Long-term retention of "short-term" motor learning: Effects of age and stroke

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A requirement of locomotor flexibility is the ability to adapt, or adjust movements to new demands through trial-and-error practice. Since the motor system can rapidly adapt to external perturbations and then deadapt when the perturbation is removed, it can be tempting to view adaptation as short-term learning. However, there is evidence that memory of an adapted pattern persists for at least 24 hours[1,2], as indicated by faster re-learning rates or "savings". Here, we investigated long-term retention of a walking adaptation task. Our objectives were to determine (1) if faster re-adaptation persists long-term (up to 1 month), (2) if, in addition to faster re-adaptation, changes in locomotor coordination (i.e. aftereffects) can be maintained long-term, and (3) if aging or cerebral damage due to stroke affects long-term retention of walking adaptation.

We used a well-characterized split-belt treadmill adaptation task, in which two treadmill belts drive each leg at a different speed[3]. In Experiment 1, baseline walking coordination was assessed in neurologically-intact adults (n=10, aged 20-38 years) during tied-belt walking (both belts at 0.5m/s). Subjects then adapted to split-belts (0.5:1.5m/s) for 16 min. They returned for similar testing sessions 24 hrs ("Day 2") and 4 weeks ("1 Month") later. The experimental paradigm is shown in Figure 1. In Experiment 2, people with stroke (n=11, age 35-69 years) and age-matched controls (n=10, age 35-65 years) were tested in a similar paradigm, except the split-belt speeds were 0.5:1.0 m/s. Our main outcome measure was step length symmetry, as an indication of overall symmetry in interlimb coordination.

In Experiment 1, we found that people could recall the adapted pattern up to 1 month following exposure to split-belts. People re-adapted faster to split-belts on Day 2 and 1 Month, compared to Day 1 (Figure 1B, 2C&D). They also retrieved aftereffects at the beginning of Day 2 and 1 Month baseline (tied-belt) testing (Figure 1B, 2A&B). This suggests that a memory of the adapted pattern persists long-term, even after only 1-2 exposures to split-belts, and can it be retrieved when people are placed back in the adaptation environment. In experiment 2, preliminary data show that there are large changes in baseline interlimb coordination between the stroke and control groups on Day 1 – people with stroke were asymmetric at baseline (Figure 3, top right). Aside from this difference, stroke and control participants adapted similarly to split-belts across days. In contrast to the younger controls in Experiment 1, neither the stroke nor the older control group showed faster re-adaptation on Day 2 or 1 Month, compared to Day 1 (Figure 3, bottom). However, stroke and older controls did appear to store aftereffects that could be retrieved up to 1 Month post-exposure (Figure 3, top), similar to younger controls. This suggests that "savings" (i.e. faster re-adaptation) and retention of aftereffects are dissociable processes[4] that are differently affected by age.

Overall, these experiments show that memory of an adapted walking pattern can be retained long-term, even if walking coordination returns to normal. Faster re-adaptation rates upon re-exposure to split-belts were not evident in older controls and stroke participants –this may indicate a compromised ability to use prior experience to modify gait in response to environmental changes. If extended to real-world gait, this may increase the risk of falling or reduce gait efficiency.

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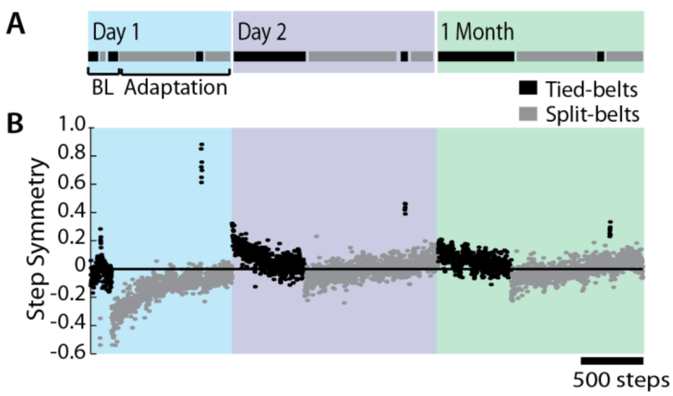

Figure 1. ***A,*** Experimental paradigm. Black lines represent tied belt walking and gray lines represent split-belt walking. On Day 1, baseline (BL) coordination was measured during tied-belt walking. Belts were split briefly during this period to expose all subjects to split-belts[1]. Following baseline, subjects were adapted to split-belts. Near the end of split-belt adaptation, belts were briefly tied to measure aftereffects. Day 2 and 1 Month sessions followed a similar paradigm. ***B,*** Step-by-step plot of step length symmetry from a single participant. A value of 0 represents symmetry.

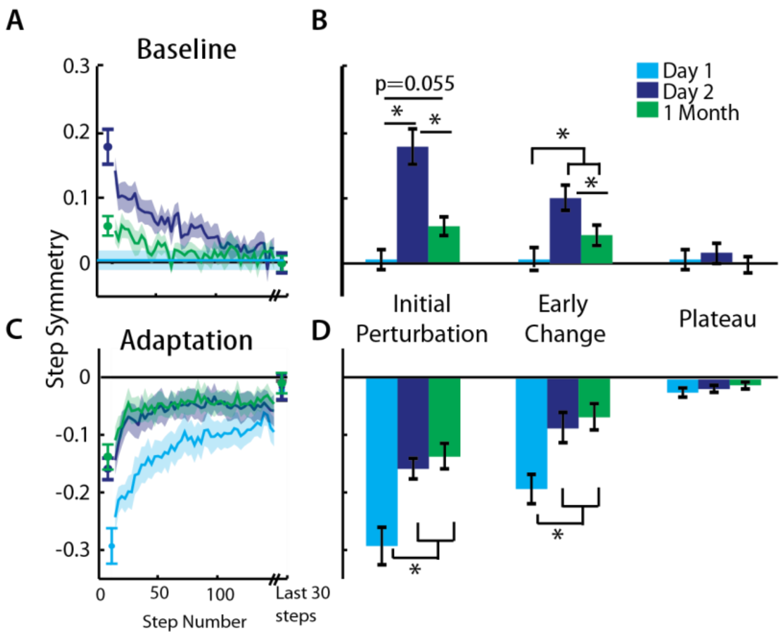

Figure 2. ***A,*** Step length symmetry during baseline period (tied-belts) across days. The first point of each curve shows the average of the first three steps (± SE), followed by plots of steps 4-150 (mean ± SE), and finally the plateau values (mean ± SE of last 30 steps). Curves were smoothed by averaging every 3 steps. Baseline on Day 1 was plotted as a constant value equal to the mean step length symmetry during this period. ***B,*** Comparison of Initial Perturbation (mean 1st 3 steps), Early Change (steps 4-30), and Plateau (last 30 steps) across days. ***C,*** Step length symmetry during adaptation period (split-belts) across days. Data are as shown in (A). ***D,*** Comparison of adaptation values across days (data as shown in B). Asterisks indicate significance (p<0.05).

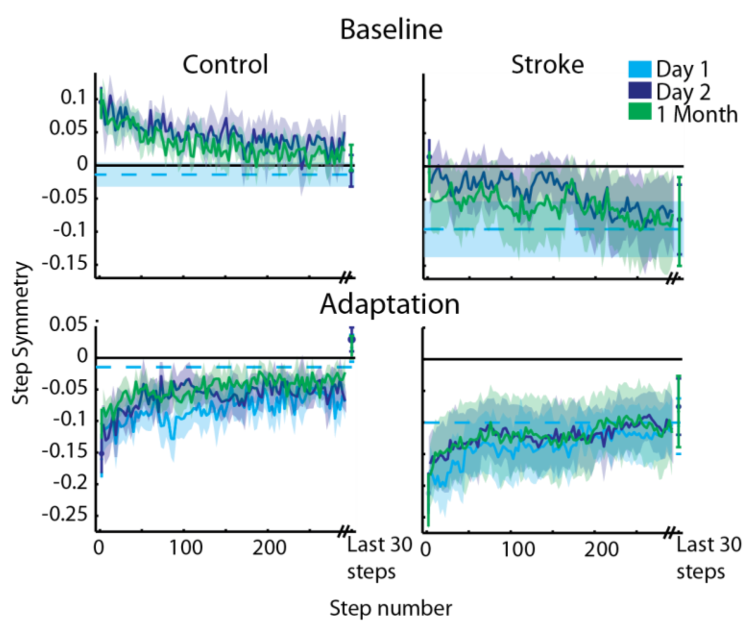

Figure 3. Step length symmetry during baseline (top) and adaptation (bottom) in stroke participants (right) and age-matched controls (left). Data are as shown in Figure 2A and C. Light blue dashed lines indicate baseline symmetry on Day 1, for reference. Data from 10 control participants (35-65 years old) and 11 stroke participants (35-69 years old) were included in these plots.