SUPPLEMENTARY MATERIAL

Supplementary Methods

Participants in Experiment 2 were asked to complete a battery of neuropsychological tests to examine basic cognitive abilities. Two older control participants completed only the visuomotor rotation experiment but were unable to complete this associated cognitive assessment battery; thus they were excluded from this secondary analysis. We examined two tasks from that battery here: the Digit Span subtest of the Wechsler Adult Intelligence Scale to examine working-memory capacity (Wechsler, 1997), and a modified version of the Rey-Osterrieth Complex-Figure test to examine visuospatial memory (Rey, 1941).

In the Digit Span test (Wechsler, 1997), participants listened to a series of three to eight numbers and repeated them in either a forward or backward order. An overall score was calculated by taking the average of the forward and backward scores.

In the modified Rey-Osterrieth Complex-Figure test, participants observed the stimulus on a computer monitor and drew the figure on a digitizing tablet (Wacom Intuos) with unrestricted time limits at four time points: copying while the stimulus was visible, and drawing from memory 0, 3, or 30 minutes after completing the copy condition (Slapik *et al.*, 2018). We computed the mean recall performance at 0 minutes, 3 minutes, and 30 minutes because performance at these time points did not differ significantly across participants (repeated measures ANOVA of time by group, effect of time, $F(2,1) = 0.25$, $p = 0.78$), and used this score as a probe of spatial memory. We did not include the copy score to distinguish it from working memory as examined in the Digit Span test. Drawing movements were recorded at 133 Hz using MovAlyzer (Neuroscript LLC, USA) software and were displayed in real time on the computer monitor. Performance was scored according to established criteria (Rey, 1941; Meyers and

Meyers, 1995), which assessed accuracy and placement of 18 figure elements. Elements received a score of 2 if drawn and placed correctly, 1 if accurate or correctly placed but not both, 0.5 if neither accurate nor correctly placed but recognizable, and 0 if unrecognizable or omitted. Scores were determined by a consensus among two raters, ignoring imperfections arising from tremors or other coordination disturbances for the patients with ataxia.

Stepwise regressions were performed to examine the relationship between learning extent and motor and cognitive assessments in the patient and older control groups in Experiment 2. These regressions included terms representing performance in prior rotation bouts, as well as Digit Span (as a broad assay for working-memory capacity), Rey-Osterrieth Complex-Figure recall (as an assay of spatial memory), and ICARS (as an indicator of disease severity). Stepwise regressions were performed using the stepAIC function in the *MASS* package (Venables et al., 2002), which compares regressions according to the Aikake Information Criterion. In recognition of the criticisms regarding of the reliability of stepwise regression outcomes, analogous LASSO analyses were performed in R using the *glmnet* package (Friedman et al., 2010) and were found to yield similar results; to be concise we report only the stepwise regression outcomes. The conditional effect of each factor in the final multiple regression from the stepwise procedure was visualized using added-variable (partial regression) plots using the *car* package in R (Fox and Weisberg, 2011), which plot the residuals of regressing the response variable to all the remaining independent variables against the residuals of regressing the factor of interest to the remaining independent variables. The resulting plot has a slope and residuals that correspond to the coefficient of the factor of interest in the multiple regression, allowing for visualization of the influence of that factor alone on the total model.

Supplementary Results

A successful target-error-based strategy correlated with spatial memory capacity

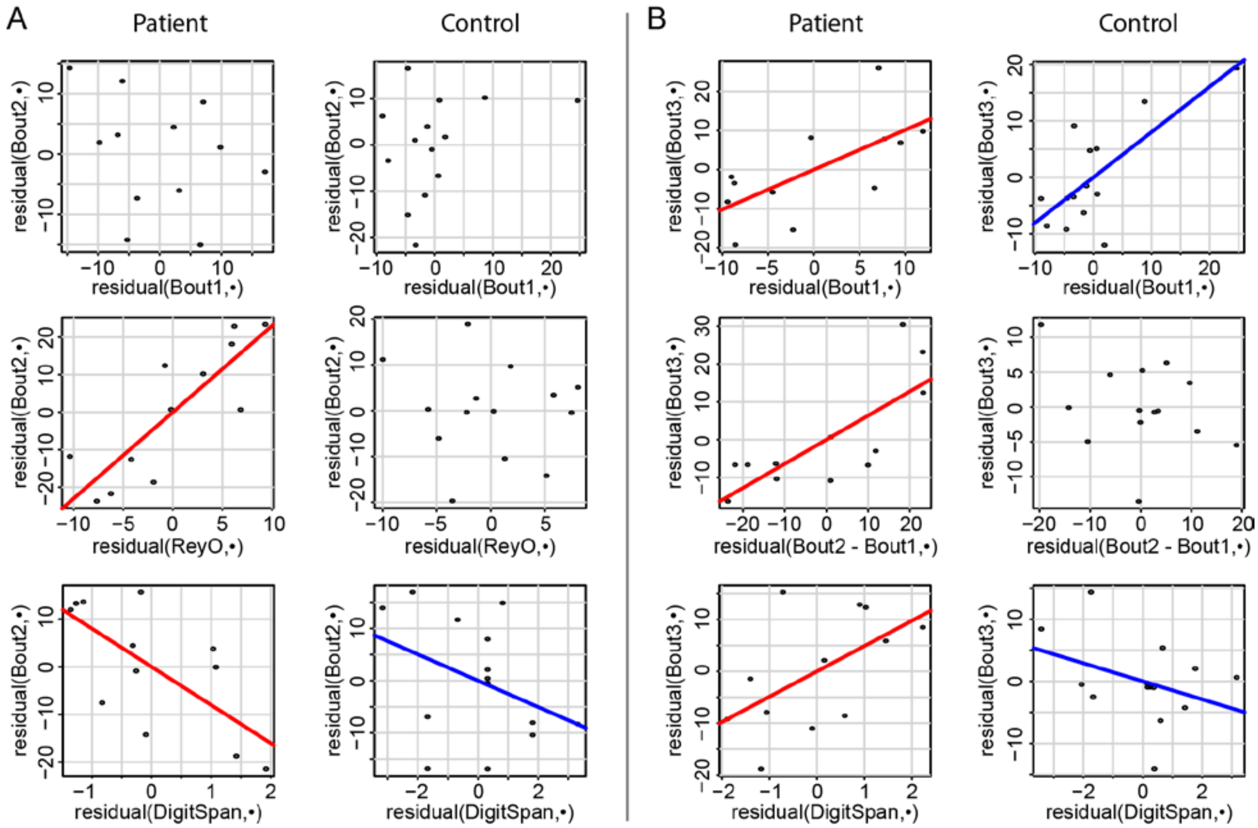
The results of Experiment 2 revealed that patients had a latent capacity to increase their use of strategies to help compensate for their SPE deficits. This raises the question of why patients and older controls exhibited differences throughout the task. To explore one potential reason for this difference, we took advantage of the large amount of inter-subject variability in responses to the visuomotor rotation to examine correlations between adaptation ability and performance in other tasks. We focused on two cognitive tests: Digit Span, which assayed working-memory capacity, and the Rey-Osterrieth Complex-Figure Test (Rey, 1941), which examined visuospatial memory ability; and one gross assessment of motor ability, the ICARS score ((Trouillas *et al.*, 1997); see Table 1). Because these tasks assess the best performance achievable by individuals, evidence of a correlation with adaptation extent suggests that performance in both tasks may be limited by the same underlying cognitive resource, thereby providing insight into how participants complete each phase of the adaptation task.

As a group, performance on the two cognitive assessments was not significantly different between patients and age-matched controls (Rey-Osterrieth Complex-Figure Test: patients: 14.91 ± 2.12, controls: 16.32 ± 1.37, $t(24) = -0.56$, $p = 0.58$; Digit Span: patients: 8.83 ± 0.37, controls: 9.18 ± 0.44, $t(24) = 0.56$, $p = 0.58$). Moreover, post-experiment questionnaires revealed that both patients and older controls developed similar types of strategies to counter the perturbation. Specifically, while a few participants expressed a global "rotation" strategy to address the visuomotor perturbation (i.e., aiming clockwise or counter-clockwise), most older participants reported the use of target-specific aiming strategies that were uniquely associated with one of the four targets (e.g. aiming "to the left", which would only lead to the correct response on one of the four targets). Thus at least on the surface there was little reason for any performance differences between groups.

We next examined stepwise regressions between adaptation extent and these cognitive assessments for the older control participants. These regressions revealed that there were no correlations between any cognitive tests and adaptation performance in Bout 1, consistent with the hypothesis that the default learning mechanism in adaptation tasks is SPE-based learning. In Bout 2, performance correlated negatively to Digit Span (Supplementary Fig. 1A), suggesting that people with high working memory capacity used it to aim in Bout 1 to improve their performance, whereas those with lower capacity may have only used it in Bout 2 when they were unable to rely on SPE-learning. While interpreting correlations performed on small numbers of participants can be problematic, we saw a similar negative correlation in the patient group in Bout 2 (examined independently) as well as for the Control group in Bout 3, providing us some confidence in this somewhat counterintuitive finding. In Bout 3, in addition to this negative correlation with Digit Span, performance was also positively correlated to initial performance in Bout 1 (Supplementary Fig. 1B), suggestive of a return to largely SPE-based learning in Bout 3.

In contrast, the stepwise regressions for patients with cerebellar ataxia differed from controls during Bout 2 when vision of the hand was available. In this bout, in addition to a negative correlation with Digit Span, adaptation extent was positively correlated with the Rey-Osterrieth score, suggesting that the formulation of a TE-based strategy was limited by spatial memory capacity. In Bout 3, adaptation performance for patients correlated positively with Digit Span – suggestive of needing working memory to facilitate use of the TE-based strategy in the absence of visual information about the cursor-hand discrepancy. Bout 3 also correlated with Bout 1, again suggesting at least a partial return to SPE-based learning in Bout 3. However, a greater involvement of TE-based learning alongside SPE-based learning in Bout 3 is suggested by the positive correlation of Bout 3 performance with the change in performance from Bouts 1 to 2 in the patient group.

Supplementary Figure 1



Supplemental Figure 1. Added-variable plots of the outcomes of the stepwise regressions. Added-variable plots reveal the influence (correlation) of a particular variable in a multiple regression by accounting for the influence of all the other parameters included in the model, represented by (•) in the axis labels. These independent variables include the average ReyO recall score, the mean Digit Span score, the ICARS score (for patients), and performance in any preceding adaptation bouts. Thus, what is plotted on the abscissa are the residuals of the factor of interest regressed against the other independent variables, and on the ordinate are the residuals of the dependent variable regressed against all other independent variables except the factor of interest. The resulting graph has a slope equal to the regression coefficient for the factor of interest from the original multiple regression, since the influences of all other independent variables have been removed. Plots are shown for all terms that were significant in either the patient or the control stepwise regressions for Bout 2 (panel A) and Bout 3 (panel B) in Experiment 2.

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