TOPIC: Memory and Drift

Warning signals, receiver psychology and predator memory

Michael P.Speed

Animal Behaviour. Volume 60, Issue 3, September 2000, Pages 269-278

Abstract

This review identifies four receiver psychology perspectives that are likely to be important in the design and evolution of warning signals. Three of these perspectives (phobia, learning and prey recognition) have been studied in detail, and I include a brief review of recent work. The fourth, a memory perspective, has received little attention and is developed here. A memory perspective asks, 'how might warning signals function to reduce forgetting of avoidances between encounters?'. To answer this question I review data from psychology literature that describe important features of animal long-term memory. These data suggest that components of warning signals may function to reduce forgetting (and therefore increase memorability) by (1) preventing forgetting of learnt prey discriminations; (2) jogging the memories of forgetful predators; and (3) biasing forgetting in favour of prey avoidance when the warning signal of a defended aposematic species is copied by an edible Batesian mimic. A combination of a learning and a memory perspective suggests that the features of aposematic prey that accelerate avoidance learning may also be the features that decelerate forgetting processes. If correct, this would have important implications for the comprehension of signal design. Finally, I suggest that the cryptic appearance of an edible prey may decelerate predator learning and accelerate predator forgetting, to the benefit of the prey. In terms of learning and memory, crypsis may be an antisignal.

A Model for Stochastic Drift in Memory Strength to Account for Judgments of Learning.

Sikström, S., & Jönsson, F. (2005). A Model for Stochastic Drift in Memory Strength to Account for Judgments of Learning. Psychological Review, 112(4), 932–950.

Abstract

Previous research has shown that judgments of learning (JOLs) made immediately after encoding have a low correlation with actual cued-recall performance, whereas the correlation is high for delayed judgments. In this article, the authors propose a formal theory describing the stochastic drift of memory strength over the retention interval to account for the delayed-JOL effect. This is done by first decomposing the aggregated memory strength into exponential functions with slow and fast memory traces. The mean aggregated memory strength shows power-function forgetting curves. The **drift** of the memory strength is large for immediate JOLs (causing a low predictability) and weak for delayed JOLs (causing a high predictability). Consistent with empirical data, the model makes a novel prediction of JOL asymmetry, or that immediate weak JOLs are more predictive of future performance than are immediate strong JOLs. The JOL distributions for immediate and delayed JOLs are also accounted for.

A diffusion model analysis of adult age differences in episodic and semantic long-term memory retrieval.

Spaniol, J., Madden, D. J., & Voss, A. (2006). A diffusion model analysis of adult age differences in episodic and semantic long-term memory retrieval. Journal of Experimental Psychology: Learning, Memory, and Cognition, 32(1), 101–117.

Abstract

Two experiments investigated adult age differences in episodic and semantic long-term memory tasks, as a test of the hypothesis of specific age-related decline in context memory. Older adults were slower and exhibited lower episodic accuracy than younger adults. Fits of the diffusion model (R. Ratcliff, 1978) revealed age-related increases in nondecisional reaction time for both episodic and semantic retrieval. In Experiment 2, an age difference in boundary separation also indicated an age-related increase in conservative criterion setting. For episodic old-new recognition (Experiment 1) and source memory (Experiment 2), there was an age-related decrease in the quality of decision-driving information (drift rate). As predicted by the context-memory deficit hypothesis, there was no corresponding age-related decline in semantic drift rate.

Modeling the effects of payoff on response bias in a perceptual discrimination task: Bound-change, drift-rate-change, or two-stage-processing hypothesis

Adele Diederich & Jerome R. Busemeyer

Perception & Psychophysics volume 68, pages 194–207 (2006)

Abstract

Three hypotheses—the bound-change hypothesis, drift-rate-change hypothesis, and two-stage processing hypothesis—are proposed to account for data from a perceptual discrimination task in which three different response deadlines were involved and three different payoffs were presented prior to each individual trial. The aim of the present research was to show (1) how the three different hypotheses incorporate response biases into a sequential sampling decision process, (2) how payoffs and deadlines affect choice probabilities, and (3) the hypotheses' predictions of response times and choice probabilities. The two-stage-processing hypothesis gave the best account, especially for the choice probabilities, whereas the drift-rate-change hypothesis had problems predicting choice probabilities as a function of deadlines.

Individual differences in components of reaction time distributions and their relations to working memory and intelligence.

Schmiedek, F., Oberauer, K., Wilhelm, O., Süß, H.-M., & Wittmann, W. W. (2007). Individual differences in components of reaction time distributions and their relations to working memory and intelligence. Journal of Experimental Psychology: General, 136(3), 414–429.

Abstract

The authors bring together approaches from cognitive and individual differences psychology to model characteristics of reaction time distributions beyond measures of central tendency. Ex-Gaussian distributions and a diffusion model approach are used to describe individuals' reaction time data. The authors identified common latent factors for each of the 3 ex-Gaussian parameters and for 3 parameters central to the diffusion model using structural equation modeling for a battery of choice reaction tasks. These factors had differential relations to criterion constructs. Parameters reflecting the tail of the distribution (i.e., τ in the ex-Gaussian and **drift rate** in the diffusion model) were the strongest unique predictors of working memory, reasoning, and psychometric speed. Theories of controlled attention and binding are discussed as potential theoretical explanations.

Aging and emotional memory: Cognitive mechanisms underlying the positivity effect.

Spaniol, J., Voss, A., & Grady, C. L. (2008). Aging and emotional memory: Cognitive mechanisms underlying the positivity effect. Psychology and Aging, 23(4), 859–872.

Abstract

Younger adults tend to remember negative information better than positive or neutral information (negativity bias). The negativity bias is reduced in aging, with older adults

occasionally exhibiting superior memory for positive, as opposed to negative or neutral, information (positivity bias). Two experiments with younger (N = 24 in Experiment 1, N = 25 in Experiment 2; age range: 18?35 years) and older adults (N = 24 in both experiments; age range: 60?85 years) investigated the cognitive mechanisms responsible for age-related differences in recognition memory for emotional information. Results from diffusion model analyses (R. Ratcliff, 1978) indicated that the effects of valence on response bias were similar in both age groups but that Age × Valence interactions emerged in memory retrieval. Specifically, older adults experienced greater overall familiarity for positive items than younger adults. We interpret this finding in terms of an age-related increase in the accessibility of positive information in long-term memory.

"*Such a theory is provided by the diffusion model (e.g., Ratcliff, 1978; Ratcliff & McKoon, 2008; Ratcliff & Rouder, 1998; Ratcliff, Van Zandt, & McKoon, 1999). The basic assumptions of the diffusion model approach are that during a binary decision information accumulates continuously and that this accumulation of information can be described by a Wiener diffusion process. This Wiener diffusion process is characterized by a constant systematic component,* ***the so-called drift****, and by normally distributed random noise. The drift rate deter-mines the average slope of the information accumulation process, that is, the speed and direction of information accumulation. The assumption of random noise explains that repeated processing of the same stimulus – or the same type of stimulus – results in different response times, and sometimes in different (i.e., erroneous) responses. Most importantly, the diffusion model can explain the skew typ-ically found in empirical response time distributions* (Ratcliff, 2002)." (p.2)

Differentiation and response bias in episodic memory: Evidence from reaction time distributions.

Criss, A. H. (2010). Differentiation and response bias in episodic memory: Evidence from reaction time distributions. Journal of Experimental Psychology: Learning, Memory, and Cognition, 36(2), 484–499.

Abstract

In differentiation models, the processes of encoding and retrieval produce an increase in the distribution of memory strength for targets and a decrease in the distribution of memory strength for foils as the amount of encoding increases. This produces an increase in the hit rate and decrease in the false-alarm rate for a strongly encoded compared with a weakly encoded list, consistent with empirical data. Other models assume that the foil distribution is unaffected by encoding manipulations or the foil distribution increases as a function of target strength. They account for the empirical data by adopting a stricter criterion for strongly encoded lists relative to weakly encoded lists. The differentiation and criterion shift explanations have been difficult to discriminate with accuracy measures alone. In this article, reaction time distributions and accuracy measures are collected in a list-strength paradigm and in a response bias paradigm in which the proportion of test items that are targets is manipulated. Diffusion model analyses showed that encoding strength is primarily accounted for by changes in the rate of accumulation of evidence (i.e., drift rate) for both targets and foils and manipulating the proportion of targets is primarily accounted for by changes in response bias (i.e., starting point). The diffusion model analyses is interpreted in terms of predictions of the differentiation models in which subjective memory strength is mapped directly onto drift rate and criterion placement is mapped onto starting point. Criterion shift models require at least 2 types of shifts to account for these findings.

Effects of aging and IQ on item and associative memory.

Ratcliff, R., Thapar, A., & McKoon, G. (2011). Effects of aging and IQ on item and associative memory. Journal of Experimental Psychology: General, 140(3), 464–487.

Abstract

The effects of aging and IQ on performance were examined in 4 memory tasks: item recognition, associative recognition, cued recall, and free recall. For item and associative recognition, accuracy and the response time (RT) distributions for correct and error responses were explained by Ratcliff's (1978) diffusion model at the level of individual participants. The values of the components of processing identified by the model for the recognition tasks, as well as accuracy for cued and free recall, were compared across levels of IQ (ranging from 85 to 140) and age (college age, 60–74 years old, and 75–90 years old). **IQ had large effects on drift rate in recognition and recall performance**, except for the oldest participants with some measures near floor. Drift rates in the recognition tasks, accuracy in recall, and IQ all correlated strongly. However, there was a small decline in drift rates for item recognition and a large decline for associative recognition and cued recall accuracy (70%). In contrast, there were large effects of age on boundary separation and nondecision time (which correlated across tasks) but small effects of IQ. The implications of these results for single- and dual-process models of item recognition are discussed, and it is concluded that models that deal with both RTs and accuracy are subject to many more constraints than are models that deal with only one of these measures. Overall, the results of the study show a complicated but interpretable pattern of interactions that present important targets for modeling.

Diffusion model drift rates can be influenced by decision processes: An analysis of the strength-based mirror effect.

Starns, J. J., Ratcliff, R., & White, C. N. (2012). Diffusion model drift rates can be influenced by decision processes: An analysis of the strength-based mirror effect. Journal of Experimental Psychology: Learning, Memory, and Cognition, 38(5), 1137–1151.

Abstract

Improving memory for studied items (targets) often helps participants reject nonstudied items (lures), a pattern referred to as the strength-based mirror effect (SBME). Criss (2010) demonstrated the SBME in diffusion **model drift rates**; that is, the target drift rate was higher and the lure drift rate was lower for lists of words studied 5 times versus lists of words studied once. She interpreted the drift rate effect for lures as evidence for the differentiation process, whereby strong memory traces produce a poorer match to lure items than do weak memory traces. However, she noted that strength may have also affected a model parameter called the drift criterion—a participant-controlled decision parameter that defines the zero point in drift rate. We directly contrasted the differentiation and drift-criterion accounts by manipulating list strength either at both encoding and retrieval (which produces a differentiation difference in the studied traces) or at retrieval only (which equates differentiation from the study list but provides the opportunity to change decision processes based on strength). **Across 3 experiments, results showed that drift rates for lures were lower on strong tests than on weak tests, and this effect was observed even when strength was varied at retrieval alone.** Therefore, results provided evidence that the SBME is produced by changes in decision processes, not by differentiation of memory traces.

A novelty effect in phonetic drift of the native language

Charles B. Chang

Journal of Phonetics, Volume 41, Issue 6, November 2013, Pages 520-533

Abstract

Previous findings on adult second-language (L2) learners showed systematic phonetic changes in their production of the native language (L1) starting in the first weeks of L2 learning [Chang, C. B. (2012). Rapid and multifaceted effects of second-language learning on first-language speech production. Journal of Phonetics, 40, 249–268]. This "phonetic drift" of L1 production in novice L2 learners was consistent with reports of phonetic drift in advanced L2 learners; however, the fact that novice learners showed relatively pronounced drift was unexpected. To explore the hypothesis that this pattern is due to a novelty effect boosting the encoding and retrieval of elementary L2 experience, the current study compared the inexperienced learners analyzed previously (learners with no prior knowledge of the L2) to experienced learners enrolled in the same language program. In accordance with the hypothesis, experienced learners manifested less phonetic drift in their production of L1 stops and vowels than inexperienced learners, suggesting that progressive familiarization with an L2 leads to reduced phonetic drift at later stages of L2 experience. These findings contradict the assumption that L2 influence on the L1 is weakest at early stages of L2 learning and argue in favor of viewing the L1 and L2 both as dynamic systems undergoing continuous change.

Intonation in unaccompanied singing: Accuracy, drift, and a model of reference pitch memory

Matthias Maucha, Klaus Frielerb, and Simon Dixon

The Journal of the Acoustical Society of America 136, 401 (2014)

ABSTRACT

This paper presents a study on intonation and intonation drift in unaccompanied singing, and proposes a simple model of reference pitch memory that accounts for many of the effects observed. Singing experiments were conducted with 24 singers of varying ability under three conditions (Normal, Masked, Imagined). Over the duration of a recording, ∼50 s, a median absolute intonation drift of 11 cents was observed. While smaller than the median note error (19 cents), drift was significant in 22% of recordings. **Drift magnitude** did not correlate with other measures of singing accuracy, singing experience, or the presence of conditions tested. Furthermore, it is shown that neither a static intonation memory model nor a memoryless interval-based intonation model can account for the accuracy and drift behavior observed. The proposed causal model provides a better explanation as it treats the reference pitch as a changing latent variable.

Advancing Research on Cognitive Processes in Social and Personality Psychology: A Hierarchical Drift Diffusion Model Primer

David J. Johnson, Christopher J. Hopwood, Joseph Cesario

Journal of Social Psychology and Personality Science (May 2017). Volume 8 Issue 4

Abstract

We provide a primer on a hierarchical extension of the **drift diffusion model** (DDM). This formal model of decisions is frequently used in the cognitive sciences but infrequently used in social and personality research. Recent advances in model estimation have overcome issues that previously made the hierarchical DDM impractical to implement. Using examples from two paradigms, the first-person shooter task and the flash gambling task, we demonstrate that the hierarchical DDM can provide novel insights into cognitive processes underlying decisions. Finally, we compare the DDM to dual-process models of decision-making. We hope this primer will provide researchers a new tool for investigating psychological processes.

Testing the validity of conflict drift-diffusion models for use in estimating cognitive processes: A parameter-recovery study

Corey N. White, Mathieu Servant & Gordon D. Logan

Psychonomic Bulletin & Review, 29 March 2017. Volume 25, pages 286–301 (2018)

Abstract

Researchers and clinicians are interested in estimating individual differences in the ability to process conflicting information. Conflict processing is typically assessed by comparing behavioral measures like RTs or error rates from conflict tasks. However, these measures are hard to interpret because they can be influenced by additional processes like response caution or bias. This limitation can be circumvented by employing cognitive models to decompose behavioral data into components of underlying decision processes, providing better specificity for investigating individual differences. A new class of drift-diffusion models has been developed for conflict tasks, presenting a potential tool to improve analysis of individual differences in conflict processing. However, measures from these models have not been validated for use in experiments with limited data collection. The present study assessed the validity of these models with a parameter-recovery study to determine whether and under what circumstances the models provide valid measures of cognitive processing. Three models were tested: the dual-stage two-phase model (Hübner, Steinhauser, & Lehle, Psychological Review, 117(3), 759–784, 2010), the shrinking spotlight model (White, Ratcliff, & Starns, Cognitive Psychology, 63(4), 210–238, 2011), and the diffusion model for conflict tasks (Ulrich, Schröter, Leuthold, & Birngruber, Cogntive Psychology, 78, 148–174, 2015). The validity of the model parameters was assessed using different methods of fitting the data and different numbers of trials. The results show that each model has limitations in recovering valid parameters, but they can be mitigated by adding constraints to the model. Practical recommendations are provided for when and how each model can be used to analyze data and provide measures of processing in conflict tasks.

Drift in Neural Population Activity Causes Working Memory to Deteriorate Over Time

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Journal of Neuroscience 23 May 2018, 38 (21) 4859-4869

Abstract

Short-term memories are thought to be maintained in the form of sustained spiking activity in neural populations. Decreases in recall precision observed with increasing number of memorized items can be accounted for by a limit on total spiking activity, resulting in fewer spikes contributing to the representation of each individual item. Longer retention intervals likewise reduce recall precision, but it is unknown what changes in population activity produce this effect. One possibility is that spiking activity becomes attenuated over time, such that the same mechanism accounts for both effects of set size and retention duration. Alternatively, reduced performance may be caused by drift in the encoded value over time, without a decrease in overall spiking activity. Human participants of either sex performed a variable-delay cued recall task with a saccadic response, providing a precise measure of recall latency. Based on a spike integration model of decision making, if the effects of set size and retention duration are both caused by decreased spiking activity, we would predict a fixed relationship between recall precision and response latency across conditions. In contrast, the drift hypothesis predicts no systematic changes in latency with increasing delays. Our results show both an increase in latency with set size, and a decrease in response precision with longer delays within each set size, but no systematic increase in latency for increasing delay durations. These results were quantitatively reproduced by a

model based on a limited neural resource in which working memories drift rather than decay with time.

SIGNIFICANCE STATEMENT Rapid deterioration over seconds is a defining feature of short-term memory, but what mechanism drives this degradation of internal representations? Here, we extend a successful population coding model of working memory by introducing possible mechanisms of delay effects. **We show that a decay in neural signal over time predicts that the time required for memory retrieval will increase with delay, whereas a random drift in the stored value predicts no effect of delay on retrieval time.** Testing these predictions in a multi-item memory task with an eye movement response, we identified drift as a key mechanism of memory decline. These results provide evidence for a dynamic spiking basis for working memory, in contrast to recent proposals of activity-silent storage.

Diffusion modeling and intelligence: Drift rates show both domain-general and domain-specific relations with intelligence.

Lerche, V., von Krause, M., Voss, A., Frischkorn, G. T., Schubert, A.-L., & Hagemann, D. (2020). Diffusion modeling and intelligence: Drift rates show both domain-general and domain-specific relations with intelligence. Journal of Experimental Psychology: General, 149(12), 2207–2249.

Abstract

Several previous studies reported relationships between speed of information processing as measured with the drift parameter of the diffusion model (Ratcliff, 1978) and general intelligence. Most of these studies utilized only few tasks and none of them used more complex tasks. In contrast, our study (N = 125) was based on a large battery of 18 different response time tasks that varied both in content (numeric, figural, and verbal) and complexity (fast tasks with mean RTs of ca. 600 ms vs. more complex tasks with mean RTs of ca. 3,000 ms). Structural equation models indicated a strong relationship between a domain-general drift factor and general intelligence. Beyond that, domain-specific speed of information processing factors were closely related to the respective domain scores of the intelligence test. Furthermore, speed of information processing in the more complex tasks explained additional variance in general intelligence. In addition to these theoretically relevant findings, our study also makes methodological contributions showing that there are meaningful interindividual differences in content specific drift rates and that not only fast tasks, but also more complex tasks can be modeled with the diffusion model.