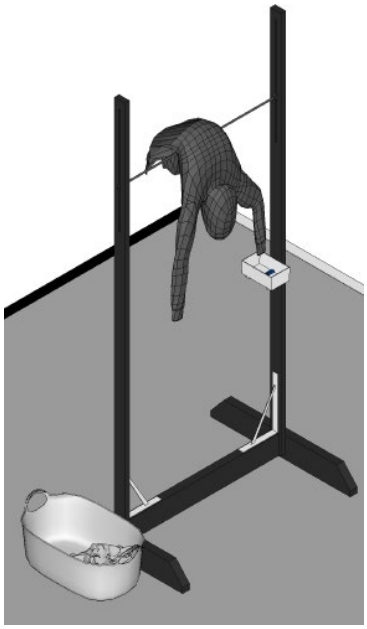
Pilots must hang a t-shirt on the clothesline using a blue clothespin, put on a hooded sweater, and hang it over the clothesline. The hooded sweater has a blue zip slider. Insert: Initial position of the clothespin in the box.

- Initially, the t-shirt and the sweater are randomly placed in the hamper.
- The sweater has a blue zip slider and is initially open. The sweater will be selected according to the size of the pilot (XS / S / M / L / XL / XXL).
- The height of the clothesline will be the pilot's body height + 0.1 m.

7.4.4.3 Task rules

ARM-LAUNDRY-1 The pilot must go through the following steps with the sweater. If any step is not executed correctly, the task is failed.

- The sweater must be put on correctly (both arms inserted fully through the sleeves).
- The zipper must be closed above the mark when wearing the sweater.
- The zipper must be opened completely to take off the sweater.
- The sweater must hang on the clothesline, when the pilot crosses the finish line of the task (e.g., throw the sweater over the clothesline).



Comment on ARM-LAUNDRY-1: The referee will confirm if the zipper is closed above the mark with "Okay go", and the pilot may continue.

ARM-LAUNDRY-2 The blue zip slider is only allowed to be pulled by the prosthetic hand.

Comment on ARM-LAUNDRY-2: For inserting the zipper, the non-prosthetic hand can touch (but not grasp) the blue zip slider and the non-blue parts of the zipper.

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

Comment on ARM-LAUNDRY-3: It is permitted to hang the t-shirt over the line and then attach it with the blue clothespin.

7.4.5 Do-it-yourself

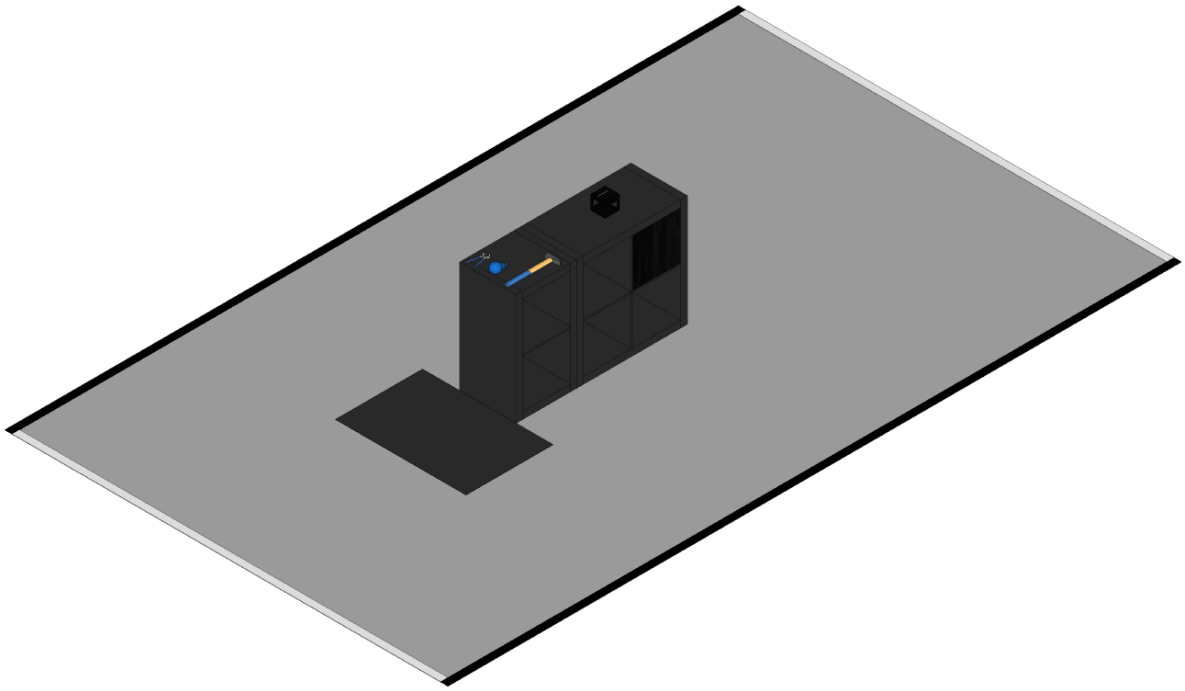
7.4.5.1 Introduction

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.

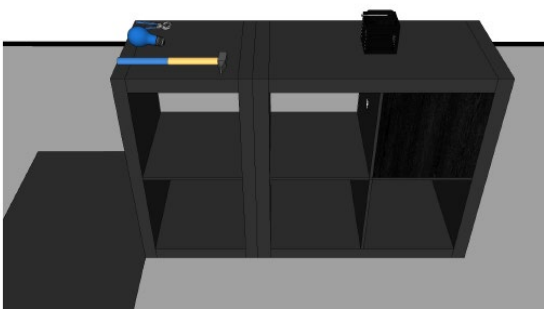
Image source

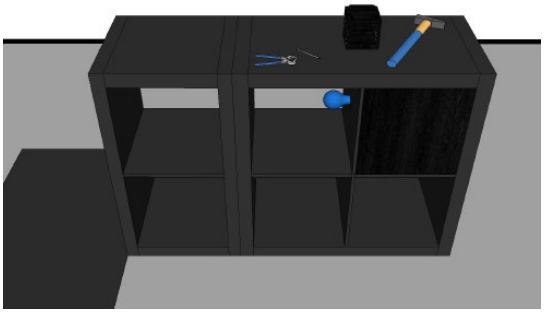
7.4.5.2 Task set-up & description



Pilots must drive a nail into a piece of 'wood' using a hammer and remove it using pliers. The handles of both the hammer and the pliers are blue. In addition, 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. The tools can be located anywhere on the top surface of the shelf.





7.4.5.3 Task rules

ARM-DIY-1 The nail must be driven into the 'wood' (represented by a 3D printed plate) using only the blue hammer until its tip breaks the bottom surface of the plate. Once the nail has broken the bottom surface of the plate, the nail it must be fully removed from the wood using only the pliers.

Comment on ARM-DIY-1: The referee will confirm the breaking of the tip through the bottom surface of the plate with "Okay go".

ARM-DIY-2 The blue lightbulb must light up after it is screwed into the bulb holder.

Comment on ARM-DIY-2: In case of a technical defect, the referee can confirm the correct montage of the lightbulb with "Okay go".

ARM-DIY-3 It is not allowed to touch the non-blue parts of the tools or the light bulb with the prosthetic or non-prosthetic hand.

ARM-DIY-4 While standing on the mat with both feet in their entirety, it is allowed to use the non-prosthetic hand to support positioning the tools or the light bulb in the prosthetic hand. For the positioning while standing on the mat, the non-prosthetic hand can touch the blue parts and the non-blue parts of the tools or the light bulb.

Comment on ARM-DIY-4: It is not allowed to touch the tools or the light bulb with the non-prosthetic hand while standing off the mat.

ARM-DIY-5 If the 3-D printed plate is pulled off the fixation, the task is failed.

Comment on ARM-DIY-5: We recommend pushing down and stabilizing the 3D-printed plate with the non-prosthetic hand.

7.4.6 Containers

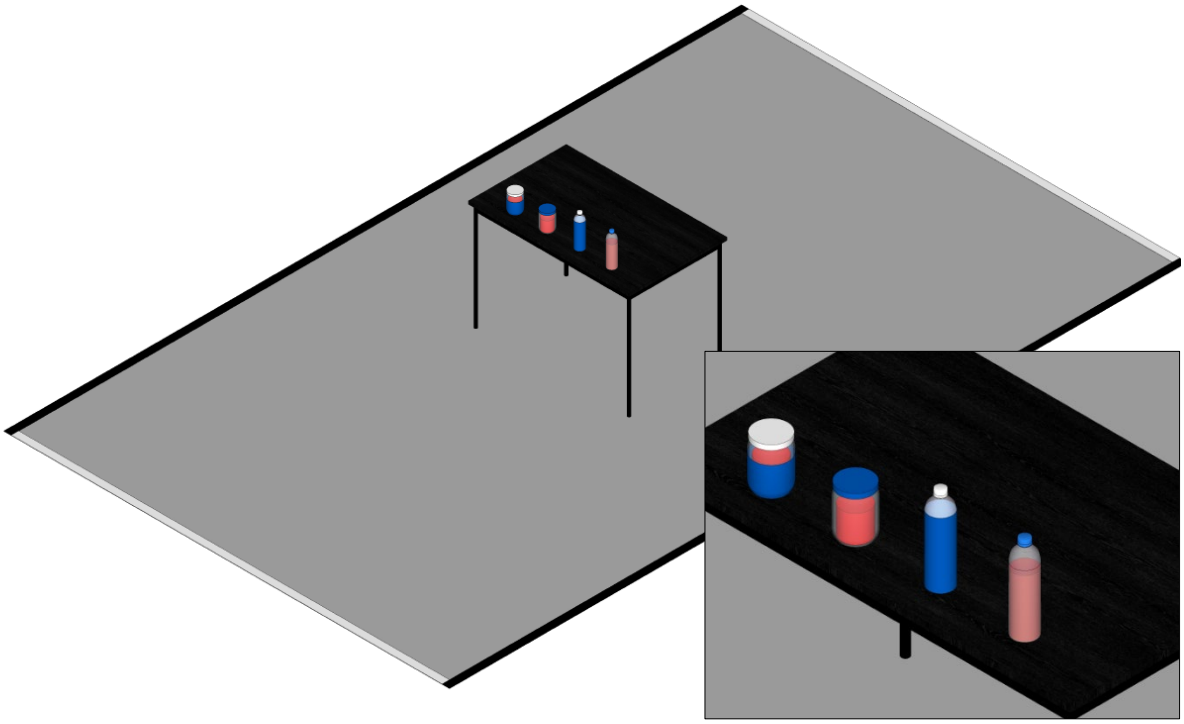
7.4.6.1 Introduction

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.

Image source

7.4.6.2 Task set-up & description



Pilots must open two bottles and two jam jars. Insert: Close-up of all containers on the table.

Description of the containers:

- One bottle has a blue lid, and the other has a blue bottle body.
- One jar has a blue lid, and the other jar has a blue jar-body.
- All containers are filled with red coloured water.

7.4.6.3 Task rules

ARM-CONT-1	The blue cap of the transparent PET bottle must be removed. If any of the content of the bottle is spilled the task is failed.
ARM-CONT-2	The white cap of the blue PET bottle must be removed. If any of the content of the bottle is spilled the task is failed.
ARM-CONT-3	The blue lid must be separated from the transparent jar. If any of the content of the jar is spilled, the task is failed.
ARM-CONT-4	The white lid must be separated from the blue jar. If any of the content of the jar is spilled, the task is failed.

7.4.7 Haptic Bag

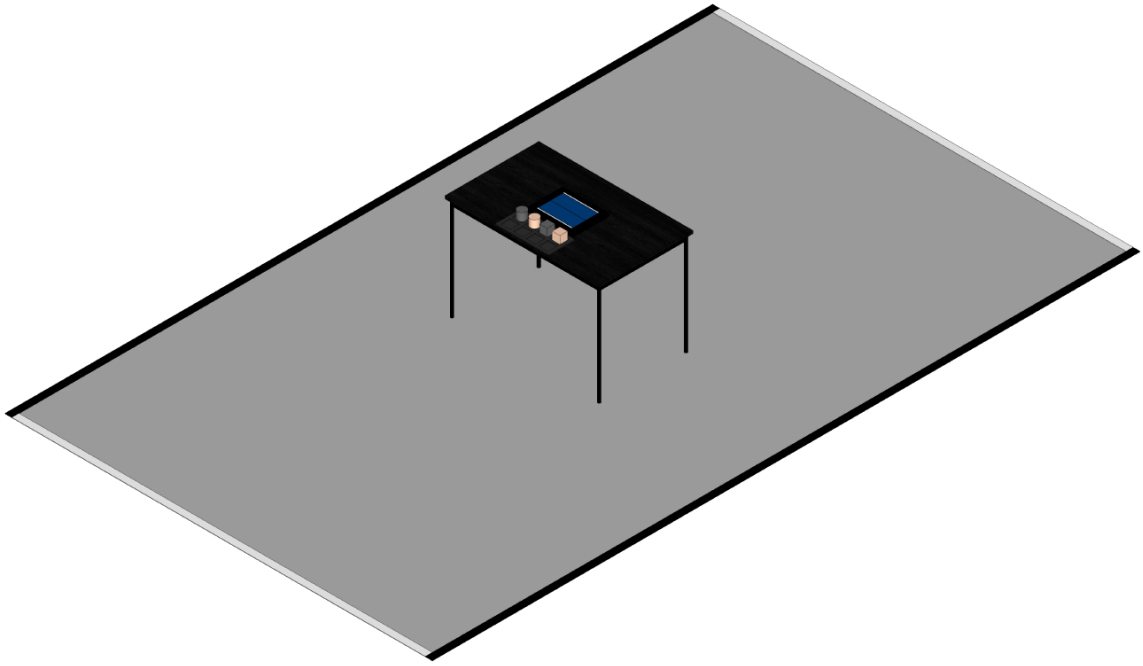
7.4.7.1 Introduction

The availability of sensory feedback can improve a user's control over the prosthesis and increases the acceptance and embodiment of the device.

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

Image source

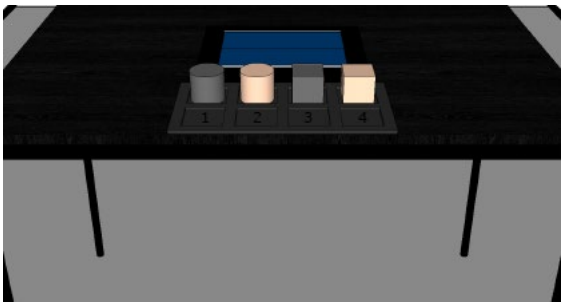
7.4.7.2 Task set-up & description

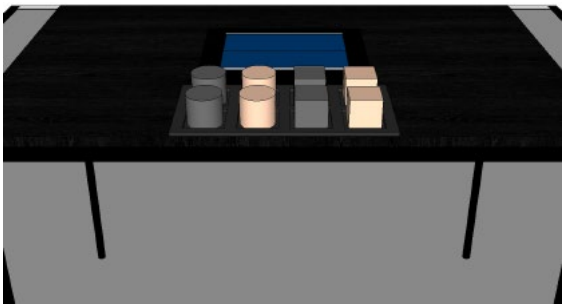


Pilots must reach into the bag only with their prosthetic hand to retrieve the objects in a predefined order (1-4, see below).

Four different objects are placed in the bag: a hard cylinder, a soft cylinder, a hard cube and soft cube (grey: hard, apricot soft). The order of the target objects on the rack is randomised. The pilots have no sight of their workspace during shape and compliance exploration and identification.

Below left: Example of randomized starting position. Below right: Corresponding target position.





7.4.7.3 Task rules

ARM-HAPT-1 The objects must be removed from the bag in the order in which they are initially presented on the table (1-4).

ARM-HAPT-2 Only the prosthetic hand must be inserted into the bag through the blue opening. The bags must not be touched with the other hand.

ARM-HAPT-3 It is not allowed to push the objects inside the bag against the table or the edges of the haptic bag in order to deduce the compliance or shape of the objects.

ARM-HAPT-4 Only one object at a time must be removed from a bag.

ARM-HAPT-5 If a wrong object is removed at least partly from the bag (the referee sees the object), the task is failed.

ARM-HAPT-6 All forms of imaging and sensors are allowed to detect the objects (including sensors that use visible light, electromagnetic waves, lasers or similar).

ARM-HAPT-7 It is not allowed to intentionally look into the bag.

ARM-HAPT-8 The feedback to the pilot is not allowed to be the streamed image from inside the bag.

Comment on ARM-HAPT-8: The feedback to the pilot is allowed to be visual (e.g., icons or text representing the objects), auditive or haptic.

7.4.8 Hot Wire

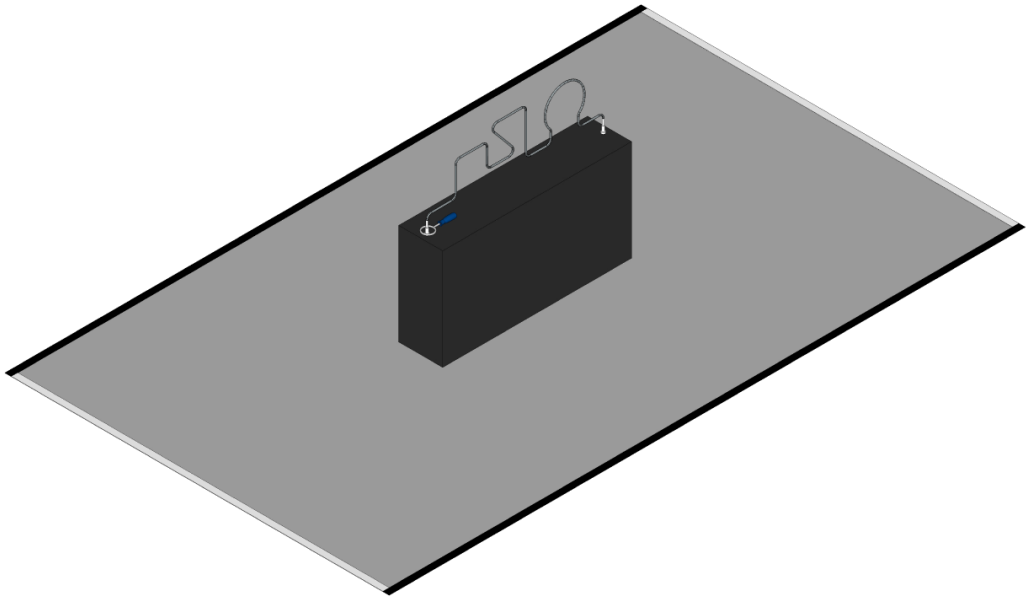
7.4.8.1 Introduction

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.

Image source

7.4.8.2 Task set-up & description



Pilots must move the metal loop with the blue handle around the wire to reach the target location, without touching the wire. The start and the target area of the bent wire are marked with white insulating plastic.
Insert: Close-up of the metal loop with the blue handle .

7.4.8.3 Task rules

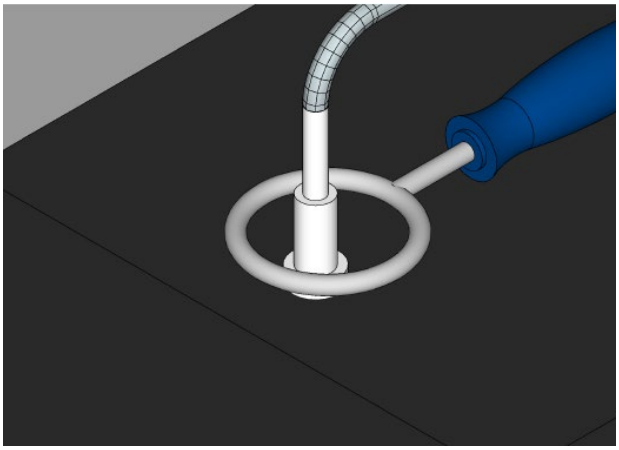
ARM-WIRE-1 The task must be started and finished in the designated regions (start area and finish area), where pilots grasp and drop the loop respectively.

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 handle lights up and the task is failed.

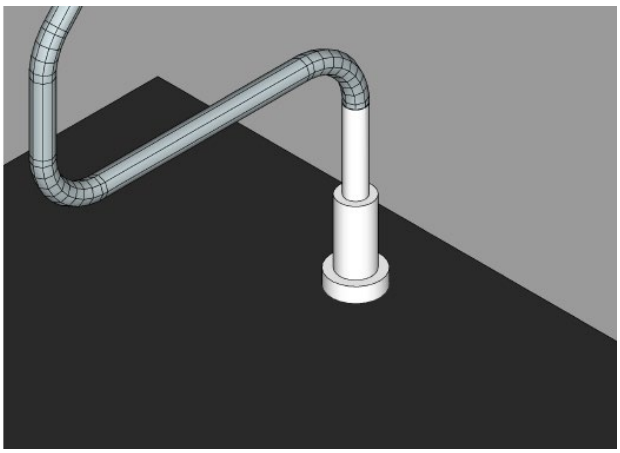
Comment on ARM-WIRE-2: In case of a technical defect, the referee can confirm the contact between the wire and the loop with “Task fail”.

ARM-WIRE-3 It is allowed to touch the silver part of the handle with the non-prosthetic hand to support positioning the handle while the loop is in the start area of the bent wire.

ARM-WIRE-4 If the silver part of the handle or the loop is touched with the prosthetic or non-prosthetic hand outside of the start and finish area, the task is failed.



Start area (white part)



Finish area (white part)

7.4.9 Stacking

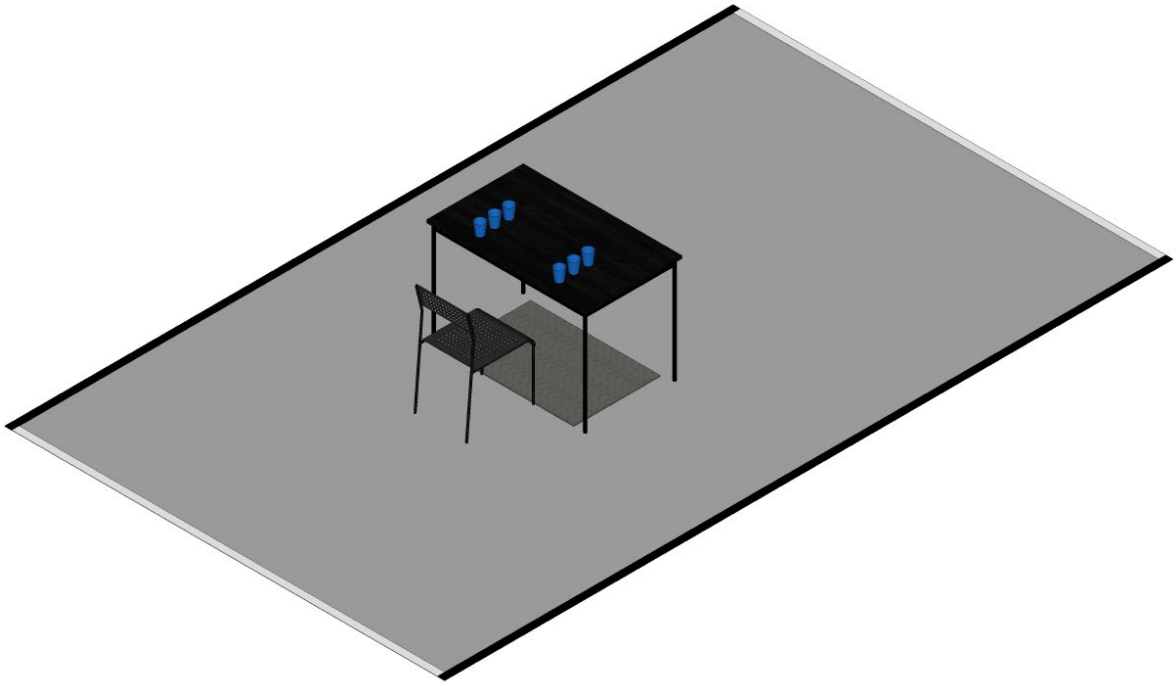
7.4.9.1 Introduction

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.

Image source

7.4.9.2 Task set-up & description



Pilots must stack the cups to a pyramid and then dissemble them again.

Below left: initial position of the blue cups; centre: blue cups stacked to a vertical pyramid; right: blue cups stacked to a single pile.

7.4.9.3 Task rules

ARM-STACK-1 All blue cups must be stacked to a three-level vertical pyramid (3-2-1) on the table. The opening of the blue cups must face downwards in the pyramid.

ARM-STACK-2 The pilot must be sitting on the chair while stacking and disassembling the blue cups. To ensure sitting, from the first touch of a cup, the pilot's feet (in their entirety) must be placed on the mat below the table.

Comment on ARM-STACK-2: The pilot is allowed to move the chair to comfortably sit down.

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

Comment on ARM-STACK-3: The referee confirms the placement of the two hands on the table with "Okay go".

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

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

Comment on ARM-STACK-5: 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.

7.4.10 Clean Sweep

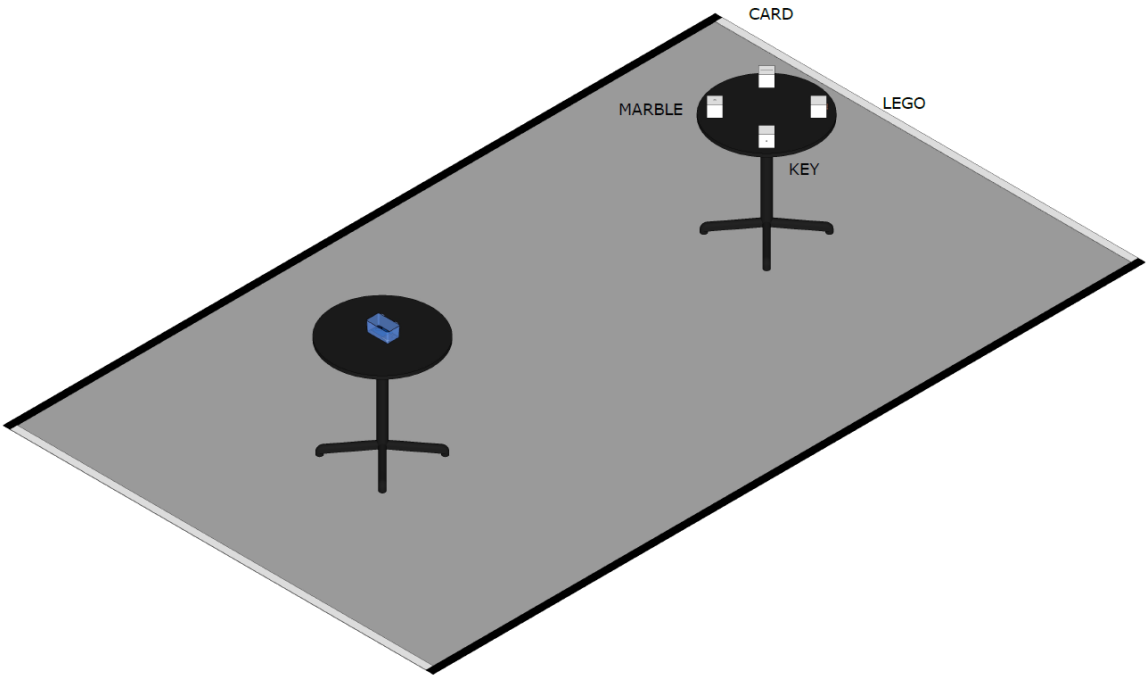
7.4.10.1 Introduction

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.

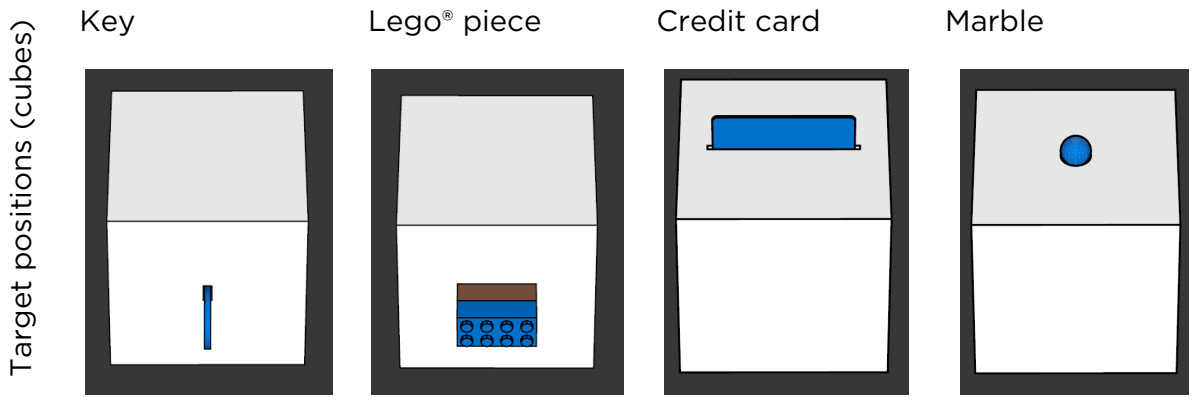
In this task, pilots are asked to grasp and move blue objects individually with their prosthetic hand from their random, initial position on a table surface to a target position on a neighbouring table.

Image source

7.4.10.2 Task set-up & description



The blue objects located on the table near the start line must be placed at their respective target positions on the table near the finish line.



7.4.10.3Task 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.

Comment 1 on ARM-CLEAN-1: The target positions (cubes) are fixed on the table (e.g., with tape or screws). 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.

Comment 2 on ARM-CLEAN-1: The long side of the box is parallel to the start line. There is no lid on the box.

ARM-CLEAN-2 It is not allowed to transport the blue objects using the blue box. While the pilot is placing blue objects to their designated target position, the blue box must remain on the table near the start line.

ARM-CLEAN-3 If not all blue objects are located at their designated target position on the table near the finish line when the pilot passed the finish line of the task, the task is failed.

7.5 Competition mode and scoring

Points per task: 10

Time limit: 8 min

8 Leg Prosthesis Race

LEG pilot solving the Tilted Path task during CYBATHLON 2020 Global Edition.

8.1 Introduction

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 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. 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. 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 disarticulation or more proximal amputation of at least one leg.

Comment on LEG-PIL-1: The pilot should not have any residual function in the knee.

8.2.2 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 LEG race:

LEG-TEC-1 The prosthesis can have any number of actively driven (i.e., powered) joints.

LEG-TEC-2 The residual leg (including the hip) can be instrumented and electronically and/or mechanically connected to the prosthesis to actuate the prosthesis. Mechanical or electronical connection to any other body part (above the hip) to actuate the prosthesis is not allowed.

General comments on the prostheses:

- Any kind of unpowered or powered prosthesis is allowed.
- 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 aids (e.g., crutches, canes, or similar) during the competition is not allowed.

LEG-2 It is 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). However, it is allowed to use such aids to carry components of the device (e.g., batteries, control units, tools, replacement equipment).

LEG-3 Any blue area must only be touched with the prosthetic leg (including the shoe). Stabilizing by propping oneself on the floor or an object that the pilot steps on, is not allowed. If the pilot touches the floor or any objects that the pilot may steps on (e.g., stones, boxes, stairs, slopes, ladder, etc.) with any part of the assistive device or the body, except for with the feet/shoes, the task is failed.

Comment on LEG-3: Stabilizing by propping oneself on another object on the task area (e.g., bench, table, crates, shelf, etc.) is allowed.

LEG-4 It is not allowed to support movement of the prosthetic leg with the hands, arms, or any other body part.

LEG-5 It is allowed to change the modality or function of the prosthesis e.g. use a switch or press a button on the prosthesis, while the prosthesis is not in direct contact with any competition infrastructure.

8.4 Task definitions

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

8.4.1 Balance Beam

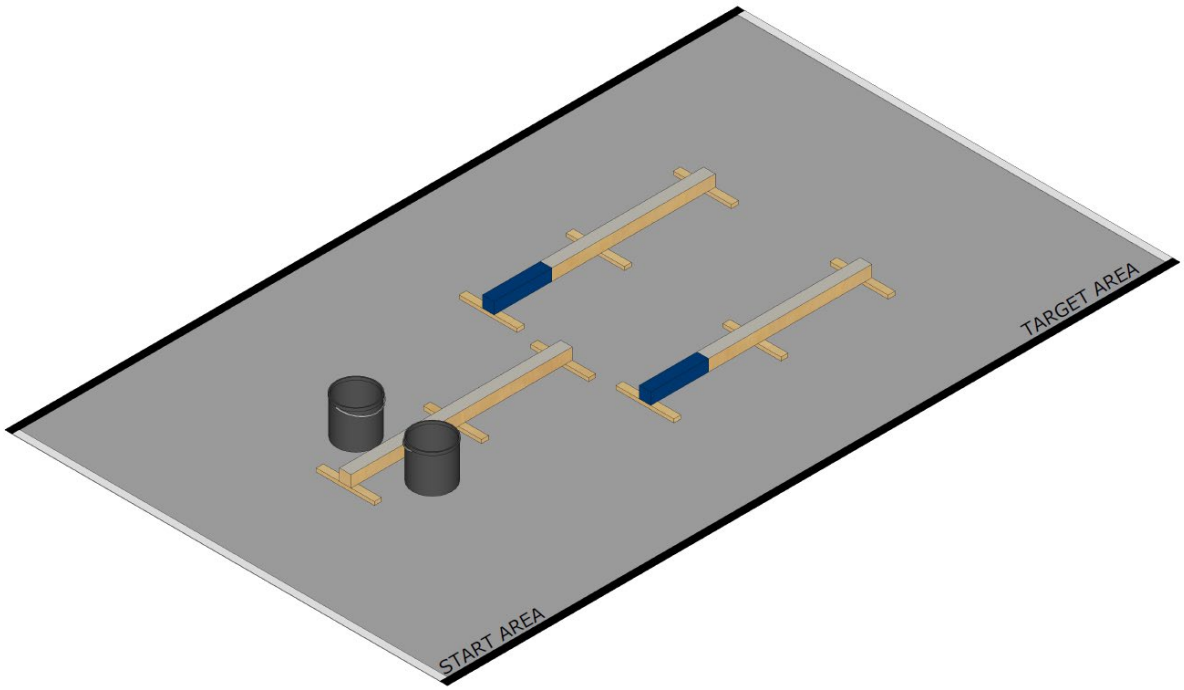
8.4.1.1 Introduction

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 must individually pick up and carry two buckets to a target area while walking across narrow wooden beams.

Image source

8.4.1.2 Task set-up & description



Pilots must start the task by stepping on the first beam in the start area. Pilots must then carry the empty buckets (one at a time) to the end of each beam and place it in the target area.

8.4.1.3 Task rules

LEG-BEAM-1 Once the pilot steps on the balance beam, the pilot must only touch the ground when both buckets are located in the target area.

Comment on LEG-BEAM-1: The target area is defined as the floor behind the end of the two beams with the blue parts.

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

Comment on LEG-BEAM-2: The pilot can choose the order of placing the bucket, i.e., to the left or to the right first.

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 balance beam.

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

LEG-BEAM-7 It is not allowed to touch the ground or the beam supporting structures on the left and right side of the beams with any part of assistive device or pilot's body. If that part of the ground or supporting structure is touched, the task is failed.

8.4.2 Stairs

8.4.2.1 Introduction

Stairs and steps are very common in daily life. To ascend or descend stairs, users of transfemoral prostheses must usually apply specific strategies and adapt their gait pattern. 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 commonly used as an auxiliary mean. However, they are often absent, not reachable or can't be used when the hands are occupied.

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

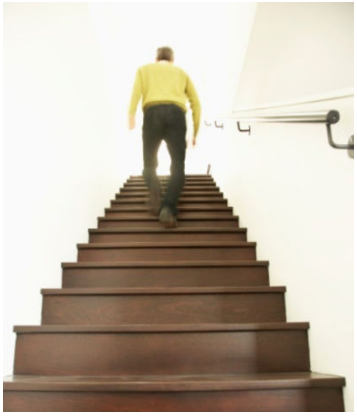
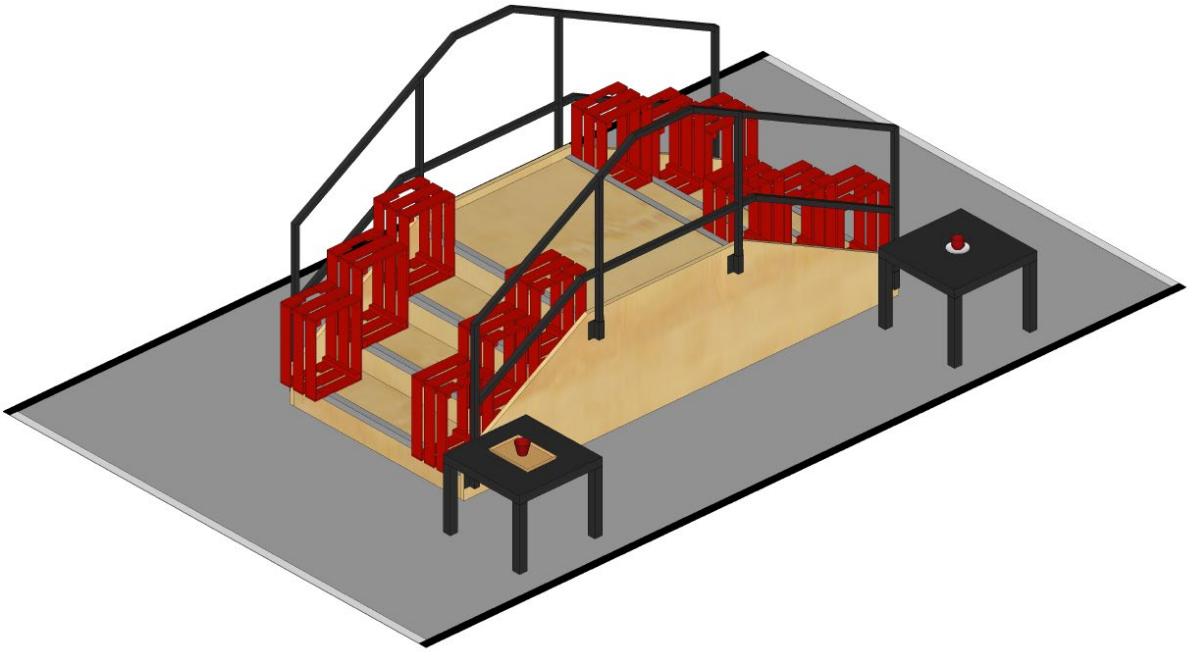


Image source

8.4.2.2 Task set-up & description



Pilots must cross the staircase three times. The tray with the cup and the saucer with the coffee mug must be carried to the other sides. The width of the staircase is limited to passageway with red crates.

8.4.2.3 Task rules

LEG-STAIRS-1 The pilot must cross the staircase three times:

- During the first crossing, the pilot must carry the tray with the red cup from table 1 to table 2.
- During the second crossing, the pilot must carry the saucer with the red mug from table 2 to table 1.
- During the third crossing, the pilot must not carry any objects.

LEG-STAIRS-2 The red cup must be standing on the tray when the pilot crosses the finish line of the task.

LEG-STAIRS-3 Each step (excluding the top platform of the stairs) must be stepped on by one foot only. The leading leg must alternate (except on the top platform of the stairs).

Comment 1 on LEG-STAIRS-3: It is not allowed to place two feet on one step.

Comment 2 on LEG-STAIRS-3: It is allowed to place both feet on the platform on the top of the stairs.

LEG-STAIRS-4 It is not allowed to omit single steps or jump over steps.

LEG-STAIRS-5 It is not allowed to touch the ground on the left and right side of the stairs with any part of the assistive device or pilot's body. If that part of the ground is touched, the task is failed.

8.4.3 Step-over

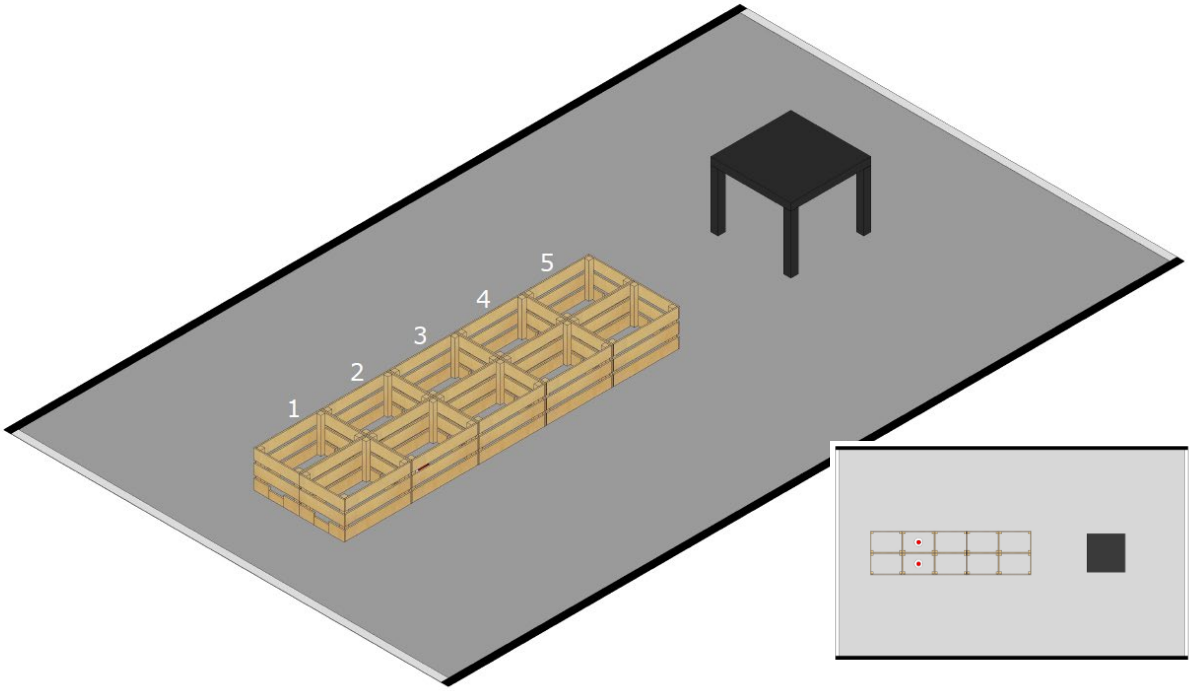
8.4.3.1 Introduction

Items that are randomly lying around or fell on the floor (e.g., a child's toys) can obstruct a path and sometimes require the ability to lift the feet and accurately controlling the placement of the feet to avoid the items. One might want to pick up the objects to either use them or to stow them away.

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 and pick up the two plates, one at the time, and place them on the table.

The crates are arranged in five pairs (rows 1-5). Red mugs on plates are initially placed in each crate of row 2.
Insert: Top view of the crates with the plates and mugs placed in row 2.

8.4.3.3 Task rules

LEG-CRATES-1 The plates with the red mug must be located on the table when the pilot crosses the finish line of the task.

LEG-CRATES-2 Only one plate with a red mug must be carried at a time.

LEG-CRATES-3 It is not allowed to touch the ground on the left and right side of the crates with any part of the assistive device or the pilot's body. If that part of the ground is touched, the task is failed.

8.4.4 Slopes

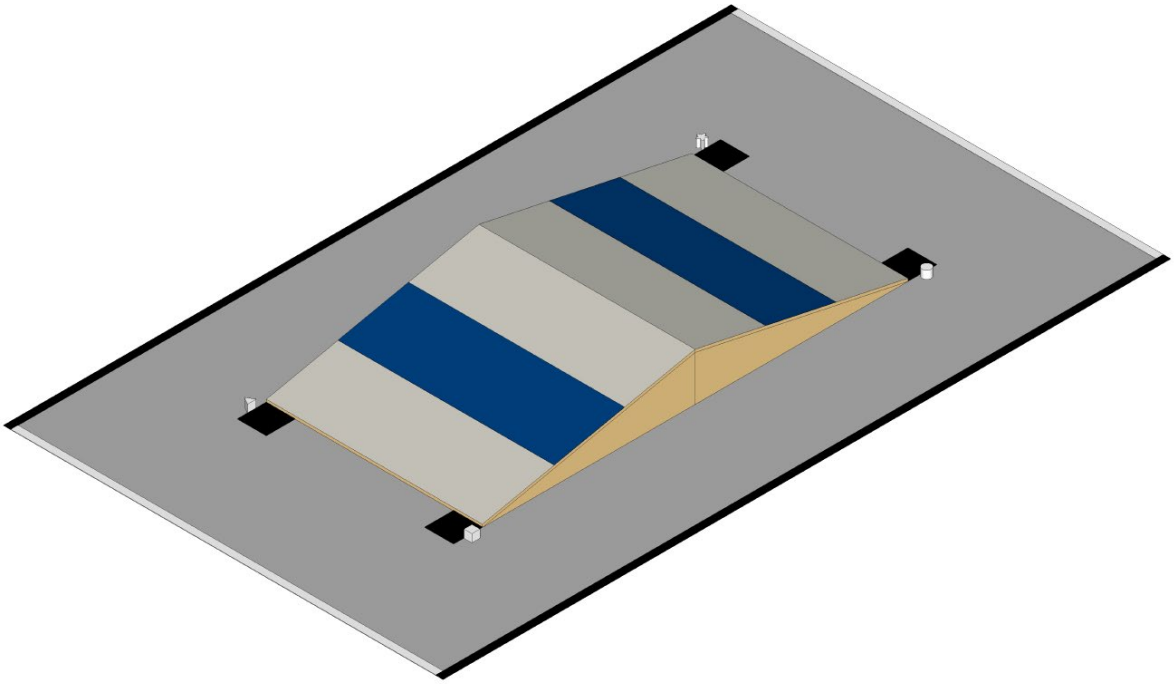
8.4.4.1 Introduction

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.

Image source

8.4.4.2 Task set-up & description



Pilots must place the four objects on their target locations, diagonally across the slope.

8.4.4.3 Task rules

LEG-SLOPE-1 The pilot must place their prosthetic feet with its entirety on the blue zone of the obstacle when the pilot crosses this blue zone with the non-prosthetic leg.

LEG-SLOPE-2 Each of the four objects must be located on top of their respective target location at the diagonal corner across the slope when the pilot crosses the finish line of the task.

LEG-SLOPE-3 Only one object must be carried at a time.

LEG-SLOPE-4 If the ground on the left and right side of the slopes are touched with any part of assistive device or pilot's body, the task is failed.

LEG-SLOPE-5 The object must only be touched when both pilot's feet are in their entirety on the slope.

LEG-SLOPE-6 Once the pilot has stepped on the slope with both feet, it is not allowed to touch the ground, before all objects have been placed at their target location. If the pilot touches the ground, before all objects are at their target location, the task is failed.

8.4.5 Bench & Table

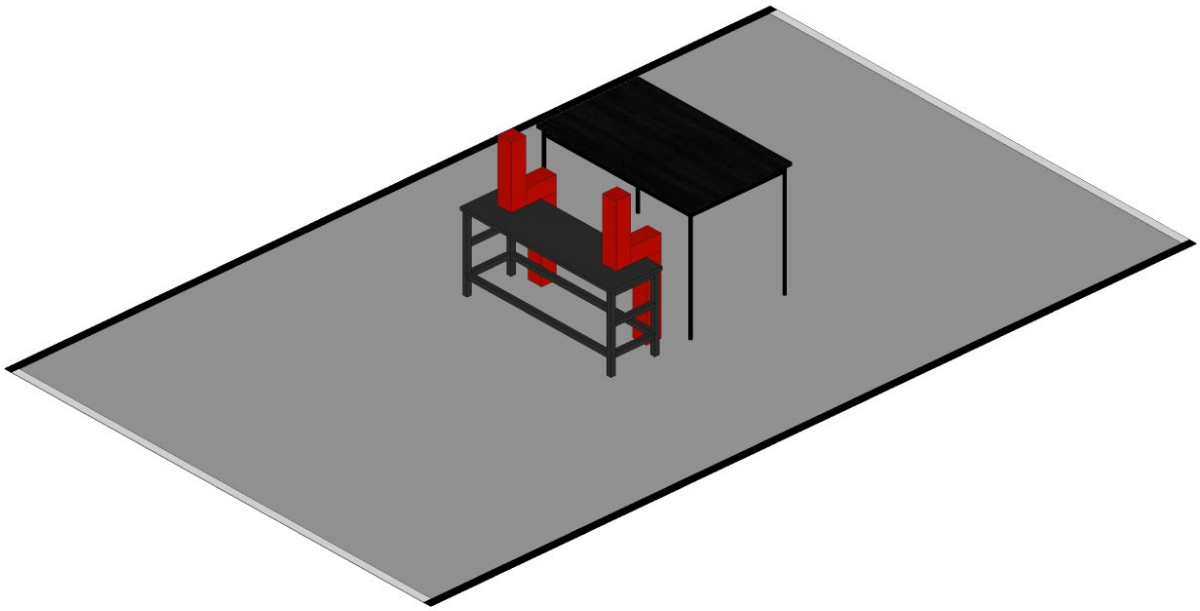
8.4.5.1 Introduction

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.

Image source

8.4.5.2 Task set-up & description



Pilots must take a seat at the centre of the bench between the two red S-shapes and get up again.

8.4.5.3 Task rules

LEG-BENCH-1 The pilot must enter between the red S-shapes, take a seat on the bench and get up again between the S-shapes.

Comment on LEG-BENCH-1: It is allowed to touch the bench and the table with any part of the body or the assistive device.

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

LEG-BENCH-3 The pilot must sit on the bench, place both feet on the floor underneath the table and place both elbows on the table.

Comment on LEG-BENCH-3: The referee confirms the correct sitting position with “Okay go”.

8.4.6 Wobbly Steps

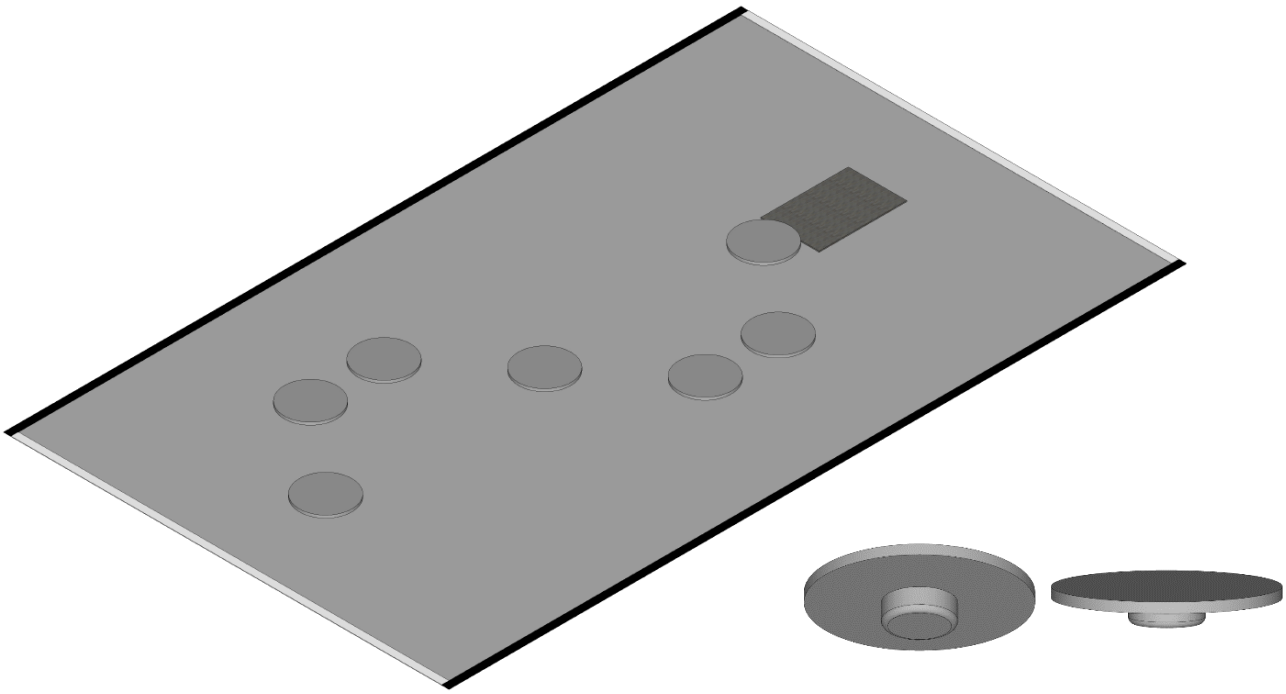
8.4.6.1 Introduction

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.

Image source

8.4.6.2 Task set-up & description



Pilots must cross the series of wobbly stones without touching the ground. The route of the wobbly stones can be mirrored between races.
Insert: close-up of the wobbly steps (including showing one wobbly stone from the bottom).

8.4.6.3 Task rules

LEG-WOBB-1	The pilot must enter the path by stepping on the first wobbly stone from behind the stone in the direction of the race.
LEG-WOBB-2	The pilot must walk from the first wobbly stone to the last wobbly stone close to the finish line without touching the ground. If the pilot touches the ground after the non-leading foot has left the ground to step on the first stone, until stepping on the mat, the task is failed.
LEG-WOBB-3	Pilots must alternate the leading leg to transition between two wobbly stones.
LEG-WOBB-4	Each stone must be stepped on at least once.
LEG-WOBB-5	Wobbly stones can be stepped on with both feet at a time.
LEG-WOBB-6	The pilot must leave the path by stepping on the mat beyond the last stone. The pilot's leading leg (in its entirety) must be placed on the mat.
LEG-WOBB-7	It is not allowed to position or reposition the stones intentionally.
Comment on LEG-WOBB-7:	It is allowed, that the stone moves when stepping on it.

8.4.7 High Step

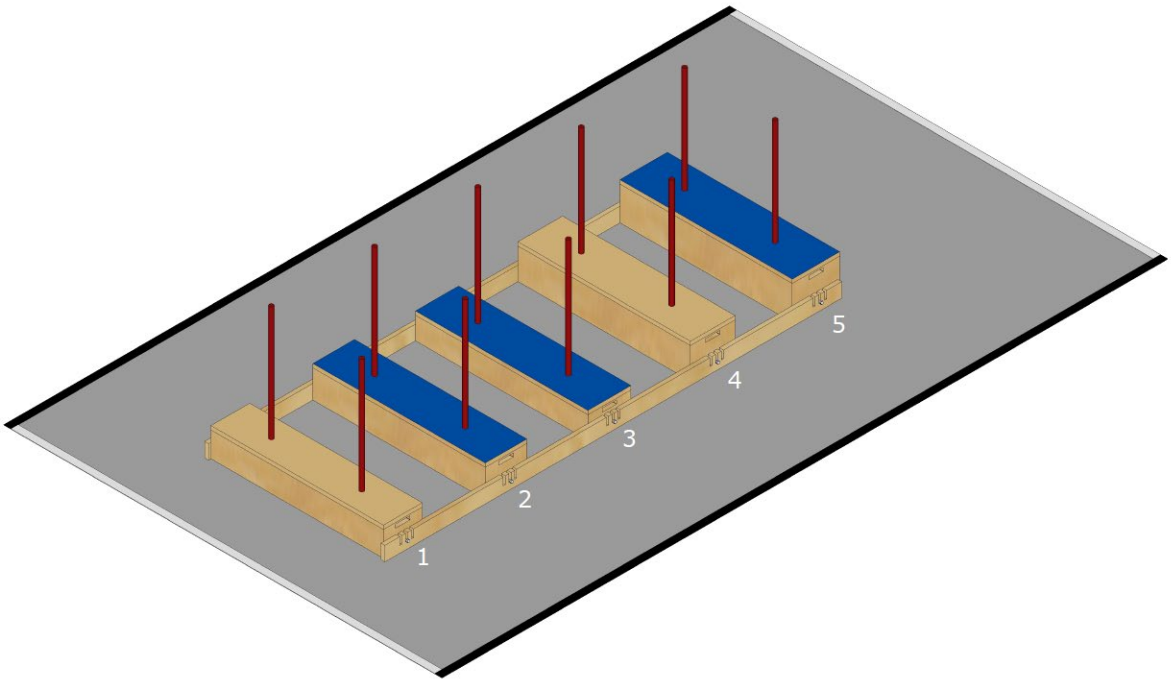
8.4.7.1 Introduction

Crossing large steps or gaps is challenging since it requires adaptable step length and balance, especially after large steps. Walking on surfaces that dictate irregular steps can be required when walking in the nature or in cities. For example, stepping into public transport requires various step height and length, depending on the vehicle and platform.

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

Image source

8.4.7.2 Task set-up & description



Pilots must step across the sequence of boxes.

The boxes are set according to the following rules:

- Three of the five boxes have a blue top surface.
- The boxes are presented in random order.
  - In each randomization of the boxes, two boxes with blue surface are presented in direct sequence.
  - The third blue box cannot be next to the two blue boxes in sequence.

8.4.7.3 Task rules

LEG-STEP-1	Pilots must cross the sequence of boxes by passing between the red poles once in the direction of the race.
LEG-STEP-2	The boxes with 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-STEP-3	It is not allowed to place two feet on one box.
LEG-STEP-4	It is not allowed to omit single boxes or jump over boxes.
LEG-STEP-5	The floor between the boxes must be touched with at least one foot.
LEG-STEP-6	It is not allowed to touch the ground on the left and right side of the obstacle with any part of assistive device or pilot's body. If that part of the ground is touched, the task is failed.

8.4.8 Ladder

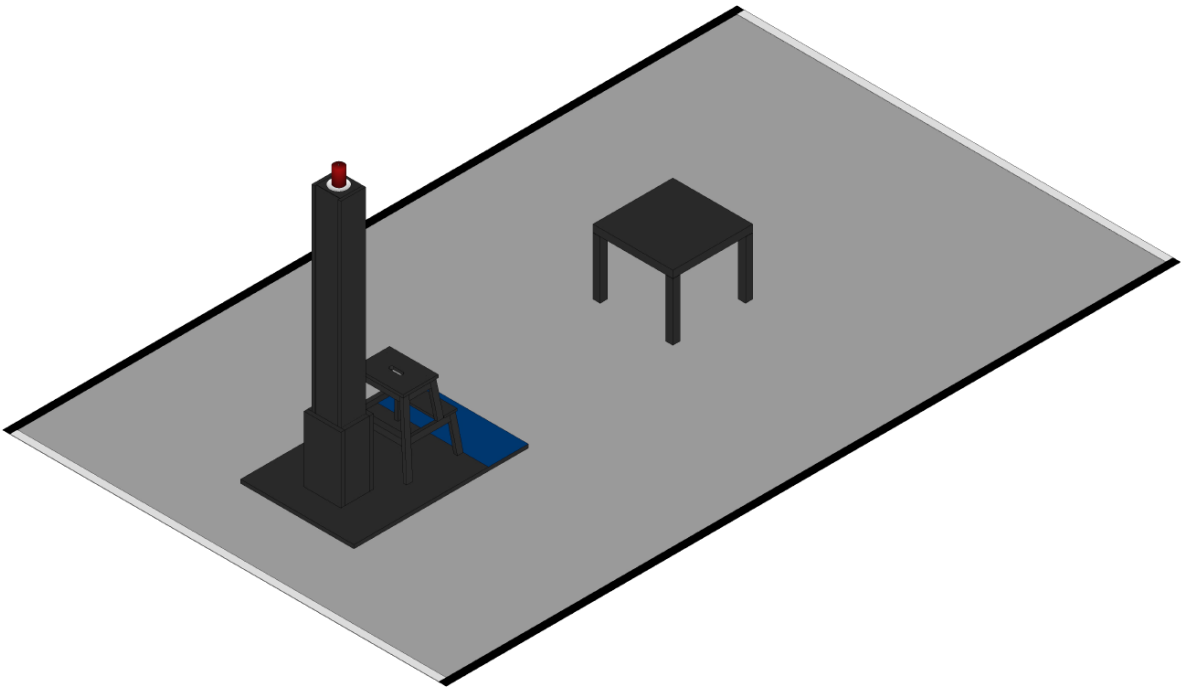
8.4.8.1 Introduction

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 predefined locations while balancing a candle on a plate.

Image source

8.4.8.2 Task set-up & description



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

8.4.8.3 Task rules

LEG-LADDER-1	It is not allowed to omit single steps of the stepladder when ascending or descending the ladder. If any step is omitted, the task is failed.
LEG-LADDER-2	The blue area must be stepped on with the prosthesis (including the shoe) when ascending and descending ladder.
LEG-LADDER-3	Step 1 must be stepped on only by the non-prosthetic foot while climbing and descending the stepladder.
LEG-LADDER-4	Picking-up the plate is only allowed when standing on the top platform with both feet. When crossing the finish line of the task, the plate with the red candle must be located on the table.

8.4.9 Cross Country

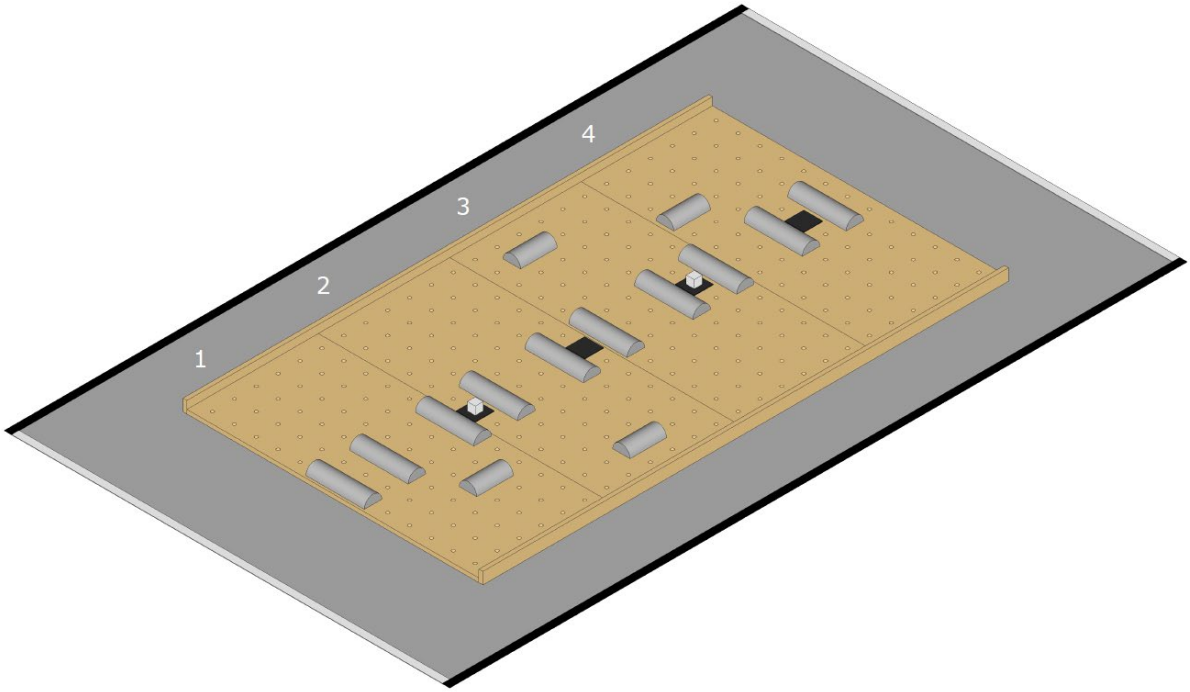
8.4.9.1 Introduction

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 and picking up and put down items.

Image source

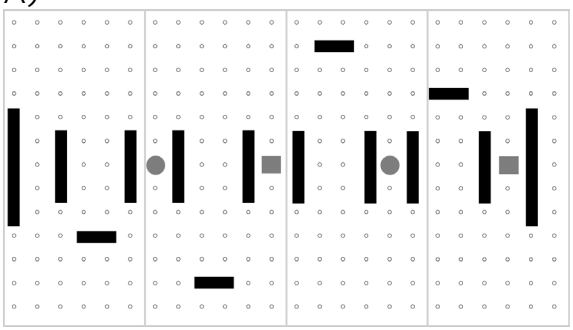
8.4.9.2 Task set-up & description



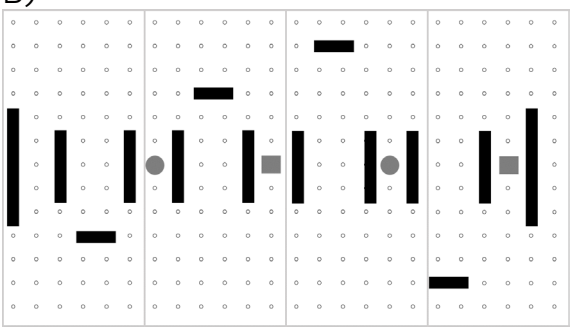
Pilots must walk over the stone route. Along their way they must pick up the cubes and place them on the following black discs. The arrangement of the stones is randomised.

Potential Randomizations:

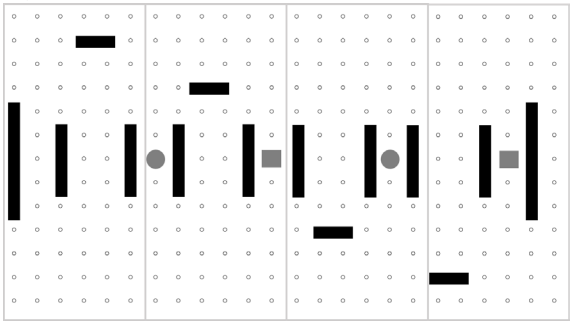
A)



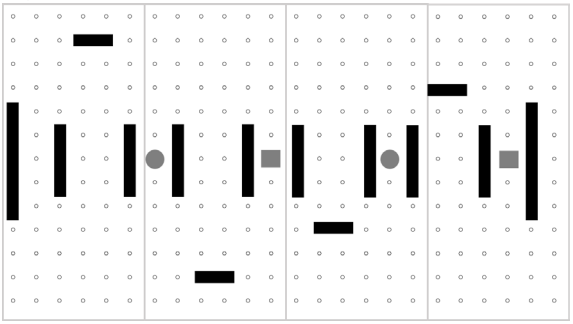
B)



C)



D)



8.4.9.3 Task rules

LEG-CROSS-1	Each stone must be stepped on with only one foot.
LEG-CROSS-2	Pilots must use alternating steps. If any of the stones is omitted the task is failed.
LEG-CROSS-3	The cubes must be picked up, carried, and placed on the next black target area.
LEG-CROSS-4	If the pilot touches the base plates with any body part or the device, the task is failed.
LEG-CROSS-5	If the pilot touches the ground on the left or right side of the base plates, the task is failed.
LEG-CROSS-6	If a stone falls out, the task is failed.

8.4.10 Hurdles

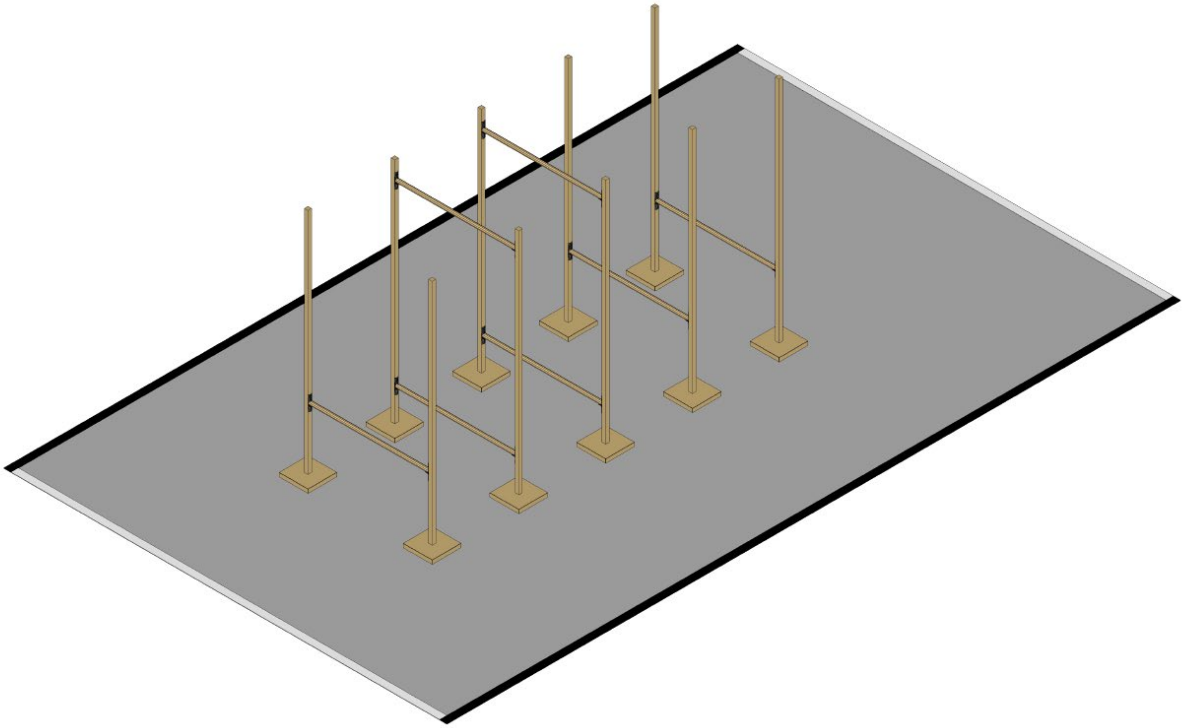
8.4.10.1 Introduction

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 must pass a series of hurdles.

Image source

8.4.10.2 Task set-up & description



Pilots must pass once between each pair of poles without knocking down any of the poles or crossbars. The vertical poles that are connected by at least one crossbar are considered a pair.

8.4.10.3 Task rules

LEG-HURD-1	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	It is not allowed to grasp any crossbar or pole with the hand or steady it with any other part of the body.
LEG-HURD-5	It is not allowed to touch the ground on the left and right side of the hurdles with any part of assistive device or pilot's body. If that part of the ground is touched, the task is failed.

8.5 Competition mode and scoring

Points per task: 10

Time limit: 6 min

9 Exoskeleton Race

EXO pilot solving the Tilted Path task during CYBATHLON 2020 Global Edition.

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-info-pages.com/levels.html).
EXO-PIL-2	Pilots must have sufficient voluntary control and strength of the upper body to control the exoskeleton.
Comment 1 on EXO-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.
Comment 2 on EXO-PIL-2:	Pilots can have a spastic or non-spastic lesion.

9.2.2 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 EXO race:

EXO-TEC-1	Crutches or canes are allowed.
EXO-TEC-2	Load transfer to the ground via wheels, crawlers, or similar 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. Helmet must be compliant to the EN 1078 standard.

EXO-2 If canes, crutches, or any other walking aids are used, they must be carried by the pilot during the entire race. The crutches can be temporarily deposited anywhere on the task space, if they are not used or impede the pilot (e.g., 9.4.1 Train Compartment)

Comment on EXO-2: All rules specifying the use of 'crutches' apply to all kinds of walking aids.

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 defined, the direction of the race is (bottom) left to (top) right in all the following figures.

9.4.1 Train Compartment

9.4.1.1 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.

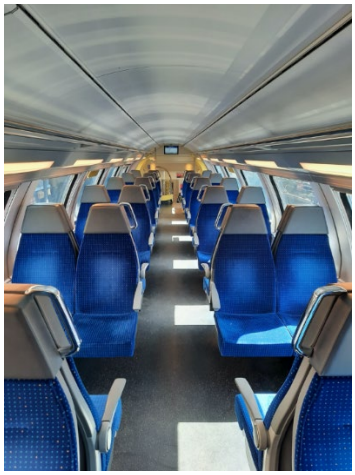
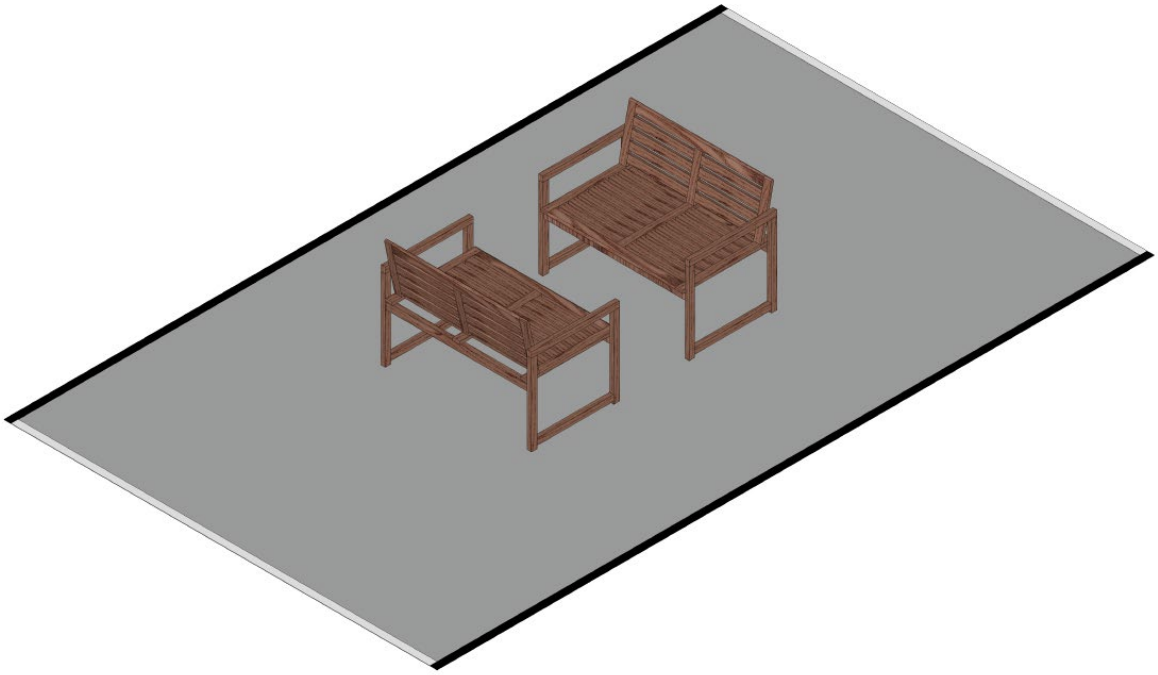


Image source

9.4.1.2 Task set-up & description



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

9.4.1.3 Task rules

EXO-TRAIN-1	The pilot must sit down on and get up from one of the two benches. While sitting, the crutches must be lifted from the ground once and at the same time, if crutches are used.
Comment 1 on EXO-TRAIN-1:	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.
Comment 2 on EXO-TRAIN-1:	The idea of the task is that the pilot is sitting with its full weight on the bench.
Comment 3 on EXO-TRAIN-1:	The referee confirms the sitting (with lifted crutches) with “Okay go”.

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.

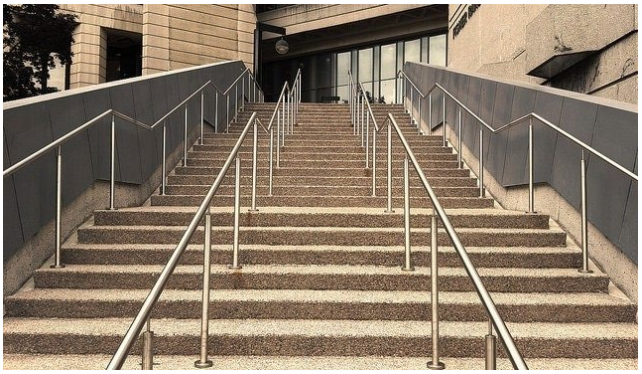
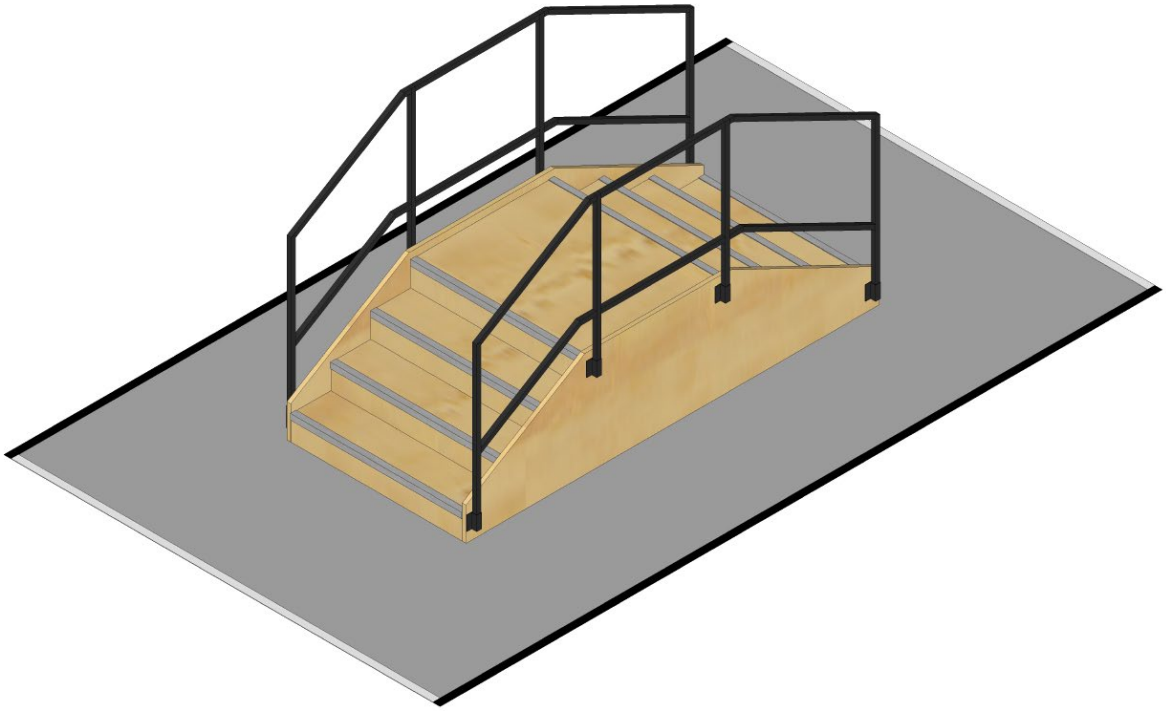


Image source

9.4.2.2 Task set-up & description



Pilots must cross the stairs once in direction of the race. The slope of the stairs differs on the two sides. The ascent is steeper than the descent.

9.4.2.3 Task rules

EXO-STAIR-1 The pilot must cross the stairs once in the direction of the race. If the pilot passes on the right or left side of the obstacles, the task is failed.

EXO-STAIR-2 The pilot is allowed to place two feet on one step at the same time.

EXO-STAIR-3 The pilot is not allowed to omit single steps. Thus, each step must be stepped on with at least one foot.

9.4.3 Moving Parcel

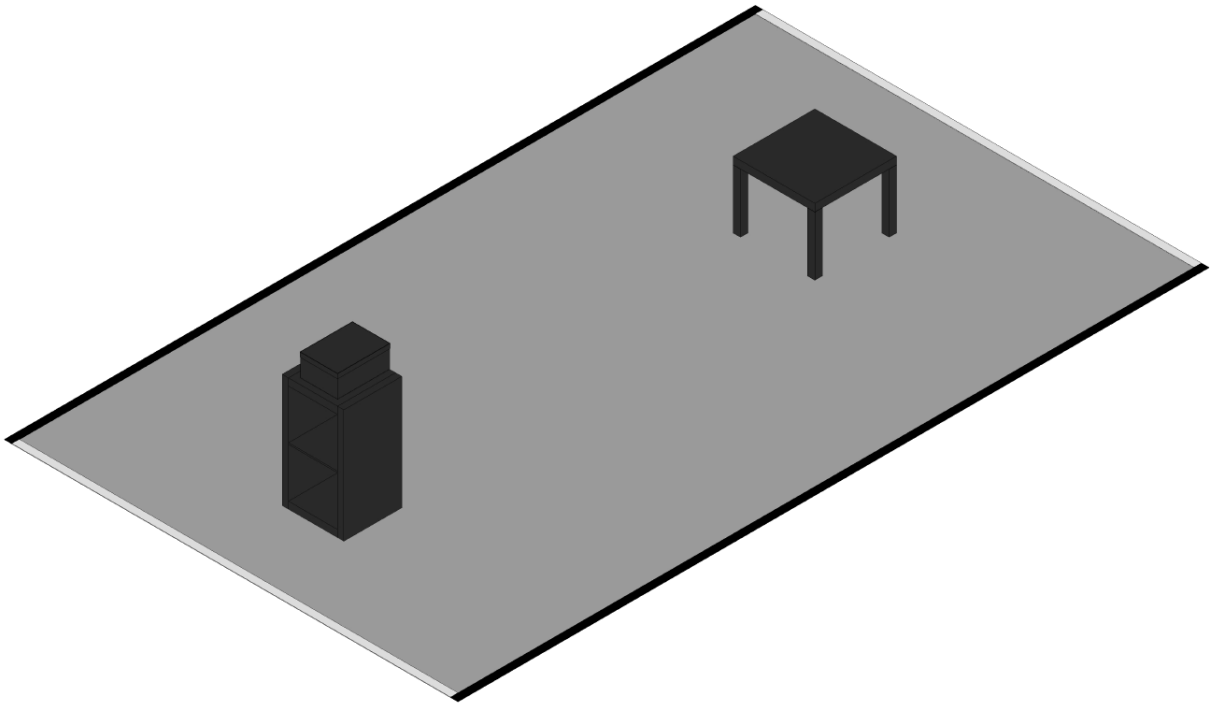
9.4.3.1 Introduction

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 parcel to a target location while walking in their exoskeleton.

Images source

9.4.3.2 Task set-up & description



Pilots must pick up the cardboard box from its initial location on the shelf and place it on the table near the finish line of the task. The box contains two full 0.5 l PET bottles.

9.4.3.3 Task rules

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

Comment on EXO-PARCEL-1: The pilot is allowed to temporarily set the parcel back onto the first shelf to improve the hold on the parcel.

Comment on EXO-PARCEL-1 The parcel may be carried using the hands, body or a tool which the pilot brings along, such as a bag.

EXO-PARCEL-2 The parcel must be intact when the pilot crosses the finish line of the task, see also GR-37. If the parcel has a tear or a puncture, the task is failed.

Comment on EXO-PARCEL-2: Marks or dents on the parcel are accepted.

9.4.4 Tilted Path

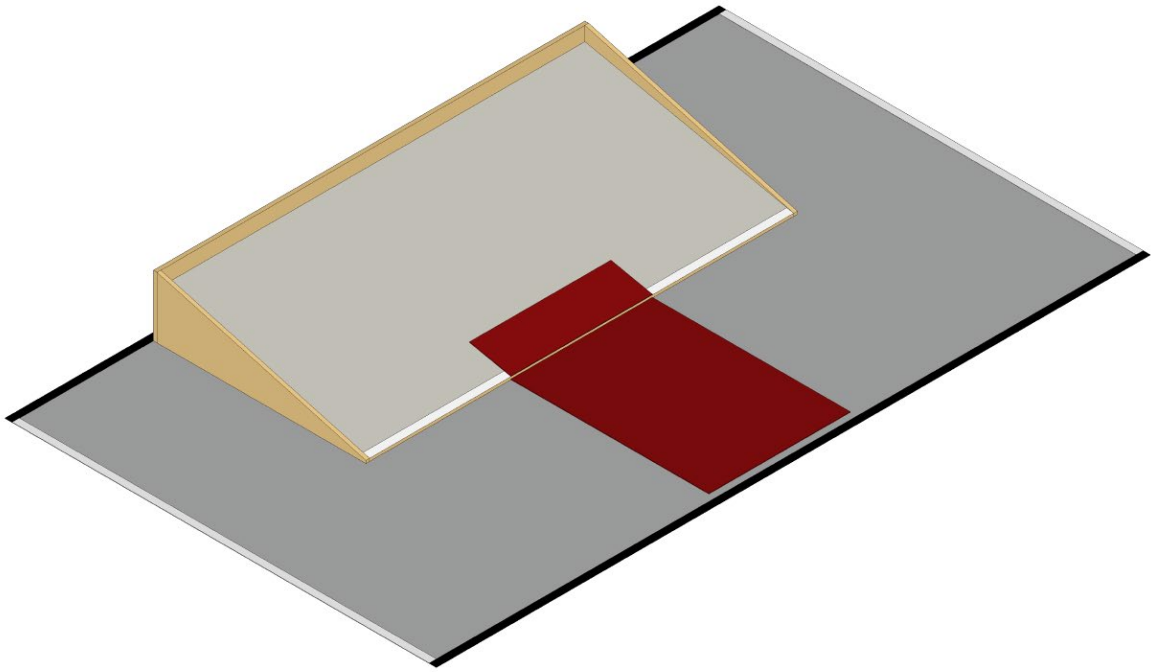
9.4.4.1 Introduction

In daily life, some paths are tilted perpendicular to the direction of travel (e.g., 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.

Image source

9.4.4.2 Task set-up & description



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

9.4.4.3 Task rules

EXO-TILT-1 The pilot must walk across the tilted path once in the direction of the race without touching the red area.

EXO-TILT-2 The pilot must enter the obstacle crossing the white line with both feet and exit the obstacle by the white line with both feet. If the pilot steps over the wooden sideboard, the task is failed.

9.4.5 Free Walking

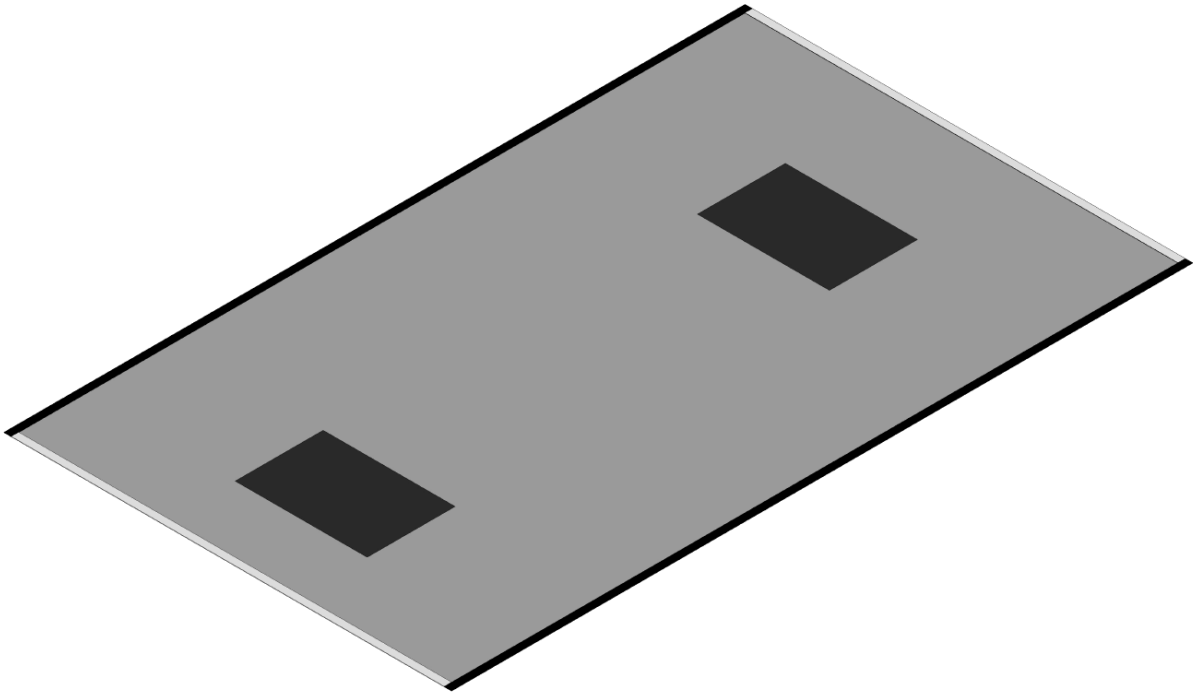
9.4.5.1 Introduction

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.

Image source

9.4.5.2 Task set-up & description



Pilots must walk from the first mat (the one closer to the start line of the task) to the second mat (the one closer to the finish line of the task) without using their crutches to maintain balance.

9.4.5.3 Task rules

EXO-FREE-1 If the crutches touch the ground between the first and second mat, the task is failed.

EXO-FREE-2 Both feet must be placed in their entirety on the first mat. As soon as the first foot leaves the mat (beyond the mat in the direction of the race) the crutches must not be used, i.e., be elevated from the ground.

EXO-FREE-3 Both feet must be placed in their entirety on the second mat. As soon as both feet are in their entirety on the mat, the crutches are allowed to be used again (e.g., touching the ground).

Comment on EXO-FREE-3: The crutches are allowed to be placed on the mat or on the ground behind, aside or in front of the second mat as soon as both feet are placed in their entirety on the second mat.

EXO-FREE-4 The crutches are allowed to be handed over to a spotter on the first mat while the pilot's feet are in their entirety on the first mat and returned by the spotter to the pilot on the second mat while the pilot's feet are in their entirety on the second mat. The spotter can further hand the crutches over to the team official in case carrying the crutches hinders the spotter from ensuring safety of the pilot.

Comment on EXO-FREE-4: The pilots can also keep the crutches.

9.4.6 Crowd

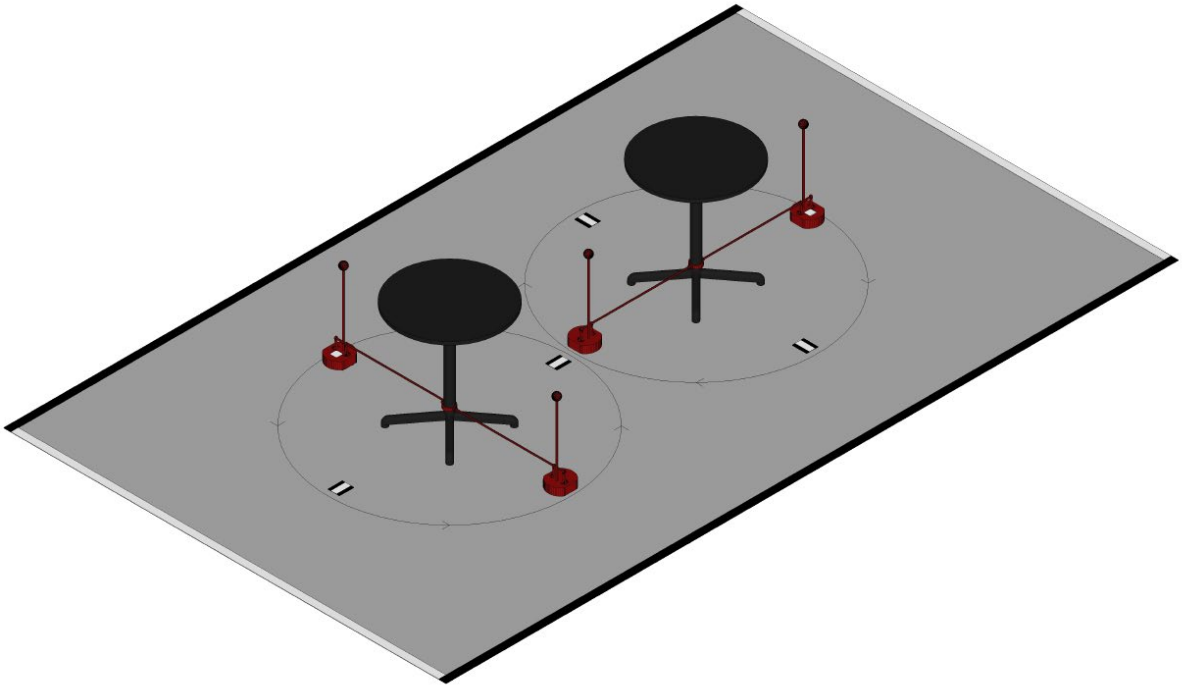
9.4.6.1 Introduction

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.

Images source

9.4.6.2 Task set-up & description



Pilots must pass between the tables without touching the orbiting robots and their attachments.

Information about the robots:

- The starting position of the robots is as indicated in the picture.
- The first two orbits for one robot take appr. 36 s. Thereafter, the orbit duration increases 0.12 s per s whereas an update of the speed only occurs whenever the robot passes one of the eight marks. When the orbit duration has reached 72 s, the orbit duration will be kept constant.
- 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 robots are set in motion the moment the pilot crosses the start line of the task.
- A fixation system attached to the table guides the robots rigidly around the table.

9.4.6.3 Task rules

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

Comment on EXO-CROWD-1: The first piece of furniture can be passed on the left- or on the right-hand side.

9.4.6.4 Comments

- If the orbiting robots stops, the responsible CYBATHLON official will remove the robot including the attachment to the table. The pilot can continue the task with less orbiting robots. The responsible CYBATHLON official is a pre-defined role.

9.4.7 High Step

9.4.7.1 Introduction

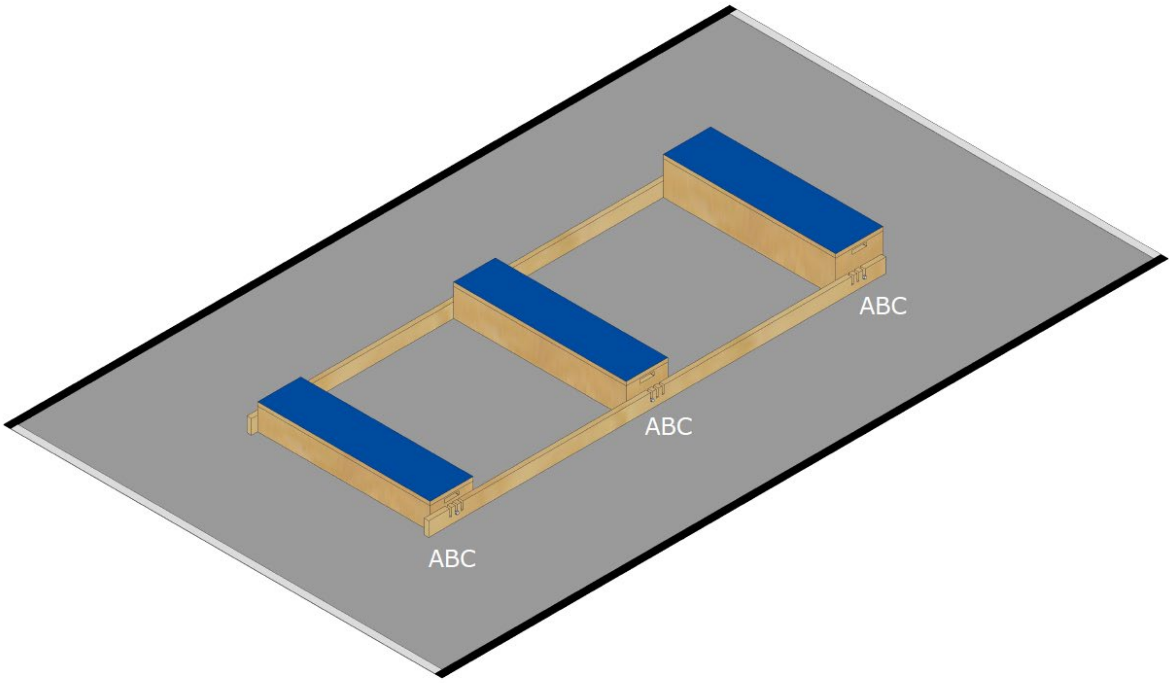
Crossing large steps or gaps is challenging since it requires adaptable step length and balance, especially after large steps.

Walking on surfaces that dictate irregular steps can be required when walking in the nature or in cities. For example, stepping into public transport requires various step height and length, depending on the vehicle and platform.

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

Image source

9.4.7.2 Task set-up & description



Pilots must step on a sequence of three boxes. Pilots must step on each box with at least one foot.

The placement of the boxes is according to the following set of rules:

- Three boxes with different heights are used.
- At each position there are three slots, which define the exact location of the boxes: A, B, and C.
- The order of the boxes and the used slots are randomized.

9.4.7.3 Task rules

EXO-STEP-1 The pilot must cross the sequence of boxes once in the direction of the race.

EXO-STEP-2 The pilot must step on each box with at least one foot.

Comment on EXO-STEP-2: The foot does not need to be put in its entirety on the box but may partly be in the air.

EXO-STEP-3 The pilot is not allowed to place one foot on one side of the box while having the other foot on the other side of the box at the same time.

Comment on EXO-STEP-3: The idea is to hinder pilots to just tip the surface of the box with their foot and then step over the box.

EXO-STEP-4 It is not allowed to touch the ground on the left and right side of the obstacle with any part of the pilot's body or the crutches. If that part of the ground is touched, the task is failed.

Comment on EXO-STEP-4: The pilot must enter the obstacle on the side facing the start line of the task and exit over the side facing the finish line of the task.

9.4.8 Door

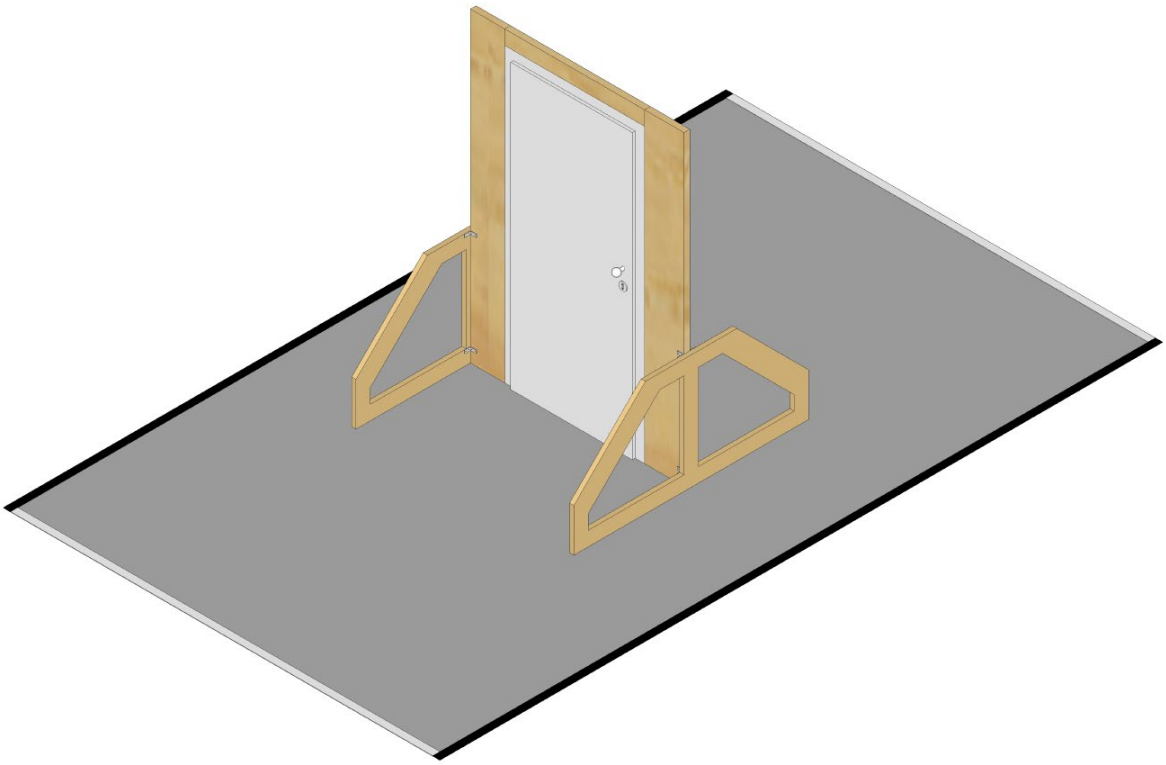
9.4.8.1 Introduction

Opening and closing doors is challenging as an exoskeleton user since the crutches must be carried and precise foot placement in changing directions (i.e., step backwards and sidewards) is required. There are different mechanisms technologies to open the door (e.g., doorhandle or doorknob) and not all doors require the same amount of force to push or pull them open.

Images source

In this task, pilots must open, pass through, and close a door.

9.4.8.2 Task set-up & description



Pilots must open, pass through, and close the door (initially closed). The door is equipped with a doorknob (frontside) and doorhandle (backside).

9.4.8.3 Task rules

EXO-DOOR-1 The door must be opened (by pulling), passed through, and closed (i.e., clicked shut) once in the direction of the race. If the door is not clicked shut when the pilot crosses the finish line of the task, the task is failed.

EXO-DOOR-2 The door must be opened by using the doorknob.

Comment on EXO-DOOR-2: It is not allowed to open the door by the doorhandle (e.g., by reaching around the doorframe).

EXO-DOOR-3 If the pilot passes by the left or right of the doorframe, the task is failed.

9.4.9 Stony Path

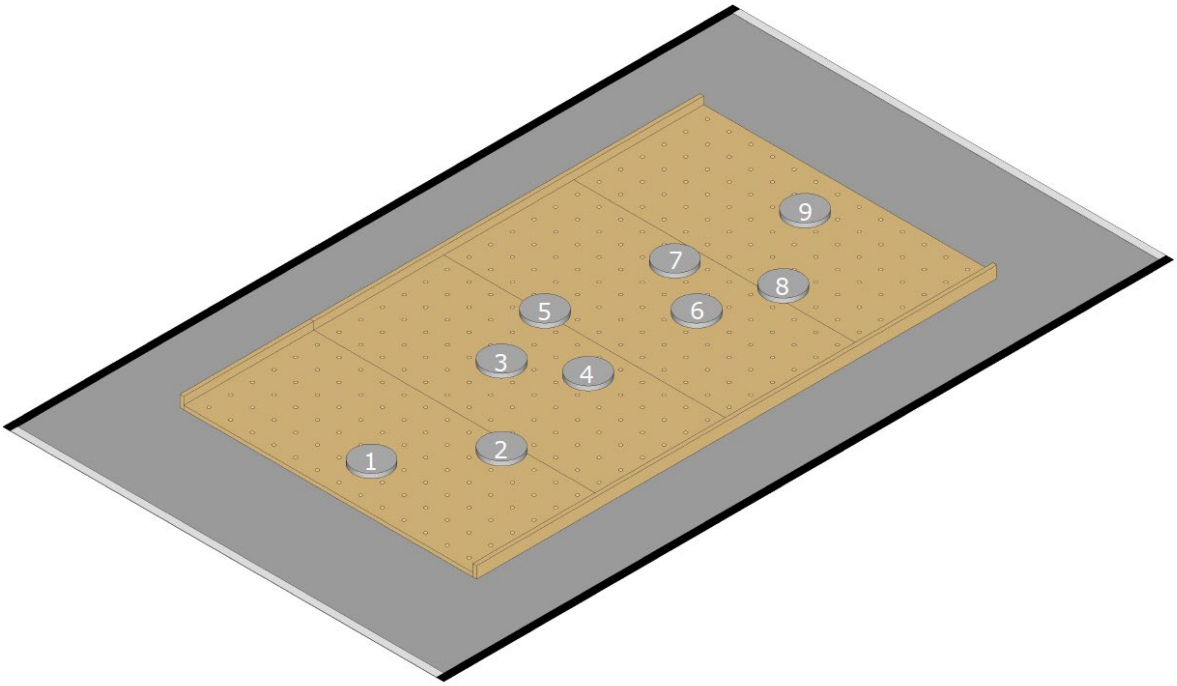
9.4.9.1 Introduction

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.

Image source

9.4.9.2 Task set-up & description



Pilots must walk across a series of stones.

The route of stones is randomised between races according to the following rules:

- There are nine stones (1-9) in total.
- The stones 1 and 9 are always placed at the locations as illustrated above.
- The location of the stones 2 to 8 is random considering the following conditions:
    - The step from one stone to the next is always in direction of the race.
    - The distance between the stones can be short (in the example above from 3 to 4) or long (in the example above from 5 to 6).
    - The step from one stone to the next is alternating from the left to the right (or vice versa).
    - The deviations to the left and to the right can be either small (in the example above 3 to 4) or large (in the example above 7 to 8).

9.4.9.3 Task rules

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

Comment on EXO-STONES-1: It is allowed to step on one stone with both feet.

EXO-STONES-2 If the pilot touches the baseplates with any body part or the part of the device, the task is failed.

EXO-STONES-3 It is allowed to place the crutches on the baseplates and the stones.

EXO-STONES-4 It is not allowed to touch the ground on the left and right side of the baseplates with any part of the pilot's body or the crutches. If that part of the ground is touched, the task is failed.

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.

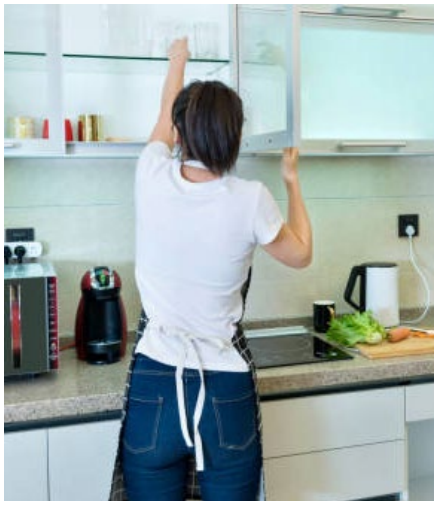
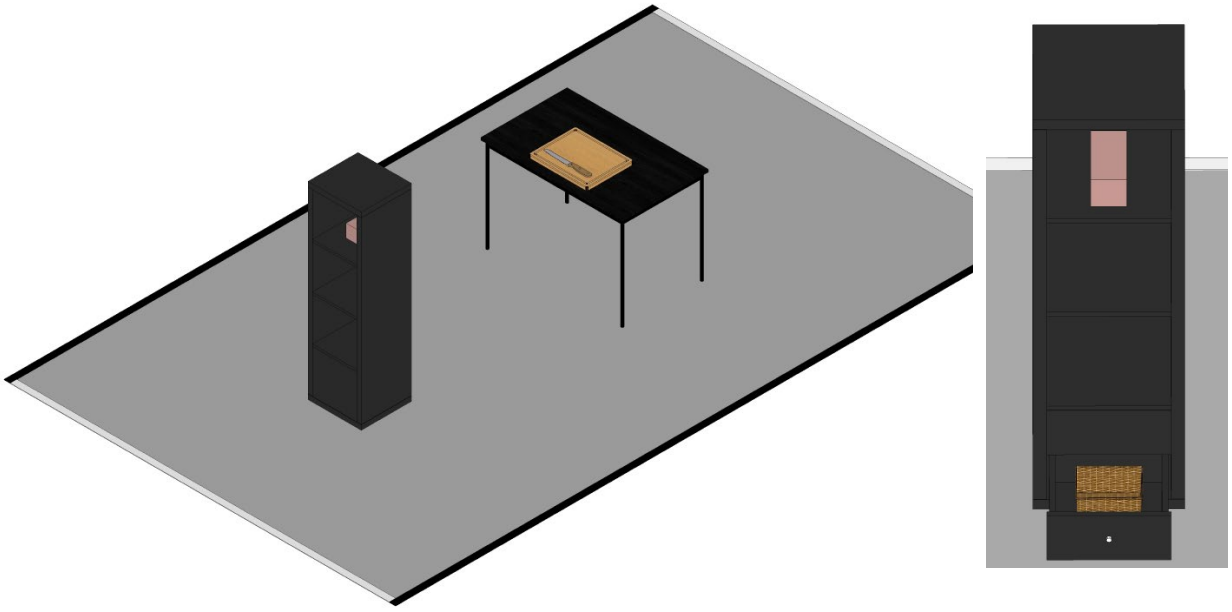


Image source

9.4.10.2 Task set-up & description



Pilots must carry the 'bread' (represented by a piece of foam) and the basket from the cupboard to the table, cut a slice of 'bread' and place it in the basket.
Insert: The shelf shown with an open drawer for illustration purpose only. Since the basket is not fixed in the drawer, it can potentially move in the drawer when it is opened.

9.4.10.3 Task rules

EXO-KITCHEN-1 The 'bread' and the basket must be taken from the cupboard and carried with the hands from the cupboard to the table. If the 'bread' and the basket are carried by the crutches, the task is failed.

Comment on EXO-KITCHEN-1: The 'bread' and the basket are allowed to touch parts of the crutches, but not used to get the items out of the shelf or principally carried by the crutches (e.g., the tips of the crutches).

EXO-KITCHEN-2 A cuboid slice must be cut off the foam on the breadboard, using the breadknife. The slice must be placed in the bread-basket.

Comment on EXO-KITCHEN-2: We recommend cutting off a slice with sufficient thickness to assure a cuboid slice which is clearly separated from the rest of the foam.

EXO-KITCHEN-3 The basket (containing the cut slice of foam), the knife, the remaining foam, and the breadboard must be located on the table (no specific target location) when the pilot crosses the finish line of the task.

9.5 Competition mode and scoring

Points per task: 10

Time limit: 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.

Comment on WHL-TEC-1: Concepts like e-motion wheelchairs are not allowed since it is not possible to distinguish if the energy comes from the user or the device.

WHL-TEC-2 The energy required for actuating the robotic manipulator (e.g., positioning, actuate door handle, open/close door in the Door task) must not be provided by the pilot.

WHL-TEC-3 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-4 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 is allowed.
- It is recommended that the width of the wheelchair does not exceed 860 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. Helmet must be compliant to the EN 1078 standard.

WHL-2 Any object that must be manipulated in the task, must only be touched and manipulated using the robotic manipulator.

Comment 1 on WHL-2: In case the robotic manipulator is not a robotic arm mounted to the wheelchair in the Wheelchair Race, the eligibility of the manipulator is evaluated in the TecCheck.

Comment 2 on WHL-2: Pilot and the manipulator must be located in the same task space at a given time. For example, the pilot, located on task 1, cannot send the manipulator ahead to start completing task 2.

WHL-3 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 on WHL-3: The safe state for a given robotic manipulator is subject to agreement between the head of discipline and the team during the TecCheck procedure.

WHL-4 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 on WHL-4: 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.

10.4 Task definitions

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

10.4.1 Restaurant

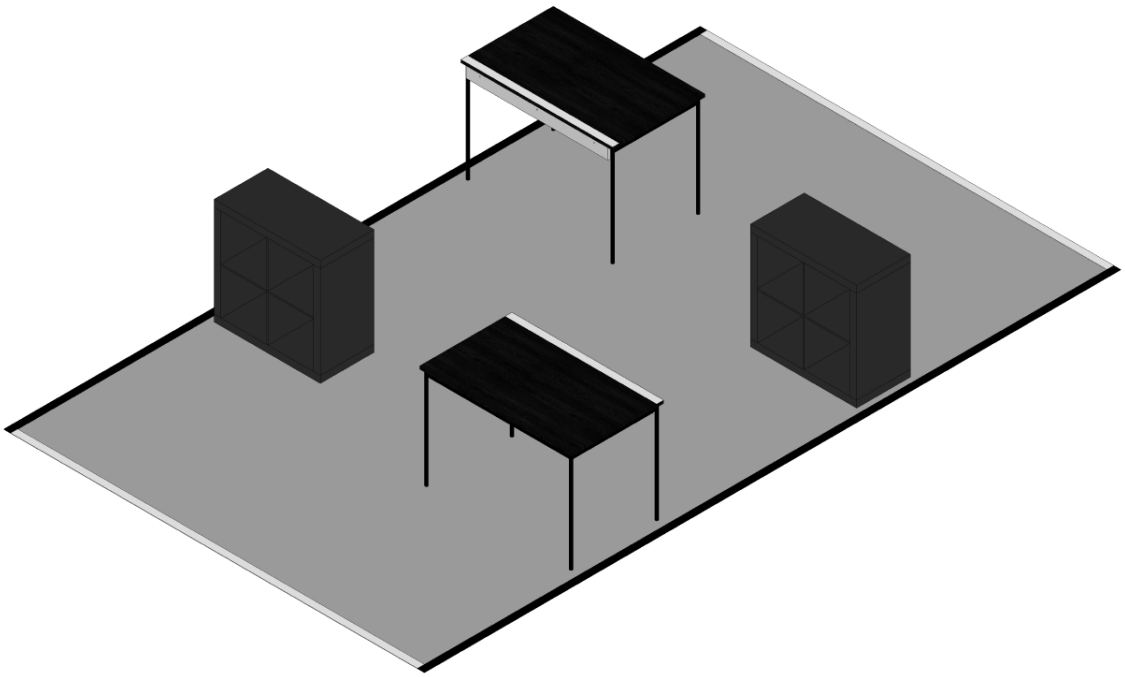
10.4.1.1 Introduction

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).

In this task pilots must drive close to a table in such a way that the thighs of the pilot fit below the tabletop, without moving any furniture.

Image source

10.4.1.2 Task set-up & description



Pilots must approach the two tables on the long sides that are marked with a white line. At both tables half of the pilot's thigh must be covered by the tabletop.

10.4.1.3 Task rules

WHL-REST-1 The pilot must approach the two tables at the side marked with a white line until both knees and half of the thighs are covered by the long side of the table.

Comment on WHL-REST-1: The referee confirms the correct position at the tables (both knees and half of the thighs are covered by the table) with “Okay go”.

WHL-REST-2 The pilot must first approach the table closer to the start line and second the table closer to the finish line of the task.

WHL-REST-3 It is not allowed to remove their feet from the footrest as they approach the target 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 must ascend and descend a straight staircase. Pilots must bring their wheelchair to a standstill while on the ascent and descent from the stairs to show that they are able to stop at any time.

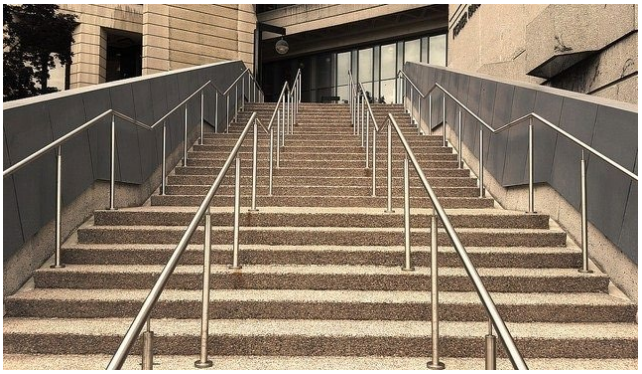
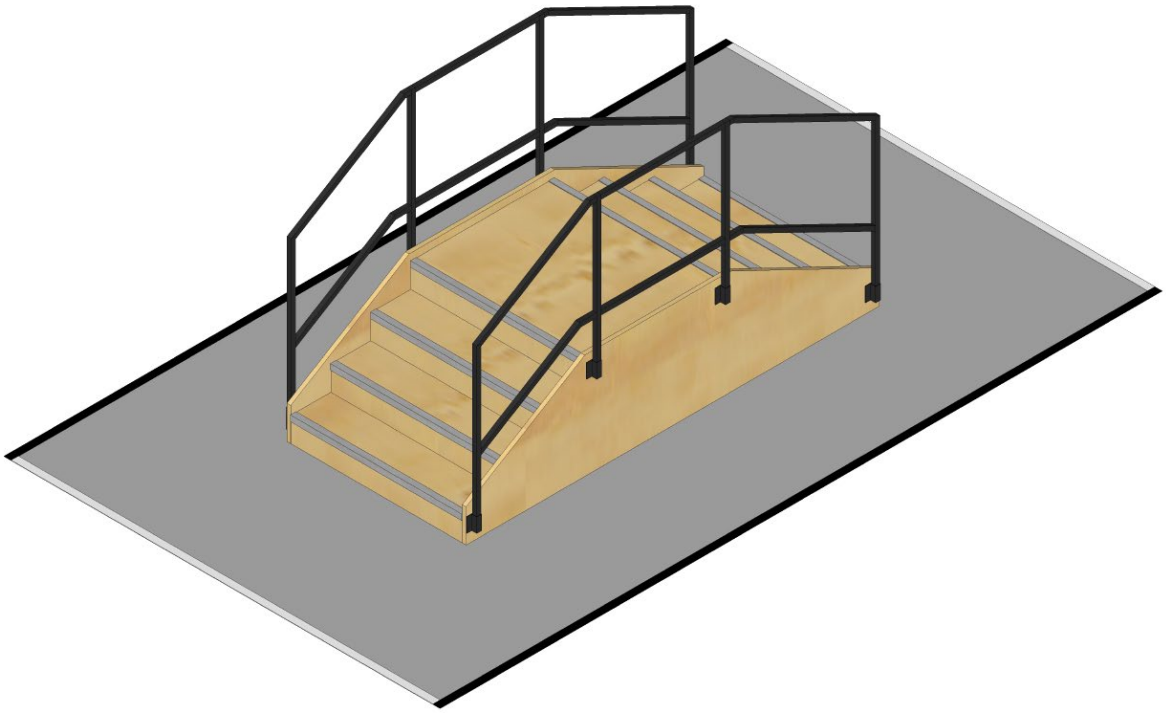


Image source

10.4.2.2 Task set-up & description



Pilots must cross the stair once in the direction of the race. The slope of the stairs differs on the two sides. The ascent is steeper than the descent.

10.4.2.3 Task rules

WHL-STAIR-1 The pilot must cross the stairs once in the direction of the race. If the pilot passes on the right or left side of the obstacles, the task is failed.

WHL-STAIR-2 When ascending the stairs, the pilot must bring the wheelchair to a full standstill while the foremost part of the wheelchair is in contact with the top of the third step (the last step before the top platform).

Comment on WHL-STAIR-2: The referee confirms the standstill with “Okay go”.

WHL-STAIR-3 When descending the stairs, the pilot must bring the 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.

Comment on WHL-STAIR-3: The referee confirms the standstill with “Okay go”.

10.4.3 Pick-up

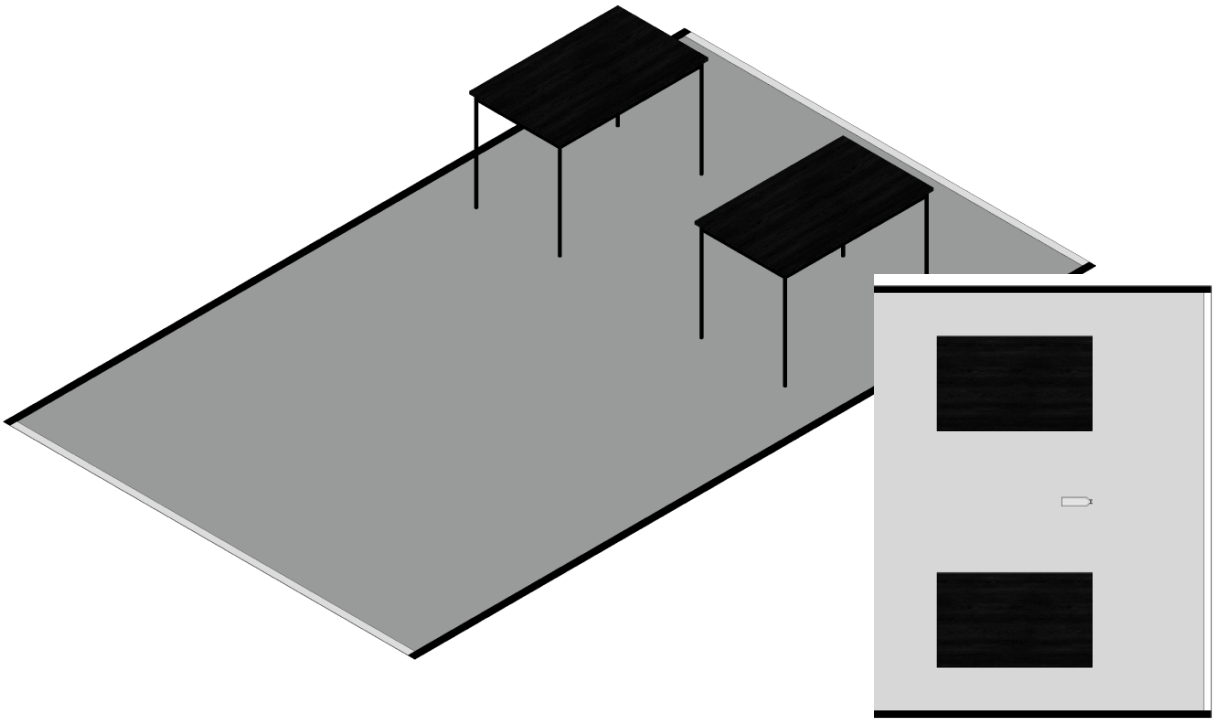
10.4.3.1 Introduction

Small items that are randomly lying around or fell on the floor (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.

Image source

10.4.3.2 Task set-up & description



The filled 1.5 l PET bottle that blocks the pilot's way must be picked up and placed on one of the tables.
Insert: Top view of the task space; the bottle will initially be placed in the direction of the race, with the tap towards the finish line.

10.4.3.3 Task rules

WHL-PICK-1 The bottle must be located on one of the tables when the pilot crosses the finish line of the task.

Comment on WHL-PICK-1: The bottle can be placed on the table upright or lying.

WHL-PICK-2 If the bottle touches the ground again after it has been completely lifted off the ground, the task is failed.

10.4.4 Tilted Path

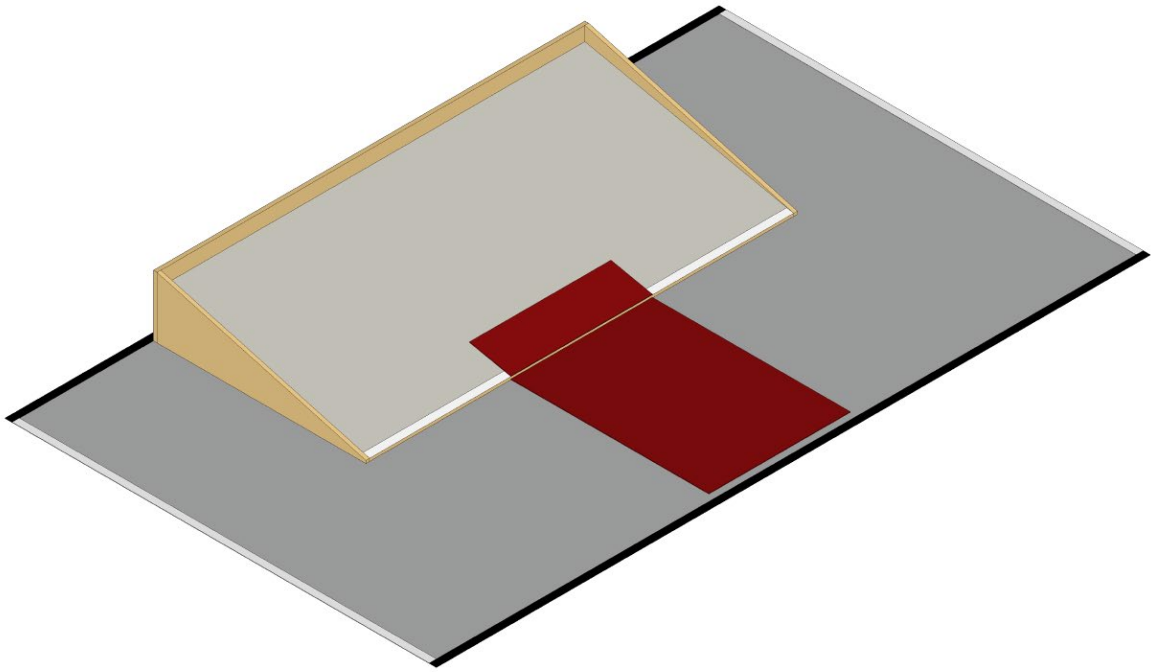
10.4.4.1 Introduction

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, pilot 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.

10.4.4.3 Task rules

WHL-TILT-1 The pilot must navigate the wheelchair across the tilted path once in direction of the race without touching the red area with any part of the wheelchair or the pilot's body.

WHL-TILT-2 The pilot must enter the obstacle crossing the white line on the obstacle and exit the obstacle crossing the white line on the obstacle. All parts of the wheelchair touching the ground (wheels, tracks or other means) must cross the white line.

10.4.5 Uplift

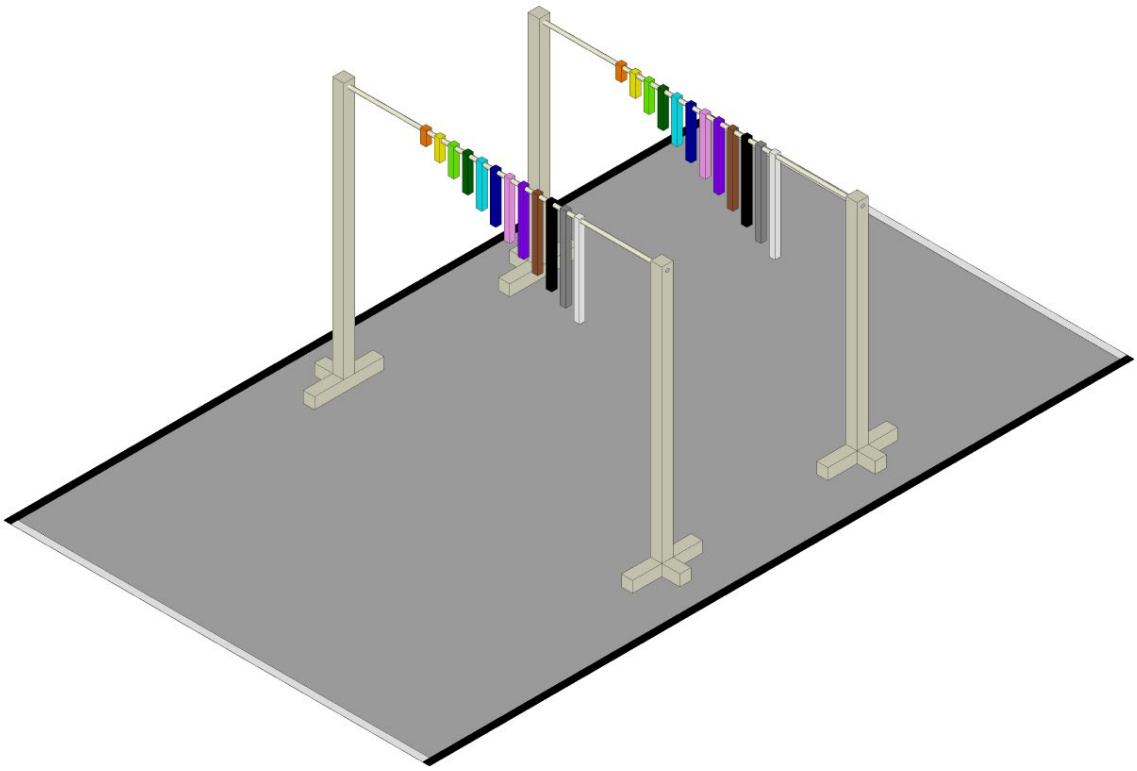
10.4.5.1 Introduction

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 shelf 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 the two gates once in the direction of the race. The rods on the first gate are mounted 30cm higher than the rods of the second gate.

10.4.5.3 Task rules

WHL-LIFT-1 The pilot must pass between the two gates once in the direction of the race.

WHL-LIFT-2 The pilot defines the individual target rod (colour) by passing through the first gate. The shortest rod (highest) that is touched by the pilot's head (or headrest) defines the target rod.

Comment on WHL-LIFT-2: If a pilot's headrest extends above the head, the highest part of the headrest may be used as a reference for touching the rods. In this case, the headrest is the reference for all the rules.

WHL-LIFT-3 The headrest must not move relative to the head during the entire task.

WHL-LIFT-4 At the second gate, the pilot must pass below the target rod. If the target rod is touched with the head (or headrest) the task is failed.

WHL-LIFT-5 The pilot is not allowed to actively move the body towards or away from the rods to contribute to task solving. The pilot's posture must be the same throughout the task.

10.4.6 Crowd

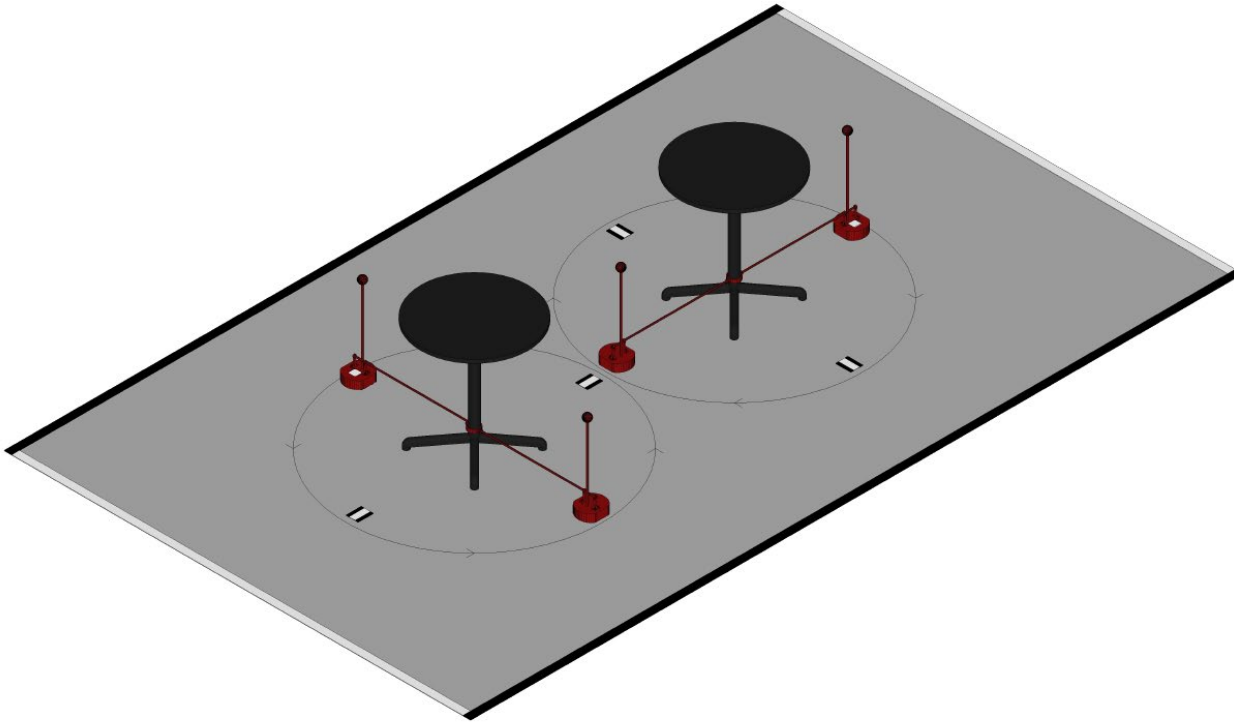
10.4.6.1 Introduction

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.

Images source

10.4.6.2 Task set-up & description



The pilot must pass between the tables without touching the orbiting robots and their attachments

Information about the robots:

- The starting position of the robots is as indicated in the picture.
- The first two orbits for one robot take appr. 36 s. Thereafter, the orbit duration increases 0.12 s per s whereas an update of the speed only occurs whenever the robot passes one of the eight marks. When the orbit duration has reached 72 s, the orbit duration will be kept constant.
- 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 robots are set in motion the moment the pilot crosses the start line of the task.
- A fixation system attached to the table guides the robots rigidly around the table.

10.4.6.3 Task rules

WHL-CROWD-1 The pilot must pass once between the two tables.

Comment on WHL-CROWD-1: The first piece of furniture can be passed on the left- or on the right-hand side.

10.4.6.4 Comments

- If the orbiting robots stops, the responsible CYBATHLON official will remove the robot including the attachment to the table. The pilot can continue the task with less orbiting robots. The responsible CYBATHLON official is a pre-defined role.

10.4.7 Winding Stairs

10.4.7.1 Introduction

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

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

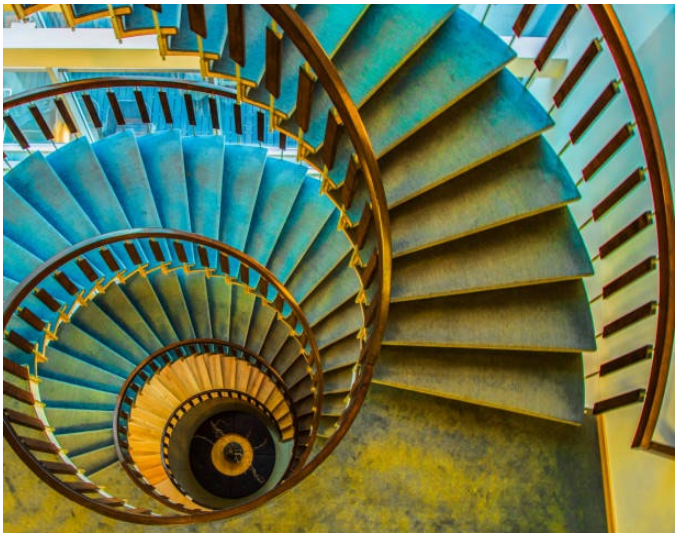
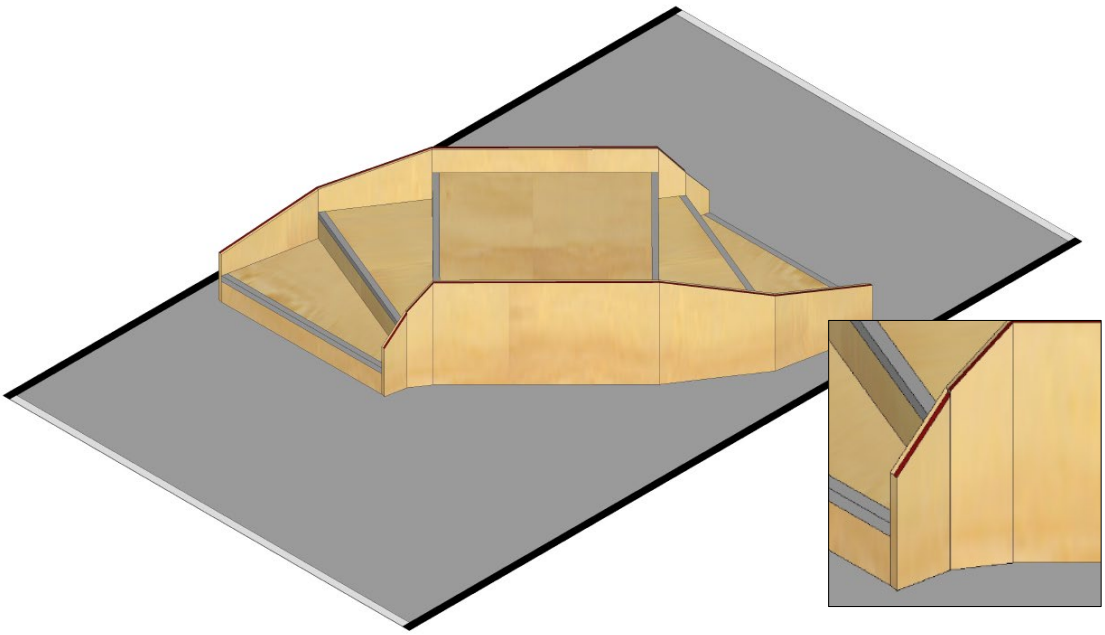


Image source

10.4.7.2 Task set-up & description



The flight of winding stairs must be climbed and descended once in the direction of the race. Insert: close up of the red colouring on the outer half of the roll over protection.

10.4.7.3 Task rules

WHL-WIND-1	The pilot must cross the obstacle once in the direction of the race.
WHL-WIND-2	It is not allowed to touch the ground to the left or right side of the obstacle. If that part of the ground is touched, the task is failed.
WHL-WIND-3	The pilot must enter the obstacle on the side facing the start line of the task and exit over the side facing the finish line of the task.

10.4.8 Door

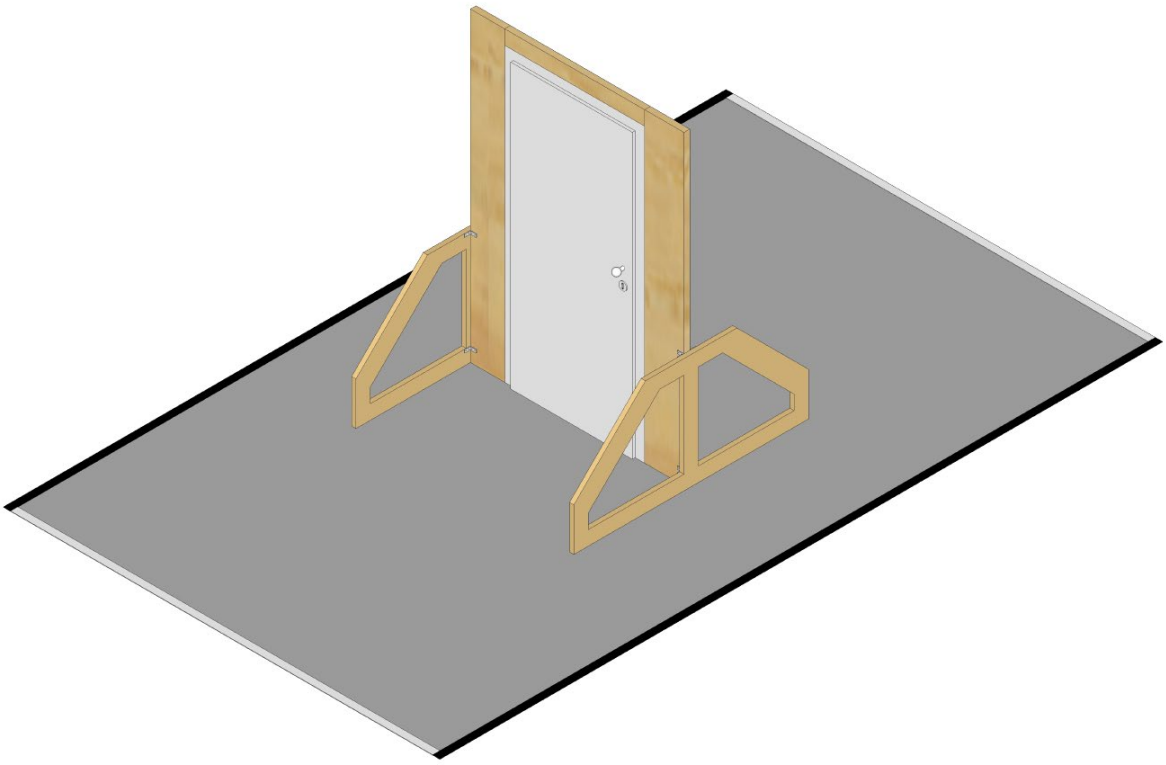
10.4.8.1 Introduction

Opening and closing doors is challenging as a wheelchair user. There are different mechanisms to open the door (e.g., doorhandle or doorknob) and not all doors require the same amount of force to push or pull them open.

In this task, pilots must open, passthrough and close a door using an external robotic manipulator.

Images source

10.4.8.2 Task set-up & description



Pilots must open, pass through, and close the door (initially closed). The door is equipped with a doorknob (frontside) and a doorhandle (outside).

10.4.8.3 Task rules

WHL-DOOR-1 The door must be opened (by pulling), passed through, and closed once in the direction of the race (i.e., clicked shut). If the door is not clicked shut when the pilot crosses the finish line of the task, the task is failed.

WHL-DOOR-2 If the pilot passes by the left or right of the doorframe, the task is failed.

WHL-DOOR-3 The door must be opened by the doorknob.

Comment on WHL-DOOR-3: It is not allowed to open the door by the doorhandle (e.g., by reaching around the doorframe).

10.4.9 Rocky Terrain

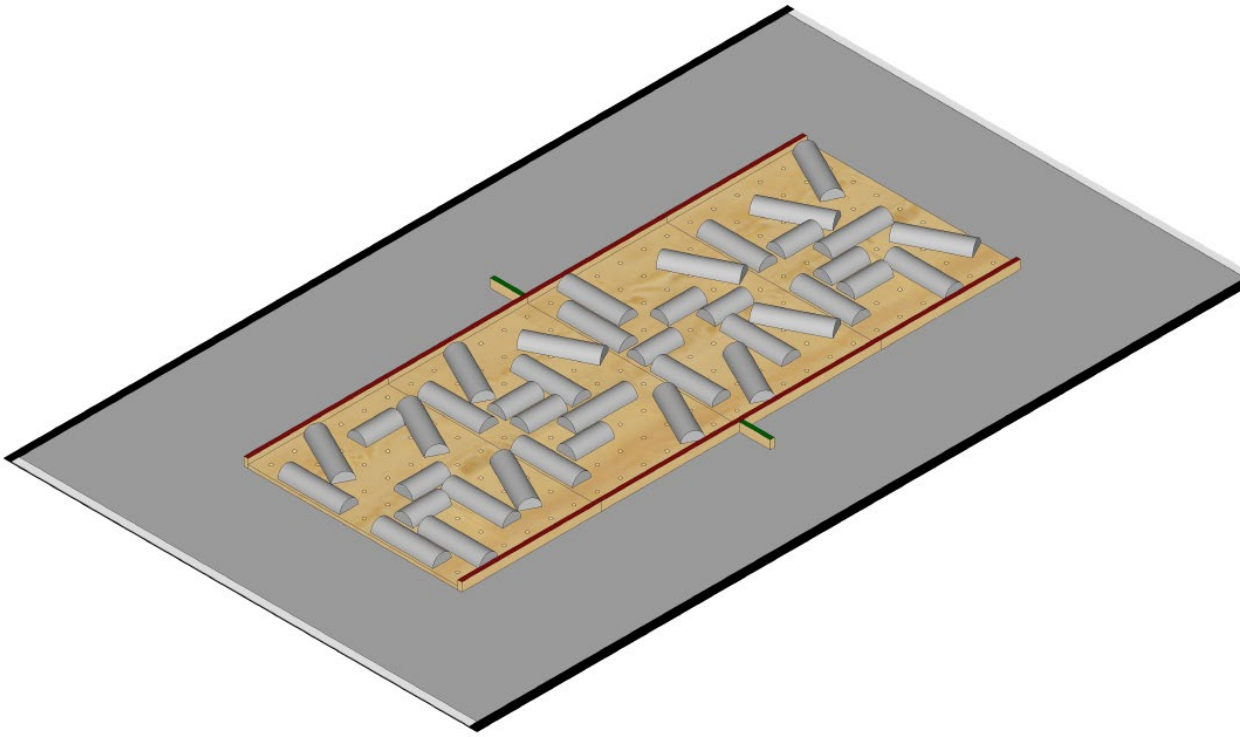
10.4.9.1 Introduction

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.

Image source

10.4.9.2 Task set-up & description



Pilots must cross the stony path once in direction of the race and bring the wheelchair to a full standstill in the second half of the obstacle.

The obstacle consists of four base plates:

- On each of the baseplates the 'rocks' are set up in a different layout.
- The order of the baseplates will be randomised.

10.4.9.3 Task rules

WHL-ROCKY-1 The pilot must cross the obstacle once in direction of the race.

WHL-ROCKY-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 plates 1 or 2 during standstill, the task is not fulfilled. If the wheelchair touches the ground after the stony path before it has reached standstill, the task is failed.

Comment on WHL-ROCKY-2: The referee confirms the standstill with "Okay go".

WHL-ROCKY-3 If the pilot touches the ground on the left or right side of the baseplates with any part of the device or pilot's, the task is failed.

Comment on WHL-ROCKY-3: The pilot must enter the obstacle on the side facing the start line of the task and exit over the side facing the finish line of the task.

10.4.10 Doorstep

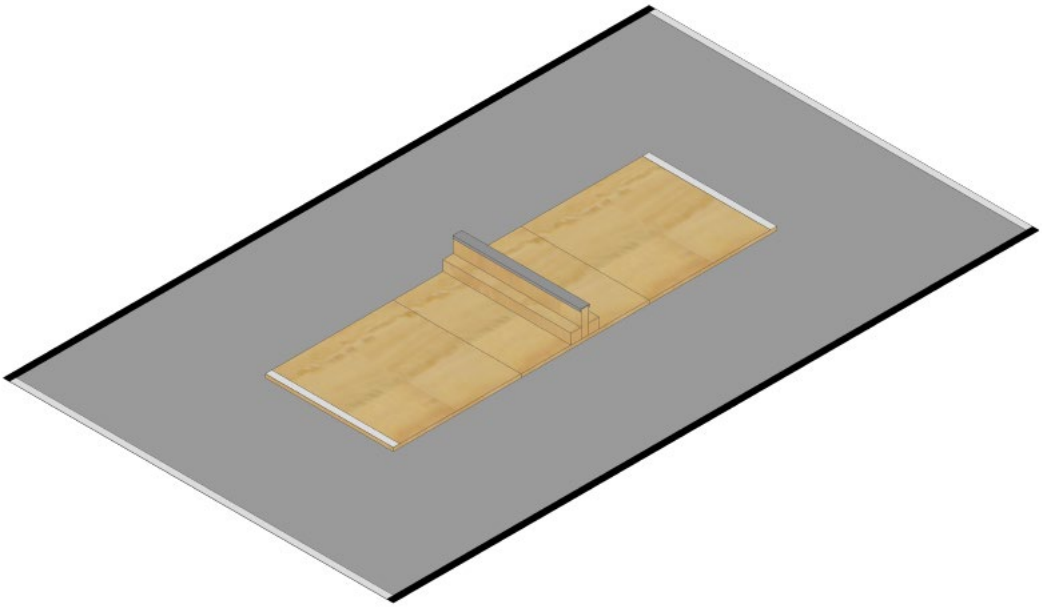
10.4.10.1 Introduction

Crossing the doorstep is often the first step when entering a building or room. They come in many different sizes (main door, terrace, boat door, etc.), 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 a doorstep.

Image source

10.4.10.2 Task set-up



Pilots must cross the obstacle once in the direction of the race.

10.4.10.3 Task rules

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

WHL-STEP-2 It is not allowed to touch the ground on the left and right side of the obstacle with any part of the wheelchair or pilot's body. If that part of the ground is touched, the task is failed.

WHL-STEP-3 The pilot must enter the obstacle on the side facing the start line of the task crossing the white line on the obstacles and exit over the side facing the finish line of the task, crossing the white line on the obstacles. All parts of the wheelchair touching the ground (wheels, tracks or other means) must cross the white line.

10.5Competition mode and scoring

Points per task: 10

Time limit: 8 min

11 Assistance Robot Race

A personal assistance robot passes an apple to wheelchair user at the CYBATHLON Challenges 2023.

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 fulfil 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.

ROB-PIL-2 Pilots must have sufficient ability to control their wheelchair and the robot at any time. Thus, the pilots must have sufficient voluntary control of head, shoulder, hand, finger, tongue and/or voice to operate an input device (exception for the emergency stop, see also comment on GR-85).

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 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.

Examplary 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.

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 131).

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

General comments:

- ISO 13482:2014 provides a helpful guideline to design the personal assistance robot. Compliance with ISO 13482:2014 (or similar regulations applied in the country of development) is recommended for prototypes.
- 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 one or multiple mobile platforms 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 energy required to manipulate the task objects must come entirely from the robot and not from the pilot.

Comment on ROB-1: The operation of the robot by the pilot is excluded from this rule.

ROB-2 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-3 Any object that must be manipulated in the task, must only be manipulated using the robotic manipulator.

ROB-4 It is 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-4: 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.

In case a pilot uses one or more auxiliary mobile platforms as the assistive device, the following additional rules apply:

ROB-5 One referee observes the pilot (pilot-referee), and one referee observes each assistance robot (robot-referee).

ROB-6 Task completion is based on the location of the pilot and assistance robot(s). A task is considered completed when the task is solved, and all entities (pilot and assistance robot(s)) crossed the finish line. Once the pilot or an assistance robot have crossed the finish line of the task, neither of them is allowed to go back.

Comment on ROB-6: In case of task fail, the time of the next task starts, when the last entity crosses the start line of the next task.

ROB-7 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 an assistance robot ahead to start completing task 3.

Comment on ROB-7 : In case an assistance robot goes ahead and causes task fail, the responsible robot-referee will mark the task fail, e.g., with a pylon or similar, at the sidelines (the details of this system will be introduced at a later).

11.4 Task definitions

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

11.4.1 Mailbox

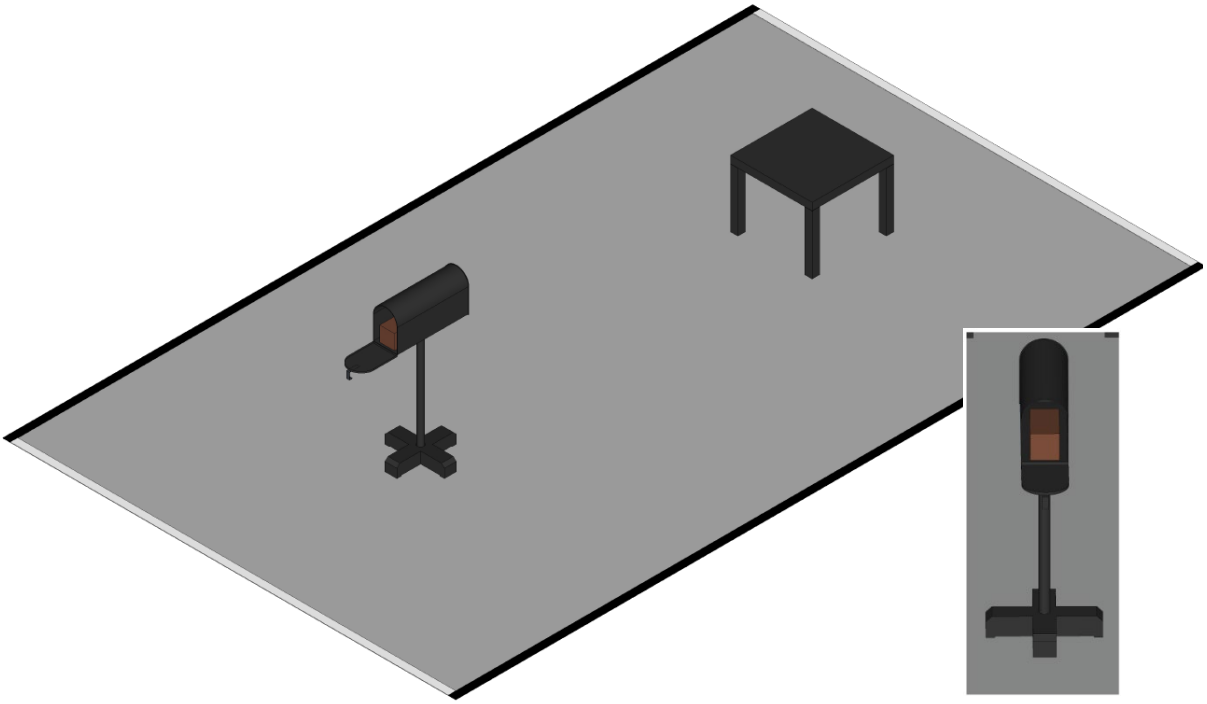
11.4.1.1 Introduction

Grasping objects from within confined space can be of particular challenge to robotic grippers. Such tasks are further exacerbated if the object offers little to no opportunity to be gripped (e.g., the lack of a handles).

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

Image source

11.4.1.2 Task set-up & description



The parcel must be removed from the mailbox and placed on the table.

11.4.1.3 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 parcel must be intact when the pilot crosses the finish line of the task, see also GR-37. If the parcel has a tear or a puncture, the task is failed.

Comment on ROB-MAIL-2: Marks or dents from the gripper on the parcel are allowed.

11.4.2 Toothbrush

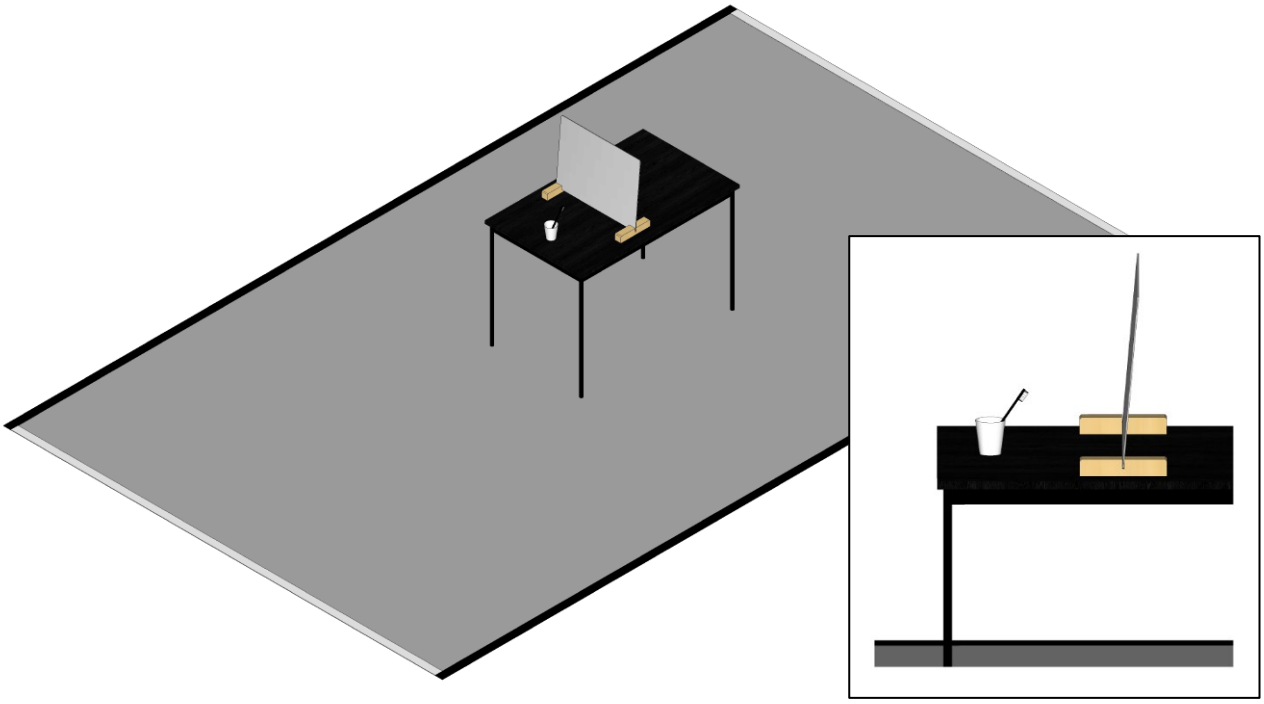
11.4.2.1 Introduction

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 due to the required interaction between the device and the pilot, during which safety must be guaranteed at any time.

In this task, pilots must use a toothbrush.

Image source

11.4.2.2 Task set-up & description



Pilots must 'brush' the teeth.
Insert: Close up showing position of the toothbrush and angle of the mirror.

11.4.2.3 Task rules

ROB-TOOTH-1 The brush of the toothbrush must be brought in contact with the pilot's teeth or lips.

Comment 1 on ROB-TOOTH-1: The referee confirms the contact between the lips and the toothbrush with "Okay go".

Comment 2 on ROB-TOOTH-1: The toothbrush can be placed on the table or in the cup after the contact with the pilot's teeth or lips.

ROB-TOOTH-2 It is not allowed to actively move towards the toothbrush, respectively with their trunk or head as the device approaches the pilot (from the timepoint the toothbrush is lifted from the cup).

Comment on ROB-TOOTH-2: We suggest that the pilot keeps the head rested at the headrest (if available) to avoid unintentional movement.

ROB-TOOTH-3 It is allowed to move the cup. If the cup is lifted off the table, the task is failed.

ROB-TOOTH-4 If the cup tips over, the task is failed.

11.4.3 Pick-up

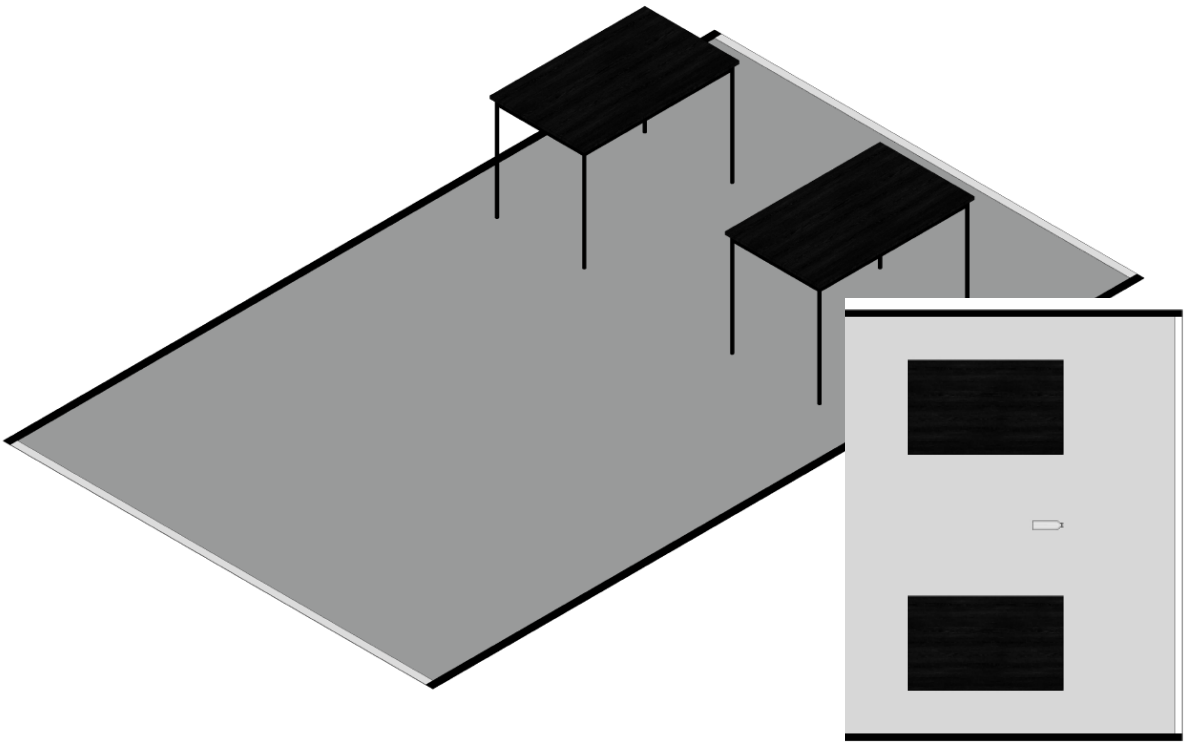
11.4.3.1 Introduction

Items that are randomly lying around or felt on the floor (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, pilots must pick up a bottle from the floor and place it on a table.

Image source

11.4.3.2 Task set-up & description



The, filled 1.5 l PET bottle that blocks the pilot's way must be picked up and placed on one of the tables.
Insert: Top view of the task space; the bottle will initially be placed in the direction of the race, with the tap towards the finish line.

11.4.3.3 Task rules

ROB-PICK-1 The bottle must be located on one of the tables when the pilot crosses the finish line of the task.

Comment on ROB-PICK-1: The bottle can be placed upright or lying.

ROB-PICK-2 If the bottle touches the ground again, after it has been completely lifted off the ground, the task is failed.

11.4.4 Scarf

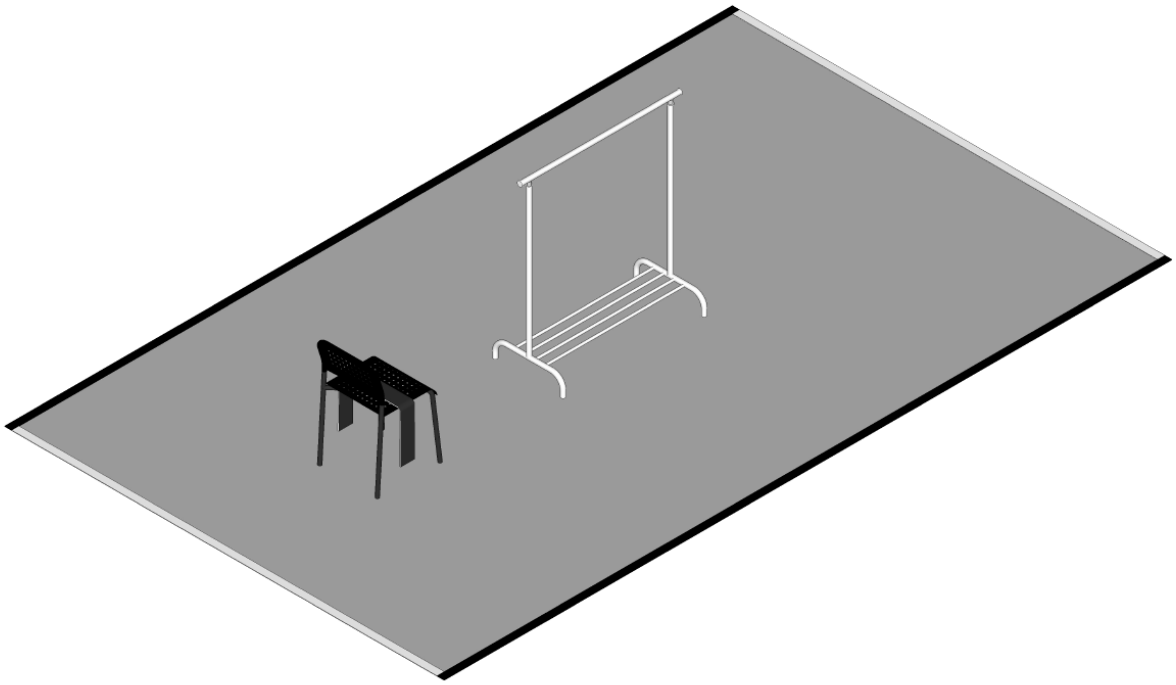
11.4.4.1 Introduction

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, pilots must hang a scarf on a clothesline.

Image source

11.4.4.2 Task set-up & description



The scarf that is initially placed on the chair must be hanged on the clothesline.

11.4.4.3 Task rules

ROB-SCARF-1	The scarf must be hanging on the clothesline when the pilot crosses the finish line of the task.
ROB-SCARF-2	The scarf must hang flat on the clothesline. If the scarf has a fold when the pilot crosses the finish line of the task, the task is failed.

11.4.5 Eating

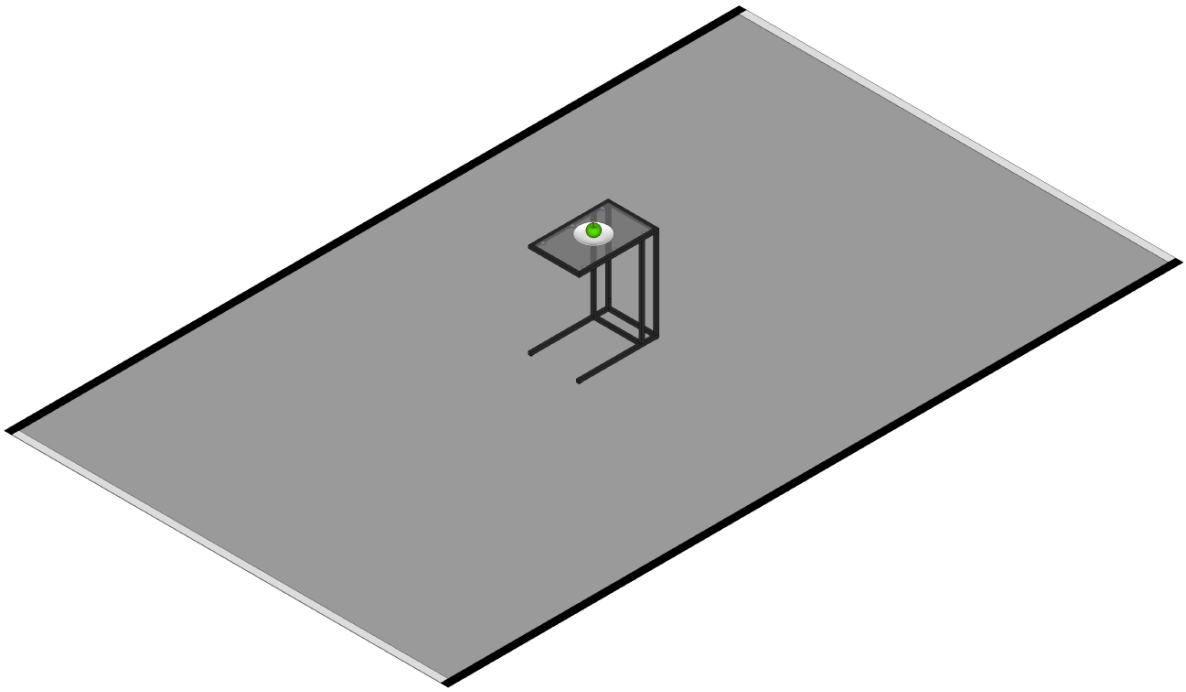
11.4.5.1 Introduction

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

Image source

In this task, pilots must 'eat' an apple.

11.4.5.2 Task set-up & description



An apple must be brought in contact with the pilot's mouth.

11.4.5.3 Task rules

ROB-EAT-1 The apple must be grasped from the plate and brought to the pilot's mouth, i.e., there must be contact between the lips or teeth and the apple.

Comment on ROB-EAT-1: The referee confirms the contact between the lips or teeth and the apple with "Okay go".

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

ROB-EAT-3 It is not allowed to actively move towards the apple with their trunk or head as the device approaches the pilot (from the timepoint the apple is taken off the plate).

Comment on ROB-EAT-3: We suggest that the pilot keeps the head rested at the headrest (if available) to avoid unintentional movement.

11.4.6 Crowd

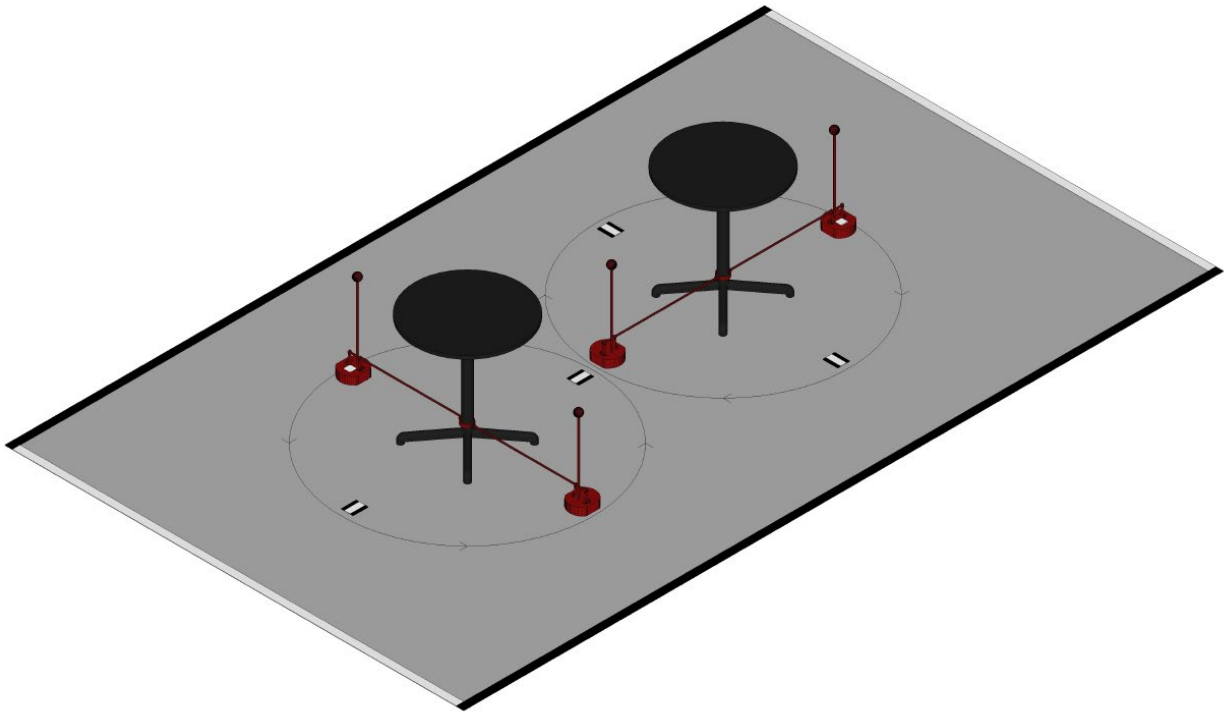
11.4.6.1 Introduction

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.

Images source

11.4.6.2 Task set-up & description



The pilot and the assistance robot must pass between the tables without touching the orbiting robots and attachments.

Information about the robots:

- The starting position of the robots is as indicated in the picture.
- The first two orbits for one robot take appr. 36 s. Thereafter, the orbit duration increases 0.12 s per s whereas an update of the speed only occurs whenever the robot passes one of the eight marks. When the orbit duration has reached 72 s, the orbit duration will be kept constant.
- 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 robots are set in motion the moment the pilot crosses the start line of the task.
- A fixation system attached to the table guides the robots rigidly around the table.

11.4.6.3 Task rules

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

Comment on ROB-CROWD-1: The first piece of furniture can be passed on the left- or on the right-hand side.

11.4.6.4 Comments

- If the orbiting robots stops, the responsible CYBATHLON official will remove the robot including the attachment to the table. The pilot can continue the task with less orbiting robots. The responsible CYBATHLON official is a pre-defined role.

11.4.7 Spice-up

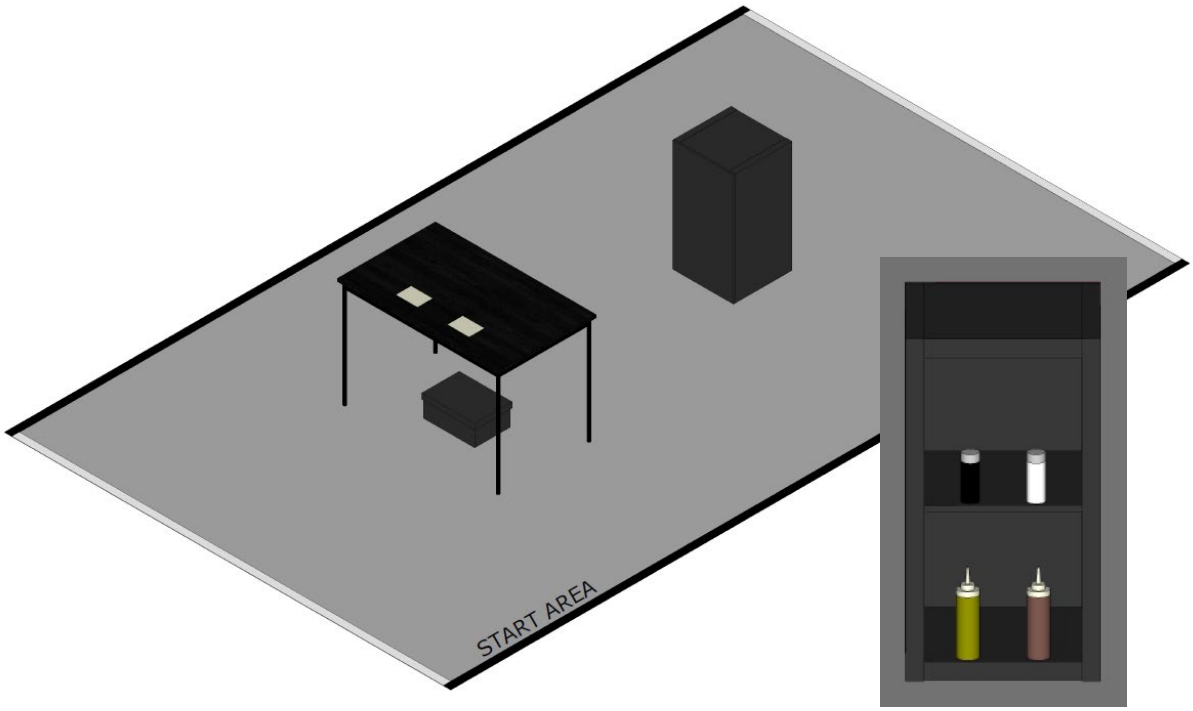
11.4.7.1 Introduction

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

In this task, pilots must grab the correct object and place it at a predefined location.

Image source

11.4.7.2 Task set-up & description



Pilots must place two out of four objects on top of the shelf. The referee reveals the cards with the two target items one after the other (cards on the table).

Insert: View into the shelf from the finish line of the task.
Please note, that the line defining the start area is only for illustration and will not be marked on the task space.

Initially, four objects are placed in the shelf (salt/pepper and oil/vinegar). The referee reveals the first card on the table. The corresponding object in the shelf must be moved to the top of the shelf. The second card is only revealed when the pilot's wheelchair is in the start area. Hence, if the manipulator is on a separate device, the pilot can stay in the start area and the robot moves the objects. However, if the manipulator is mounted on the wheelchair, the pilot must go back to the start area, after the first object is placed on top of the shelf.

11.4.7.3 Task rules

ROB-SPICE-1 Two out of four objects (salt or pepper and oil or vinegar) 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.

Comment on ROB-SPICE-1: In each race run the referee will reveal; salt or pepper, and oil or vinegar. The target item and the order in which the target items are revealed is random.

ROB-SPICE-2 If a non-target item is placed onto the top surface of the shelf, the task is failed.

ROB-SPICE-3 The card with the first target item is revealed by the referee when the pilot crosses the start line of the task. The card of the second target item is only revealed when the pilot's wheelchair, in its entirety, is located in the start area. The start area is defined as the floor infront of the table. For the card of the second item to be revealed, the first item must been placed on top of the shelf.

ROB-SPICE-4 Both target items must be located on the top surface of the shelf when the pilot and the assistance robot cross the finish line of the task.

11.4.8 Door

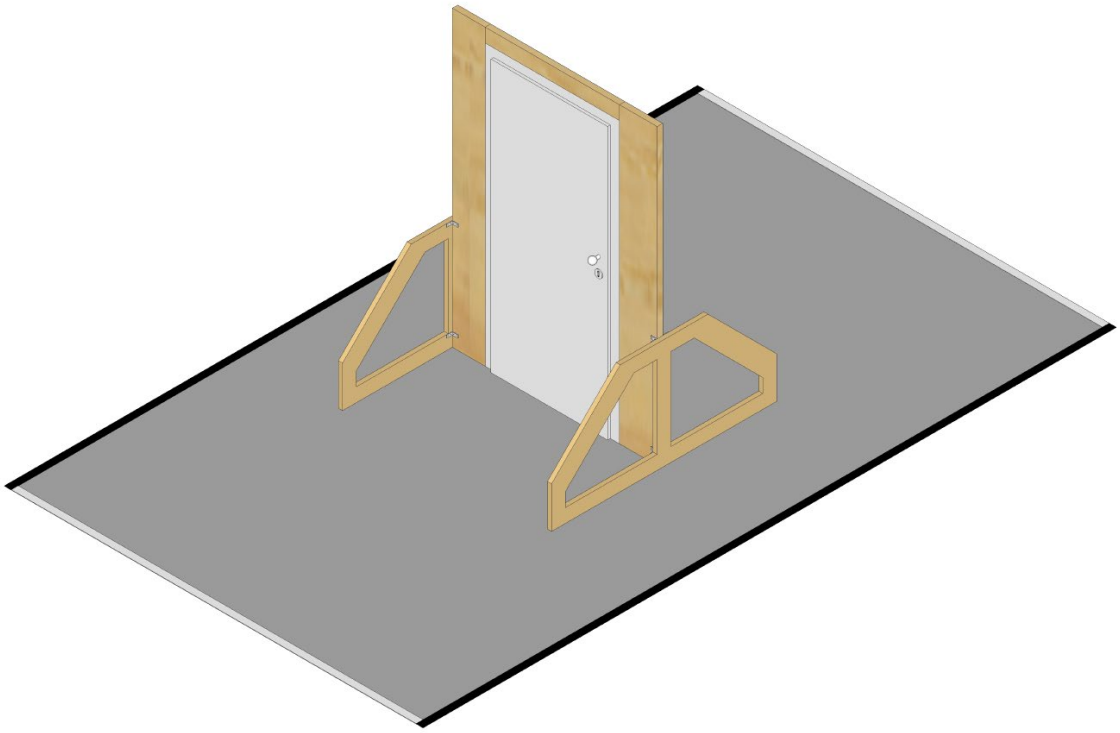
11.4.8.1 Introduction

Opening and closing doors is challenging as a wheelchair user. There are different mechanisms to open the door (e.g., doorhandle or doorknob) and not all doors require the same amount of force to push or pull them open.

In this task, pilots must open, pass through, and close a door

Images source

11.4.8.2 Task set-up & description



The pilot and the assistance robot must open, pass through, and close the door (initially closed) The door is equipped with a doorknob (frontside) and door handle (hindside).

11.4.8.3 Task rules

ROB-DOOR-1 The door must be opened (by pulling), passed through, and closed once in the direction of the race. If the door is not clicked shut when the pilot crosses the finish line of the task, the task is failed.

Comment on ROB-DOOR-1: If the robot is a separate device, ROB-DOOR-1 applies also for the robot.

ROB-DOOR-2 If the pilot and/or the assistive devices passes by the left or right of the doorframe, the task is failed.

ROB-DOOR-3 The door must be open by the doorknob.

Comment on ROB-DOOR-3: It is not allowed to open the door by the doorhandle (e.g., by reaching around the doorframe).

11.4.9 Touchscreen

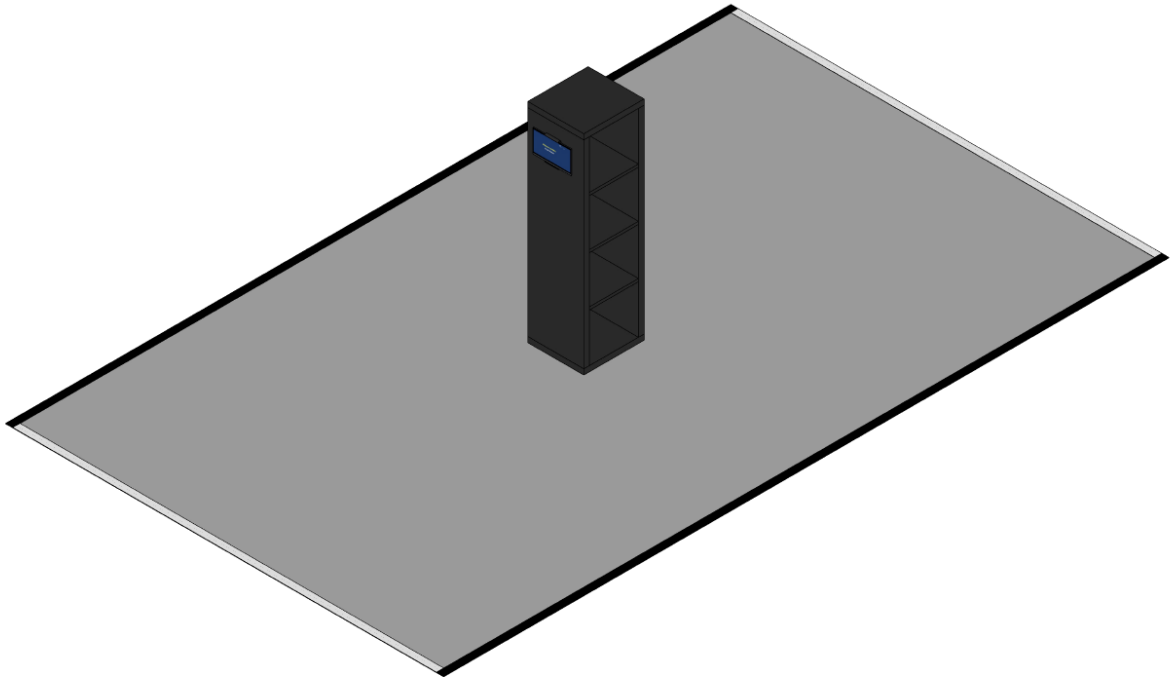
11.4.9.1 Introduction

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 must navigate a touchscreen and order a predefined item from a variety of foods.

Image source

11.4.9.2 Task set-up & description



Pilots must order fruit salad on a touchscreen offering a variety of foods (total of 16 items). The items are arranged randomly on the screen, within a rectangular box of 4x4 items. The app is provided to the registered teams.

11.4.9.3 Task rules

ROB-SCREEN-1 If any food other than the fruit salad is selected, the task is failed.

Comment on ROB-SCREEN-1: It is allowed to touch/press the area next to the buttons. It will have no consequences on the touchscreen.

ROB-SCREEN-2 It appears “correct” on the screen when the pilot selects the correct target item (fruit salad).

Comment on ROB-SCREEN-2: In case of a technical defect, the referee can confirm the correct selection with “correct”.

ROB-SCREEN-3 It appears “fail” on the screen when the pilot selects the wrong item.

Comment on ROB-SCREEN-3: In case of a technical defect, the referee can determine the wrong selection with “fail”.

11.4.10 Dishwasher

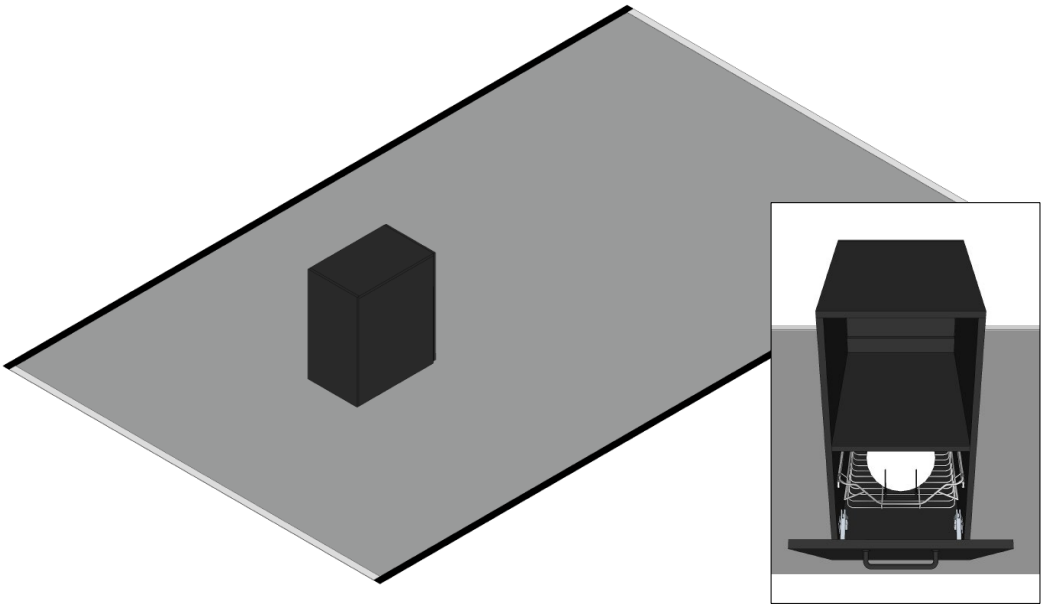
11.4.10.1 Introduction

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, pilots must empty a dishwasher.

Image source

11.4.10.2 Task set-up & description



The plate initially located in the dishwasher must be removed and placed on the top of the dishwasher. The dishwasher is initially closed.
Insert: View of half-opened dishwasher showing the position of the plate, for illustration purpose only.

11.4.10.3 Task rules

ROB-DISH-1 The plate must be located on the dishwasher when the pilot crosses the finish line of the task.

Comment 1 on ROB-DISH-1: The dishwasher can be opened by the handle or by grasping the door.

Comment 2 on ROB-DISH-1: The pilot can leave the dishwasher open.

11.5 Competition mode and scoring

Points per task: 10

Time limit: 10 min

12 Vision Assistance Race

A blind person using an app to solve a task at the CYBATHLON Challenges 2023.

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

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 with remaining vision will be completely blindfolded during the competition. The blindfold must be applied according to the guidelines provided by the CYBATHLON organising committee.

VIS-2 The referee touches the back or the shoulder of the pilot during the countdown and lifts it off when the race starts.

VIS-3 A team official can accompany the pilot to the competition field. Once the race has started the accompanying team official is not allowed to coach the pilot or give any information about the track.

VIS-4 The team official is allowed to inform the pilot regarding the past or remaining time for the race run.

VIS-5 After a task fail or after a pilot skipped a task, the pilot can call the accompanying team official for assistance. The accompanying team official can guide the pilot to the middle of the start line of the next task (behind the start line – not on the start line).

Comment on VIS-5: We recommend bringing the pilot not closer than ~0.3 m in front of the finish line. The accompanying team official shall not be on the racetrack when the pilot crosses the start line of the next task.

VIS-6 As soon as pilots and accompanying team official have left the call room, i.e., the accompanying team official can see/scan the racetrack, the accompanying person is not allowed to talk to the pilot anymore.

Comment on VIS-6: This rule prevents that the accompanying team official provides information to the pilot about the configuration of the objects on the tasks that shall remain unknown prior to the race.

VIS-7 As soon as the pilot left the call room, i.e., can scan the racetrack, the pilot is not allowed to connect to any person by video call or similar, i.e., use “Be My Eyes”.

12.4 Task definitions

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

12.4.1 Dish up

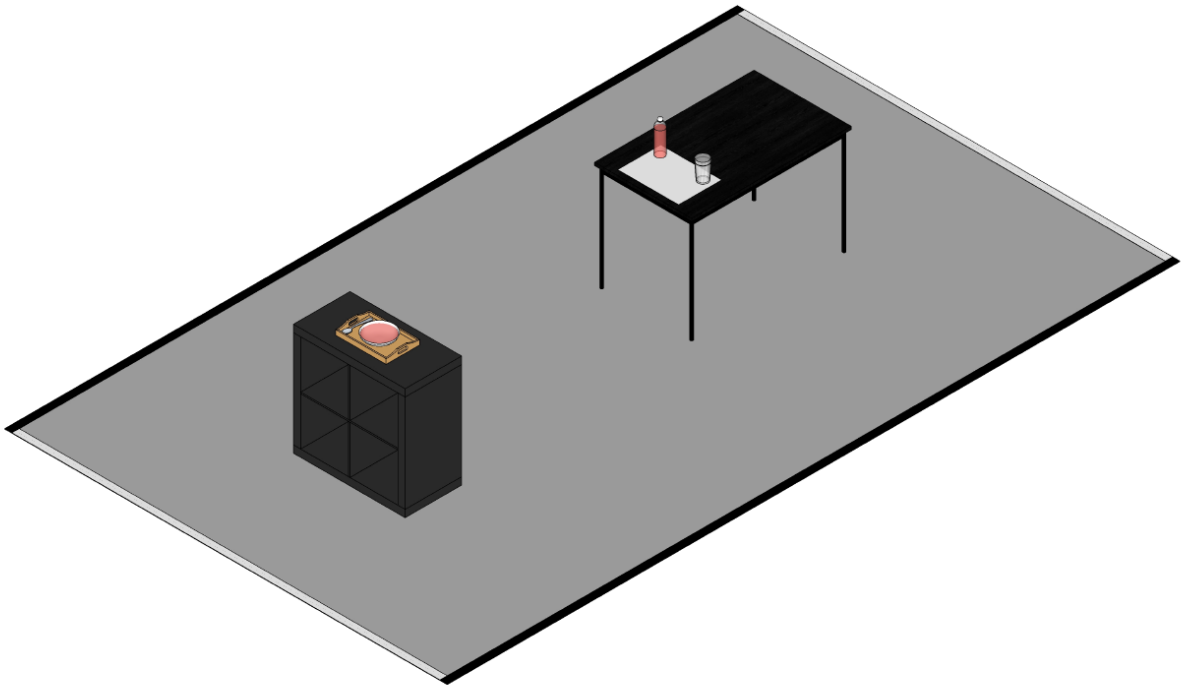
12.4.1.1 Introduction

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 on the table.

Image source

12.4.1.2 Task set-up & description



Pilots must carry a soup plate and a spoon to the table near the finish line and fill a glass at the table.

The plate is filled with 0.2l of red liquid. The bottle is initially closed with a bottle cap and filled with 0.5 l red liquid.

12.4.1.3 Task rules

VIS-DISH-1 The glass must be filled at least to the mark (2 cm below rim of the glass). If the filling of the glass is below the mark when passing the finish line, the task is failed.

Comment on VIS-DISH-1: It is not allowed to touch the liquid with a sensor or any other part of the body or device. The idea is to not touch food or drinks.

VIS-DISH-2 It is allowed to carry the soup plate and spoon with or without using the tray.

VIS-DISH-3 The bottle, filled glass, spoon, and the soup plate must be located on the table mat when the pilot crosses the finish line of the task. All these items must be on the table mat in their entirety.

Comment on VIS-DISH-3: The tray can be located on the shelf or table when the pilot crosses the finish line of the task.

VIS-DISH-4 The bottle cap must be on the bottle when the pilot crosses the finish line of the task.

VIS-DISH-5 If the spoon touches the red liquid, the task is failed.

VIS-DISH-6 If any of the red content of the glass or of the soup plate is spilled, the task is failed.

12.4.2 Doorbell

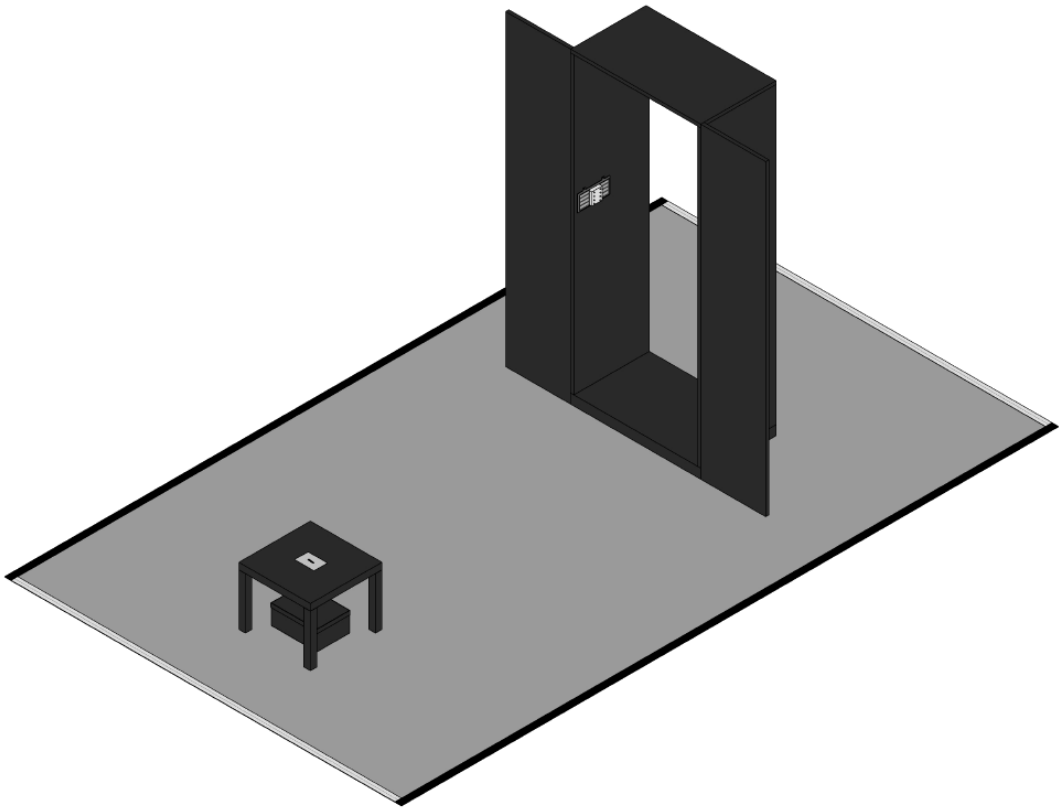
12.4.2.1 Introduction

Finding the right bell on a large doorbell panel is often very demanding for blind people. The confined space, and the variety of name combinations are especially challenging for assistive technologies.

In this task, pilots must find the correct name on the doorbell panel and ring the bell.

Image source

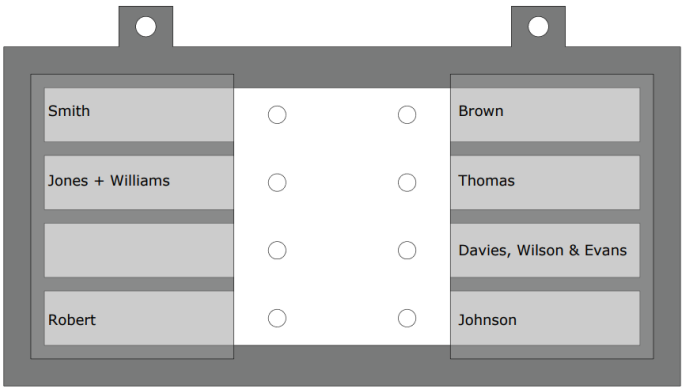
12.4.2.2 Task set-up & description



Pilots must ring the correct doorbell. The target name to be rang will be written on a card located on the table near the start line of the task.

The arrangement of the names on the doorbell panel will be varied between races:

- The following names are used: Smith, Jones, Williams, Brown, Taylor, Davies, Wilson, Evans, Thomas, Robert, Johnson.
- All names are presented in each race (randomized arrangement of the names).
- Each name tag contains zero, one, two, or three names.
- In each house (door panel configuration used in the races) there is one apartment which:
  - is occupied by a couple (e.g., “Smith & Jones” or “Smith + Jones”, or “Smith, Jones”)
  - is occupied by a shared flat (e.g., “Smith, Jones & Williams”)
  - is empty (no name on the name tag)



12.4.2.3 Task rules

VIS-DOOR-1 If the pilot rings the correct doorbell, the nametag lights up in green. If the pilot rings the wrong doorbell, the nametag lights up red and the task is failed.

Comment on VIS-DOOR-1: The referee confirms the ringing of the correct doorbell with “correct” and the ringing of the wrong doorbell with “fail”.

VIS-DOOR-2 Pilots must pass through the entrance. If the pilot passes on the right or left side of the entrance, the task is failed.

VIS-DOOR-3 In case of a technical defect, the referee can confirm the correct selection with “correct” and the wrong selection with “fail”.

VIS-DOOR-4 It is allowed to move the card with the target name. The card must be on the table when the pilot crosses the finish line of the task.

12.4.3Empty Seats

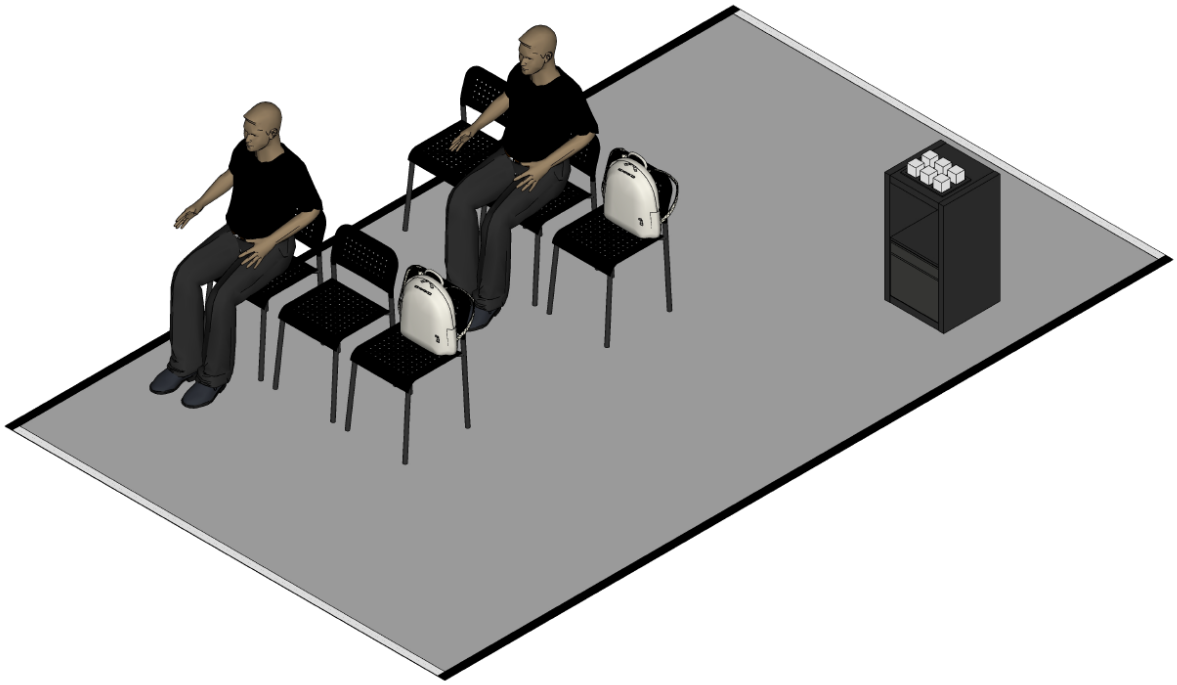
12.4.3.1 Introduction

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

In this task, pilots must identify the empty seats.

Image source

12.4.3.2 Task set-up & description



For each row, pilots must indicate the location of the empty seat.

Some or all seats in each row are occupied by persons or backpacks:

- There are two rows of seats with three seats each (left, middle, right).

- Pilots indicate the empty seats using the display located at the right towards the finish line of the task. Initially, cubes are placed on the recesses corresponding to the two rows. The pilot must remove the cube from the recess that corresponds to the location of the empty seat (left, middle, right) and place these cubes on the shelf below.
- There are always two persons sitting on any of the seats and at least one backpack placed on any seat. Overall, there is at least one, and maximal three empty seats.
- The backpacks are initially placed against the backrest of the chairs with the straps around the backrest.
- The people wear dark pants, sweatshirt, and shoes.
- The people have their hands placed on their thighs.

12.4.3.3 Task rules

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

Comment on VIS-SEAT-1: The pilot must remove the cubes corresponding to the empty seats.

VIS-SEAT-2 All cubes must be either on the correct position on the rack or on the shelf below when the pilot crosses the finish line.

VIS-SEAT-3 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).

12.4.4Grocery

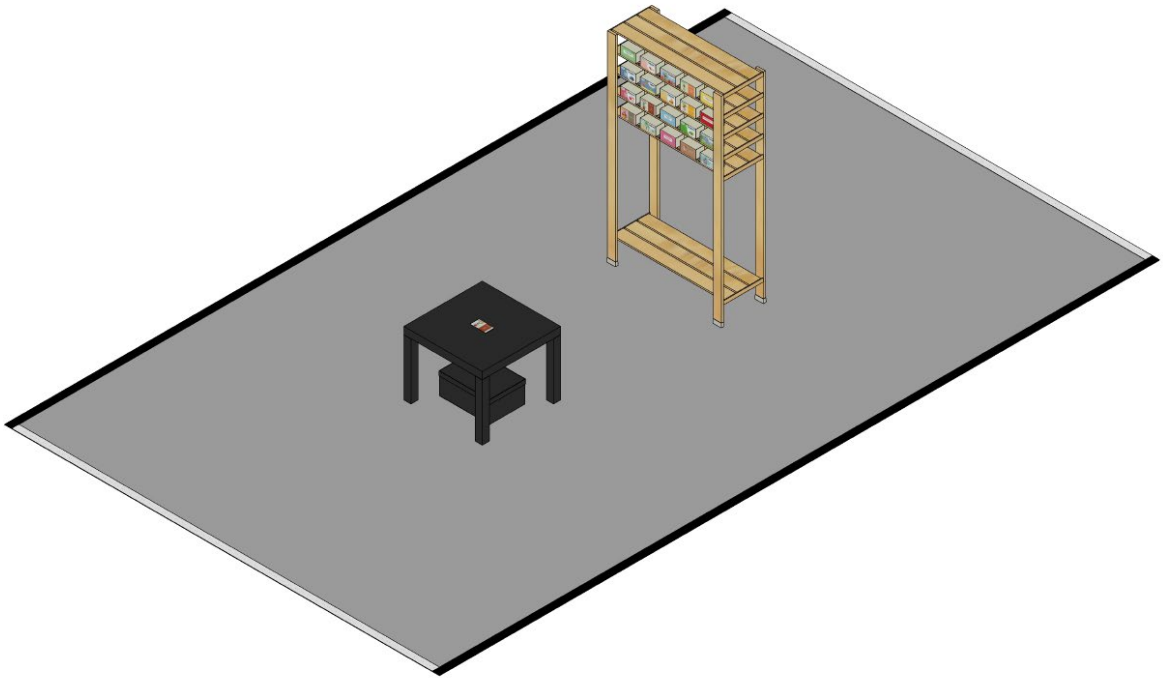
12.4.4.1 Introduction

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

In this task, pilots must find a specific product in the shelf.

Image source

12.4.4.2Task set-up & description



A specific product must be collected from the shelf and placed on the table in front of it.

- The initial order of the products (20 cardboard boxes with tea labels) in the shelf varies between races.
- The label of the target product is printed on a card (same size as the tea label in the shelf) and placed on the table.
- The 20 tea labels are given in the Appendix I.
- The label is correctly aligned when you stand between the table and the shelf and look towards the start line.

12.4.4.3 Task rules

VIS-GROCERY-1	The target product must be placed on the table when the pilot crosses the finish line of the task. If the target object is not on the table, when the pilot crosses the finish line, the task is failed.
VIS-GROCERY-2	The non-target products must be located in the shelf when the pilot crosses the finish line of the task.
VIS-GROCERY-3	It is allowed to move the label of the target product which is initially placed on the table. The label with the target product must be on the table when the pilot crosses the finish line of the task.

12.4.5 Sidewalk

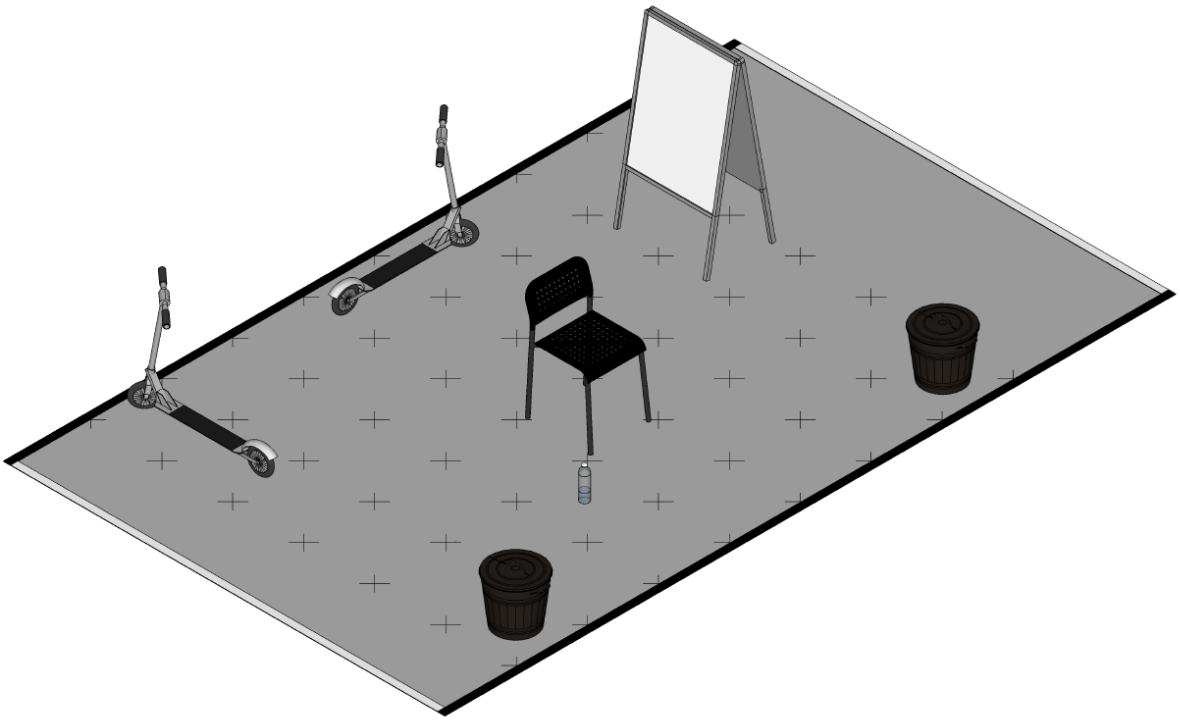
12.4.5.1 Introduction

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). This may lead to collisions and falls.

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

Image source

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 7 rows and 6 columns.
- Seven objects (1 customer stopper, 2 bins, 1 bottle, 1 chair, 2 scooter) 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.

12.4.5.3 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.

12.4.5.4 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.
- There are always two paths without an obstacle. The path width is at least 0.49 m.

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 must locate and grasp a specific object from a group of other objects.

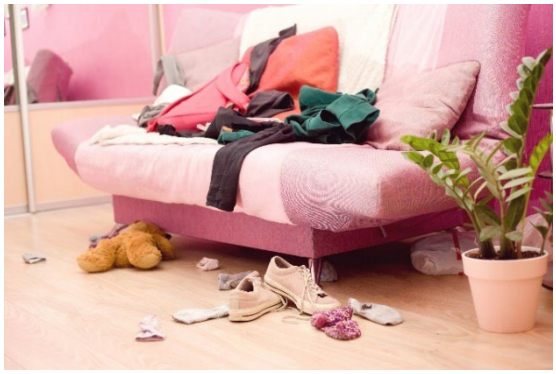
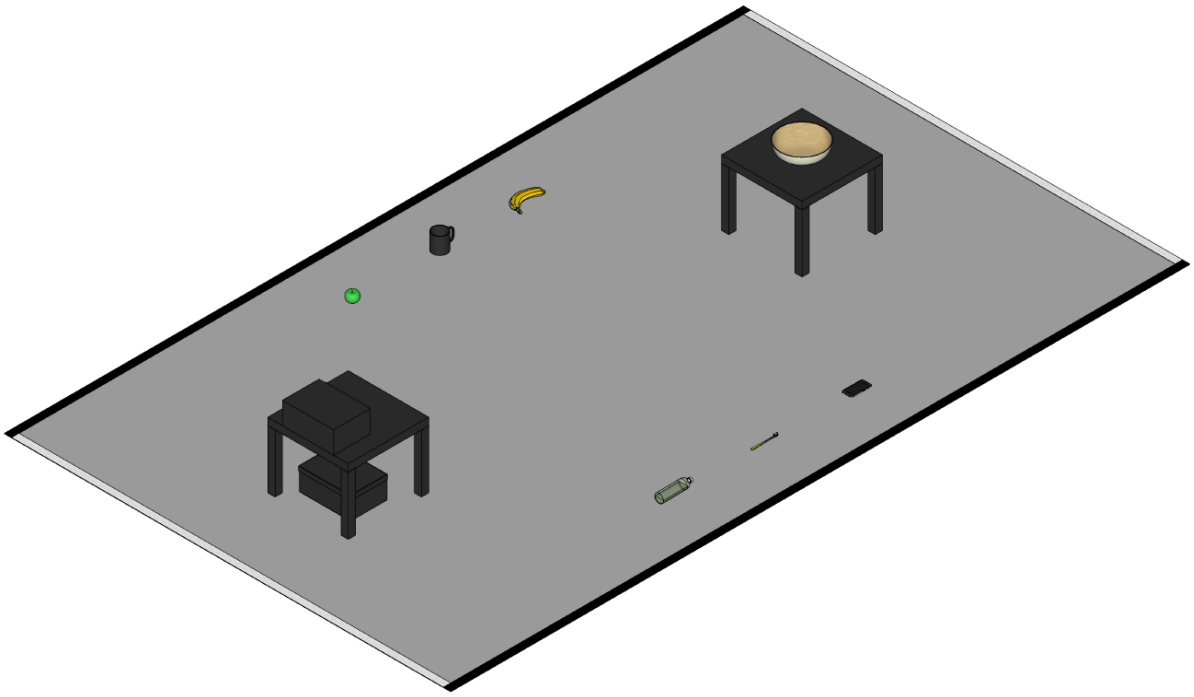


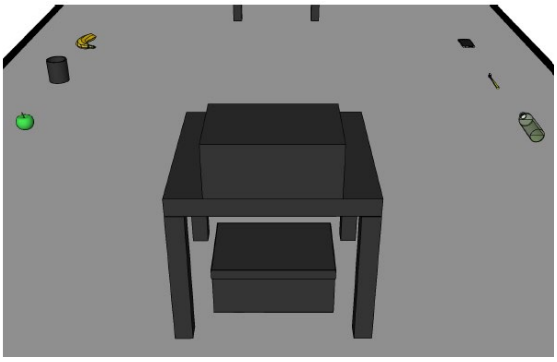
Image source

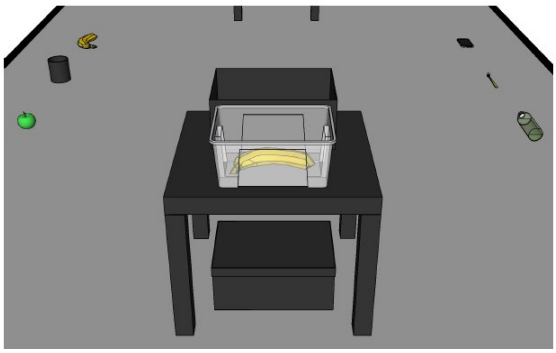
12.4.6.2 Task set-up & description



Pilots must pick up the target object from the floor and place it in the bowl on the table near the finish line.

- The target object is random.
- The target item is indicated by an identical item inside a box on the table near the start line.
- The pilot must open the lid of the box to identify the target object.
- The six objects are randomly allocated to six predefined locations on the ground.





12.4.6.3 Task rules

VIS-FIND-1 The target object on the floor must be located and placed in the bowl on the table near the finish line when the pilot crosses the finish line of the task.

VIS-FIND-2 If the pilot or any assistive device (including the white cane) touches any of the non-target objects, the task is failed.

VIS-FIND-3 The pilot is allowed to touch the target item in the box to identify it. If the item from the box is not in the box, when the pilot crosses the finish line of the task, the task is failed.

VIS-FIND-4 It is allowed to move the bowl on the table surface. If the bowl is lifted off the table, the task is failed.

12.4.7 Footpath

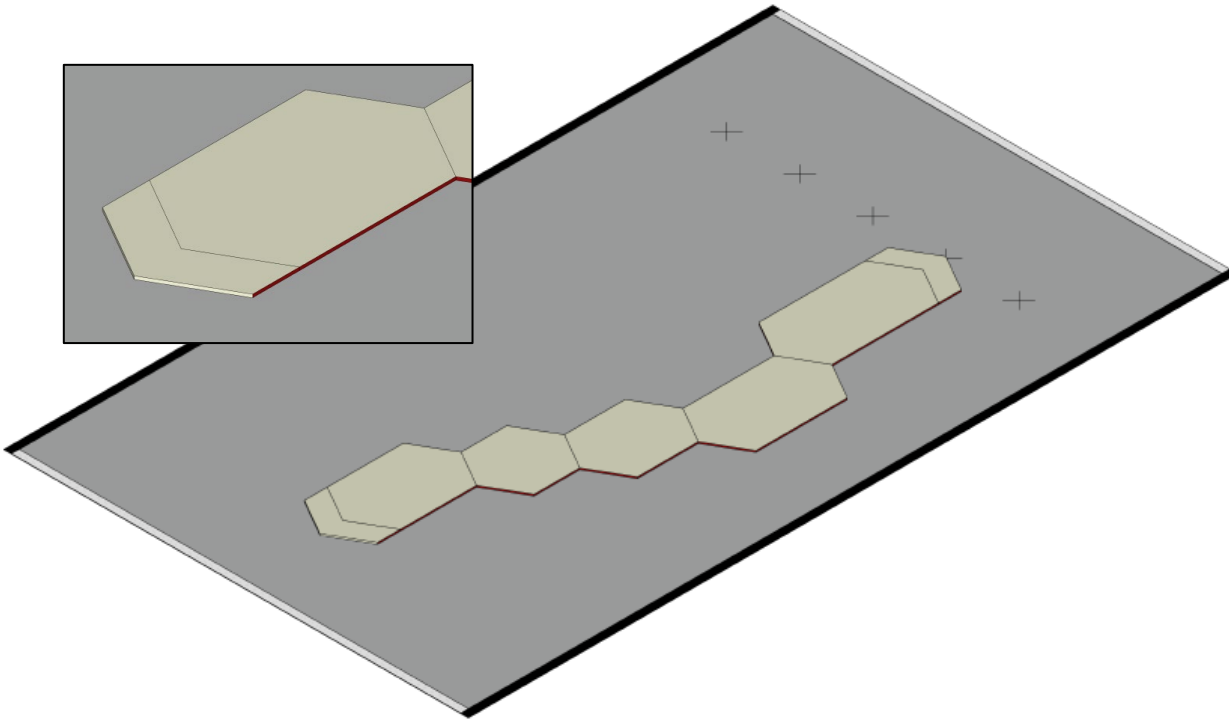
12.4.7.1 Introduction

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 pot-holes which is unpleasant for the user.

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

Image source

12.4.7.2 Task set-up & description



Pilots must follow the path without touching the ground to the left and to the right. Insert: Close-up of the path facing the start line for the illustration of the red edges.

- The path is made of five hexagonal plates and two pentagon arrow shaped plates at its ends.
- 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.

12.4.7.3 Task rules

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

VIS-PATH-2 The pilot (and the assistive device) must enter the path over the arrowhead facing the start line and leave the path over the arrowhead facing the finish line.

VIS-PATH-3 It is not allowed to haptically explore the red edge of the path by using the feet or an assistive device (including a white cane).

VIS-PATH-4 It is not allowed to cross the red edges and touch the ground beyond it in any direction, i.e., stepping off or stepping on the path.

Comment 1 on VIS-PATH-4: It is allowed that body parts above the feet (e.g., hip, torso, arms) or the assistive device are going beyond the vertical projections of the edge of the plates. Note that the task is failed, if any body part or the assistive devices touches the edges of the plates.

Comment 2 on VIS-PATH-4: While standing on the plate, it is not allowed to protrude over the plate with the feet.

Comment 3 on VIS-PATH-4: It is not allowed to haptically explore the edge of the plate with the assistive device.

12.4.8 Colours

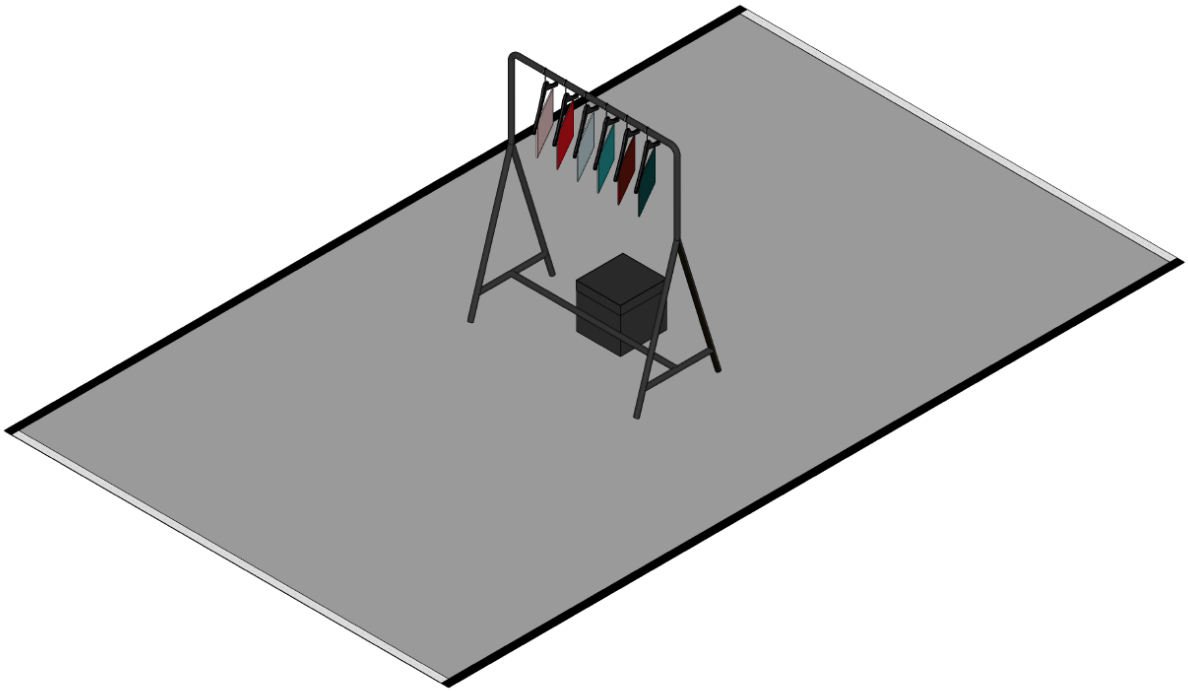
12.4.8.1 Introduction

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 gradations.

Image source

12.4.8.2 Task set-up & description



Pilots must sort the fabric sheets by colour and within each colour by gradation.

- A subset of two colours from a pool of five predefined colours, each in three different colour gradations will be presented in each race.

- The two presented colours are one of the following pairs: red & green, red & cyan, red & blue, magenta & green, magenta & cyan, green & blue. These colours and its gradations are clearly distinguishable for the human eye (without any colour-blindness).
- The clothes hangers with subset to be sorted will initially be placed randomly at predefined locations (evenly spaced in the centre) on the clothesline.
- The clothes hangers are placed in such a way that they can be grasp and taken off from the side closer to the start line.
- The colours and gradation (including the CYMK codes), are defined in Appendix I.

12.4.8.3 Task rules

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

Comment on VIS-COLOUR-1: Pilots are free to choose for each base colour if they sort the gradation of the colours from left to right or from right to left.

12.4.9 Touchscreen

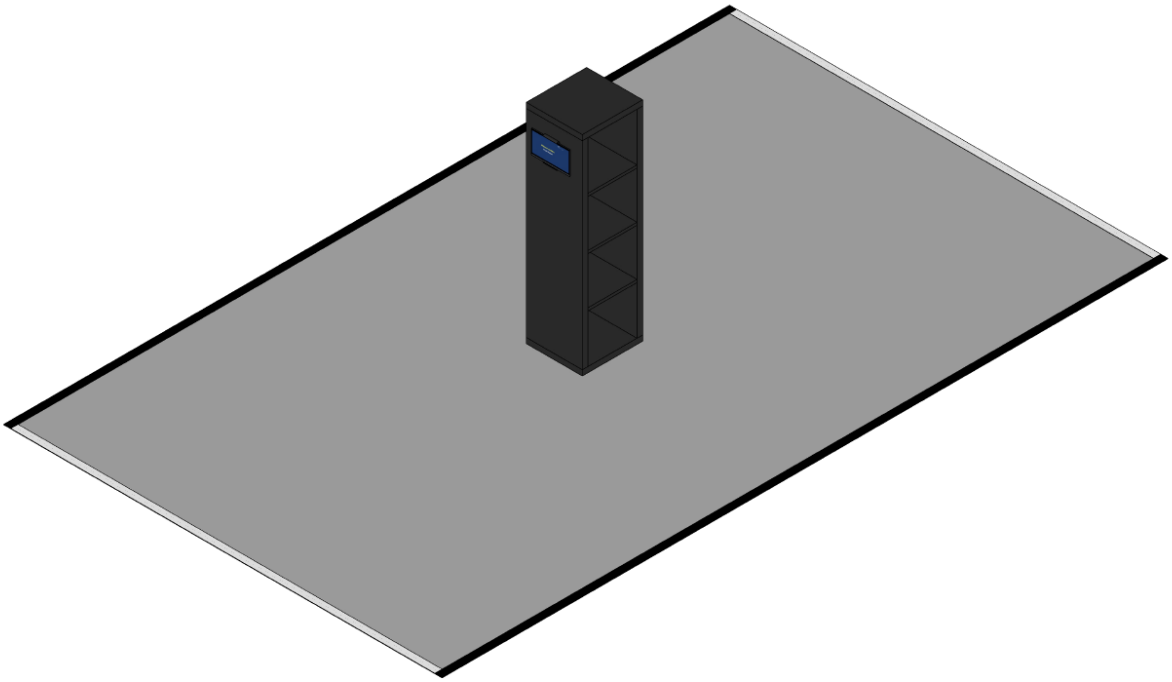
12.4.9.1 Introduction

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 a blind person.

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

Image source

12.4.9.2 Task set-up & description



Pilots must order fruit salad on a touchscreen offering a variety of foods (total of 16 items). The items are arranged randomly on the screen, within a rectangular box of 4x4 items. The app is provided to the registered teams.

12.4.9.3 Task rules

VIS-SCREEN-1 If any food or drink other than the fruit salad is selected, the task is failed.

Comment on VIS-SCREEN-1: It is allowed to press the area next to the buttons. It will have no consequences on the touch screen.

VIS-SCREEN-2 It appears “correct” on the screen when the pilot selects the correct target item (fruit salad). The referee reads aloud “correct”.

Comment on VIS-SCREEN-2: In case of a technical defect, the referee can confirm the correct selection with “correct”.

VIS-SCREEN-3 It appears “fail” on the screen when the pilot selects the wrong item. The referee reads aloud “fail”.

Comment on VIS-SCREEN-3: In case of a technical defect, the referee can determine the wrong selection with “fail”.

12.4.10 Forest

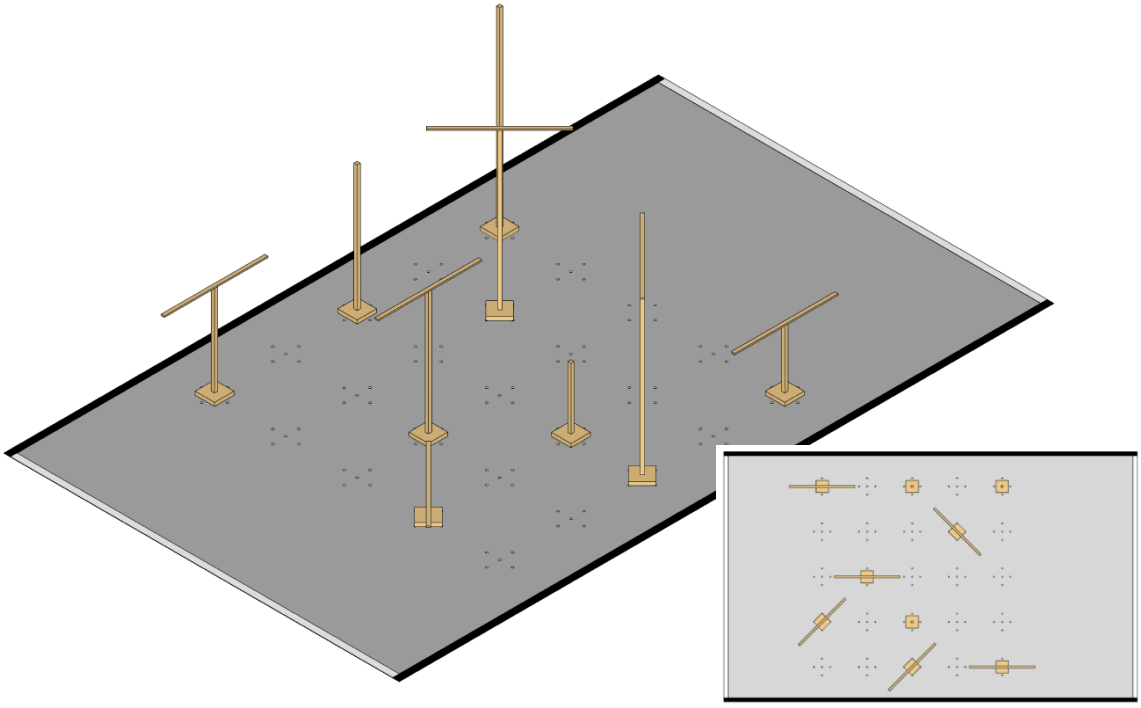
12.4.10.1 Introduction

Objects that are located at different heights (e.g., a tree's branch that hangs on the walkway, or truckers' tail lift) 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 different heights.

Image source

12.4.10.2 Task set-up & description



Pilots must navigate through the maze.
Insert: Top view of the task space.

- The task space is divided into a virtual grid of five rows and five columns.
- Nine obstacles are randomly placed on the grid on the task:
    - Six ”T”s with a height of 0.25 m, 0.5 m, 0.75 m, 1.0 m, 1.25 m and 1.5 m respectively. The length of the crossbars is 0.8 m.
    - Three poles with a height of 0.5m, 1.0m, and 1.25m respectively.
    - The path of the maze will be alternated between races. In each race, there will be at least one free path with a width of at least 0.7m.

12.4.10.3 Task rules

VIS-FOR-1 If the socket, poles, or crossbars are touched, the task is failed. This includes touching them with a white cane or any other assistive device.

12.5 Competition mode and scoring

Points per task: 10

Time limit: 8 min

Appendix I: Competition Infrastructure

This separate document contains all relevant information to rebuild the competition tasks.

The current version is V 1.10

Find the Appendix I here for download:
https://cybathlon.ethz.ch/en/events/edition/cybathlon-2024/download-centre

Appendix II: Appeals

This separate document contains all relevant information related to the appeals procedures. Registered Teams find the document in the *Download Centre*, linked in your dashboard.

The current version is V 1.2.

Find the Appendix II here for download:
https://cybathlon.ethz.ch/en/events/edition/cybathlon-2024/download-centre