Journal Club

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# Don't Let It Slip: Predictive Control of Grip Force After Changes in Task Goals

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Review of Danion and Sarlegna (http://www.jneurosci.org/cgi/content/full/27/47/12839)

Conventional models of the neural control of movement suggest that movements are first planned, and then executed via the appropriate motor commands (Flash and Hogan, 1985; Uno et al., 1989). These motor commands also appear to be mapped to sensory processing areas within the brain. Wolpert and Flanagan (2001) suggest that this mapping could reflect a predictive controller that provides estimates of the sensory consequences of motor commands before actual sensory feedback becomes available. When transporting an object, for example, this controller could anticipate the mechanical effects of arm motion and accordingly modulate grip force on the object to prevent it from slipping. Whether such predictions remain fixed based on the initial movement plan or whether these predictive processes are also available on-line, during the course of voluntary movement, remains unknown. In a recent study in *The Journal of Neuroscience*, Danion and Sarlegna (2007) attempt to resolve this question by examining grip force modulation after random target displacements during movement. The authors assert that if predictive control is a continuous process, it should remain intact when motor commands are modified on-line, after changes in task goals.

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In a cleverly designed experimental task, subjects moved an object to one of three visual targets (8, 16, or 24 cm away) [Danion and Sarlegna (2007), their Fig. 1 (http://www.jneurosci.org/cgi/content/full/27/47/12839/F1)]. Occasionally, after movement initiation, the target was displaced either farther from the middle target (16→24 cm) or back toward the start position (16→8 cm). To accurately reach the displaced targets, subjects initiated arm movement corrections, which were detected by measuring changes in the load force imposed by a spring attached to the object. To assess whether predictive changes occurred in grip force, the authors examined the latency of grip force corrections in response to the target displacement, relative to changes in load force.

To establish the onset of load force and grip force corrections, the authors compared baseline (no target displacement) and target-displacement trajectories in a two-dimensional phase space consisting of normalized average force amplitude and the rate of change of force [Danion and Sarlegna (2007), their Fig. 2 (http://www.jneurosci.org/cgi/content/full/27/47/12839/F2)]. The distance between trajectories was calculated within the phase plot at each instant in time. The time at which this distance exceeded a threshold of 0.1 for load force and 0.25 for grip force was taken as the onset of correction. Using this analysis, the authors report that load force corrections were initiated ~284 ms after target displacements, whereas grip force corrections were initiated ~209 ms after the forward target displacement and ~346 ms after the backward target displacement. It must be pointed out that although the grip force corrections were initiated slightly later than load force corrections when the target was displaced backwards, the difference between these latencies was not statistically significant. This is likely because of the large variability in the grip force data under these conditions (SD, ±160 ms). Although these values of correction latencies appear reasonable, we have some reservations about the method used by the authors for their calculation, which we address later. Nevertheless, the main finding in this study was that grip force modifications were initiated either before (on average ~71 ms) or simultaneous with changes in load force. Moreover, grip force changes were optimal with respect to the task-dependent changes in load force: grip force increased when the target was displaced forward and decreased when the target jumped backward.

The authors then assessed whether these predictive changes in grip force were dependent on the target being displaced or whether such changes also occurred during baseline conditions. Using an intelligent calculation procedure, they evaluated the time lag between normalized grip force and load force trajectories under the baseline condition over a 100 ms window before and after the time that grip force corrections were observed in the target-displacement trials. They report that predictive control of grip force was intact in baseline conditions, thus implying that grip-load force coordination was independent of the target displacement. Across all conditions, grip force corrections preceded load force corrections by ~22 ms [Danion and Sarlegna (2007), their Fig. 4 (http://www.jneurosci.org/cgi/content/full/27/47/12839/F4)].

Danion and Sarlegna (2007) interpret this rapid modulation of grip force as being driven by predictive mechanisms that operate continuously throughout the movement. The finding that grip force modifications preceded arm movement corrections in response to target displacements strongly supports this notion. Thus, predictive control is not limited to movement planning stages, but remains intact even in the face of changing movement goals. Although this interpretation is intriguing, our primary concern is that it hinges solely on the estimated latencies of grip force and load force corrections. One fundamental limitation of the methods used by the authors to estimate these latencies is the failure to take into account both intertrial and intratrial variability of the force data. Although statistical techniques that take into account inherent noise, such as iterative *t* tests (Shapiro et al., 2004), have extensively been used for signal comparison, the authors employ a less rigorous method that considers only the averages of load force and grip force trajectories. This is problematic because it is difficult to justify the onset of a correction when it is consistent with baseline trial-to-trial fluctuations in load force and grip force. It is likely that estimates of latencies would increase if the variability in force data were considered. This would not affect the current interpretation of results if load force and grip force correction latencies increased equally. As the authors point out, however, "background fluctuations" in load force and grip force data were not equivalent. Although the authors attempted to resolve this inconsistency by varying the threshold criterion for load force and grip force corrections, justification for these values is lacking. Thus it is difficult to interpret whether the current estimate would be consistent with values obtained using other statistical procedures. Accounting for the noise characteristics could either diminish or amplify the differences between load force and grip force correction latencies in this study, which could significantly alter the conclusions that the authors draw.

Although the explanation the authors provide based on their results and calculation procedures is satisfying to a large degree, another highly likely mechanism underlying these observations should also be addressed. It is possible that low-level visuomotor feedback controllers mediate the early changes in grip force, whereas the later arm movement corrections are the result of detailed processing of visual information by higher-level controllers. In fact, Day and Brown (2001) demonstrated differential contributions of subcortical and cortical visuomotor pathways to trajectory modifications in response to changes in visual information. Such pathways might underlie the early grip force and late load force corrections observed by Danion and Sarlegna (2007). Future experiments that selectively inhibit visuomotor pathways during movement might provide more insight and clarification in this matter.

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