environment of reduced or eliminated gravity, as well as enhanced gravity. Such a system can be used to provide infinite support via haptically rendered rigid objects, or to provide forces along the vertical axis scaled to a subject's limb weight. In this way, the system is able to reduce or increase the amount of abduction torque a subject is required to create at the shoulder in order to work in the environment. Using an instrumented arm rest and adjustable gimbal on the end effector of such a system, finger/wrist/elbow/shoulder angles (kinematics) and forces/moments (kinetics) can be monitored during movement. Finally, the system may also include a supporting means, such as, but not limited to, a chair, a bed, a back support, and a trunk support, that will constrain movements of the trunk during the monitoring/therapy of arm movements. Furthermore, such a supporting means should have various adjustable and marked degrees of freedom that will allow the experimenter/therapist to place a test subject in the same position for subsequent measurement/therapy sessions.

[0142] We disclose herein that even highly impaired subjects are able to increase available workspace of the hand when gravity and the need to activate anti-gravity muscles are eliminated. Similarly, mildly impaired subjects may revert to similar patterns when required to work in environments of enhanced gravity, where they are required to generate abduction torques greater than that to lift the weight of their own limb. These patterns and movement characteristics as well as their treatment are elucidated using a variety of protocols, as described by example below.

[0143] Reaching in a plane can be explored with the system of the invention while concurrently measuring shoulder/elbow/wrist and finger forces and torques. This allows back calculation of shoulder and elbow torques as well as wrist and finger forces/torques, which is a highly relevant output measure of the system. The system should also allow for the monitoring of higher speed movements during which subjects will be able to perform ballistic reaches in several conditions: fully supported by a rigid plane passing though the center of rotation of the shoulder, and with various levels of support that virtually reduce or enhance gravity.

[0144] To reduce the impact that hyperexcitable stretch reflexes (or spasticity) may also have on the compromised arm, a second protocol emphasizes slow movements. Subjects are asked to slowly make the largest circle they can with their arm. Like the ballistic reaching protocol, this is done under rigid support from a haptic table, or while the subject is concurrently producing particular levels of active limb support. By reducing the impact of spacticity, the best picture of available work area can be constructed.

[0145] A third way that the device can be used is to characterize free reaching that is not confined to a plane. By unlocking the position of the gimbal and removing rigid haptic constraints, a subject's freely selected path can be studied. The effects of gravity can still be studied in the same manner by applying bias forces at the end effecter, as in previous protocol descriptions. This method removes external constraints and restrictions and provides a potentially more relevant look at movement following brain injury.

[0146] A fourth ability that the haptic system should have is to allow for the introduction of particular fields and external perturbations to the arm. Such a system can then be used to investigate the effect anti-gravity muscle activity on the expression of spasticity. The system can be used to provide a quick constant acceleration perturbation to the elbow joint, shoulder joint, or a combination of the two. Using system analysis techniques and information obtained from EMGs, excitability of the reflex can be elicited and compared to the level of active limb support requirements.

[0147] A fifth property of the system is that it should be able to measure kinetics of the wrist and fingers during the monitoring of the effect of gravity on reaching and retrieval motions with the arm.

[0148] Finally, viscous fields can be implemented to the system during all or parts of the movement to induce velocity dependent resistance against movement. This may allow us to more fully characterize the movement patterns of more mildly impaired subjects.

[0149] These protocols, or combinations thereof, can be used as outcome measures for the intervention protocols described in the next section, or as a means of more specifically quantifying impairments that result from the presence of gravity and need to drive activation of shoulder abduction/external rotation muscles.

[0150] Under the guidance of our gravity-induced discoordination concept as disclosed above, several therapeutic intervention protocols can be realized. A protocol in which gravity is progressively re-introduced during outward reaching over a period of 8 weeks can be used. Training can be further extended or shortened according to a subject's clinical needs. More specifically, subjects can be trained to reach outward towards virtually displayed targets that are situated on a horizontal plane associated with the height of the shoulder. Progressive gravity re-introduction training can be expanded beyond reaching on a shoulder-height horizontal plane to three-dimensional or free reaching. Such a protocol would include reaching toward outward targets positioned on the three dimensional surface defined by the most distant reaching points throughout the entire volume of the arm's range of motion. Gravity could be progressively re-introduced as in the previous protocol over a period of time as a subject is trained to reach outward toward randomized targets in their three-dimensional work area.

[0151] The acquisition of targets during progressive gravity re-introduction training can also be expanded upon by integrating functional electrical stimulation (FES) of the elbow, wrist, and finger extensors during antigravity reaching and subsequent grasping of virtual objects. In the absence of FES subjects progressive generate greater finger and wrist flexion forces when lifting up more of the weight of their arm (see **FIG. 13**). Artificial stimulation of extensors would assist in counteracting abnormal flexor activity that occurs during reaching toward targets in the presence of gravity (**FIG. 14**). This assistance may facilitate the changes resultant from progressive gravity re-introduction by triggering appropriate muscle activity.

[0152] Progressive gravity re-introduction training during horizontal and free reaching with and without functional electrical stimulation can also be employed in the presence of horizontal viscous fields, inertial fields simulating the transport of objects, or controlled joint angular velocities (isokinetic reaching). The implementation of these various forms of horizontal resistance against the direction of reaching would have a strengthening effect that may facilitate the changes resultant from progressive gravity re-introduction.