Chapter 1

General Discussion

1.1 Summary of results

The work described throughout this thesis has centered around how prediction is used in sensory processes such as object recognition and prolonged learning. The work was heavily motivated by the LeabraTI (TI: Temporal Integration) framework (Chapter **??**) which leverages the laminocolumnar structure of the neocortex (Mountcastle, 1997; Buxhoeveden & Casanova, 2002; Horton & Adams, 2005) to learn to predict temporally structured sensory inputs. Predictive learning in the LeabraTI framework is made possible by temporally interleaving predictions and sensory processing across the same populations of neurons so that powerful error-driven learning mechanisms (O'Reilly & Munakata, 2000; O'Reilly, Munakata, Frank, Hazy, & Contributors, 2012) can be used to compute a prediction error that can be learned against to minimize the difference between predictions and sensory events over time.

LeabraTI relies on a 10 Hz prediction-sensation period as its core "clock cycle", suggested to correspond to the widely studied alpha rhythm observable across posterior cortex using scalp EEG (Palva & Palva, 2007; Hanslmayr, Gross, Klimesch, & Shapiro, 2011; VanRullen, Busch,

Drewes, & Dubois, 2011). Chapter **??** investigated the role of the alpha rhythm in prediction by using an entrainment paradigm (Schroeder, Lakatos, Kajikawa, Partan, & Puce, 2008; Calderone, Lakatos, Butler, & Castellanos, in press) in which stimuli were presented rhythmically at 10 Hz so that predictions and sensory information could be interleaved regularly at the optimal rate proposed by LeabraTI. The experiment made use of three-dimensional objects that required integration over multiple sequential views to extract their three-dimensional structure. Thus, relatively rapid predictive learning mechanisms that operate over subsequent 100 ms periods could be leveraged to optimally encode the the objects. The spatial coherence between views and temporal onset of each view were independently manipulated to determine their effect on stimulus encoding quality and the putative role of the alpha rhythm in predictive processing.

The results of the Chapter **??** experiment indicated that spatial coherence and predictable temporal onset of each stimulus in an entraining sequence enhanced discriminability of a subsequently presented probe stimulus. Temporal predictability of entrainers also speeded response times. EEG amplitude averaging indicated separable time courses for spatial and temporal prediction over posterior sites with temporal predictability always preceding the onset of stimuli and spatial predictability manifesting at the onset of stimuli and persisting for over 100 ms after in the case of the probe. Oscillatory analyses indicated strong bilateral alpha power and phase coherence modulation as a function of stimulus predictability. Specifically,

Right hemisphere sites exhibited superadditive effects of combined spatial and temporal probe predictability on EEG amplitude and 10 Hz phase coherence peaking 200 ms after probe onset. Exploratory analyses indicated that oscillatory effects in the lower frequency delta-theta (5 Hz) band, which has also been associated with predictive processing (Arnal & Giraud, 2012; Giraud & Poeppel, 2012) were similar to those in the alpha band, if not more prominent.

Given the

1.2 Outstanding issues

1.3 Conclusions

References

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