



Dextreme™

Clinical Overview

A decade of rigorous clinical validation demonstrating the effectiveness of error augmentation training in neurological rehabilitation.

CLINICAL EVIDENCE PORTFOLIO

A foundation built on a decade of research.

Dextreme™'s error augmentation technology has been rigorously tested across diverse patient populations — from healthy subjects to acute and chronic stroke survivors. Our comprehensive clinical program demonstrates consistent, significant improvements in upper limb motor function and activity.

10

years of clinical research

4

peer-reviewed studies

80+

study participants

366%

MAS improvement vs. control

Why error augmentation is effective

- ✓ **Automatic, non-cognitive adaptation**
Error augmentation triggers instinctive correction responses rather than conscious cognitive effort, enabling effective learning without mental fatigue.
- ✓ **Enhanced motor learning**
The process strengthens natural adaptive responses and accelerates the formation of internal movement models.
- ✓ **Quality over speed**
Promotes smoother, more coordinated movements while maintaining natural velocity through repetitive practice cycles.
- ✓ **Consistency across populations**
Demonstrated effectiveness across healthy individuals and stroke patients — acute, subacute, and chronic — over a wide range of motion capabilities.
- ✓ **Personalised & safe training**
Real-time force adaptation ensures optimised challenge levels. High-dose protocols are well tolerated, with no systematic pain or stiffness reported.

Subacute Stroke · 2014

Error Enhancement of Velocity Component in Stroke Patients

Givon-Mayo, R.; Simons, E.; Ohry, A.; Karpin, H.; Israely, S.; Carmeli, E.
International Journal of Therapeutic Rehabilitation, 2014

Objective

Investigate the efficacy of robot-assisted rehabilitation using velocity error-enhancement training to improve arm-reaching movements in post-stroke hemiparesis patients.

Study Design

PARTICIPANTS

18 post-stroke hemiparesis patients total (7 completed: 4 experimental, 3 control)

EXPERIMENTAL GROUP

Velocity error-enhancement training; robot applied forces augmenting deviations from optimal bell-shaped velocity profiles

PROTOCOL

5 weekly sessions with Motor Assessment Scale and kinematic assessments at pre-test, mid-test, and post-test

ROBOTIC SYSTEM

Programmed with kinematic data from healthy subjects to calculate optimal trajectory and velocity profiles

DURATION

5 weeks of intensive robot-assisted therapy

CONTROL GROUP

Identical reaching tasks with passive robotic therapy (no error augmentation forces)

STATISTICAL ANALYSIS

Group-level comparisons with significance testing ($p < 0.05$)

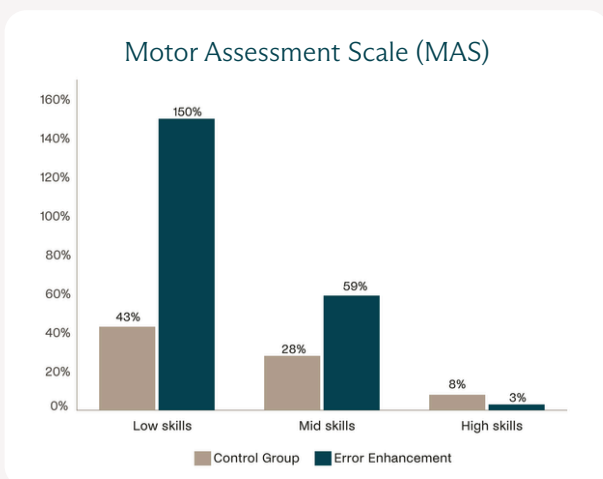


Figure 1a. Motor Assessment Scale (MAS) improvement by baseline skill level: control vs. error enhancement.

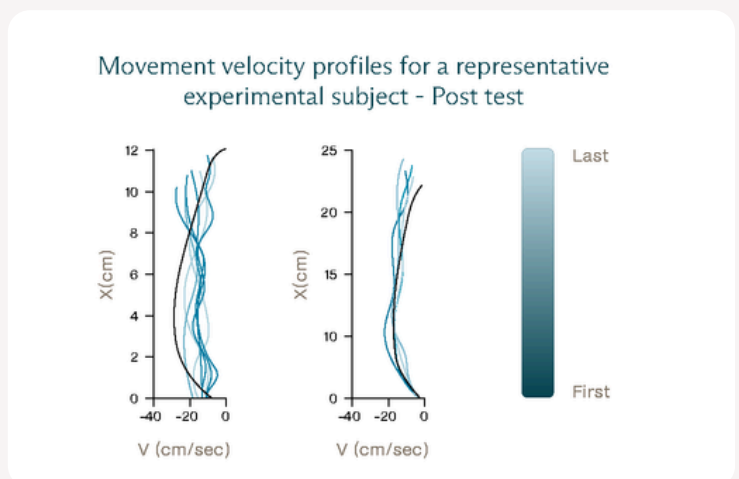


Figure 1b. Movement velocity profiles: normalized patterns post-test showing control vs. error enhancement convergence.

SUBACUTE STROKE STUDY · 2014

Key results & benefits

Key Results

- **40% functional improvement:** Two of four experimental participants showed 27–40% improvement in Motor Assessment Scale scores vs. less than 12% in controls
- **Normalized movement profiles:** Experimental group velocity profiles converged toward optimal bell-shaped pattern; controls only decreased velocity
- **Maintained natural speed:** Experimental group maintained velocity (quality improvement), while controls slowed by 14.1 ± 8.7 cm/sec
- **Reduced variability:** Statistically significant group-level improvements in reaching path trajectories and velocity error ($p < 0.05$)

Key Benefits Demonstrated



Achieve up to 40% improvement in upper limb functional scores after just 5 weeks of Bioxtreme robotic therapy



Significantly reduce movement errors with velocity profiles converging toward optimal smoothness and regularity



Maintain natural movement speed while enhancing control



Healthy Subjects · 2018

Improvement in Hand Trajectory by Error Augmentation

Israely, S.; Leisman, G.; Carmeli, E.
Medical Biology, 2018

Objective

Investigate whether adaptive responses to error-augmentation force fields induce decreased trajectory errors in hand-reaching movements across multiple directions in healthy individuals.

Study Design

PARTICIPANTS

41 healthy subjects (randomized controlled trial)

STUDY GROUP

Error-augmentation force fields applied to hand during reaching movements

MEASUREMENTS

Hand trajectory deviation from straight line path measured throughout each game set

KEY FEATURE

Real-time force adjustment algorithm personalized to each subject's arm length, power, and performance

DESIGN

Multi-session training across 7 randomized game sets with multi-directional 3D reaching tasks

CONTROL GROUP

Identical protocol in null-field environment (no augmentation forces)

ANALYSIS

Mixed-model ANOVA investigating group × time interaction effects on movement error magnitude

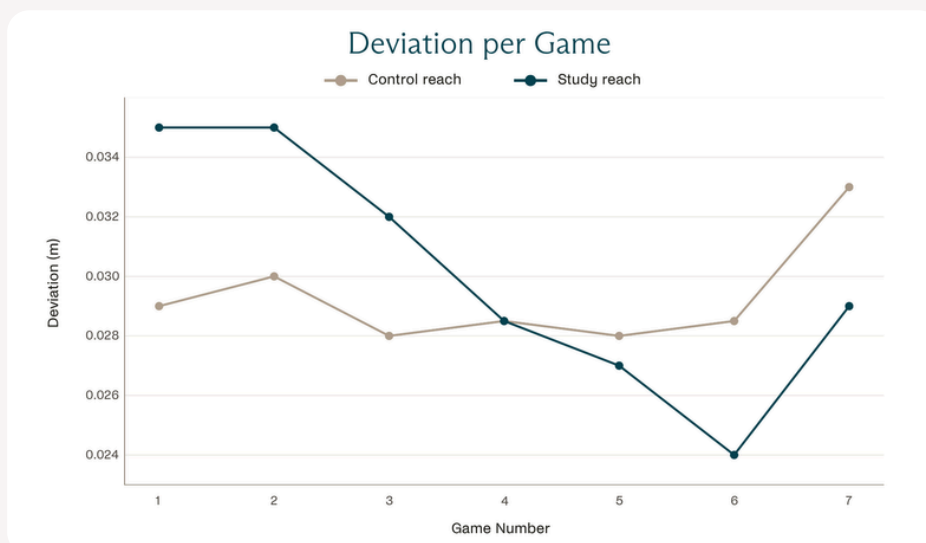


Figure 2. Deviation from straight trajectory per game number for control and study reach groups.

HEALTHY SUBJECTS STUDY · 2018

Key results & benefits

Key Results

- **14.8% improvement:** Error-augmentation training significantly decreased hand trajectory errors compared to null-field training
- **Enhanced proprioceptive feedback:** EA training engages proprioceptive feedback beyond visual feedback alone
- **Sustained performance:** Multi-directional practice with EA forces promotes improved motor performance without plateau
- **Personalized algorithm:** Bioxtreme system adjusts forces in real-time, tailored to user's arm length, power, and performance

Key Benefits Demonstrated



Dextreme™ reduces hand movement errors by nearly 15% through advanced error-augmentation training



Personalized, real-time force adjustments ensure safe and effective motor skill improvement for each user



Multi-directional reaching training delivers sustained improvement without performance plateauing



41 healthy subjects demonstrated improvement in motor skills across diverse reaching patterns



Acute/Subacute Stroke · 2023

Robotically Driven Error Augmentation Enhances Post-Stroke Motor Recovery

Carmeli, E.; Israely, S.; Barel, H.; Zalesov, O.; Zaygraykin, N.; Mansour, R.; Leisman, G. Engineering Reports, 2023; e12720

Objective

Investigate the effectiveness of robotically driven error augmentation (EA) training on motor recovery after stroke, comparing it to standard robotic training in null field.

Study Design

PARTICIPANTS

16 subacute stroke patients with hemiparesis (9 EA group, 7 control) - double-blinded RCT

INTERVENTION

Dextreme™ system with Market Stand & Alchemist games in immersive 3D VR environment

CONTROL GROUP

Identical protocol with null-field robotic training (no EA forces)

SECONDARY OUTCOMES

Kinematic measures (movement errors, jerkiness) analyzed via two-way ANOVA

DURATION

2 weeks (6 sessions total, 3x/week, 20 min each) + standard rehabilitation protocol

EXPERIMENTAL GROUP

Robotically-driven Error Augmentation (EA) force fields enhancing proprioceptive feedback

PRIMARY OUTCOMES

Blinded Fugl-Meyer Assessment (FMA) and Motor Assessment Scale (MAS) scores

CORRELATION ANALYSIS

Pearson correlation between FMA and MAS improvements ($r=0.541$, $p=0.03$)

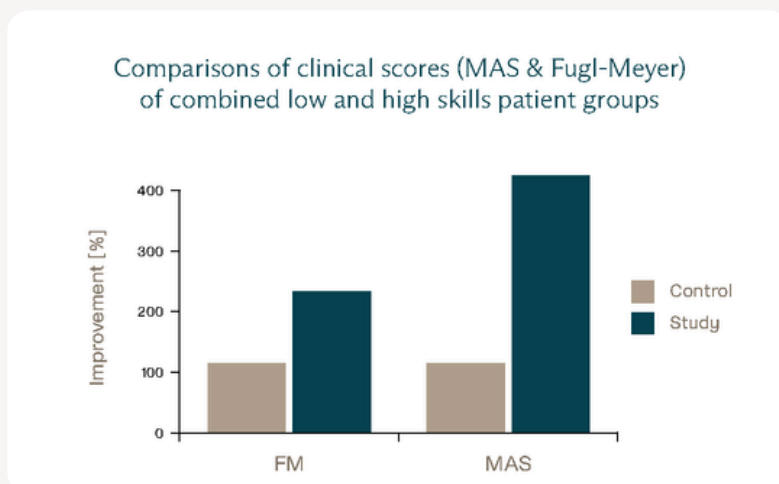


Figure 3. Fugl-Meyer Assessment (FM) and Motor Assessment Scale (MAS) improvements comparing control vs. error augmentation training in acute/subacute stroke patients.

ACUTE/SUBACUTE STROKE STUDY · 2023

Key results & benefits

Key Results

- **366% greater MAS improvement:** Error Augmentation training boosted Motor Assessment Scale scores 366% more than standard robotic training
- **188% greater FM improvement:** Fugl-Meyer scores improved 188% more with EA vs. controls
- **Rapid motor adaptation:** Initial movement errors vanished after just 10 treatments with significantly reduced jerkiness ($p < 0.0001$)
- **Correlated improvements:** MAS and FM improvements were significantly correlated ($p = 0.03, r = 0.541$), confirming consistent EA benefits
- **Superior efficacy:** EA robotic therapy proved superior for acute/subacute stroke, especially those with moderate impairments

Key Benefits Demonstrated



Boost post-stroke arm recovery: achieve up to 366% greater functional improvement than standard robotic therapy



Experience faster, smoother motor improvements—clinically proven rapid motor adaptation and reduced jerkiness



Cutting-edge technology boosts rehabilitation outcomes to significantly increase motor function scores



Chronic Stroke · 2024

Error Enhancement in Chronic Phase Stroke: 5-Day Intervention Study

Coremans, M.; Carmeli, E.; De Bauw, I.; Essers, B.; Lemmens, R.; Verheyden, G. Sensors, 2024; 24(471)

Objective

Investigate the effects of novel robotic error augmentation training on upper limb motor function, self-perceived arm use, and movement quality in chronic stroke survivors.

Study Design

PARTICIPANTS

22 chronic stroke survivors (mean age 57 years, mean 1571 days post-stroke, 12M/10F)

INTERVENTION

Dextreme™ robot delivering error augmentation forces during 3D reaching movements

CLINICAL OUTCOMES

Fugl-Meyer Assessment-UE (FMA-UE), Action Research Arm Test (ARAT)

KINEMATIC ASSESSMENT

KINARM robotic evaluation of position sense and proprioceptive control

DESIGN

5-day pre-post intervention (5×1-hour sessions of high-intensity robotic training)

TRAINING DOSE

Mean 1,043 goal-directed reaching movements across 5 sessions

PATIENT-REPORTED

Motor Activity Log (MAL) Amount of Use and Quality of Movement subscales

SAFETY MEASURES

Visual Analog Scale (VAS) for pain and muscle tone monitoring

I have the feeling that...

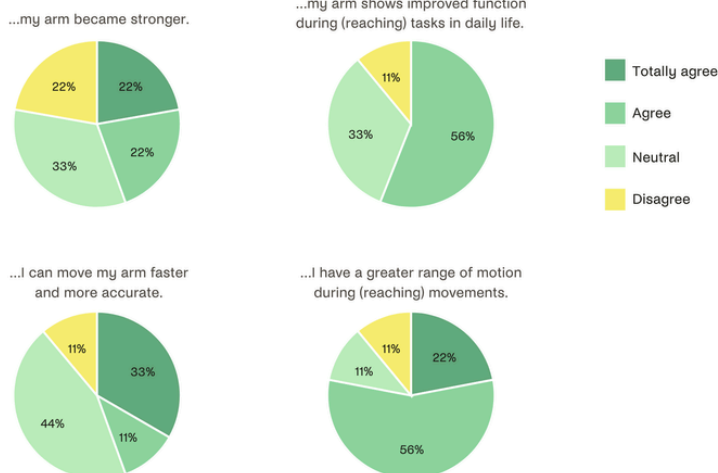


Figure 4. Self-perceived arm use and movement quality in patients following Dextreme™ treatment.

Key results & benefits

Key Results

- **Measurable clinical improvements:** Significant gains on FMA-UE and ARAT with large effect sizes despite short intervention
- **Improved arm use in daily life:** Patients reported using their affected arm more and with better quality on Motor Activity Log scales
- **High-dose training efficiency:** Mean ≈1,043 reaching movements over 5 sessions demonstrates intensive, task-specific training
- **Safe and well-tolerated:** No systematic increase in upper limb pain or stiffness (VAS pain and tone did not worsen)
- **Enhanced proprioception:** Objective KINARM assessment showed significant improvement in arm position sense and proprioceptive control
- **Gold-standard outcomes:** Results on consensus-recommended FMA-UE, ARAT, MAL measures ensure strong clinical credibility

Key Benefits Demonstrated



Intensive 5-session Dextreme™ training improved upper limb motor function and arm activity in chronic stroke survivors, even years after stroke



Stroke survivors reported using their affected arm more often and with better quality in daily life after Dextreme™ training



Dextreme™ delivers over 1,000 targeted reaching movements in just five one-hour sessions—truly high-dose, task-specific therapy



High-repetition training was well tolerated with no increase in upper limb pain or stiffness in appropriately screened patients



CLINICAL STUDIES SUMMARY

A decade of evidence, at a glance.

STUDY	YEAR	POPULATION	DURATION	SAMPLE SIZE	KEY IMPROVEMENT
Velocity Enhancement	2014	Subacute stroke	5 weeks	7 patients (4 exp / 3 ctrl)	40% MAS
Hand Trajectory	2018	Healthy subjects	Multi-session training	41 subjects	14.8% accuracy
Acute / Subacute Recovery	2023	Acute / Subacute stroke	2 weeks (6 sessions)	16 patients (9 EA / 7 ctrl)	366% vs. ctrl (MAS)
Chronic Phase	2024	Chronic stroke	5 days (5 sessions)	22 patients	Large effect sizes (FMA-UE, ARAT)

Common themes across studies

CONSISTENT EFFICACY

All four studies demonstrate significant improvements in upper-limb motor function and movement quality.

FUNCTIONAL GAINS

Improvements translate to real-world arm use and quality-of-life benefits.

RAPID ADAPTATION

Even short interventions (5 days) produce measurable clinical gains.

ERROR-AUGMENTATION ADVANTAGE

EA training consistently outperforms passive or null-field control conditions.

SAFETY PROFILE

High-dose training is well tolerated across all populations with no adverse effects.

DIVERSE POPULATIONS

Proven effective in healthy subjects and stroke survivors across all phases.

A decade of rigorous clinical research — from foundational studies in healthy subjects to proof of concept in stroke survivors across acute, subacute, and chronic phases — establishes Dextreme™ as a clinically validated, evidence-based approach to upper-limb neurorehabilitation. Consistent and substantial improvements in motor function, movement quality, and real-world arm use highlight not only its ease of use for both patients and clinicians, but also its exceptional potential to transform motor learning across diverse populations, disciplines, and neurological pathologies.