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Can We Resolve Contradictions between Process Dissociation Models?

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Wainwright and Reingold (1996) presented equations for various versions of the process dissociation procedure that has been used to separate conscious and unconscious memory processes. In the present reply it is suggested that these equations, though helpful, may not capture some of the key theoretical possibilities that could help to resolve apparent contradictions and paradoxes in the empirical literature. Specifically, there could be an independence of *processes* that might be estimated to a sufficient degree of accuracy for some theoretical purposes despite a violation of the assumption of *stochastic* independence.

Wainwright and Reingold (1996) have done an important service by providing an expanded set of equations for variations of the process dissociation model. I will leave to others the question of whether the multinomial approach actually has the limitations that they say it does, as well as the question of whether all of the models that they examined actually remain viable. What I want to focus on instead is the continued need to judge models on all relevant theoretical grounds and not just on mathematical grounds. We must avoid adopting an approach in which the aim is to ''pick one'' of the many models that were provided. Instead, we must remain on the lookout for new resolutions of apparent contradictions in the empirical literature.

One important contradiction has to do with the independence versus dependence of the conscious (C) and unconscious (U) processes in memory. On one hand, studies such as that of Jacoby, Toth, and Yonelinas (1993) have demonstrated that a divided attention task alters C dramatically without changing the value of U. Cowan and Stadler (in press) evaluated a spectrum of models with varying amounts of overlap between C and U (ranging all the way from the exclusivity model to the redundancy model) and found that none of these models with a fixed amount of overlap could account for the divided attention results with the same parsimony as that exhibited by the independence model.

On the other hand, Curran and Hintzman (1995) showed that, for their data at least (using a word stem completion procedure, not recognition), the conscious and unconscious processes did not appear to exhibit stochastic independence. Across five experiments, their results showed impressive correlations between the baseline rate

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of stem completion for a particular item and the propensity of that item to seem familiar after a study exposure. There were also consistent correlations between that baseline rate for an item and the conscious recollection parameter, and between the U and C parameters for item means.

Perhaps these apparently contradictory findings can be resolved if we focus on the distinction between *stochastic independence,* which may not exist, and *process independence,* which may exist nevertheless. First, regarding stochastic dependence, it may be that certain items are more likely to elicit a feeling of familiarity, not only raising the baseline rate of responding for that item (or, for recognition experiments, leading to an inappropriate feeling of having seen the item in the experiment before) but also raising the magnitude of the boost in that feeling of familiarity resulting from a study exposure. Moreover, these same items that inspire a high familiarity might also be the ones that are most likely to be recollected consciously after they are presented. That is not stochastic independence.

Second, regarding process independence, there almost certainly are study condition manipulations that will affect the boost in familiarity without altering the baseline response rates, and there may well be attentional manipulations that affect conscious recollection without altering either the baseline rate or the feeling of familiarity. These can operate even without stochastic independence of the processes. To see why, consider the following analogy for the separation of U and C. In this analogy, a crowd of people is attempting to board a bus, but there is insufficient room for all of the people. Some people will be more aggressive than others, and that will influence which people actually board the bus. However, it need not influence how many people board the bus. The capacity of the bus can be determined independently of the aggressiveness of the potential boarders. To make the analogy explicit, the capacity of the bus is like the attentional condition and the different levels of aggressiveness of the potential boarders are like the different baseline rates of different items. To extend the analogy further, if someone is passing out coffee (representing a study exposure) while the crowd waits, this might increase the aggressiveness of people who are prone to aggression anyway more than it affects the relatively passive people; that is, there are larger familiarity effects for high-baseline items. This analogy is meant to suggest that there can be conditions that influence the level of recall even when there is stochastic dependence in the recall of particular items across conditions.

There still are important theoretical details to work out regarding this potential resolution of results. Curran and Hintzman (1995) claimed that stochastic dependence necessarily results in inappropriate estimates for at least one parameter in the original process dissociation model because the parameters are estimated with an assumption of stochastic independence. However, it is not clear that the estimates are inappropriate under all sets of assumptions. If the nature of item differences were to help determine *which* items are more likely to be familiar or to be consciously recollected, but other capacity limitations primarily were to determine *how many* items are familiar or consciously recollected, then it seems possible that the stochastic independence assumption could fail on technical grounds but nevertheless serve as a pragmatically adequate basis for comparing familiarity and recollection parameters across experimental conditions.

On the other hand, to say that stochastic independence is not critical in the estima-

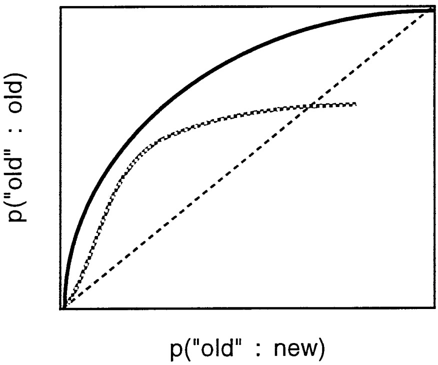

FIG. 1. A schematic depiction of ROC curves produced by the standard signal detection procedures (solid curve) and by the results of the process dissociation procedure as summarized by Yonelinas et al. (1995) (asymmetrical dashed curve). The straight dashed line represents a d' of 0. Not shown in the figure, the curves for the inclusion procedure are at a higher level than the curves for the exclusion procedure, though both take a similar asymmetrical form.

tion of memory parameters is not to say that it is without potential theoretical consequences. Consider the application of signal detection theory to the process dissociation procedure (e.g., Yonelinas, Regehr, & Jacoby, 1995). This method has been contrasted to other corrections for guessing on the basis of the form of the receiver operating characteristic (ROC) curves that are generated. These curves plot the proportion of trials in which the subject claimed to recognize an item that was actually new (false alarms) as a function of the proportion of trials in which the subject correctly recognized old items (hits) across various values of an experimentally controlled response bias. ROC curves generated by signal detection theory assumptions match the data far better than the curves generated by alternative corrections for guessing (Yonelinas et al., 1995; Banks & Prull, 1994). The empirical ROC curves and the curves predicted by signal detection theory both are strongly curvilinear, whereas several other corrections for guessing inappropriately yielded linear ROC curves. The unsuccessful models include two versions of a ''hits minus false alarms'' correction, as well as a correction in which guessing is independent from other processes (comparable, I should admit, to what was suggested by Cowan, 1995).

There is still room for varying interpretation, however. The ROC curves that should be generated according to a pure form of signal detection theory are symmetrical. A ''pure form'' means equal variances in the distribution of the amount of sensation (or in this case feeling of familiarity) resulting on each trial and a fixed amount of boost in the sensation caused by a signal presentation (or in this case a study exposure). However, the ROC curves for the process dissociation experiments were asymmetrical, as shown schematically by the dashed curve in Fig. 1. The account of this asymmetry offered by Yonelinas et al. (1995) was that the signal detection process is pure but applies only to familiarity, whereas the ROC curve is generated by this process along with the separate contribution of a conscious recollection process.

A slightly different interpretation is possible, however, and seems more consistent with the stochastic dependence of processes observed by Curran and Hintzman

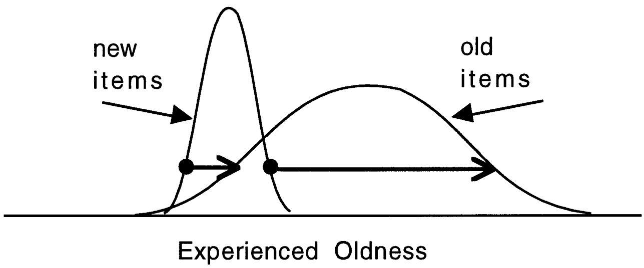

FIG. 2. A schematic depiction of a modified signal detection theory application in which the familiarity and recollection procedures both are said to contribute to ''experienced oldness'' and in which the distribution of this experienced oldness has a larger variance for old items than for new ones. In keeping with the findings of Curran and Hintzman (1995), the items that start high in the new item distribution receive a larger boost from study exposure.

(1995). In that interpretation, depicted in Fig. 2, the *x* axis of the signal detection process is not ''familiarity,'' but an experience of ''oldness'' of the item, which is meant to include both the familiarity and the recollection processes. If the items that elicit higher baseline feelings of familiarity on an a priori basis also are boosted the most in the study phase familiarity and recollection processes, then the result would be greater variance in the distribution of oldness for old items than for new items. This type of situation could account for the shape of the ROC curves that Yonelinas et al. observed, for reasons illustrated in Fig. 3. As the criterion for saying ''old'' shifts leftward from Point A to Point B, the proportion of hits increases with little increase in the proportion of false alarms. Then, as the criterion shifts leftward beyond Point B, there is a sudden surge in the proportion of false alarms. This biphasic curve matches what was observed empirically by Yonelinas et al. (1995) and Banks and Prull (1994). If the peaks of the curves were close enough together, one might even account for a crossing of the ROC curve below the diagonal (Yonelinas et al., 1995) because, following a study exposure, some of the lower items in the ''new item'' distribution would be mapped downward instead of upward onto the ''old item'' distribution.

I do not resolutely favor this alternative interpretation over the one that Yonelinas et al. (1995) provided. However, it does reconcile their findings with those of Curran

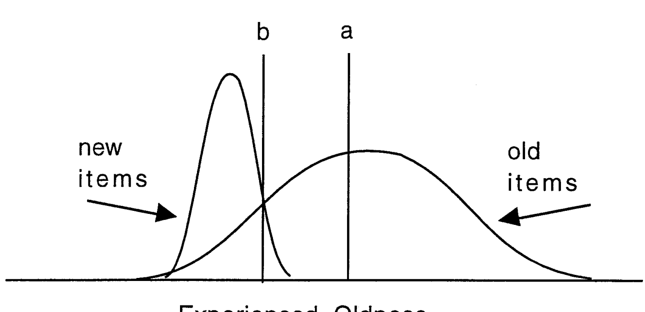

FIG. 3. The modified signal detection theory application of the previous figure with two criterion lines that help to illustrate how asymmetrical ROC curves could result.

and Hintzman (1995). It is important to determine which interpretation is correct because the d' estimates that Yonelinas et al. obtained were derived from a least squares model and would change if the underlying model changed.

Banks and Prull (1994) applied signal detection theory in a manner somewhat similar to what I have proposed, except that (a) they did not grapple with the unequal-variance issue, instead using a nonparametric sensitivity measure, and (b) they imposed a model with separate sensitivity values for conscious and unconscious memory. They obtained estimates of unconscious memory near zero, bringing into question the usefulness of the process dissociation approach. However, this result appears to conflict with what Yonelinas et al. (1995) obtained. It will be interesting to learn the basis of this apparent discrepancy.

The main thrust of the present commentary is not to question the assumption that there are functionally separate conscious recollection and unconscious familiarity processes in memory, but to examine the more constraining stochastic independence assumption and its ramifications. The intent is certainly not to impede the use of the process dissociation procedure, which is likely to play an important role in research in the near future. It is, however, a call for further methodological investigation, so that we will truly understand the procedure that we use. It seems likely that this intent is shared by Wainwright and Reingold (1996), Buchner, Erdfelder, and Vaterrodt-Plünnecke (1995), Currant and Hintzman (1995), Banks and Prull (1994), and many others.

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