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Research Statement

The broad goal of my research program is to understand memory. Perhaps no other function of the cognitive system is as important as memory, nevertheless the basic processes underlying the human memory system are not yet fully understood. To best facilitate the development of a comprehensive and accurate model of memory, I focus on testing existing models with the goal of identifying the core assumptions and critical data necessary to model memory. Fully understanding memory requires the development of models that account for a range of tasks and a range of effects. A notable few such models have been developed (e.g., Anderson, Bothell, Byrne, Douglass, Lebiere, & Qin, 2004; Humphreys, Bain & Pike, 1989; Shiffrin & Steyvers, 1997). However, the majority of models are task specific, leaving a fractured landscape and preventing significant advances in theoretical development. I have adopted a multidisciplinary approach, spanning experimental psychology, gerontology, computational science, and cognitive neuroscience thus laying the groundwork for a unified mechanistic account of memory.

The role of differentiation as a critical mechanism of memory

One prominent area of my research has been to conduct a programmatic and thorough investigation of differentiation. Differentiation is the notion that the more that is known about an item, the less confusable that item is with other items. Specifically, the more accurate a given memory trace, the more likely that it will match its corresponding studied target (increasing the hit rate) and the less likely that it will match a non-studied foil (decreasing the false alarm rate). Accordingly, differentiation models are particularly well suited for describing the mechanism that underlies how practice and repetition improve memory. My research has aimed to systematically assess the empirical validity of the theoretical mechanism of differentiation.

The introduction of the differentiation models was revolutionary and allowed such models to account for data that no existing model could explain (Shiffrin & Steyvers, 1997 and McClelland & Chappell, 1998). Although the details of these models sometimes differ and in some cases the models make different predictions (Criss & McClelland, 2006), they share the core assumption of differentiation. The focus of my research has been the shared predictive power of differentiation. My initial strategy was to generate critical predictions from the differentiation models. Differentiation models predict an interaction between amount of practice for study items (e.g., total study time) and the similarity between targets and foils; predictions which were confirmed for both younger (Criss, 2006) and older adults (Criss, Aue, & Kilic, submitted). Having established that differentiation is a viable mechanism underlying memory, I conducted an extensive body of work comparing the empirical evidence for differentiation against a commonly accepted alternative, the criterion placement hypothesis. The criterion placement hypothesis predicts that the observed reduction in the false alarm rate is due to criterion placement rather than the reduced confusability of foils to stored memory traces resulting from differentiation. Evidence from multiple domains, including behavioral and neurophysiological measures, favors differentiation as a mechanistic account of memory. A sophisticated analysis of response time distributions (Criss, 2010), and of participant-generated distributions of subjective memory strength (Criss, 2009), supports differentiation. This line of research has stimulated active research exploring all sides of the debate (e.g., Starns, Ratcliff, & White, 2012; in press; Starns, White, & Ratcliff, 2010).

In addition to behavioral and modeling evidence, my research program has obtained neural signatures of differentiation with both functional magnetic resonance imaging (fMRI; Criss, Wheeler, & McClelland, under revision) and event-related potentials (ERPs; Hemmer, Criss, & Wyble, 2012). Both studies demonstrated that ERP components and brain regions sensitive to memory strength also show differences in their response to strong and weak foils whereas components and regions sensitive to criterion placement do not. In totality, my research has largely confirmed that the theoretical mechanism of differentiation is necessary to describe memory as evidenced in experiments using simple memory decisions, ratings of subjective memory strength, diffusion analysis of response time distributions, EEG, and fMRI.

Sources of interference in memory

Another focus of my research program has been evaluating what sources of information cause interference within and across memory tasks. Understanding the degree of interference caused by different sources of information is critical to theory development because memory is quite imperfect and models of memory must be able to accurately predict the source of this imperfection. Further, different models make different assumptions about what information does and does not cause interference in memory, therefore theoretical progress requires resolution of this debate. My research has established that information identifying the item and the surrounding contextual details both cause interference in a recognition memory task (i.e., *did you see this during study?*). More generally my research supports the class of item-noise models that assume item information (e.g., semantic, orthographic, etc.) is the principal source of interference. The amount of interference increases as the number of items similar to the test item increases during study (Criss & Shiffrin, 2004a) and during test (Criss, Malmberg, & Shiffrin, 2011; Malmberg, Criss, Gangwani, & Shiffrin, 2012) and as the similarity between contextual information at study and test increases (Criss & Shiffrin, 2004a; Klein, Shiffrin, & Criss 2007). Items with orthographically common features suffer more interference than items with orthographically distinct features and this interference can be mitigated by shifting encoding to semantic rather than orthographic features (Criss & Shiffrin, 2004b; Criss & Malmberg, 2008). The same factor that leads to this interference, e.g., shared information, can also benefit memory. For example, when the category of information being tested changes to a different category, there is a release from the interference that had been accumulating (Malmberg, Criss, Gangwani, & Shiffrin, 2012). This line of research has initiated substantial and productive empirical and theoretical debate regarding the merits of item-noise models (e.g., Dennis & Chapman, 2010; Dennis, Lee, & Kinnell, 2008; Kinnell & Dennis, 2011; 2012; Maguire, Humphreys, Dennis, & Lee, 2010; Neely & Tse, 2009).

The research just described, and indeed most literature in the field, focuses on measuring memory for individual items. Clearly, the world is much more complex than a series of individual items and the human memory system is quite capable of remembering these complexities. Toward the goal of advancing theoretical development to include more complex memoranda, I have conducted a systematic evaluation comparing memory for individual items to memory for associations between those very same items. The properties that cause interference in memory for single items differs from the properties that cause interference in memory for associations (Criss & Shiffrin, 2004c; Criss & Shiffrin, 2005; Criss, Aue, & Smith, 2011; Aue, Criss, & Fischetti, 2012). This line of research, funded by an NSF CAREER award suggests that models need to have more complex representations of stimuli to successfully account for memory. In a recently developed model, we describe how temporal information can be part of this complex representation (Howard, Shankar, Aue, & Criss, in revision) and used for forming associations between items (Kilic, Criss, & Howard, in press). Having gathered the necessary empirical data, we are now working on advancing a model that successfully accounts for both memory for items and memory for associations.

I have advanced empirical and theoretical accounts of memory by using the diverse approach of adopting multiple techniques. In particular, employing the sophisticated analysis of response time distributions (Criss, 2010) and fMRI data (Criss, Wheeler, & McClelland, under revision) to evaluate models of memory is a unique approach that has potential to revolutionize the field of memory. My research program will continue to provide the necessary foundational work for advancing a unified mechanistic account of memory.

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