Differentiating serial cue prediction from motor sequence learning during long term skill training

Brighid Lynch, Alissa Ting, Sophia Whilemi, Daniel Marchetto,Timothy Verstynen
Department of Psychology & Center for the Neural Basis of Cognition, Carnegie Mellon University

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Background

Planning and execution of sequential actions requires the recruitment of many cognitive processes that are distributed across the brain (see Doyon et al. 2008). Over days and weeks of practice serially cued actions become "bound" or "chunked" together. Yet the representational level (i.e., cues or motoric responses) that this learning occurs on remains poorly understood.

Hypothesis

At long time scales of training, learning a serial order of cues will happen at a different rate than learning a serial order of motoric actions.

Methods

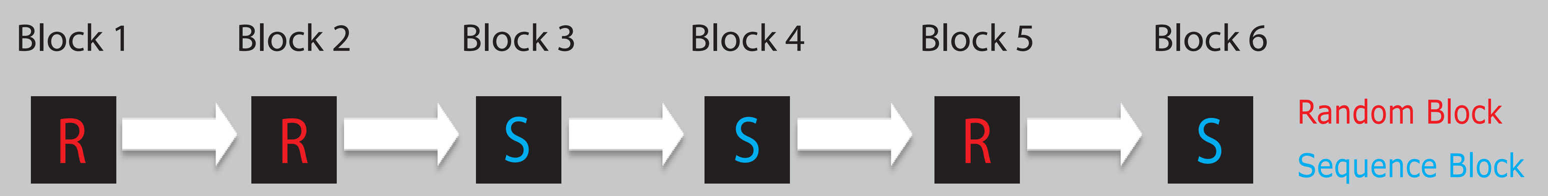
Participants

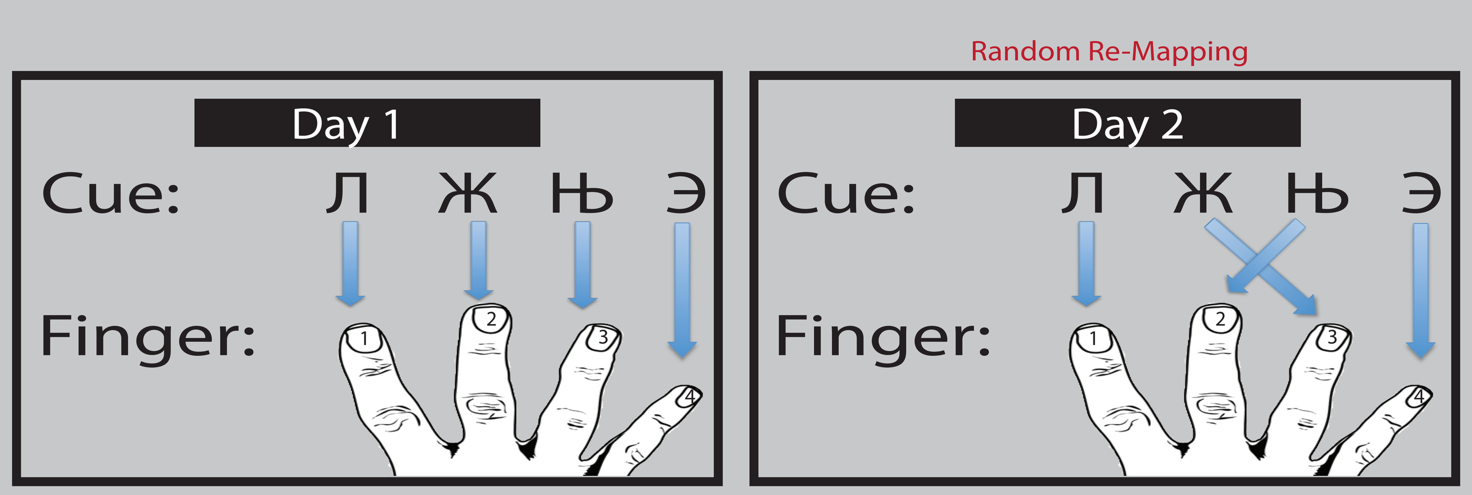
Healthy adults (N=47) were recruited via Carnegie Mellon University's paid participant website and all subjects were college aged adults. Two subjects dropped out leaving a total of 45 subjects, 15 in each testing group. All testing was approved by the local IRB.

Serial Reaction Time Task

On each trial, a centrally presented symbol (Cyrillic letters) cued subjects to press one of 4 keys on a keyboard with their right hand. On each day, the mapping from cue to key was pseudo-randomly assigned and subjects were trained to learn this new mapping. After two blocks (144 trials per block) of randomly ordered cues, subjects were trained on a hidden 12 item sequence for two blocks, followed by another random block and then a final sequence block.

Sequence : 1-4-2-3-1-3-2-4-1-2-3-4

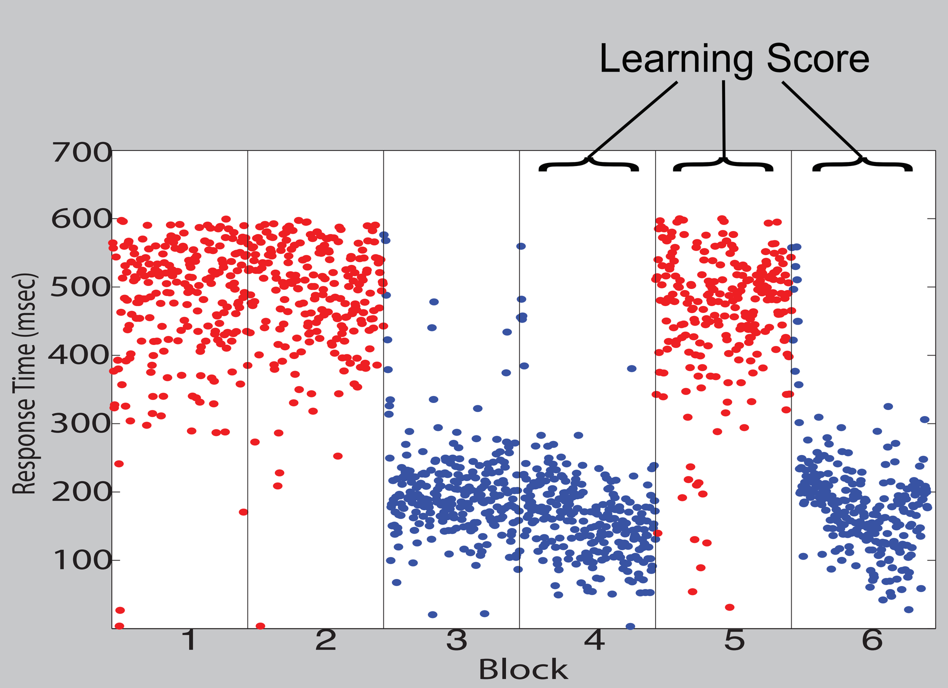




The Cue Group (N=15, 6 male): repeated sequence of visual cues over all 5 training days.

The Motoric group(N=15, 6 male): repeated sequence of motoric actions over all 5 training days.

The Control Group(N=15, 5 male): repeated sequence of actions & cues over all 5 training days.



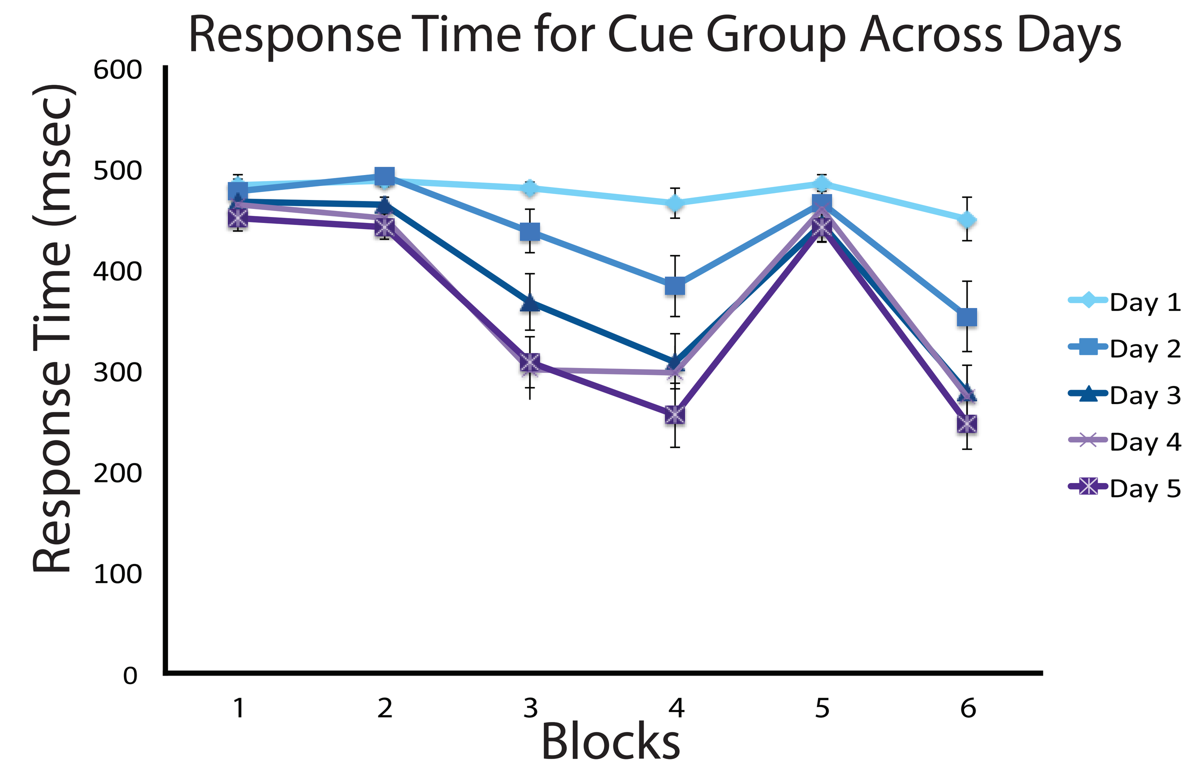
RT Learning Score

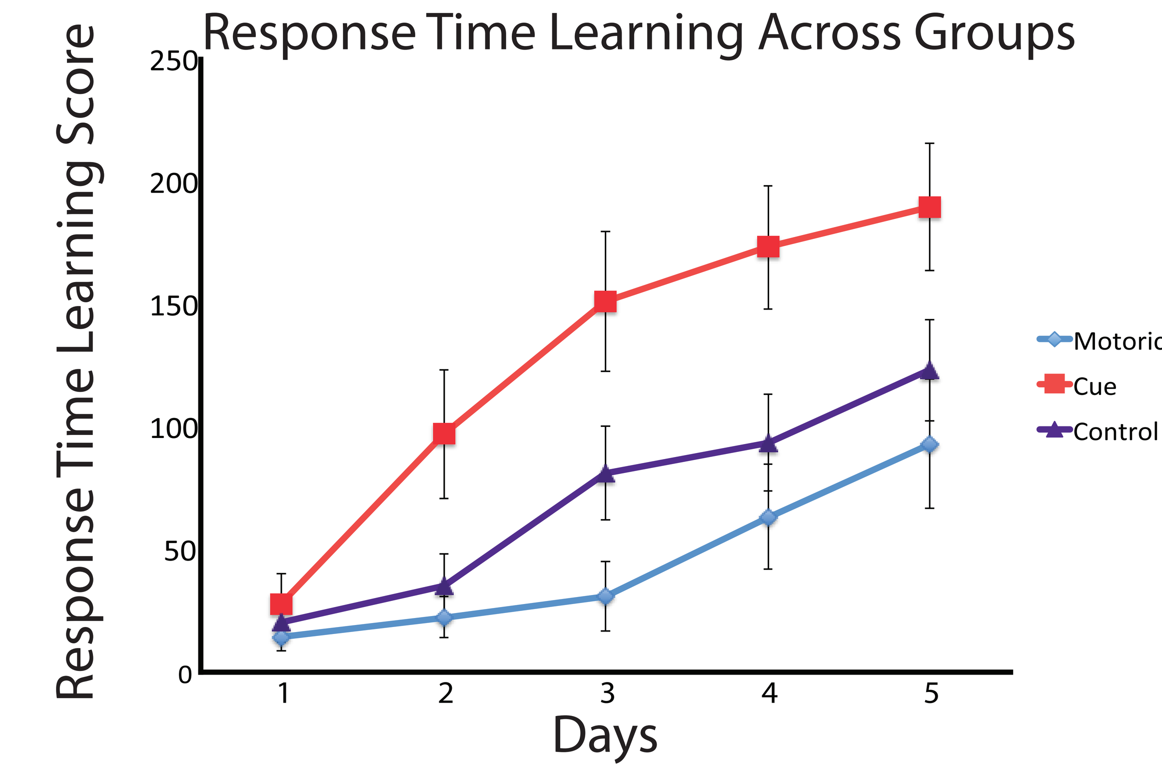
$$\mu_5^{Random} - \left(\mu_4^{Sequence} + \mu_6^{Sequence}\right)\Big/2$$

Accuracy Learning Score

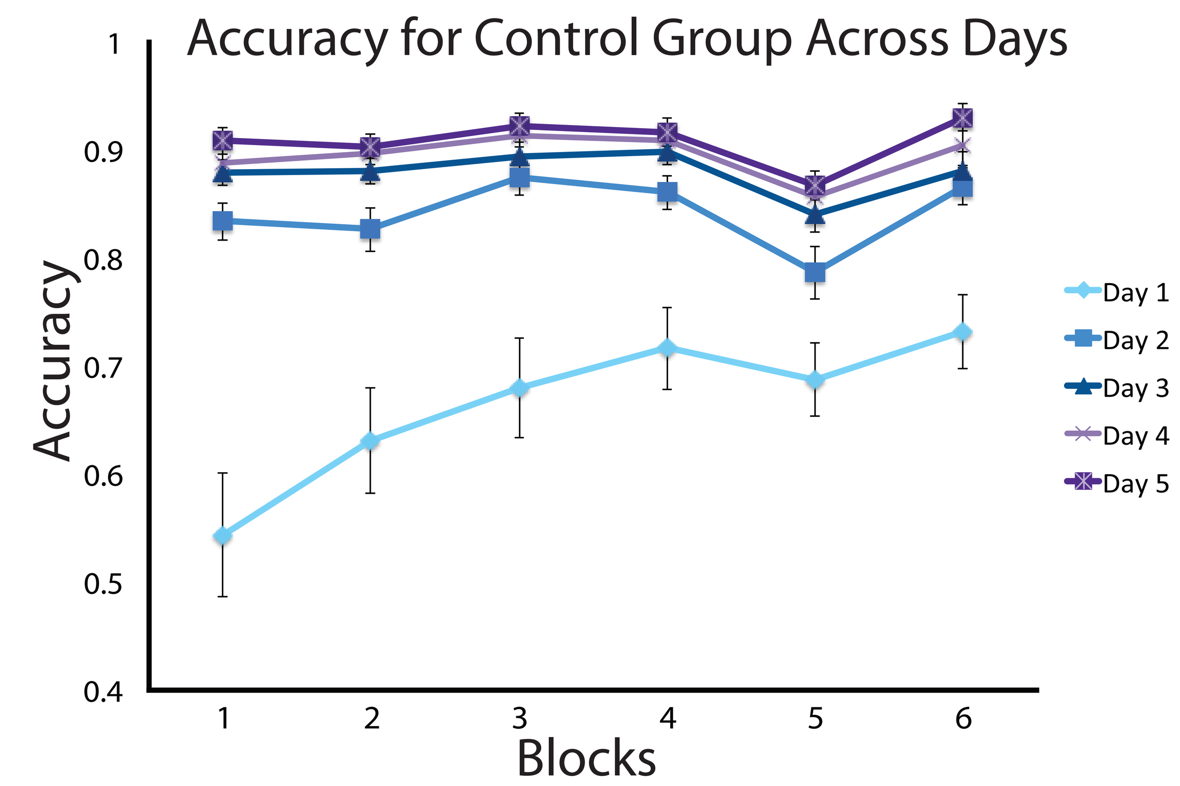
$$\left(\mu_4^{Sequence} + \mu_6^{Sequence}\right)\Big/2 - \mu_5^{Random}$$

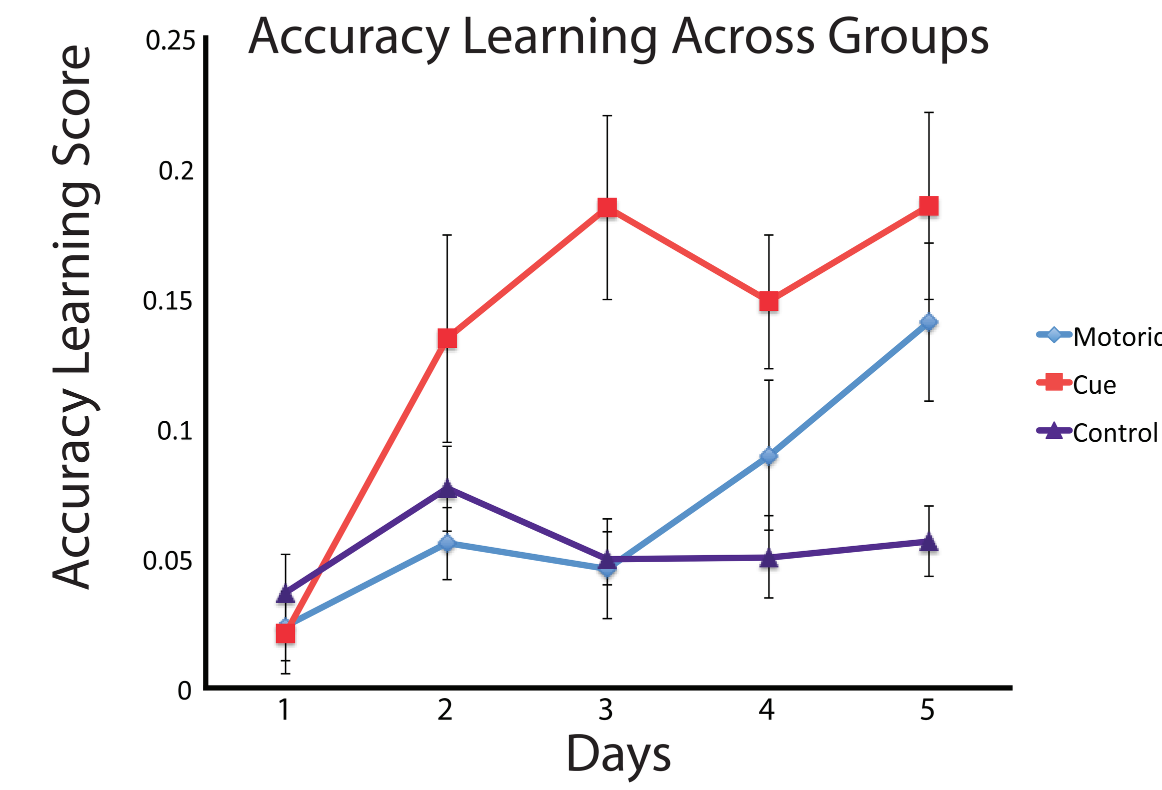
Response Time and Accuracy





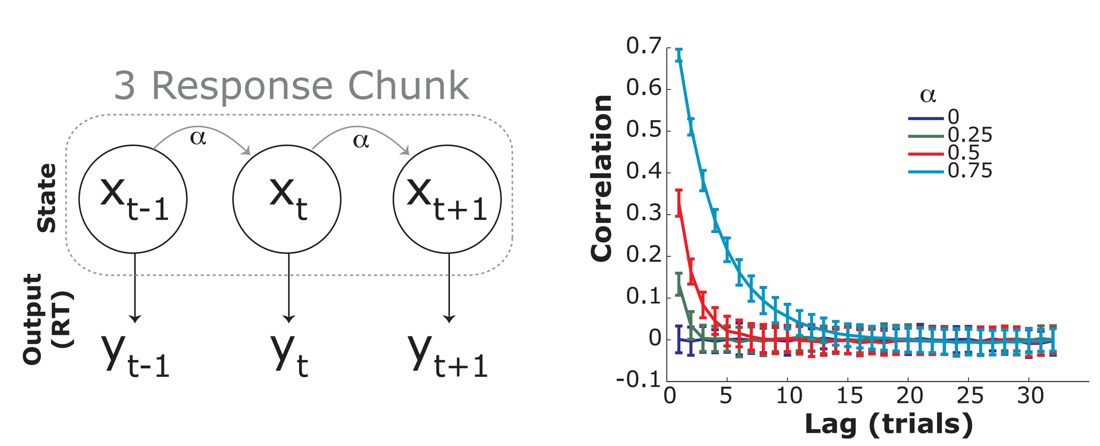
The Cue group showed more learning on response speeds across training (F(4,8)= 2.422, p=0.017) than both the Motoric and the Control groups.





Accuracy learning was also better in the Cue Group (F(4,8)=3.25, p=0.005).

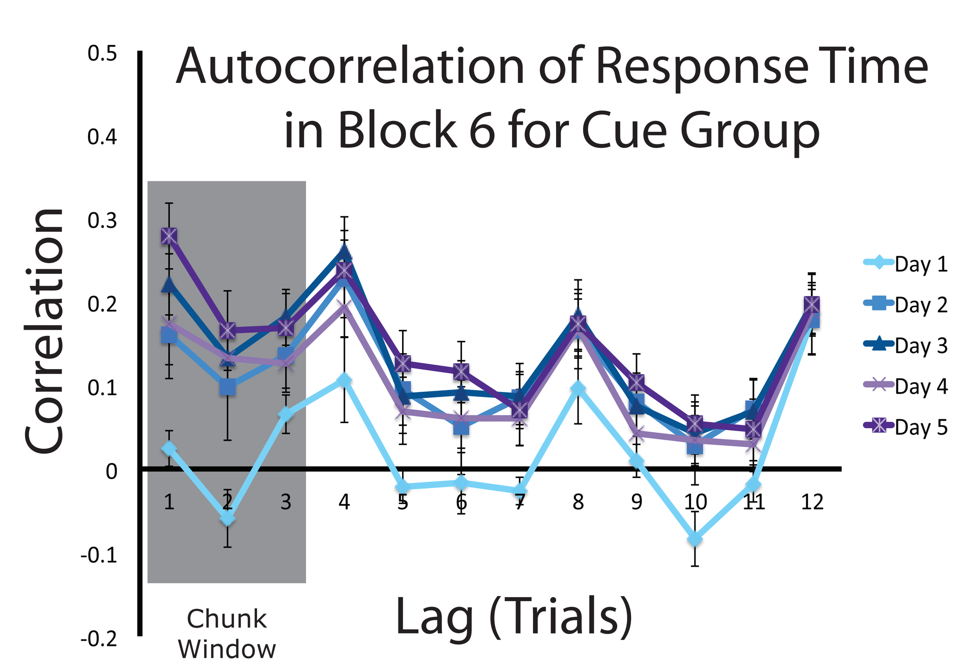
Response Binding Across Groups

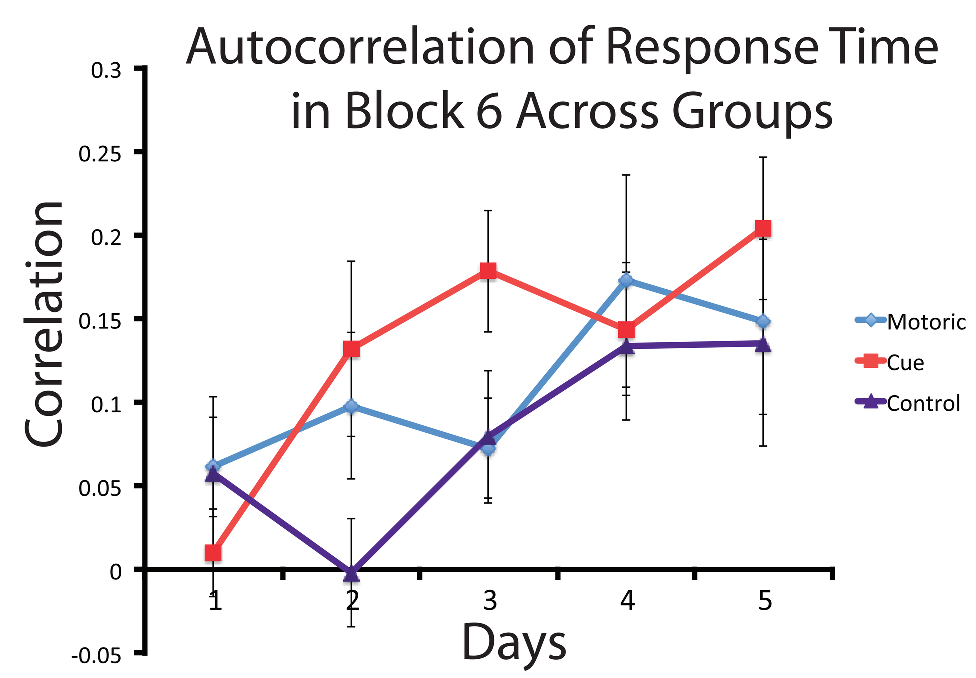


Before learning each response plan (X_t) is independent of temporally adjacent responses (X_{t-1} & X_{t+1}); however with training these responses become bound together to a certain degree (α). This causes the autocorrelation function to become non-zero for adjacent lags (see Verstynen et al. 2012).

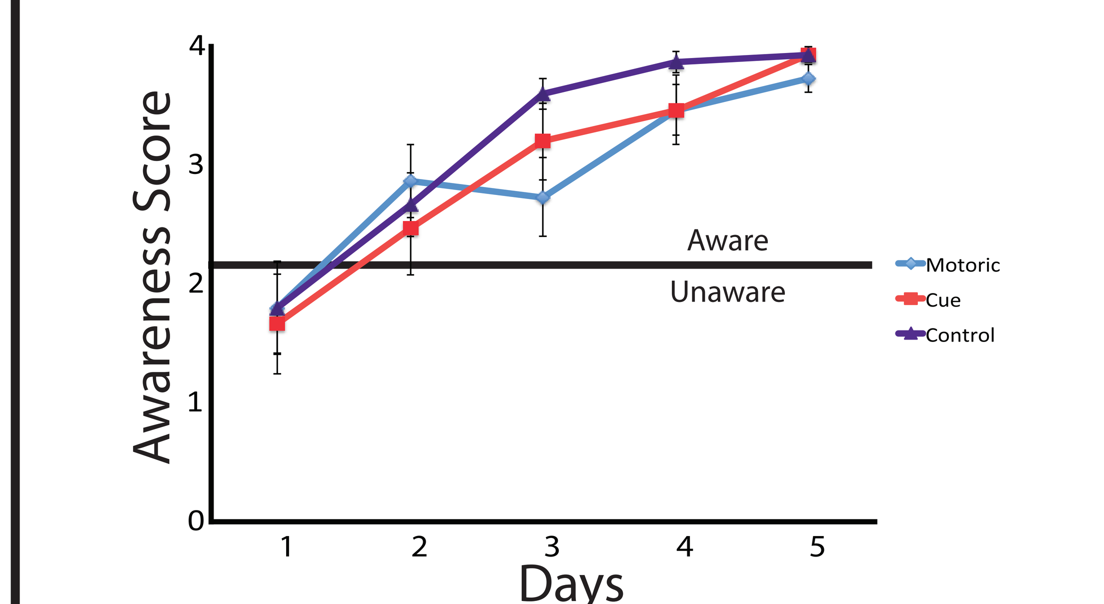
All subjects showed an increase in non-zero auto-correlations (for the first three lags) across training (F(4,8) = 5.59, p<0.001).

There was no effect of group in the degree of response chunking (F(4,8)=1.399, p=0.227).





Explicit Awareness of Pattern



Based on post-session questionnaires, all subjects became explicitly aware of the sequence at the same rate.

Conclusion

Learning a sequence of symbolic cues happens at a faster rate than learning a sequence of motoric actions.

The presence of the motoric sequence appears to interfere with cue seqeunce learning.

All groups appeared to bind their repsonses into local "chunks" at the same rate across the testing sessions.

References

1. Doyon, J. Motor sequence learning and movement disorders. Current opinion in neurology 21, 478-83 (2008).
2. Verstynen, Timothy, et al. "Dynamic sensorimotor planning during long-term sequence learning: the role of variability, response chunking and planning errors." PloS one 7.10 (2012): e47336.