The fast and slow process differ with feedback but not age

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Two-Rate Model for Motor Learning

People can learn and adapt many movements, simultaneously engaging multiple processes at different time scales. We test if a two-process model explains effects of feedback and age. The two-rate model (Smith et al., 2006; McDougle et al., 2015) sets the motor output on trial t as the sum of a slow and fast process:

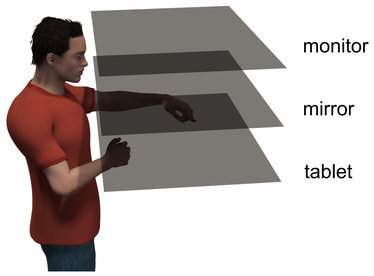
$$X_t = S_t + F_t$$

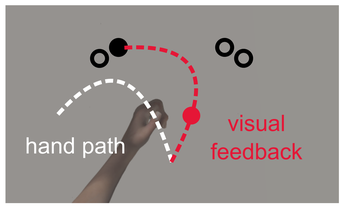
which are each determined by a learning rate L and retention rate R:

$$S_{t+1} = \mathrm{Ls} \cdot e_t + \mathrm{Rs} \cdot S_t$$

$$F_{t+1} = \mathrm{Lf} \cdot e_t + \mathrm{Rf} \cdot F_t$$

Both processes learn from errors on previous trials (e_t) and retain some previous adaptation (F_t, S_t). Constraints: Ls < Lf and Rs > Rf. The model explains a rebound after a brief reversal of the rotation.





Experimental Procedure

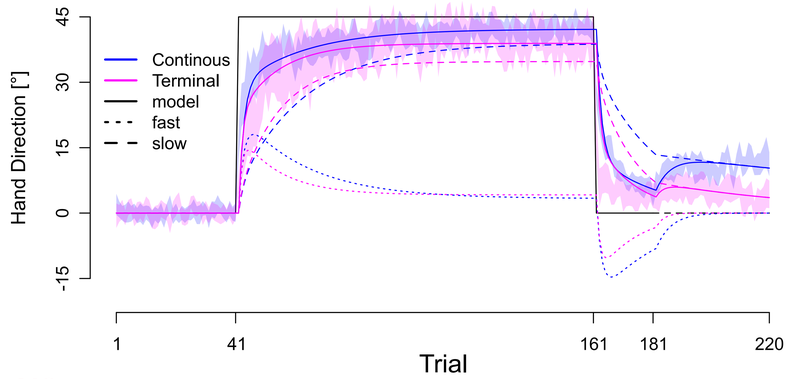
Four of the five experiments had participants complete fully active reaches to the targets shown above. They were exposed to a 45 degree rotation either abruptly or gradually for 140 trials before the rotation was abruptly removed. Following 20 aligned trials, the participants experienced clamp trials where the cursors movement was unrelated to the hands trajectory. The no-cursor experiment had a different design, which matched that of the original two-rate paradigm, with participants experiencing both rotation directions and then clamp trials.

Model Parameters

Condition	Rs	Ls	Rf	Lf
Continous N= 34	0.993	0.094	0.818	0.214
Terminal N= 34	0.982	0.101	0.681	0.218
No-Cursor N= 32	0.991	0.037	0.773	0.127
Older Abrupt N= 14	0.995	0.140	0.704	0.345
Younger Abrupt N= 27	0.993	0.111	0.776	0.310

Terminal Feedback: One-Rate Learning

Terminal feedback might slow down the dynamics, which could benefit modeling, so we compare continuous and terminal feedback. However, terminal feedback shows no rebound so that only one process is necessary.



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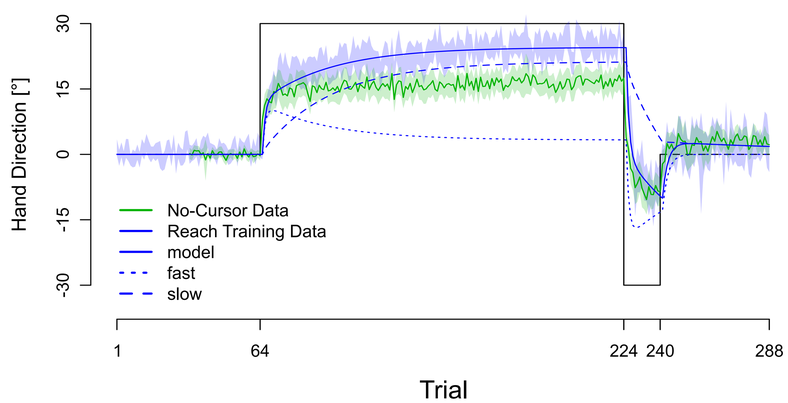
Condition	One-Rate	Two-Rate	Likelihood
Continous	33.51	25.71	0.020
Terminal	31.21	32.16	0.631

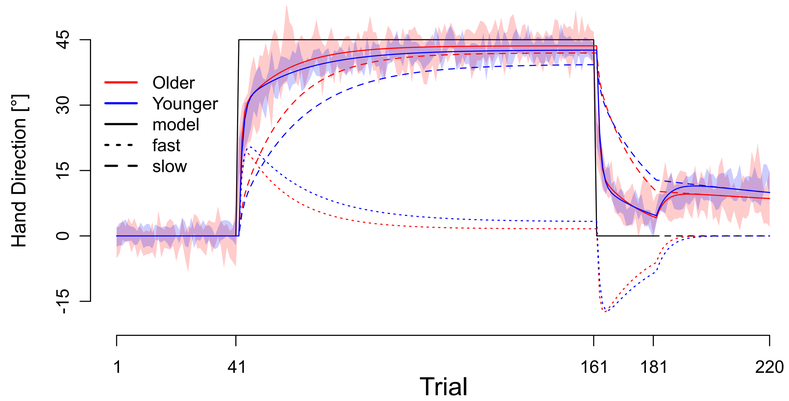
Reach Aftereffects Appear Quickly: Not Slow Process

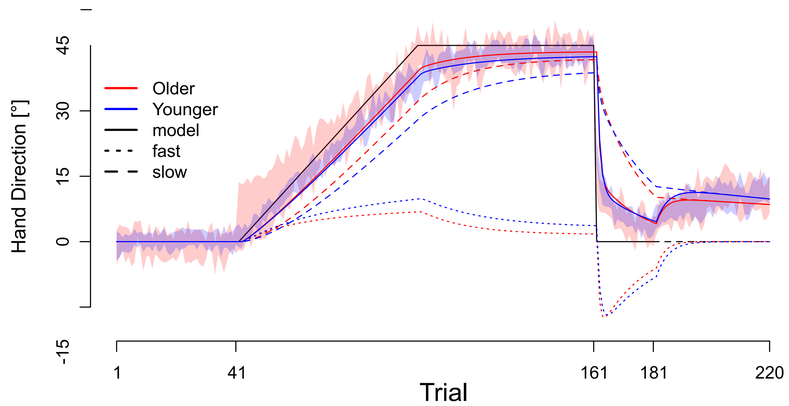
No-cursor reaches are believed to measure the implicit component of learning, 'reach aftereffects'. The two-rate models slow process has recently been proposed to be the implicit process in motor learning and here we show that the pattern of behaviour in the no-cursor trials does not match that of the slow process.



No Effect of Age on Two-Rate Learning

Older (N=14, age>55) and younger (N=27, age<35) adults adapted to both a gradually and an abruptly introduced rotation (counterbalanced order, target location and rotation direction). We wanted to see if the dynamics of the two-rate model change with age, especially the fast process, but there was no effect of age. The abrupt parameters are used to model the gradual data.





Two-rate learning requires continuous feedback

Reach aftereffects do not match slow process

Two-rate learning is robust with age

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