Multiple spatial coordinate systems for new maps between sensory information and motor commands.

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Humans can learn to make accurate movements when the required map between sensory inputs and motor commands changes, such as when using tools that alter limb dynamics or when sensory information is distorted. Moreover, motor learning can also involve a "use-dependent" component that biases subsequent movements towards those repeated during practice, but that does not require the correction of movement errors. A key question regarding the sensorimotor adaptations that underlie this flexibility is the spatial frame of reference in which remapping is encoded. Are new sensorimotor maps defined according to the particular joint angles or torques required for movement, the native coordinate systems of the relevant sensory information (e.g. retinotopic motion direction), or composite extrinsic coordinate systems such as Cartesian space relative to the body? We have addressed this question in a series of visuomotor adaptation studies in which subjects had to move a cursor to visual targets by exerting isometric forces with the finger or wrist. We assessed how adaptation of the initial movement direction generalised to new target directions, postures and between left and right limbs, to systematically manipulate the alignment of the learned perturbation in various spatial coordinate systems. For transfer of visuomotor adaptation between left and right limbs, and generalisation of visuomotor gain adaptation, transfer of adaptation only occurred when visuomotor distortion had identical effects in eye- and joint-based coordinates bilaterally. However, generalization of visuomotor adaptation to different postures within a single limb, and bias in force direction generated in response to repetition of a single movement direction were expressed according to a purely extrinsic or visual (rather than limb-based) reference frame. The results imply that new visoumotor maps are encoded in neural circuits associated with both intrinsic and extrinsic movement representations, but that the behavioural outcomes of remapping (i.e. generalisation patterns) depend on the sensory context.