Cognitive Psychology 64 (2012) 1–34

Contents lists available at SciVerse ScienceDirect

Cognitive Psychology

journal homepage: www.elsevier.com/locate/cogpsych

Evaluating the unequal-variance and dual-process explanations of zROC slopes with response time data and the diffusion model

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A R T I C L E   I N F O

Article history:
Accepted 12 October 2011
Available online 11 November 2011

Keywords:
Recognition memory
Receiver operating characteristic (ROC)
Sequential sampling models
Signal detection models
Dual process theory

A B S T R A C T

We tested two explanations for why the slope of the z-transformed receiver operating characteristic (zROC) is less than 1 in recognition memory: the unequal-variance account (target evidence is more variable than lure evidence) and the dual-process account (responding reflects both a continuous familiarity process and a threshold recollection process). These accounts are typically implemented in signal detection models that do not make predictions for response time (RT) data. We tested them using RT data and the diffusion model. Participants completed multiple study/test blocks of an "old"/"new" recognition task with the proportion of targets and the test varying from block to block (.21, .32, .50, .68, or .79 targets). The same participants completed sessions with both speed-emphasis and accuracy-emphasis instructions. zROC slopes were below one for both speed and accuracy sessions, and they were slightly lower for speed. The extremely fast pace of the speed sessions (mean RT = 526) should have severely limited the role of the slower recollection process relative to the fast familiarity process. Thus, the slope results are not consistent with the idea that recollection is responsible for slopes below 1. The diffusion model was able to match the empirical zROC slopes and RT distributions when between-trial variability in memory evidence was greater for targets than for lures, but missed the zROC slopes when target and lure variability were constrained to be equal. Therefore, unequal variability in continuous evidence is supported by RT modeling in addition to signal detection modeling. Finally, we found that a

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doi:10.1016/j.cogpsych.2011.10.002

two-choice version of the RTCON model could not accommodate the RT distributions as successfully as the diffusion model.

1. Introduction

Even the simplest decisions take time to make, and a complete account of decision making cannot ignore this temporal dimension. In recognition memory experiments, for example, participants are asked to decide whether words were previously studied (“old”) or not (“new”). The resulting response time (RT) distributions show systematic changes in location and spread across experimental conditions and are invariably positively skewed in shape (Ratcliff & Murdock, 1976; Ratcliff & Smith, 2004; Ratcliff, Thapar, & McKoon, 2004). Unfortunately, recognition memory researchers have paid little attention to the rich information available in RT data; instead, theories of recognition are predominantly tested only in terms of the accuracy of memory decisions. The current work addresses a popular topic in recognition memory with the goal of showing what can be gained by considering RT in addition to accuracy.

1.1. Accuracy models and ROCs

In the early 1990s, Egan’s (1958) pioneering work on recognition memory receiver operating characteristics (ROCs) was revived as a method for testing memory theories (Ratcliff, McKoon, & Tindall, 1994; Ratcliff, Sheu, & Gronlund, 1992; Yonelinas, 1994). ROCs are plots of the hit rate (“old” responses to old items) against the false alarm rate (“old” responses to new items) across conditions in which response bias varies but memory evidence is constant. In many cases, the hit and false alarm rates are converted to *z*-scores, and the resulting function is called a zROC. This conversion often makes it easier to assess model predictions; for example, zROCs should be linear under the assumption that memory evidence is normally distributed.

zROC functions are usually based on confidence ratings, but they can also be formed from an “old”/”new” task in which bias is manipulated experimentally. In the current experiment, for example, we varied the proportion of targets on the test to produce different levels of bias. Specifically, participants studied multiple lists that were each followed by a 56-item “old”/”new” recognition test. Tests had either 12 (.21), 18 (.32), 28 (.50), 38 (.68), or 44 (.79) targets, and participants were informed of the target proportion after each study list just before they began the test list. To manipulate memory performance, we used high and low frequency words, and each study list included words studied once, twice, or four times.

Fig. 1 shows stereotypical zROC functions from a paradigm like our own, with the circles representing words studied once and the triangles representing words studied four times. Words studied four times should be more easily recognized than words studied once, leading to a higher hit rate in all of the conditions. Test lists with a low proportion of targets promote a bias to say “new,” leading to a low hit rate and a low false alarm rate (the leftmost points). As the proportion of targets increases, participants become more willing to say “old,” and the hit and false alarm rates increase for all item types. The displayed zROCs follow linear functions with slopes less than one, both of which are benchmark characteristics of zROCs from recognition experiments (Egan, 1958; Glanzer, Kim, Hilford, & Adams, 1999; Ratcliff et al., 1992, 1994; Wixted, 2007; Yonelinas & Parks, 2007).

zROC modeling has sustained a heated debate about the nature of memory evidence, with controversy focused on two models offering contrasting explanations for why zROC slopes are less than one (Wixted, 2007; Yonelinas & Parks, 2007). The unequal-variance signal detection (UVSD) model assumes that decisions are based on a single evidence variable, frequently conceptualized as the degree of match between a probe and memory traces (Clark & Gronlund, 1996; Dennis & Humphreys, 2001; Shiffrin & Steyvers, 1997). Match values are normally distributed for targets and lures, with a higher mean and greater variability for the target items (Cohen, Rotello, & Macmillan, 2008; Heathcote, 2003; Hirshman & Hostetter, 2000; Mickes, Wixted, & Wais, 2007). Participants establish a response crite-