Kinarm Labs: supporting diverse basic and clinical research interests in one platform.

1 Introduction

"The brain is our most important organ, and yet we continue to assess its function by tests developed for specific conditions. Neurologists look at a stroke patient's movement problems, but not their thinking; neuropsychologists look at thinking, but not motor. Neither are looking at the whole picture of brain function.
We designed Kinarm to gather all of the information on brain function – motor, cognitive, sensory – all of the building blocks that allow people to interact with the world.
We're now taking what we've learned with the Kinarm and applying it to every disease we can find."

- Dr. Stephen Scott, neuroscientist, Queen's University at Kingston, and inventor of Kinarm

Robots and other advanced technologies have had, and will continue to have, a profound influence on exploring human motor behaviour and how regions of the brain are involved in sensorimotor control in humans and non-human primates. We believe that robotics can play a leading role in addressing the need for objective systems to quantify **sensory, motor, and cognitive functions**. If successful, we hope to contribute to an enhanced understanding of brain function and support the development of improved treatments for brain injury, resulting in better patient outcomes. To this end we have created and commercialized **Kinarm Labs™.**

As of September 2019, we have installed 94 Kinarm Labs at leading research institutions around the world. The research objectives and hence equipment needs of these universities, institutes and hospitals are diverse. That diversity of interests underscores the case for inclusion of a Kinarm Lab in your "departmental" or "central" equipment list.

2 What can you do with a Kinarm Lab?

All Kinarm labs share a common robotic paradigm that enables a subject/patient to interact via their arm and hand with a two dimensional robot in a virtual reality environment. The Kinarm robots can monitor what the subject is doing (i.e. where the robot is moved to) and can also perturb or move itself (i.e. move the subject's hand or arm). The subject being assessed interacts with the robot in a virtual reality environment that provides visual feedback of the limb and/or objects presented in the (horizontal) plane of motion of the limb.

To **basic researchers**, a Kinarm Lab provides the ***most*** flexible robotic platform for undertaking sensory, motor and cognitive research to study:

- Coordination of multi-joint and multi-limb motor actions with or without joint-based loads in human *and* NHP subjects
- Learning in altered visual and mechanical environments
- Solving complex cognitive problems

- Perceptual aspects of proprioception and body image

To **clinical researchers,** Kinarm Standard Tests, running on a Kinarm Lab, provides validated sensitive and objective measures of sensory, motor, and cognitive brain functions through the precise measurement of human behaviour – a method we call ***behaviourography***. By using the suite of standardized protocols, a clinical researcher can assess the neurological impairments of a subject in a Kinarm Lab in 30 to 60 min. Importantly, no programming or analysis skills are required.

Kinarm Standard Tests allows clinical researchers to:

- **Differentiate**: Identify subject-specific behavioural measures that uniquely characterize the subject's neurological deficit
- **Select:** Choose subjects for research protocols based on their deficit profile
- **Target:** Develop new patient-centred therapies to address the patient-specific impairment of the brain injury or disease
- **Measure:** Collect objective data on the subject's response to therapies
- **Advance:** Translate treatments for brain injury from lab to clinic

3 KEY BENEFITS TO A KINARM LAB

- **Flexibility:** Our labs are not limited to measuring "one thing" or creating "one phenomena". All Kinarm Labs use our proprietary control software Dexterit-E to run the ***researcher's*** preferred research protocol that **they** have programmed in a Custom Task Program. Further, once programmed, the Custom Task Program can be customized "on the fly" within Dexterit-E without going back to the programming environment.
- **Validated:** If the team is focused on clinical research, a researcher can instantly tap into decades of neuroscience research on sensory, motor and cognitive impairments through the "packaged knowledge" of Kinarm Standard Tests. These tests bring over a decade of fundamental neuroscience research to the door of clinical research through a suite of tasks that have been validated through peer-reviewed top-tier publications.
- **Familiarity of "standard tools":** we have leveraged the 'best-in-class' expertise and functionality of MathWork's and its real-time and programming tool-boxes. Customers can apply their existing knowledge of MATLAB ("the analysis tool of choice") to create Custom Task Programs in MathWork's Simulink® and Stateflow™. This provides familiarity to even the most junior trainee. Further, Dexterit-E runs in a user-friendly Windows environment.
- **Fitting a range of Users' skills:** Dexterit-E allows operators to create completely custom tasks to suit each end-user's unique needs. There are two layers of task customization provided by Dexterit-E. Each of these layers provides a different level of flexibility and requires a different level of expertise. This dual-level approach allows novice users the flexibility to modify parameters of pre-built tasks without any programming, while simultaneously allowing the experienced user the flexibility to create a completely novel task. With the graphical programming language of Simulink, you don't need to be a professional programmer. Alternatively, Kinarm Standard Tests can be purchased which requires no programming or data analysis skills whatsoever.

- **Translation across models:** Our Kinarm Exoskeleton Lab was first designed for NHP use. Following its active use for 5 years, a human version was designed, preserving the two-dimensional paradigm of all Kinarm Labs. For those doing clinical translation research from NHP to Human, this consistency of model provides a unique opportunity to translate new paradigms and to lower the risk and cost of pharmaceutical drug development.
- **Technology integration:** Our vision of "advanced technologies for assessment" doesn't end with robotics. To achieve whole body assessment, more than just robotics is required. To that end the Kinarm team has spent a lot of time integrating other companies' instruments to work seamlessly in Kinarm Labs. These technologies include the Kinarm Gaze-Tracker (OEM: SR Research), force plates (OEM: Bertec) and force-torque sensors (OEM: ATI).
- **Multiple Users are the norm, not a special case:** As our customers' labs and collaborations have grown, we have implemented features to Dexterit-E to ensure we can support multiple users, with multiple studies, with multiple ethics protocols wanting to share data between multiple sites. User logins, study protocols, data export filters and availability of Dexterit-E Explorer, our data viewer and analyzer, ensure compact subject-specific data files can be stored, exported, backed-up, added to central databases, and shared with others.
- **Accountability to Multiple Users:** Departments are commonly billing the cost of centralized equipment to the various users and/or grants who are using that piece of equipment. Dextertit-E can export a Usage Log that provides information on date/time, username, operator, study(ies) run, etc., to ensure the department is able to share the cost of the system by their preferred method.
- **Robustness:** All Kinarm Labs are designed and manufactured to provide a lifetime of research support. We source the best quality components to ensure long life. We believe the extra investment up front is worth the long term returns. All Kinarm Labs are manufactured in Kingston, Ontario. If a repair is needed in the future, we will conduct the repair – not a supplier. Some labs have been in operation for over 15 years with little to no maintenance.
- **Quality:** With robustness in mind, we implemented a Quality Management System compliant to medical device standards, early in the Kinarm's development. All of our operations are managed in accordance with the demanding standards of ISO 13485:2016. That system extends to our suppliers from whom we source components from around the world. They must meet our demands for consistency and conformity to our specifications – or they are no longer a supplier. Cost-saving by cutting corners on quality does not enter our purchasing equation. We are rigorously audited by our ISO registrar once a year to ensure continuing compliance with our system. From a customer perspective, you know that you will receive consistent product and service from all of the employees at BKIN who are committed to our Quality Policy: *"We at Kinarm, are committed to delivering fault-free products on time, complying with regulatory and all other requirements and maintaining the effectiveness of the Quality Management System in order to satisfy our customers' needs."* We expect our customers to hold us to this commitment.
- **Service costs minimized:** We have maintained a policy of low annual subscription costs for its basic research customers. Currently, we provide unlimited technical support, Dexterit-E software upgrades and unlimited Dexterit-E Explorer downloads for $CAD 998 per annum, per Kinarm Lab. Clinical

researchers currently pay $CAD 6,500 per annum for the full suite of Kinarm Standard Tests. Multi-year discounts are available, as are individual task licenses.

- **Maintenance costs managed:** We pride ourselves on our record of field repairs. With a complex mechatronic system such as Kinarm Labs, some maintenance is necessary and we provide a list of system checks in our user guides. Typically fewer than 5% of labs need a hardware repair in a given year. These costs are typically under $CAD 2,500/repair. We also recommend that users budget to replace the computers every 5 years.

4 KINARM PLATFORMS

4.1 KINARM EXOSKELETON LAB™

Figure 1 Classic Kinarm Exoskeleton Lab first introduced in 2002

Over the past 15 years, an apparatus that could address the need for objective measurement was conceived and developed by Dr. Stephen Scott of the Centre for Neuroscience Studies at Queen's University at Kingston. Scott created a unique paradigm called Kinarm™ (Kinesiological Instrument for Normal and Altered Reaching Movements; Scott, 1999), to address a major stumbling block for identifying the nature of neural representation in primary motor cortex (MI) during a reaching movement. Today its use has expanded greatly to not only be essential instrumentation to researchers studying sensorimotor control in NHP and human, but to also provide objective and quantified assessment for neurologically impaired humans and NHPs to advance the study of neurological disease and development of therapies.

History: Kinarm was first designed to address the difficulty of quantifying and manipulating the mechanics of multi-joint motion in the NHP. Scott extended the design to a human-sized version providing further insight on motor learning (e.g. Singh and Scott, 2003). He then modified the system to a make it more clinically-friendly and include two robots, one for each limb (Nozaki et al., 2006).

This technology has been influential in uncovering many novel aspects of voluntary motor control. Scott lab (https://www.queensu.ca/limb/research-areas) has had over a dozen Nature series publications (Scott et al., 2001; Gribble and Scott, 2002; Singh and Scott, 2003; Kurtzer et al., 2005; Nozaki et al., 2006; Pruszynski et al., 2011); others such as Hatsopoulos Lab (Rubino et al., 2006) and Carmena Lab (Gangully et al., 2011) have had similar success. Scott is currently focused on optimal feedback control (OFC) as a theory of voluntary control (Todorov and Jordan, 2002). Scott has been one of the leaders in the field articulating the importance and impact of this new theory, particularly its implications on the neural basis of control (Scott, 2004). He has demonstrated that "following an external perturbation, motor responses in upper-limb and hand muscles expressed synchronized, target-directed modulation in ~60 ms. This finding cannot be explained by internal predictions from forward models… Instead, our results suggest that in such context, stable control of grasp is also mediated by goal-directed feedback coordination of upper-limb and hand muscles" (Crevecoeur et al, 2016).

Recently the Kinarm Exoskeleton has been used in the clinical research field to quantify impairments related to a number of neurological disorders. A complete list of clinical research related publications with Kinarm is given below. The first publications were in stroke (Coderre et al., 2010; Dukelow et al., 2010) and cerebellar dysfunction (Bhanpuri et al., 2012). Now the system is used in a wide range of published and ongoing studies (see complete list below) including: stroke, cardiac arrest, transient ischemic attack, mild traumatic brain injury, sport concussion and Parkinson's disease.

System Description: Kinarm uses a four-bar linkage to permit planar movements of the arm in the horizontal plane involving flexion and extension movements at the shoulder and elbow joints. Torque motors record the motion of the arm in the horizontal plane and apply loads to each joint independently. The design provides feedback from, and control of, the shoulder and elbow joints thus permitting loads to be applied to the shoulder and/or elbow joints (or hand-based loads). Patterns of joint motion and muscular torques can be computed from the system. A virtual-reality system permits control over visual stimuli and even vision of the limb. The application of loads directly to the upper arm and forearm is unique and resulted in issued US, Canadian and European Patents. (U.S. Patent No. 6,155,993; 8,347,710 & 8,800,366; Canadian Patent No. 2,267,821; EP 2,150,175). Each Kinarm Lab includes Dexterit-E™ behavioural control and data acquisition software, which combines the power of a real-time operating system with the ease of a Windows™-based interface. Kinarm Standard Tests can be used immediately for data collection, analysis and reporting. Custom Task Programs can be created using high-level graphical programming tools.

In 2016, we released the Kinarm Exoskeleton Lab (pictured below) to address customer requests for greater stiffness and better access to the head. The linkage was totally redesigned to provide complete unimpaired access to the head. It is particularly suitable for subjects with stroke, spinal cord injury or cerebral palsy as the exoskeleton design provides gravity support to the subject's upper limbs. Thus, even though a subject may have significant weakness in their arm, they may have sufficient motor function to attempt a behavioural task and provide an assessment.

Figure 2 Kinarm Exoskeleton lab in 2016

To properly fit the Exoskeleton to the subject, a 5-10 minute set-up by a trained technician is required. Children as young as 5 and as old as 85 have been assessed in the Kinarm Exoskeleton. Additional options to the Kinarm Exoskeleton Lab include: a unilateral optional; pediatric sized arm-troughs; secondary encoders for higher resolution position feedback to increase the effective stiffness of the system; and integrated gaze-tracking for eye-hand coordination studies.

Figure 3 NHP Kinarm Exoskeleton

Similar to the human lab, the NHP Kinarm Exoskeleton Lab was also re-designed to provide:
Greater Stiffness: End-point mechanical stiffness 10 times better than with the Classic;
Greater peak torque pulse: 4Nm at shoulder, 3Nm at elbow;
Improved Operator Access to the NHPs: for enhanced safety and enjoyment by the NHPs.
This lab is in use in basic research and clinical research labs doing drug development.

4.2 Kinarm End-Point Lab™

Figure 4 Kinarm End-Point Lab

The Kinarm End-Point robot was introduced in 2010 to provide researchers with a stiff, graspable robot that can create highly complex mechanical-visual environments. The system is modular enabling a phased purchasing strategy, without compromising the ability to have fully integrated bimanual robotic control. For clinical researchers, the Kinarm End-Point enables rapid subject assessment with minimal set-up time. Additional options include an adjustable height stand with integrated force plates for (standing) postural assessment, integrated gaze-tracking (US Patent No. 8,730,266) and a rollable version for point-of-care applications such as an emergency room. We also offer a deluxe subject chair to enable safe assessment of neurologically impaired subjects.

4.3 Integrated Peripherals

Kinarm has integrated instruments manufactured by other suppliers to enable a vision of "whole body assessment". These technologies include the Kinarm Gaze-Tracker (OEM: SR Research), force plates (OEM: Bertec) and force-torque sensors (OEM: ATI). All calibration and data capture activities are integrated seamlessly into the Kinarm Lab workflow. Most popular is our Kinarm Gaze-Tracker.

4.4 Which Kinarm is right for your research?

The key differences between the robotic labs are:

- Exoskeleton robot provides feedback from, and control of, the shoulder and elbow joints. End-Point does not because it only has information/action at the hand. If you need joint-based information or action, then you will want an Exoskeleton.

- Exoskeleton provides gravity support for subjects with upper arm weakness such as in subjects with stroke, spinal cord injury or CP.

- Where "assessment time" is short, and gravity support of the upper limb is not required, time can be saved (~10 minutes) by using the End-Point Lab as opposed to the Exoskeleton Lab.

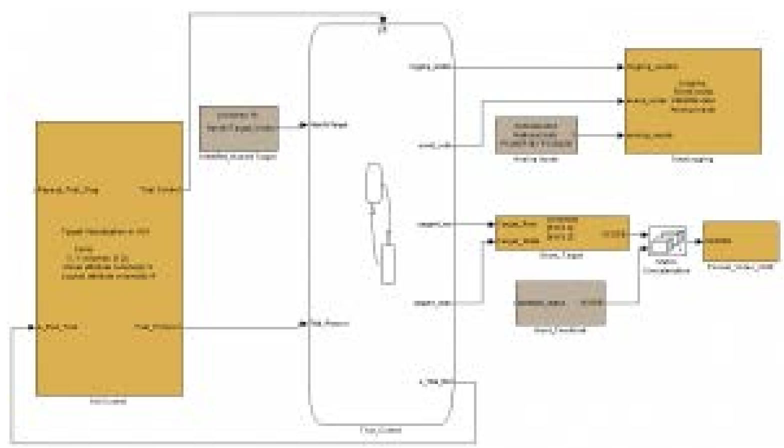
- End-Point robot is stiffer than the Exoskeleton, allowing much higher feedback gains in the control loop. For example, force channels are possible with the Kinarm End-Point robot, whereas they are a little "soft" in the Kinarm Exoskeleton.

- If budget is a constraint, the End-Point is the preferred platform. To fit your budget, you can, for example, choose a unilateral configuration now and then upgrade later to a bilateral configuration. Further, you can expand the system beyond a seated posture to the Adjustable Height Configuration Kinarm End-Point Lab. This lab comes with VR/AR presentation of visual stimuli, integrated gaze-tracking and integrated force plates, in a fully automated or custom control environment using our Dexterit-E operating system with Kinarm Standard Tests.

5 Dexterit-E: How you control a Kinarm Lab

Kinarm Lab's Operating & Control software, Dexterit-E™, allows users to rapidly implement their research protocol without having to be a professional programmer. Dexterit-E is a behavioural control and data acquisition software that operates Kinarm Labs. Dexterit-E is operated through an easy-to-use interface on a Microsoft Windows® computer, but runs the Kinarm Lab through a real-time computer providing precise, reliable control and measurement of the system under study. There are multiple levels of customization and flexibility.

Kinarm Labs give users unparalleled flexibility to create the "experiment" you want.



To create an experiment to run on a Kinarm, you must create a Custom Task Program: a small program used by Dexterit-E that defines and controls the system Behaviour during a single trial of a task.

Task Programs are created in MathWork's Simulink® development environment, a high-level, graphical programming language. Use of Simulink enforces a formalized structure that facilitates error-free implementation of desired Behaviour. A library of Simulink blocks and ready-to-run demonstration tasks assist with rapid Custom Task Program creation. MathWork's Stateflow® is the tool used for defining "an event-driven system" or "finite state-machine." It can be thought of as a flowchart that defines system behaviour.

End-User Customization of Custom Task Programs

Dexterit-E allows operators to create completely custom tasks to suit each end user's unique needs. There are two layers of task customization provided by Dexterit-E. Each of these layers provides a different level of flexibility and requires a different level of expertise. This dual-level approach allows novice users the flexibility to modify parameters of pre-built tasks without any programming, while simultaneously allowing the experienced user the flexibility to create a completely novel task.

Level 1:

The first layer of customization involves the Task Protocol. Users of Dexterit-E must choose and load a Task Protocol in order to 'run' a task. Once loaded, the parameters that make up a Task Protocol can be modified and a new Task Protocol can be saved. Examples of typical Task Protocol parameters include: number, order and randomization of trials, target locations, loading conditions, pause conditions and many others. Specification of a Task Protocol occurs directly within the Dexterit-E user inter face, using parameter tables. No programming is necessary to alter a Task Protocol.

Level 2:

The second layer of customization is more advanced and more powerful: the ability to create and/or customize a Task Program. Task Programs are programs used by Dexterit-E that define and control system Behaviour during a task. They are created using Simulink® and Stateflow® (from MathWorks) outside of Dexterit-E.

6 Why Use the Upper Limb for Brain Function Assessment?

All Kinarm Labs rely on the common principle that the upper limb can give a wealth of information about the function of the brain. But how do we know this?

Over the last 40 years, our understanding of how the brain supports sensory, motor, and cognitive function has substantially increased due to availability of advanced technologies, such as robotics. Behavioural studies on humans have identified how we use sensory input to the brain to perceive the world around us, make decisions, and guide our highly skilled and flexible motor actions. Through the study of these behaviours with the upper limb, we now know:

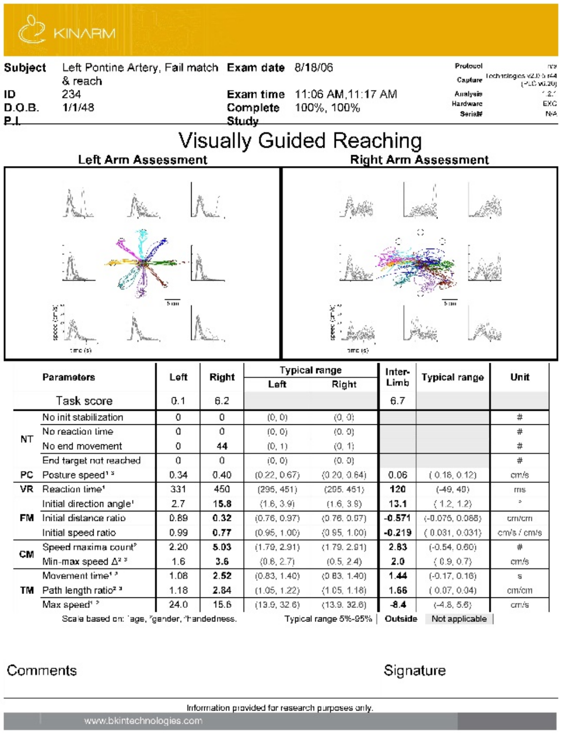
1) sensory and motor systems work together to permit us to move and interact in the environment and create our perception of the world;

2) a given function is supported by a highly distributed network in the brain; and

3) the ability to perform sensory, motor, and cognitive functions requires substantial learning so that brain processing is highly plastic and altered by experience. (Scott et al, 2011).

Many publications are available that elucidate these three key findings.

Given the breadth of sensory and motor processes now studied, it is well-recognized that numerous neurological diseases and injuries will disrupt the complex network that moves the upper limb and that such disruption can now be quantified with the assistance of robotics. With Kinarm Labs, the possibility now exists to identify sensitive biomarkers of healthy performance against which impairments can be identified.


KINARM

Subject: Left Pontine Artery, Fail match & reach
ID: 234
D.O.B.: 1/1/48
P.I.
Exam date: 8/18/06
Exam time: 11:06 AM,11:17 AM
Complete: 100%, 100%
Study
Protocol
Capture
Analysis
Hardware: EXC
Serial#: N/A

Visually Guided Reaching

Left Arm Assessment | Right Arm Assessment

	Parameters	Left	Right	Typical range Left	Typical range Right	Inter-Limb	Typical range	Unit
	Task score	0.1	6.2			6.7		
NT	No init stabilization	0	0	(0, 0)	(0, 0)			#
NT	No reaction time	0	0	(0, 0)	(0, 0)			#
NT	No end movement	0	**44**	(0, 1)	(0, 1)			#
NT	End target not reached	0	0	(0, 0)	(0, 0)			#
PC	Posture speed[1,3]	0.34	0.40	(0.22, 0.67)	(0.20, 0.64)	0.06	(0.16, 0.12)	cm/s
VR	Reaction time[1]	331	450	(295, 451)	(295, 451)	**120**	(-49, 49)	ms
FM	Initial direction angle[1]	2.7	**15.8**	(1.6, 3.9)	(1.6, 3.9)	**13.1**	(1.2, 1.2)	°
FM	Initial distance ratio	0.89	**0.32**	(0.76, 0.97)	(0.76, 0.97)	**-0.571**	(-0.075, 0.068)	cm/cm
FM	Initial speed ratio	0.99	**0.77**	(0.95, 1.00)	(0.95, 1.00)	**-0.219**	(0.031, 0.031)	cm/s / cm/s
CM	Speed maxima count[2]	2.20	**5.03**	(1.79, 2.91)	(1.79, 2.91)	**2.83**	(-0.54, 0.60)	#
CM	Min-max speed Δ[2,3]	1.6	**3.6**	(0.6, 2.7)	(0.5, 2.4)	**2.0**	(0.9, 0.7)	cm/s
TM	Movement time[1,2]	1.08	**2.52**	(0.83, 1.40)	(0.83, 1.40)	**1.44**	(-0.17, 0.16)	s
TM	Path length ratio[2,3]	1.18	**2.84**	(1.05, 1.22)	(1.05, 1.18)	**1.66**	(0.07, 0.04)	cm/cm
TM	Max speed[1,2]	24.0	15.6	(13.9, 32.6)	(13.9, 32.6)	**-8.4**	(-4.8, 5.6)	cm/s

Scale based on: [1]age, [2]gender, [3]handedness. Typical range 5%-95% | **Outside** | Not applicable

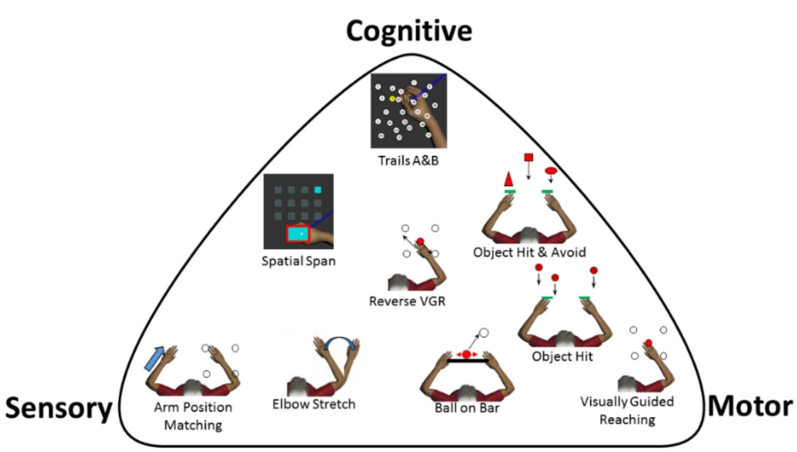
Comments | Signature

Information provided for research purposes only.

www.bkintechnologies.com

For example, a motor task such as the finger-to-nose test (a complex visually-guided reaching movement to a target) is currently quantified by the clinician asking the patient to touch his finger and their nose repeatably and scored 0, 1 or 2. With a Kinarm lab, the robot first numerically characterizes a healthy subject with kinematic variables such as reaction time, speed differences between limbs and direction errors to assemble a large normative database of age-matched controls. The impaired subject performs the same task and their performance is then compared and parameter flagged if performance is beyond the 5-95 confidence interval (Coderre, et al., 2010). This paradigm has been repeated in numerous behavioural tasks by Scott and others, and has enabled us to develop Kinarm Standard Tests.

7 KINARM STANDARD TESTS™



KST provides a precise, quantitative profile of the neurological impairments of a subject, thus allowing a researcher to identify and characterize neurological impairments, to help understand disease progress, and thus develop new therapies.

Kinarm Standard Tests provides the foundation for a broad-based sensory, motor, and cognitive assessment of brain function (Patents: US 8,277,396; 8,740,794; JP 5,368,311; CN ZL20078004765.6; CA 2,668,364; 2,749,487). The selection and design of these behavioural tasks is based on principles of neuroscience and theories of sensorimotor control. Each behaviour is generated by neural processing across many brain regions and each brain region participates in a range of behavioural tasks. The integration across a range of different tasks permits separation of different brain regions or circuits to identify the foci of potential brain injury. Some of these tasks have been correlated anatomically (Kenzie, et al, 2014).

7.1 SUMMARY OF TASKS

The suite has 9 tests (Dexterit-E 3.7) with normative data available for 18-85 year olds on both end-point and exoskeleton platforms. New assessment tasks and child normative models are in development. Further, training tasks, which are being studied for their therapeutic benefit are being developed.

Kinarm Standard Tests™		
Behavioural Task	Brain Function	Time
Arm Position Matching	Somatosensory processing for perception Position-sense	3 min
Elbow Stretch Test	Assess presence of spasticity and high tone	5 min/ arm
Visually Guided Reaching	Motor coordination Visuomotor skills Postural control of arm	2 min/ arm
Ball on Bar	Bi-manual coordination Visuomotor skills	3 min/ arm
Object Hit	Rapid visuomotor skills Bi-manual motor planning Spatial attention	2.5 min
Object Hit & Avoid	Rapid motor decisions Bi-manual motor planning Spatial attention Executive function: attention and inhibitory control	2.5 min
Reverse Visually Guided Reaching	Visuomotor skills Cognitive ability to override automatic motor responses	3 min/ arm
Spatial Span	Visuospatial working memory	4 min
Trails A&B	Executive function: task switching	4 min

Details on each task, parameters and exemplary reports are available in the KST Summary available for download on our website (http://www.bkintechnologies.com/download/kst-summary-analysis-version-3-7/). All tests have been published in leading, peer reviewed publications (Bourke et al, 2016; Lowrey et al, 2014; Hawkins et al, 2015; Tyryshkin et al, 2014; Dukelow et al, 2010; Coderre et al, 2010.)

With Kinarm Standard Tests, each user is able to:

- Run a subject in a battery of standard behavioural tasks
- Quantify subject performance in an objective and comprehensive manner
- Score the subject against age-matched normal populations
- Generate an electronic report that may be viewed/shared later along with trial by trial viewing capability with Dexterit-E Explorer

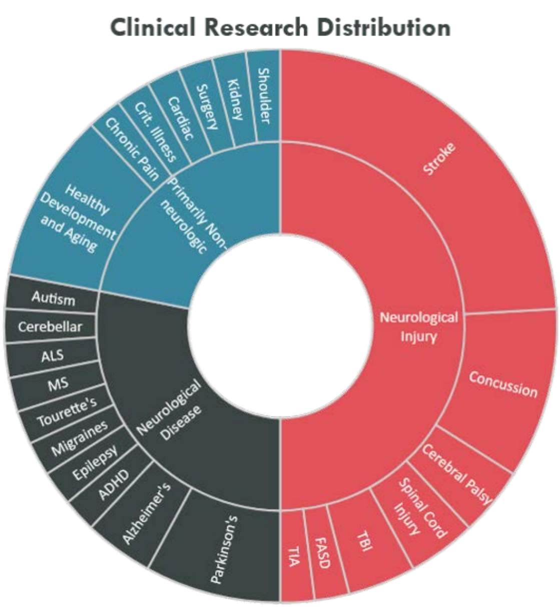
This will allow researchers to:

- Identify a behavioural "finger-print" unique to the subject's neurological deficit
- Select patients for research protocols based on their deficit profile
- Demonstrate statistically relevant change in response to new therapies

Limitations:

1. Kinarm Standard Tests are for research purposes only. An approved ethics protocol is required to use them.
2. Parameters captured by integrated peripherals such as the Kinarm Gaze-Tracker and force-plate(s) are not included in the standardized analysis or reporting features. They are available for independent analysis.

7.2 Clinical Research Studies Currently Underway with Kinarm Standard Tests



Notable studies include:

- Quantification of Stroke impairments (Queen's, University of Calgary, Keio University, Toronto Rehab, Univ of Maryland; indication with greatest depth of clinical research; dozens of peer-reviewed articles);
- Identifying measureable residual impairments from transient ischemic attack; separation of TIA and Migraines presented in an ERM (Queen's/KHSC);
- Impacts of CABG on the brain: quantifying neurological impairment in cardiac surgery patients (Queen's/KGH)
- Baseline and post-concussion assessment of varsity and elite athletes (Winsport Canadian Sport Institute & Univ Calgary; >1,000 athletes assessed);
- Identifying malingering TBIs in an emergency room environment (Univ Cincinnati);
- Measurement of sensorimotor deficits in children with cerebral palsy (Queen's, Univ of Calgary);
- Deficits in Reaching with Children in Fetal Alcohol Syndrome (Queen's);
- Cerebellar Dysfunction (pediatric and adult) and Autism (pediatric) (Johns Hopkins);
- Assessing the effects of dopamine replacement therapies on parkinsonian bradykinesia, rigidity and postural instability using the Kinarm Parkinson's (Queen's/KGH);

- Quantification of deficits in ALS (Queen's/KGH);
- Effects of Chronic Pain on Motor Acquisition and Retention (Laval);
- Quantification of sensorimotor and cognitive deficits in MS (Queen's/KGH)
- Differentiating clinical populations using robotic assessment (MS, TIA, PD, Stroke; Queen's/KGH)
- Impact of kidney failure on brain function (Queen's/KGH)
- Quantification of sensorimotor deficits in Alzheimer's (MSU and MTU)

8 About Us

History

Unsatisfied with the available tools for assessing upper-limb voluntary motor control, Dr. Stephen Scott of Queen's University invented the first Kinesiological Instrument for Normal and Altered Reaching Movement (KINARM) prototype in 1998. He used it in his basic research to quantify and manipulate the mechanics of multi-joint motion in the NHP while recording neural function (Scott, 1999). After this initial study, it became apparent that the KINARM model was useful for studying not only motor control, but also a range of other sensory and cognitive functions. Dr. Scott soon began receiving requests from other researchers who wanted to use the technology in their research, and so in 2002, partnered with Dr. Ian Brown in order to assist with its development. Together they extended the robot to a human-sized version, and in 2004, founded BKIN Technologies Ltd., with the guidance Queen's University's PARTEQ Innovations.

Since its establishment, the company has expanded significantly. In 2006, the original system was modified to a more clinic-friendly version called the Kinarm Exoskeleton Lab, and included two robots, one for each limb (Nozaki et al., 2006). A second platform called the Kinarm End-Point Lab was released in 2010, offering researchers greater ability to provide feedback to the hand and enabling tasks where the patient is standing rather than being seated. In 2019, the company was renamed from BKIN Technologies to Kinarm, unifying its corporate identity and its products.

Through years of commitment to creating advanced, innovative products, Kinarm is now able to offer sophisticated technology labs complete with a fully automated operating control software, and integrated gaze-tracking and force plates. To date, there are more than 90 Kinarm labs in 11 countries worldwide. The Kinarm has been used in over 275 basic and clinical research publications, setting a new standard for the sensitivity and quality of neurological assessment tools. Kinarm enables behaviorography for not just for the neuroscience community, but for the clinical research community as well.

In 2019, we renamed the company Kinarm to reflect our singular focus on providing interactive robotic solutions for basic and clinical researchers studying the brain. We employ 8 people who are specialists in software and hardware design and development, analytical analysis and advanced manufacturing techniques. We have installed more than 90 human and NHP Kinarm Labs in our 15 year history. All of our labs are manufactured in Kingston with primary electronic and mechanical component sourcing from the United States, Canada and Japan.

For more information contact:

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