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Process, Not Representation: Reply to Radvansky (1999)

John R. Anderson and Lynne M. Reder
Carnegie Mellon University

The size of fan effects is determined by processes at retrieval, not by whether or not information is represented as situations. Evidence contradicts G. A. Radvansky's (1999) claim that time to retrieve information from a situation does not depend on the number of elements in the situation. Moreover, Radvansky's principles for ascribing situational models to experiments appear to be post hoc ways of redescribing the data. On the other hand, the evidence does support the Adaptive Control of Thought—Rational (ACT–R) assumption that participants can adjust their attentional weightings and so produce differential fan effects. Moreover, the ACT–R theory of the fan effect is consistent with many other findings.

In our original article, we tried to show that the retrieval processes in Adaptive Control of Thought—Rational (ACT–R) provide a successful account of a wide range of phenomena surrounding the fan effect. One of these phenomena was the variation in the size of the fan effect for various concepts across experiments. We used some of Radvansky's data documenting the variation that can occur in the size of fan effects. Radvansky (1999) challenges our claim to have plausibly accounted for the impressive amount of data he has amassed and instead argues that they can be better accounted for by situation models. In this article, we argue that ACT–R provides both a more precise and a more plausible theory.

Like Radvansky, we believe that participants frequently set up rich representations of situations (e.g., Anderson & Reder, 1979). The issue is not between situational representations and ACT–R representations. As Radvansky notes in his article, ACT–R chunks could quite easily implement situational representations. The issue concerns the retrieval processes that operate on the representations, situational or otherwise. The data support the retrieval process in ACT–R. The ACT–R retrieval process could easily apply to situational representations, although we do not think that participants in Radvansky's experiments are creating the situational representations that he ascribes to them. In any case, the ACT–R retrieval model is neutral on this representational issue and does not, as Radvansky claims, "reduce the experimental situation to a paired-associate learning task." We next discuss the ACT–R retrieval assumptions and then Radvansky's assumptions.

John R. Anderson and Lynne M. Reder, Department of Psychology, Carnegie Mellon University.

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Correspondence concerning this article should be addressed to John R. Anderson, Department of Psychology, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213. Electronic mail may be sent to ja+@cmu.edu.

ACT–R Retrieval Theory

The following is a fairly succinct characterization of the ACT–R retrieval process:

1. On the basis of the concepts in the probe, some cues are selected with which to attempt retrieval. These are the *j*s in Equation 1 of our original article.

2. Attentional weights, W_j, are distributed to these concepts subject to the capacity constraint in Equation 4 of our original article. Activation will spread from the cues proportional to these weights.

3. The amount of activation going from cue *j* to cue *i* is proportional to the strength of association, S_{ji}, between *j* and *i*. According to Equation 2 of our original article, this strength will reflect the fan.

4. According to Equation 3 of our original article, latency to retrieve a chunk *i* is an exponential function of the amount of activation reaching chunk *i*.

Thus, the fan effect arises because the strengths of associations determine the amount of activation (Point 3). The fan effect of a particular concept can be modulated by attentional weighting (Point 2). The fundamental activation formula in ACT–R (Equation 1 in our original article), which combines weights and strengths, is a common formula in connectionist models (e.g., Rumelhart & McClelland, 1986). Under a logarithmic transformation, it is also equivalent to the familiarity equation in the Search of Associative Memory (SAM) model (Raaijmakers & Shiffrin, 1981). Thus, our basic retrieval process reflects a common understanding in cognitive science.

Radvansky claims that ACT–R assumes that concepts that have been given high attentional weights (W_j) are integrated in memory and those that have been given low weights are not integrated. This is simply not so, and his comments about ACT–R in the section titled "Organization" are incorrect. To reiterate, ACT–R's retrieval processes have no implications for the organization of the stored information in memory. The differential weights reflect differential attention at retrieval, and this occurs after the information has been organized during encoding.

We believe the ACT–R account because it explains so many phenomena from a single set of assumptions. Radvan-

sky notes that ACT has been used to explain reduced fan effects associated with extended practice, the min effect, plausibility judgments, and preexperimental associations. He implies that these are alternative explanations of the same phenomenon within the ACT theory, but this is simply wrong. These are among the many phenomena that are explained within the same framework.

His Table 2 reports the fit of the ACT–R model to a wide range of his experiments. We were extremely gratified by the high quality of the fits across so many experiments. Moreover, the *I*, *F*, and *S* parameters stay relatively constant across these experiments.[1] The *F* parameter varies the most, and, as we noted in Footnote 4 of our original article, the estimate of *F* should vary with factors such as amount of practice. We regard Table 2 as an unexpected triumph for the ACT–R theory.

It is clear that Radvansky does not view Table 2 in the same terms we do. He believes that there is something implausible about the fact that the relative weightings given to various concepts vary so much across experiments. He thinks that it is somehow implausible in the ACT–R theory that certain concepts should be given near-zero weightings. From our perspective, zero attentional weightings can be given very plausible interpretations; participants just are not attending to that concept at all. Any retrieval situation offers many potential cues (all of the various words in the sentence, along with many contextual cues), and any organism has to attend to some and ignore others. The attentional learning literature (Anderson, 1995) is full of situations in which one cue completely overshadows another.

Suppose a participant completely ignored (did not read) the concept. Would one expect its fan to have an effect on retrieval time? It is not clear what Radvansky's prediction would be, but the ACT–R model is committed to predicting no effect. This can be tested by not presenting one of the concepts from a sentence and looking at time to recognize the rest of the sentence. Anderson (1974) found no effect of the fan of the concept that was not presented, which is what ACT–R would predict.

Possible Retrieval Assumptions for Situation Theory

Radvansky does not really present a retrieval theory. In his commentary, he states that situation theory has "little to nothing to say about the process of memory retrieval." Elsewhere, Radvansky admits to a "primitive account of how mental models are retrieved" (Radvansky & Zacks, 1991, p. 947) and makes some assertions about the retrieval processes. Without retrieval assumptions, he cannot make predictions about a retrieval experiment. Although he is less than explicit, these are what we think are the two key assumptions behind his predictions:

1. On the basis of the concepts in the probe, a situation is retrieved. Somehow the retrieval process is slowed to the extent that there are multiple similar situations in memory. This is what produces the fan effect when one is obtained.

2. The retrieved situation is inspected to determine whether it contains the elements in the probe. This inspection time at most is only a little affected by the number of elements in the situation. This is what produces the lack of fan effect when the fan effect is not obtained.

These assumptions can be explained with respect to Radvansky's basic design, illustrated in Table 1. He manipulates, from one to three, the fan of one concept, which he takes as providing the means for organizing the information into a situation model, and almost orthogonally manipulates from one to three the fan of the other concept, which he takes to provide the elements of that situation. In the case of the high element fan (row 3 of Table 1), the elements will appear in multiple situations, making the situations more similar and harder to retrieve (Retrieval Step 1 just described). In the case of the high situation fan (column 3 of Table 1), all of the elements will be in the same situation, and time to inspect the situation will not be affected (Retrieval Step 2). Thus, an effect is predicted for the element fan but not the situation fan. It varies from experiment to experiment what constitutes the elements and what constitutes the situations.

We have little difficulty with the first retrieval assumption. This is basically an equivalent to the ACT–R mechanism for the fan effect. However, we have difficulty with the second assumption, that the time to inspect a situation is not much affected by the number of elements in the situation. Anderson (1976, Table 8.15) manipulated the number of arguments in a study proposition (e.g., *A janitor chased a cat in an office* vs. *A janitor chased a cat*) and looked at the time to recognize a subset of the arguments. Presumably, each studied proposition would be encoded in a single situation, and more arguments in the proposition mean more elements in that situation. In contrast to what Radvansky would predict, the time to recognize the same subset increased substantially with the number of arguments in the full proposition.

In Radvansky's own studies, he finds an effect of situation fan when the element fan is greater than 1 (e.g., contrasting cells 3–1 and 3–3 in Table 1). He prefers only to consider the situation fan when the element fan is 1 (i.e., contrasting cells 1–1 and 1–3) and sometimes does not report the other cells (which he considers fillers); at other times, he reports those data in appendixes. Thus, there can be strong effects of what Radvansky interprets as the number of elements in the situation. Under the ACT–R analysis, interactions such as these are to be expected because there will be a greater effect of any concept's fan when the fan of the other concepts in the probe is high. This was the min effect discussed in our original article.

Cause of Differential Effects

In summary, we do not find the retrieval assumptions implied by Radvansky to be supported by the facts. However, there remains the question of the source of the differential fan effects he obtains. The ACT–R explanation of the fan asymmetry in Radvansky's experiments turns on differential attention at the time of retrieval. In contrast, in

[1] These parameters do trade off in their estimates. We consider the constraints Radvansky sets on *S* as a good model-fitting practice and as not problematic.

Table 1
Radvansky's Basic Experiment Design

Element fan	Situation fan 1	2	3
1	1–1	1–2	1–3
2	2–1		2–3
3	3–1	3–2	3–3

Radvansky's account, the cause is the differential organization at study. We cited a number of studies that showed that the size of the fan effect can be influenced by conditions at retrieval. Radvansky counters that none of these studies show a differential fan effect. In his view, differential fan effect refers to a result in which different fan effects are obtained for different concepts. Thus, he concedes that retrieval conditions can produce different fan effects for the same material and participants but holds his result of differential fan effects as special. We can think of one manipulation at retrieval that has been shown to produce a differential fan effect. This is precuing with one of the concepts in the to-be-retrieved memory. Anderson (1974, Experiment 3) found a nonsignificant greater fan for the precued concept; King and Anderson (1976) found a highly significant greater fan for the nonprecued concept; and Radvansky and Zacks (1991) found a reduced fan with location cues. These effects are instances of the frustrating lack of consistency in differential fan effects. Later we elaborate further on this lack of consistency, but for now we simply note that retrieval manipulations can produce highly significant differential fan effects.

Radvansky assumes that fan effects are attenuated or not obtained for concepts that provide situational structures. The original Radvansky model, in which location served as situation and objects were elements in the location, had intuitive appeal when explained in these terms. However, Radvansky has subsequently found the reverse asymmetry, a large fan effect for the location (when occupied by people). To explain these results, he assumes that participants can organize situations by people. However, if participants can develop person-based and location-based organizations, it is not clear to us why they do not use both and so avoid his fan effects entirely. That is, if there are multiple people in a location, participants can organize this into a location-based situational model; if a person appears in multiple locations, they can organize this into a person-based situation model. Another peculiarity is that Radvansky, Spieler, and Zacks (1993) found no effect of using indefinite versus definite articles (i.e., no difference between *A lawyer is in a bank* and *The lawyer is in the bank*). Given the semantics of indefinite and definite articles, we would have expected a greater tendency to create a single situation in the case of definite articles.

The intuitive plausibility of the situation-based explanation varies from experiment to experiment in the Radvansky set. The explanation we find least plausible is the report by Radvansky, Wyer, Curiel, and Lutz (1997), who found a person-based organization when the verb *buy* was used but not when the verb *own* was used. We do not see why one cannot have a person-based organization in both cases.

Radvansky, Zwaan, Federico, and Franklin (1998) found reduced fan effects when the events could all occur at the same time but not when different times were involved. They claimed that participants will represent events happening at different times as parts of different situations. We find this a somewhat intuitive claim. However, in other cases, Radvansky claims one can organize a situation across times. For instance, Radvansky claims that this is what participants do in the case of people in small locations (and a person cannot be in multiple locations at the same time). There seem to be no a priori principles for predicting when participants will use time as a factor in selecting a situation model and when they will not.

Across all of the Radvansky experiments, a pattern is evident of postulating a situation-based organization whenever there is no fan effect and denying one whenever there is a fan effect. This strikes us as post hoc: There is no formal theory for predicting in advance when situation-based organizations will be used and when they will not. We are left with intuition. Sometimes we find Radvansky's claims intuitive and sometimes not. We find it hard to determine any consistent pattern in the explanations evoked over what is now a very large range of experiments. So the situation theory is not really an explanation, but just a way of redescribing whatever results are obtained. As we said in our original article, there is no converging evidence for the situation models assumed for Radvansky's various experiments. In response to this assertion, Radvansky cites studies of other researchers showing that participants sometimes use these kinds of situation models in other experiments. However, he has no converging evidence that participants in his experiments are using the situation models he ascribes to them.

If Radvansky's situational models do not offer an explanation, what is the explanation of the differential fan effects? Although ACT–R has an attentional mechanism that can produce differential fan effects, it does not explain why participants give more attention to some concepts than others. Looking over his materials, we noticed that many aspects of these materials were not well controlled. In our original article we commented on two features that varied across these experiments. First, it seemed that the items that showed larger fan effects were more concrete. As we noted in our original article, there is a long history of more concrete terms producing larger cuing effects. However, as Radvansky notes, this will not explain all of his results. We have also just completed an experiment with the person-location materials and failed to find a concreteness effect over the range of concreteness values found in his materials. Although we still suspect concreteness can have an effect, it does not seem to for his materials.

We were also struck by the fact that sometimes the items with larger fan effects had more words ("back room's tanning bed" vs. "lawyer"). The obvious way to represent such material in ACT–R would be to make each content word in one of these phrases a separate cue. Even if each cue were weighted equally, the total weight for these phrases

would be greater. For instance, we have done experiments in which we manipulated the fan of location, subject, and verb and found approximately equal fan effects (Anderson, 1976, Table 8.4). However, if two of these were treated as a single term in the analysis, we would have seen larger fan effects for that term because it is really two concepts.

Radvansky argues that not all of his results have such material problems. There is his unpublished doctoral dissertation, for example. Another experiment he points to is Radvansky et al. (1997), in which the use of *buy* versus *own* seemed to determine whether there was a person fan effect for the same individuals. As we noted earlier, we fail to find his situational models for this experiment plausible. Moreover, inspection of those data does not reveal such a strong pattern. With the verb *buy* (and the right types of objects: things that are found in drugstores), he claims there should be a fan effect for objects (objects associated with multiple people) but not a fan effect for people (person associated with multiple objects). Over the two experiments that satisfied these conditions, the fan effects were 271 ms for objects and 88 ms for people. Over the four experiments that did not satisfy his conditions (either because the verb was *own* or because the objects were not drugstore objects), the fan effects were 189 ms for objects and 121 ms for people. The relative size of the effects is different between the two classes of experiments, but we are more struck by their similarity. Everywhere it seems that people concepts show less of a fan effect. It is also striking that the sum of the two fan effects was not smaller in the conditions in which one of the fan effects was supposed to be eliminated ($271 + 88 = 359$ ms) than in the conditions in which neither was supposed to be eliminated ($189 + 121 = 310$ ms). ACT–R's attentional theory basically allows a constant fan effect to be distributed among the concepts in a probe. Attending to one concept will increase its fan effect but decrease the fan effect of the other concept because of decreased attention to it.

The relative size of fan effects for different concepts strikes us as a capricious variable, changing in unsystematic ways from experiment to experiment. It seems just the sort of effect that would be due to participant strategy and that is appropriately modeled in ACT–R by an attention allocation policy at retrieval. However, we do not pretend to have a priori principles for predicting which way it turns out in each of Radvansky's experiments. We do not think Radvansky has either.

Although the relative size of the fan effect is capricious, the existence of a fan effect is not. Every one of Radvansky's experiments has shown a fan effect. ACT–R is committed to the prediction of a fan effect in all of these experiments. Moreover, it is committed to a relative constancy of the overall size of these effects, reflected in the relative constancy of the F and S parameters. Radvansky's model is not committed to the prediction of a fan effect because a participant could, in principle, adopt different situational models to eliminate the fan for both concepts. Moreover, as we tried to document in our original article and have elaborated here, there are a host of other fan-effect phenomena predicted by ACT–R, including the new experiment that we report.

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