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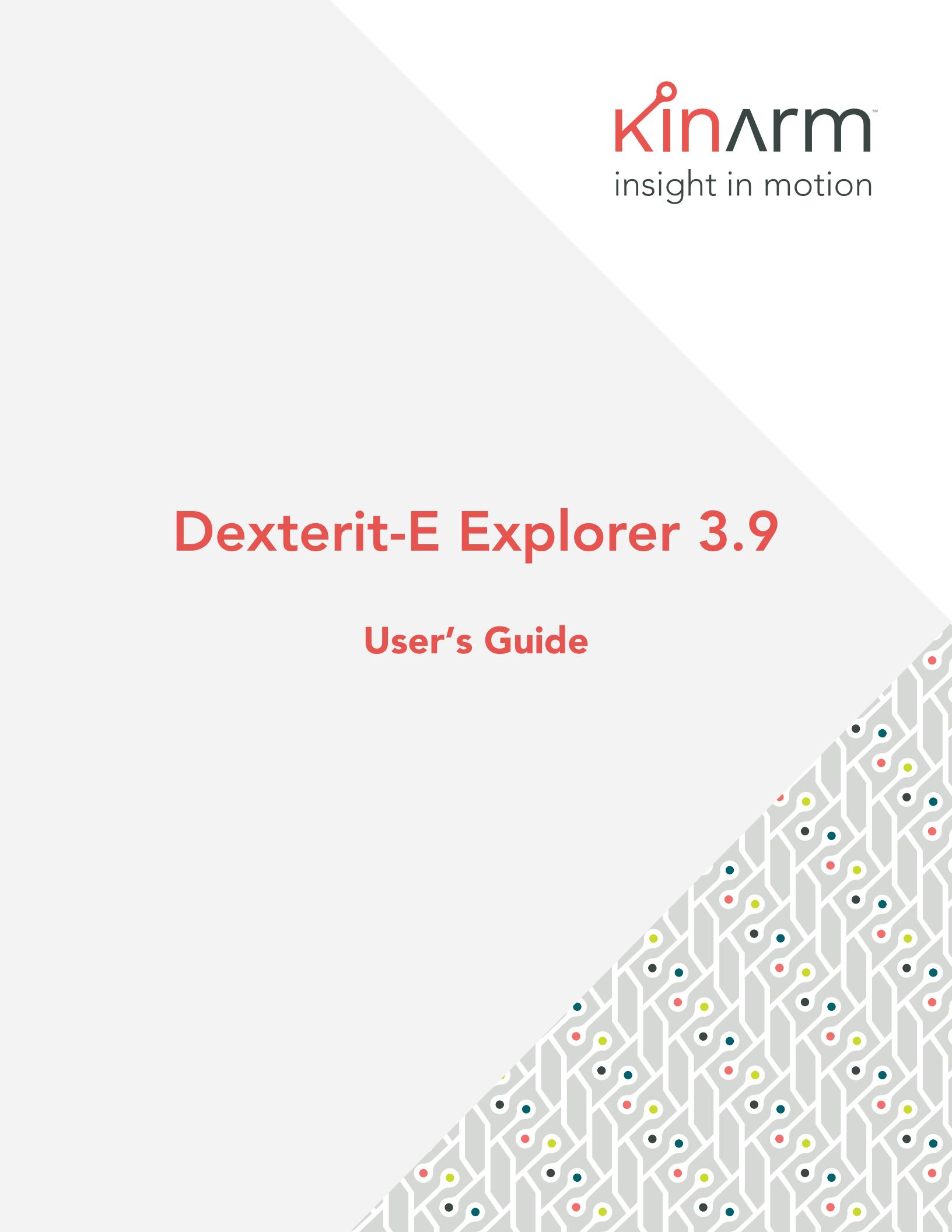
Dexterit-E Explorer 3.9

User's Guide



CE

When installed in accordance with this manual and verified by a BKIN technician, the equipment described in this guide is in conformity with the relevant Essential Health and Safety Requirements of the following Directives:

- 2004/108/EC (relating to electromagnetic compatibility)
- 2006/95/EC (relating to electrical equipment designed for use with certain voltage limits)
- 2006/42/EC (on machinery)

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Contents

1 Revision History

Revision	Description	Date	Approved By
1	Initial release.	19-Feb-14	DMM
2	Updated for release 1.1.1.	07-Jul-14	DMM
3	Updated for release 1.2.	23-Jan-15	IEB
4	Updated for release 1.3.	27-Oct-16	DMM
5	Updated for release 1.4.	28-Mar-18	IEB
6	Updated for release 1.5.	02-Dec-19	DMM
7	Conversion to DITA. Updated for release 3.9.	22-Mar-21	IEB

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**Contraindications

Kinarm Standard Tests are not indicated for research subjects who do not have adequate cognitive functioning to understand the task instructions, who do not have visual and/or auditory acuity to permit adequate perception of instructions or task stimuli, and/or who are of an age falling outside of 18-85.

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- Bulleted lists indicate general information and choices related to a function or procedure. They do not imply a sequential procedure.
- Control names and menu items or titles are spelled as they are on the system and they appear in highlighted text.
- Click or select means to move the pointer to an object or menu item and press the primary mouse button.
- Right-click means to point at an item and then press and immediately release the right mouse button without moving the mouse.

NOTE: Notes bring your attention to important information that will help you operate the product more effectively.

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CAUTION: Cautions highlight ways you could injure yourself or the subject or damage your product and consequently void your warranty or service contract.

WARNING: Warnings highlight information vital to the safety of you, the operator, and the subject.

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3 In This Guide

Welcome to the Dexterit-E Explorer™ User Guide. This reference guide describes how to use Dexterit-E Explorer to view your Kinarm Lab's data. This guide assumes that you are familiar with Dexterit-E™ software and the data files it creates, in particular the relationship between exams, data files, trials, channels and events.

This version of the Dexterit-E Explorer User Guide is intended for use with Dexterit-E Explorer 3.9.

NOTE: The previous version of Dexterit-E Explorer was 1.5. The revision numbering has been modified to match the concurrent version of Dexterit-E.

4 Dexterit-E Explorer Software

4.1 Key Features of Dexterit-E Explorer

Dexterit-E Explorer software is designed to allow a user to review any data files captured with Dexterit-E software and a Kinarm™ Lab. Installers are available to run Dexterit-E Explorer software on either Microsoft Windows™ or Mac OS X™ operating systems. Key features include:

- Anyone can download Dexterit-E Explorer to allow shared viewing of Kinarm data; a current maintenance contract is not required.
- Supported operating systems include: Windows 7, Windows 10 or Mac OS X.
- Shows animations of subject behaviour collected using Dexterit-E software, including limb positions and visual stimuli presented on the subject display.
- Shows time-based graphs of data collected during an exam, including time-stamped event markers.
- Allows the creation of high quality movies and images of subject behaviour and/or data traces.
- Allows for creation and viewing of Kinarm Standard Test (KST) Reports and exporting of analysis results as a CSV file.
- Allows viewing of experiment-related parameters collected during an exam.

4.2 Intended Uses of Dexterit-E Explorer

- Reviewing subject behaviour post-experiment:
  - to ensure that task instructions were followed;
  - to better understand details of subject behaviour so as to guide/lead possible approaches to analysis (e.g. using MATLAB™).
- Reviewing system behaviour during custom task development to ensure proper functioning of the system.
- For visually disseminating/explaining research studies collected in Kinarm Labs.
- For creating task instructional videos for use with a Kinarm Lab.

NOTE: Any data recorded with Dexterit-E 3.2 and earlier can only be rendered with the arm positions in Dexterit-E Explorer animations. Targets and other visual stimuli that were displayed to the subject will not be shown. Any data recorded with Dexterit-E 3.3 and later will render accurately everything that the subject saw during an exam. This difference is because before Dexterit-E 3.3 visual stimuli were not saved with a data file.

5 The Subject Database

Dexterit-E software has the capability to create and manage a database of subjects and their data. Dexterit-E Explorer software reads the Dexterit-E database to show all subjects, subject information, data files and reports.

5.1 Select a Database

The first time Dexterit-E Explorer software is run, it will point to the default location of the Dexterit-E database:

- `My Documents\Dexterit-E Data`

1. To select a different database location, select **Database** -> **Open database** and select the root directory you would like to use for the database.
2. If you have multiple databases and would like to switch between databases more quickly, you can use **Database** -> **Recent databases...** to select a database you have used in the past.
3. If Dexterit-E Explorer is run on your Kinarm Lab's Dexterit-E computer there will be an option to open the Verification database, which will display data collected when Dexterit-E is in Verification Mode. To access this option select **Database** -> **Verification database**. In order to leave the Verification database, you need to select a different database from the Database menu.

5.2 Viewing a Database

Once a database has been selected, the list of subjects in that database will be displayed in the Subject database panel as shown in *Figure: 5-1*. The width of the panel can be changed by dragging the bar separating this panel from the Exam review tab. The Subject panel allows the user to select a subject from the list and view their subject information (by selecting the down arrow to the right of Subject information block below the Subject database) as well as any associated data files appearing in the Exams & Reports sub-section. Data file types are either Dexterit-E files (indicated by Kinarm logo icon) or KST reports (indicated by Adobe Acrobat icon).

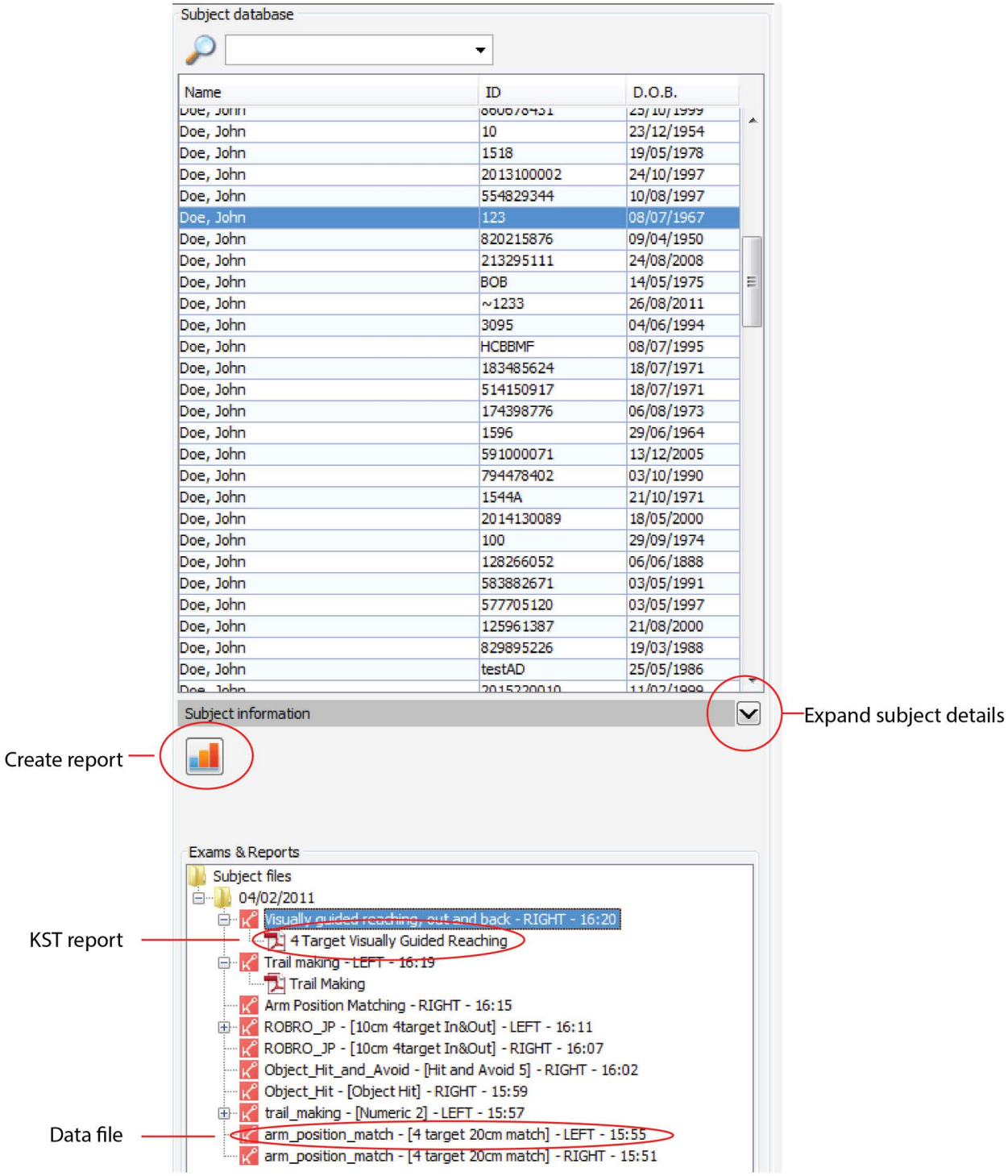
The search field above the list of subjects can be used to filter the subject list. The filtering works against all visible fields.

The files in the Exams & Reports tree are grouped into nodes by date of data collection, with the files for each date listed chronologically in one of three ways:

- **By Exam** - all data files are listed as nodes. If a report has been generated from any of the data files then the report will be listed as a sub-node under the associated data file;
- **By Report** - all reports are listed as nodes. If present in the database, the data file(s) used to generate the report are listed as sub-node(s) under the report; or
- **Flat** - all reports and data files are listed sequentially.

The file grouping method used for the *Exams & Reports* tree can be changed by selecting **View** -> **Organize files by**, or by right-clicking on a file in the *Exams & Reports* tree and selecting **Organize files by** in the context menu.

Figure 5-1: Sample Subject Database



If a data file or report is right-clicked, a context-sensitive menu appears with the options listed in *Table: 5-1*.

Table 5-1: Exams and Reports Context Menu

Name	Description
Organize files by	Use this option to change the organization of the data files and reports displayed in the exam file tree.
Export analysis CSV	This option is available for data files created using KST. See *Section: 7.4 Exporting Analysis of KST Exams to CSV*.
Generate report	This option is available for data files created using KST. See *Section: 7.1 Creating Task Reports*.
Delete file	Use this option to delete a file from the database.
Copy location to clipboard	Use this option to copy the full text of the path to the file in the system clipboard so that it can be pasted into another application (such as Windows Explorer or MATLAB).
Open exam in MATLAB	Use this option to open the exam file for analysis in MATLAB. See *Section: 8.4 Review Data with the Integrated MATLAB Functionality*.
View task protocol	This option is available if a data file is selected. Use this option to view the Task Protocol used while recording the data file. See *Section: 8.1 Viewing and Editing Task Protocols*.
Export exam as CSV	Use this option to export the exam in CSV format. See *Section: 8.3 Exam CSV Export*.
Export analysis image	This option is available for KST Reports. Use this option to save a copy of the image that was used in the KST Report. See *Section: 7.5 Extracting Images from Standard Reports*.

5.3 Refresh the Database

If the database is updated externally to Dexterit-E Explorer while Dexterit-E Explorer software is open (e.g. via data collection in Dexterit-E), then you can refresh the database data to reflect the changes made.

1. Choose **Database** -> **Refresh database** to see the new entries created in the Dexterit-E database.

5.4 Importing Files into the Database

Data files or subjects that have been exported from a database using Dexterit-E can be imported into the Dexterit-E Explorer database. Once you have exported the appropriate files from Dexterit-E then in Dexterit-E Explorer you can use one of the following operations to import the data.

1. Choose **File** -> **Import subjects...** and select the folder with the subject data you want to import.

   This selection opens a standard *File Open* dialog which is used to select the appropriate subject folder to import. It is also possible to select a folder that contains several subject folders.

2. Choose **File** -> **Import exams...** to open the *Subject Selection* dialog that presents a list showing all subjects in the database. The operator can select a target subject. Once selected, the user can browse to the data files for import.

5.5 Export Summaries from the Database

It is possible to export information about subjects and visits to a file using CSV format. In Dexterit-E Explorer you can export the following:

- Subject list - this option creates a CSV file with a line for each subject in the database.
- Visit list - this option creates a CSV file with a line for each date that a subject has exams.
- Exam list - this option creates a CSV file with a line for each exam in the database.

1. Choose **File** -> **Export database summary...**.

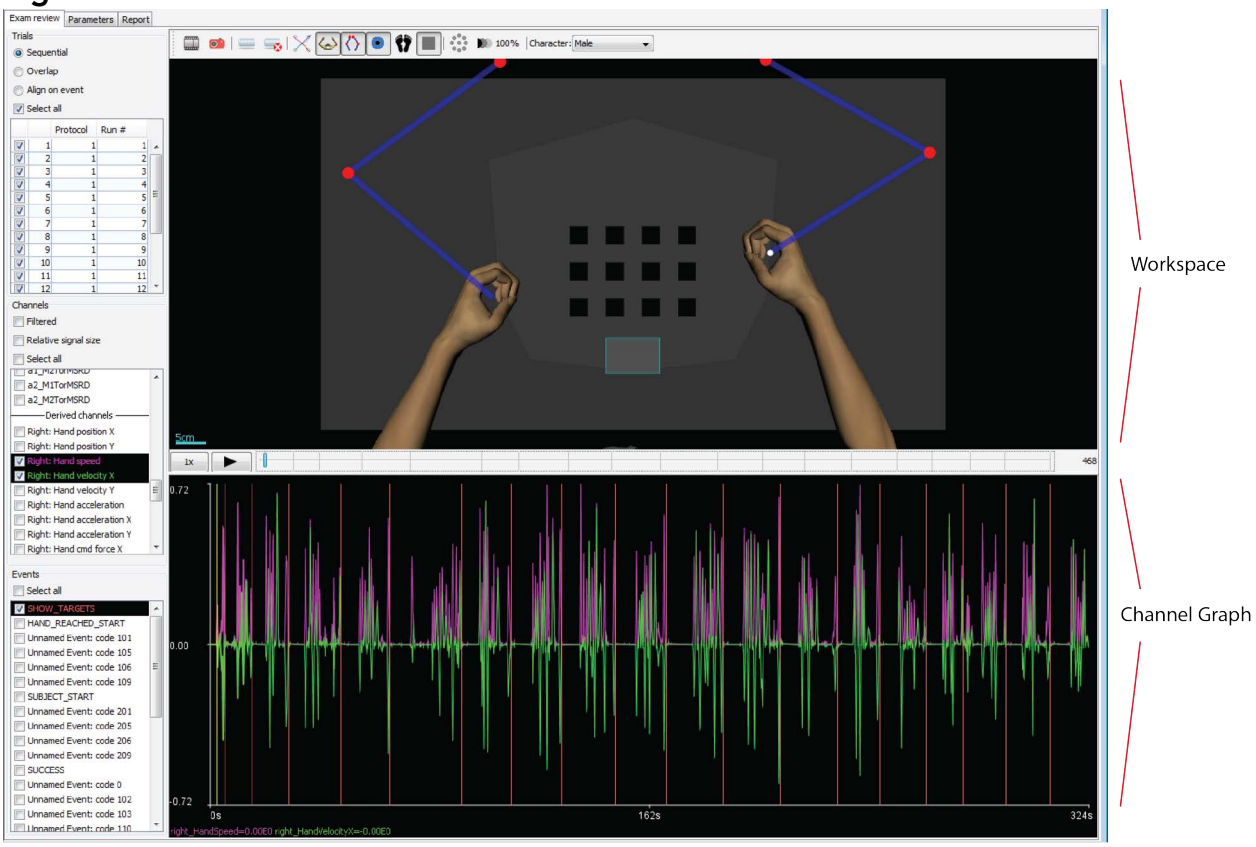
   The *Export database summary* dialog opens.

2. Select the option that reflects the type of CSV file you want to create.

6 Exam Data

Dexterit-E Explorer's power is in its flexible data reviewing capabilities. It offers two viewing spaces to review data from an exam: the workspace, which shows an animation of subject behaviour along with visual stimuli presented to the subject, and the channel graph, which shows plots of selected channel data (e.g. kinematics) versus time. The data shown in these two views are synchronized.

Figure 6-1: Exam Review Tab



6.1 Selecting a Data File

Before reviewing a data file you must first select the desired subject from the subject database (see *Section: 5.2 Viewing a Database*). Once a subject is selected, the list of data files for that subject is presented in the Exams & Reports sub-section of the Subject database panel (*Figure: 5-1*). Clicking or double-clicking a data file, indicated by the Kinarm icon, will open it for review in the Exam Review tab.

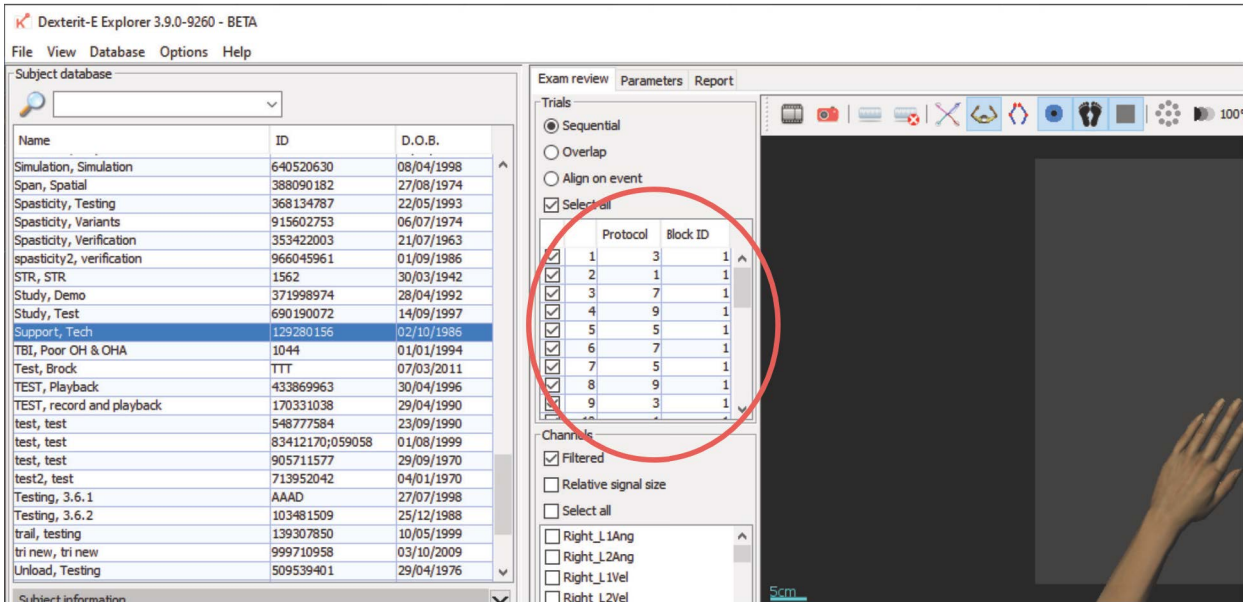
Some data files may be too large to fit into available memory. If a data file is too large to fit in available memory then during the loading process the data will be decimated to a size that does fit in memory (e.g. only displaying every 5th data point). The decimation process does not change the raw data file.

NOTE: If you have an exam file that is not in your database, it can be viewed by dragging and dropping it onto the Dexterit-E Explorer user interface.

6.2 Selecting Trials

Once a data file has been selected, all of the trials in that data file are listed in the Trials table of the Exam Review tab as shown in *Figure: 6-2*.

Figure 6-2: Trials Table



The options in the Trials table allow you to change which trial's data are available in the channel graph, as well as which trials are included in the animation of the workspace view. Trials can be selected or deselected manually, or the **Select All** box can be checked/unchecked. Additionally, if you right-click on a trial in the Trials table, a drop-down list will let you optionally select: only this trial, all trials with the same trial protocol, all trials from the same block, or select all. If you click and highlight multiple trials in the Trials table then you can right-click to select or deselect the highlighted trials.

After one or more trials have been selected, data from those trials will be shown in the channel graph and the first frame of the first selected trial will be shown in the workspace view. In addition, the frame slider between the workspace view and channel graph will be updated to include grey ticks to mark the boundaries between each selected trial (see *Figure: 6-1*). Hovering the mouse pointer on the frame slider will give a tool tip summarizing details on the trial that the mouse pointer is hovering over. Right-clicking on the frame slider will present a context menu allowing you yet another set of options for selecting trials.

NOTE: Trials containing less than 5 kinematic frames of data will not be shown in the list of available trials.

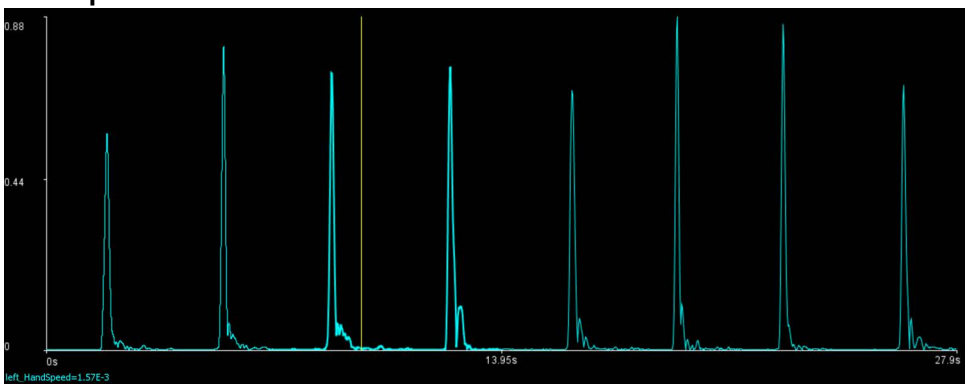
6.3 Trial Alignment and Viewing Options

There are several options for displaying data in the channel graph: Sequential, Overlap and Align on event.

6.3.1 Sequential View

Sequential view displays all of the data from the selected trials in the channel graph, in the order that the selected trials were run. This view is useful for looking at the selected trials as presented to the subject. *Figure: 6-3* shows an example of a sequential view of channel data from several trials. The channel data from the current trial (as determined by the current playback position) is always highlighted slightly.

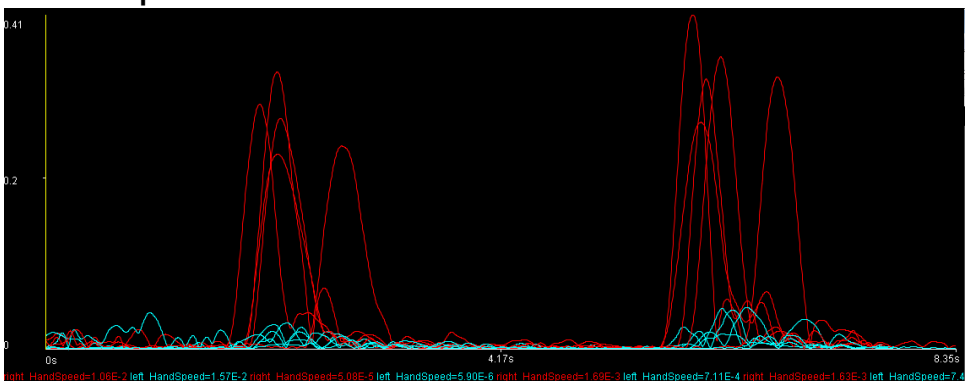
Figure 6-3: Sequential View of Channel Data



6.3.2 Overlap View

Overlap view displays all selected channel data on top of each other in the channel graph as though each trial started at time zero (see *Figure: 6-4* and compare to the sequential view shown in *Figure: 6-3*). Overlap view is one means for comparing channel graphs from trial to trial.

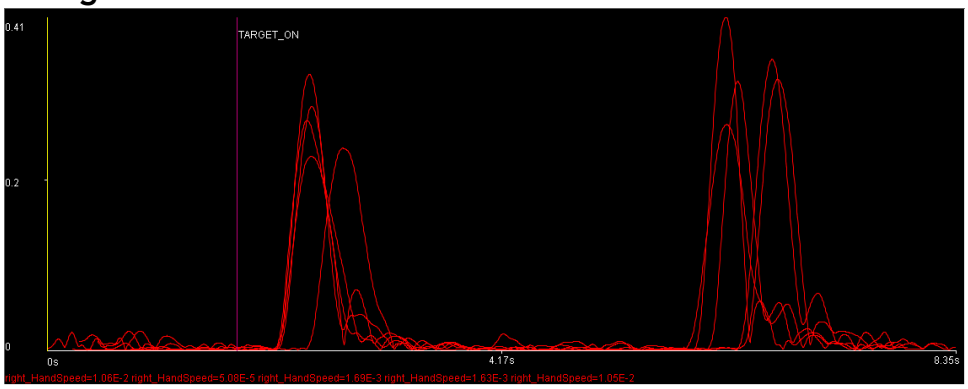
Figure 6-4: Overlap View of the Channel Data



6.3.3 Align on Event View

Align on event view is similar to overlap view, but instead of aligning the selected trials in the channel graph to the start of each trial, when Align on event view is checked the first event selected in the event list is used to align the data in the channel graph. For example, if the first event selected is an event called "TARGET_ON", then each trial has its start shifted such that each trials' TARGET_ON event is aligned in time (see *Figure: 6-5* and compare to Overlap view in *Figure: 6-4*). This method provides a second means for comparing channel graphs between trials. In order to use Align on event, you need to have created appropriate events in your task prior to data collection.

Figure 6-5: Align on Event View



6.4 Channel Selection

The channels list allows you to select which channel data are rendered in the channel graph. For a channel to appear in the channel graph you must first select it in the channel list, as shown in *Figure: 6-6*. When a channel is selected, its name is highlighted in the colour that is used to render the channel in the channel graph.

There are two types of channels in the channels list: recorded and derived. Recorded channels are those recorded during an exam and saved to the data file. The recorded channels are always listed first in the channels list. Derived channels are those calculated at load time by Dexterit-E Explorer software. All derived channels are listed after the "Derived channels" marker in the channel list. The derived channels are not saved to the data file; they are calculated every time the file is opened. The list of derived channels can be found in *Table: 6-1*.

Hovering your pointer over a channel name provides a tool tip description of that channel. Right-clicking on a channel name to select a new colour for drawing the channel.

Figure 6-6: Channel List

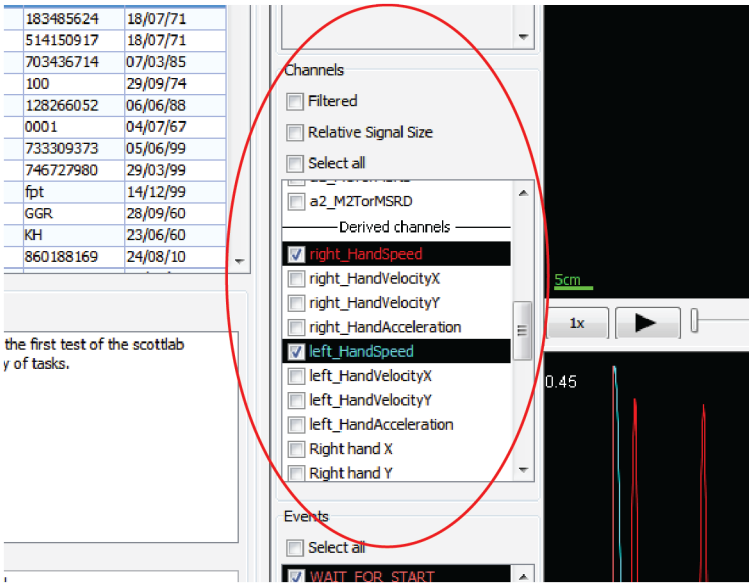


Table 6-1: Derived Channels (Sheet 1 of 2)

Name	Description	Units
[Right/Left]: Hand position X	Position of the hand in the X-direction.	m
[Right/Left]: Hand position Y	Position of the hand in the Y-direction.	m
[Right/Left]: Hand speed	The speed of the hand.	m/s
[Right/Left]: Hand velocity X	The velocity component of the hand speed in X.	m/s
[Right/Left]: Hand velocity Y	The velocity component of the hand speed in Y.	m/s
[Right/Left]: Hand acceleration X	The acceleration of the hand in the X-direction.	m/s^2
[Right/Left]: Hand acceleration Y	The acceleration of the hand in the Y-direction.	m/s^2
[Right/Left]: Hand acceleration	The acceleration of the hand.	m/s^2
[Right/Left]: Hand cmd force X	The commanded force at the hand in the X-direction.	N
[Right/Left]: Hand cmd force Y	The commanded force at the hand in the Y-direction.	N
[Right/Left]: Hand cmd force total	The total commanded force at the hand.	N
[Right/Left]: Shoulder angle	The angle of the shoulder.	rad
[Right/Left]: Elbow angle	The angle of the elbow.	rad
[Right/Left]: Shoulder velocity	The angular velocity of the shoulder.	rad/s
[Right/Left]: Elbow velocity	The angular velocity of the elbow.	rad/s
[Right/Left]: Shoulder acceleration	The angular acceleration of the shoulder.	rad/s^2
[Right/Left]: Elbow acceleration	The angular acceleration of the elbow.	rad/s^2
[Right/Left]: Cmd shoulder torque	The commanded torque at the shoulder.	N·m
[Right/Left]: Cmd elbow torque	The commanded torque at the elbow.	N·m
Force plate [1/2]: COP X	Location of the centre of pressure on the force plate, X-component.	m
Force plate [1/2]: COP Y	Location of the centre of pressure on the force plate, Y component.	m

Table 6-1: Derived Channels (Continued) (Sheet 2 of 2)

Name	Description	Units
Video frame interval time	The time between video frames being acknowledged.	ms
Video frame drop rate	The count of video frames that were not drawn so far in the task.	count

NOTE: Shoulder and elbow based channels are in a "local" coordinate frame. For the right arm the angles are counter clockwise, for the left arm the angles are clockwise. Having the upper arm parallel to the subject's back equates to a shoulder angle of 0°. Having the forearm parallel to the upper arm equates to an elbow angle of 0°.

6.5 Channel Viewing Options

6.5.1 Channel Data Filtering

When the **Filtered** checkbox is checked all channels that can be filtered will be displayed in the channel graph after being filtered with a 6th order, 10 Hz, double-pass Butterworth filter. Some of the derived channels do not allow filtering, so this setting will have no effect on them.

6.5.2 Signal Size in the Channel Graph

Channels are normally drawn with absolute heights, where the Y scale maximum is based on the highest absolute value for all channels (see *Figure: 6-7*). When **Relative Signal Size** is checked, all channels are drawn in the channel graph showing their maximum spread (see *Figure: 6-8*).

Figure 6-7: Absolute Channel Size - Scale Determined by the Largest Signal

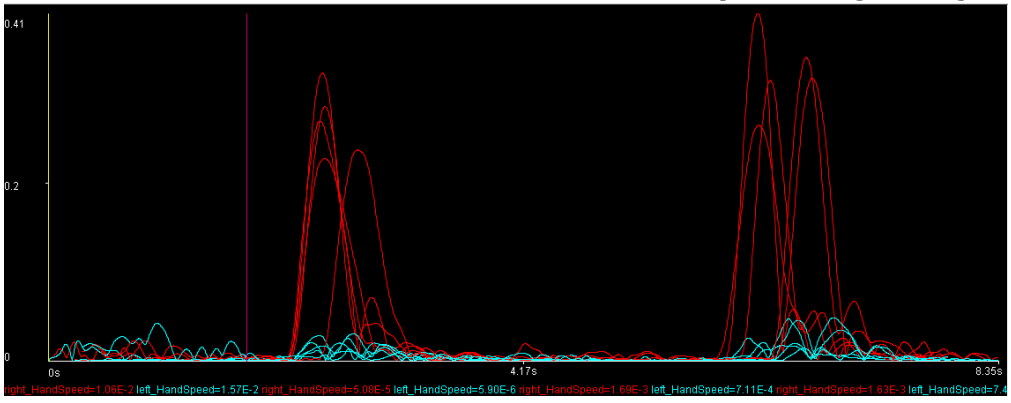
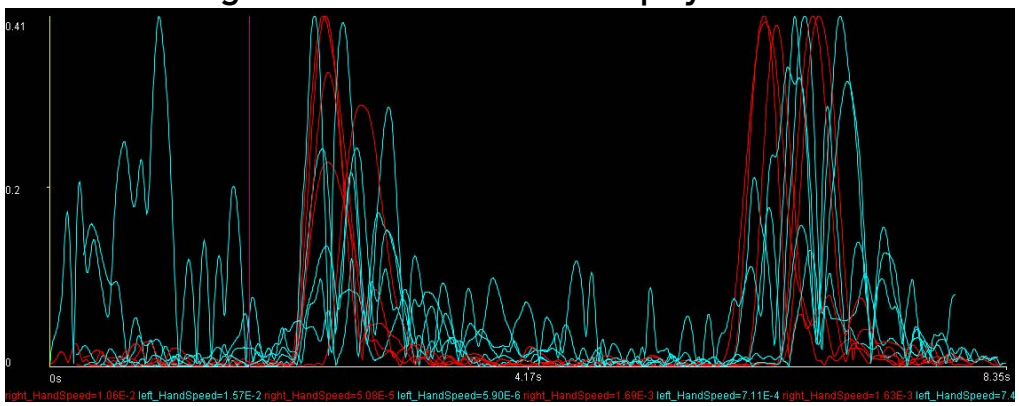


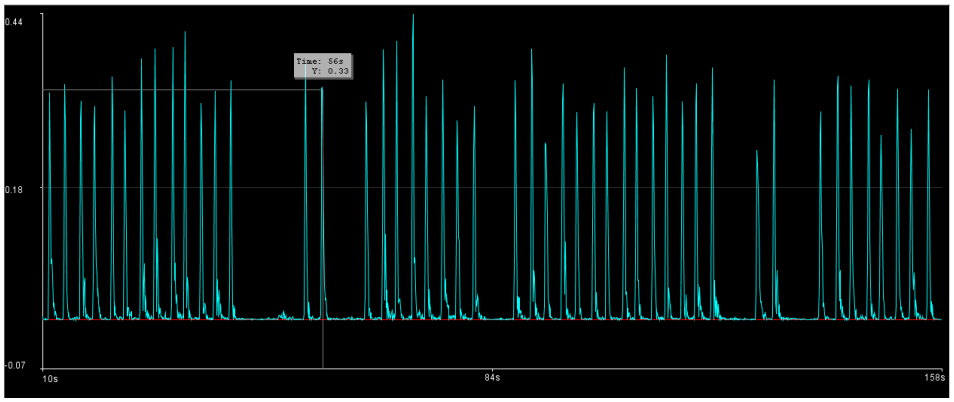
Figure 6-8: Relative Signal Size - Each Channel Displayed at Maximum Scale



6.5.3 The Data Cursor

Right-clicking on the channel graph displays a context menu listing the **Data cursor** option. When selected, the graph is displayed in data cursor mode. As the mouse pointer is moved around the graph, the time and Y-values of the cursor are displayed in a tool tip as shown in *Figure: 6-9*. Data cursor mode does not function when **Relative Signal Size** is checked as a *Channel graph* option.

Figure 6-9: The Data Cursor



6.5.4 Channel Graph Zoom Capabilities

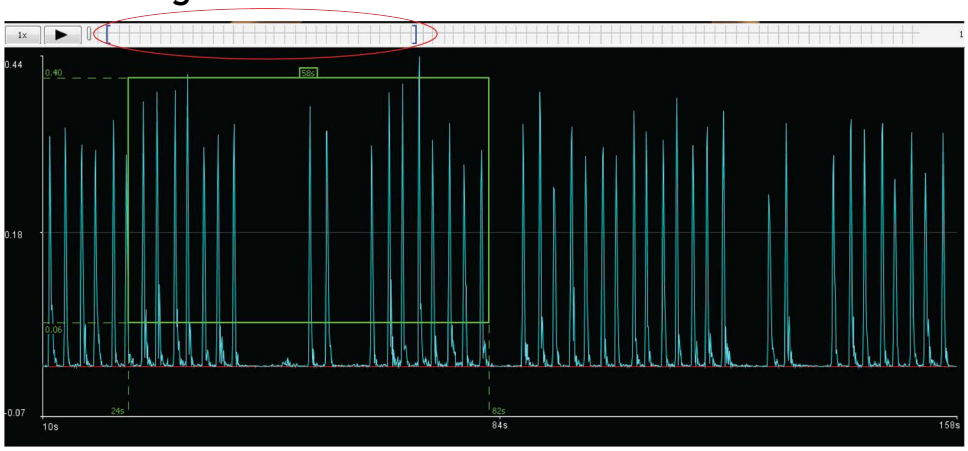
It is possible to zoom into any section of the channel graph. Dragging the mouse in the region to the left of the Y axis will change the visible height of the channel. Dragging the mouse in the region below the time axis will zoom into a given time region of the graph. Dragging the mouse within the limits of the graph will change both the visible height and time simultaneously.

When the time is zoomed there will be blue markers on the frame slider indicating the portion of the selected trials that are zoomed into, as shown in *Figure: 6-10*. Right-clicking on the channel graph provides the option of resetting the view/range to the original view or undoing the last zoom.

If you click the mouse on the graph then you can use the following keys to alter the zoom:

- Arrow keys slide the zoom window around the graph (hold the **Shift** key while pressing the arrow keys to increase the size of shifts).
- **Ctrl + +** zoom into the graph.
- **Ctrl + -** zoom out of the graph.
- **Ctrl + Z** undo previous zooming

Figure 6-10: Zooming

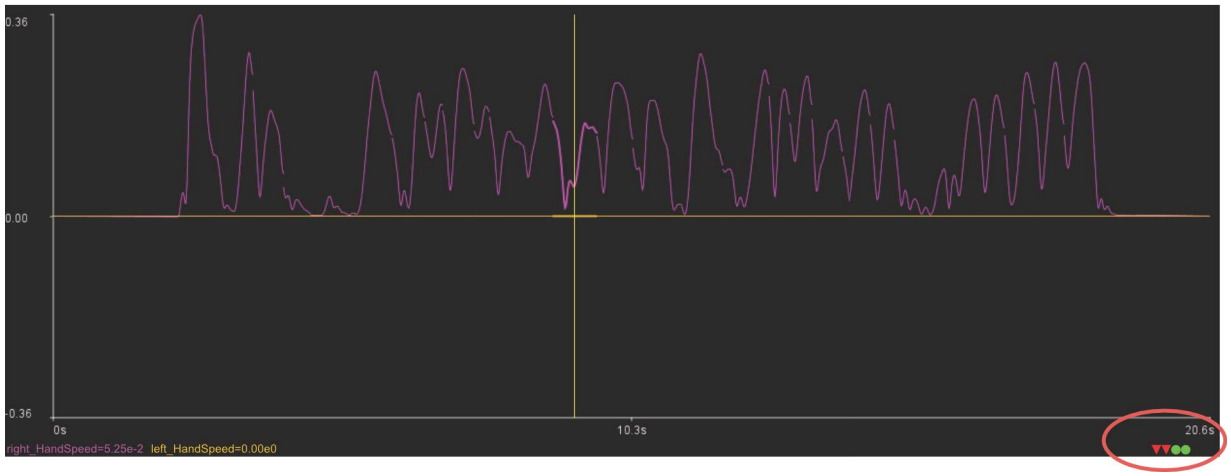


6.5.5 Status Indicators

In the bottom right corner of the channel graph are a set of status indicator icons that mirror what the operator would have seen in Dexterit-E. There are status icons for:

- The status of each motor
  - Green circle - the motors were working
  - Red triangle - the motors were disabled
  - Yellow triangle - the current to the motors was limited (i.e. forces were clipped)
- The status of the grip sensors on a Kinarm End-Point Lab (PN 14332 and later only)
  - Green circle - the subject was holding the handle
  - Red triangle - the subject was not holding the handle

Figure 6-11: Status icons



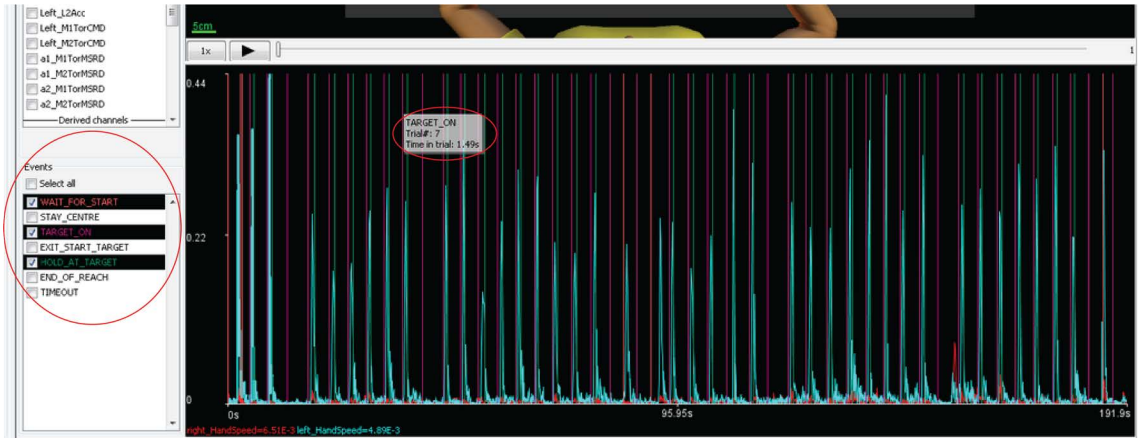
NOTE: The data used to display these status indicators comes from the `StatusBits` channel that is stored in the exam file. See the Dexterit-E User Guide for details on how to interpret the data when analyzing data in MATLAB.

6.6 Event Selection

Events are named time-stamps that the creator of a Task Program specifies and defines in the Task Program. They are recorded in the data file when the event criteria is fulfilled. For example, a task creator could define an event named "TARGET_ON" such that the task will save this event when a target is turned on. Within the Dexterit-E Explorer channel graph, you can see events overlaid at the time they occurred. Similar to channels, events are colour-coded.

- Hovering over an event in the *Events* list will show the description of the event that the task creator defined.
- When an event is checked in the *Events* list, its name will be displayed in the event's highlighted colour in the list.
- If you right-click on an event in the *Events* list you can select the colour the event is drawn with.
- Hovering over an event's vertical line in the channel graph will give a tool tip showing the event's name as shown in *Figure: 6-12*.

Figure 6-12: Events List



6.7 Workspace View Options

When reviewing a data file in the Dexterit-E Explorer workspace view (*Figure: 6-13*) a viewer can customize the animation using tools listed in the **Review tools...** tool bar. This tool bar may be moved within the window. These options are summarized in *Table: 6-2*.

Figure 6-13: Workspace View

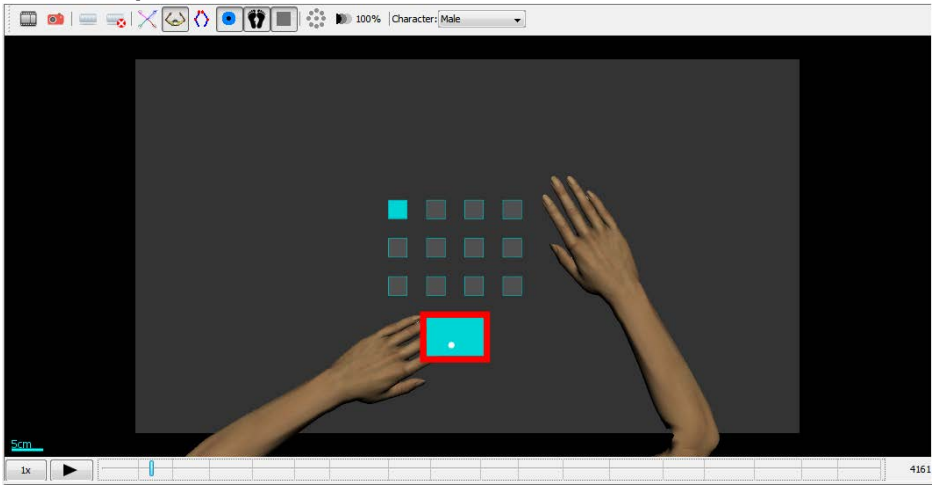


Table 6-2: Workspace View Options (Sheet 1 of 3)

Icon	User Action	Description
	Record movie	Use current settings to record a movie in QuickTime (MOV) or AVI format.
	Take snapshot	Use the current settings to save the workspace view and or the channel graph as a: JPG, PNG, or SVG image.

Table 6-2: Workspace View Options (Continued) (Sheet 2 of 3)

Icon	User Action	Description
	Place calipers in workspace view	When in caliper mode, dragging the mouse on the workspace view draws a caliper which can be used to measure distance.
	Remove all calipers	Remove all calipers that have been drawn in the workspace view.
	Show hand paths	Display or hide the complete hand path traces for all selected trials. Hand path style options can be controlled via the **Options** -> **Exam** review options. The options include seeing the full hand path at all times or just the last N seconds of the path.
	Show subject	Display or hide the animated subject.
	Show robot linkages	Display or hide the drawn robot arms.
	Show gaze position	Display or hide the subject's gaze position if it was collected during the exam and saved to the data file.
	Show centre of pressure	Display or hide the subject's centre of pressure on each force plate if it was collected during the exam and saved to the data file.
	Show the workspace limits	Display or hide the rectangle that denotes the limits of the subject's workspace.
	Show targets in Target Table	Display or hide all targets defined in the Target Table that were used in the task. If your task has VCODES available for animation then this will not be available as an option.
	Adjust the visual stimuli opacity	Adjust the opacity of the visual stimuli that were displayed to the subject. The subject's arms are drawn under the visual stimuli so this makes the arms more visible.
	Select a character from the drop-down list	Changes the animated subject between a male, female, child and NHP character.
	Mouse click-and-drag	Shifts the position of the image in the workspace view.

Table 6-2: Workspace View Options (Continued) (Sheet 3 of 3)

Icon	User Action	Description
	Mouse wheel	Zooms the workspace view in and out.
	Right-click (or double-click)	Resets the workspace view to the default zoom level and position.

6.7.1 Distance Measurement with Calipers

As mentioned in *Table: 6-2*, calipers can be overlaid on the workspace view to measure the distance between two points. Once a caliper is in place, it can be adjusted in one of two ways. When the mouse is over the main line of the caliper, the caliper will be highlighted and at that point the mouse can be used to drag the caliper around the workspace view. When the mouse is over one end of a caliper the end will be highlighted, at that point the mouse can be used to drag the end of the caliper to change the measurement.

When a caliper is highlighted, a right-click will display a context menu which gives the option to remove the caliper. The same context menu can also be used to remove all calipers from the workspace view.

6.8 Extracting Movies from Exams

Creating movies from data files is one of the central functions of Dexterit-E Explorer software. When a movie is created the exact contents of the workspace view and/or the channel graph are recorded. You have the option of recording subject behaviour for an entire exam, or only a part of the exam.

6.8.1 Selecting a Portion of an Exam for a Movie

In order to record only part of an exam, first select only the trials you would like in the Trials table (see *Figure: 6-2*). If desired, you can additionally time-zoom in the channel graph the selection of time you wish to record (see *Figure: 6-12*).

6.8.2 Movie Options

The options available when making a movie are shown in *Figure: 6-14* and described in *Table: 6-3*.

Figure 6-14: Movie Saving Options

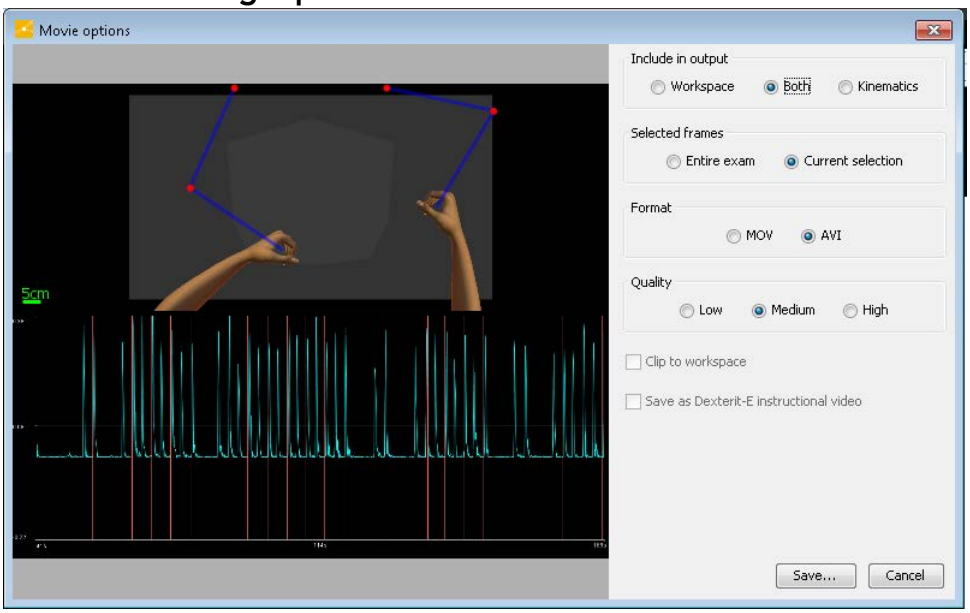


Table 6-3: Movie Making Options (Sheet 1 of 2)

Option	Description
Included in output	When making the movie, you can decide what is recorded: • Just the animation in the workspace area, • Just the channel graph, or • Both.
Selected frames	By default the subject behaviour for the entire data file will be recorded. If there is a sub-set of trials selected, or a portion of the data file has been selected by zooming into a particular time region in the channel graph, then the **Current Selection** option will be available to allow you to record a sub-set of the data file.
Format	Movies can be saved in QuickTime (MOV) format for Mac computers or AVI format for Windows computers (although both formats can technically be read on either platform, these are the recommended formats).
Quality	The quality refers to the amount of compression applied to the movie. The greater the compression, the lower the quality of the movie, but the smaller the file size. The correct balance between quality and size will depend on your needs.

Table 6-3: Movie Making Options (Continued) (Sheet 2 of 2)

Option	Description
Clip to workspace	Selecting **Clip to workspace** means that the limits of the output video will match the subject's workspace. This option is only available when **Include in output** is set to **Workspace**.
Save as Dexterit-E instructional video	This option will set all preferences appropriately for the creation of a video suitable for use within Dexterit-E's instructional video feature. When combined with **Clip to workspace**, this option produces a video that is displayed to a subject at the exact size of the original data (i.e. 1:1 scaling).

6.9 Snapshot of Exam

Snapshots are images of what is shown in the workspace view, channel graph or both. In order to create a snapshot, first set up the workspace view and or channel graph as you would like (e.g. *Figure: 6-15*), then click the **Take snapshot** button in the tool bar. Available options for creating the snapshot are described in *Table: 6-4*.

Figure 6-15: Snapshot Saving Options

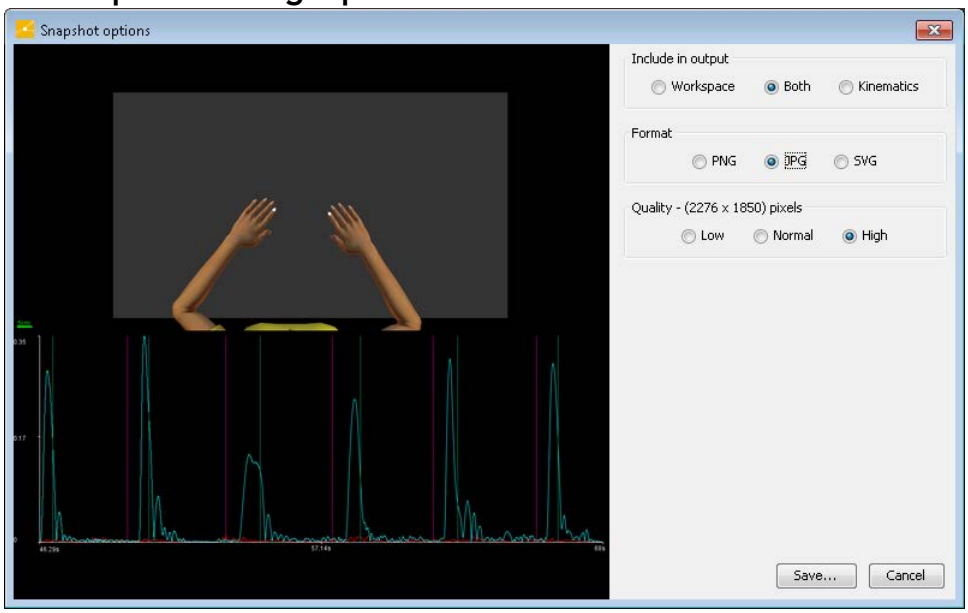


Table 6-4: Snapshot Options

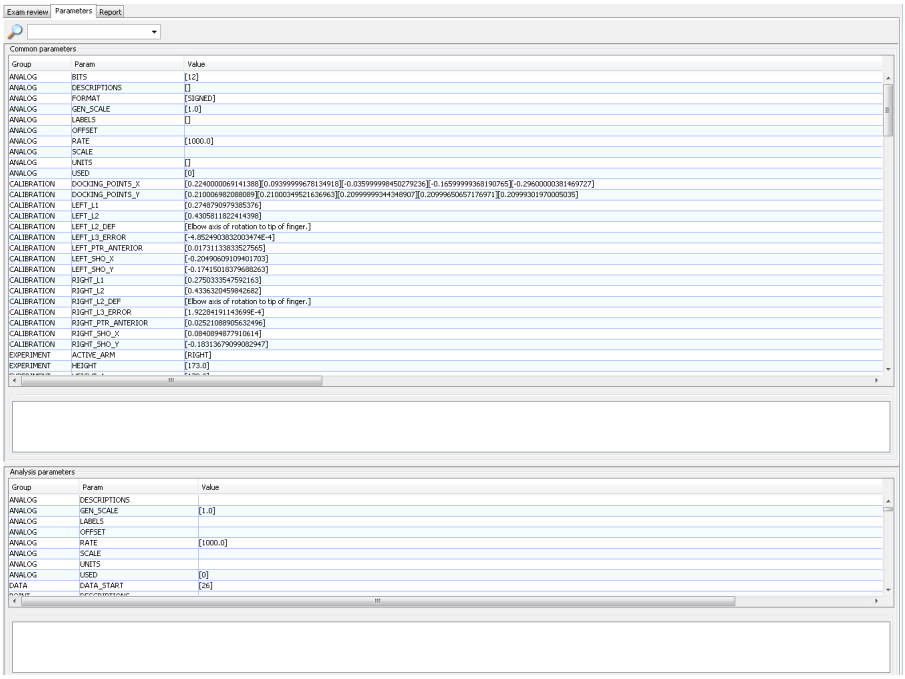
Option	Description
Format	Available formats are: PNG, JPG, and SVG. • PNG - widely readable, lossless (i.e. what is on the screen is what is in the image), scales larger well but will have scaling artifacts at larger sizes. • JPG - widely readable, lossy (i.e. the image can look smudged compared to what's on the screen), does not scale larger very well. • SVG - not widely readable, vector graphic format (i.e. what's on the screen is in the image with no smudging at any scaling), scales larger very well.
Quality	• Low - the snapshot will be 1/2 the size and resolution of the workspace view on the screen. • Normal - the snapshot will be the size and resolution of the workspace view on the screen. • High - the snapshot will be twice the size and resolution of the workspace view on the screen. This is the only setting for SVG graphics as scale does not affect the image.
Include in output	When making the snapshot, you can decide what is recorded: • Just the animation in the workspace view, • Just the channel graph, or • Both.

6.10 Data File Parameters

When a data file is selected for viewing, the parameters in the data file are loaded into the Parameters tab (*Figure: 6-16*). In the Parameters tab all of the common parameters saved with the data file are available. If the exam was collected as part of KST and has been analyzed, then the results of the analysis are also available in the Parameters tab, in the Analysis parameters sub-section.

The parameters can be searched using the search box at the top of the page. Searching scans both parameter names and values.

Figure 6-16: Parameters Tab



7 Reporting and Analysis of KST Exams

Dexterit-E Explorer is capable of working with Kinarm Standard Test (KST) data files. A user can: export analysis, create Standard Reports, and view Standard Reports.

NOTE: There are three types of Standard Reports:

- Task Report: provides a summary of the subject performance for a specific task.
- Session Report: when Study Protocols are used, provides a summary of the subject's performance for all KST completed in a single Session.
- Longitudinal Report: when Study Protocols are used, provides a summary of the subject's performance for all KST completed for all Sessions defined by the Study Protocol.

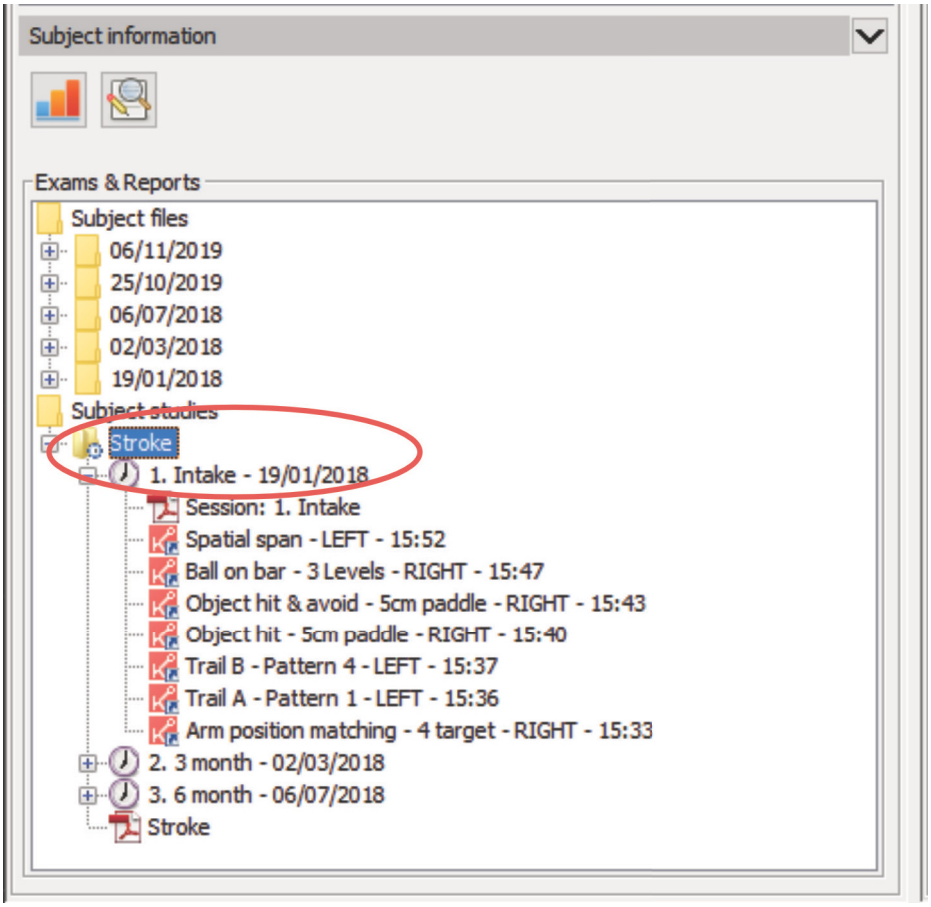
7.1 Creating Task Reports

In order to create a Task Report in Dexterit-E Explorer, first select the KST data file that you would like to use to generate the report. Once the data file is selected, the **Create report** button from *Figure: 5-1* will become enabled and can be used to generate the report. If a report requires 2 exam data files (e.g., Arm Position Matching) then a dialog will be presented to allow you to select the second data file. Once the report has been created it will be added to the database and opened immediately for viewing.

7.2 Creating Session and Longitudinal Reports

It is possible to create session and longitudinal reports using Dexterit-E Explorer. These report types require that exams are recorded using the Study tab in Dexterit-E 3.8 or later and therefore will have been recorded as part of a Study Session. Exams recorded as part of a Study Session are displayed as shown in *Figure: 7-1*.

Figure 7-1: Study Session Exam Tree



Selecting a Study folder (e.g. "Stroke" in *Figure: 7-1*) enables the button to create reports. Clicking the **Create report** button while a Study folder is selected will create a Longitudinal Report that takes data from all sessions in that Study.

Selecting a Session time point (e.g. "1. Intake" in *Figure: 7-1*) also enables the button to create reports. Clicking the **Create report** button while a Session time point is selected will create a Session Report.

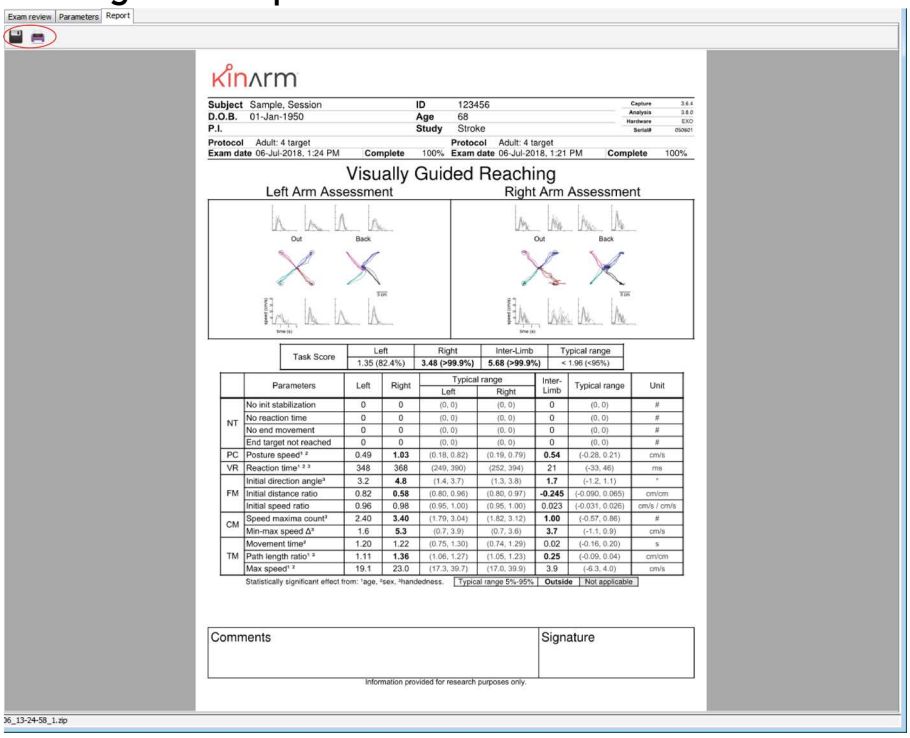
Further information on longitudinal and session reports can be found in *Section: 9.2.6 Session and Longitudinal Reports*.

NOTE: Exams within sessions can be removed from a session or moved to other sessions in the same study by right-clicking the exam reference and selecting the appropriate option from the context menu.

7.3 Viewing a KST Report

Any Standard Reports that have been created as part of Kinarm Standard Tests (KST) can be viewed using Dexterit-E Explorer software. To view a report simply double-click the report in the Exams & Reports list (as indicated by the Adobe Acrobat™ icon). Once a report is open you have the option to print or save the report using icons in the tool bar at the top (*Figure: 7-2*).

Figure 7-2: Viewing a KST Report



7.4 Exporting Analysis of KST Exams to CSV

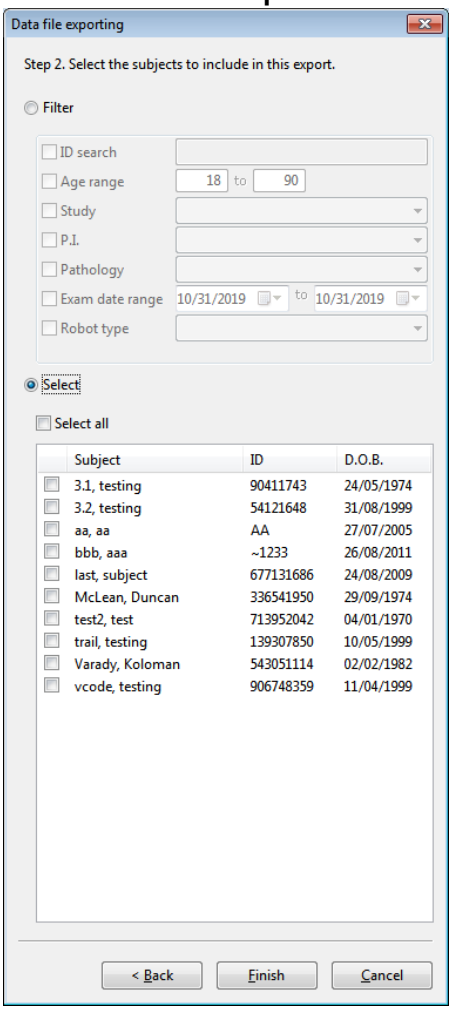
Dexterit-E Explorer is able to analyze exams created with Kinarm Standard Tests in Dexterit-E and export the analysis results in CSV format (suitable for importing into any spreadsheet program - e.g., Microsoft-Excel). This output will exactly match that from Dexterit-E. For complete details on Kinarm Standard Tests, the analysis values generated and the normative databases used see *Section: 9.2 Common Features of Standard Tests* and *Section: 10 KST Version History*.

In order to generate a CSV file, select **File** -> **Export analysis…** The presented wizard first allows you to select the type of Kinarm Standard Test you would like to analyze. In the next stage of the wizard you will be asked to filter the Subjects/Exams you would like to export into the CSV file. *Figure: 7-3* shows the available filtering options. You are allowed to filter based on:

- Subject or exam criteria. The filter is an "and" filter, meaning all specified criteria must be met.
- Manually selected subjects.
- IDs supplied in a CSV file. The CSV file supplied must have a column titled either ID or Subject ID. The subject IDs in the CSV file will be used to determine which subjects can be included in the output.

In addition you can optionally anonymize the data which removes names and date-of-birth from the CSV output file.

Figure 7-3: Exam File Selection for CSV Output



7.5 Extracting Images from Standard Reports

Sometimes it can be useful for presentation purposes to extract the image used to create a Standard Report. Images can be extracted in several ways. The images are all exported in the JPG file format.

1. To extract images from a report, right-click on the KST report and use the **Extract report images** context menu option.
2. To extract images from all exams performed on a specific date, right-click on the date node in the file tree and use the **Extract report images** context menu option. This option will extract all report images for exams collected on the given date into a single folder.
3. To generate a directory of images from selected files, use **File** -> **Extract report images**. This option takes you through a selection process very similar to export CSV analysis. The final result will be a directory of images from the selected reports.

8 Additional Features

8.1 Viewing and Editing Task Protocols

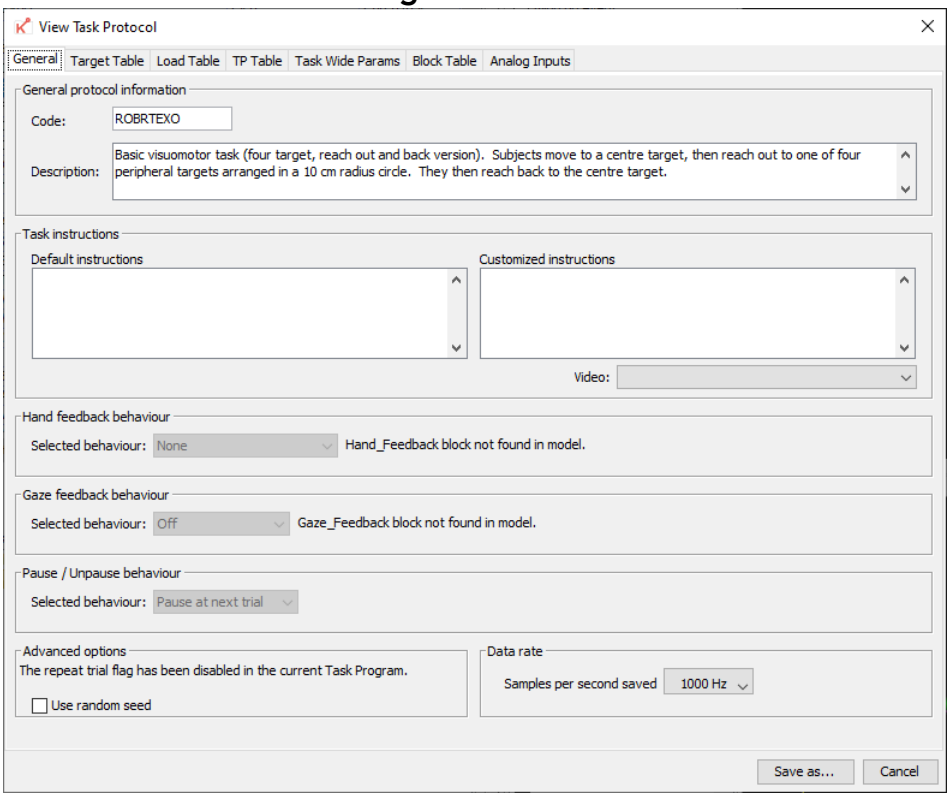
There are three methods for viewing and editing Task Protocols.

- Opening a Task Protocol file (*.DTP) directly. Opening a Task Protocol file directly is accessed from **File** -> **Edit stand alone protocol**.
- Opening a Task Protocol from an exam file. For data collected using Dexterit-E 3.6 and later Dexterit-E Explorer is capable of accessing Task Protocols indirectly by creating a copy of, and displaying, the Task Protocol that was used when the exam file was created. This functionality can be accessed by right-clicking on a data file in the exam tree and selecting **View task protocol**.
- *.DTP files can be dragged and dropped onto Dexterit-E Explorer.

All methods allow the option of editing and saving a copy of the Task Protocol file.

Figure: 8-1 shows the View Task Protocol dialog. The dialog works similarly to the *View Task Protocol* dialog in Dexterit-E (please refer to the Dexterit-E User Guide for more details).

Figure 8-1: View Task Protocol Dialog



8.2 Set the Date Format

The software supports the following date formats:

NOTE: The format you choose is used throughout the application and when generating reports.

- ISO-8601: yyyy-MM-dd
- CDASH: dd-MMM-yyyy
- System default: dd/MM/yyyy

1. From the **View** menu, choose **Date Format...**
2. Select the desired option.

8.3 Exam CSV Export

As part of your Kinarm lab, you have access to the Kinarm Analysis Scripts. With these scripts you can load exam files directly into MATLAB. For working with other programming languages, Dexterit-E Explorer also allows you to export exams as CSV files.

It is possible to export exams as CSV files either in bulk or one at a time. To export exams in bulk, select **File** -> **Export exams as CSV**. You will be able to select the types of exams to export and further filter similar to *Figure: 7-3*. When exporting this way, all CSV files are exported into a separate folder for each subject. Alternatively, you can right-click on an exam file in the *Exams & Reports* tree and select **Export exam as CSV**.

The format of the exported CSV is, as follows:

- File name: [name of the source file]
- File label: [label displayed in the file tree for the exam file]
- ===, Common
  - What follows are parameters that apply to all trials in the CSV export
  - [parameter group], [parameter name], [description], [value], [value], ...
- <Blank line>
- ===, New trial
  - What follows are parameters that apply to a specific trial
  - [parameter group], [parameter name], [description], [value], [value], ...
  - <Blank line>
  - Kinematics:
  - Trial # - The trial number in the exam. This is in the first row of data only.
  - TP Row - The row in the TP Table this trial is for. This is in the first row of data only.
  - Block Row - The row in the block table this trial is for. This is in the first row of data only.

  - Sample duration (s) - The duration of each sample in the list. This is in the first row of data only.
  - Sample count - The number of samples (rows) in the trial. This is in the first row of data only.
  - Event name - Name of an event that occurred.
  - Event time (s) - The time from the start of the trial at which the event occurred.
  - Video frame sent - The ID of a video frame that was sent at the event time.
  - Video frame ACKed - The ID of a video frame acknowledgment that was received at the event time.
  - Frame # - A monotonically increasing number for each frame of data.
  - Frame time (s) - The time from the start of the trial to the time of the frame of data.
  - One column for each stored or calculated kinematic type.
- <Blank line>

NOTE: Kinarm Support provides example code in Python and Java for reading the CSV format output.

8.4 Review Data with the Integrated MATLAB Functionality

It is possible, from within Dexterit-E Explorer, to export data directly to MATLAB. You can perform a data review in Dexterit-E Explorer and follow it with a more comprehensive review and analysis in MATLAB, using the same data.

NOTE: This feature is only available on Microsoft Windows platform versions of Dexterit-E Explorer.

NOTE: For the integration to work properly, you will need to ensure that the Kinarm Analysis Scripts (available on the Kinarm Support website) are in the MATLAB path.

1. If not already done so, set up the MATLAB/Dexterit-E Explorer integration:
   a. Choose **Options** -> **MATLAB integration**.

      The integration setup dialog automatically finds supported versions of MATLAB currently installed on your computer. Supported MATLAB versions are those that are supported by Dexterit-E for task development.

   b. Select the version of MATLAB you want to integrate with.
   c. Click the **Test integration** button.

      MATLAB should open and Dexterit-E Explorer will inform you if the Kinarm Analysis Scripts were properly found.

2. With the integration enabled, choose from the following:
   - To run the zip_load() script on the selected file, right-click on the exam in the *Exams & Reports* tree and select **Open Exam in MATLAB**.
   - To copy the currently displayed channel data into MATLAB, right-click on the Channel graph and select **Send channels to MATLAB**. When the copy is complete, the destination variable name for the transferred data is displayed.
   - To copy the currently displayed channel data into MATLAB for plotting in a new figure, right-click on the Channel graph and select **Plot channel in MATLAB**. When the copy is complete, the destination variable name for the transferred data is displayed.

8.5 Generate a Log File

Generating a log file allows you to send various information to Kinarm Support. Generating a log automatically finds relevant files for Kinarm Support and places them in a ZIP file on the computer's desktop. The ZIP file will have a name like DexEx_logs.zip; the name of the file will be given to you once the log is generated. Please email the ZIP file to Kinarm Support along with a complete description of the problem you are seeing and also any relevant details on how to re-create the problem and/or what caused it in the first place.

1. Choose **Help** -> **Generate log**.

   A ZIP file is generated on your computer's desktop.

9 Kinarm Standard Tests

Kinarm Standard Tests (KST) are composed of Standard Tasks and their associated Standard Reports. Standard Tasks are accessible from the *Standard tasks* and *Study* tabs. Most of the tests have a database of normative scores (see *Section: 10 KST Version History*), which are used to present typical ranges of behaviour on the Standard Report (see *Section: 9.2.5 Features of Standard Reports*) and also to generate Z-scores for more detailed comparison and subsequent analysis (see *Section: 9.2.7 Standard Data Exported to CSV*).

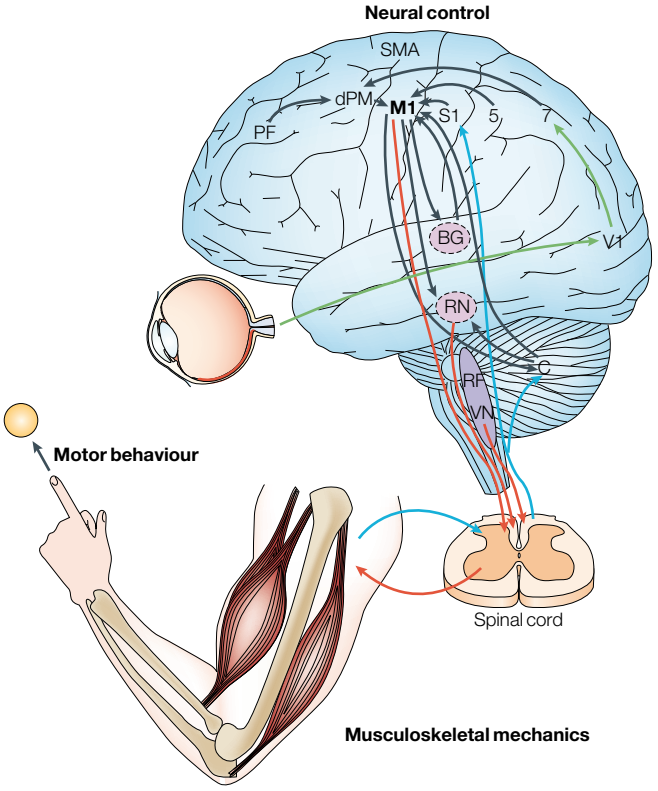
NOTE: Kinarm Standard Tests are an optionally licensed product available for your Kinarm Lab. If you do not see the *Standard tasks* tab when you start Dexterit-E then your license does not include Kinarm Standard Tests. Please contact **Kinarm Support** if you wish to enable this feature.

9.1 Overview

Kinarm Standard Tests provide an objective and sensitive approach to quantify cognitive, motor and sensory functions through the precise measurement of human behaviour - a method we call behaviourography™. By using this suite of standardized protocols, a clinical researcher can conduct a broad-based assessment of brain function in a short period of time (30 to 60 min, depending on the tasks selected and the severity of a subject's impairment; see *Section: 9.2.1 KST Task Durations*).

It is important to recognize that any human behaviour inherently reflects sensory perception, cognition and motor actions to varying degrees, and that each of these processes are generated by distinct yet overlapping neural circuits (e.g., see *Figure: 9-1*). Each Standard Task is grounded in the principles of neuroscience in order to emphasize one or more of these processes to quantify specific impairments in a given brain function as well as impairments in how different brain circuits interact to generate purposeful behaviour. Further, some behavioural tasks build on other tasks to help separate and isolate different brain functions, notably cognitive versus motor impairments. *Figure: 9-2* and *Table: 9-1* loosely classify each task based on its dominant focus on cognitive, motor or sensory function.

Figure 9-1: Neural Circuits Controlling Human Behaviour



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Nature Review Neuroscience (Scott SH, 2004 Jul;5(7):532-46),
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Nature Reviews | Neuroscience

Each task is also specifically designed to have simple instructions and be short in duration. The analysis produces parameters that: demonstrate face validity; are repeatable and responsive; provide high resolution, sensitive and objective measurements; and minimize floor and ceiling effects.

All tasks developed to-date, were originally developed for adults. In Dexterit-E, Task Protocols for adults are available as a standard option; child versions of the protocols have been added recently and are now included as standard as well. Normative models have been developed for ages 18 - 85 years old for the adult protocols. Adult-sized individuals under 18 years old can perform the adult protocols, and their performance can be quantified. However, Z-scores and typical ranges of performance for 15-17 year olds are calculated as if they were 18 years old; Z-scores and typical ranges of performance are not provided for those younger than 15. Normative models are under development for the child protocols, and will be released as part of a future release of KST.

Kinarm Standard Tests are not indicated for subjects who do not have adequate cognitive function to understand task instructions, and/or who do not have visual and/or auditory acuity to permit adequate perception of instructions or task stimuli.

The original citation(s) used in the design of each task is included in the Test section descriptions that follow. It is also listed on the publications page of Kinarm's website (http://www.kinarm.com/clinical-applications/publications-by-research-area/). We encourage you to review the original citation to fully understand the Test and behaviour being quantified.

Figure 9-2: Cognitive, Motor and Sensory Contributions

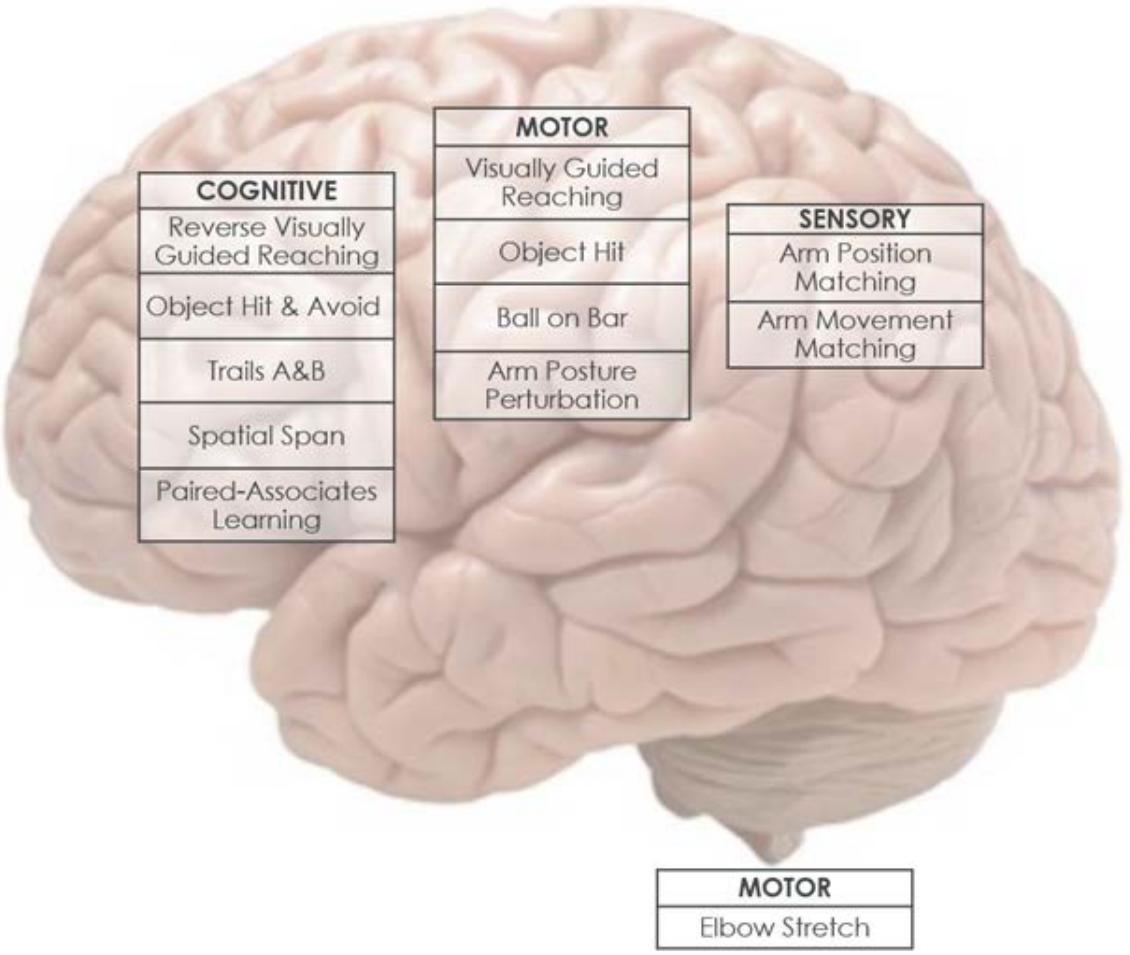


Table 9-1: Brain Functions Associated with KST (Sheet 1 of 2)

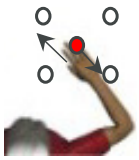
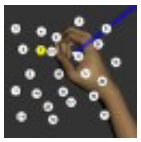
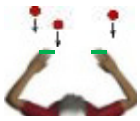
Kinarm Standard Tests™		
Test	**Behavioural Task**	**Brain Function**
COGNITIVE		
Reverse Visually Guided Reaching 	Subject reaches from a central target to a peripheral target where the visual feedback is reversed compared to the actual hand position.	Cognitive control of visuomotor skills Inhibitory control Attention
Object Hit & Avoid 	Subject hits away targets with either hand and avoids distractors. Speed and number of objects increase with time.	Rapid motor decisions Inhibitory control Spatial attention
Trails A&B 	Trail A: trace a sequence of targets numbered 1 to 25; Trail B: trace alternating numeric-alpha sequence of targets 1-A-2-B etc.	Executive function: task switching
Spatial Span 	Sequence of squares displayed; subject replays sequence by reaching to the appropriate squares in sequence.	Visuospatial working memory
MOTOR		
Visually Guided Reaching 	Subject reaches from a central target to a peripheral target.	Visuomotor skills Multi-joint coordination
Object Hit 	Subject hits away balls with either hand. Speed and number of balls increase with time.	Rapid visuomotor skills Spatial skills
Ball on Bar 	Subject moves a virtual ball balanced on a bar held by both hands to spatial targets.	Bimanual coordination Visuomotor skills
Arm Posture Perturbation 	Subject maintains hand at target and returns to the target after an unexpected disturbance (Exo only).	Goal-directed motor corrections

Table 9-1: Brain Functions Associated with KST (Continued) (Sheet 2 of 2)

Kinarm Standard Tests™		
Test	**Behavioural Task**	**Brain Function**
Elbow Stretch 	Subject relaxes; robot extends and flexes the elbow repeatedly (Exo only).	Assess presence of spasticity and high tone
SENSORY		
Arm Position Matching 	Robot moves one arm; the subject mirror-matches position with their other arm.	Somatosensation: position sense
Arm Movement Matching 	Robot moves one arm; the subject mirror-matches movement with their other arm.	Somatosensation: kinesthesia

9.2 Common Features of Standard Tests

9.2.1 KST Task Durations

Nominal task duration can be an important consideration when creating a Study Protocol and deciding which tasks to include. The following table includes p90 duration for both healthy controls and a sample group of impaired subjects.

Table 9-2: Nominal KST Task Duration (Sheet 1 of 2)

Behavioural Task	Protocol	Typical Duration[1] "Healthy" (p90)	Additional Time for "Impaired"[2] (p90)
Arm movement matching	v1	5.5 min/arm	+0.5 min/arm
	v2	3.0 min/arm	-
Arm position matching	v1	4.0 min/arm	+0.5 min/arm
	v2	2.0 min/arm	-
Arm posture perturbation	All	2.0 min/arm	+0.5 min/arm
Ball-on-Bar	All	3.5 min/arm	+0.5 min/arm
Elbow Stretch	All	2.0 min/arm	+3.0 min/arm for subjects with spasticity or tone

Table 9-2: Nominal KST Task Duration (Continued) (Sheet 2 of 2)

Behavioural Task	Protocol	Typical Duration[1] "Healthy" (p90)	Additional Time for "Impaired"[2] (p90)
Object Hit	All	2.5 min	-
Object Hit & Avoid	All	2.5 min	-
Reverse Visually Guided Reaching	All	3.5 min/arm	+2.0 min/arm
Spatial Span	All	5.5 min	-
Trails A&B	All	2.5 min	+4.5 min
Visually guided reaching	v1	7.5 min/arm	+1.5 min/arm
	v2	2.0 min/arm	+1.5 min/arm

1. Excluding time for instructions, which is typically ~1 min per task.
2. Impaired behaviour as observed from a large-cohort acute stroke population in a rehabilitation hospital setting.

9.2.2 Task Instructions

Standardized task instructions, with certified translations in several languages, are provided to the operator at the start of every task. They should be read exactly as written to ensure appropriate and accurate comparison to the normative data and consistency of results between operators.

9.2.3 Interfacing with External Data Acquisition Systems

If you are using KST and simultaneously recording other data with an external data acquisition system (e.g., EEG) then you can make use of built in TTL pulses in the KST exams to enable post-experiment synchronization of the Kinarm data with these other data. By default, these TTL outputs are disabled (in case you are already making using of your Kinarm Lab's DIO signals for other purposes).

In order to turn on the TTL bits you must select **Options** -> **Enable Standard Task digital sync pulses**. Kinarm Labs that have built in NI-6229 cards must then connect the following digital outputs to their external data acquisition system (see the relevant Kinarm Hardware Guide for further details on the NI-6229):

- **DO 2** - Strobe pulse. Produces a 0.5 ms pulse, 0.5 ms after a change on ANY other DO bit. This output can be used to strobe/trigger an external data bus that only records when a strobe signal is sent.
- **DO 3** - Clock. Pulse train from the time the model starts: low for 10 ms, high for 5 ms.
- **DO 4** - Task running. Outputs high as long as the task is running (i.e. the play button has been pressed).
- **DO 5** - Recording. Outputs high as long as Dexterit-E is recording data to an exam file. Some parts of some exams may not be recorded (e.g., reaches back to a center location).
- **DO 6** - Trial start. When a new trial starts this goes high for 50 ms.
- **DO 7** - Trial count (serial). The number of trials run during the task. This output produces a 10 bit digital number serially. It is high for 35 ms, followed by each of the 10 bits (LSB first) in synchrony with the clock pulses (DO 3).

After a task is run, the exam file will contain a channel of data called "TTL_bits". This channel is a bit packed version of DO 3-7.

9.2.4 Modification of Standard Task Protocols

It is possible to make limited modifications to Task Protocols for Standard Tasks. The modification of KST Task Protocols can only be done within strict limits in order to ensure that Dexterit-E's automated algorithms can analyze the task dataset. Tasks performed using modified protocols for Standard Tasks can still be analyzed and create reports. However those Standard Reports will have no normative measures. For details on how to modify protocols for Standard Tasks please contact **Kinarm Support**.

9.2.5 Features of Standard Reports

There are three types of Standard Reports:

- Task Report: provides a summary of the subject performance for a specific task.
- Session Report: when Study Protocols are used, provides a summary of the subject's performance for all KST completed in a single Session.
- Longitudinal Report: when Study Protocols are used, provides a summary of the subject's performance for all KST completed for all Sessions defined by the Study Protocol.

Each report contains information on subject performance in a consistent layout. Standard Reports are generated and saved as PDF files. After exporting from Dexterit-E, they can be modified/signed using third-party PDF software capable of such operations (e.g. Adobe Acrobat®). At the top of each report is a header containing information about the subject, as well as data collection and analysis versions. The footer contains optional notes.

Newer versions of Dexterit-E and Dexterit-E Explorer come with improved analyses and normative models, and it is recommended that reports be regenerated after an upgrade. Reports must be regenerated manually within Dexterit-E or Dexterit-E Explorer.

Common Data Elements

Common fields for all three types of standard reports are listed in *Table: 9-3*.

Table 9-3: Common Fields for Standard Reports (Sheet 1 of 2)

Field	Description
Subject	Subject's first and last name. This field is blank if the report is generated with the anonymous option.
ID	The ID of the subject in the database.
D.O.B/Age	The subject's date of birth, or if the report was generated with the anonymous option then the subject's age at the time of the exam.
Exam Date	Date the exam was performed.
Exam Time	The time of day (local time) the exam was performed.
Complete	The percentage of the exam that was completed.
Study	The study the exam was collected under.
P.I.	The primary investigator that the subject was linked to at the time the exam was collected.
Protocol	The name of the Task Protocol used to collect the data.
Capture	The version of Dexterit-E used to capture the data.
Analysis	The version of Dexterit-E used to analyze the exam.
Hardware	The type of Kinarm Lab used to record the exam: EP (End-Point) or EXO (Exoskeleton).
Serial #	The serial number of the Kinarm Lab used to record the exam.

Table 9-3: Common Fields for Standard Reports (Continued) (Sheet 2 of 2)

Field	Description
Posture	The subject's posture (seated or standing) during the exam. This information will only be present for data collected using an Adjustable Height Configuration of the Kinarm EP Lab.
Task Score	All KST have a Task Score that indicates overall performance on the task. It provides a measure of subject performance with a value of zero denoting best performance and larger values denoting poorer performance. (see *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*.)

Dexterit-E may generate notes that are placed in the Comments section of a report. For a list of possible notes and their meanings please see *Table: 9-5*.

Task Report

In the Task Report, the main body of the report consists of graphics that visualize key aspects of subject behaviour for that task, along with scores that quantify subject performance. Because of the unique nature of each Standard Task, the contents of the main body (i.e. the graphic and scores) are different for each task. Example reports for each KST are shown in the following sub-chapters specific to each test.

Within a Task Report, ranges of typical values are displayed for each parameter. Some of the parameter values are influenced by age, sex or handedness of the subject ($p < 0.01$), as indicated by a superscript beside the parameter. The value the subject scored for any given parameter is bolded if their performance is outside the normal range for their age, sex and handedness:

- No highlight - within 5%-95% of the typical normal range.
- Bold, slightly larger text - outside the typical normal range
- Greyed out - not applicable

9.2.6 Session and Longitudinal Reports

When Study Protocols are used, Session and Longitudinal reports can be created, based on the Study Sessions defined within the Study Protocol (where each session includes the data collected as part of a single assessment; see the Dexterit-E User Guide for more details on Study Sessions). In a Session or Longitudinal Report, the main body of the report consists of a bar or line chart of the Task Scores for all included tasks in the Session or Study Protocol. Example reports are shown below. Sessions were introduced in Dexterit-E 3.8 to enable data to be grouped by when it was collected (e.g. pre-treatment, 0 days post-treatment, 90 days post-treatment). They are defined within a Study Protocol.

Within a report, the value the subject's Task Score is bolded if their performance is outside the normal range for their age, sex and handedness:

- No highlight - Task Scores <1.96 (representing the 95th percentile); within the typical normal range.
- Bold, slightly larger text - outside the typical normal range
- Greyed out - not applicable

When Sessions are defined in Study Protocols, Kinarm provides two types of reports for viewing a subject's aggregate performance: Session Reports and Longitudinal Reports. A Session Report captures a subject's performance across all KST undertaken in a single assessment or Session. A Longitudinal Report captures a subject's performance across multiple Sessions of a study. For both report types, the Session(s) must be defined in a Study Protocol. Both reports only report Task Scores. Any Custom Tasks included in the Study Protocol are not reported. See the Dexterit-E User Guide for defining Study Protocols and Sessions.

NOTE: Sessions were introduced to Study Protocols in Dexterit-E 3.8 to enable data to be grouped by when it was collected (e.g. pre-treatment, 30 days post-treatment, 90 days post-treatment). Data collected in Dexterit-E 3.7 or earlier cannot be viewed in these aggregate reports.

NOTE: Session and Longitudinal Reports are only available in Dexterit-E Explorer. See the Dexterit-E Explorer User Guide for details on how to create these reports.

Session Reports

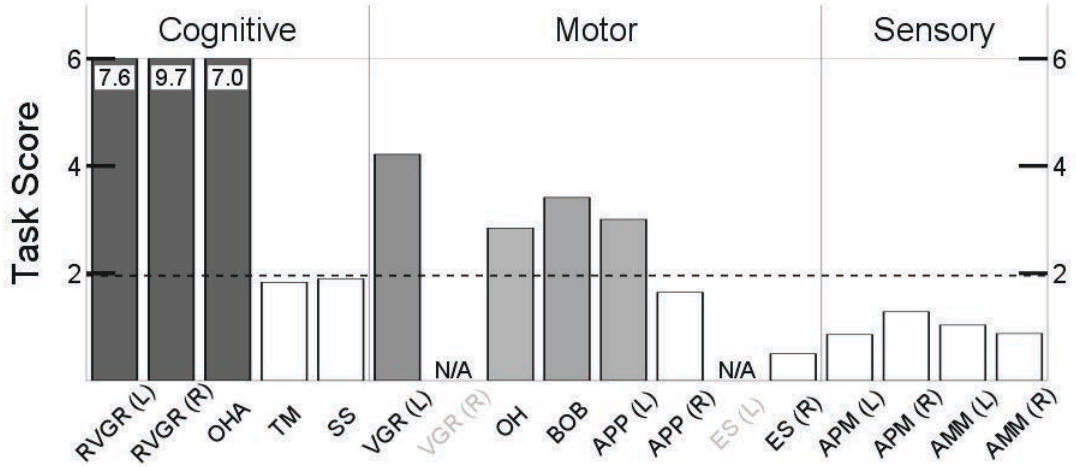
Session Reports are used to view a subject's overall performance from a single time point or data collection point. Session Reports show a subject's Task Scores across all KST that were run as part of a single Session. *Figure: 9-3* shows an example of a Session Report. Tasks are grouped by domain: sensory, motor or cognitive. The horizontal dashed line indicated at a Task Score of 1.96 represents the threshold for being in the 95th percentile. Task Scores above this line are considered outside of the typical range.

Figure 9-3: Session Report

Kinarm

Subject	Sample, Session	**ID**	123456	**Capture**	3.9.0, 3.6.4
D.O.B.	01/01/1950	**Age**	68, 71	**Analysis**	3.9.0
P.I.		**Study**	all the KST and then some, Art Therapy	**Hardware**	EXO
				Serial#	050601, 150101
Protocol	n/a	**Exam date**	10/03/2021, 1:47 p.m.		

Session: 1. Intake



Domain	Code	Task type	Protocol	Task Score		
				L	R	IL
Cognitive	RVGR	Reverse Visually Guided Reaching	Adult	**7.55**	**9.66**	**6.46**
	OHA	Object Hit & Avoid	Adult		**7.03**	
	TM	Trail Making	Adult: Trail A - Pattern 1 Adult: Trail B - Pattern 4		1.83	
	SS	Spatial Span	Adult		1.90	
Motor	VGR	Visually Guided Reaching	Adult v2 (4 target)	**4.22**		
	OH	Object Hit	Adult		**2.84**	
	BOB	Ball on Bar	Adult		**3.41**	
	APP	Arm Posture Perturbation	Adult and Child	**3.01**	1.65	
	ES	Elbow Stretch	Adult and Child v2		0.50	
Sensory	APM	Arm Position Matching	Adult v2 (4 target)	0.86	1.28	
	AMM	Arm Movement Matching	Adult v2 (3 repeats)	1.04[1]	0.88[1]	

Typical range < 1.96 (<95%)	**Outside**	Not applicable

Comments	Signature
1. Task scores were derived from Kinarm Classic exams	

Information provided for research purposes only.

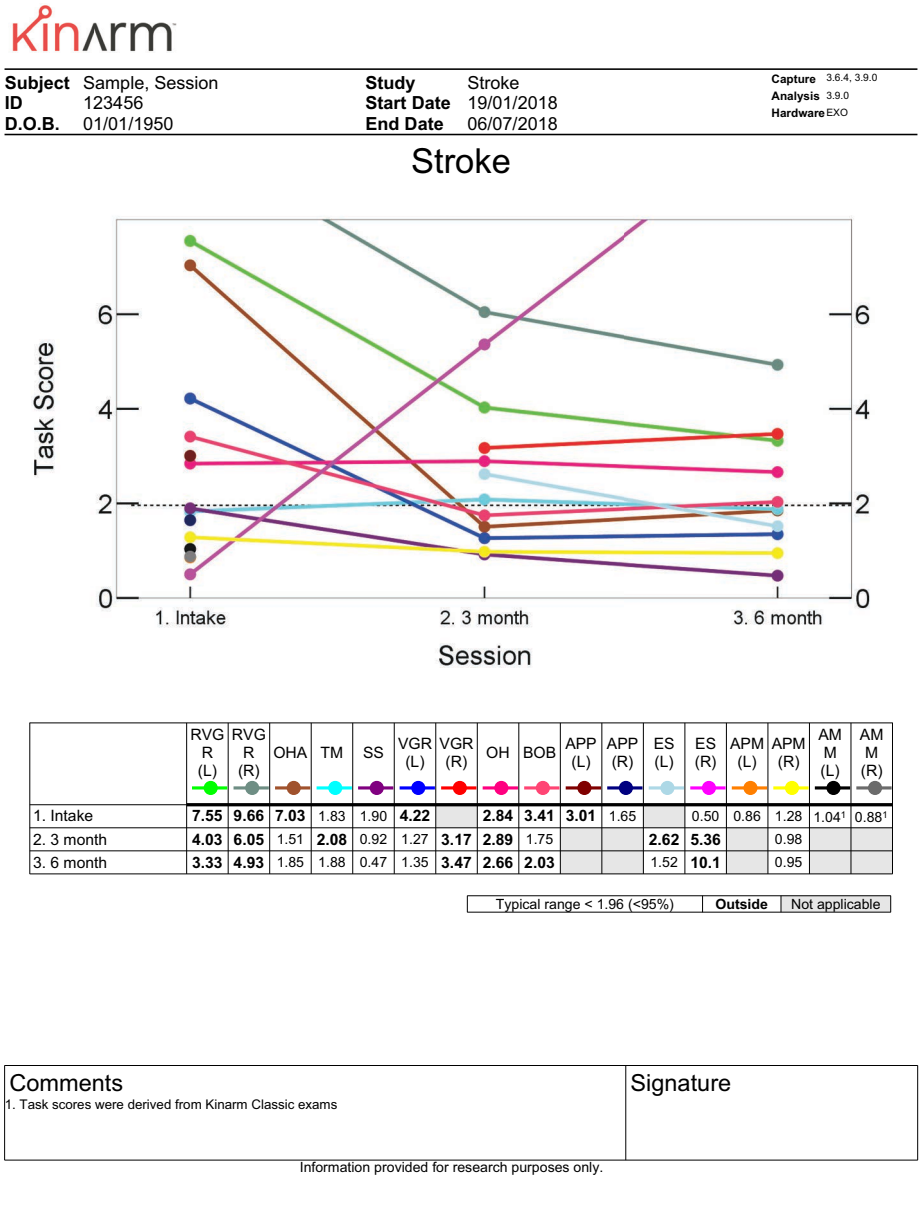
NOTE: If the same KST is run multiple times during a single session then the last instance that was run is used in the Session Report.

Longitudinal Reports

Longitudinal Reports are used to view a subject's change in performance across multiple Sessions. Longitudinal Reports show a subject's Task Scores for the KST that were included in all of the Sessions defined by the Study Protocol. An example of a Longitudinal Report is shown in *Figure: 9-4*. The horizontal dashed line at a Task Score of 1.96 indicates the threshold for being in the 95th percentile. Task Scores which are above this line are considered outside of the typical range. Each KST is represented in the graph as a different coloured line. The line colours are defined in the table below the graph in the report.

Sessions in the Longitudinal Report are listed in the order they were defined within the Study Protocol. This order may be different from the order in which the Sessions were run. Sessions are spaced evenly across the graph; there is no scaling effect to account for the actual length of time between Sessions.

Figure 9-4: Longitudinal Report



Kinarm

Subject	Sample, Session	**Study**	Stroke	**Capture**	3.6.4, 3.9.0
ID	123456	**Start Date**	19/01/2018	**Analysis**	3.9.0
D.O.B.	01/01/1950	**End Date**	06/07/2018	**Hardware**	EXO

Stroke

	RVGR (L)	RVGR (R)	OHA	TM	SS	VGR (L)	VGR (R)	OH	BOB	APP (L)	APP (R)	ES (L)	ES (R)	APM (L)	APM (R)	AMM (L)	AMM (R)
1. Intake	**7.55**	**9.66**	**7.03**	1.83	1.90	**4.22**		**2.84**	**3.41**	**3.01**	1.65		0.50	0.86	1.28	1.04[1]	0.88[1]
2. 3 month	**4.03**	**6.05**	1.51	**2.08**	0.92	1.27	**3.17**	**2.89**	1.75			**2.62**	**5.36**		0.98		
3. 6 month	**3.33**	**4.93**	1.85	1.88	0.47	1.35	**3.47**	**2.66**	**2.03**			1.52	**10.1**		0.95		

Typical range < 1.96 (<95%) | **Outside** | Not applicable

Comments	Signature
1. Task scores were derived from Kinarm Classic exams	

Information provided for research purposes only.

NOTE: If the same KST is run multiple times during a single session then the last instance that was run is used in the Longitudinal Report.

Table: 9-4 shows the mapping of KST names to abbreviations in the longitudinal report.

Table 9-4: KST Abbreviations for Longitudinal Reports

Task	Abbreviation
Arm Movement Matching	AMM
Arm Position Matching	APM
Arm Posture Perturbation	APP
Elbow Stretching	ES
Visually Guided Reaching	VGR
Reverse Visually Guided Reaching	RVGR
Object Hit	OH
Object Hit and Avoid	OHA
Ball on Bar	BOB
Spatial Span	SS
Trail Making	TM

9.2.7 Standard Data Exported to CSV

Within Dexterit-E and Dexterit-E Explorer, any task performed as a Standard Task has a set of associated analysis routines including comparisons to normative models. These automated analyses are used by generating Standard Reports or by exporting CSV files of the analysis results (i.e. for subsequent importing into a spreadsheet package or other statistical analysis software). When exam results are exported to CSV files there are common data fields included in each CSV file. The CSV file also includes much more detailed information and results than what is shown in the Standard Reports. The table below describes each column of standard data exported.

Table 9-5: Standard Data Exported to CSV (Sheet 1 of 4)

Column	Excel	Name	Description
1	A	Subject ID	The ID of the subject in the Dexterit-E database.
2	B	Surname	The subject's surname. Blank for anonymous exports.
3	C	Given Name	The subject's given name. Blank for anonymous exports.
4	D	D.O.B.	The subject's date of birth. Blank for anonymous exports.

Table 9-5: Standard Data Exported to CSV (Continued) (Sheet 2 of 4)

Column	Excel	Name	Description
5	E	Age	The age of the subject when the exam was performed.
6	F	Sex	The subject's sex: M or F.
7	G	Handedness	The subject's handedness: L or R.
8	H	Subject weight (kg)	Weight of the subject at the time the exam was collected.
9	I	Subject height (m)	Height of the subject at the time the exam was collected
10	J	Current Study Protocol	The study the subject is currently assigned to.
11	K	Exam Study Protocol	The study the subject was assigned to when the exam was performed.
12	L	Exam Study Session	The session name used in the Study Protocol that the data were recorded with.
13	M	Current Pathology	The pathology the subject currently has listed.
14	N	Exam Pathology	The pathology the subject was listed with when the exam was performed.
15	O	Current PI	The PI the subject currently has listed.
16	P	Exam PI	The PI the subject was listed with when the exam was performed.
17	Q	Exam Date	The date the exam was performed on.
18	R	Exam Time	The time of day the exam was started at.
19	S	Exam duration	The amount of time the exam ran for. Format is mm:ss.
20	T	Exam UID	A unique identifier for the exam.
21	U	Arm to be Assessed	The arm that was selected in Dexterit-E when the exam was performed: LEFT or RIGHT.
22	V	Model	The name of the model file used to perform the exam.
23	W	Protocol	The name of the Task Protocol file used to perform the exam.
24	X	Protocol Code	The Task Protocol code stored in the Task Protocol used to perform the exam.

Table 9-5: Standard Data Exported to CSV (Continued) (Sheet 3 of 4)

Column	Excel	Name	Description
25	Y	Description	The description of the file given in Dexterit-E.
26	Z	Robot	The type of Kinarm Lab used to perform the exam: EXO or EP.
27	AA	System Serial	The serial number of the system used to perform the exam.
28	AB	Location	The location of the system used to perform the exam.
29	AC	Collection Version	The version of Dexterit-E used to perform the exam.
30	AD	Analysis Version	The version of Dexterit-E used to analyze the exam.
31	AE	Operator	The name of the operator selected when the exam was performed.
32	AF	Fraction Complete	The fraction of the exam that was completed: 0-1.
33	AG	Contralateral Exam	If another exam was used to help generate any of the values in the analysis the name of that file is listed here. If no alternate exam is required this column will not be present.
...	...	<Parameter Name>	Parameter score for each parameter calculated for a given test. See test specific section for details.
...	...	SD - <Parameter Name>	The standard deviation of the given parameter name across all trials (only exists if a standard deviation can be calculated for that parameter).
...	...	* - Task Score	See *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*.
...	...	* - M-Score	See *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*.
...	...	Z - Task Score	See *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*.
...	...	Z - M-Score	See *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*.
...	...	Z - <Parameter Name>	The Z-scores of the given parameter name.

Table 9-5: Standard Data Exported to CSV (Continued) (Sheet 4 of 4)

Column	Excel	Name	Description
...	...	P - <Parameter Name>	The percentile of the given parameter name, based on the Z-score.
… (last)	...	Notes	Notes are added if there are no Z-scores provided to explain why, or if the Z-scores provided are extrapolations outside the range of the given models. See *Table: 9-6*.

Table 9-6: Possible Notes in CSV Export or Reports (Sheet 1 of 2)

Note	Meaning
Z-scores/typical ranges are for an 18 year old	Normative models for this Task Protocol were developed using subjects 18 years old and above. Subjects that are 15-17 are treated as though they are 18 for the purposes of generating Z-scores and typical ranges.
No Z-scores/typical ranges because subject was < 15 years old	Normative models for this Task Protocol were developed using subjects 18 years old and above. Subjects that are < 15 years old will not produce comparisons to normative data because development effects on subject behaviour for younger subjects cannot be reliably extrapolated from adult behaviour. Subjects who are < 18 years old should use a different Task Protocol that was designed for use with children.
No Z-scores/typical ranges because the protocol was custom	If the exam was collected as part of a Custom Standard Task (see *Section: 9.2.4 Modification of Standard Task Protocols*) then we cannot provide normative comparisons because we do not know how the protocol varied from the standard version.
Z-scores/typical ranges were derived from Kinarm Classic exams	Prior to Dexterit-E 3.7, all Kinarm Exoskeleton normative data were collected using Kinarm Classic Labs (PN 10755). This note is meant to alert the operator that the normal models are not guaranteed to be correct in an absolute sense, which means that data collected on different Kinarm Lab types should not be directly compared. Dexterit-E 3.7 includes Kinarm Exoskeleton (PN 13568) normative models.

Table 9-6: Possible Notes in CSV Export or Reports (Continued) (Sheet 2 of 2)

Note	Meaning
Z-scores/typical ranges were extrapolated from a data set with younger subjects	This note indicates that the subject is older than the oldest subject in the database used to generate the normative models. For parameters with an age effect the Z-scores and typical values were extrapolated beyond the bounds of the model and therefore should be used with caution.
No Z scores/typical ranges because no database for the given Kinarm Lab exists	This note is returned when an analysis is attempted for a standard task protocol where no normative database exists.

9.2.8 Normative Models and Z-Scores for Task Parameters

In addition to the actual parameter scores, Z-scores and percentiles for all appropriate parameters are included as part of any CSV file exported with Dexterit-E if there is a normative data set available for the Standard Task.

The Z-score (i.e., standardized score) is the distance, measured in standard deviations, that a particular value is from the mean; i.e. a Z-score of 1 means a value was 1 standard deviation above mean, a Z-score of -1.5 means that the value was 1.5 standard deviations below the mean. The reported Z-scores included in a CSV file always take into account any age, sex, handedness and Kinarm platform effects that were found in the normative distributions for a parameter. Only those normative distributions that can be transformed into a close-to-normal distribution, as defined below, have Z-scores and percentiles.

All KST have a consistent methodology for developing the normal models to calculate Z-scores for each parameter. The original distribution of parameter scores from the normative data set is transformed using a Box-Cox power transform (Box and Cox, 1964) and the transformed data are fit using weighted linear regression to account for age, sex, handedness and robotic platform, with weights inversely proportional to variance to account for heteroskedasticity (although see individual KST description for additional factors included in some models, e.g. *Section: 9.7 Elbow Stretch*). The standard deviation of the residuals following this first regression is then modeled using a second weighted linear regression with the same factors as the first regression (i.e. age, sex, handedness and robotic platform). Z-scores are calculated for each parameter score using the residuals from the first regression and the standard deviation modeled by the second regression. The distribution of these Z-scores is tested for normality using the Shapiro-Wilk test, and the Box-Cox transform producing the most normal distribution of Z-scores is selected. Data points whose residuals lie outside of ±3.29 standard deviations from the mean (i.e. nominally 1 in 1000) are classified as outliers and those data are removed from the normative data set. Task Scores and M-scores are then calculated (*Section: 9.2.9 Task Score and M-Score*) and if a subject's Task Score or M-score is > 3.29 (i.e. nominally 1 in 1000) then that subject is classified as an outlier for that task and all of that subject's data are removed for that task.

Outliers are removed from the normative data sets to improve the robustness of the modeling process. Even in larger datasets with hundreds of subjects, outliers can have adverse effects on the various characterization steps. Furthermore, our control sample was random and community-based, and therefore, it is possible that some individuals in our healthy cohort had undiagnosed underlying conditions that negatively affected performance. Race and ethnicity data were not collected from normative subjects which could influence normative ranges. Most of the data were collected in Canada.

The skew and kurtosis of the final distribution of Z-scores is then calculated and compared to the criteria shown in the equations below to ensure that the distribution is "close-to-normal". These criteria were selected based on the work of Pearson and Please (1975) to ensure that the distribution is close enough to normal so that it is statistically valid to use parametric statistical tests with the Z-scores:

- skew: $abs\left(\sqrt{\beta_1}\right) \leq 0.8, \sqrt{\beta_1} = \frac{\mu_3}{\sigma^3}$
- kurtosis: $2.4 \leq \beta_2 \leq 3.6, \sqrt{\beta_2} = \frac{\mu_4}{\sigma^4}$

If it is not possible to use a Box-Cox power transform to transform the data into a close-to-normal distribution, then the distribution is left untransformed and no Z-scores are reported. These untransformed distributions are still tested for age effects (where subjects <40 years old are compared to subjects >65 years old using the Wilcoxon rank-sum test), and if positive, split into three groups (<40 years old, 40 to 65 years old, >65 years old).

Typical applications of a Z-score

- Z-scores provide a common framework or language based on the performance observed for healthy subjects. This facilitates comparisons of performance between individuals, between task parameters for a given task or even between tasks.
- Z-scores provide a measure that accounts for the effects of age, sex and handedness, which means that Z-scores from subjects can be grouped together for statistical analysis.
- Z-scores are based on normal (i.e. Gaussian) distributions, enabling the use of parametric statistical tests when comparing a sample to the normative population (e.g. t-test, etc).
- Z-scores can be easily converted to percentiles based on the normal distribution (i.e. Z-score of 0.0 is 50%, a Z-score of 2.0 = 97.7%, etc.)

Citations

Box, G.E.P. and Cox, D. R. (1964). An analysis of transformations. J. R. Stat. Soc., Series B. 26 (2): 211–252.

Pearson, E.S. and Please, N.W. (1975). Relation Between the Shape of Population Distribution and the Robustness of Four Simple Test Statistics. Biometrika. 62(2): 223-241.

9.2.9 Task Score and M-Score

Task Score

A Task Score provides a global measure of a subject's performance for a given task. Specifically, it measures how far from best performance was the subject's performance. Task Scores are always positive; a score of 0 denotes best performance and increasing values represent poorer performance. It can be found on both Standard Reports and in exported CSV files.

Calculating the Task Score

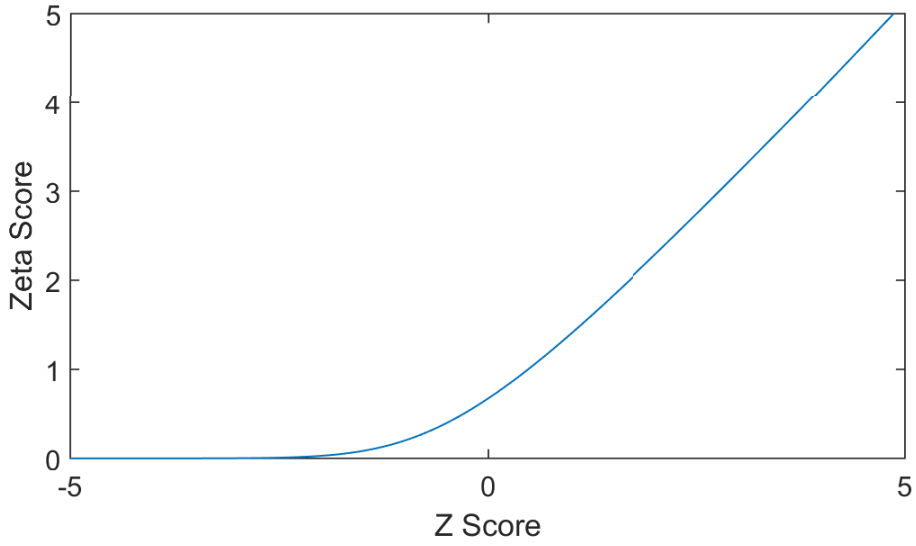
The first stage in calculating the Task Score requires converting the task parameter scores into standardized Z-scores, as described in *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*. The second stage requires identifying whether best performance for a given metric reflects large negative Z-scores (e.g. reaction time for visually guided reaching), large positive Z-scores (e.g. objects hit for the object hit task) or Z-scores near zero (e.g. parameters that compare limb symmetry, such as hand speed difference for object hit). For those parameters in which best performance is one-sided (i.e. large positive or large negative Z-scores), the Z-scores are transformed into Zeta-scores using the following.

- Z to Zeta transform: $\zeta = \sqrt{2} \cdot erfc^{-1}\left(\frac{1}{2} \cdot erfc\left(\frac{\pm z}{\sqrt{2}}\right)\right)$

  NOTE: '+' used when poor performance is positive, '-' used when poor performance is negative. The poor performance direction of a parameter score is indicated with an arrow in the parameter tables found in the following sub-chapters for each KST (with a double-sided arrow meaning that the parameter is two sided and therefore it is not converted to a Zeta-score).

The effects of this transform can be seen in *Figure: 9-5*, which plots the relationship between Z-score and Zeta-score for the above equation (using "+z"). As can be seen in the figure, for large negative Z-scores (i.e. best performance), the Zeta-score approaches 0. Thus by using this transform, the data are all converted into a form in which the best performance is indicated by a value of 0. The form of this transform was derived by ensuring that the cumulative distribution function (CDF) of Z-score^2 for a Normal distribution, is identical to the CDF of Zeta-score^2 for a Normal distribution that is first transformed by the above Z to Zeta transform equation. This constraint ensures that the statistical contributions of Zeta-scores and Z-scores to Task Score are equivalent.

Figure 9-5: Z-Score to Zeta-Score Transformation



The final stage of processing calculates Task Scores based on performance of healthy controls. To begin, the root-sum-square (RSS) distance of the Z-scores and Zeta-scores for healthy controls are calculated as per the following equation:

- $\text{rssDistance} = \sqrt{\sum_i z_i^2 + \sum_j \zeta_j^2}$

  NOTE: $\sum_i z_i^2$ includes all two-sided parameters and $\sum_j \zeta_j^2$ includes all one-sided parameters.

An example of this equation is illustrated in *Figure: 9-6* (RSS-distance is also known as the Euclidean distance). The RSS-distance is then transformed into a Z-score via a Box-Cox transform using the same methods described for transforming parameter scores in *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*. The Z-score of the RSS-distance is then transformed using the Z-score to Zeta-score transformation to a one-sided statistic. As shown in *Figure: 9-6*, the resultant Task Score distribution for healthy controls shares key percentiles with the Normal distribution: Task Scores of 1, 2, and 3 are the 68.3rd, 95.4th, and 99.7th percentiles for healthy subject performance.

Figure 9-6: RSS Distance Calculation (for Three Dimensions)

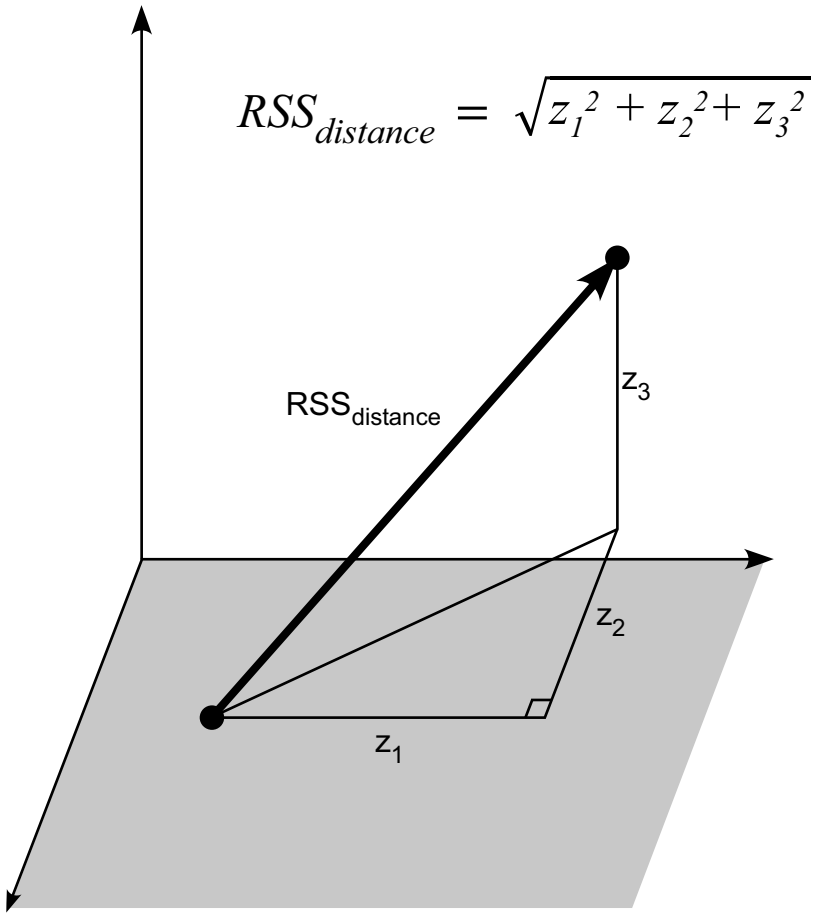
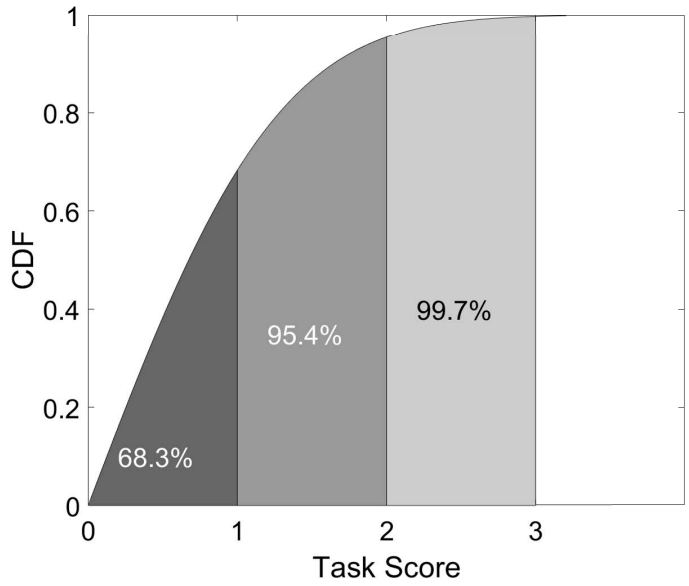


Figure 9-7: Cumulative Distribution Function (CDF) for Task Score and M-Score



NOTE: The cumulative distribution function of (Task Score) is identical to the distribution of sqrt(χ^2) with 1 degree of freedom.

The calculation described above nominally provides equal weighting to all parameters. However, as detailed in the specifications of each KST, some parameters are explicitly excluded from Task Score due to high correlations with other parameters (i.e. r > 0.9), and as outlined below in this sub-chapter, there are additional weighting factors for Visually Guided Reaching and Reverse-Visually Guided Reaching.

M-Score

In addition to the Task Score, a related M-score is calculated for each KST. M-score does not appear in the Standard Report, but it can be found in CSV file output, along with its Z-score equivalent. Both Task score and M-score are calculated using the same set of Task parameters, but the M-score is derived from the Mahalanobis distance (Mahalanobis, 1936) rather than the RSS distance (i.e. the following equation is used). The primary difference is that the Mahalanobis distance accounts for correlations between parameters, and therefore can detect patterns of abnormal behaviour that are not obvious from single parameters. The M-distance is converted to an M-Score using analogous steps to those described above for RSS-distance and Task Score. Therefore, the M-Score has a CDF of the same form as the Task Score (*Figure: 9-7*).

- $$\text{MDistance} = \sqrt{\vec{z}^{\,T} \cdot {S_{corr}}^{-1} \cdot \vec{z}}$$

NOTE: Although the nominal definition of the Mahalanobis distance uses the inverse covariance matrix to account for both correlation and scale, because we already

account for scale via the use of the Z-scores and Zeta-scores, the inverse correlation matrix (S_{corr}^{-1}) is used instead.

Contributions of Discrete Parameters and Weighted Parameters

For some KST, there are some trial count parameters that also contribute to Task Score and M-score and which are both highly-discrete and one-sided (e.g. the parameter **No Initial Stabilization** for Visually Guided Reaching (VGR)).These parameters do not have a distribution that can be transformed into one that is close-to-normal, so these parameters are treated differently. They are converted to Zeta-scores by taking the square root of the fraction of trials and then linearly scaling the result; the linear scaling factor is calculated by fitting the pre-transformed distribution from the normal population to the PDF of the nominal Zeta-distribution (i.e. a Normal distribution transformed by z to zeta transform). The fraction of trials is used for this calculation rather than count of trials to handle partially completed exams.

Some KST additionally have weightings applied to many of the parameters contributing to Task Score, based on the number of successful trials. For example, many of the parameters for VGR and RVGR are only calculated for successful trials, so the accuracy of any such parameter decreases as the fraction of successful trials decreases. To ensure that parameter score inaccuracies that result from fewer successful trials do not incorrectly influence Task Score, we weight the contributions of these parameters to Task Score. A weighting factor of w_i = n/N (i.e. number successful trials / number of executed trials) was chosen because sampling uncertainty is proportional to 1/sqrt(n), Thus as the number of successful trials decreases, the relative contribution of the unweighted parameters (i.e. **No Initial Stabilization** and **No Movement End** for VGR) increases, such that the uncertainties in the weighted parameters have little effect on Task Score and M-score. In the extreme, where there were no successful trials, then the weighted parameters do not contribute to either Task Score or M-score.

- $$\text{rssDistance} = \frac{\sqrt{\sum_i w_i \cdot z_i^2 + \sum_j w_j \cdot \zeta_j^2}}{\sqrt{\sum_i w_i + \sum_j w_j}}$$

NOTE: $\sum_i$ includes all two-sided parameters and $\sum_j$ includes all one-sided parameters.

Citations

Mahalanobis, P.C. (1936). On the generalised distance in statistics. Proceedings of the National Institute of Sciences of India 2(1): 49–55.

9.2.10 Verification and Quantification of Normative Models

A number of techniques were used to verify and quantify various aspects of the algorithms for these normative models.

Outlier Removal

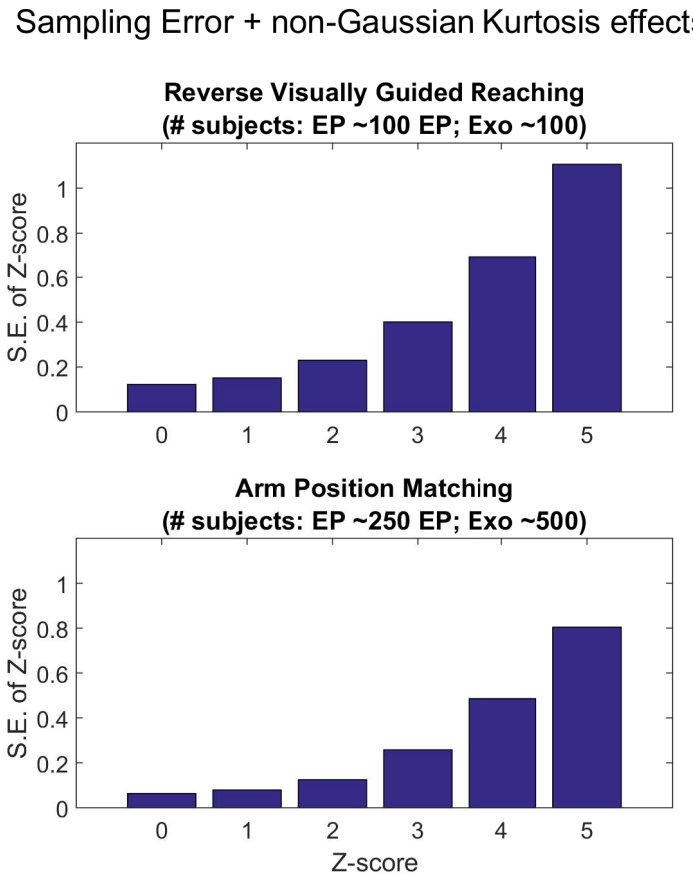
Monte Carlo simulations using samples randomly drawn from Gaussian distributions were run to quantify the rate of outlier removal for various samples. As the sample size increases, the outlier removal rate asymptotes as expected at 0.1% following one round of outlier removal. After three rounds, the rate asymptotes at a marginally increased rate of 0.11%.

The actual rate of outlier removal varies across normative models, but is typically ~1%. This higher value, as compared to the Monte Carlo simulations, reflects two issues: small deviations from normality in the true distributions, and the potential presence of subjects with possible undiagnosed conditions.

Z-Score Accuracy

The absolute accuracy of a Z-score is dependent on the modeling algorithm, the sample size, the assumptions that the model is based on, and the nominal Z-score. While the uncertainty in means and standard deviations based on sample size can be derived theoretically, Monte Carlo simulations were used to determine the uncertainty due to the Box-Cox transformations. The uncertainty due to the assumption of a Gaussian kurtosis can also be considered, given that we limit the kurtosis as outlined above in *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*. The results show that overall accuracy depends heavily on the nominal Z-score of the parameter, but is also quite dependent on the sample size of the normative data. *Figure: 9-8* plots standard error (S.E.) vs. Z-score for two different KST with different sample sizes.

Figure 9-8: Z-Score Accuracy



The standard errors calculated in the analysis of Z-score accuracy and shown in *Figure: 9-8* include: (1) sampling error, which affects the accuracy of the model's estimates for the mean, standard deviation and optimal Box-Cox transform; (2) the impact of non-Gaussian kurtosis, based on the range of kurtosis values observed in normative data.

9.3 Arm Movement Matching

9.3.1 Test Purpose

The purpose of the Arm Movement Matching test is to assess the ability of a subject to perceive motion of their arm in the horizontal workspace. This sense of limb motion (kinesthesia) is one aspect of proprioception. The task requires passive motion sense of the arm moved by the robot, and transfer of that information to drive a motor action and active motion sense of the other arm (Semrau et al., 2013).

NOTE: This task was originally published by Semrau et al. (2013) as the "Kines" task.

9.3.2 Task Description and Task Protocols

During the task, the Kinarm robot will move the subject's arm to be assessed via a controlled trajectory to a given position. The subject is instructed to move their other arm to mirror match the speed and direction of the movement. Vision of the subject's arms is blocked so that the subject can only use somatosensation from the arm to perceive arm position.

This process is repeated a number of times to both explore the workspace and to measure trial-to-trial variability.

There are four protocols available with the following differences:

- Adult v2 (3 repeats) - There are 3 targets arranged in an inverted triangle spaced 20 cm apart. There are 3 blocks of 6 trials, consisting of one movement between each pair of targets in each direction.
- Child v2 (3 repeats) - Similar to Adult v2, but the targets are spaced at 12 cm apart.

There are 2 legacy protocols:

- Adult v1 (6 repeats) - Similar to Adult v2 except there are 6 blocks of 6 trials.
- Child v1 (6 repeats) - Similar to Child v2 except there are 6 blocks of 6 trials.

9.3.3 Report

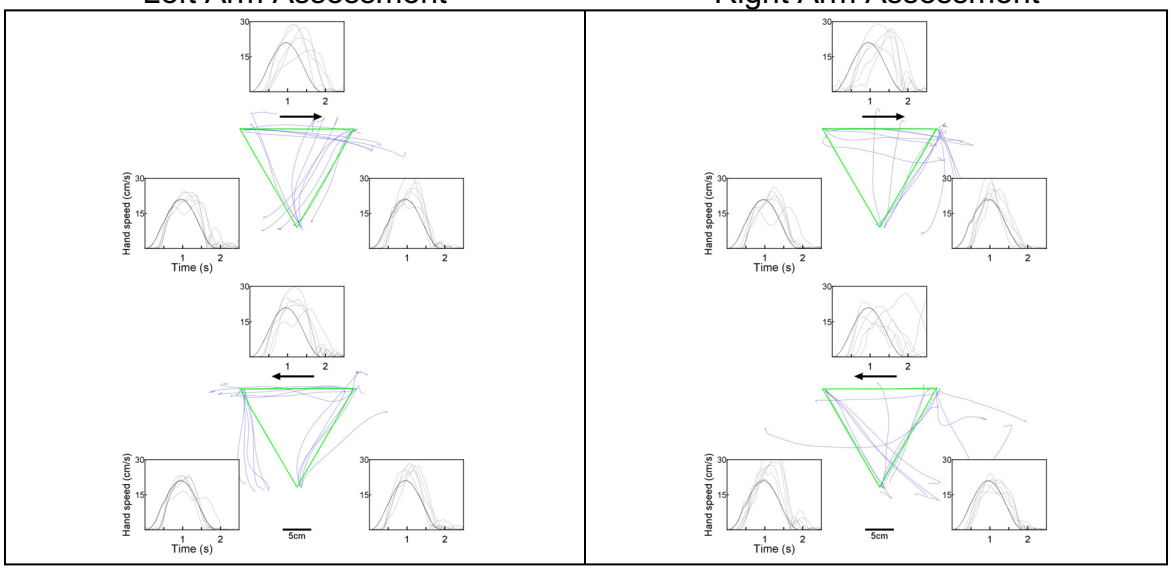
Figure: 9-9 shows an example of an Arm Movement Matching report for a subject that had experienced a cardiac event. In the report, "Complete" refers to the percentage of expected trials that were completed. The green lines indicate the path the arm to be assessed took and the blue lines indicate the path the subject used to mirror match. The hand speed plots show the speed of the subject's movements for both arms as well.

Figure 9-9: Arm Movement Matching report

Subject		**ID**	554829344	**Capture**	3.4.3
D.O.B.		**Age**	50	**Analysis**	3.9.0
P.I.		**Study**	Cardiac Event	**Hardware**	EP
				Posture	Seated
				Serial#	120701
Protocol	Adult v1	**Exam date**	12-Feb.-2015, 11:17 a.m.	**Complete**	100%

Arm Movement Matching

Left Arm Assessment | Right Arm Assessment



Task Score	Left	Right	Typical range
	0.19 (15.1%)	**2.54 (98.9%)**	< 1.96 (<95%)

Parameters	Left	Right	Typical range		Unit
			Left	Right	
Failed trial	0 / 30	**1 / 30**	(0, 0)	(0, 0)	#
Reaction time[3]	236	267	(190, 368)	(181, 358)	ms
Initial direction angle[1 3]	11.8	**34.2**	(5.6, 18.9)	(5.0, 15.9)	°
Peak speed ratio	1.16	1.16	(0.88, 1.45)	(0.93, 1.39)	cm/s / cm/s
Path length ratio[2]	1.09	1.09	(0.94, 1.23)	(0.94, 1.21)	cm/cm

Statistically significant effect from: [1]age, [2]sex, [3]handedness. Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-7 defines the parameters presented in the report.

Table 9-7: Arm Movement Matching Parameters

Parameter (Contribution to Task Score)[1]	Meaning
Movement onset (Exclude)	The first time the given arm is moving above 10% of the maximum speed the arm attained for the trial.
Movement end (Exclude)	The first time after movement onset that the given arm's speed goes below 10% of the maximum speed the arm attained for the trial.
Failed trials (->)	Count of trials where any of the following happened: • Speed of the contralateral arm is > 20% of its maximum speed at Movement Onset for the arm to be assessed • Speed of the contralateral arm does not go above 20% of the maximum speed of the arm to be assessed. • The time between movement onset for both arms is > 3 s. • The Movement end and Movement Onset for the contralateral arm is < 0.35 s
Reaction time (->)	Time difference between movement onset for the contralateral arm and movement onset for the arm to be assessed. Reported as the mean across trials.
Initial direction angle (->)	The absolute angular deviation between initial movement directions for the two arms. For each arm, the initial movement direction is a vector going from the hand position at movement onset to the hand position at maximum speed. Reported as the mean across trials.
Peak speed ratio (<->)	Ratio of (a) maximum hand speed for the contralateral arm to (b) maximum hand speed for the arm to be assessed. Reported as the mean across trials.
Path length ratio (<->)	Ratio of (a) distance the contralateral arm moved from movement onset to movement end to (b) distance the arm to be assessed moved from movement onset to movement end. Reported as the mean across trials.

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.

NOTE: The first block is not used in the analysis of any parameters.

9.3.4 Citations

Semrau, J.A., Herter, T.M., Scott, S.H., Dukelow, S.P. (2013). Robotic identification of kinesthetic deficits after stroke. Stroke. 44:3414-3421 doi: 10.1161/STROKEAHA.113.002058. Epub 2013 Nov 5

Semrau JA, Herter TM, Scott SH, Dukelow SP. (2017). Inter-rater reliability of kinesthetic measurements with the KINARM robotic exoskeleton. J Neuroeng Rehabil. 2017 May 22;14(1):42. doi: 10.1186/s12984-017-0260-z.

9.4 Arm Position Matching

9.4.1 Test Purpose

The purpose of the Arm Position Matching test is to assess the ability of a subject to perceive the position of their arm in the horizontal workspace. Position sense is one aspect of proprioception. The task requires passive position sense of the arm moved by the robot, transfer of that information to drive a motor action and active position sense of the other arm (Dukelow et al., 2010).

9.4.2 Task Description and Task Protocols

During the task, the Kinarm robot will move one of the subject's arms to a given position, and the subject is instructed to move their other arm to the mirror-image position. Vision of the subject's arms is blocked so that the subject can only use somatosensation from the arm to perceive arm position. After the subject's hand is moved to a spatial location by the robot, they indicate to the operator when they have moved their other hand to a mirror-matched position. The operator then advances to the next trial by clicking **Continue**, which is found on the task panel of the Dexterit-E screen below the **Play** button.

This process is repeated a number of times to both explore the workspace and to measure trial-to-trial variability.

There are four task protocols available, with the following differences:

- **Adult v2 (4 target)** - There are 4 targets spaced on a 2 x 2 grid, at 20 cm intervals in the X and Y directions. There are 6 blocks of trials, which include 1 trial for each target. The same target is never repeated sequentially.
- **Child v2 (4 target)** - Similar to Adult v2 (4 target), but the targets are spaced 12 cm apart.

There are 2 legacy protocols:

- **Adult v1 (9 target)** - Same as Adult v2 (4 target), but includes nine targets spaced on 3 x 3 grid at 10 cm intervals (i.e. the outer 4 corner targets are the same as the 4 target grid). This protocol takes significantly longer compared to the 4 target version and so is not typically recommended.
- **Child v1 (9 target)** - Similar to Adult v2 (9 target), but the targets are spaced 6 cm apart.

9.4.3 Report

Figure: 9-10 shows an example of an Arm Position Matching report for a stroke subject. In the report, "Complete" refers to the percentage of expected trials that were completed. The green lines displayed for each assessment connect the mean hand positions of the arm that was moved by the Kinarm robot. The solid blue lines connect the mean hand positions of the opposite arm that the subject mirror-matched. The ellipses at each point show the variability of those hand positions as determined using Principal Component Analysis; larger ellipses mean the subject was more variable (i.e. less consistent) at finding a placement for the arm. The dotted blue lines are a mirroring of the solid blue lines across the subject's mid-line (after accounting for shifts in shoulder positions). This mirrored image helps to more easily visualize how accurate the subject was at judging the end-positions of their arm.

Figure 9-10: Arm Position Matching Report

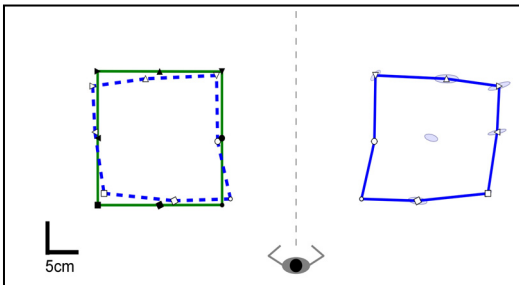
Subject	**ID**	anon	
D.O.B.	**Age**	38	
P.I.	**Study**		

Capture	3.3.1
Analysis	3.8.0
Hardware	EP
Posture	Seated
Serial#	091001

Protocol	Adult: 9 target			**Protocol**	Adult: 9 target		
Exam date	18-Jan-2013, 12:04 PM	**Complete**	100%	**Exam date**	18-Jan-2013, 12:01 PM	**Complete**	100%

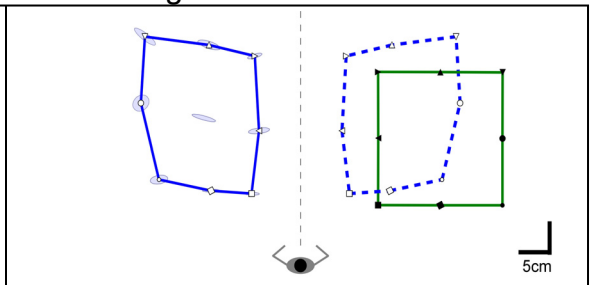
Arm Position Matching

Left Arm Assessment



Robot moved left arm. Subject matched with right.

Right Arm Assessment



Subject matched with left. Robot moved right arm.

Task Score	Left	Right	Typical range
	0.17 (13.4%)	1.58 (88.6%)	< 1.96 (<95%)

Parameters	Left	Right	Typical range		Unit
			Left	Right	
Absolute error X[1 3]	2.1	6.5	(2.0, 8.5)	(1.9, 7.9)	cm
Absolute error Y[1]	1.2	3.2	(0.9, 3.4)	(0.9, 3.6)	cm
Absolute error XY[1 3]	2.6	7.4	(2.5, 8.8)	(2.5, 8.5)	cm
Variability X[1 3]	2.2	3.0	(1.6, 4.5)	(1.5, 4.3)	cm
Variability Y[1]	1.0	1.3	(0.7, 2.0)	(0.7, 2.0)	cm
Variability XY[1 3]	2.4	3.3	(1.9, 4.8)	(1.8, 4.7)	cm
Contraction/Expansion ratio X[1]	1.00	0.86	(0.70, 1.19)	(0.71, 1.18)	cm/cm
Contraction/Expansion ratio Y[1 2]	0.88	1.07	(0.85, 1.14)	(0.86, 1.14)	cm/cm
Contraction/Expansion ratio XY[1]	0.88	0.94	(0.63, 1.28)	(0.64, 1.27)	cm/cm
Shift X[2]	-0.5	-6.4	(-7.4, 4.5)	(-7.6, 4.0)	cm
Shift Y[1 3]	0.1	**3.1**	(-2.8, 2.4)	(-3.2, 2.1)	cm
Shift XY[1]	**0.5**	7.2	(0.7, 8.6)	(0.7, 8.2)	cm

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable |

Comments	Signature

Information provided for research purposes only.

Table: 9-8 defines the parameters given in the report.

Table 9-8: (Sheet 1 of 2)

Parameter (Contribution to Task Score)[1]	Meaning[2]
Absolute error X (->)	Mean absolute distance error in the X-direction across all trials.
Absolute error Y (->)	Mean absolute distance error in the Y-direction across all trials.
Absolute error XY (Exclude)	Mean absolute distance error across all trials.
Variability X (->)	Mean value of the standard deviations of the subject's hand position for each target in the X-direction.
Variability Y (->)	Mean value of the standard deviations of the subject's hand position for each target in the Y-direction.
Variability XY (Exclude)	Root-sum-square (RSS) of X and Y variabilities. $\mathrm{var}_{xy} = \sqrt{\mathrm{var}_x{}^2 + \mathrm{var}_y{}^2}$
Contraction/Expansion ratio X (<->)	Ratio of range of movement in X-direction (arm moved by the subject compared to the arm moved by the robot). Range is calculated as the absolute difference between the mean positions of the left targets versus the right targets (i.e. for the 9 target protocol, the mean positions for the 3 left-most targets, relative to the subject, versus the mean positions for the 3 right-most targets). $ContExp_x = \frac{range_{x,\text{ arm moved by subject}}}{range_{x,\text{ arm moved by robot}}}$
Contraction/Expansion ratio Y (<->)	Ratio of range of movement in Y-direction (arm moved by the subject compared to the arm moved by the robot). Range is calculated as the absolute difference between the mean positions of the distal targets versus the proximal targets (i.e. for the 9 target protocol, the mean positions for the 3 distal targets, relative to the subject in the Y-direction, versus the mean positions for the 3 proximal targets).
Contraction/Expansion ratio XY (Exclude)	Ratio of the range of area moved over (arm moved by the subject compared to the arm moved by the robot). The area of the polygon made by the arm moved by the subject divided by the area of the polygon made by the arm moved by the robot. The two areas are calculated based on mean target positions across trials (centre target is ignored for 9-target protocol).

Table 9-8: (Continued) (Sheet 2 of 2)

Parameter (Contribution to Task Score)[1]	Meaning[2]
Shift X (<->)	Mean difference between the mirrored X-position of the arm moved by the subject and the X-position of the arm moved by the robot. Positive values are for lateral shifts, negative values for medial shifts.
Shift Y (<->)	Mean difference between the mirrored Y-position of the arm moved by the subject and the Y-position of the arm moved by the robot. Positive values are for distal shifts, negative values for proximal shifts.
Shift XY (Exclude)	Root-sum-square (RSS) of the X and Y shifts. $shift_{xy} = \sqrt{shift_x{}^2 + shift_y{}^2}$

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.
2. For the Kinarm Exoskeleton, the fingertip positions used in the parameter calculations are all relative to the subject's fingertip position when their shoulder/elbow is at 30°/90°.

9.4.4 Additional Parameters in CSV Export

In addition to the parameter scores described above, a CSV export will include the standard deviations of each parameter. The standard deviation is calculated across targets for absolute errors and variabilities, and across blocks for contraction/expansion ratios and shifts.

If a CSV export is selected for a single data file, then the target specific values for each parameter will also be listed in the CSV file, with the exception of contraction/expansion ratio.

9.4.5 Citations

Dukelow, S.P., Herter, T.M., Moore, K.D., Demers, M.J., Glasgow, J.I., Bagg, S.D., Norman, K.E., Scott, S.H. (2010) Quantitative Assessment of Limb Position Sense Following Stroke. Neurorehabilitation and Neural Repair. 24:178-187.

Scott, S.H., Brown, I.E. Method and Apparatus for Assessing Proprioceptive Function. U.S. Patent 8,277,396, issued October 2, 2012; CN Patent ZL200780047665.6, issued April 25, 2012; JP Patent 5368311, issued September 20, 2013; CA Patent No. 2,668,364, issued June 14, 2016.

9.5 Arm Posture Perturbation

9.5.1 Test Purpose

The purpose of the Arm Posture Perturbation task is to assess the ability of a subject to respond to unexpected disturbances of the arm when maintaining their hand at a spatial goal (Bourke et al., 2015). Good performance requires the ability to generate rapid corrective responses (Lowrey et al., 2019).

9.5.2 Task Description and Task Protocols

During this task, the subject is shown a target to move to. Once the subject moves a cursor representing their hand position into the target a background load in one of 4 directions is turned on slowly over a period of 1000 ms. After a random wait of 1750 - 2250 ms the background load is ramped off quickly over 10 ms. During initial trials the target location is displayed constantly. In later trials the target location is turned off when the forces are ramped down. The trial is over 3 seconds after forces are ramped off.

This task is only for Kinarm Exoskeleton robots.

There is one protocol for this task:

- Adult and Child

9.5.3 Report

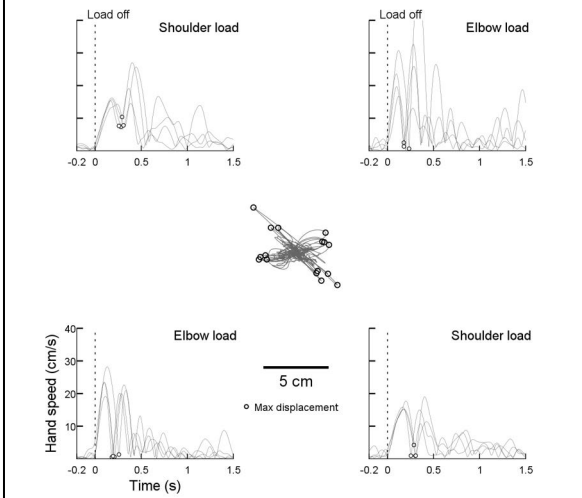
Figure: 9-11 shows an example Arm Posture Perturbation report for a stroke subject. The report image shows the movements of the subject's hand during the task. The circles imposed on the hand paths indicate the maximum displacement from the starting position during a trial. The graphs show the subject's hand speeds immediately after forces are ramped off.

Figure 9-11: Arm Posture Perturbation report.

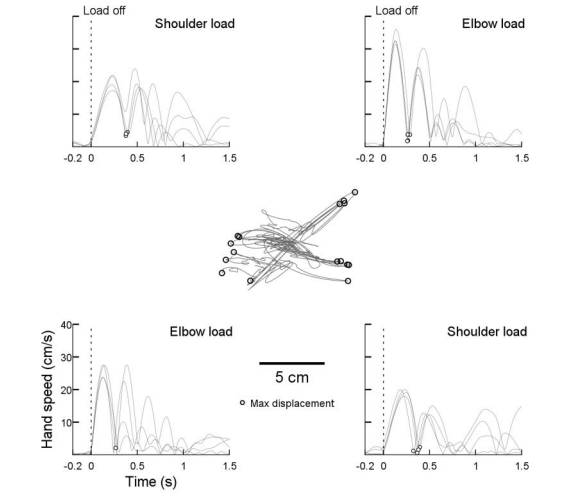
Subject		**ID**	554829344	**Capture**	3.6.4
D.O.B.		**Age**	53	**Analysis**	3.9.0
P.I.		**Study**	Stroke	**Hardware**	EXO
				Serial#	050601
Protocol	Adult and Child	**Exam date**	26/04/2018, 12:53 p.m.	**Complete**	100%

Arm Posture Perturbation

Left Arm Assessment



Right Arm Assessment



Task Score	Left	Right	Typical range
	1.25 (78.8%)	**2.58 (99.0%)**	< 1.96 (<95%)

Parameters	Left	Right	Typical range		Unit
			Left	Right	
Analyzed trials	16 / 16	16 / 16			#
Posture speed[1]	1.09	0.56	(0.39, 1.26)	(0.36, 1.31)	cm/s
Deceleration time[1]	0.24	0.31	(0.16, 0.35)	(0.16, 0.35)	s
Return time[2]	0.34	**1.12**	(0.26, 0.72)	(0.25, 0.74)	s
Final displacement[2]	0.78	**2.04**	(0.23, 0.97)	(0.24, 0.98)	cm
Maximum displacement[1,2]	2.92	**4.81**	(1.38, 4.13)	(1.33, 4.09)	cm

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-9 defines the parameters in the report.

Table 9-9: Arm Posture Perturbation Parameters

Parameter (Contribution to Task Score)[1]	Meaning[2]
Analyzed trials (Excluded)	The count of trials used for analysis. If the subject failed to stabilize at the target then the trial cannot be used for analysis. Displayed relative to the total number of trials (excluding failed trials that were subsequently repeated successfully)
Posture speed (->)	Median hand speed in the interval from 500 ms before forces ramp off until forces ramp off. Reported as the median across trials.
Deceleration time (->)	The time of the first hand speed minima after forces ramp off. Reported as the mean across trials.
Return time (->)	Time from the forces ramping off to the time for the hand to return to near the final hand position. 1) In the time interval from forces being ramped off until the end of the trial, find the maximum distance the hand was from the final hand position. i) If max distance is > 1 cm then set threshold to 1 cm ii) If max distance is <= 1 cm but > 0.5 cm then threshold = 0.5 cm iii) If max distance is <= 0.5 cm then threshold = N/A 2) If a threshold is found then start searching for Return Time after the later of Deceleration Time or first-time-outside of the threshold. Return time is the first time that the hand is within the threshold distance o the hand position at the end of the trial. 3) If no threshold was found then Return Time is the time of the first hand speed minimal after Deceleration Time Reported as the mean across trials.
Final displacement (->)	Distance of the hand from the target at the end of the trial. Reported as the mean across trials.
Maximum displacement (->)	In the time interval from forces ramping off to the end of the trial find the greatest distance that the hand was from the starting hand position (where starting hand position is measured 50 ms before the forces ramp off). Reported as the mean across trials.

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.

2. For the Kinarm Exoskeleton, the fingertip positions used in the parameter calculations are all relative to the subject's fingertip position when their shoulder/elbow is at 30°/90°.

9.5.4 Citations

Bourke T.C., Coderre A.M., Bagg S.D., Dukelow S.P., Norman K.E., Scott S.H. (2015) Impaired corrective responses to postural perturbations of the arm in individuals with subacute stroke. J NeuroEngineering. Rehabil. 2015 Jan 20; 12(1):7.

Lowrey, C.D., Bourke, T.D., Bagg, S.D., Dukelow, S.P., Scott, S.H. (2019) A postural unloading task to assess fast corrective responses in the upper limb following stroke. J Neuroeng Rehabil. 16:16. doi.org/10.1186/s12984-019-0483-2

9.6 Ball on Bar

9.6.1 Test Purpose

The Ball on Bar test assesses the ability of subjects to perform a motor action that requires coordination of the two arms (i.e. bimanual coordination) (Lowrey et al., 2014).

9.6.2 Task Description and Task Protocols

In this task a virtual bar is presented between the subject's hands and a virtual ball is placed on the bar. There are 4 target circles that are presented to the subject one at a time. The objective of the task is to move the virtual ball on the bar into each presented target as quickly and accurately as possible. The bar length is maintained by a virtual spring between the subject's hands.

The task has three levels. On the first level the ball is fixed to the centre of the bar. On the second level the ball's position on the bar is a function of the angle of the bar - when the bar is horizontal the ball will be in the middle of the bar and as the bar tilt angle increases the ball moves nearer to the end of the bar, falling off when the tilt angle reaches 20°. In the final level the ball can roll freely on the bar. On levels two and three the ball can fall off of the bar; if the ball falls off the bar then the ball re-appears fixed to the centre of the bar (similar to level 1) and the target the subject was reaching for turns red. Once the subject moves the ball into the target and the next target appears, the ball will again move on the bar.

If the subject takes longer than 10 s to reach a target (or 15 s for level 3), then the target disappears and the next one is shown.

NOTE: If the subject is unable to reach one or both of the start targets, the operator can initiate an additional step in which the robot will move the subject's hands to the start targets, following which the task will progress as described above.

There are two task protocols available:

- **Adult** - As described above, each level lasting 1 minute. There are four targets, located 10 cm from centre (up/down/left/right). The bar length is 30 cm.
- **Child** - Similar to Adult protocol, but targets are 6 cm from the centre, and the bar length is 20 cm.

9.6.3 Report

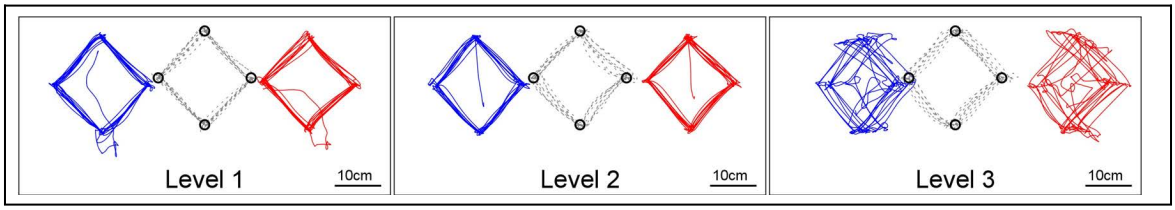
Figure: 9-12 shows an example of a Ball on Bar report for a healthy control. In the report, "Complete" refers to the percentage of the total task time completed by the subject (3 minutes maximal).The graphic shows the hand paths (blue for left, red for right) and the ball path (light grey) for each of the levels.

Figure 9-12: Ball on Bar Report

Subject	**ID**	anon	
D.O.B.	**Age**	39	
P.I.	**Study**		
Protocol Adult	**Exam date** 2014-05-14, 1:48 PM		**Complete** 100%

Capture	3.8.0
Analysis	3.8.0
Hardware	EP
Posture	Seated
Serial#	091001

Ball on Bar



Task Score	Typical range
0.55 (41.5%)	< 1.96 (<95%)

	Parameters	Lvl 1	Typical range	Lvl 2	Typical range	Lvl 3	Typical range	Unit
TM	Targets complete[1] [2]	**37**	(26, 37)	**36**	(20, 35)	**32**	(6, 32)	#
	Drops			0	(0, 0)	0	(0, 4)	#
	Drops / Targets			0.00	(0.00, 0.00)	0.00	(-0.02, 0.57)	#/#
HB	Time to target[1] [2]	0.55	(0.55, 1.21)	0.62	(0.62, 1.77)	**0.67**	(0.77, 4.31)	s
	Ball speed[1] [2]	10.3	(6.7, 10.4)	10.5	(5.7, 11.3)	10.3	(4.3, 11.5)	cm/s
	Right hand speed[1] [2] [3]	9.9	(6.6, 10.2)	9.2	(5.1, 9.4)	10.2	(3.1, 13.0)	cm/s
	Left hand speed[1] [2] [3]	10.3	(6.6, 10.4)	9.5	(5.2, 9.6)	10.4	(3.1, 12.9)	cm/s
	Right hand speed peaks[2] [3]	**313**	(163, 284)	277	(150, 302)	219	(130, 251)	#
	Left hand speed peaks[2] [3]	255	(163, 274)	259	(150, 296)	213	(131, 247)	#
BM	Mean bar tilt[1] [2]	0.8	(-1.2, 1.5)	1.0	(-0.9, 1.6)	0.0	(-0.7, 0.6)	°
	Bar tilt stdev	1.3	(1.3, 4.2)	1.1	(1.1, 2.9)	3.0	(1.9, 10.9)	°
	Bar length variability[1] [2]	1.66	(0.72, 2.34)	1.29	(0.54, 1.92)	1.68	(0.61, 2.31)	%
IL	Reaction time: abs diff[1]	31	(20, 47)					ms
	Hand speed diff[1]	19.8	(13.3, 23.2)	19.8	(12.9, 23.6)	25.2	(18.6, 46.4)	%
	Hand speed peaks bias	**0.102**	(-0.058, 0.073)	0.034	(-0.070, 0.069)	0.014	(-0.066, 0.075)	#
	Hand path length bias	-0.019	(-0.029, 0.012)	-0.014	(-0.026, 0.010)	-0.008	(-0.050, 0.042)	cm/cm

Statistically significant effect from: [1]age, [2]sex, [3]handedness. Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-10 defines the parameters in the report:

Table 9-10: Ball on Bar Parameters (Sheet 1 of 2)

Type	Parameter (Contribution to Task Score)[1]	Meaning
Total Metric (TM)	Targets complete (<-)	Number of successful targets touched by the ball and held without a ball drop.
	Drops (->)	Number of times the ball fell off the bar. The ball is fixed to the bar for level one so this parameter does not apply to that level.
	Drops/Target (->)	Ratio of Drops to Targets completed. If no targets were completed successfully for the level then this value is set equal to the number of Drops.
Hand and Ball (HB)	Time to target (Exclude)	Mean time to reach a target. For successful reaches, time to target is the time from target on to first time the target is touched. For unsuccessful reaches, time to target equals the time that the target was shown for (10 s for Levels 1 and 2, 15 s for Level 3). Incomplete reaches at the end of a level are excluded. On the first level the first 4 targets are not counted in this metric.[2,3]
	Ball speed (<-)	Mean speed of the ball during the level (cm/s).[2]
	Right/Left hand speed (Exclude)	Mean speed of the hand during the level (cm/s).[2]
	Right/Left hand speed peaks (Exclude)	Count of the speed maxima for the hand for the level, excluding maxima at first or last data points.[2]
Bi-Manual (BM)	Mean bar tilt (Exclude)	Mean angle of the bar during the level. Horizontal = 0, positive is counter-clockwise.[2]
	Bar tilt stdev (->)	Standard deviation of the bar angle during the level.[2]
	Bar length variability (->)	Standard deviation of bar length/mean bar length for the level. This is also known as the coefficient of variation.[2]

Table 9-10: Ball on Bar Parameters (Continued) (Sheet 2 of 2)

Type	Parameter (Contribution to Task Score)[1]	Meaning
Inter-Limb (IL)	Reaction time: abs diff (Exclude)	Mean of the absolute difference between right and left hand reaction times for each completed target in a level. The reaction time for levels 2 and 3 are not calculated because the movement of the ball (and therefore the hands to stabilize) makes an exact reaction time difficult to interpret. Valid reaction times for both hands must be found for at least 5 completed targets, otherwise this value is reported as NaN. The first four successful reaches are excluded from this calculation. $\text{Reaction time: abs diff} = \overline{abs(t_{R.H.} - t_{L.H.})}$
	Hand speed diff (->)	Difference in hand speeds normalized by the mean of the hand speeds, where RHS = Right hand speed and LHS = Left hand speed, and where each sum is the sum over all kinematic frames.[2] $\text{Hand speed diff} = \frac{\sum abs(RHS - LHS)}{0.5 \cdot \sum abs(RHS + LHS)}$
	Hand speed peaks bias (<->)	Relative bias in number of hand speed peaks, where $HSP_{D/ND}$ = #Dominant/non-Dominant hand speed peaks.[2] $\text{Hand speed peaks bias} = \frac{HSP_D - HSP_{ND}}{HSP_D + HSP_{ND}}$

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.
2. Data from after the ball leaves the bar until the next target is touched is not included in the calculation because the ball is not behaving as it would normally be during the level, i.e. it is fixed to the centre of the bar.
3. The description above applies to data collected using Dexterit-E 3.7 and later. Prior to Dexterit-E 3.7, there were no timeouts for targets, so if there were no successful reaches, then this parameter's value is set equal to the duration of the level (i.e. 60 s).

9.6.4 Additional Parameters in CSV Export

Some parameters are provided in the CSV export, but are not available in the report. The parameters that are in all CSV exports but not in the report are listed below.

Table 9-11: Ball on Bar Additional CSV Parameters

Parameter	Meaning
Failed to contact target (#)	Number of times that the subject failed to contact the target, prior to a target's time-out. For levels 2 and 3 this count includes the reaches following a dropped ball, when the ball is fixed on the bar. If the level ends before a target's time-out, then that reach is not counted.
Failed to stabilize at target (#)	Number of times that the subject failed to stabilize at a target, prior to a target's time-out. For levels 2 and 3, this count includes the reaches following a dropped ball, when the ball is fixed on the bar. If the level ends before a target's time-out, then that reach is not counted.

9.6.5 Citations

Lowrey,C.R., Jackson, C.P.T., Bagg, S.D., Dukelow, S.P. and Scott, S.H. (2014) A Novel Robotic Task for Assessing Impairments in Bimanual Coordination Post-Stroke. Int J Phys Med Rehabil. S3:002 doi: 10.4172/2329-9096.S3-002.

9.7 Elbow Stretch

9.7.1 Test Purpose

The Elbow Stretch test assesses the response of a subject to passive stretch of the elbow at two different speeds, in order to quantify any increase in muscle tone or an uncontrollable increase in muscle activity due to joint position or motion.

9.7.2 Task Description and Task Protocols

The task is a passive task that requires a Kinarm Exoskeleton lab. During the task the robot rotates a subject's elbow over a specified angular range within a specified duration. If the subject resists the motion (actively or passively), then the movement will be slowed and possibly stop short of the intended final angle. Different durations (i.e. speeds) are used for the test in order to help differentiate if the speed of stretch influences the subject's response; both elbow flexion and extension are tested.

There are two task protocols available:

- **Adult and Child v2**: the robot will attempt to flex and extend the elbow 5 times over 85°, with intended movement durations of 1.5 s, followed by 5 more flexion and extensions each with an intended movement duration of 0.6 s. The shoulder is locked at 45°.
- **Adult and Child v1**: the same as the v2 protocol except for the Kinarm Classic (PN 10755) the shoulder is locked at 60° whereas for the Kinarm Exoskeleton (PN 13568) the shoulder is locked at 30°.

9.7.3 Normative Models

As per *Section: 9.2.8 Normative Models and Z-Scores for Task Parameters*, the standard approach for all KST is that Z-scores for all parameters are generated using models that account for age, sex, handedness and robotic platform. In addition to these standard factors, the normative models for Elbow Stretch parameters also account for subject weight.

9.7.4 Report

Figure: 9-13 shows an example of an Elbow Stretch Task Report. In the report, "Complete" refers to the percentage of expected trials that the subject completed. The graphics indicate the angular positions and velocities during extension and flexion.

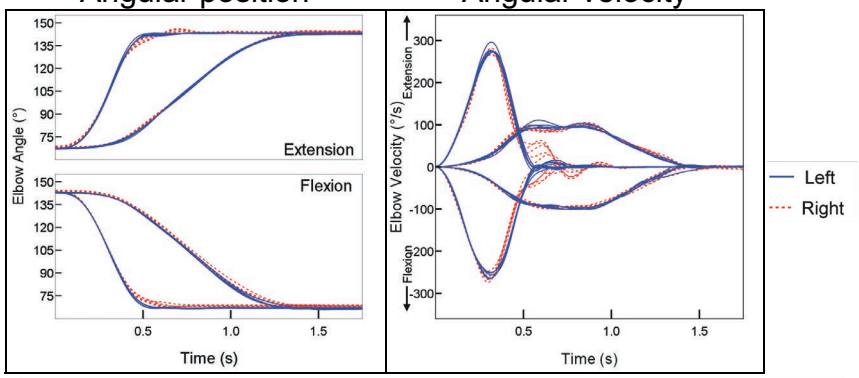
Figure 9-13: Elbow Stretch Report

Subject		**ID**	0001	**Capture**	3.7.2
D.O.B.		**Age**	51	**Analysis**	3.9.0
P.I.		**Study**	Control 2019	**Hardware**	EXO
				Serial#	170202

Protocol	Adult and Child v1			**Protocol**	Adult and Child v1		
Exam date	05-Mar.-2019, 2:41 p.m.	**Complete**	100%	**Exam date**	05-Mar.-2019, 2:40 p.m.	**Complete**	100%

Elbow Stretch

Angular position | Angular velocity



Task Score	Left	Right	Inter-Limb	Typical range
	0.81 (58.1%)	0.80 (57.4%)	**2.09 (96.3%)**	< 1.96 (<95%)

Stretch duration	Direction	Parameters	Left	Right	Typical range	Inter-Limb	Typical range	Unit
Slow 1500 ms	Flexion	Peak speed[1 2]	100	**98**	(99, 110)	1	(-5, 5)	°/s
		Final angle[1 2]	67	68	(66, 70)	-1	(-2, 2)	°
		Creep distance	-0.4	-0.1	(-0.4, 0.1)	-0.3	(-0.4, 0.5)	°
		Catch angle	-	-				°
	Extension	Peak speed[1 3]	102	104	(100, 109)	-2	(-6, 6)	°/s
		Final angle[1 2 3]	143	144	(142, 145)	**-1**	(-1, 2)	°
		Creep distance	0.0	-0.0	(-0.1, 0.1)	0.1	(-0.2, 0.1)	°
		Catch angle	-	-				°
Fast 600 ms	Flexion	Peak speed[1]	258	263	(221, 279)	-5	(-25, 22)	°/s
		Final angle[1 2]	67	69	(66, 70)	-1	(-1, 2)	°
		Creep distance	-0.1	-0.0	(-0.4, 0.1)	-0.1	(-0.2, 0.2)	°
		End torque[1 2]	**-2.59**	-1.59	(-2.20, -0.37)	**-1.00**	(-0.46, 0.77)	N·m
		Catch angle	-	-				°
	Extension	Peak speed[1 2]	279	273	(232, 286)	6	(-21, 19)	°/s
		Final angle[1 2 3]	143	144	(142, 145)	**-1**	(-1, 2)	°
		Creep distance	-0.0	0.0	(-0.1, 0.1)	-0.0	(-0.2, 0.1)	°
		End torque[1 2]	**-2.23**	-1.17	(-2.00, -0.69)	**-1.06**	(-0.61, 0.49)	N·m
		Catch angle	-	-				°

*Deviations in final angle from typical range can influence parameters in the opposite movement direction

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-12 defines the parameters in the report.

Table 9-12: Elbow Stretch Parameters

Parameter (Contribution to Task Score)[1]	Meaning[2]
Extension/Flexion peak speed (<-)	Peak angular speed of the elbow in the direction of intended movement, taken as a mean across all trials.
Extension/Flexion Final Angle (Extension: <-) (Flexion: ->)	Final angle attained by the elbow at the end of the trial taken as a mean across all trials.
Extension/Flexion end torque (600 ms: ->) (1500 ms: Exclude)	The mean torque applied by the robot during the latter part of the movement. Calculated from the time of the planned peak movement speed to the time that planned movement speed decreases to 5% of the peak speed. The planned speed is based on the nominal desired trajectory of the movement. These parameters are only reported for the fast movement speed.
Extension/Flexion creep (Exclude)	Difference between the elbow angle 1 s after the nominal end of the movement duration and the final angle - taken as the mean across all trials. Movement continuing towards the expected final angle is always positive, movement back to the expected final angle after an overshoot is always negative.
Extension/Flexion catch angle (Exclude)	Using both a right and left exam, this is the angle at which the velocity difference between the arms first deviates by more than the 99th percentile as calculated by a large normal database. The mean kinematic data across trials are used for this analysis. For subjects without large enough differences in inter-arm velocities to identify a catch angle, this value will be '-' on the report.

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.
2. Inter-limb values are always calculated as (Dominant arm value) - (Non-dominant arm value)

9.7.5 Additional Parameters in CSV Export

Some parameters are provided in the CSV export, but are not available in the report. The parameters that are in the CSV export but not in the report are listed below.

Table 9-13: Elbow Stretch additional CSV parameters

Parameter	Meaning
Extension/Flexion start torque	The mean torque applied by the robot during the initial part of the movement. Calculated from the time the planned movement speed is 5% of the peak planned movement speed to the peak planned movement speed. The planned speed is based on the nominal desired trajectory of the movement.
1.5 s Extension/Flexion end Torque	This is calculated the same as 0.6 s Extension/Flexion end torque.

9.7.6 Citations

Centen A, Lowrey C.R., Scott S.H., Yeh, T.T., Mochizuki G. (2017) KAPS (Kinematic Assessment of Passive Stretch): a tool to assess elbow flexor and extensor hypertonicity after stroke using a robotic exoskeleton. J Neuroeng Rehabil. 14(1):59. doi: 10.1186/s12984-017-0272-8.

9.8 Object Hit

9.8.1 Test Purpose

The Object Hit test assesses rapid motor skills across the workspace. It was developed to assess the ability of a subject to select and engage motor actions with both hands over a range of speeds and a large workspace. Good performance requires the ability to generate a goal-directed motor action to a moving target, bimanual planning to select which arm to use to hit each object, and spatial awareness across the workspace (Tyryshkin et al., 2014).

9.8.2 Task Description and Task Protocols

In this task, virtual paddles appear at the subject's hand. The subject is instructed to use these paddles to hit and push away balls that appear randomly from various locations (i.e. bins) across the top of the screen, and which are moving towards the subject. As the task proceeds, the balls move at greater speeds and appear more often, making the task more difficult as time progresses. Haptic feedback is provided (small force pulse from the robot) when contact with a ball is made by a subject.

There are two task protocols available:

- **Adult** - A total of 300 balls are dropped during the task, 30 from each of 10 bins that are evenly distributed over 80 cm workspace. The paddles are 5 cm wide.
- **Child** - Similar to Adult protocol, but the width of the workspace is 50 cm, and the paddles are 3 cm wide. The size of the ball is 75% of adult version.

9.8.3 Report

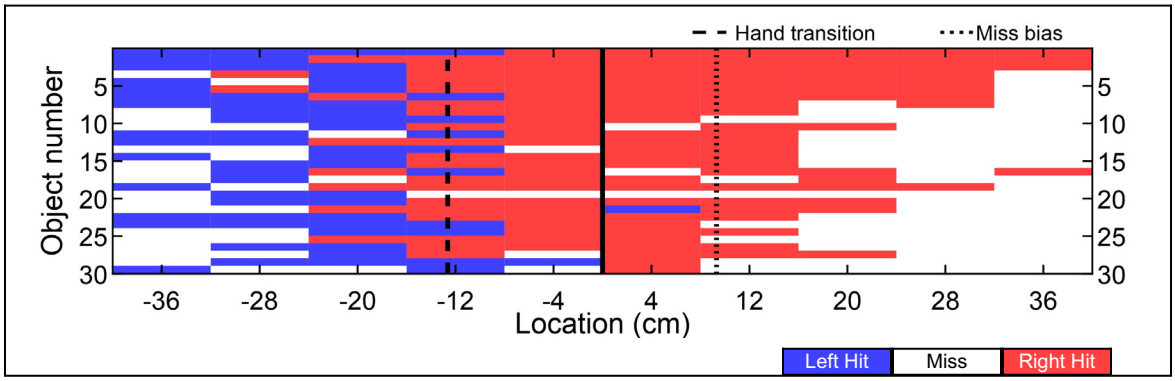
Figure: 9-14 shows an example of an Object Hit report for a healthy control. In the report, “Complete” refers to the percentage of balls that were dropped before the task was stopped. The graphic in the report shows the hits and misses during the task, as well as which hand contacted each ball first. Location indicates the X-position of the bin from where a ball was dropped, relative to the midline of the subject. Object number indicates the cumulative number of balls dropped from each bin. Hits by the subject are indicated by blue for the left hand and red for the right hand. Missed balls are indicated by white. In addition, dashed and dotted lines representing the spatial location of the Hand Transition and Miss Bias parameters are indicated on this graphic.

Figure 9-14: Object Hit Report

Subject	**ID**	anon	
D.O.B.	**Age**	62	
P.I.	**Study**		
Protocol Adult	**Exam date** 16-Jun-2016, 10:45 AM		**Complete** 100%

Capture	3.5.2
Analysis	3.9.0
Hardware	EP
Posture	Seated
Serial#	120701

Object Hit



Task Score	Typical range
5.38 (>99.9%)	< 1.96 (<95%)

Parameters		Score	Typical range	Unit
Task Level	Target hits[1 2]	**64**	(75, 94)	%
	Median error[1 2]	**64**	(66, 85)	%
	Miss bias	9.3	(-13.5, 10.9)	cm
Right Hand	Hand speed[2 3]	50.2	(24.5, 53.8)	cm/s
	Movement area[2 3]	2240	(1130, 2400)	cm²
Left Hand	Hand speed[2 3]	**17.1**	(24.1, 52.4)	cm/s
	Movement area[2 3]	**980**	(1080, 2330)	cm²
Inter-Limb	Hand bias hits[1]	**0.337**	(-0.045, 0.170)	#/#
	Hand transition	**-12.6**	(-7.1, 2.8)	cm
	Hand selection overlap[1]	16.1	(6.4, 20.5)	%
	Hand speed bias	**0.492**	(-0.077, 0.129)	cm/s / cm/s
	Movement area bias	**0.392**	(-0.074, 0.132)	cm²/cm²

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable |

Comments	Signature

Information provided for research purposes only.

Table: 9-14 defines each of the parameters in the report.

Table 9-14: Object Hit Parameters (Sheet 1 of 2)

Type	Parameter (Contribution to Task Score)[1]	Meaning
Task Level	Target hits (<-)	Percentage of balls hit out of total balls dropped. A ball is considered to be 'hit' if its final trajectory moves it off the screen anywhere other than the bottom of the screen (i.e. other than the border nearest the subject).
	Median error (<-)	Percentage of the way through the task when the subject made half of his or her errors (based on number of balls, not time).
	Miss bias (<->)	Quantifies any bias of misses toward one side of the work space or the other (X-direction only). This parameter is reported in cm to show where in the work space the bias is located. It is computed by counting the number of misses for each of the ten bins and then calculating the weighted mean of the resulting distribution over the ten bins, as defined below (x_i is the X-position of the i^{th} bin, and the weight $w_{m,i}$ is the number of misses in the i^{th} bin). $\text{weighted mean} = \frac{\sum_{i=1}^{10} x_i \cdot w_{m,i}}{\sum_{i=1}^{10} w_{m,i}}$
Left/Right Hand	Hand speed (<-)	Mean hand speed of the subject during the task.
	Movement area (<-)	Area of space the subject used with each hand during the task. This parameter is determined by defining a convex hull that encompasses the subject's complete hand path.
Inter-Limb	Hand bias hits (<->)	A value from -1 to 1 that quantifies which hand is used more often for hitting the balls (hand dominance). It is calculated as per the following, where $n_{RH/LH}$= # targets hit with right/left hand.[2] $\text{Hand bias hits} = \frac{n_{RH} - n_{LH}}{n_{RH} + n_{LH}}$

Table 9-14: Object Hit Parameters (Continued) (Sheet 2 of 2)

Type	Parameter (Contribution to Task Score)[1]	Meaning
	Hand transition (<->)	Shows where the subject's preference for using one hand over the other switches in the work space. It is computed by taking the mean of two values: the right hand and the left hand weighted means of hit distributions. The weighted mean of hit distributions for each hand are calculated independently for each hand using a subset of bins, including only those where both hands made hits (overlapping bins) plus one additional bin on each side of the overlap bins. In the special case where no overlap occurs, the subset of bins used includes the right most bin in which hits were made by the left hand and the left-most bin where hits were made with the right hand. (x_i is the X-position of the i^{th} bin, and the weight $w_{h,i}$ is the number of hits in the i^{th} bin if that bin is part of the subset identified above, otherwise $w_{h,i} = 0$).[2] $\text{weighted mean} = \frac{\sum_{i=1}^{10} x_i \cdot w_{h,i}}{\sum_{i=1}^{10} w_{h,i}}$
	Hand selection overlap (<-)	Summation of hand switches for each bin, divided by the target total hits. Captures how effective subjects are at using both hands and how often they overlap hands (i.e. hit balls with both the right and left hands in the same area of the work space).
	Hand speed bias (<->)	A value from -1 to 1 which describes the bias in Hand Speed between the hands. It is calculated as per the following, where $s_{RH/LH}$ = mean speed of right/left hand.[2] $\text{Hand speed bias} = \frac{s_{RH} - s_{LH}}{s_{RH} + s_{LH}}$
	Movement area bias (<->)	A value from -1 to 1 which describes the bias in movement area between the hands. It is calculated as per the following, where $A_{RH/LH}$ = area of region over which the right/left hand moved.[2] $\text{Movement area bias} = \frac{A_{RH} - A_{LH}}{A_{RH} + A_{LH}}$

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.
2. Z-scores and normative comparisons for these inter-limb comparisons are based on dominant vs. non-dominant hand, even though the parameter scores are reported as right vs. left hand.

9.8.4 Additional Parameters in CSV Export

Some parameters are provided in the CSV export, but are not available in the report. The parameters that are in the CSV export but not in the report are listed below in *Table: 9-15*.

Table 9-15: Object Hit Additional CSV Parameters

Parameter	Meaning
Target total hits	Count of balls successfully hit. This value is out of a possible 300.
Hits with the right/left (#)	Count of balls successfully hit with each hand.

9.8.5 Citations

Tyryshkin K., Coderre A., Glasgow J.I., Herter T.M., Bagg S.D., Dukelow S.P., Scott S.H. (2014) A robotic object hitting task to quantify sensorimotor impairments in participants with stroke.J Neuroeng Rehabil. 11(1):47. doi: 10.1186/1743-0003-11-47

Scott, S.H. Method and apparatus for assessing or detecting brain Injury and neurological disorders. US Patent 8,740,794 issued June 3, 2014; other jurisdictions pending.

9.9 Object Hit and Avoid

9.9.1 Test Purpose

This task requires subjects to generate rapid motor actions across the workspace using both arms, like Object Hit, but also requires subjects to select the correct objects to hit based on shape while avoid hitting other objects with different shapes. Thus, this task requires additional attention to the shape of each object and inhibitory control to avoid contacting the incorrect objects (Bourke et al., 2016).

9.9.2 Task Description and Task Protocols

At the start of the task the subject is shown 2 target shapes which the subject is instructed to memorize as the only two shapes to hit during the task; they are instructed to avoid all other shapes (there will be 6 other shapes or distractors). When a virtual paddle attached to the hand contacts a target, the target is pushed away and there is haptic feedback during contact (i.e. small force pulse from the robot). If the paddle contacts a distractor, it passes through the paddle and there is no haptic feedback, thereby providing immediate and ongoing feedback to the subject that the object was a distractor and not a target.

There are two task protocols available:

- **Adult** - A total of 300 objects are dropped, including 20 targets and 10 distractors from each of 10 bins that are evenly distributed over an 80 cm wide workspace. The paddles are 5 cm wide.
- **Child** - Similar to Adult protocol, but the width of the workspace is 50 cm, and the paddles are 3 cm wide. Object dimensions are ~75% of adult version.

NOTE: For both Adult and Child protocols, when selected, 1 of 6 possible variants will be chosen by Dexterit-E. Each variant includes one short target and one tall target, and the two targets have different geometric shape (i.e. circle and triangle). Each time a subject performs this task, Dexterit-E examines their previous data file (if one exists) and the next combination is chosen

NOTE: If you would like to select a specific combination, you can right-click on the protocol. The context menu will show a check mark beside the currently selected protocol version (i.e. one of the 6 combinations). You can select the target combination you wish to run from this list.

9.9.3 Report

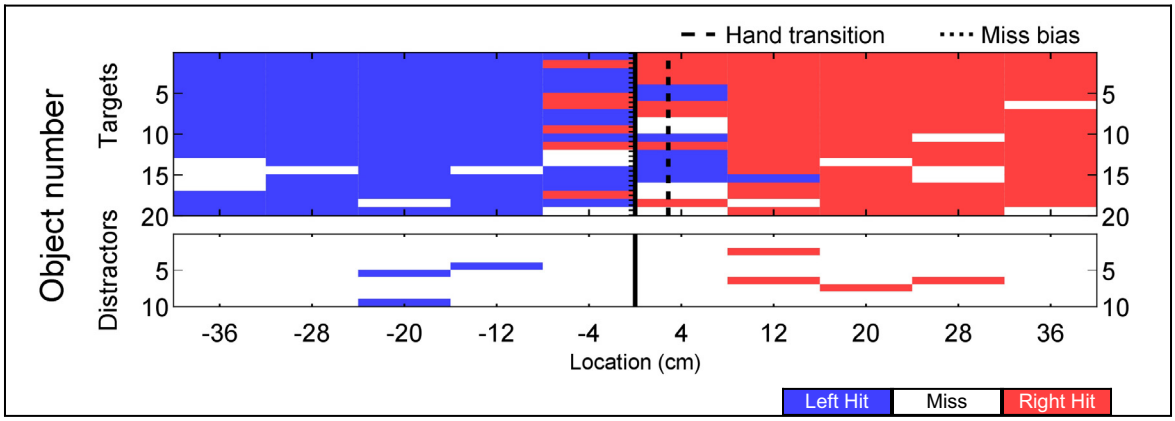
Figure: 9-15 shows an example of an Object Hit and Avoid report for a healthy control. In the report, "Complete" refers to the percentage objects out of 300 that were dropped before the task stopped. Similar to the Object Hit report, the top graphic in this report shows the target hits and misses during the task, which hand contacted a target first and dashed and dotted lines representing the spatial location of the Hand Transition and Miss Bias parameters. The report contains a second graphic which shows which distractors were hit and by which hand. Location indicates the X-position of the bin from where a ball was dropped.

Figure 9-15: Object Hit and Avoid Report

Subject	**ID**	anon	
D.O.B.	**Age**	38	
P.I.	**Study**		
Protocol Adult	**Exam date** 18-Jan-2013, 12:26 PM		**Complete** 100%

Capture	3.3.1
Analysis	3.8.0
Hardware	EP
Posture	Seated
Serial#	091001

Object Hit and Avoid



Task Score	Typical range
0.26 (20.6%)	< 1.96 (<95%)

Parameters		Score	Typical range	Unit
Task Level	Target hits[1] [2]	89	(71, 94)	%
	Distractor hits[1]	7	(1, 22)	%
	Median error[1]	74	(61, 83)	%
	Miss bias	-0.4	(-9.2, 11.6)	cm
	Objects hit[1] [2]	62	(51, 66)	%
	Distractor proportion[1] [2]	4	(1, 12)	%
	Object processing rate[1] [2]	2.72	(2.16, 3.11)	#/s
Right Hand	Hand speed[1] [3]	25.4	(17.7, 35.0)	cm/s
	Movement area[1] [2] [3]	1500	(1040, 2100)	cm²
Left Hand	Hand speed[1] [3]	26.9	(16.9, 33.3)	cm/s
	Movement area[1] [2] [3]	1570	(970, 1980)	cm²
Inter-Limb	Hand bias hits[2]	-0.034	(-0.078, 0.159)	#/#
	Hand transition[1]	2.9	(-7.2, 3.2)	cm
	Hand selection overlap[1]	10.1	(4.0, 16.1)	%
	Hand speed bias[2]	-0.029	(-0.098, 0.134)	cm/s / cm/s
	Movement area bias[1] [2]	-0.02	(-0.12, 0.14)	cm²/cm²

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

The parameters collected for this task include those for the Object Hit task (*Table: 9-14*), plus an extra parameter outlined below in *Table: 9-16*.

Table 9-16: Object Hit and Avoid Additional Parameters

Parameter (Contribution to Task Score)[1]	Meaning
Distractor Hits (Exclude)	Percentage of distractor objects the subject hit.
Median Error (<-)	Percentage of the way through the task when the subject made half of his or her errors (based on number of balls, not time). Errors are targets missed and distractors hit.
Objects Hits (Exclude)	Percentage of objects (targets and distractors) the subject hit.
Distractor Proportion (->)	Number of distractors hit as a percentage of the total number of objects (targets and distractors) the subject hit.
Object Processing Rate (<-)	Number of objects correctly processed per second at the time when 80% of the objects in the task have entered the screen.

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.

9.9.4 Additional Parameters in CSV Export

Some parameters are provided in the CSV export, but are not available in the report. The parameters that are in the CSV export but not in the report are listed below in *Table: 9-17*.

Table 9-17: Object Hit and Avoid Additional CSV Parameters

Parameter	Meaning
Target Hits Total (#)	Count of targets successfully hit with either hand.
Targets Hit Left/Right (#)	Count of targets successfully hit with the hand.
Distractor hits total (#)	Count of distractor objects hit with either hand.
Distractor hits Left/Right (#)	Count of distractor object hits with the hand.

9.9.5 Citations

Bourke, T.C., Lowrey, C.R., Dukelow, S.P., Bagg, S.D. Norman, K.E., Scott S.H. (2016) A robot-based behavioural task to quantify impairments in rapid motor decisions and actions after stroke. J Neuroeng Rehabil. 13:91. doi: 10.1186/s12984-016-0201-2.

Scott, S.H. Method and apparatus for assessing or detecting brain Injury and neurological disorders. US Patent No. 8,740,794 issued June 3, 2014; other jurisdictions pending.

9.10 Reverse Visually Guided Reaching

9.10.1 Test Purpose

The Reverse Visually Guided Reaching test assesses the ability of subjects to perform goal-directed motor actions when there is a need to inhibit the automatic motor response to move the hand towards the goal, and to use a cognitive rule to move in the opposite direction to attain the goal (Tippett & Sergio, 2006).

9.10.2 Task Description and Task Protocols

Reverse Visually Guided Reaching is similar to the Visually Guided Reaching task (see *Section: 9.13 Visually Guided Reaching*), however, after reaching the initial central target at the beginning of the task, the movement of the cursor (white circle) representing hand position is mirror reversed, relative to the central target (i.e. movement of the hand to the right and away from the subject leads to movement of the cursor to the left and towards the subject). The task requires subjects to cognitively override and inhibit the natural response to move the hand directly to a target. Corrective responses to reach the goal must also override the normal coupling between somatosensory and visual feedback.

There are two protocols for this task:

- **Adult** - This protocol uses the same target locations as the Visually Guided Reaching Task Adult: 4 target protocol, including a movement back to the central target. The main differences with this protocol over Visually Guided Reaching is that the subject has 6 seconds to reach the peripheral target instead of 3 seconds, and there are 5 'catch' trials in which there is no peripheral target presented in the trial, instead of 4 catch trials.
- **Child** - Similar to Adult protocol, this protocol uses the same target locations as the Visually Guided Reaching Task Child: 4 target protocol.

9.10.3 Report

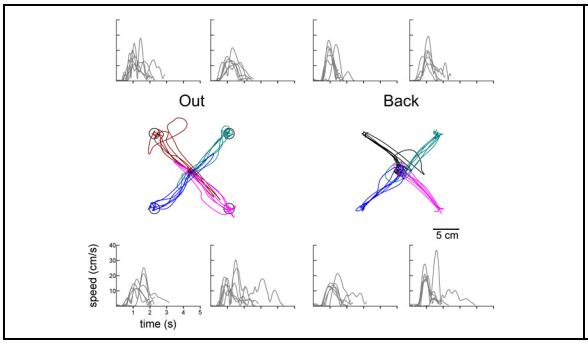
Figure: 9-16 shows an example of a Reverse Visually Guided Reaching report for a healthy control. In the report, "Complete" refers the percentage of expected trials that the subject completed.

Figure 9-16: Reverse Visually Guided Reaching Report

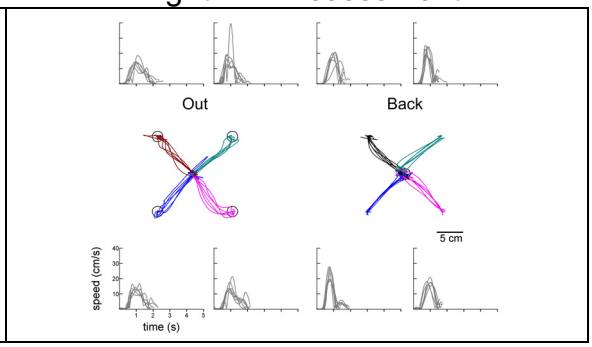
Subject		**ID**	anon	**Capture**	3.5.4
D.O.B.		**Age**	42	**Analysis**	3.8.0
P.I.		**Study**	Control IRR 2017	**Hardware**	EXO
				Serial#	101202
Protocol	Adult	**Protocol**	Adult		
Exam date	20-Jun-2017, 11:35 AM	**Complete**	100%		
Exam date	20-Jun-2017, 11:38 AM	**Complete**	100%		

Reverse Visually Guided Reaching

Left Arm Assessment



Right Arm Assessment



Task Score	Left	Right	Inter-Limb	Typical range
	1.66 (90.4%)	0.18 (14.1%)	**2.26 (97.6%)**	< 1.96 (<95%)

	Parameters	Left	Right	Typical range		Inter-Limb	Typical range	Unit
				Left	Right			
NT	No init stabilization	0	0	(0, 0)	(0, 0)	0	(0, 0)	#
	No reaction time	0	0	(0, 0)	(0, 0)	0	(0, 0)	#
	No end movement	1	0	(0, 1)	(0, 1)	**-1**	(0, 1)	#
	End target not reached	0	0	(0, 0)	(0, 0)	0	(0, 0)	#
PC	Posture speed[2 3]	0.125	0.114	(0.086, 0.357)	(0.11, 0.37)	-0.01	(-0.11, 0.13)	cm/s
VR	Reaction time[1]	**534**	424	(285, 523)	(292, 518)	**-110**	(-65, 68)	ms
FM	Initial direction angle[1 2]	5.9	4.2	(2.8, 10.6)	(2.8, 10.6)	-1.7	(-3.8, 4.0)	°
	Initial distance ratio[1 2]	0.73	0.81	(0.13, 0.93)	(0.18, 0.91)	0.08	(-0.27, 0.28)	cm/cm
	Initial speed ratio[1 2 3]	0.87	0.95	(0.75, 0.98)	(0.76, 0.98)	0.080	(-0.093, 0.106)	cm/s / cm/s
	Direction errors[1 2 3]	10	3	(0, 12)	(0, 11)	**-7.00**	(-6, 5)	#
	Correction time[1 2 3]	**124**	21	(2, 87)	(-0, 76)	**-102**	(-42, 32)	ms
CM	Speed maxima count[1 2]	2.98	2.33	(2.12, 5.12)	(2.14, 5.18)	-0.65	(-1.07, 1.38)	#
	Min-max speed Δ	1.5	1.2	(0.7, 3.0)	(0.7, 3.2)	-0.3	(-0.7, 0.9)	cm/s
TM	Movement time[1 2]	1.63	1.37	(1.00, 2.06)	(0.99, 2.07)	-0.27	(-0.30, 0.33)	s
	Path length ratio[3]	**1.44**	1.18	(1.09, 1.43)	(1.08, 1.43)	**-0.26**	(-0.14, 0.27)	cm/cm
	Max speed[1 2]	17.1	17.7	(11.2, 31.8)	(10.9, 32.6)	0.6	(-3.5, 3.5)	cm/s

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable |

Comments	Signature

Information provided for research purposes only.

The Reverse Visually Guided Reaching report includes parameters from Visually Guided Reaching (see *Table: 9-18*). All shared parameters are calculated in the same way, with the exception that the position of the cursor is used rather than the position of the hand. The report includes the following additional parameters described in *Table: 9-18*.

Table 9-18: Reverse Visually Guided Reaching Additional Parameters

Type	Parameter (Contribution to Task Score)[1]	Meaning
First Movement (FM)	Direction Errors (->, w_i = n/N)	Number of times the subject initially moved the cursor away from the end target.
	Correction Time (->, w_i = n/N)	If there is a direction error, the mean time before the subject started to move the cursor towards the end target. If the subject's initial movement was toward the end target then the value for that trial is zero. Otherwise the correction time is calculated as the amount of time from the end target turning on to the time the subject was the farthest from the end target.

1. Direction of arrow indicates sidedness of poor performance. Parameters may be weighted based on ratio of number of successful trials / number of executed trails (i.e. n / N). See *Section: 9.2.9 Task Score and M-Score*.

9.10.4 Additional Parameters in CSV Export

See *Section: 9.13 Visually Guided Reaching* for additional parameters in CSV export for Reverse Visually Guided Reaching.

9.10.5 Citations

Tippett, W. J. & Sergio, L. E. (2006). Visuomotor integration is impaired in early stage Alzheimer's disease. Brain Res., 1102, 92-102

9.11 Spatial Span

9.11.1 Test Purpose

The Spatial Span test is a variant of a classic test to assess visuospatial working memory to identify the capacity of subjects to remember recently identified spatial locations in the workspace (Berch et al., 1998; Owen et al., 1990, 1995, 1996).

9.11.2 Task Description and Task Protocols

This task derives from the Corsi block-tapping task (Berch et al., 1998). During each trial of the task, the subject must reach to a starting location, after which 12 squares are displayed in a 3x4 grid. A sequence of squares will light up in random order. The subject is instructed to replay the sequence by reaching and pausing at the appropriate squares. If the subject can correctly replay the sequence, then on the next trial the length of the sequence will increase by 1, up to a maximum of 12. If the subject makes an error or takes too long then on the next trial the length of the sequence will be shorter by 1, down to a minimum of 1. A trial will time out if the subject takes longer than (sequence length + 1) * 3 seconds to complete a sequence. For instance, if the sequence length is 4 then the maximum time for the trial is 15 seconds ((4+1) * 3). There are a total of 18 trials. The first 2 trials are considered warm up trials and are therefore not used when calculating parameter scores.

There are two task protocols available:

- **Adult** - the 3x4 grid is composed of 3 x 3 cm squares, with 6 cm centre-to-centre spacing.
- **Child** - the 3x4 grid is composed of 2.5 x 2.5 cm squares, with 4 cm centre-to-centre spacing.

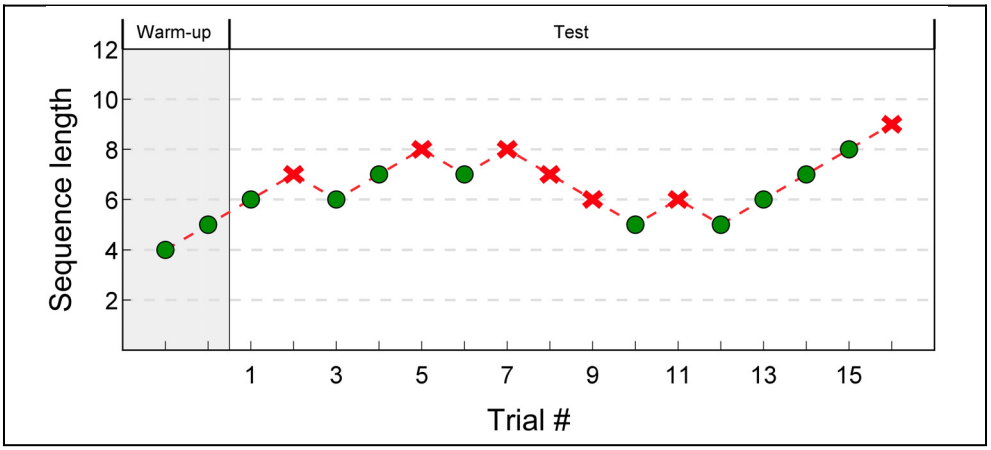
9.11.3 Report

Figure: 9-17 shows an example of a Spatial Span report for a healthy control. In the report, “Complete” refers to the percentage of expected trials that the subject completed. The graphic indicates the sequence length that was shown to the subject for each trial; trials that were completed correctly are indicated by a green circle and trials with an error by a red ‘x’. The first 2 trials are not used for score calculations, as indicated by the grey region of the graph.

Figure 9-17: Spatial Span Report

Subject		**ID**	anon	**Capture**	3.4.0
D.O.B.		**Age**	38	**Analysis**	3.8.0
P.I.		**Study**		**Hardware**	EP
				Posture	Seated
				Serial#	091001
Protocol	Adult	**Exam date**	09-Jan-2014, 1:39 PM	**Complete**	100%

Spatial Span



Task Score	Typical range
0.11 (9.1%)	< 1.96 (<95%)

Parameters	Score	Typical range	Unit
Total score[1] [2]	101	(64, 104)	#
Mean score[1] [2]	6.3	(4.0, 6.5)	#
Total time[1]	217	(181, 258)	s
Time per target[1] [2]	**0.92**	(1.01, 1.63)	s
Longest correct sequence	8.0	(6.0, 8.0)	#
Shortest failed sequence	6.0	(4.0, 7.0)	#
Unfinished sequences	0.0	(0.0, 0.0)	#

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable |

Comments	Signature

Information provided for research purposes only.

Table: 9-19 defines each of the parameters in the report.

Table 9-19: Spatial Span Parameters

Parameter (Contribution to Task Score)[1]	Meaning
Total Score (Exclude)	Sum of trial scores. The score for a trial is the sequence length for a successful trial and the sequence length - 1 for a trial with at least one error.
Mean Score (<-)	Mean trial score.
Total Time (Exclude)	Duration of the exam.
Time per Target (Exclude)	Total time the subject is allowed to move/total targets displayed to the subject.
Longest Correct Sequence (Exclude)	Longest sequence that the subject completed correctly.
Shortest Failed Sequence (Exclude)	Shortest sequence that the subject failed to complete correctly.
Unfinished Sequences (Exclude)	Number of trials that timed out (i.e. trials in which the subject did not move to the total number of targets for that sequence).

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.

NOTE: The first 2 trials are not used in calculating any parameters.

9.11.4 Citations

Berch, D.B., Krikorian, R. and Huha, E.M. (1998) The Corsi Block-Tapping Task: Methodological and Theoretical Considerations. Brain Cogn. 38: 317–338.

Owen, A.M., Downes, J.J., Sahakian, B.J., Polkey, C.E., and Robbins, T.W. (1990) Planning and spatial working memory following frontal lobe lesions in man. Neuropsychologia, 28(10):1021-1034.

Owen, A.M., Sahakian, B.J., Semple, J., Polkey, C.E., and Robbins, T.W. (1995) Visuo-spatial short-term recognition memory and learning after temporal lobe excision or amygdalo-hippocampectomy in man. Neuropsychologia, 33(1):1-24.

Owen, A.M., Evans, A.C., and Petrides, M. (1996) Evidence for a Two-Stage Model of Spatial Working Memory Processing within the Lateral Frontal Cortex: A Positron Emission Tomography Study. Cerebral Cortex. 6:31-38;

9.12 Trail Making

9.12.1 Test Purpose

Trail Making A/B tests are a common pen and paper test used to assess task switching (Bowie & Harvey, 2006; Corrigan & Hinkeldey, 1987). The version implemented for the Kinarm Labs is similar to the standard pen and paper version, but with additional measures to quantify subject performance.

9.12.2 Task Description and Task Protocols

There are two parts to the overall test. In the first part, the subject must trace through a sequence of targets numbered 1 to 25 as quickly as possible (Trail A). Next the subject must trace through an alternating alpha-numeric sequence of targets 1-A-2-B etc. up to 13, again for a total of 25 targets (Trail B). The most widely used result of this cognitive test comes from comparing the time to complete Trail B relative to Trail A. Each Trail Making task starts with a practice trial that has 5 targets. Once the subject has completed this practice trial and the operator is convinced that the subject understands the task, then the operator advances to the full task and the subject completes the task.

During the task there is always a line connecting the subject's finger tip location to the last valid target touched. If the subject touches an incorrect target then the previous target is changed to red and the subject must return to that target before continuing.

There are several Task Protocols available:

- Adult: Trail A - A numeric sequence of 25 numbers described above. When selected, 1 of 200 possible variants will be chosen. Each variant is either a rotation or flipping of original patterns coupled with a random starting position. The rotation and flipping provide 8 patterns, all of which have the same path length and because there are 25 targets, there are 25 possible starting positions resulting in a total of 200 possible variations. Each time a subject performs the Trail Making task,

Dexterit-E examines their previous data file (if one exists) and the next pattern (from the possible 8 patterns) is selected, along with a random starting position.

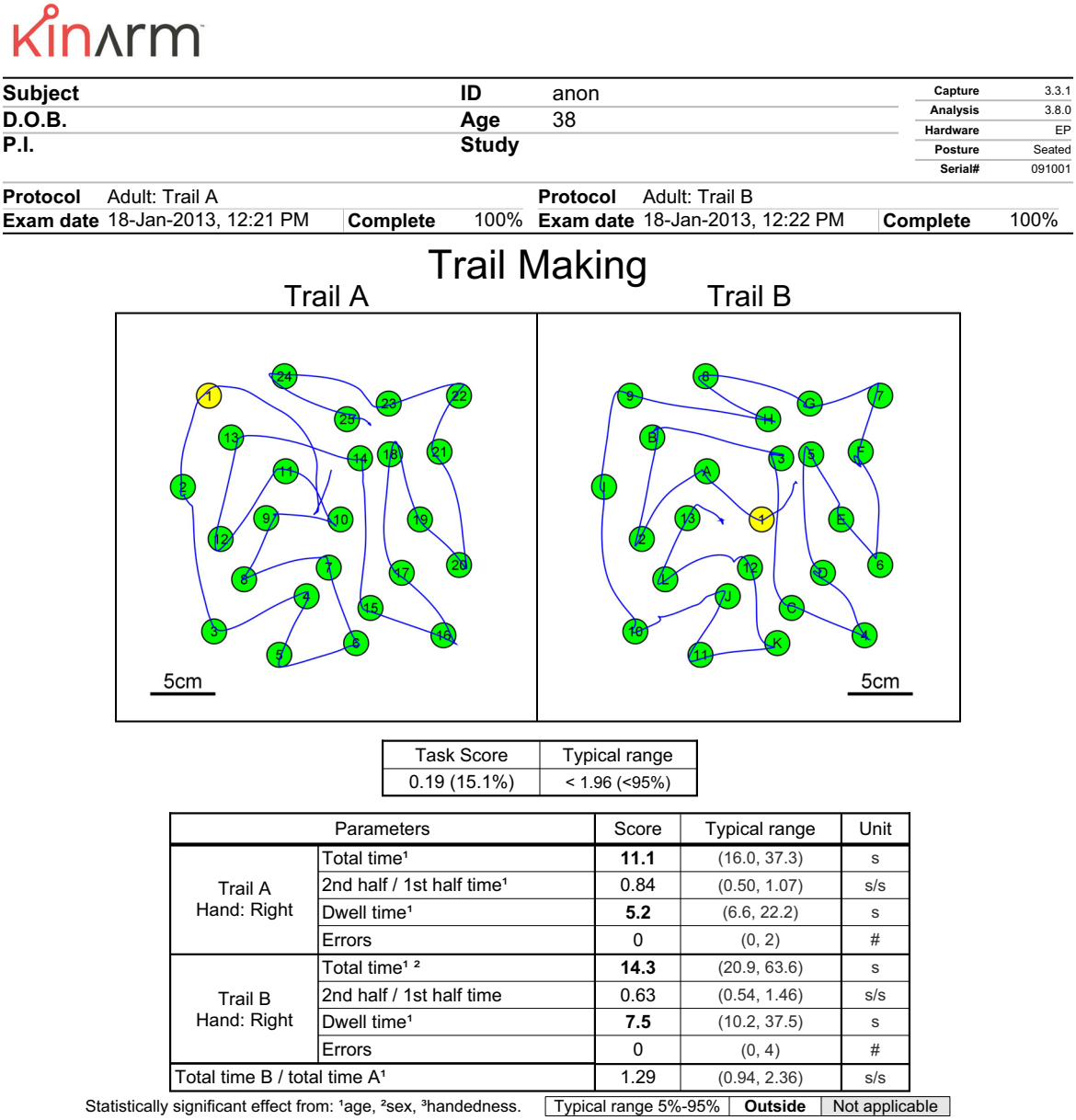
- **Adult Trail B** - Alphanumeric sequence described above, also with 200 possible variants as per Trail A and also with the option to select a specific pattern with a random start position.
- **Adult: Trail A - Pattern 1/2/3** - These are 3 Task Protocols for Trail A that have specific patterns and starting positions, so that the task details will always be exactly the same every time one of these Task Protocols is selected.
- **Adult: Trail B - Pattern 4/5/6** - These are 3 Task Protocols for Trail B that have specific patterns and starting positions, so that the task details will always be exactly the same every time one of these Task Protocols is selected.
- **Child: Trail A - Pattern 1/2/3** - Similar to the adult versions, but the targets dimension are ~10% smaller, and the region over which the targets are located is now elliptical and ~20% smaller in the Y-direction.
- **Child: Trail B - Pattern 4/5/6** - Similar to the adult versions, with analogous changes to those described for Child: Trail A - Pattern 1/2/3.

NOTE: If you would like to select a specific pattern for Adult Trail A, but with a random start position, to run consistently with a subject or study, you can right-click on the Trail A protocol. The context menu will show a check mark beside the currently selected protocol version (i.e. one of the 8 patterns). You can select the pattern you wish to run from this list, keeping in mind that the starting position will still be randomly chosen.

9.12.3 Report

Figure: 9-18 shows an example of a Trail Making report for a healthy control. In the report, “Complete” refers to the percentage of targets the subject reached to out of 25 targets total. The blue paths show the path the subject’s hand took while doing the task.

Figure 9-18: Trail Making Report



Subject	**ID**	anon	
D.O.B.	**Age**	38	
P.I.	**Study**		

Capture	3.3.1
Analysis	3.8.0
Hardware	EP
Posture	Seated
Serial#	091001

Protocol	Adult: Trail A			**Protocol**	Adult: Trail B		
Exam date	18-Jan-2013, 12:21 PM	**Complete**	100%	**Exam date**	18-Jan-2013, 12:22 PM	**Complete**	100%

Task Score	Typical range
0.19 (15.1%)	< 1.96 (<95%)

Parameters		Score	Typical range	Unit
Trail A Hand: Right	Total time[1]	**11.1**	(16.0, 37.3)	s
	2nd half / 1st half time[1]	0.84	(0.50, 1.07)	s/s
	Dwell time[1]	**5.2**	(6.6, 22.2)	s
	Errors	0	(0, 2)	#
Trail B Hand: Right	Total time[1] [2]	**14.3**	(20.9, 63.6)	s
	2nd half / 1st half time	0.63	(0.54, 1.46)	s/s
	Dwell time[1]	**7.5**	(10.2, 37.5)	s
	Errors	0	(0, 4)	#
Total time B / total time A[1]		1.29	(0.94, 2.36)	s/s

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-20 defines each of the parameters in the report.

Table 9-20: Trail Making Parameters

Parameter (Contribution to Task Score)[1]	Meaning
Total Time (->)	Total time from the targets being illuminated to touching the last target.[2]
2nd Half / 1st Half Time (-> if both Trail A and Trail B, Exclude if Trail B only)	Total time for targets 13-25 / total time for targets 1-13.[2]
Dwell Time (Exclude)	Total amount of time spent with the hand feedback dot at the targets.[2]
Errors (Exclude)	Number of times an incorrect target was touched.
Total Time B / Total Time A (-> if both Trail A and B, Exclude if Trail B only)	Total time for Trail B / the total time for Trail A.

1. Direction of arrow indicates sidedness of poor performance. See *Section: 9.2.9 Task Score and M-Score*.
2. For incomplete tasks, the values for incomplete targets are set equal to the mean value of all completed targets.

9.12.4 Citations

Bowie, C.R. and Harvey, P.D. (2006), Administration and interpretation of the Trail Making Test. Nature Protocols. 1(5): 2277. Nature publishing group. doi:10.1038/nprot.2006.390.

Corrigan, J.D. and Hinkeldey, N.S. (1987) Relationships between Parts A and B of the Trail Making Test, J. Clin. Psych. 43:402-409.

9.13 Visually Guided Reaching

9.13.1 Test Purpose

The purpose of the Visually Guided Reaching test is to quantify goal-directed voluntary control (Coderre et al., 2010). This task assesses postural control, visuomotor response time, and arm motor coordination.

9.13.2 Task Description and Task Protocols

During this task, a central target is presented and subject must move a cursor (white circle) representing hand position to this target. Once there, a peripheral target appears and the subject must move quickly and accurately to this target. This process is repeated a number of times both to explore the workspace and to measure variability of the subject's responses.

There are two recommended task protocols available, with the following differences:

- **Adult v2 (4 target)** - A central target with 4 peripheral targets spaced 90° apart and 10 cm from the central target. The subject first reaches from the central target to the peripheral target, then after a brief period of time the central target re-illuminates and the subject must reach back to the central target. Subjects reach to each peripheral target 5 times presented in a pseudo-random order. There are 4 'catch' trials in which there is no peripheral target presented in the trial: one which is the first trial in the task; and one which is the last trial. Data analysis includes movements to and from the peripheral target.
- **Child v2 (4 target)** - Similar to Adult: 4 target, but targets are 6 cm from the initial centre target.

There are two legacy protocols:

- **Adult v1 (8 target)** - 8 peripheral targets spaced 45° apart around a circle, all 10 cm from the initial central target. There are 8 blocks of trials with a block including 1 trial for each peripheral target presented in a random order within the block and 2 'catch' trials in which there is no peripheral target. Only the reach out to the peripheral target is utilized for analysis. This protocol takes significantly longer compared to the 4 target reach out and back and so is not typically recommended.
- **Child v1 (8 target)** - Similar to Adult protocol: 8 target, but targets are 6 cm from the initial centre target.

9.13.3 Report

At the end of the task, a report can be generated which provides measures of the subject's behaviour related to: postural control of the arm, visuomotor response, initial movement parameters, corrective movement parameters, and total movement metrics. *Figure: 9-19* shows an example of a Visually Guided Reaching report for a healthy control and the Adult: 4 target protocol.

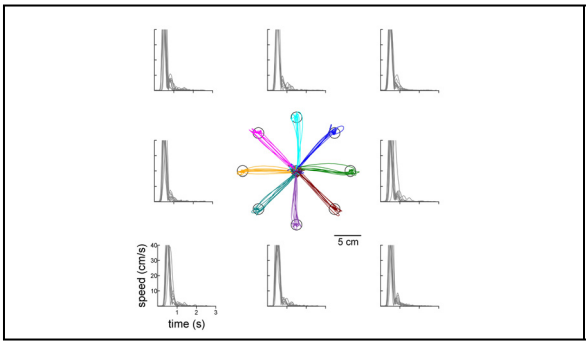
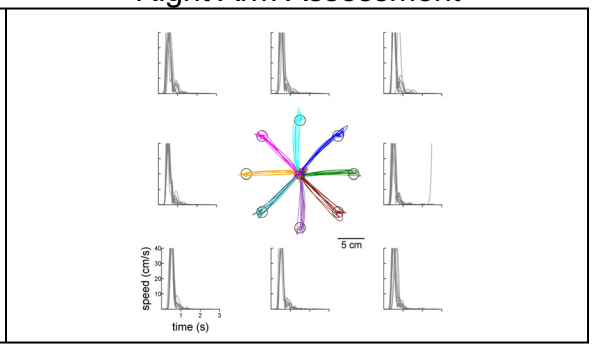
In the report, "Complete" refers to the percentage of expected trials that the subject completed. The image provided for each arm shows the hand paths that the subject used while reaching as well as graphs showing the hand speed for each direction. The hand speed plots show the hand speed for trials from movement onset (as detected algorithmically) until 3 seconds after movement onset. For the 8 target protocols, the graphic is slightly different, showing hand trajectory plots and hand speed plots only for reaches out to the peripheral target.

Figure 9-19: Visually Guided Reaching Report

Subject		**ID**	anon	**Capture**	3.3.1
D.O.B.		**Age**	38	**Analysis**	3.8.0
P.I.		**Study**		**Hardware**	EP
				Posture	Seated
				Serial#	091001

Protocol	Adult: 8 target			**Protocol**	Adult: 8 target		
Exam date	18-Jan-2013, 12:07 PM	**Complete**	100%	**Exam date**	18-Jan-2013, 12:14 PM	**Complete**	100%

8 Target Visually Guided Reaching

Left Arm Assessment	Right Arm Assessment
	

Task Score	Left	Right	Inter-Limb	Typical range
	1.13 (74.3%)	**1.98 (95.2%)**	1.24 (78.6%)	< 1.96 (<95%)

	Parameters	Left	Right	Typical range		Inter-Limb	Typical range	Unit
				Left	Right			
NT	No init stabilization	0	0	(0, 0)	(0, 0)	0	(0, 0)	#
	No reaction time	0	0	(0, 0)	(0, 0)	0	(0, 1)	#
	No end movement	0	0	(0, 0)	(0, 0)	0	(0, 1)	#
	End target not reached	0	0	(0, 0)	(0, 0)	0	(0, 1)	#
PC	Posture speed[1] [2]	0.151	**0.051**	(0.080, 0.368)	(0.081, 0.352)	**-0.100**	(-0.061, 0.128)	cm/s
VR	Reaction time[1]	266	280	(246, 350)	(246, 351)	14	(-27, 42)	ms
FM	Initial direction angle[1]	1.6	2.1	(0.9, 2.5)	(0.9, 2.5)	0.5	(-0.6, 0.6)	°
	Initial distance ratio[1]	0.92	**0.90**	(0.91, 0.99)	(0.91, 0.99)	-0.019	(-0.042, 0.042)	cm/cm
	Initial speed ratio	1.00	0.98	(0.94, 1.00)	(0.94, 1.00)	-0.016	(-0.046, 0.046)	cm/s / cm/s
CM	Speed maxima count[2]	2.55	**2.94**	(1.76, 2.75)	(1.78, 2.72)	0.39	(-0.51, 0.49)	#
	Min-max speed Δ[2] [3]	1.9	**2.5**	(0.3, 2.3)	(0.3, 2.1)	**0.6**	(-0.7, 0.6)	cm/s
TM	Movement time[1] [2]	0.88	0.88	(0.75, 1.27)	(0.72, 1.29)	-0.01	(-0.16, 0.17)	s
	Path length ratio[3]	1.18	**1.20**	(1.04, 1.19)	(1.04, 1.15)	0.02	(-0.07, 0.03)	cm/cm
	Max speed[1] [2]	**51.1**	**50.4**	(18.5, 45.8)	(17.6, 46.8)	-0.8	(-4.5, 4.1)	cm/s

Statistically significant effect from: [1]age, [2]sex, [3]handedness. | Typical range 5%-95% | **Outside** | Not applicable

Comments	Signature

Information provided for research purposes only.

Table: 9-21 defines the parameters in the report.

Table 9-21: Visually Guided Reaching Parameters (Sheet 1 of 3)

Type	Parameter (Contribution to Task Score)[1]	Meaning[2]
NT - No Trial	No init stabilization (->, w_i = 1)	Count of trials where the subject failed to stabilize at the starting target. "Count of trials" is converted to "Fraction of trials" before calculating the contribution to Task Score.
	No reaction time (Exclude)	Count of trials where no movement onset could be calculated.
	No end movement (->, w_i = 1)	Number of trials for which movement offset is not detected before the end of trial (see movement offset[3] definition). Trials with false starts are excluded from this count. "Count of trials" is converted to "Fraction of trials" before calculating the contribution to Task Score.
	End target not reached (Exclude)	Count of trials where the end target was not reached. Trials with false starts are excluded from this count.
PC - Posture Control	Posture Speed (->, w_i = n/N)	Median hand speed when the hand should be at rest. The median value of all trials is reported.
VR - Visual Reaction	Reaction Time (->, w_i = n/N)	Time between illumination of the end target and movement onset[4]. The median value of all trials[5] is reported. Note: the time from a target display command until it is actually displayed on the screen is approximately 50 ms, this extra 50 ms is included in the Reaction Time.

Table 9-21: Visually Guided Reaching Parameters (Continued) (Sheet 2 of 3)

Type	Parameter (Contribution to Task Score)[1]	Meaning[2]
FM - First Movement	Initial Direction Angle (->, w_i = n/N)	Angular deviation between (a) a straight line from the hand position at movement onset[4] to the hand position after the initial phase of movement and (b) a straight line from the hand position at movement onset to the end target. For each trial, the absolute value of this deviation is calculated and used. The median value of all trials[5] is reported.
	Initial Distance Ratio (<-, w_i = n/N)	Ratio of (a) the distance the hand traveled during the subject's initial phase of movement[6] to (b) the distance the hand traveled between movement onset[5] and movement offset. The median value of all trials[5] is reported.
	Initial Speed Ratio (Exclude)	Ratio of (a) the maximum hand speed during the subject's initial phase of movement[6] to (b) the maximum hand speed between movement onset[4] and movement offset[3] (i.e. Max Speed). The mean value of all trials[5] is reported.
CM - Corrective Movement	Speed Maxima Count (->, w_i = n/N)	Number of maxima in hand speed between movement onset[4] and movement offset[3]. The mean value of all trials[5] is reported.
	Min-Max Speed (->, w_i = n/N)	Mean difference between pairs of adjacent local hand speed minima and maxima, for all such pairs between the time of Max Speed, and movement offset[3]. The mean value of all trials[5] is reported.

Table 9-21: Visually Guided Reaching Parameters (Continued) (Sheet 3 of 3)

Type	Parameter (Contribution to Task Score)[1]	Meaning[2]
TM - Total Movement	Movement Time (->, w_i = n/N)	Total time elapsed from movement onset[4] to movement offset[3]. The median value of all trials[5] is reported.
	Path Length Ratio (->, w_i = n/N)	Ratio of (a) the distance travelled by the hand between movement onset[4] and movement offset[3] and (b) the straight line distance between those two hand positions. The mean value of all trials[5] is reported.
	Max Speed (<-, w_i = n/N)	Maximum hand speed between movement onset[3] and movement offset[3]. The median value of all trials[5] is reported.

1. Direction of arrow indicates sidedness of poor performance. Parameters may be weighted based on ratio of number of successful trials / number of executed trails (i.e. n / N). See *Section: 9.2.9 Task Score and M-Score*
2. Inter-limb values are always calculated as (Dominant arm value) - (Non-dominant arm value)
3. Movement offset is nominally the time at which the subject finished their movement in the end target. If the end target was not reached or if it was reached but end of movement was not detected algorithmically then No Movement End count is increased and movement offset is set to the end of the trial, which is the next time a visual cues changes (i.e. when the end target turns off for 8 target reach protocols or when the next trial's end target turns on for 4 target in and out protocols). Movement offset is always defined if movement onset is defined.
4. Movement onset is nominally the time that movement towards the end target was detected, if such a movement can be detected prior to a time-out event. If such a movement cannot be detected algorithmically then movement onset is set to the first time that the subject left the start target following illumination of the end target. Movement onset is not defined if the hand never reaches the start target, never stabilizes at the start target or never leaves the start target.
5. Excluding trials for which movement onset was not defined or a false start was detected. A false start is defined by too fast a reaction time to be a true reaction.
6. Initial phase of movement is used here to mean the time from movement onset[4] to the earlier of the first speed minima after movement onset or movement offset[3].

9.13.4 Additional Parameters in CSV Report

Some parameters are provided in the CSV export, but are not available in the report. The parameters that are in all CSV exports but not in the report are listed below. In addition, if a CSV export is selected for a single data file, then the target specific values for each parameter will also be listed, with the exception of posture speed. In addition to the parameter score described below, a CSV export will include the standard deviations of each parameter across trials.

Table 9-22: Visually Guided Reaching Additional CSV Parameters

Parameter	Meaning
False Starts	Count of trials where the movement start was detected <130 ms after the end target was turned on.

9.13.5 Citations

Coderre, A.M., Abou Zeid, A., Dukelow, S.P., Demmer, M.J., Moore, K.D., Demers, M.J., Bretzke, H., Herter, T.M., Glasgow, J.I., Norman, K.E., Bagg, S.D. and Scott, S.H. (2010) Assessment of Upper-Limb Sensorimotor Function of Subacute Stroke Patients Using Visually Guided Reaching. Neurorehabilitation and Neural Repair. 24:528-541.

10 KST Version History

This section describes the history of all changes that have occurred to Kinarm Standard Tests (KST), including modifications to Standard Tasks, Task Protocols and/or normative models and data sets for each test, as well as the Dexterit-E version in which the changes were first introduced. See *Section: 9.2 Common Features of Standard Tests* for details on each of the tests.

Newer versions of Dexterit-E come with improved analyses and normative models. We recommend that reports and CSV output be regenerated to take advantage of the improvements. In the upper right corner of each report will be information regarding the analysis version used. Reports must be regenerated manually within Dexterit-E. As described in *Section: 9.2.7 Standard Data Exported to CSV*, anytime that KST results are exported to a CSV file, data are re-analyzed using the current analysis and normative models.

All tables use the following abbreviations to reference the Kinarm platform used for collecting data:

- For Dexterit-E 3.6 and earlier:
  - Exo - refers to data collected using a Kinarm Classic (formerly called the Kinarm Exoskeleton Lab, pre 2016; PN 10755).
  - EP - refers to data collected using a Kinarm End-Point Lab (PN 10288).
- For Dexterit-E 3.7 and later:
  - Exo Classic - refers to data collected using a Kinarm Classic (PN 10755).
  - Exo UTS - refers to data collected using a Kinarm Exoskeleton Lab (PN 13568).
  - EP - refers to data collected using a Kinarm End-Point Lab (PN 10288 or PN 14332).

10.1 Updates to Normative Models and Z-Scores

Table 10-1: Normative Model Versions (Sheet 1 of 4)

Dexterit-E Version	Summary of Change	Description of Change
3.0	Initial Release	
3.4	Use Z-Scores to identify outliers.	For parameters that can be normalized to produce Z-scores, outlier classification is based on the normalized residuals now.

Table 10-1: Normative Model Versions (Continued) (Sheet 2 of 4)

Dexterit-E Version	Summary of Change	Description of Change
3.5	Small changes to outlier removal for non-Normal data.	For discrete, non-normal distributions the method used to estimate of 3.29 SD for outlier classification was improved.
3.6	Updated outlier removal process to more accurately classify exams as outliers.	Exams that are classified as outliers for a task have all of their data for that task removed from the normative data set. In previous versions of Dexterit-E, exams were classified as an outlier for a task if they had at least one parameter classified as an outlier. This approach classified too many exams as outliers. Starting in Dexterit-E 3.6, exams are now classified as outliers for a task based on their Task Score or M-score. This change has dropped the number of exams classified as outliers significantly.
3.6.1	Normal models now used for subjects who are 15-17 years old.	Subjects who are 15-17 years old will now use normal models for 18 year old subjects. Because this is an extrapolation, a warning is given in the notes of the Standard Report or CSV export.
	Normative models no longer separated by sex or handedness.	When generating the normative models, the data sets are no longer split by sex or handedness. See *Figure: 10-1* for comparison of Z-scores due to model accuracy between this version and prior versions of Dexterit-E.

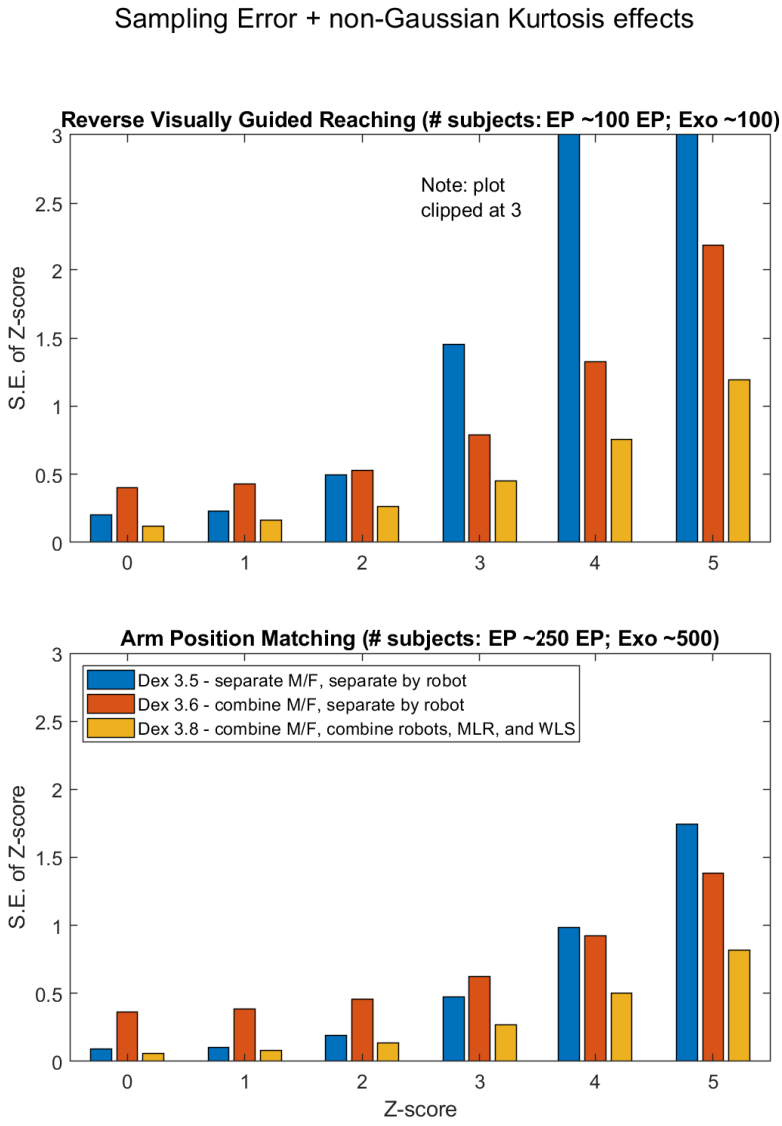
Table 10-1: Normative Model Versions (Continued) (Sheet 3 of 4)

Dexterit-E Version	Summary of Change	Description of Change
3.7	Normal models generated using MLR to account for sex and handedness.	Data from subjects with different sex, handedness, platforms and postures are combined when fitting a normal model, with the contributions from the different factors accounted for by use of multiple linear regressions (one for the mean value and one for standard deviation). See *Figure: 10-1* for comparison of Z-scores due to model accuracy between this version and prior versions of Dexterit-E.
	Distributions are treated as normal if they are "close to normal".	The algorithm to produce normal models now classifies a distribution as "normal" if it is close-to-normal, based on skew and kurtosis measures, rather than if it is statistically classified as normal.
	Z-scores that are beyond the range of the normative model are no longer clipped to ±10.	When a Z-score for a parameter value is calculated, it is possible for the parameter to be outside of the range for which it is mathematically possible to calculate a Z-score. In such a case, the reported Z-score value will be maximum/minimum Z-score value that is theoretically possible.

Table 10-1: Normative Model Versions (Continued) (Sheet 4 of 4)

Dexterit-E Version	Summary of Change	Description of Change
3.8	Linear regressions of both parameter values and parameter standard deviations now use weights.	Because the data have heteroskedasticity (i.e. non-constant variance), ordinary least-squares (O.L.S.) regression does not produce the Best Linear Unbiased Estimator. We addressed this problem by using by using weighted least-squares (W.L.S.) regression, in which the weights which are inversely proportional to variance, because W.L.S. does produce the Best Linear Unbiased Estimator. For large data sets and/or data sets with relatively small heteroskedasticity, the effect of using W.L.S. instead of O.L.S. is negligible. The only task in which there was a significant impact on using W.L.S. was Elbow Stretch. See *Section: 10.7 Elbow Stretch* for more details. In addition, interlimb correction time for Reverse Visually Guided Reaching had minor effects (see *Section: 10.10 Reverse Visually Guided Reaching*).
3.9	Added age-based weighting to data used to generate normative models for newer and updated data sets.	Some of the data sets used to create normal models have higher numbers of young subjects than old. This disparity can potentially cause an age-based bias during model creation, particularly for the smaller datasets. To compensate for this issue, a weighting factor is applied to a subject's data if the subject is below a threshold age. The threshold age is determined empirically as needed for each data set. Only normative models that are new or that have been updated will have the new age weighting applied.

Figure 10-1: Comparison of Z-Score Accuracy Between Dexterit-E 3.5, 3.6, and 3.8



The errors included in the models used to generate the values in *Figure: 10-1* include: (1) sampling error, which affects the mean/linear regression coefficients, the standard deviation estimates and the optimal Box-Cox transform; (2) modeling approximations (i.e. assumption of identical means and standard deviations for males and females in Dexterit-E 3.6) which were based on the results of Dexterit-E 3.7; (3) the impact of non-Gaussian kurtosis, based on the standard deviation of kurtosis values observed in Dexterit-E 3.7 results.

The errors for Dexterit-E 3.7 are not shown separately in this figure because under most conditions they are nearly identical to those for shown for Dexterit-E 3.8. The exception are for parameters in which there was significant heteroskedasticity, in which case the Dexterit-E 3.7 error can be far larger.Heteroskedasticity was handled correctly in Dexterit-E 3.8 with the change to using weighted least-squares fitting, so for parameters with heteroskedasticity, the data should be re-analyzed with Dexterit-E 3.8. See the update notes below for Elbow Stretch and Reverse VGR for affected parameters.

10.2 Updates to Task Score and M-Scores

Table 10-2: Task Score and M-Score Versions (Sheet 1 of 2)

Dexterit-E Version	Summary of Change	Description of Change
3.6	Initial Release of Task Score and M-score.	Task Score and M-score were introduced to provide metrics that quantify the overall performance of a subject during an exam.

Table 10-2: Task Score and M-Score Versions (Continued) (Sheet 2 of 2)

Dexterit-E Version	Summary of Change	Description of Change
3.7	M-distance now uses correlation matrix instead of covariance matrix.	The calculation of M-distance nominally requires the inverse covariance matrix, which accounts for both scaling and correlation. For data that are already normalized (i.e. Z-scores), the inverse correlation matrix is identical to the covariance matrix. For data which are treated as one-sided, the covariance matrix incorrectly scales these data, so the correlation matrix needs to be used instead.
	Some exams now include non-normal parameters as contributors to the overall scores.	VGR and RVGR now include some non-normal parameters as contributors to the overall scores. These parameters are pre-scaled to match Z-score scaling so that their contribution is equivalent to that of a Z-score.
	Some exams now weight parameter contributions to overall scores based on the parameter accuracy.	VGR and RVGR now include scaling factors on those parameters whose value depends on successful trials (i.e. fewer successful trials decreases the accuracy of those parameters, so their contribution is scaled appropriately).
	Bug fix: Directionality of one-sided parameters fixed for M-score.	Some of the parameter scores that form the bases for Task Score and M-score are transformed to a one-sided statistic (as per *Section: 9.2.9 Task Score and M-Score*). That transform was not applied for M-scores in Dexterit-E 3.6.
3.8	Change to calculation of Task Score and M-Score for Ball on Bar.	Two parameters no longer contribute to Task Score and M-Score for Ball on Bar, to reduce the number of false positives. See *Section: 10.6 Ball on Bar* for more details.
3.9	No change.	

10.3 Arm Movement Matching

Table 10-3: Arm Movement Matching versions

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.9	Initial release of v1 and v2 protocols.	Exo: 204 subjects, 88 male, 116 female, ages 18-93. All data collected with Kinarm Classic. EP: 133 subjects, 62 male, 71 female, ages 18-81. Exo and EP data are modeled separately.

10.4 Arm Position Matching

Table 10-4: Arm Position Matching Versions (Sheet 1 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.0	9 target (initial release)	150 subjects, 70 male, 80 female, ages: 20-82. All data collected with Kinarm Exoskeleton.
3.2	No changes.	212 subjects, 96 male, 116 female, ages 18-90. All data collected with Kinarm Exoskeleton.

Table 10-4: Arm Position Matching Versions (Continued) (Sheet 2 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.4	9 target (no change) 4 target (initial release) **Analysis Update**: Added Absolute Error as a new analysis parameter.	The 4 target protocol has been shown to give statistically identical results to the 9 target protocol for the Kinarm Exoskeleton Lab. Exo: 241 subjects, 112 male, 129 female, ages: 18-93. Normative data from both 4 target and 9 target protocols are combined for the Kinarm Exoskeleton Lab. EP: 163 subjects, 70 male, 93 female, ages: 18-97. The only normative data collected on the Kinarm EP lab is from the 4 target protocol. Normative comparisons for both protocols use the 4 target normative data set.
3.5	No changes.	Exo: 461 subjects, 214 male, 247 female, ages: 18-93. Normative data from both 4 target and 9 target protocols are combined for the Kinarm Exoskeleton Lab. EP: 239 subjects, 103 male, 136 female, ages: 18-87. Normative data from both 4 target and 9 target protocols are combined for the Kinarm EP Lab. Small changes to outlier removal for non-Normal data.
3.6	No changes.	Exo: 494 subjects, 232 male, 262 female, ages: 18-93. Normative data from both 4 target and 9 target protocols are combined for the Kinarm Exoskeleton Lab. EP: 262 subjects, 116 male, 146 female, ages: 18-87. Normative data from both 4 target and 9 target protocols are combined for the Kinarm EP Lab. EP Standing: 103 subjects, 51 male, 52 female, ages 18-80. Updated outlier removal process to more accurately classify subjects as outliers.

Table 10-4: Arm Position Matching Versions (Continued) (Sheet 3 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.6.2	Task instructions updated for clarity and brevity.	No changes.
3.7	**Task Update:** • The task was updated to wait 1.5 s at the start of the task before trying to move the subject. • If the emergency stop is down, then the task will not progress at all. • Torque limits reduced to prevent possible motor over-heat. • Task Protocols re-named. • New Task Protocol called Child: 4-target.	799 Subjects, 2227 exams. Ages 18-93. 363 Males, 436 females. • Exo Classic: 1284 exams. • Exo UTS: 90 exams. • EP Sitting: 604 exams. • EP Standing: 249 exams.
3.8	**Analysis Update**: Update to using W.L.S. regression (*Section: 10.1 Updates to Normative Models and Z-Scores*).[1]	No change.
3.9	Task Update: • Pause behaviour changed to pause at the end of the current trial Naming Update: • 4 target versions renamed to indicate version 2 • 9 target versions renamed to indicate version 1	No change.

1. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Arm Position Matching.

10.5 Arm Posture Perturbation

Table 10-5: Arm Posture Perturbation versions

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.9	Initial release for Kinarm Exoskeleton	143 subjects, 59 male, 84 female, ages 19-84.

10.6 Ball on Bar

Table 10-6: Ball on Bar Versions (Sheet 1 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.5	Initial release.	Exo: 174 subjects, 74 males, 100 females, ages 19-87. EP: 153 subjects, 65 males, 88 females, ages 18-80.
3.6	No changes.	Exo: 206 subjects, 86 males, 120 females, ages 19-87. EP: 180 subjects, 74 males, 106 females, ages 18-80. EP Standing: 109 subjects, 57 males, 52 females, ages 18-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.2	Task instructions updated for clarity and brevity.	No change.
3.6.3	If the subject is unable to reach the start targets, the operator can initiate an additional step in which the robot will move the subject to the start targets.	No change.

Table 10-6: Ball on Bar Versions (Continued) (Sheet 2 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.7	**Task update:** • The locations of the initial starting targets prior to level 1 were moved to be more central. • Timeouts were added for reaching a target. • Torque limits reduced to prevent possible motor over-heat. • Task Protocol re-named "Adult". • New Task Protocol called "Child". **Analysis Update**: • Drops / Target is now set equal to # Drops if no targets were reached successfully on a level. • If a target is not reached within 10 s (15 s for Level 3), then Time to target parameter is set equal to 10 s (15 s for Level 3). • Two new parameters are reported in CSV file: Failed to contact target and Failed to stabilize at target. • Some parameter names have been updated in the CSV file to match those on the report. • Right/Left hand speed peaks and Time to Target are now both excluded from Task Score and M-score. • Bug fix.[1]	511 Subjects, 841 exams. Ages 18-89. 219 Males, 292 females. • Exo Classic: 429 exams. • Exo UTS: 43 exams. • EP Sitting: 241 exams. • EP Standing: 128 exams.

Table 10-6: Ball on Bar Versions (Continued) (Sheet 3 of 3)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.8	**Analysis Update**: • Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[2] • Mean bar tilt and path length bias no longer contribute to Task Score and M-score.[3]	No change.
3.9	**Task update:** • Pause behaviour changed to pause at the end of the current trial.	No change.

1. Bug fix (v 3.7.0): Mean bar tilt contribution to Task Score is now correctly treated as two-sided. This change will have a small effect on both Task Score and M-score.
2. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Ball on Bar.
3. Enhancement (v 3.8.0): Review of normative data revealed that a small fraction of healthy controls have Z-scores for mean bar tilt and path length bias that are $|z| > 10$, despite having no impairments on any other parameter. Manual review of the data showed that these subjects simply employed a different strategy, but were still able to complete the task successfully. Because these high Z-scores do not reflect any actual impairment, these two parameters were removed from contributing to Task Score and M-score.The effect of this change is that a small percentage of subjects (~2%) that were previously classified as non-normal now produce Task Scores and M-scores that are within the normal range (i.e. a reduction in false positives).

10.7 Elbow Stretch

Table 10-7: Elbow Stretch Versions (Sheet 1 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.6	Initial release.	Exo: 110 subjects, 51 male, 59 female, ages 19-84
3.7	Task Protocol renamed. **Analysis Update**: • Peak velocity re-named peak speed. • All creep distance parameters are forced to be non-normal and excluded from Task Score and M-score. • For catch angle, the 99th percentile of max(abs(speed-diff)) is calculated using a normative model developed using the same methods as for other KST parameters, instead of just using the 99th percentile from the CDF. • Bug fix.[1]	212 Subjects, 491 exams. Ages 18-84. 95 Males, 117 females. • Exo Classic: 406 exams. • Exo UTS: 85 exams.

Table 10-7: Elbow Stretch Versions (Continued) (Sheet 2 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[2]	265 Subjects, 706 exams. Ages 18-84. 120 males, 145 females.
3.9	**Task update:** • Pause behaviour changed to pause at the end of the current trial. • New Task Protocol uses a 45° shoulder angle for all versions of the Kinarm Exoskeleton. This is version 2 of the task. • Original Task Protocol re-named as v1. **Analysis update:** • Normative models use age-based weighting • Updated normative modeling to account for subject weight. • Added End Torque parameters for fast movements to report and Task Score • Added Start and End Torque parameters to CSV export.	285 Subjects, 1140 exams. Ages 18-84. 125 males, 160 females. • Exo classic: 700 exams • Exo UTS: 440 exams

1. Bug fix (3.7.0): Directions of one-sided contribution of peak speeds to Task Score and M-score were corrected for flexion movements. This change could have a significant impact on Task Score and M-score for impaired subjects, if their peak flexion speeds were significantly outside of the normal range.
2. Enhancement (v 3.8.0): The update to using W.L.S. regression had a moderate effect on many unilateral parameters (e.g. new Z-scores can be up to 25% different). In contrast, the update had a very large effect on interlimb parameters for females using the Kinarm Exoskeleton (PN 13568) (i.e., this very large effect does not happen for males, nor does it affect females on the Exoskeleton Classic, PN 10755). The interlimb parameter most affected was 1.5 s Extension Peak speed: new Z-scores for females using the Exoskeleton can be up to 200% different (and change sign).

10.8 Object Hit

Table 10-8: Object Hit Changes by Dexterit-E Versions (Sheet 1 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.1	Initial Release.	Not available.
3.2	No changes.	Exo: 234 subjects, 113 males, 121 females, ages 18-89. EP: 121 subjects, 60 males, 61 females, ages 18-89.
3.4	No changes.	Exo: 265 subjects, 130 males, 135 females, ages 18-89. EP: 193 subjects, 87 males, 106 females, ages 18-89.
3.5	No changes.	Exo: 429 subjects, 207 males, 222 females, ages 18-93. EP: 199 subjects, 91 males, 108 females, ages 18-89. Small changes to outlier removal for non-Normal data.
3.6	No changes.	Exo: 433 subjects, 209 males, 224 females, ages 18-93. EP: 202 subjects, 91 males, 108 females, ages 18-89. EP Standing: 105 subjects, 53 males, 52 females, ages 19-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.1	**Analysis Update**: Three new parameters are now calculated (for CSV export only): total targets hit, targets hit with right hand and targets hit with left hand.	No change.
3.6.2	Task instructions updated for clarity and brevity.	No change.

Table 10-8: Object Hit Changes by Dexterit-E Versions (Continued) (Sheet 2 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.7	• Task Protocol re-named "Adult". • New Task Protocol called Child.	764 Subjects, 1021 exams. Ages 18-93. 350 Males, 414 females. • Exo Classic: 598 exams. • Exo UTS: 42 exams. • EP Sitting: 215 exams. • EP Standing: 166 exams.
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[1]	No change.
3.9	**Task Update**: • Pause button will stop and reset the task.	No change.

1. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Object Hit.

10.9 Object Hit and Avoid

Table 10-9: Object Hit and Avoid Versions (Sheet 1 of 3)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.1	Initial release.	Not available.
3.2	No changes.	Exo: 150 subjects, 65 males, 85 females, ages 18-89. EP: 110 subjects, 49 males, 61 females, ages 18-89.
3.4	No changes.	Exo: 285 subjects, 128 males, 157 females, ages 18-89. EP: 190 subjects, 85 males, 105 females, ages 18-89. Small changes to outlier removal for non-Normal data.

Table 10-9: Object Hit and Avoid Versions (Continued) (Sheet 2 of 3)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.6	No changes.	Exo: 293 subjects, 134 males, 159 females, ages 18-89. EP: 195 subjects, 88 males, 107 females, ages 18-89. EP Standing: 106 subjects, 55 males, 51 females, ages 19-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.1	**Analysis Update**: Added three new parameters: Objects hit, Distractor proportion and Object processing rate. Additionally, six new parameters are now calculated for CSV export only: total targets hit, targets hit with right hand, targets hit with left hand, total distractors hit, distractors hit with right hand and distractors hit with left hand.	No change.
3.6.2	Task instructions updated for clarity and brevity.	No change.
3.7	• Task Protocol re-named "Adult". • New Task Protocol called Child. **Analysis Update**: • Distractors hit and Objects hit now excluded from Task Score and M-score. • Distractor proportion calculation is now calculated based on objects hit, not targets hit. • Bug fix.[1] • Bug fix.[2]	674 Subjects, 942 exams. Ages 18-93. 298 Males, 376 females. • Exo Classic: 509 exams. • Exo UTS: 44 exams. • EP Sitting: 220 exams. • EP Standing: 169 exams.

Table 10-9: Object Hit and Avoid Versions (Continued) (Sheet 3 of 3)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[3]	No change.
3.9	**Task update**: • Pause button will stop and reset the task.	No change.

1. Bug fix (3.7.0): Directionality of distraction proportion contribution to overall scores was corrected from being two-sided to one sided.
2. Bug fix (3.7.0): Z-score for left-handed subjects for four parameters was corrected (hand bias hits, hand transition, hand speed bias, movement area bias). In prior releases, the true Z-score for left-handed subjects was the negative of the reported Z-score). This bug had no effect on Task Score, but will have affected M-scores for left-handed subjects.
3. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Object Hit & Avoid.

10.10 Reverse Visually Guided Reaching

Table 10-10: Reverse Visually Guided Reaching Versions (Sheet 1 of 2)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.5	Initial release.	Exo: 84 subjects, 40 males, 44 females, ages 19-84. EP: 87 subjects, 43 males, 44 females, ages 19-84.
3.6	**Analysis Update**: • Bug fix.[1] • Bug fix.[2]	Exo: 91 subjects, 41 males, 50 females, ages 19-84. EP: 106 subjects, 47males, 59 females, ages 19-84. EP Standing: 107 subjects, 56 males, 51 females, ages 18-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.2	Task instructions updated for clarity and brevity.	No change.

Table 10-10: Reverse Visually Guided Reaching Versions (Continued) (Sheet 2 of 2)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.7	• Task Protocol re-named "Adult". • New Task Protocol called Child. **Analysis Update**: See *Section: 10.13 Visually Guided Reaching*.	288 Subjects, 1044 exams. Ages 18-84. 127 Males, 161 females. • Exo Classic: 449 exams. • Exo UTS: 85 exams. • EP Sitting: 265 exams. • EP Standing: 245 exams.
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[3]	No change.
3.9	**Task Update:** • Pause behaviour changed to pause at the end of the current trial. **Report Update**: • Count parameters are now shown as n / N, where N is the total number of trials run.	No change.

1. Bug fix (3.6): Corrected a problem calculating "% complete" when a trial is paused. This bug had no effect on exams in which there was not a pause.
2. Bug fix (3.6): Corrected an issue where the Correction Time parameter could be a negative number for certain trials. This issue would typically only affect severely impaired subjects.
3. Enhancement (v 3.8.0): The update to using W.L.S. regression (*Section: 10.1 Updates to Normative Models and Z-Scores*) had a moderate effect on inter-limb, correction time. For Z-scores $|z| > 3$, the new inter-limb, correction time Z-scores can be up to 25% different. Other parameters have negligible effects.

10.11 Spatial Span

Table 10-11: Spatial Span Versions

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.4	Initial release.	Not available.
3.5	No changes.	Exo: 97 subjects, 44 males, 53 females, ages 19-84. EP: 104 subjects, 47 males, 57 females, ages 19-81.
3.6	**Analysis Update**: In previous versions of the analysis the total score and mean score did not use the first two practise trials but all other parameters did. Now the first two practise trials are excluded from all parameters.	Exo: 99 subjects, 44 males, 55 females, ages 19-84. EP: 108 subjects, 48 males, 60 females, ages 19-81. EP Standing: 109 subjects, 57 males, 52 females, ages 19-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.2	Task instructions updated for clarity and brevity.	No change.
3.7	• Task Protocol re-named "Adult". • New Task Protocol called Child. • Torque limits reduced to prevent possible motor over-heat. **Analysis Update**: Some parameter names have been updated in the CSV file to match those on the report.	302 Subjects, 546 exams. Ages 18-89. 134 Males, 168 females. • Exo Classic: 241 exams. • Exo UTS: 44 exams. • EP Sitting: 131 exams. • EP Standing: 130 exams.
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[1]	No change.
3.9	**Task update**: • Pause behaviour changed to pause at the end of the current trial.	No change.

1. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Spatial Span.

10.12 Trail Making

Table 10-12: Trail Making Versions (Sheet 1 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.1	Trail A (initial release) Trail B (initial release)	Not available.
3.2	No change.	Exo: 158 subjects, 74 males, 84 females, ages 18-88. EP: 126 subjects, 57 males, 69 females, ages 18-81.
3.4	Trail A (no change) Trail B (no change) Trail A - 1, 2, 3 (static pattern and sequence) Trail B - 4, 5, 6 (static pattern and sequence)	Exo: 278 subjects, 126 males, 152 females, ages 18-88. EP: 201 subjects, 91 males, 110 females, ages 18-89. Normative data not available for static pattern and sequences.
3.5	No changes.	Exo: 269 subjects, 127 males, 142 females, ages 18-89. EP: 190 subjects, 87 males, 103 females, ages 18-89. Small changes to outlier removal for non-Normal data.
3.6	**Analysis Update**: Bug fix.[1]	Exo: 275 subjects, 129 males, 146 females, ages 18-89. EP: 195 subjects, 90 males, 105 females, ages 18-89. EP Standing: 110 subjects, 57 males, 53 females, ages 19-80. Updated outlier removal process to more accurately classify subjects as outliers.
3.6.2	Task instructions updated for clarity and brevity.	No change.

Table 10-12: Trail Making Versions (Continued) (Sheet 2 of 2)

Dexterit-E Versions	Task Protocols (and Task Updates) and Analysis	Normative Data
3.7	• Task Protocols re-named "Adult...". • New Task Protocols named "Child..." **Analysis Update**: • For incomplete tasks, total time and dwell time are extrapolated based on the mean per target times. • Some parameter names have been updated in the CSV file to match those on the report.	644 Subjects, 1055 exams. Ages 18-93. 284 Males, 360 females. • Exo Classic: 547 exams. • Exo UTS: 44 exams. • EP Sitting: 308 exams. • EP Standing: 156 exams.
3.8	**Analysis Update**: Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[2]	No change.
3.9	**Task Update**: • Pause button will stop and reset the task.	No change.

1. Bug fix (3.6): Corrected the analysis of 2nd half/1st half time to be: (time from target 13 to target 25) / (time from target 1 to target 13). Previously reported values were too low (typically < 10% change).
2. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for Trail Making.

10.13 Visually Guided Reaching

Table 10-13: Visually Guided Reaching Versions (Sheet 1 of 5)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.0	8 target (Initial release)	Single limb data: 162 subjects, 79 male, 83 female. Inter-limb data: 99 subjects, 41 male, 58 female. Ages: 20-82. All data collected with Kinarm Exoskeleton.
3.1	8 target (The current target now disappears as you leave it when reaching.)	No change.
3.2	No change.	160 subjects, 78 male, 82 female, ages: 20-84. All data collected with Kinarm Exoskeleton.

Table 10-13: Visually Guided Reaching Versions (Continued) (Sheet 2 of 5)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.4	8 target (no change) 4 target (reach out and back - initial release) **Analysis Update (3.4)**: • Bug fix.[1] • Trials with very fast reaction times are now excluded from the parameter analysis.[2] • If movement onset is not detected algorithmically, then movement onset is now defined as the first time the start target was left.[3] • Movement onset must occur before a standardized timeout.[4] • If movement offset is not detected algorithmically, then movement offset is now defined as the end of trial.[5] **Analysis Update (3.4.2-3.4.4)**: • Bug fix.[6] • Bug fix.[7] • Two new parameters added to CSV output: No Initial Stabilization and End Target Not Reached.[8] • Bug fixes.[9]	Exo: • 8 target:149 subjects, 75 male, 74 female, ages: 20-83. • 4 target reach out and back: 142 subjects, 64 male, 78 female, ages: 20-87. EP: • No normative data have been collected on the Kinarm End-Point Lab for the 8 target protocol. Normative comparisons are to the 8-target Kinarm Exoskeleton normative dataset. • 4 target reach out and back: 80 subjects, 36 male, 44 female, ages: 20-88.

Table 10-13: Visually Guided Reaching Versions (Continued) (Sheet 3 of 5)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.5	Changed parameter name from Initial Direction Error to Initial Direction Angle.	Exo: • 8 target:157 subjects, 77 male, 80 female, ages: 19-83. • 4 target reach out and back: 249 subjects, 106 male, 143 female, ages: 18-93. EP: • 8 target:74 subjects, 32 male, 42 female, ages: 19-84. • 4 target reach out and back: 178 subjects, 71 male, 107 female, ages: 18-88. Small changes to outlier removal for non-Normal data.
3.6	• Bug fix.[10] • Bug fix.[11]	Exo: • 8 target:178 subjects, 89 male, 89 female, ages: 19-83. • 4 target reach out and back: 291subjects, 125 male, 166 female, ages: 18-93. EP: • 8 target:90 subjects, 41 male, 49 female, ages: 19-84. • 4 target reach out and back: 196 subjects, 78 male, 118 female, ages: 18-88. EP Standing: • 4 target reach out and back: 112 subjects, 58 male, 54 female, ages: 18-80. Updated outlier removal process to more accurately classify subjects as outliers.

Table 10-13: Visually Guided Reaching Versions (Continued) (Sheet 4 of 5)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.6.2	Task instructions updated for clarity and brevity.	No change.
3.7	• Task Protocols re-named "Adult:..." and "Child:...". • Child: 4 target protocol has had two timing changes to match the adult version: (1) the start target now turns off immediately after the subject exits, instead of after 500 ms; (2) the end target is displayed for only 500 ms after reaching, instead of 1500 ms. To access the version of the protocol that was available in Dexterit-E 3.6, please contact **Kinarm Support**. **Analysis Update**: • Contribution to overall scores from parameter scores that depend on a successful trial are weighted by the fraction of successful trials. • No Initial Stabilization and No End Movement now contribute to overall scores.	4 target: 514 Subjects, 1708 exams. Ages 18-93. 220 Males, 294 females. • Exo Classic: 834 exams. • Exo UTS: 86 exams. • EP Sitting: 452 exams. • EP Standing: 336 exams. 8 target: 307 Subjects, 613 exams. Ages 18-84. 152 Males, 155 females. • Exo Classic: 401 exams. • EP Sitting: 212 exams.

Table 10-13: Visually Guided Reaching Versions (Continued) (Sheet 5 of 5)

Dexterit-E Version	Task Protocols (and Task Updates) and Analysis	Normative Data
3.8	**Analysis Update**: • Corrected an issue where the normative scores for subjects collected using the Adult: 8 Target protocol on a Kinarm Exoskeleton were not correct. • Update to using W.L.S. regression (see *Section: 10.1 Updates to Normative Models and Z-Scores*).[12]	No change.
3.9	**Task update:** • Pause behaviour changed to pause at the end of the current trial. **Report Update**: • Count parameters are now shown as n / N where N is the total number of trials run. Naming Update: • 4 target versions renamed to indicate version 2 • 8 target versions renamed to indicate version 1	No change.

1. Bug fix (3.4.0) The analysis in Dexterit-E 3.0 - 3.3 would have slightly underestimated the initial distance ratio for rare trials in which the hand was slowing down as it left the start target.
2. Trials with very fast reaction time (i.e. false start trials) are now excluded in calculations of any parameter other than Posture Speed. Trials with such false starts indicate anticipation and not a true reaction, so the new calculations will provide a more accurate measure of the parameter.

3. If a nominal movement onset cannot be identified algorithmically then movement onset is now set to the first time that the subject left the start target after the end target is displayed and that trial is now included in the calculation of any parameter that uses movement onset (i.e. all parameters except for Posture Speed and No Movement End). Previously movement onset was not calculated for these trials and these trials were not used for other parameter calculations. This change will have negligible impact on parameter scores for healthy controls, but for subjects whose behaviour is outside of normal, much more data will now be utilized providing parameter scores that more accurately reflect actual behaviour.
4. The interval over which a movement onset is searched for is now ended by a timeout, rather than the end of trial. This change ensures consistency in the analysis. This change will have negligible impact on parameter scores for healthy controls, but for subjects whose behaviour is outside of normal they may register more No Reaction Time counts due to this change as compared to earlier versions of Dexterit-E.
5. If a nominal movement offset cannot be identified algorithmically then movement offset is now set to the end of trial and that trial is now included in the calculation of any parameter that uses movement offset (i.e. all parameters except for Posture Speed, Reaction Time and No Movement End). Previously movement offset was not calculated for these trials and so these trials were not used for other parameter calculations. This change will have negligible impact on parameter scores for healthy controls, but for subjects whose behaviour is outside of normal, much more data will now be utilized providing parameter scores that more accurately reflect actual behaviour.
6. Bug fix (3.4.2): The analysis in 3.0 - 3.4.1 erroneously reported the mean Initial Distance Ratio and the median Mix-Max speed instead of the median Initial Distance Ratio and the mean Mix-Max speed.
7. Bug fix (3.4.3): The analysis in 3.4.0 - 3.4.2 erroneously did not count trials where the subject failed to stabilize in the start target as having No Reaction Time and No Movement End. Therefore, counts for No Reaction Time and No Movement End could have been under-reported in Dexterit-E 3.4.0 - 3.4.2.
8. No Initial Stabilization is incremented by 1 for each trial that the subject fails to stabilize at the start target, End Target Not Reached is incremented by 1 for each trial that times out before the subject reaches the end target. These parameters only appear in the CSV file, not in the report.
9. Bug fix (3.4.4): For subjects with certain movement problems, the analysis in 3.4.0 to 3.4.3 could incorrectly calculate Path Length Ratio and/or set movement offset 500 ms too early and/or not report units for some of the parameters. As a result, Path Length Ratio could have been under-reported, any parameter using movement offset could have been slightly incorrect and/or units may not have appeared on the Standard Report.
10. Bug fix (3.6): Corrected a problem calculating “% complete” when a trial is paused.
11. Bug fix (3.6): Corrected an issue where severely disabled subjects could get reaction times of -1.
12. Enhancement (v 3.8.0): This change had negligible impact on Z-scores for VGR.