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# Interlimb transfer of reach adaptation does not require an intact corpus callosum: Evidence from patients with callosal lesions and agenesis

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1 **Interlimb transfer of reach adaptation does not require an intact corpus callosum:**  
2 **Evidence from patients with callosal lesions and agenesis.**

3 *Abbreviated Title: Interlimb transfer despite callosal abnormalities*

4  
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11  
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13 research, O.F., E.T. and P.R. contributed to unpublished reagents/analytic tools; P.A.T. analyzed  
14 data; P.A.T. wrote the first draft of the paper; P.A.T., O.F., E.T., P.R. and F.R.S. wrote the paper.

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31 Authors report no conflict of interest.

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39 **Abstract**

40 Generalization of sensorimotor adaptation across limbs, known as interlimb transfer, is a well-  
41 demonstrated phenomenon in humans, yet the underlying neural mechanisms remain unclear.  
42 Theoretical models suggest that interlimb transfer is mediated by interhemispheric transfer of  
43 information via the corpus callosum. We thus hypothesized that lesions of the corpus callosum,  
44 especially to its midbody connecting motor, supplementary motor and premotor areas of the two  
45 cerebral hemispheres, would impair interlimb transfer of sensorimotor adaptation. To test this  
46 hypothesis, we recruited three patients: two rare stroke patients with recent, extensive callosal  
47 lesions including the midbody and one patient with complete agenesis. A prismatic adaptation  
48 paradigm involving unconstrained arm reaching movements was designed to assess interlimb  
49 transfer from the prism-exposed dominant arm to the unexposed non-dominant arm for each  
50 participant. Baseline results showed that spatial performance of each patient did not significantly  
51 differ from controls, for both limbs. Further, each patient adapted to the prismatic perturbation,  
52 with no significant difference in error reduction compared to controls. Crucially, interlimb  
53 transfer was found in each patient. The absolute magnitude of each patient's transfer did not  
54 significantly differ from controls. These findings show that sensorimotor adaptation can transfer  
55 across limbs despite extensive lesions or complete absence of the corpus callosum. Therefore,  
56 callosal pathways connecting homologous motor, premotor and supplementary motor areas are  
57 not necessary for interlimb transfer of prismatic reach adaptation. Such interlimb transfer could  
58 be mediated by transcallosal splenium pathways connecting parietal, temporal and visual areas,  
59 ipsilateral cortico-spinal pathways or subcortical structures such as the cerebellum.

60 **Significance Statement**

61 Theoretical models suggest that interlimb transfer of sensorimotor adaptation is mediated by  
62 interhemispheric interactions via the corpus callosum, specifically between motor cortices. We  
63 thus hypothesized that interlimb transfer of prism adaptation in a reaching task would be  
64 impaired in patients with callosal abnormalities, especially those affecting midbody pathways  
65 connecting the motor cortices. Contrarily, we found interlimb transfer in each patient, to a level  
66 comparable to that of controls. Our findings show that callosal pathways connecting motor,  
67 premotor and supplementary motor areas are not necessary for the interlimb transfer of prismatic  
68 reach adaptation. Alternatively, this transfer could be mediated by ipsilateral cortico-spinal  
69 pathways, subcortical structures such as the cerebellum or callosal splenium pathways  
70 connecting parietal, temporal and visual areas.

71

72 **Introduction**

73 When we are exposed to novel properties of the body or the environment, motor behaviour is  
74 optimized through trial-by-trial fine-tuning of sensorimotor neural networks, an adaptation  
75 thought to evolve through the iterative comparison of the planned and executed movements  
76 (Luauté et al., 2009; Shadmehr et al., 2010; Wolpert et al., 2011). One feature of this  
77 sensorimotor adaptation is that it is not necessarily specific to the conditions in which it was  
78 acquired, but can generalize to a different task (Morton and Bastian, 2004) or a different effector  
79 (Green and Gabriel, 2018; Lee et al., 2010; Stöckel et al., 2016; Taylor et al., 2011; Wang and  
80 Sainburg, 2003). Transfer between effectors, termed interlimb transfer, has been repeatedly  
81 evidenced in studies of upper-limb movements aiming to determine the local or global nature of  
82 the adaptive process (Criscimagna-Hemminger et al., 2003; Dizio and Lackner, 1995; Harris,  
83 1965; Joiner et al., 2013; Malfait and Ostry, 2004; Renault et al., 2020), yet the underlying neural  
84 mechanisms remain unclear (Ruddy and Carson, 2013).

85 Longstanding theoretical models of the neural mechanisms of interlimb transfer highlight the key  
86 role of the corpus callosum, the largest white matter tract connecting the two cerebral  
87 hemispheres (Parlow and Kinsbourne, 1990, 1989; Taylor and Heilman, 1980). The Callosal  
88 Access Model (Taylor and Heilman, 1980) proposes that unimanual adaptation is encoded within  
89 the contralateral hemisphere and is accessible, via the corpus callosum, to the opposite  
90 hemisphere-arm system (see also Sainburg and Wang, 2002). The Cross-Activation Model  
91 (Parlow and Kinsbourne, 1990, 1989) proposes that unimanual adaptation is encoded in the  
92 contralateral hemisphere, and copied, via the corpus callosum, to the opposite hemisphere-arm  
93 system. Lee et al. (2010) later provided neurophysiological evidence that both the contralateral  
94 and ipsilateral motor cortices are involved in both adaptation and interlimb transfer of adaptation.

95 Perez et al. (2007a) also provided evidence that interlimb transfer of sequence learning is driven  
96 by bilateral supplementary motor areas, connected via the corpus callosum midbody (Fabri et al.,  
97 2014; Ruddy et al., 2017). Further, Perez et al. (2007b) reported that interlimb transfer was  
98 related to modulations of the transcallosal midbody pathways connecting homologous motor  
99 cortices (see also Ruddy and Carson, 2013). These studies thus suggest that the corpus callosum,  
100 and in particular its midbody segment that connects motor, supplementary motor and premotor  
101 regions bilaterally, plays a key role in interlimb transfer.

102 One approach which has led to key insights into the functional role of callosal pathways has been  
103 to study neurological individuals with corpus callosum abnormalities (Volz and Gazzaniga,  
104 2017). Using this approach, interlimb transfer was shown to be impaired in agenesis patients and  
105 split-brain patients (de Guise et al., 1999), and multiple sclerosis patients with corpus callosum  
106 atrophy (Bonzano et al., 2011). The results of these studies are in line with the aforementioned  
107 theoretical models (Parlow and Kinsbourne, 1990, 1989; Taylor and Heilman, 1980). However,  
108 Thut et al. (1997) found interlimb transfer of proximal drawing movements in agenesis patients  
109 and a traumatic brain injury patient with corpus callosum damage. Criscimagna-Hemminger et  
110 al. (2003) also reported interlimb transfer of force-field reach adaptation in a split-brain patient,  
111 whose corpus callosum was surgically sectioned to alleviate severe epilepsy. These two studies  
112 thus cast doubt on the generalizability of the dominant theories of interlimb transfer.

113 The present study aimed to determine the role of the corpus callosum in the interlimb transfer of  
114 sensorimotor adaptation by assessing transfer in one patient with complete agenesis as well as  
115 two stroke patients with callosal damage. The two stroke patients presented a rare opportunity to  
116 assess the impact of recent, non-surgical callosal lesions in typically developed adults with no  
117 epilepsy. Patients and matched controls were tested on a prism adaptation paradigm involving

118 unconstrained arm reaching movements. This paradigm, used in both fundamental and  
119 rehabilitation contexts (Harris, 1963; Martin et al., 1996a; Rossetti et al., 1998), is known to  
120 result in after-effects on the exposed arm but also on the non-exposed arm, evidencing interlimb  
121 transfer (Hamilton, 1964; Renault et al., 2020). The methodological procedure employed here  
122 was based on previous work (Dizio and Lackner, 1995; Harris, 1963; Kitazawa et al., 1997;  
123 Lefumat et al., 2015; Martin et al., 1996a) and allowed assessment of transfer for each individual  
124 (Renault et al., 2020), a critical issue when studying unique patients (Lefumat et al., 2016).  
125 Based on previous research highlighting the role of the corpus callosum in interlimb transfer, we  
126 hypothesized that patients lacking callosal connections between motor, premotor and  
127 supplementary motor areas would show impaired interlimb transfer of sensorimotor adaptation.

128 **Materials and Methods**

129 *Participants*

130 Three patients with corpus callosum disorders (MS, MM and AM) and 16 healthy individuals  
131 participated in the study. The number of healthy participants reflect the sample size used in  
132 similar studies (Bao et al., 2020; Fleury et al., 2020; Leclere et al., 2019; Lefumat et al., 2015;  
133 Morton and Bastian, 2004; O’Shea et al., 2014; Perez et al., 2007a; Renault et al., 2020; Striemer  
134 et al., 2019; Wang and Sainburg, 2003). Patient MS was a 51-year-old left-handed female with  
135 recently acquired lesions of the body of the corpus callosum, sparing the splenium and the genu.  
136 Patient MM was a 29-year-old right-handed male also with recently acquired lesions of the  
137 corpus callosum, sparing only the splenium. Patient AM was a 50-year-old right-handed male  
138 with complete agenesis of the corpus callosum (see Table 1 and full patient descriptions below).  
139 All patients and controls had normal or corrected-to-normal vision, with control participants  
140 declaring no previous or current sensorimotor or neurological deficits. Handedness was  
141 determined using the 10-item version of the Edinburgh Handedness Inventory (Oldfield, 1971).  
142 Considering the patients’ characteristics, two control groups were recruited: Group A: age =  $52 \pm$   
143 4 years,  $n = 8$  (5 right-handed males; 3 left-handed females) and Group B: age =  $29 \pm 4$  years,  $n$   
144 = 8 (8 right-handed males). As developed later, the differences between the patients led us to  
145 compare each patient (instead of the group of patients) to control participants.

146 Before taking part in the experiment, participants were presented with an information sheet on  
147 the protocol, filled out the Edinburgh Handedness Inventory, and gave their written informed  
148 consent to participate. Participants could leave the experiment at any time and were free to ask  
149 questions to the experimenter; they were kept as naïve as possible to the exact purpose of the

150 study. The study was approved by the local institutional review board and performed in  
151 accordance with the standards laid out by the Declaration of Helsinki (1964).

152

### 153 *Patients' profiles*

154 Patient MS was a left-handed female (Laterality Quotient: -100%), 51-years-old at the time of  
155 testing (March 2017). MS had suffered from a ruptured brain aneurysm in the anterior cerebral  
156 artery 2.5 years previously at 48-years old (August 2014). This resulted in damage to the whole  
157 body of the corpus callosum, with only the anterior (genu) and posterior (splenium) regions  
158 being preserved (Figure 1B), as well as hemosiderin deposits in the left and right cingulum.  
159 Patient MS thus presented a rare haemorrhagic stroke subtype (Li et al., 2015), which allowed us  
160 to study the impact of an insult to the corpus callosum in an individual with a normal  
161 development and no known neurological disorder (e.g. no epilepsy) prior to the corpus callosum  
162 damage. With regards to motor function, clinical tests (see Table 1) indicated slight ideomotor  
163 apraxia in performing gestures with the left hand and impaired somatosensory transfer between  
164 the two arms. In the months following the acute haemorrhage, she also reported recurrent  
165 conflicts between the two hands as depicted in the setting of corpus callosum injury under the  
166 terms of diagonistic dyspraxia (Akelaitis, 1945) or alien hand syndrome (Biran et al., 2006). For  
167 instance, patient MS stated that when trying to open the wardrobe with one hand to select an item  
168 of clothing, the other hand would shut it. When tested for this experiment, the patient reported  
169 that intermanual conflicts had mostly resolved, with very occasional symptoms reappearing with  
170 stress or fatigue. Neuropsychological assessments undertaken between 2015 and 2017 indicated

171 a normal global cognitive functioning with below average attentional capacity and short-term  
172 memory.

173 Patient MM was a right-handed male (Laterality Quotient: 75%), 29-years-old at the time of  
174 testing (January 2019). MM had an ischemic stroke in the territory of the bilateral anterior  
175 cerebral arteries following an intravascular thrombus in August 2018. This resulted in extensive  
176 lesions to the anterior and mid cingulate gyrus, and the rostrum, genu and body of the corpus  
177 callosum, sparing only the posterior (splenium) region (Figure 1C). Clinical testing (see Table 1)  
178 showed that the patient displayed moderate motor slowing with a mild motor apraxia  
179 predominantly on the left side and occasional troubles in movement initiation. The patient also  
180 reported intermanual conflicts, with the left hand interfering with the actions performed by the  
181 right hand. For example, when opening a door with the right hand, the left hand would try to shut  
182 it. Neuropsychological assessments also revealed sustained attention and memory deficits.  
183 Patient MM thus provided another rare opportunity to study the effect of a recent lesion  
184 involving the corpus callosum in an adult with typical development.

185 Patient AM was a right-handed male (Laterality Quotient: 80%), 50-years-old at the time of  
186 testing (February 2018). AM had complete congenital agenesis of the corpus callosum (Figure  
187 1D) and posterior commissure, left hippocampal sclerosis, and a history of complex partial  
188 seizures in the setting of mesial temporal lobe epilepsy. Full patient details can be found in  
189 Ridley et al. (2016), but in summary, AM endured status epilepticus in March 2012. One month  
190 later, despite full resolution of epileptic seizures, AM developed intermanual conflicts: for  
191 instance, when putting on a pair of trousers with the left hand, the right hand would pull them off  
192 (Ridley et al., 2016). Neuropsychological assessment revealed right-sided constructional apraxia,  
193 right ideomotor apraxia and right visual anomia, showing signs of inter-hemispheric

194 disconnection. Global cognitive functioning was low to average. Follow-up assessments carried  
195 out in the following years indicated significant amelioration of diagnostic dyspraxia and inter-  
196 hemispheric disconnection features (see Table 1). Testing patient AM allowed us to explore the  
197 influence of complete absence of the corpus callosum throughout development.

198

### 199 *Experimental setup*

200 Participants were seated in front of a horizontal table positioned at waist height. The table was  
201 equipped with a raised, red start button (2cm in diameter) located at  $0^\circ$  (straight-ahead)  
202 according to the body midline, directly in front of the participants chest. The start button was  
203 present at all times during the experiment. Given that the lights of the experimental room were  
204 on throughout the experiment, participants could thus both see and feel for the start button  
205 position. Red light-emitting diodes (3mm in diameter) on the table were used as visual targets  
206 (Figure 2). Three targets were used in this study, all located 37cm from the starting position: a  
207 middle target located at  $0^\circ$  (straight-ahead), a rightward target located at  $+20^\circ$  and a leftward  
208 target located at  $-20^\circ$  with respect to the body midline. Participants were required to wear either  
209 standard (control) goggles or altered ( $17^\circ$  rightward deviating prismatic) goggles equipped with  
210 30-diopter Fresnel 3M Press-on plastic lenses (3M Health Care, St Paul, Minn., USA), as used in  
211 Martin et al. (1996b). Welding goggles were used so that vision was only possible through the  
212 lenses (O'Shea et al., 2014). The use of a head restraint was avoided based on results of  
213 Hamilton (1964) showing that restraining the head precludes interlimb transfer of prism  
214 adaptation.

215 Infrared active markers were taped to the right and left index fingertips and their positions were  
216 sampled at 350Hz using an optical motion tracking system (Codamotion cx1 and MiniHub,  
217 Charnwood Dynamics Ltd, Leicestershire, UK). The experimenter controlled the motion tracking  
218 system as well as the protocol using a customized software and a real-time acquisition system  
219 (ADwin-Pro, Jäger, Lorsch, Germany). An infra-red camera allowed continuous real-time  
220 monitoring by the experimenter of the participants' behaviour and progression of the experiment.  
221 A standard video-camera was also placed, just above the height of the table in front of the  
222 participant, for replay in case of technical, kinematic or other issues. Data loss from the  
223 Codamotion motion tracking system on a crucial after-effect trial for one of the patients led to  
224 analysis performed on the video-camera recording (detailed in the legend of corresponding  
225 figures).

226

### 227 *Experimental procedure*

228 The experiment consisted of a series of arm reaching movements, performed with either the  
229 dominant or the non-dominant arm, from the starting position toward a visual target. The visual  
230 target was flashed 1s after the beginning of a trial for a short duration of 0.3s, so that by the time  
231 participants had reached the target, it had disappeared. Two auditory tones were then used to  
232 inform participants of key timepoints of the trial: a 100ms-long beep occurring 1.6s after trial  
233 onset to inform participants they could return slowly to the starting location and a 600ms-long  
234 beep occurring 7.4s after trial onset to inform the participant that the trial had ended. This timing  
235 was chosen to allow a slow return movement back to the start button in order to reduce the  
236 impact of the return phase on the adaptation process, as Kitazawa et al. (1997) showed velocity-

237 specific prismatic adaptation and the return phase was not analysed within the results. Each trial  
238 was 8s long in total and the next trial started automatically once the previous trial had ended.

239 Participants were instructed to reach as fast and as accurately as possible toward the visual target  
240 in a natural, unconstrained movement. Participants were asked to lift their finger off the table,  
241 rather than slide directly across the table and not correct the end position of their finger once it  
242 had hit the table. On the return movement, participants were asked to go back slowly to the  
243 starting position to minimize the effect of this return phase on the adaptation process.  
244 Participants were allowed to return to the start position by sliding their finger along the table. In  
245 order to achieve consistent task completion and reduce learning effects during baseline,  
246 participants were familiarized with the task by performing 30 reaching movements with both  
247 arms under normal visual conditions without prisms before starting the experimental phases.  
248 Lastly, participants were instructed not to move their opposite arm during and between trials  
249 being performed with the designated arm.

250 To assess sensorimotor adaptation and interlimb transfer, we employed a procedure inspired by  
251 previous work (Dizio and Lackner, 1995; Harris, 1963; Kitazawa et al., 1997; Lefumat et al.,  
252 2015; Martin et al., 1996a) and recently used by Renault et al. (2020). The experimental session  
253 consisted of 3 phases (presented in Figure 2): a baseline pre-exposure phase under normal vision  
254 (baseline phase), a prism exposure phase with prismatic perturbation (prism phase) and a post-  
255 exposure phase under normal vision (post phase). During the baseline phase, participants  
256 performed 30 reaching movements with the dominant arm, then 30 movements with the non-  
257 dominant arm toward one of the three targets while wearing standard control goggles. The  
258 targets were presented in a randomised order which was the same for each participant with,  
259 ultimately, 10 trials per target for each arm. The order of experimental conditions in the baseline

260 phase was not counterbalanced, as in other studies (Lefumat et al., 2015; Renault et al., 2020;  
261 Wang et al., 2011), because it was desired that all controls and patients performed exactly the  
262 same protocol to strengthen control-patient comparisons. When the baseline phase was over,  
263 participants had a 2-minute break during which they were asked to stay motionless with the eyes  
264 closed while the control goggles were replaced with prismatic goggles.

265 During the following prism phase, participants performed 100 movements (Control Group A,  
266 patient MS and patient AM) or 50 movements (Control Group B and patient MM) toward the  
267 middle 0° target with the dominant arm while wearing the 17° rightward deviating prismatic  
268 goggles. Patient MM, and subsequently Control Group B, completed 50 of the desired 100  
269 movements due to patient MM experiencing tiredness of the right shoulder during this prism  
270 phase. The group factor was thus included in the statistical design. At the end of this phase,  
271 another 2-minute break was given during which participants were instructed to keep their eyes  
272 closed and remain motionless, while the prismatic goggles were replaced with the control  
273 goggles.

274 During the post phase, participants first performed 30 reaching movements with the unexposed  
275 non-dominant arm, before performing 30 movements with the dominant arm again resulting in  
276 10 trials per target per arm under normal vision. During this post phase, the first target presented  
277 (post 1 trial) was always the middle straight-ahead 0° target, before all remaining targets were  
278 presented in a randomised fashion. The order of experimental phases was selected, as in previous  
279 studies (Lefumat et al., 2015; Renault et al., 2020), to have the non-dominant arm baseline and  
280 post-phases immediately before and after the dominant arm prism adaptation phase. Any  
281 difference in non-dominant arm performance could thus be directly attributed to dominant arm  
282 prism adaptation, thus showing interlimb transfer.

283 Interlimb transfer of sensorimotor adaptation was investigated from dominant arm to non-  
284 dominant arm based on experimental studies showing unidirectional transfer from the dominant  
285 arm to the non-dominant arm (Balitsky Thompson and Henriques, 2010; Galea et al., 2007;  
286 Mostafa et al., 2014) and, in particular, the study by Criscimagna-Hemminger et al. (2003) which  
287 also challenged the role of the corpus callosum in the interlimb transfer of sensorimotor  
288 adaptation. Adaptation during the prism phase was performed only toward the middle 0° target  
289 so that it would be possible to explore, for both arms, the extent of generalization across target  
290 directions in the post phase compared to the baseline phase. This was based on previous  
291 literature (Lefumat et al., 2015; Renault et al., 2020), which found significant generalization for  
292 the exposed arm but not the unexposed arm. However, to keep the main message of the article  
293 clear and not unnecessarily lengthen the manuscript, analysis of the movements toward the  
294 lateral targets was not included in the manuscript. Interlimb transfer was thus assessed by  
295 comparing baseline movements toward the middle target, performed just before prism  
296 adaptation, to the first movement of the post phase toward the middle target, performed just after  
297 prism adaptation. This movement was thus performed immediately after prism adaptation and  
298 was not influenced by movements to the lateral targets. The experiment took approximately one  
299 hour.

300

### 301 *Kinematic data analysis*

302 Data were analysed using Matlab (Mathworks, Natick, MA, USA) and Microsoft Excel 2017. A  
303 few trials (1.8%) had to be discarded due to either the participant not making a movement toward  
304 the target, the participant moving before the target had appeared, or technical problems. Position

305 data from the markers on the right and left index fingertips were low-pass filtered with a dual-  
306 pass, no-lag Butterworth filter (cut-off frequency: 8Hz; order: 2). Movement onset and offset  
307 were defined as the first time at which hand velocity went above 3cm/s or dropped below 3cm/s  
308 respectively (as in Lefumat et al., 2015; Renault et al., 2020). Kinematic variables calculated and  
309 reported included: initial movement direction, final movement direction, end point accuracy,  
310 maximum perpendicular deviation, peak velocity, time to peak velocity, movement time and  
311 reaction time. Initial movement direction was computed as the angle between the vector from the  
312 start position to the target position and the vector from the start position to the hand position at  
313 peak velocity (Wang and Sainburg, 2003; Renault et al., 2020). Final movement direction was  
314 calculated as the angle between the vector from the start position to the target position and the  
315 vector from the start position to the hand position at movement offset. End point accuracy was  
316 computed as the Euclidian distance in cm between the hand end position and the target position.  
317 Maximum perpendicular deviation was calculated as the maximum horizontal (x axis) distance in  
318 cm between the movement trajectory path and the theoretical straight line connecting the start  
319 position and the target position (Malfait and Ostry, 2004; Shadmehr and Moussavi, 2000).

320 The kinematic variable of interest for examining the prismatic effects throughout the experiment  
321 was the initial movement direction as this mostly reflects the initial motor plan before visual  
322 feedback loops influence the movement (O'Shea et al., 2014; Reichenbach et al., 2014; Sarlegna  
323 and Mutha, 2015). Maximum perpendicular deviation was also reported to verify prismatic  
324 adaptation and transfer effects, noted as giving similar results by Malfait and Ostry (2004).

325

326 *Statistical data analysis*

327 R3.6.0 (R Core Team, 2018), Statistica 8 (StatSoft, Tulsa, OK, USA) and Excel 2017 were used  
328 to perform statistical analysis. Statistica was used to assess normal distribution with the  
329 Kolmogorov-Smirnov method, perform t-tests and ANOVAs, and carry out Tukey post-hoc  
330 analysis of control data. Excel 2017 was used to calculate individual 98% confidence interval  
331 boundaries for both controls and patients, using individual participant's own baseline data.  
332 Confidence intervals were constructed for the normally distributed data using confidence interval  
333 formula including the mean ( $\bar{x}$ ), two-tailed t value (t) standard deviation (s) and sample size (n).  
334 A two-tailed design at 98% confidence was used in order to test for deviation in either direction  
335 with an  $\alpha/2$  of 0.01 ( $p < 0.02$ ) and t values were used due to a small sample size of baseline trials  
336 ( $n < 30$ ) (Moore et al., 2009; Pek et al., 2017), with 10 trials per target per arm. R using parts of  
337 the *psycho* (v0.5.0; Makowski, 2018) package, was used to perform Crawford's modified t-test.  
338 This method, adapting an independent sample pooled t-test for use with a sample of  $n = 1$  (one  
339 patient), was used to compare each patient's performance to that of a control sample (Crawford  
340 and Garthwaite, 2007). Results were compared with a Bayesian method using the software  
341 *Single\_Bayes\_ES*, with similar results obtained (Crawford et al., 2010). Z values were reported  
342 as an indicator of effect size. The Kolmogorov-Smirnov method showed all data to be normally  
343 distributed.

344 Analysis of control group baseline kinematics consisted of 2x2 ANOVAs including the 2  
345 Groups: Group A and Group B and 2 Arms (repeated measures): dominant arm and non-  
346 dominant arm. The factor group (2 Groups: Group A: age =  $52 \pm 4$  years, 100 trials,  $n = 8$  and  
347 Group B: age =  $29 \pm 4$  years, 50 trials,  $n = 8$ ) was included within all analyses to check for  
348 putative effects. Kinematic variables assessed included: initial movement direction, final

349 movement direction, end point accuracy, maximum perpendicular deviation, peak velocity, time  
350 to peak velocity, movement time and reaction time. Patient values were then compared to the  
351 control group for each patient, across each arm individually, using Crawford's modified t-test.

352 Analysis of controls' dominant arm adaptation consisted of a 2x16 ANOVA on initial movement  
353 direction including the 2 groups: Group A and Group B, and 16 dominant arm phases (repeated  
354 measures): baseline 10 trial average, prism trials 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, prism 11-20 10 trial  
355 average, prism 21-30 average, prism 31-40 average and the prism 41-50 last common average, as  
356 well as the post 1 trial. On an individual level, including both controls and patients, prismatic  
357 effects and after-effects according to initial movement direction and maximum perpendicular  
358 deviation were explored by comparing specific trials (prism phase trials and the post 1 trial  
359 respectively) to the individual's baseline 98% confidence intervals. Trials falling above or below  
360 the baseline 98% confidence interval boundaries were deemed to be significantly different to  
361 baseline. The number of trials for each participant to reduce errors caused by the prismatic  
362 perturbation (error-reduction rate) was taken as the first prism phase trial to return within the  
363 98% baseline confidence intervals. The prismatic-effect and after-effect for the dominant arm of  
364 each individual were then quantified by calculating the difference between the baseline phase  
365 average and the prism 1 and post 1 values respectively. Patient prismatic-effects, error-reduction  
366 rates and after-effects were then compared to the control group average using Crawford's  
367 modified t-test.

368 Analysis of control group non-dominant arm data exploring interlimb transfer effects consisted  
369 of a 2x2 ANOVA on initial movement direction data including the 2 groups: Group A and Group  
370 B and the 2 phases (repeated measures): baseline 10 trial average and post 1. For each individual,  
371 the non-dominant arm post 1 trial was compared to the baseline 98% confidence intervals to

372 determine the presence of interlimb transfer according to both initial movement direction and  
373 maximum perpendicular deviation. A post 1 trial falling above or below the baseline 98%  
374 confidence interval boundary was deemed to be significantly different compared to baseline and  
375 thus showing interlimb transfer. The interlimb transfer value was then quantified for each  
376 individual as the difference between the baseline value and the post 1 value and transformed into  
377 an absolute value to compare the amplitude of transfer without directional effects. Patients'  
378 transfer-effects were then compared to the control group average using Crawford's modified t-  
379 test. For control group and patient-control comparisons, the significance threshold was set to  
380 0.05.

381 The ANOVAs performed on controls' data included 10-trial averages as well as individual trials,  
382 in line with previous research (Leclere et al., 2019; Lefumat et al., 2015; Morton and Bastian,  
383 2004; Renault et al., 2020; Taylor et al., 2011). This was because, in the current study, data  
384 analyses revealed some blocks of trials with homogenous performance and blocks of trials with  
385 variable performance. Averaging trials thus made sense when motor performance was stable and  
386 homogenous, as in baseline and late prism trials, to have a better estimate of performance.  
387 However, when large variations were observed between consecutive trials, such as during the  
388 initial prism error-reduction phase and post phase, individual trials were kept separate to avoid  
389 masking an effect such as interlimb transfer (Taylor et al., 2011).

390 **Results**391 *Baseline motor control*

392 Participants were asked to reach as fast and as accurately as possible toward visual targets with  
393 either the dominant (DA) or non-dominant (NDA) arm, under normal visual conditions with  
394 visual feedback of the arm at all times. Figure 3 shows baseline trajectories toward the straight-  
395 ahead target for an example control participant and three neurological patients with corpus  
396 callosum abnormalities. Figure 3 shows that controls, patients MS and MM, whose corpus  
397 callosum was severed by a stroke, as well as patient AM, who has a complete corpus callosum  
398 agenesis, were able to reach to the target. Hand path trajectories for patients and controls seemed  
399 comparably straight and accurate, suggesting that the callosal patients had a normal spatial  
400 organization of the movements.

401 Control participants' baseline data were analysed with a mixed factor 2x2 ANOVA including 2  
402 arms (DA and NDA) and 2 groups (Group A and Group B). Interlimb differences were found on  
403 certain control group kinematics (Figure 4) as the ANOVA showed a simple arm effect for final  
404 movement direction (controls average  $\pm$  standard deviation: DA =  $1.8 \pm 1.4^\circ$ , NDA =  $0.4 \pm 1.0^\circ$ ;  
405  $F_{1,14} = 17.0$ ;  $\eta_p^2 = 0.55$ ,  $p = 0.001$ ), end point accuracy (DA =  $1.5 \pm 0.5$  cm, NDA =  $1.8 \pm 0.6$  cm;  
406  $F_{1,14} = 4.6$ ;  $\eta_p^2 = 0.25$ ,  $p = 0.049$ ), peak velocity (DA =  $1.9 \pm 0.3$  m/s, NDA =  $1.7 \pm 0.2$  m/s;  $F_{1,14}$   
407 =  $7.9$ ;  $\eta_p^2 = 0.36$ ,  $p = 0.014$ ), movement time (DA =  $486 \pm 80$  ms, NDA =  $510 \pm 70$  ms;  $F_{1,14}$  =  
408  $8.0$ ;  $\eta_p^2 = 0.37$ ,  $p = 0.013$ ) and reaction time (DA =  $289 \pm 58$  ms, NDA =  $270 \pm 57$  ms;  $F_{1,14}$  =  
409  $8.5$ ;  $\eta_p^2 = 0.38$ ,  $p = 0.011$ ). There were no significant group effects nor interactions. Patient  
410 values were thus compared to the whole control group ( $n = 16$ ).

411 Each patient's baseline average was compared to the controls using Crawford's modified t-test  
412 for each kinematic variable and each arm individually. This analysis showed that the motor  
413 performance of patient AM significantly differed from controls only on maximum perpendicular  
414 deviation with a more leftward deviation than controls for both the DA (controls =  $0.5 \pm 1.2$  cm,  
415 AM =  $-2.7 \pm 0.7$  cm;  $z = -2.71$ ,  $p = 0.019$ ) and NDA (controls =  $0.9 \pm 1.2$  cm, AM =  $-2.9 \pm 0.9$   
416 cm;  $z = -3.30$ ,  $p = 0.006$ ; Figure 4D). Patient MS showed one significant difference with a longer  
417 time to peak velocity than controls, for both the DA (controls =  $170 \pm 22$  ms, MS =  $255 \pm 34$ ms;  
418  $z = 3.90$ ,  $p = 0.002$ ) and NDA (controls =  $171 \pm 17$ ms, MS =  $211 \pm 37$  ms;  $z = 2.34$ ,  $p = 0.039$ ;  
419 Figure 4F). Patient MM, tested the soonest after corpus callosum insult, showed a reduced peak  
420 velocity for both the DA (controls =  $1.9 \pm 0.3$  m/s, MM =  $1.1 \pm 0.1$  m/s;  $z = -2.96$ ,  $p = 0.011$ ) and  
421 NDA (controls =  $1.7 \pm 0.2$  m/s, MM =  $1.2 \pm 0.2$  m/s;  $z = -2.68$ ,  $p = 0.020$ ; Figure 4E), a longer  
422 time to peak velocity for both the DA (controls =  $170 \pm 22$  ms, MM =  $249 \pm 55$  ms;  $z = 3.62$ ,  $p$   
423 =  $0.003$ ) and NDA (controls =  $171 \pm 17$  ms, MM =  $255 \pm 2$  ms;  $z = 4.88$ ,  $p < 0.001$ ; Figure 4F)  
424 and a longer movement time for both the DA (controls =  $486 \pm 80$  ms, MM =  $686 \pm 41$  ms;  $z =$   
425  $2.49$ ,  $p = 0.028$ ) and NDA (controls =  $510 \pm 70$  ms, MM =  $754 \pm 56$  ms;  $z = 3.48$ ,  $p = 0.004$ ).  
426 Patient MM also exhibited a longer reaction time for the DA (controls =  $289 \pm 58$  ms, MM =  $553$   
427  $\pm 194$  ms,  $z = 0.0005$ ,  $p = 0.018$ ) but not the NDA (controls =  $270 \pm 57$  ms, MM =  $379 \pm 95$  ms;  
428  $z = 1.91$ ,  $p = 0.083$ ; Figure 4H) indicating a larger arm effect than the control group for this  
429 variable. Overall, baseline results show that all patients were able to reach accurately toward the  
430 visual target when considering initial and final errors: some temporal differences were observed  
431 but the spatial organization of the movements was comparable between the patients and controls.

432

433 *Prismatic adaptation of the dominant arm*

434 To assess sensorimotor adaptation with the DA, participants were asked to perform reaching  
435 movements with the DA before (baseline phase), during (prism phase) and after (post phase)  
436 prismatic exposure. For controls ( $n = 16$ ), a 2x16 ANOVA of peak velocity showed no  
437 significant group effect ( $F_{1, 14} = 1.78, \eta_p^2 = 0.11, p = 0.203$ ) or interaction ( $F_{15, 210} = 1.20, \eta_p^2 =$   
438  $0.08, p = 0.275$ ) and a significant effect of phase ( $F_{15, 210} = 2.25, \eta_p^2 = 0.14, p = 0.006$ ). Tukey  
439 post-hoc analysis showed that the phase effect was due to an augmented peak velocity on prism 1  
440 ( $2.0 \pm 0.4$  m/s) compared to subsequent prism trials 4,6,7,8,9 and 10, with peak velocities in the  
441 range of 1.7-1.8m/s ( $p$  value range  $< 0.001$  to  $0.046$ ). No significant differences were observed  
442 between baseline peak velocity ( $1.9 \pm 0.3$  m/s) and any of the subsequent prism phases  
443 (combined peak velocity =  $1.8 \pm 0.3$ m/s, all  $p$  values  $> 0.49$ ) or the post 1 trial ( $1.8 \pm 0.4$  m/s,  $p$   
444 value  $> 0.99$ ). For patient MS, peak velocity did not significantly differ from controls ( $n = 16$ ) in  
445 any phase. Patient AM showed few significant differences compared to controls with an  
446 increased peak velocity on prism 1 (controls =  $2.0 \pm 0.4$  m/s, AM =  $3.1$  m/s;  $z = 2.40, p = 0.035$ )  
447 and prism 5 (controls =  $1.8 \pm 0.2$  m/s, AM =  $2.4$  m/s;  $z = 2.61, p = 0.023$ ). For patient MM, peak  
448 velocity was significantly lower than controls ( $n = 16$ ) across all adaptation phases (MM range:  
449  $0.8$ - $1.1$  m/s,  $-3.35 < z < -2.52, 0.006 < p < 0.045$ ) with the exception of prism 1 (controls =  $2.0 \pm$   
450  $0.4$  m/s, MM =  $1.2$  m/s;  $z = -2.03, p = 0.069$ ) and prism 6 (controls =  $1.7 \pm 0.2$  m/s, MM =  $1.2$   
451 m/s;  $z = -1.86, p = 0.090$ ). Overall, movement speed was relatively constant for each patient,  
452 with patients MS and AM having no or few significant differences in peak velocity compared to  
453 controls, while patient MM showed reduced peak velocity.

454 Spatial hand paths of the DA showing prismatic effects can be seen in Figure 5. From this is can  
455 be seen that when control participants (Figure 5A) and patients (Figure 5B-D) wore rightward-

456 deviating prisms, the first trial with the prisms (prism 1) was deviated rightward compared to  
457 baseline, often with late online corrections toward the target. This also appears on Figure 6,  
458 which shows initial movement direction for each experimental trial. The ANOVA of controls'  
459 initial movement direction showed no significant group effect ( $F_{1, 14} = 0.75$ ,  $\eta_p^2 = 0.05$ ,  $p =$   
460  $0.402$ ) or interaction ( $F_{15, 210} = 1.13$ ,  $\eta_p^2 = 0.08$ ,  $p = 0.332$ ), and a significant effect of phase ( $F_{15,$   
461  $210} = 35.5$ ,  $\eta_p^2 = 0.72$ ,  $p < 0.001$ ) with Tukey post-hoc analysis revealing significant deviations on  
462 prism 1 compared to baseline (baseline =  $-0.2 \pm 3.1^\circ$ , prism 1 =  $10.3 \pm 5.3^\circ$ ,  $p < 0.001$ ) (Figure  
463 7A). Individual 98% confidence interval analysis on initial movement direction showed  
464 rightward deviation on prism 1 for 14/16 controls with 2/16 controls not significantly deviated.  
465 The same 98% confidence interval analysis revealed significant deviation for patient MS  
466 (baseline =  $-1.9 \pm 3.1^\circ$ , 98% CI [-4.6, 0.9], prism 1 =  $19.0^\circ$ ) (Figure 7B), patient MM (baseline =  
467  $3.0 \pm 3.8^\circ$ , 98% CI [-0.4, 6.4], prism 1 =  $6.8^\circ$ ) (Figure 7C) and patient AM (baseline =  $-1.1 \pm$   
468  $2.8^\circ$ , 98% CI [-1.3, 3.6], prism 1 =  $16.1^\circ$ ) (Figure 7D). All individuals' quantified prism effects  
469 (prism 1 – baseline) are shown in Figure 8A. Crawford's modified t-test on the prism effect  
470 showed no significant differences between controls ( $n = 16$ ) ( $10.5 \pm 5.3^\circ$ ) and patient MS (MS =  
471  $20.9^\circ$ ,  $z = 1.95$ ,  $p = 0.078$ ), patient MM (MM =  $3.8^\circ$ ,  $z = -1.27$ ,  $p = 0.239$ ) or patient AM (AM =  
472  $14.9^\circ$ ,  $z = 0.83$ ,  $p = 0.433$ ) (Figure 8B).

473 The analysis of maximum perpendicular deviation provided further evidence for patients and  
474 controls having typical prismatic effects. Individual 98% confidence interval analysis showed  
475 that on prism 1, 16/16 controls, and all 3 patients were significantly deviated rightward by the  
476 prisms compared to baseline (see Figure 9A for individuals' prism effects). According to  
477 Crawford's modified t-test, there were no significant differences between the controls' ( $n = 16$ )  
478 prism effect (controls =  $8.3 \pm 2.5$  cm) and patient MS (MS =  $5.9$  cm,  $z = 0.37$ ,  $p = 0.410$ ) or

479 patient MM (MM = 4.0 cm,  $z = -1.76$ ,  $p = 0.116$ ), while patient AM had a larger prismatic effect  
480 than controls (AM = 16.0 cm,  $z = 3.16$ ,  $p = 0.008$ ) (Figure 9B).

481 A classic pattern of error reduction was then observed following the first prism trial with less  
482 deviated trajectories on prism trials 2, 3 and 4 (Figure 5). Results from the control group  
483 ANOVA on initial movement direction showed a maintained significant deviation on prism 2  
484 compared to baseline (baseline =  $-0.2 \pm 3.1^\circ$ , prism 2 =  $5.4 \pm 3.6^\circ$ ,  $p < 0.001$ ) with this deviation  
485 no longer significant on prism 3 ( $2.7 \pm 5.2^\circ$ ,  $p = 0.212$ ). On an individual level, 14 of the 14  
486 controls perturbed by the prisms on prism 1 were still perturbed on prism 2, 8 controls on prism  
487 3 and 6 controls on prism 4. The number of trials to correct the prismatic perturbation and reduce  
488 errors, taken as the first trial to fall within the 98% baseline confidence intervals, was  $4.5 \pm 2.6$   
489 trials [range = 3 to 9 prism trials] on average for controls. Patient MS reduced errors by prism  
490 trial 4 (Figure 7B), patient MM by prism 2 (Figure 7C) and patient AM by prism 5 (Figure 7D).  
491 Crawford's modified t-test showed no significant difference in the number of trials to reduce  
492 errors between controls ( $n = 16$ ) and patients (controls =  $4.5 \pm 2.6$  trials; MS = 4 trials,  $z = -0.19$ ,  
493  $p = 0.855$ ; MM = 2 trials,  $z = -0.96$ ,  $p = 0.366$ ; AM = 5 trials,  $z = 0.19$ ,  $p = 0.854$ ).

494 Typical leftward deviated trajectories indicating an after-effect were then apparent on the first  
495 post movement (post 1) with the DA, despite this trial occurring after the NDA post phase of 30  
496 trials (Figure 5). For the control group ( $n = 16$ ), an ANOVA on initial movement direction  
497 showed that the post 1 trial was significantly deviated compared to baseline (baseline =  $-0.2 \pm$   
498  $3.1^\circ$ , post 1 =  $-10.7 \pm 6.6^\circ$ ,  $p < 0.001$ ; Figure 7A). Individual 98% confidence interval analysis  
499 showed significant deviation on post 1 for 16/16 controls, patient MS (baseline =  $-1.9 \pm 3.1^\circ$ ,  
500 98% CI [-4.6, 0.9], post 1 =  $-13.5^\circ$ ; Figure 7B) and patient AM (baseline =  $-1.1 \pm 2.8^\circ$ , 98% CI [-  
501 1.3, 3.6], post 1 =  $-14.7^\circ$ ; Figure 7D). The after-effect for patient MM (Figure 5C) was not

502 significant when analysing initial movement direction (baseline =  $3.0 \pm 3.8^\circ$ , 98% CI [-0.4, 6.4],  
503 post 1 =  $1.9^\circ$ ; Figure 7C). All individuals' after-effects (post 1 – baseline) are shown in Figure  
504 8C. Comparison of the patients' after-effects to controls ( $n = 16$ ) ( $-10.5 \pm 5.3^\circ$ ) using Crawford's  
505 modified t-test showed no significant differences for patient MS (MS =  $-11.7^\circ$ ,  $z = -0.22$ ,  $p =$   
506  $0.789$ ), patient MM (MM =  $-1.0^\circ$ ,  $z = 1.77$ ,  $p = 0.106$ ) or patient AM (AM =  $-15.9^\circ$ ,  $z = -1.01$ ,  $p$   
507 =  $0.345$ ; Figure 8D).

508 Analysis of maximum perpendicular deviation provided consistent results to the previous  
509 analysis of initial movement direction, with the exception that the after-effect of patient MM was  
510 significant. Individual 98% confidence interval analysis of post 1 compared to baseline showed  
511 significant after-effects for 16/16 controls and all 3 patients (see Figure 9C for individuals' after-  
512 effects). Crawford's modified t-test showed that there were no significant differences in the after-  
513 effect according to maximum perpendicular deviation between the controls ( $n = 16$ ) (controls = -  
514  $5.4 \pm 1.3$  cm), patient MS (MS =  $-6.1$  cm,  $z = -0.55$ ,  $p = 0.596$ ), patient MM (MM =  $-3.8$  cm,  $z =$   
515  $1.22$ ,  $p = 0.255$ ) or patient AM (AM =  $-5.9$  cm,  $z = -0.40$ ,  $p = 0.693$ ) (Figure 9D). Overall, these  
516 results indicate that all controls and all 3 patients were deviated rightward by the prisms, showed  
517 a typical pattern of error reduction during prism exposure and had characteristic leftward  
518 deviating after-effects.

519 *Transfer of prism adaptation to the non-dominant arm*

520 Interlimb transfer of sensorimotor adaptation was assessed by comparing reaching movements  
521 performed with the NDA immediately before (baseline phase) and immediately after (post 1  
522 trial) the prism phase performed with the DA. For controls ( $n = 16$ ), a 2x2 ANOVA on peak  
523 velocity including 2 groups and 2 phases showed that peak velocity did not significantly differ  
524 across the different phases (baseline average =  $1.7 \pm 0.2$  m/s, post 1 =  $1.8 \pm 0.2$  m/s,  $F_{1, 14} = 0.28$ ,  
525  $\eta_p^2 = 0.02$ ,  $p = 0.608$ ). No significant group effect ( $F_{1, 14} = 0.57$ ,  $\eta_p^2 = 0.04$ ,  $p = 0.462$ ) or  
526 interaction ( $F_{1, 14} = 0.60$ ,  $\eta_p^2 = 0.04$ ,  $p = 0.453$ ) were found. Comparison of NDA peak velocities  
527 on post 1 between controls ( $n = 16$ ) and patients showed that patient MS had no significant  
528 difference in peak velocity compared to controls, patient AM had increased peak velocity and  
529 patient MM had reduced peak velocity (controls =  $1.8 \pm 0.2$  m/s; MS = 1.6 m/s;  $z = -0.87$ ,  $p$   
530 = 0.407; AM = 2.3 m/s,  $z = 2.81$ ,  $p = 0.016$ ; MM = 0.9 m/s,  $z = -4.25$ ,  $p < 0.001$ ), consistent with  
531 previously reported results.

532 Figure 10 shows NDA trajectories for three example controls (Figure 10A) and the three patients  
533 (Figure 10B-D). Figure 10 shows that the post 1 movement of the NDA appeared deviated  
534 compared to the baseline trajectory for the majority of controls as well as patients, with three  
535 apparent patterns of transfer: initial rightward deviation, initial leftward deviation or no transfer.  
536 A 2x2 ANOVA on initial movement direction including 2 groups and 2 phases (baseline average  
537 and post 1) showed a significant effect of phase, with the post 1 initial movement direction  
538 significantly differing from baseline (baseline average =  $0.6 \pm 3.1^\circ$ , post 1 =  $-3.3 \pm 6.9^\circ$ ,  $F_{1, 14} =$   
539  $9.53$ ,  $\eta_p^2 = 0.40$ ,  $p = 0.008$ ; Figure 11A). No significant group effect ( $F_{1, 14} = 0.45$ ,  $\eta_p^2 = 0.03$ ,  $p =$   
540  $0.514$ ) or interaction ( $F_{1, 14} = 2.10$ ,  $\eta_p^2 = 0.13$ ,  $p = 0.169$ ) were found. Individual 98% confidence  
541 interval analysis of initial movement direction revealed significant interlimb transfer for 11/16

542 controls (10 leftward, 1 rightward) and no significant transfer for 5/16 controls, rightward  
543 transfer for patient MS (baseline average =  $1.7 \pm 2.3^\circ$ , 98% CI [-0.7, 4.0], post 1 =  $9.0^\circ$ ; Figure  
544 11B), leftward transfer for patient MM (baseline average =  $0.2 \pm 2.8^\circ$ , 98% CI [-2.7, 3.1], post 1  
545 =  $-6.8^\circ$ ; Figure 11C) and leftward transfer for patient AM (baseline average =  $-3.7 \pm 2.2^\circ$ , 98%  
546 CI [-5.9, -1.4], post 1 =  $-10.2^\circ$ ; Figure 11D). Individuals' magnitude of transfer (post1 –  
547 baseline) can be seen in Figure 12A. According to Crawford's modified t-test, absolute interlimb  
548 transfer did not significantly differ between any of the patients and the control group ( $n = 16$ )  
549 (controls =  $4.9 \pm 4.2^\circ$ ; MS =  $7.3^\circ$ ,  $z = 0.57$ ,  $p = 0.583$ ; MM =  $6.6^\circ$ ,  $z = 0.39$ ,  $p = 0.698$ ; AM =  
550  $7.0^\circ$ ,  $z = 0.49$ ,  $p = 0.638$ ; Figure 11B). We also compared the magnitude of interlimb transfer of  
551 each patient to the controls who were classified as presenting interlimb transfer ( $n = 11$ ). No  
552 significant difference was found in the absolute magnitude of transfer between these controls and  
553 patients using Crawford's modified t-test (controls =  $6.6 \pm 4.0^\circ$ ; MS =  $7.3^\circ$ ,  $z = 0.18$ ,  $p = 0.865$ ;  
554 MM =  $6.6^\circ$ ,  $z = -0.01$ ,  $p = 0.994$ ; AM =  $7.0^\circ$ ,  $z = 0.10$ ,  $p = 0.929$ ). Finally, a 2x2 ANOVA (2  
555 Groups, 2 Arms) on the post 1 trials (absolute values) showed a significant effect of arm ( $F_{1, 14} =$   
556  $13.08$ ,  $\eta_p^2 = 0.48$ ,  $p = 0.003$ ), with a significantly greater deviation of the dominant arm than the  
557 non-dominant arm. There was no significant group or interaction effect. Correlation analysis  
558 performed between the control groups' after-effect on the dominant arm ( $-10.5 \pm 5.3^\circ$ ) and  
559 transfer effect on the non-dominant arm ( $4.9 \pm 4.2^\circ$ ) showed no significant correlation ( $r = -0.27$ ,  
560  $p = 0.922$ ) (see Figure 6 for graphical presentation of the post values for controls and each  
561 patient). These results suggest that the magnitude of each individual's after-effect and transfer  
562 effect were not related.

563 Results were further confirmed by analysis of maximum perpendicular deviation, as individual  
564 98% confidence interval analysis showed significant interlimb transfer for the majority of

565 controls, 13/16, and all 3 patients. Crawford's modified t-test showed no significant differences  
566 in the absolute magnitude of transfer between controls and patients (controls =  $3.0 \pm 1.8$  cm; MS  
567 = 1.9 cm,  $z = -0.63$ ,  $p = 0.549$ ; MM = 2.8 cm,  $z = -0.12$ ,  $p = 0.828$ ; AM = 4.2 cm,  $z = 0.64$ ,  $p =$   
568 0.539). Comparison of patients to controls classified as presenting interlimb transfer ( $n = 13$ ) also  
569 showed no significant differences in the absolute magnitude of transfer using Crawford's  
570 modified t-test (controls =  $3.5 \pm 1.7$  cm; MS = 1.9 cm,  $z = -0.95$ ,  $p = 0.377$ ; MM = 2.8 cm,  $z = -$   
571 0.40,  $p = 0.706$ ; AM = 4.2 cm,  $z = 0.42$ ,  $p = 0.693$ ). These results indicate that all 3 patients  
572 transferred the DA adaptation to the NDA despite their corpus callosum abnormalities.

573 **Discussion**

574 We aimed to determine the role of the corpus callosum in interlimb transfer of sensorimotor  
575 adaptation in the context of unconstrained arm movements. Longstanding theoretical models of  
576 the neural mechanisms underlying interlimb transfer of motor learning highlighted the corpus  
577 callosum as a key structure mediating interhemispheric transfer of motor skills (Parlow and  
578 Kinsbourne, 1990; Taylor and Heilman, 1980). While certain studies have provided evidence  
579 towards these models (Bonzano et al., 2011; de Guise et al., 1999; Perez et al., 2007a), others  
580 have given evidence against (Criscimagna-Hemminger et al., 2003; Thut et al., 1997). Here, we  
581 found interlimb transfer of prism adaptation from the dominant arm to the naïve non-dominant  
582 arm on an arm reaching task in three corpus callosum patients, with no significant difference in  
583 terms of magnitude compared to controls. The presence of interlimb transfer in each patient  
584 suggests that on an arm reaching task, interlimb transfer of prism adaptation does not require  
585 intact callosal pathways, notably those between bilateral motor, premotor and supplementary  
586 motor areas. This would primarily suggest that the dominant theories of interlimb transfer  
587 involving the corpus callosum, developed mostly based on distal tasks, may not generalize to  
588 other tasks such as proximo-distal arm reaching. Further work is necessary to determine whether  
589 interlimb transfer relies on such pathways in healthy individuals. For instance, it is possible that  
590 the same neural mechanisms underly interlimb transfer in patients and healthy participants. On  
591 the other hand, the underlying mechanisms may differ, whereby the midbody of the corpus  
592 callosum may mediate interlimb transfer in healthy controls, whereas in the patients, brain  
593 plasticity mechanisms may have resulted in alternative neural mechanisms which maintain  
594 apparently normal profile interlimb transfer at the behavioral level.

595 *Comparable motor control and adaptation between corpus callosum patients and controls*

596 Overall, in baseline reaching performance, patient MS, with recent stroke-induced lesions to the  
597 corpus callosum (preserving only the genu and splenium), and patient AM, with corpus callosum  
598 agenesis, showed few significant differences to controls. The only patient presenting substantial  
599 differences compared to controls was patient MM, who had recent stroke-induced lesions to the  
600 corpus callosum (preserving only the splenium). For instance, patient MM had no significant  
601 differences in initial movement direction and end point accuracy compared to controls, but  
602 showed abnormally slowed temporal kinematics, with a reduced peak velocity for both arms.  
603 Detrimental effects on temporal movement features such as slowing of unimanual arm reaching  
604 have been related to the degradation of corpus callosum pathways connecting premotor areas in  
605 stroke patients (Stewart et al., 2017). In addition, patient MM was tested only 5 months post-  
606 injury, which could have contributed to this motor slowing. Despite this, we did not find any  
607 significant difference between each patient and controls for spatial performance in baseline.

608 Each patient had a significant rightward prism effect and was able to reduce initial reaching  
609 errors caused by the initial perturbation. When examining early prism exposure, no significant  
610 difference between controls and the patients was found for the number of trials to reduce prism-  
611 induced errors, with fast error reduction based on visual feedback as in other reaching studies  
612 (Gréa et al., 2002; Newport and Jackson, 2006; O’Shea et al., 2014; Pisella et al., 2004; Renault  
613 et al., 2020). While awareness of the perturbation and strategic, possibly explicit, processes could  
614 partly underlie the rapid error reduction as well as adaptation and transfer, previous research  
615 (Mazzoni and Krakauer, 2006; Newport and Jackson, 2006; Taylor et al., 2011; Wang et al.,  
616 2011) suggest that this is unlikely to fully account for the present results. Finally, a significant  
617 leftward after-effect, often referred to as a hallmark of sensorimotor adaptation, was observed on

618 the dominant arm across the control group and patients. The after-effect was equivalent to a  
619 deviation of  $-10.5 \pm 5.3^\circ$  for the control group and  $-11.7^\circ$  to  $-15.9^\circ$  for the two patients with a  
620 significant after-effect, MS and AM respectively. The third patient, MM, had a non-significant  
621 after-effect of  $-1^\circ$  at initial movement direction, but the after-effect was significant when looking  
622 at maximum perpendicular deviation. We did not find any significant correlation between the  
623 number of trials taken to de-adapt during the post phase and the magnitude of the after-effect,  
624 suggesting that the rate of non-dominant arm de-adaptation did not substantially affect the  
625 magnitude of the after-effect. The after-effect in our study ( $10.5^\circ$ ) corresponded to 61.4% of the  
626 prismatic deviation ( $17.1^\circ$ ), which was similar to the after-effect of 60.9% ( $9.1^\circ$ ) found by  
627 Facchin et al. (2019, Experiment 1) who used  $15^\circ$  right-ward deviating prisms over 150  
628 adaptation trials, and, importantly, did not test opposite arm performance prior to after-effect  
629 assessment (see also Facchin et al. 2019 – Table 1 for a summary of the after-effects reported in  
630 the literature). Our findings thus support the idea of sensorimotor adaptation in each participant,  
631 offering the opportunity to assess interlimb transfer in patients and controls.

632

### 633 *Neural mechanisms of interlimb transfer*

634 We hypothesized that corpus callosum abnormalities would interfere with interlimb transfer yet  
635 found interlimb transfer in each patient with either extensive midbody lesions or complete  
636 agenesis. Further, we found no significant difference in the magnitude of absolute interlimb  
637 transfer between each patient and matched controls. Across controls and patients, we did observe  
638 two profiles of interlimb transfer to the non-dominant arm: the majority with initial leftward  
639 deviation (opposite to the prismatic perturbation), consistent with encoding in extrinsic

640 coordinates, and a few participants with initial rightward deviation (in the same direction as the  
641 prismatic perturbation), consistent with encoding in intrinsic coordinates. Overall, these findings  
642 support and extend those found on young, healthy individuals (Kalil and Freedman, 1966;  
643 Renault et al., 2020).

644 Regarding the underlying neural mechanisms of interlimb transfer, one could argue that the  
645 transfer observed in each patient could be due to the development of compensatory  
646 interhemispheric pathways through brain plasticity. Agenesis patients, like patient AM, often  
647 have preserved interhemispheric communication linked to the formation of alternative inter-  
648 hemispheric networks or upregulated information transfer via posterior or anterior commissures  
649 (Brescian et al., 2014; Tovar-Moll et al., 2014; Van Meer et al., 2016). In other pathologies such  
650 as split-brain patients, the presence and timeline of recovery of interhemispheric connectivity  
651 due to brain plasticity is less clear (for a review, see Mancuso et al., 2019). In studies on split-  
652 brain patients, recovery of interhemispheric connectivity was shown 2-7 years post-surgery in a  
653 group of patients (Roland et al., 2017), and decades post-surgery in two separate case studies  
654 (Nomi et al., 2019; Uddin et al., 2008). Here, we tested two stroke patients (MM and MS) within  
655 5 months and 2 years post-injury, respectively. This short timescale reduces the likelihood of  
656 interhemispheric connectivity changes due to plasticity. Further, both patients had non-surgical,  
657 stroke-induced lesions following a normal development with no history of epilepsy, removing  
658 potential confounds of studying a surgically split brain due to severe epilepsy. While patient AM  
659 could have developed compensatory mechanisms for interlimb transfer during development, this  
660 explanation would be less likely for patient MS and patient MM.

661 One possibility is that preserved corpus callosum splenium fibres in patients MM and MS could  
662 underlie interlimb transfer. The splenium is known to connect bilateral posterior parietal,

663 temporal and visual areas (Putnam et al., 2009; Zarei et al., 2006), areas known to contribute to  
664 reach adaptation. In particular, posterior parietal areas underlie the planning and control of  
665 visually guided arm movements (Buneo and Andersen, 2006) while both posterior parietal and  
666 visual areas have been implicated in prismatic adaptation (Clower et al., 1996; Crottaz-Herbette  
667 et al., 2014; Luauté et al., 2009; Magnani et al., 2013; Pisella et al., 2005). While bilateral motor  
668 and premotor transcallosal connections were disrupted in patients MM and MS, it is possible that  
669 splenial connections could mediate transcallosal mechanisms of interlimb transfer between  
670 bilateral posterior parietal, temporal or visual cortex areas. In line with this, in an agenesis  
671 patient like patient AM, visual areas normally connected via the splenium, were shown instead to  
672 be connected via the anterior commissure (Van Meer et al., 2016). Further work, for instance on  
673 other patients with rare stroke types affecting specifically the corpus callosum, and in particular  
674 the splenium, would thus be necessary to test this hypothesis.

675 An alternative hypothesis is that the observed interlimb transfer does not in fact rely on  
676 interhemispheric transfer and instead involves the dominant hemisphere (contralateral to the  
677 trained dominant arm). Indeed, pioneering work on the neural basis of interlimb transfer (Taylor  
678 and Heilman, 1980) proposed that, for right-handed participants, the left hemisphere contains the  
679 effector-independent motor engram formed during learning. More recent research has further  
680 confirmed the implication of dominant left hemisphere networks in both motor control and  
681 adaptation with the right arm in right-handers (Buneo and Andersen, 2006; Dassonville et al.,  
682 1997; Luauté et al., 2009; Pool et al., 2014), including adaptation to rightward prisms (Panico et  
683 al., 2020; Schintu et al., 2020). Further, left hemisphere, but not right hemisphere, stroke patients  
684 show impaired adaptation to visuomotor rotations (Mutha et al., 2011). It is thus possible that the  
685 updated motor plans stored within the dominant hemisphere are accessible to the dominant limb

686 but also the non-dominant limb, via ipsilateral cortico-spinal pathways rather than callosal  
687 pathways. Neurophysiological findings in healthy human and non-human primates have shown,  
688 for instance, that not only the contralateral hemisphere, but also the ipsilateral hemisphere can  
689 contribute to the execution of unimanual movements (Ames and Churchland, 2019; Anguera et  
690 al., 2007; Gabbitov et al., 2016; Heming et al., 2019; Lee et al., 2010; Luauté et al., 2009). This is  
691 supported by clinical studies showing that unilateral stroke damage can affect the contralateral  
692 arm but also the ipsilateral arm (Desrosiers et al., 1996; Hermsdörfer et al., 1999; Schaefer et al.,  
693 2009) especially on proximal tasks (Jones et al., 1989). The role of ipsilateral descending  
694 pathways, comprising around 10-15% of all descending motor pathways to upper and lower arm  
695 extremities, is currently under intense investigation in both motor control and stroke  
696 rehabilitation research of the upper limb (Bradnam et al., 2013; Duque et al., 2008). Ipsilateral  
697 pathways appear to contribute more to proximal compared to distal effectors (Bawa et al., 2004;  
698 Chen et al., 2003; Müller et al., 1997; Turton et al., 1996), a finding which may be linked to  
699 reports that interlimb transfer is greater on proximal compared to distal tasks (Aune et al., 2017;  
700 Thut et al., 1997). Further, Criscimagna-Hemminger et al. (2003) showed interlimb transfer of  
701 force-field adaptation in a split-brain patient on a constrained proximo-distal reaching task,  
702 suggesting that such interlimb transfer does not rely on the corpus callosum and could be  
703 mediated by ipsilateral descending pathways. Studies finding interlimb transfer on distal (hand or  
704 finger) tasks, such as sequence learning or force tasks, however, implicate a key role of  
705 interhemispheric communication via the corpus callosum (Bonzano et al., 2011; Gabbitov et al.,  
706 2016; Lee et al., 2010; Perez et al., 2007a; Ruddy and Carson, 2013). These results correspond to  
707 motor control observations in our patients, and other patients with corpus callosum  
708 abnormalities, showing that proximo-distal arm reaching performance can be largely unaffected

709 while distal motor tasks are impaired (Gordon et al., 1971; Sauerwein and Lassoche, 1994).  
710 These findings, in combination with our results obtained on an unconstrained proximo-distal  
711 reaching task, could suggest that tasks involving distal effectors could require callosal pathways,  
712 while tasks involving proximal effectors could rely on ipsilateral descending pathways.

713 One final interpretation could be that subcortical structures such as the cerebellum could underlie  
714 this interlimb transfer. Day and Brown (2001) suggested that visuomotor integration of reaching  
715 movements involved subcortical regions, potentially the cerebellum, as an agenesis patient  
716 showed normal visuomotor reaching despite an absent corpus callosum and absent ipsilateral  
717 motor evoked responses to the lower arm muscles. Since, imaging studies have shown evidence  
718 for cerebellar recruitment in prismatic adaptation involving reaching movements (Küper et al.,  
719 2014; Luauté et al., 2009). Notably, rightward prismatic adaptation, shown to involve a  
720 dominantly left lateralized cortical network, also involves the subcortical contralateral right  
721 cerebellum (Panico et al., 2020; Schintu et al., 2020), reciprocally connected to left cortical  
722 areas including parietal and motor cortices (Kamali et al., 2010; Palesi et al., 2017). A wealth of  
723 cerebellar patient studies have also shown the role of the cerebellum in force-field and  
724 visuomotor adaptation (Donchin et al., 2012; Rabe et al., 2009; Smith and Shadmehr, 2005), and  
725 prism adaptation (Block and Bastian, 2012; Hanajima et al., 2015; Martin et al., 1996b; Pisella et  
726 al., 2005). However, while the cerebellum has been shown to play a role in adaptation, Block and  
727 Celnik (2013) showed that inhibitory cerebellar stimulation did not interfere with interlimb  
728 transfer, and only interfered with visuomotor adaptation. Contrarily, on a grasping task, Nowak  
729 et al. (2009) showed impaired interlimb transfer in cerebellar patients. As cerebellar  
730 contributions vary between different adaptation tasks (Donchin et al., 2012; Rabe et al., 2009),  
731 and given that different adaptation paradigms are not necessarily measuring the same process

732 (Fleury et al., 2019), further work is necessary to determine whether interlimb transfer of  
733 prismatic adaptation is mediated by cerebellar mechanisms, involved in a parieto-cerebellar-  
734 motor network (Newport and Jackson, 2006; Obayashi, 2004).

735 In summary, our assessment of arm reaching performance in patients with corpus callosum  
736 abnormalities revealed interlimb transfer of prismatic adaptation, with no significant differences  
737 in the magnitude of transfer compared to matched controls. The presence of interlimb transfer in  
738 each patient suggests that on an arm reaching task, interlimb transfer of prism adaptation does  
739 not require intact callosal pathways, notably those between bilateral motor, premotor and  
740 supplementary motor areas. This would primarily suggest that the dominant theories of interlimb  
741 transfer involving the corpus callosum, developed mostly based on distal tasks, may not  
742 generalize to other tasks such as proximo-distal arm reaching. Further work is necessary to  
743 determine whether interlimb transfer relies on such pathways in healthy individuals. For  
744 instance, it is possible that the same neural mechanisms underly interlimb transfer in patients and  
745 healthy participants. On the other hand, the underlying mechanisms may differ, whereby the  
746 midbody of the corpus callosum may mediate interlimb transfer in healthy controls, whereas in  
747 the patients, brain plasticity mechanisms may have resulted in alternative neural mechanisms  
748 which maintain an apparently normal profile of interlimb transfer at the behavioral level.

749 **Limitations**

750 One possible limitation of the present study is that brain plasticity in corpus callosum patients could  
751 have resulted in alternate pathways for interlimb transfer of sensorimotor adaptation, which could  
752 otherwise rely on the midbody of the corpus callosum in a normal healthy brain. This limitation  
753 could be especially relevant for the agenesis patient as previous studies on agenesis subjects have  
754 shown upregulated functionality of the anterior commissure (Brescian et al., 2014; Tovar-Moll et al.,  
755 2014; Van Meer et al., 2016), ipsilateral descending pathways (Ziemann et al., 1999), and possibly  
756 subcortical pathways (Day and Brown, 2001). Further studies using functional brain imaging or brain  
757 stimulation would be necessary to give greater insights into the underlying neural mechanisms.

758 A second limitation is that we were able to work with a relatively small number of patients. This is  
759 because there is a low prevalence of agenesis and callosal lesions in stroke patients (Giroud and  
760 Dumas, 1995; Paul et al., 2007; Sun et al., 2019). For example stroke confined to the corpus callosum  
761 was observed in 21 of 5584 patients (0.4%) in the Shanghai study with a recruitment period of 4  
762 years (Sun et al., 2019), and 3 of 282 patients (1%) in the French study with a recruitment period of 1  
763 year (Giroud and Dumas, 1995). However, previous research has shown that even only one rare  
764 patient can be enough to reveal key insights in neuroscience, as evidenced by the Nobel-prize  
765 winning research on split-brain developed by Sperry and colleagues (Gazzaniga et al., 1962; Volz  
766 and Gazzaniga, 2017). Increasing sample size would not change our observations of interlimb  
767 transfer on all three patients, and thus our conclusion, that the midbody of the corpus callosum is not  
768 necessary for the interlimb transfer of prism adaptation. However, working with more patients, and  
769 especially patients with distinct lesions, would be helpful in clarifying the neural mechanisms  
770 underlying interlimb transfer. This is consistent with the idea that heterogenous samples can give  
771 greater neurological insights (Martin et al., 1996; Willems et al., 2014). Interestingly, while Sun et  
772 al. (2019) found high prevalence of splenium lesions, we, along with Giroud and Dumas (1995),

773 found a preserved splenium in both stroke patients. A future study with patients presenting splenium  
774 lesions would be useful to test the hypothesis that interlimb transfer relies on interhemispheric  
775 transfer of information via the splenium.

776 Finally, the two stroke patients and the agenesis patient tested in our study were heterogenous in  
777 terms of laterality, sex and age, giving rise to a heterogenous control group. However, age  
778 characteristics did not appear to influence the results of visuomotor adaptation and interlimb  
779 transfer across participants. Further, on a similar prismatic adaptation study, no significant effect  
780 of laterality or sex was found in a larger group of control participants which was more  
781 homogenous in terms of age (Renault et al., 2020). Whilst we used adapted statistical analyses  
782 developed to estimate whether a single patient can be considered normal or abnormal compared to  
783 small or moderate control samples (Crawford et al., 2010; Crawford and Garthwaite, 2007),  
784 statistically non-significant results do not necessarily indicate complete lack of difference between  
785 patients and controls (Altman and Bland, 1995). Further studies with an increased number of control  
786 participants could be useful to clarify this.

787

788 **References**

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1078 **Figure Legends**

1079 **Figure 1.** Sagittal MRI cross-section spanning from right (top row) to left (bottom row)  
1080 hemisphere for **A.** A typical control participant with complete corpus callosum (T1) **B.** Patient  
1081 MS who had a brain aneurysm rupture causing lesions to the corpus callosum with only the genu  
1082 (g) and splenium (s) preserved (T2-flair) **C.** Patient MM who had a stroke causing lesions to the  
1083 corpus callosum with only the splenium (s) preserved (T1) and **D.** Patient AM with absent corpus  
1084 callosum since birth (complete callosal agenesis) (T1). Corpus callosum regions marked by  
1085 white arrows are labelled on the middle row images, based on Witelson (1989), as: rostrum (r),  
1086 genu (g), anterior midbody (am), central midbody (cm), posterior midbody (pm), isthmus (i) and  
1087 splenium (s).

1088

1089 **Table 1.** Clinical and MRI features for each patient based on neuropsychological assessments.  
1090 Columns indicate clinical features of disconnection which were either present (+) or absent (o) in  
1091 each patient, with indication of the affected arm – left (L) or right (R) when applicable. Square  
1092 brackets [ ] are used to report when symptoms were only mild or the frequency of Alien Hand  
1093 episodes. \*Alien hand episodes for Patient MS were present immediately following the stroke,  
1094 but resolved 6 months post-stroke, reoccurring only with fatigue or stress. MRI features indicate  
1095 lesioned (black) and preserved (white) areas of the corpus callosum; a cross indicates complete  
1096 absence of the corpus callosum from birth.

1097

1098 **Figure 2.** Experimental protocol, with 3 phases (baseline, prism, and post-phase) made up of  
1099 blocks of dominant or non-dominant arm reaching. In the baseline phase, participants reached

1100 under normal vision from the starting point (black plus +) to one of three flashed visual targets  
1101 (grey-white circles) 30 times with the dominant arm, then 30 times with the non-dominant arm  
1102 (totaling 10 trials per target per arm). In the following prism phase (exposure), participants  
1103 reached 100 times (Control group A, patient MS, patient AM) or 50 times (Control group B,  
1104 patient MM) with the dominant arm towards the middle, straight-ahead visual target while  
1105 wearing rightward deviating ( $17^\circ$ ) prismatic goggles. During the post phase, participants again  
1106 reached under normal vision to one of three visual targets, 30 times with the non-dominant arm,  
1107 then 30 times with the dominant arm (totaling 10 trials per target per arm).

1108

1109 **Figure 3.** Baseline phase top-down view of the 10 reaching hand paths toward the middle  
1110 straight-ahead target (red circle) for the dominant arm (DA) and non-dominant arm (NDA) for  
1111 **A.** An example control **B.** Patient MS **C.** Patient MM and **D.** Patient AM. Peak velocity is  
1112 indicated with a black star.

1113

1114 **Figure 4.** Baseline kinematics for the dominant arm (DA) and non-dominant arm (NDA)  
1115 movements to the middle straight-ahead target **A.** Initial Movement Direction **B.** Final  
1116 Movement Direction **C.** End Point Accuracy **D.** Max Perpendicular Deviation **E.** Peak Velocity  
1117 **F.** Time to Peak Velocity **G.** Movement Time and **H.** Reaction Time. Data are shown for the  
1118 control group ( $n = 16$ ) average (white circles with standard deviation error bars) and individual  
1119 average values for controls (grey dashed circles), patient MS (triangles), patient MM (diamonds)  
1120 and patient AM (squares). Significant differences between the control group DA and NDA,  
1121 according to a 2x2 (Arm x Group) ANOVA, are marked with spanning black asterisks. For each

1122 arm, significant differences between a patient and the control group, according to Crawford's  
1123 modified t-test, are indicated by black asterisks with corresponding patient initials (MS - patient  
1124 MS, MM - patient MM, AM - patient AM). \* $p$  value < 0.05, \*\*\* $p$  value < 0.01.

1125

1126 **Figure 5.** Prism-exposed dominant arm top-down view of hand paths toward the target (red  
1127 circle) for **A.** An example control **B.** Patient MS **C.** Patient MM and **D.** Patient AM. Trajectories  
1128 include: a baseline phase representative trial (black), prism trials 1 (red), 2 (dark orange), 3 (light  
1129 orange) and 4 (yellow), and the post 1 trial (blue). The blue dashed line in panel **D.** is the  
1130 estimated post 1 trial trajectory for patient AM calculated based on motion tracking of a standard  
1131 video-camera recording using imageJ manual tracking software and adjustment according to a  
1132 standard baseline velocity profile, as a technical issue on this trial caused kinematic data loss via  
1133 the Codamotion system. Occurrence of peak velocity for each trial is marked with a black star;  
1134 occurrence of maximum perpendicular deviation is marked with a white star.

1135

1136 **Figure 6.** Initial movement direction for both the dominant arm (DA, represented as black filled  
1137 symbols), and non-dominant arm (NDA, represented as white filled symbols) across movements  
1138 toward the middle target for **A.** The control group ( $n = 16$ ) average values (circles) **B.** Patient MS  
1139 (grey triangles) **C.** Patient MM (light grey diamonds) **D.** Patient AM (dark grey squares). Data  
1140 shown include: all 10 individual baseline trials toward the middle target (DA then NDA), prism  
1141 trials 1-50 toward the middle target (DA only), and all 10 individual post trials toward the middle  
1142 target (NDA then DA). Error bars in panel **A.** represent standard deviations of the control group  
1143 mean. The post 1 value for patient AM in panel **D.** was calculated from an estimated trajectory

1144 created using imageJ motion tracking of a standard video-recording and adjustment according to  
1145 a standard baseline velocity profile, as Codamotion kinematic data were lost due to a technical  
1146 issue on this trial.

1147

1148 **Figure 7.** Prism-exposed dominant arm initial movement direction across trials for **A.** The  
1149 control group ( $n = 16$ ) showing group average (white circles) and individual values (light grey  
1150 circles) **B.** Patient MS (grey triangles) **C.** Patient MM (light grey diamonds) **D.** Patient AM (dark  
1151 grey squares). Data shown include: baseline (10 trial average), prism trials 1 to 10, the last 10  
1152 prism trials average (prism 41-50) and the post1 trial. Error bars in panel **A.** represent control  
1153 group standard deviations, asterisks indicate trials which significantly differ to baseline  
1154 according to a 2x16 (Group x Phase) ANOVA. Error bars in panels **B-D.** represent the individual  
1155 patient standard deviations for baseline (10 trials) and the last common prism phase (10 trials),  
1156 asterisks indicate trials which significantly differ from the baseline average according to baseline  
1157 98% confidence interval analysis. All asterisks are indicated at the threshold  $**p$  value  $< 0.02$ .  
1158 The post 1 value for patient AM in panel **D.** was calculated from an estimated trajectory created  
1159 using imageJ motion tracking of a standard video-recording and adjustment according to a  
1160 standard baseline velocity profile, as Codamotion kinematic data were lost due to a technical  
1161 issue on this trial.

1162

1163 **Figure 8.** Prismatic effects and after-effects for each individual, quantified with initial movement  
1164 direction analysis. Panels **A.** and **C.** show initial movement direction across trials for all  
1165 individual controls (grey circles), patient MS (grey triangle), patient MM (light grey diamond)

1166 and patient AM (dark grey square), calculated as the difference between each individual's  
1167 baseline average and the individual's prism 1 or post 1 trial respectively. Notations below the  
1168 graphs indicate patient initials (MM, MS, MM) and control references (C1-C8) for each  
1169 corresponding group (Group A:  $52 \pm 4$  years-old, 100 prism trials; Group B:  $29 \pm 4$  years-old, 50  
1170 prism trials). The grey dashed lines mark the control group average, *ns.* indicates individuals for  
1171 whom the effect was not significant according to the individual's baseline 98% confidence  
1172 interval analysis. Panels **B.** and **D.** show the data in panels **A.** and **C.** respectively, with control  
1173 data represented by the control group average and standard deviation. Asterisks in panels **B.** and  
1174 **D.** indicate significant differences between the patients and the control group according to  
1175 Crawford's modified t-test. \**p* value < 0.05, \*\*\**p* value < 0.01. The post 1 value for patient AM  
1176 in panels **C.** and **D.** was calculated from an estimated trajectory created using imageJ motion  
1177 tracking of a standard video-recording and adjustment according to a standard baseline velocity  
1178 profile, as Codamotion kinematic data were lost due to a technical issue on this trial.

1179

1180 **Figure 9.** Prism effects and after-effects for each individual, quantified based on maximum  
1181 perpendicular deviation analysis. Panels **A.** and **C.** show the quantified effect values according to  
1182 maximum perpendicular deviation across all individual controls (grey circles), patient MS (grey  
1183 triangle), patient MM (light grey diamond) and patient AM (dark grey square), calculated as the  
1184 difference between each individual's exposed dominant arm baseline average and prism 1 or post  
1185 1 trial respectively. Notations below the graphs indicate patient initials (MM, MS, MM) and  
1186 control references (C1-C8) for each corresponding group (Group A:  $52 \pm 4$  years-old, 100 prism  
1187 trials; Group B:  $29 \pm 4$  years-old, 50 prism trials). The grey dashed lines mark the control group  
1188 average, *ns.* indicates individuals for whom the effect was not significant according to the

1189 individual's baseline 98% confidence interval analysis. Panels **B.** and **D.** show the data in panels  
1190 **A.** and **C.** respectively, with control data represented by the control group average and standard  
1191 deviation. Asterisks in panels **B.** and **D.** indicated significant differences between the patients  
1192 and the control group according to Crawford's modified t-test. \* $p$  value < 0.05, \*\*\* $p$  value <  
1193 0.01. The post 1 value for patient AM in panels **C.** and **D.** was calculated from an estimated  
1194 trajectory created using imageJ motion tracking of a standard video-recording and adjustment  
1195 according to a standard baseline velocity profile, as Codamotion kinematic data were lost due to  
1196 a technical issue on this trial.

1197

1198 **Figure 10.** Naïve non-dominant arm top-view of hand paths for a baseline representative trial  
1199 (black) and the post 1 trial (blue) for **A.** Three example controls showing leftward, rightward or  
1200 no initial deviation on the post 1 trial compared to baseline **B.** Patient MS showing an initial  
1201 rightward deviation **C.** Patient MM showing an initial leftward deviation and **D.** Patient AM  
1202 showing an initial leftward deviation. Occurrence of peak velocity is marked with a black star;  
1203 occurrence of maximum perpendicular deviation is marked with a white star.

1204

1205 **Figure 11.** Naïve non-dominant arm initial movement direction before and after prismatic  
1206 adaptation with the dominant arm for **A.** The control group ( $n = 16$ ) showing the group average  
1207 (white circles) and individual values (grey circles) **B.** Patient MS (grey triangles) **C.** Patient MM  
1208 (light grey diamonds) **D.** Patient AM (dark grey squares). Data show the baseline 10 trial average  
1209 and post 1 trial. Error bars in panel **A.** represent control group standard deviations, and asterisks  
1210 indicate trials which significantly differ to baseline according to a 2x2 (Group x Phase) ANOVA.

1211 Error bars in panels **B.-D.** represent each patient's baseline standard deviations, and asterisks  
1212 indicate trials which significantly differ from the baseline average according to baseline 98%  
1213 confidence interval analysis. Significance is shown at  $**p$  value  $< 0.02$  threshold.

1214

1215 **Figure 12.** Interlimb transfer for each individual, quantified with initial movement direction  
1216 analysis. Panel **A.** shows the interlimb transfer values according to analysis of initial movement  
1217 direction for all individual controls (grey circles), patient MS (grey triangle), patient MM (light  
1218 grey diamond) and patient AM (dark grey square), calculated as the difference between each  
1219 individual's naïve non-dominant arm baseline average and post 1 trial. Notations below the  
1220 graphs indicate patient initials (MM, MS, MM) and control references (C1-C8) for each  
1221 corresponding group (Group A:  $52 \pm 4$  years-old, 100 prism trials; Group B:  $29 \pm 4$  years-old, 50  
1222 prism trials). The grey dashed lines mark the control group average, *ns.* indicates individuals for  
1223 whom the effect was not significant according to the individual's baseline 98% confidence  
1224 interval analysis. Panel **B.** shows the absolute transformation of the data in panel **A.** with control  
1225 data represented by the control group average and standard deviation. Asterisks in panel **B.**  
1226 indicated significant differences between the patients and the control group according to  
1227 Crawford's modified t-test.  $*p$  value  $< 0.05$ ,  $***p$  value  $< 0.01$ .

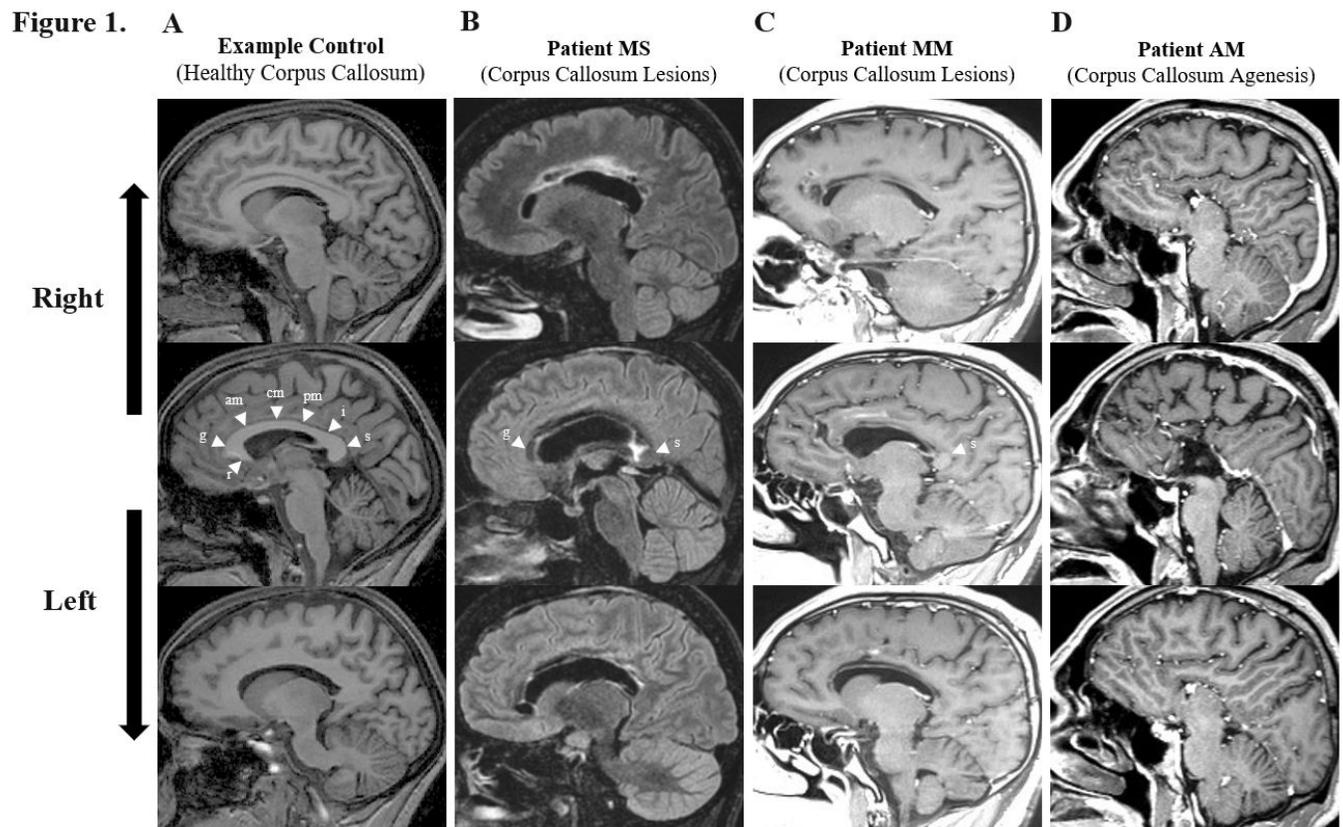


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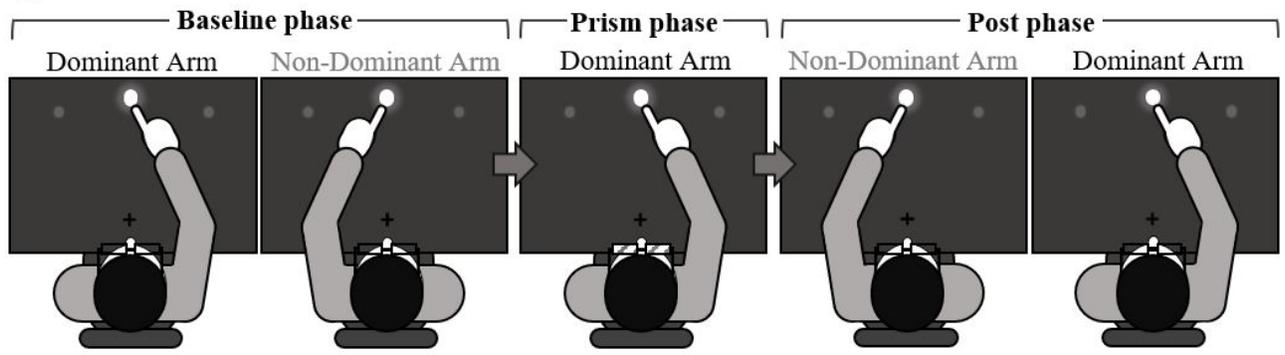


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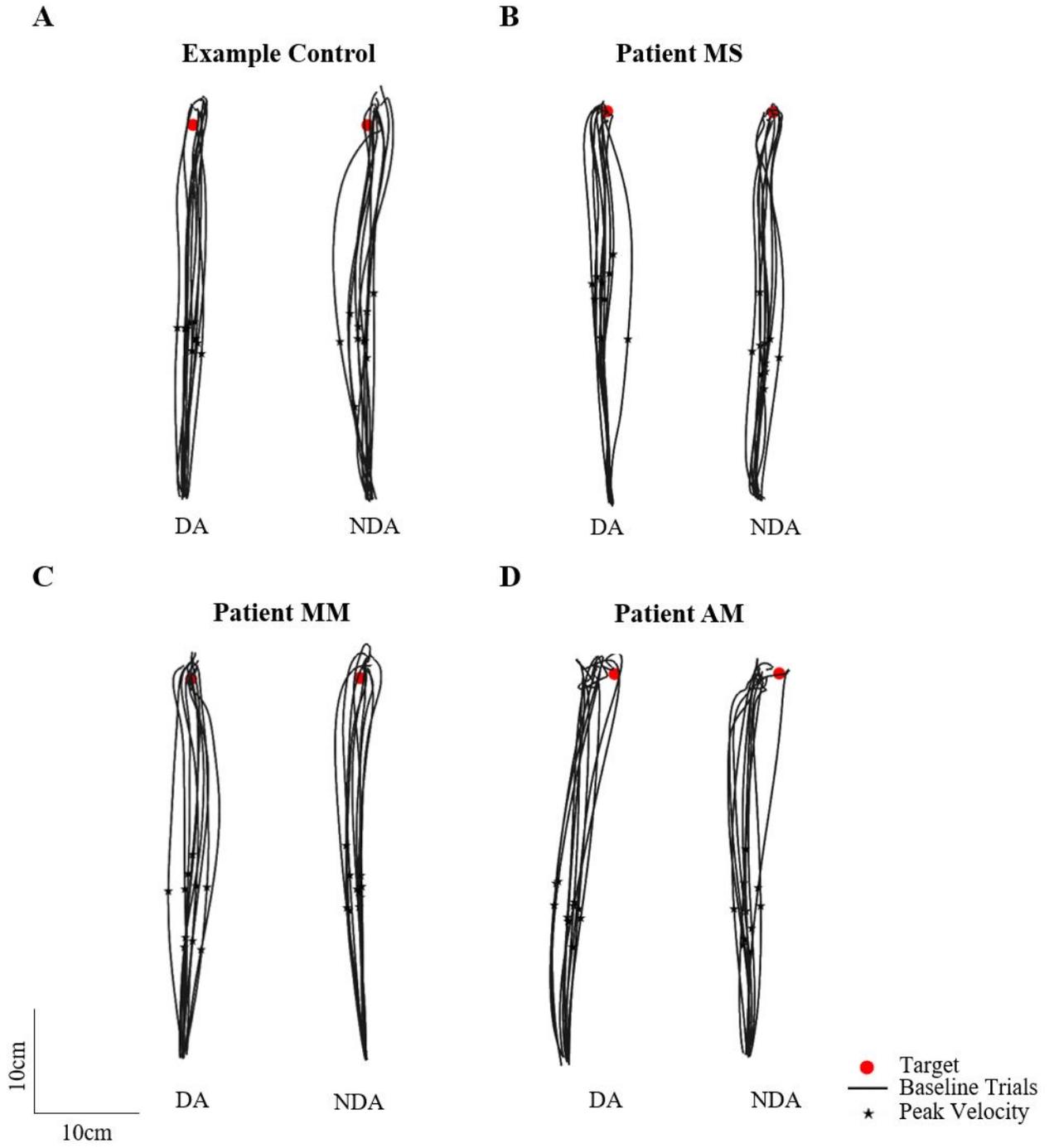


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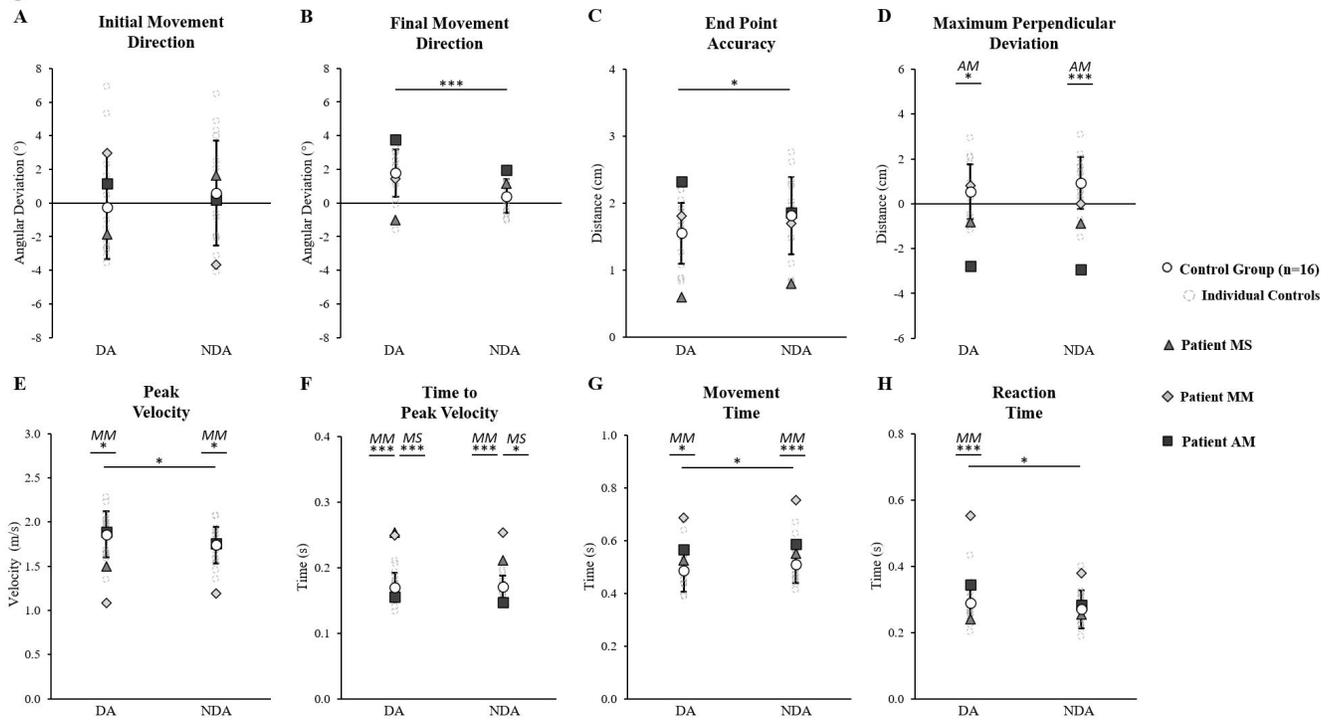


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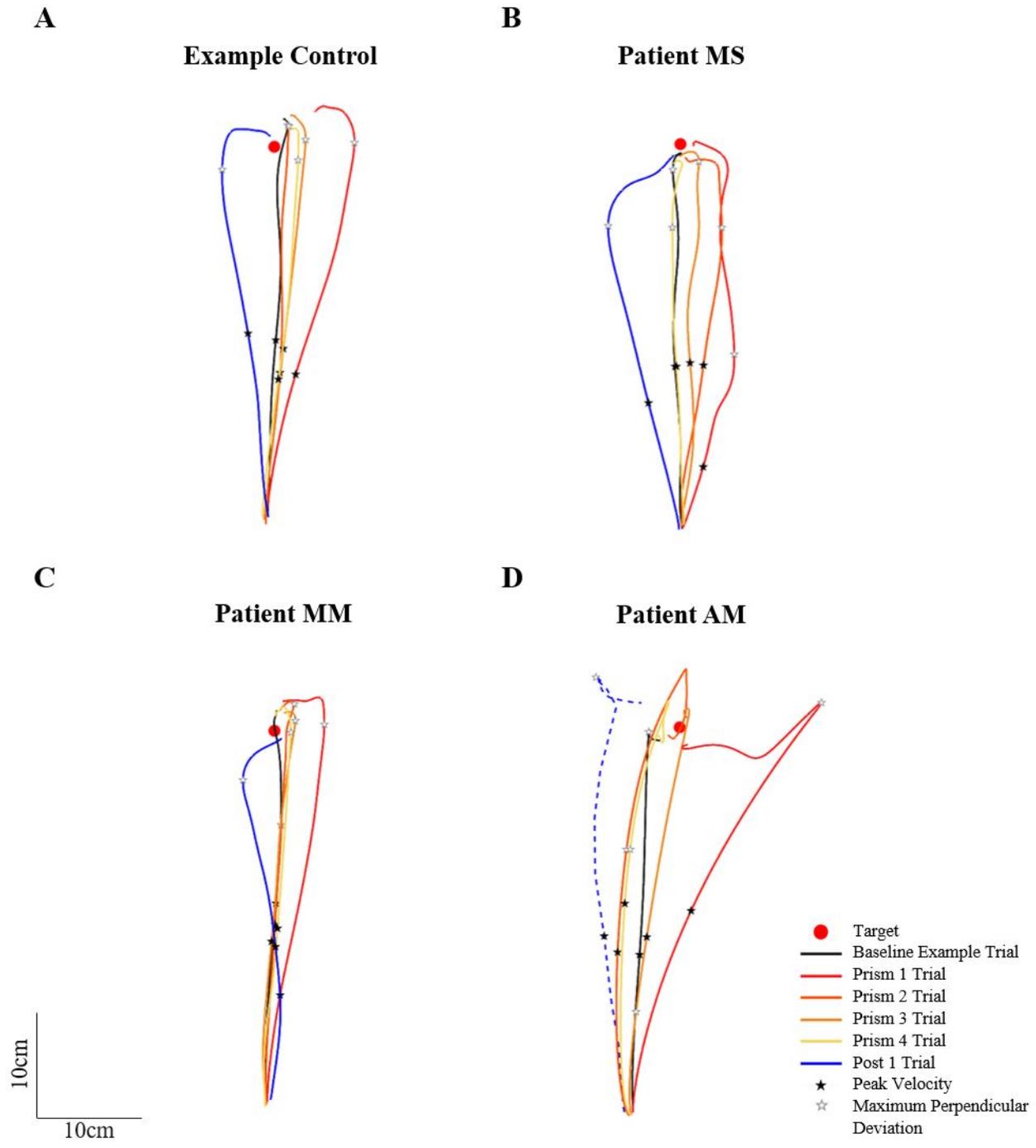


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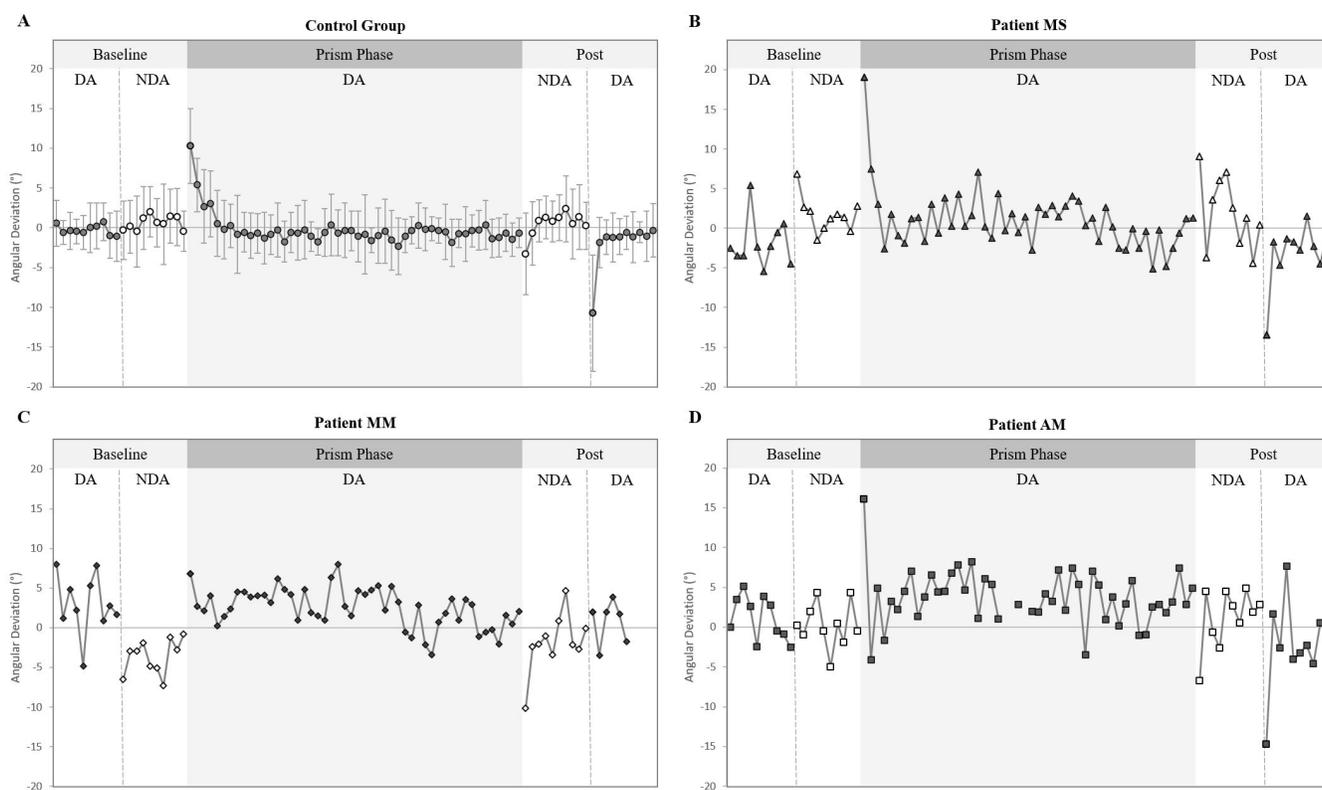
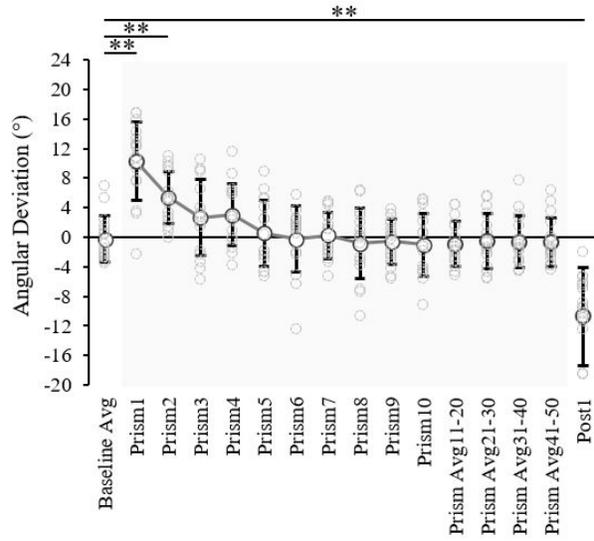
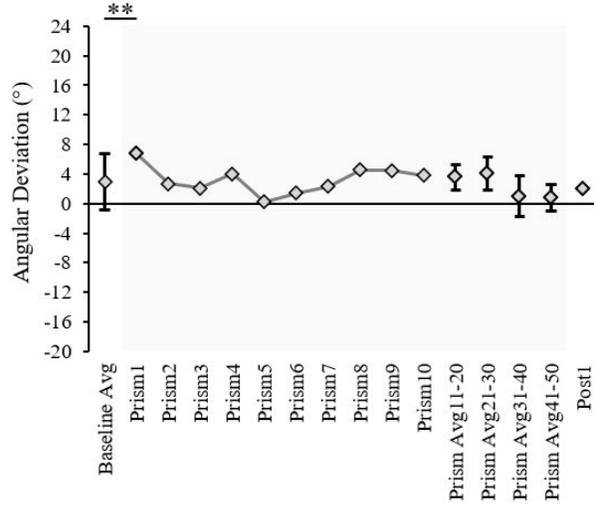


Figure 7.

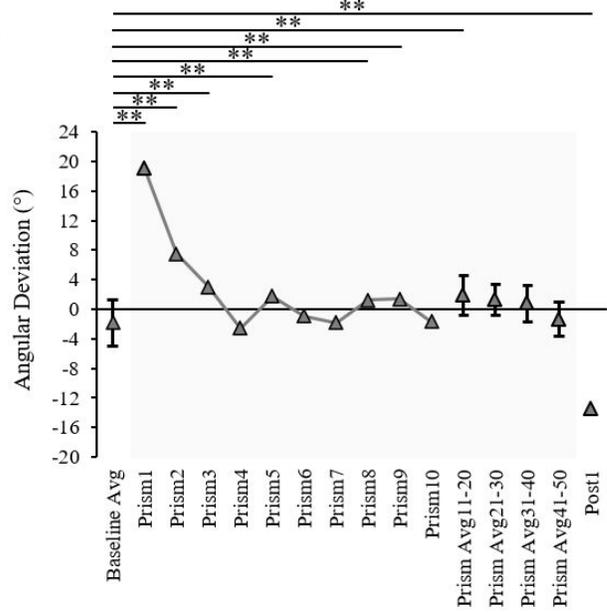
A



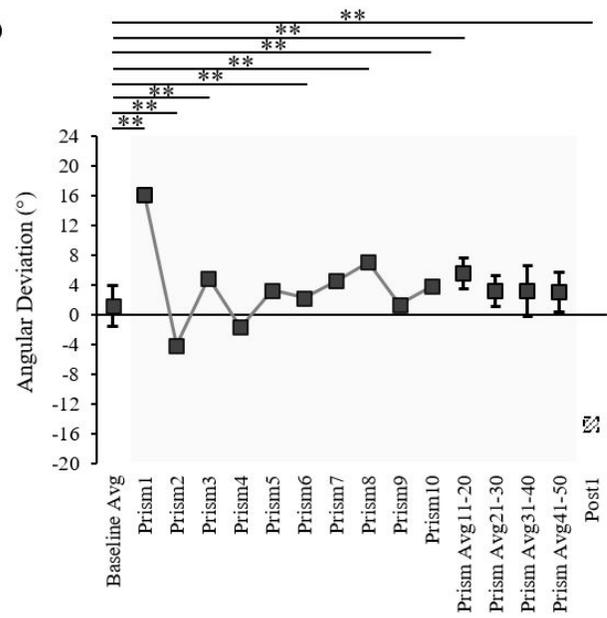
C



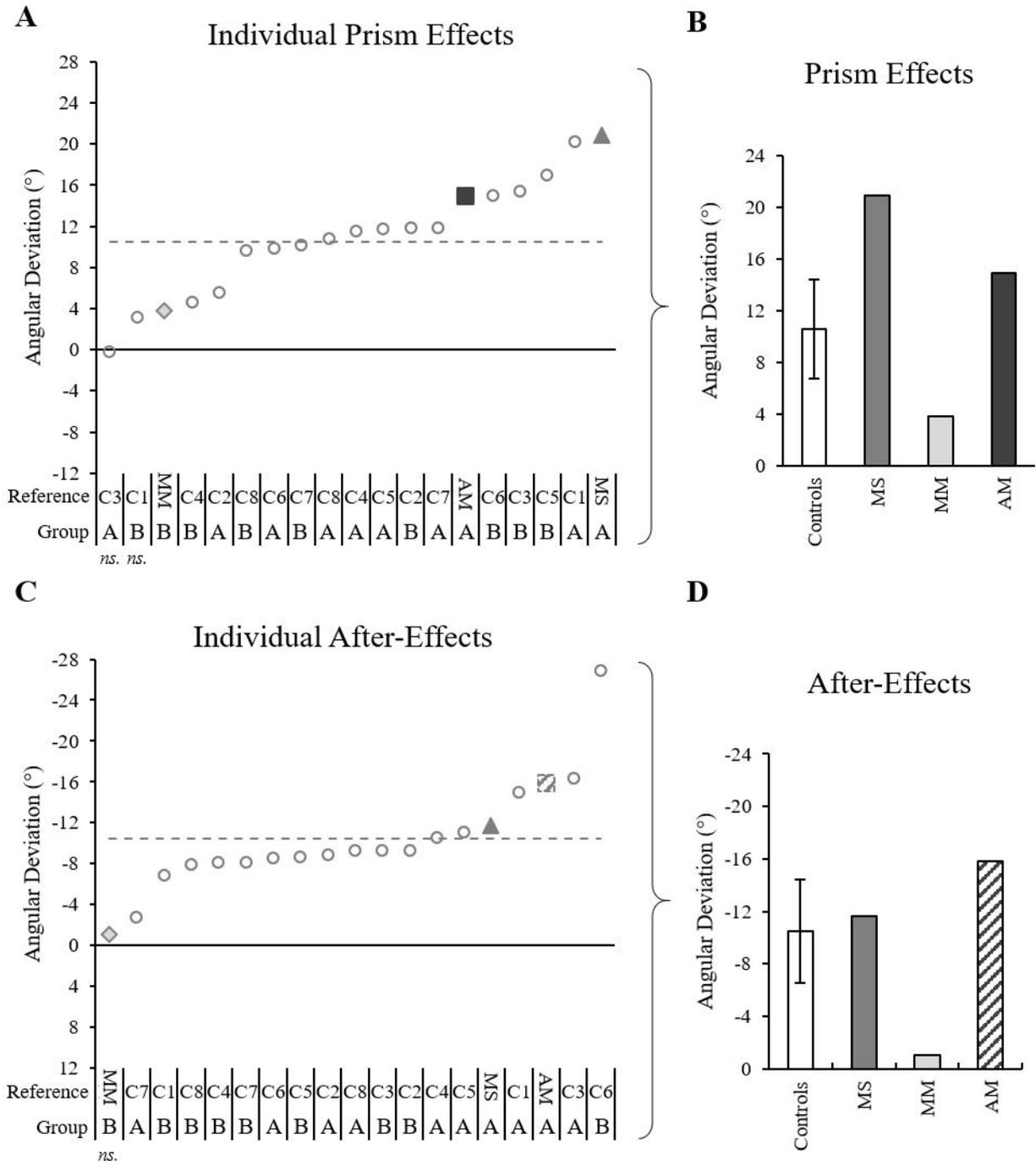
B



D



**Figure 8.**



**Figure 9.**

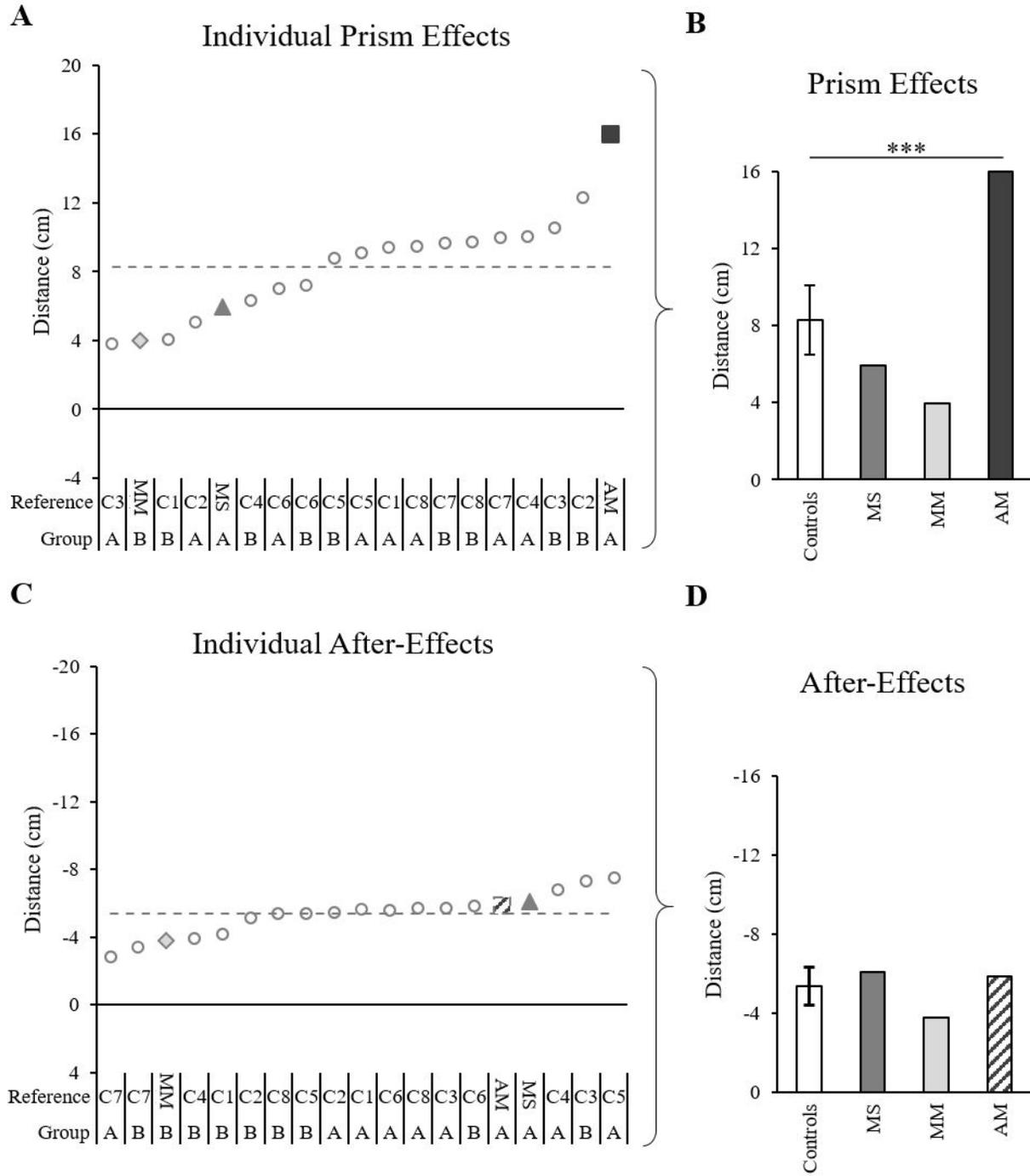


Figure 10.

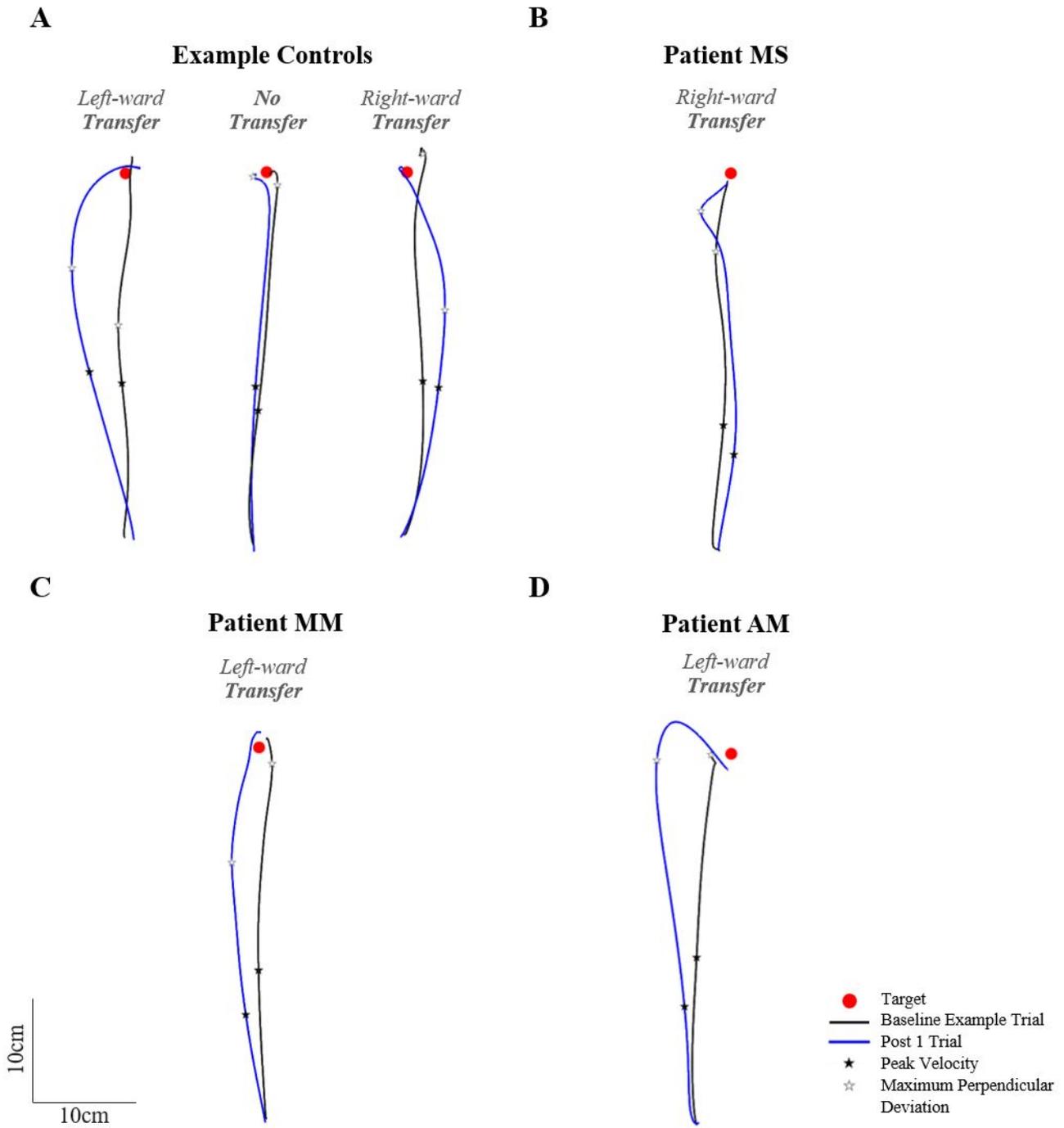
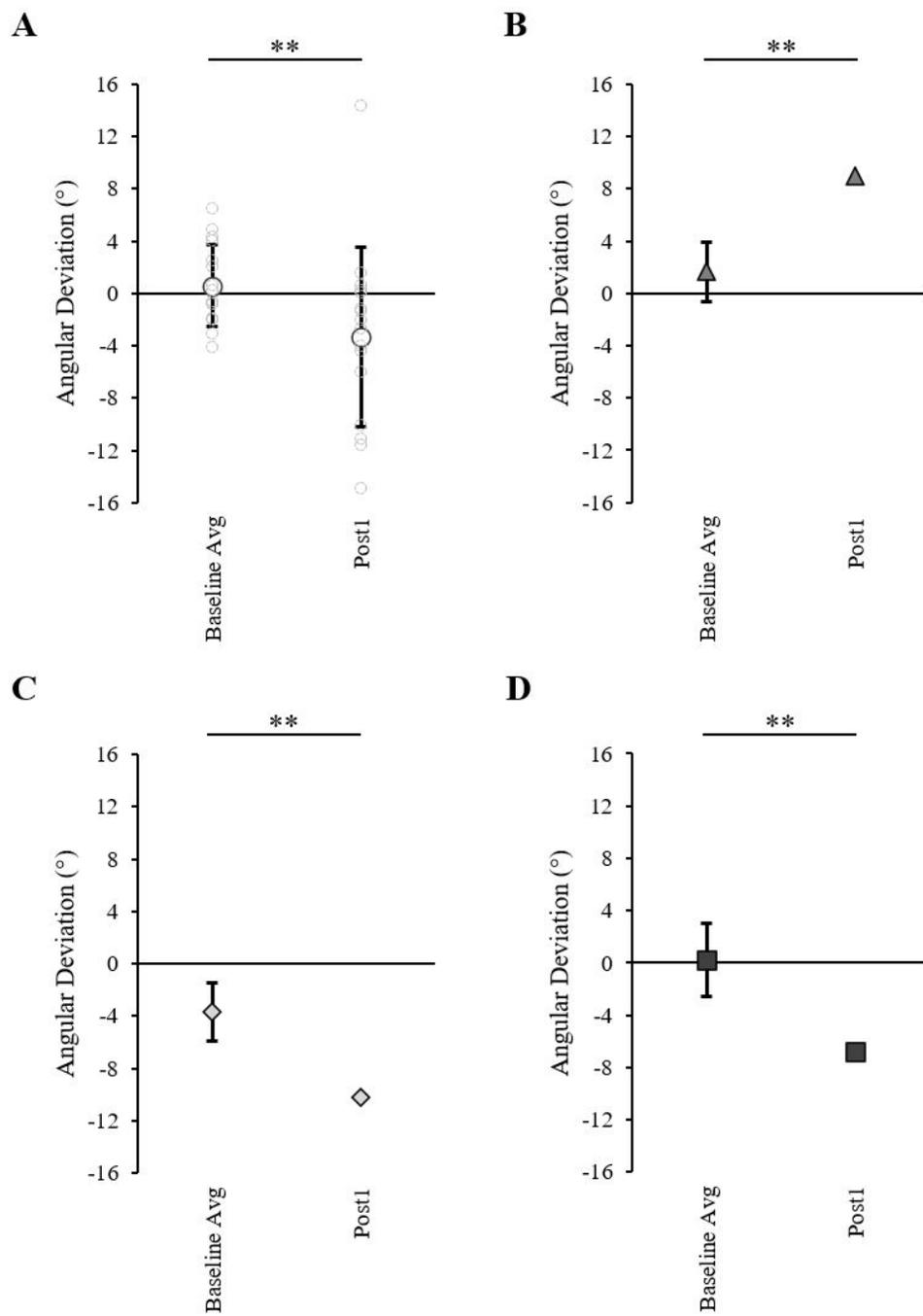
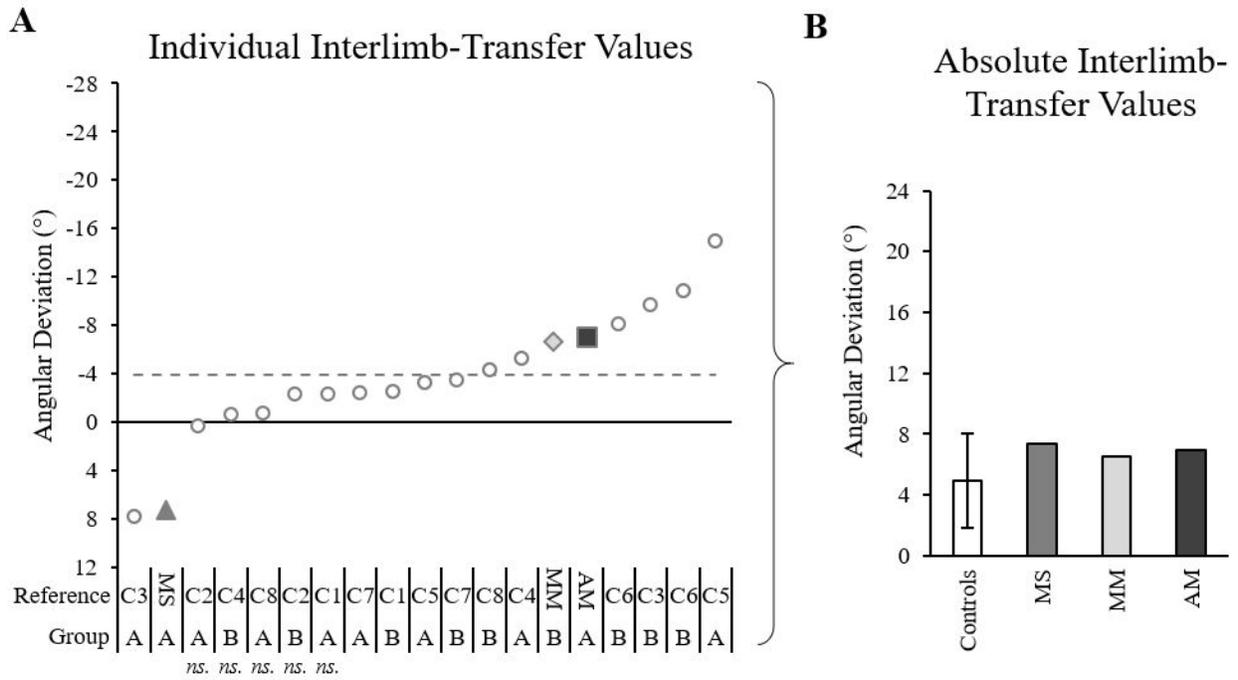


Figure 11.



**Figure 12.**



**Table 1.** Clinical and MRI features of callosal lesions

<i>Patients</i>	<i>Proprioceptive transfer</i>	<i>Visual alexia</i>	<i>Visual anomia</i>	<i>Tactile anomia</i>	<i>Agraphia</i>	<i>Constructive apraxia</i>	<i>Ideomotor apraxia</i>	<i>Alien hand (diagonistic apraxia)</i>	<i>MRI features</i>
<b>MS</b> <i>stroke-induced lesions</i>	+	o	o	o	o	o	+ (L) [mild]	+ (R) * [weekly]	
<b>MM</b> <i>stroke-induced lesions</i>	+	o	o	+ (L)	+ (L)	o	+ (L)	+ (L) [daily]	
<b>AM</b> <i>agenesis</i>	+	+ (R) [mild]	+ (R)	o	+ (R) [mild]	+ (R)	+ (R)	+ (R) [weekly]	×

Columns indicate clinical features of disconnection (based on neuropsychological assessments) which were either present (+) or absent (o) in each patient, with indication of the affected arm – left (L) or right (R) when applicable. Square brackets [ ] are used to report when symptoms were only mild or the frequency of Alien Hand episodes. \*Alien hand episodes for Patient MS were present immediately following the stroke, but resolved 6 months post-stroke, reoccurring only with fatigue or stress. MRI features indicate lesioned (black) and preserved (white) areas of the corpus callosum; a cross indicates complete absence of the corpus callosum from birth.