Journal of Experimental Psychology: General
1999, Vol. 128, No. 2, 198–206

0096-3445/99/$3.00

The Fan Effect: A Tale of Two Theories

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This article addresses J. R. Anderson and L. M. Reder's (1999) account of the differential fan effect reported by G. A. Radvansky, D. H. Spieler, and R. T. Zacks (1993). The differential fan effect is the finding of greater interference with an increased number of associations under some conditions, but not others, in a within-subjects mixed-list recognition test. Anderson and Reder concluded that the differential fan effects can be adequately explained by assuming differences in the weights given to concepts in long-term memory. When a broader range of data is considered, this account is less well supported. Instead, it is better to assume that the organization of information into referential representations, such as situation models, has a meaningful influence on long-term memory retrieval.

The fan effect (Anderson, 1974) is a classic finding in cognitive psychology. A *fan effect* is an increase in response time (or error rates, or both) on a recognition test with an increase in the number of associations with a concept in a memory probe. Simply put, the more things that are learned about a concept, the longer it takes to retrieve any one of those facts. The first demonstration of the fan effect was made by Anderson (1974) as part of a test of the adaptive control of thought (ACT) family of models (Anderson, 1976, 1983, 1993).[1] Anderson and Reder (1999) discussed two recent findings related to the fan effect that have been given alternative interpretations by people working outside of the ACT framework. The first is the absence or attenuation of the fan effect when a set of related facts can be easily interpreted as being consistent with a single situation and the presence of a standard fan effect when a set of related facts are not consistent with a situation. This finding, obtained by Radvansky, Spieler, and Zacks (1993), was called the *differential fan effect.* The second issue concerned retrieval and inhibition. I focus my discussion on the first issue; the second issue is discussed elsewhere (Radvansky, in press).

Differential Fan Effects

To review briefly, Radvansky et al. (1993) reported that when people memorized facts about objects in locations, such as "The potted palm is in the hotel," a differential fan effect was observed. A fan effect occurred for conditions in which a single object was in many locations, but not for conditions in which a single location had several objects in it. Furthermore, for sentences about people in small locations (that typically contain only one person), such as "The banker is in the phone booth," a differential fan effect was observed, but of the opposite character to the other effect: A fan effect occurred for conditions in which a single location had several people in it, but not for conditions in which a single person was in several locations.

The explanation given by Radvansky et al. (1993) was that people form situation models using the information in study sentences along with knowledge of how situations are structured in the world. A *situation model* is a representation that serves as a mental simulation of a real or fictional world (Johnson-Laird, 1983, 1989; Kintsch, 1998; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). In text comprehension, it is a representation of what the text is about rather than of the text itself (Glenberg, Meyer, & Lindem, 1987).

Situation models are multidimensional representations that capture the structure of situations as they exist in the world (Radvansky & Zacks, 1997; Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). This assumes that cognition has evolved to take advantage of regularities in the world to organize information (Shepard, 1984) and that situations have identifiable and exploitable regularities. For representing single events there is a spatial–temporal framework. Within this framework the entities in the situation (e.g., people, objects, ideas, etc.) are represented by tokens, perhaps with a set of associated properties (e.g., color, emotions, name, etc.). In addition, the relations among the entities (e.g., spatial, ownership, social, etc.) are represented. At a more global level is the representation of multiple events as episodes. At this level, the model is structured using linking relations (e.g., temporal, causal, or intentional) oriented around the various entities. For example, causal relations can be used to link events by means of a common

This article was written with partial support from a National Institutes of Health B/START grant (1RO3 MH56315-01). I thank Mike Anderson, Steve Boker, David Copeland, Jackie Curiel, Laura Carlson-Radvansky, Brad Gibson, Scott Maxwell, David Smith, and Rolf Zwaan for their helpful comments on earlier versions of this article.

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[1] The term *fan effect* refers to the number of associative links "fanning" off of a concept node in a network model, such as the ACT theory. As such, this is a theoretically loaded term. It would be better to use a more theoretically neutral way to describe this effect. One option would be to call it something like the *graded retrieval interference effect.*

entity, such as a story protagonist (Graesser, Singer, & Trabasso, 1994).

When people read a text, and they have sufficient time and motivation, they can create surface structure, propositional textbase, and situation model representations (Graesser, Millis, & Zwaan, 1997; Johnson-Laird, 1983; Kintsch, 1998; Schmalhofer & Glavanov, 1986; van Dijk & Kintsch, 1983; Zwaan, 1994; Zwaan & Radvansky, 1998). An analysis that excludes the situation model is unsatisfactory (Johnson-Laird, Herrmann, & Chaffin, 1984). If several pieces of information are consistent with the same situation, they can be integrated into one model (Ehrlich & Johnson-Laird, 1982). These models are then stored in long-term memory.

So, in Radvansky et al.'s (1993) experiments, when two or more sentences could be easily interpreted as referring to the same situation, people integrated them into a situation model. For object–location materials, the situation models were based on locations, because more than one object can fit into a location and the objects were unlikely to move from location to location. For person–small location materials, the situation models were based on a person in several locations and the locations were unlikely to contain more than one person at a time. These models are the primary basis for responding to memory probes during recognition. This integration of information reduced the fan effect because there were often no competing representations. A fan effect was clearly observed only when a concept was stored across several situation models, which could then interfere with one another during retrieval.

Anderson and Reder's Account

Anderson and Reder (1999) made five points about the ACT account of the differential fan effect. These are that (a) ACT can produce this pattern by changing the weights of concepts from the propositions, (b) meaningful differences among the concepts produce the different weightings, (c) ACT provides an understanding of the contribution of different concepts, (d) the effects of interest occur at retrieval, and (e) there is no converging evidence for the situation model view. Each point is considered in turn using a broader set of data as defined below.

Data Sets

For this analysis, I include studies that permit a test of differential fan effects and meet the following criteria: (a) there were two concepts in the study sentences whose fan was varied, (b) the first concept was held at Fan 1 and the fan of the second concept varied, and (c) the second concept was held at Fan 1 and the fan of the first varied. Criteria B and C provide a direct comparison between single- and multiple-situation model conditions. Studies that meet these criteria are listed in Table 1.[2] Using these criteria restricts us to Anderson's original study and my own studies. One cause for the exclusion of other studies is that many researchers did not hold one concept at Fan 1 while varying the fan of the other because of a suggestion that this might reduce the size of the fan effect (Anderson, 1976). However, as is apparent from my results, clear fan effects were observed under these conditions.

The experiments listed in Table 1 are divided into two classes: those in which a differential fan effect was observed (the Condition × Fan interaction was significant) and those in which similar fan effects were observed in both conditions (the Condition × Fan interaction was not significant). In the table, *high fan* refers to the condition in which the fan effect was clearly present, and *low fan* refers to the condition in which the fan effect was smaller than the high-fan condition. This effect was often absent or only nominally present.

Differential Fan Effects

In this set, *object–location* refers to sentences about objects in locations, such as "The potted palm is in the hotel."[3] Experiments 1 and 2 of Radvansky et al. (1993) were modeled by Anderson and Reder (1999). *Person–small location* refers to sentences about people in locations that typically contain only one person, such as "The banker is in the telephone booth." Experiments 5 and 6 of Radvansky et al. (1993) also were modeled by Anderson and Reder (1999).[4] *Ownership* refers to a study by Radvansky, Wyer, Curiel, and Lutz (1997) with sentences about people buying objects, such as "The lawyer is buying the magazine." For Experiments 1 and 6, the sentences referred to a specific event, and the objects could all be purchased in a similar location. Finally, the *temporal* set refers to a study by Radvansky, Zwaan, Federico, and Franklin (1998) of temporal relations.[5]

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[2] Many of these are recently published data; therefore it is not surprising that Anderson and Reder (1999) did not consider them. Also, because the nature of the materials clearly has an influence on the observed data, readers are cautioned against taking the relatively simple-minded step of averaging across materials and ignoring potentially important aspects of each experiment.

[3] Radvansky and Zacks's (1988) experiment was from my first-year project in graduate school. It was not reported in Radvansky and Zacks (1991) because it showed the same effects, but it lacked the concept-ordering manipulation and so was left out to conserve journal space. The Radvansky, Zacks, and Spieler (1991) experiment was part of an exploratory investigation of how the intertrial relations among sentences are related to the fan effect.

[4] The Radvansky (1995) experiment includes data from Radvansky (1992) as well as subsequently collected data.

[5] In Experiment 1, the sentences were about a person performing an activity during an event, such as "The doctor was adjusting his tie when the phone rang." A different person concept was used in each sentence, so the person concepts do not factor into the different fan effects. In one condition a single event had several activities occurring during it. In the other, a single activity was done during different events. In Experiment 2 the sentences were about people performing one or three activities, such as "The writer was stirring the soup." The critical manipulation involved the verb tenses when there were three activities. In one case the verb tense was always the same (low fan), whereas in the other a different verb tense (high fan) was used for each activity. The activities were such that multiple activities could be done by a person at the same time (e.g., "stirring the soup," "smiling," and

Table 1
Data for Experiments Showing Differential Fan Effects

		Studied						Nonstudied					
		Low fan			High fan			Low fan			High fan		
Experiment (Exp.)	N	1	2	3	1	2	3	1	2	3	1	2	3
Differential fan effects													
Location–object													
Radvansky & Zacks (1988)[a,b]	32	1,670	1,613	1,533	1,670	1,766	1,762	1,654	1,668	1,687	1,654	1,963	1,897
Radvansky & Zacks (1991), Exp. 1[a,b]	32	1,536	1,623	1,608	1,536	1,787	1,755	1,672	1,728	1,772	1,672	2,087	2,050
Radvansky & Zacks (1991), Exp. 2[a,b]	72	1,513	1,484	1,534	1,513	1,657	1,775	1,562	1,626	1,636	1,562	1,842	2,021
Radvansky & Zacks (1991), Exp. 3[a,b,c]	72	1,443	1,414	1,388	1,443	1,509	1,624	1,536	1,550	1,544	1,536	1,639	1,797
Radvansky et al. (1991)	32	1,466	1,379	1,365	1,421	1,592	1,772	1,536	1,508	1,584	1,532	1,801	1,927
Radvansky et al. (1993), Exp. 1	48	1,424	1,502	1,477	1,393	1,550	1,706	1,506	1,621	1,630	1,489	1,864	1,973
Radvansky et al. (1993), Exp. 2	48	1,389	1,426	1,386	1,433	1,462	1,574	1,505	1,604	1,539	1,512	1,698	1,952
Radvansky et al. (1996), Exp. 1[d]	28	1,558	1,524	1,552	1,541	1,796	1,780	1,660	1,709	1,646	1,706	1,944	2,129
Radvansky et al. (1996), Exp. 2[d]	32	1,346	1,390	1,344	1,387	1,531	1,687	1,443	1,506	1,484	1,494	1,698	2,018
Radvansky et al. (1996), Exp. 3[d]	32	1,578	1,632	1,573	1,550	1,627	1,594	1,650	1,623	1,598	1,560	1,765	1,851
Radvansky (1998), Exp. 1	48	1,565	1,581	1,530	1,531	1,671	1,748	1,584	1,631	1,669	1,571	1,832	1,917
Radvansky (in press), Exp. 1[e]	71	1,527	1,554	1,533	1,517	1,747	1,765	1,652	1,808	1,737	1,691	1,932	1,978
Radvansky (in press), Exp. 2[e]	48	1,387	1,347	1,502	1,316	1,469	1,659	1,513	1,621	1,696	1,534	1,691	1,879
Radvansky (in press), Exp. 3	48	1,327	1,357	1,433	1,367	1,464	1,489	1,577	1,583	1,647	1,465	1,699	1,847
Person–small location													
Radvansky et al. (1993), Exp. 5	24	1,370	1,383	1,358	1,284	1,406	1,579	1,431	1,512	1,510	1,449	1,686	2,003
Radvansky et al. (1993), Exp. 6	24	1,605	1,617	1,536	1,614	1,646	1,745	1,643	1,764	1,727	1,646	1,942	2,025
Radvansky (1998), Exp. 2	48	1,631	1,681	1,623	1,622	1,731	1,907	1,638	1,605	1,669	1,683	1,889	2,022
Radvansky (1995)[c]	89	1,522	1,639	1,576	1,533	1,656	1,720	1,596	1,774	1,693	1,605	1,811	1,926
Ownership													
Radvansky et al. (1997), Exp. 1	72	1,498	1,522	1,526	1,478	1,600	1,663	1,566	1,665	1,702	1,567	1,807	1,933
Radvansky et al. (1997), Exp. 6	72	1,436	1,454	1,465	1,413	1,529	1,588	1,520	1,640	1,678	1,480	1,756	1,839
Temporal													
Radvansky et al. (1998), Exp. 1	48	2,066	2,086	2,099	2,054	2,136	2,349	2,079	2,173	2,175	2,096	2,235	2,308
Radvansky et al. (1998), Exp. 2[b]	24	1,429		1,488	1,429		1,571	1,548		1,602	1,548		1,599
Radvansky et al. (1998), Exp. 3	24	1,667		1,684	1,633		1,839	1,711		1,755	1,668		1,875
Similar fan effects													
Person–location													
Anderson (1974), Exp. 1[b]	18	1,178	1,241	1,268	1,178	1,278	1,191	1,256	1,271	1,316	1,256	1,335	1,361
Anderson (1974), Exp. 2[b]	18	1,025	1,068	1,075	1,025	1,034	1,071	1,114	1,111	1,151	1,114	1,128	1,138
Anderson (1974), Exp. 3[b,c]	27	1,231	1,312	1,406	1,231	1,335	1,282	1,314	1,376	1,424	1,314	1,407	1,403
Radvansky et al. (1993), Exp. 3	24	1,204	1,418	1,427	1,292	1,427	1,512	1,396	1,572	1,553	1,478	1,683	1,859
Radvansky et al. (1993), Exp. 4	48	1,349	1,487	1,398	1,320	1,405	1,492	1,474	1,640	1,604	1,463	1,653	1,953
Ownership													
Radvansky et al. (1997), Exp. 2	72	1,260	1,298	1,348	1,297	1,351	1,404	1,430	1,492	1,526	1,427	1,579	1,618
Radvansky et al. (1997), Exp. 3	72	1,340	1,415	1,463	1,337	1,419	1,445	1,453	1,570	1,563	1,419	1,572	1,744
Radvansky et al. (1997), Exp. 4	72	1,297	1,364	1,445	1,387	1,470	1,501	1,436	1,524	1,642	1,475	1,699	1,698
Radvansky et al. (1997), Exp. 5	48	1,528	1,552	1,643	1,511	1,603	1,716	1,609	1,705	1,688	1,604	1,604	1,846

[a]Fan Level 4 was in the experiment but is not presented here. [b]Fan 1 cell data not divided up into fan and no fan. [c]Neutral precue only. [d]Young participants only. [e]Inhibition target trials not included.

There are some nominal fan effects in the low-fan condition (all but one of these are not significant). The point of the differential fan effect is the substantial difference in the size of the fan effects in the two conditions, not that no fan effect is observed in one condition. Why is there a small amount of interference in these conditions? There are a number of possibilities, including an internal search of a model with response time increasing with greater complexity, or the suppression of a model by related items on the previous trial (Radvansky, in press). Also, some people may not have completely integrated the information or may have used idiosyncratic organizations, and so the information would be stored in separate models that for most people would be stored together. Finally, some people may have had difficulty determining how information in the study sentences related to specific situations (e.g., Radvansky et al., 1997, 1998). There was likely some contribution of each

"checking the time"). Finally, in Experiment 3 the sentences had people associated with either one or three activities. The critical manipulation was whether the activities were from a set of either integratable activities (from Experiment 2; low fan) or from a set of activities that a person is unlikely to do at the same time (e.g., raking the leaves, swimming a lap, and bathing a baby; high fan).

of these factors, and any responsible account of this interference should include a consideration of them. Nevertheless, in the low-fan conditions the observed interference is substantially smaller than in the high-fan condition, with the Condition × Fan interaction being significant.

Similar Fan Effects

For this set, person–location sentences were about people in large locations, such as "The hippie is in the park." This includes Anderson's (1974) article, as well as Experiments 3 and 4 of Radvansky et al. (1993). Anderson and Reder (1999) interpreted Radvansky et al.'s data as showing a person-based organization. I am more conservative and interpret them as not showing strong evidence of any organization. The ownership sentences are similar to those in the differential fan effect sets above except that they convey simple ownership (Experiment 3), as in "The lawyer owns the magazine"; the objects were common ones that people own, such as houses, cars, and microwaves (Experiments 2 and 5); or both (Experiment 4).

Concept Weights

For Anderson and Reder (1999), the ACT model produces the differential fan effect by varying the weights of concepts, with the constraint that their sum is a predetermined value (0.67 for Anderson & Reder). In short, smaller weights lead to smaller fan effects. The mechanics of why this is so are provided by Anderson and Reder. This approach reduces the experimental situation to a paired-associate learning task and is the sixth in a series of explanations for reduced fan effects. The earlier explanations include extended practice (Pirolli & Anderson, 1985), the min effect (Anderson, 1976), "theme" nodes (Anderson, 1976), plausibility judgments (Reder & Anderson, 1980), and pre-experimental associations (Jones & Anderson, 1987).

To test the weight change idea, the ACT model was fit to the data listed in Table 1 by means of the parameter setting method used by Anderson and Reder (1999). These estimated parameters are listed in Table 2. In the initial fit, some estimates required negative association strengths between studied concept pairs. Within ACT–R (*R* meaning "rational"), a positive value corresponds to an association, whereas a negative value corresponds to a dissociation (Anderson, 1993). Thus, some of the suggested values corresponded to the unlikely possibility that concepts that had been studied together were dissociated in memory. Therefore, I recomputed estimates with the added constraint that associations between concepts could not be lower than 0.1 (a seemingly reasonable low positive value). Estimates affected by this constraint are marked with a superscript *a*.

The R^2 values gauge the correspondence between the data and the ACT-R predictions. These range from .70 to .97. The R^2_{equal} values correspond to the fit if concept weights are not allowed to vary; this provides a sense of how much of an influence varying concept weights have.

Inspection of Table 2 reveals some disturbing patterns. Although some concept weights have reasonable values, many are of a surprisingly low magnitude. For nearly two thirds of the differential fan effect experiments, the weight of the low-fan concept is .11 or less; that is, the attention allocated to one concept is 5 times or more as great as that allocated to the other. For nearly one third of the differential fan effect experiments, the low-fan concept weight is zero. Is this plausible? This would mean that people who are exposed to a concept in a sentence over and over again did not give it any weight but are focusing only on the other concept. If so, how could a person function at retrieval? Information about both concepts is needed to determine above chance whether a memory probe was a studied or nonstudied item. The two concepts are not redundant. As such, why would such a large discrepancy between concept weights occur?

Varying concept weights allows the ACT model to generate data that approximate those obtained in the experiments, but it does not provide a plausible theoretical account for the values obtained. The model could be repaired by adding a further constraint that concept weights be greater than zero, but this would weaken the fit and bring the R^2 values closer to the R^2_{equal} values. A theoretical justification of the range of reasonable concept weights in various experimental situations would also be needed.

Inherent Differences in Concepts

Anderson and Reder (1999) suggested that there are inherent differences between the concepts in the study sentences used by Radvansky et al. (1993) that resulted in the differential weighting. These differences are not definitively identified, although concreteness and concept length were mentioned. Concreteness is inadequate, because the same values were present in the person–small location studies (4.7 out of 7 [?] for both people and small locations). Concept length is inadequate, because the same lengths were present in the object–location studies (1.8 words for both objects and locations). Finally, in a cued-recall study, I (Radvansky, 1992) used versions of the person–small location concepts equated for syllable length (e.g., "blue and yellow kayak" became "kayak"), thereby equating both concreteness and length. A clear differential fan effect was still observed. Even with randomization, confounds are possible in principle in all research. Their existence must be established empirically before they are invoked to account for substantive findings.

Apart from the unidentified confounds, the strategy of giving one concept more weight (attention) than the other is challenged by data in which differential fan effects are observed when identical concepts were involved. In Experiments 1 and 3 of Radvansky et al. (1997), students memorized sentences about people and objects. A differential fan effect was observed for study sentences of the form "The *person* is buying the *object*" (Experiment 1) but not for sentences of the form "The *person* owns the *object*" (Experiment 2). The situation model explanation is that sentences of the first type could be interpreted as referring to a single event. However, sentences of the second type provide pan-situational information, and so it is unclear how

Table 2
Corrected Parameter Estimates for Differential Fan Effect Experiments

Experiment (Exp.)	I	F	S	$W_{\text{low fan}}$	$W_{\text{high fan}}$	R^2	R^2_{equal}
Differential fan effects							
Location–object							
Radvansky & Zacks (1988)[a]	1,358	486	1.21	0.00	0.67	.75	.42
Radvansky & Zacks (1991), Exp. 1[a]	1,053	1,020	1.20	0.14	0.53	.85	.73
Radvansky & Zacks (1991), Exp. 2[a]	1,086	820	1.20	0.05	0.62	.87	.65
Radvansky & Zacks (1991), Exp. 3	1,164	564	1.30	0.00	0.67	.93	.70
Radvansky et al. (1991)[a]	977	866	1.20	0.00	0.67	.92	.60
Radvansky et al. (1993), Exp. 1[a]	896	1,049	1.20	0.14	0.53	.87	.75
Radvansky et al. (1993), Exp. 2	1,006	849	1.35	0.10	0.57	.85	.73
Radvansky et al. (1996), Exp. 1[a]	1,126	850	1.20	0.00	0.67	.87	.63
Radvansky et al. (1996), Exp. 2[a]	906	901	1.20	0.00	0.67	.87	.62
Radvansky et al. (1996), Exp. 3	1,414	345	1.35	0.00	0.67	.70	.60
Radvansky (1998), Exp. 1[a]	1,235	616	1.20	0.05	0.62	.85	.64
Radvansky (in press), Exp. 1	1,145	859	1.27	0.09	0.58	.93	.79
Radvansky (in press), Exp. 2[a]	783	1,171	1.20	0.22	0.45	.96	.90
Radvansky (in press), Exp. 3	941	1,017	1.51	0.21	0.46	.93	.90
Person–small location							
Radvansky et al. (1993), Exp. 5[a]	729	1,162	1.20	0.13	0.54	.84	.73
Radvansky et al. (1993), Exp. 6	1,195	797	1.25	0.11	0.56	.83	.70
Radvansky (1998), Exp. 2[a]	1,288	653	1.20	0.00	0.67	.79	.46
Radvansky (1995)[a]	1,149	794	1.20	0.18	0.49	.87	.79
Ownership							
Radvansky et al. (1997), Exp. 1[a]	1,054	865	1.20	0.18	0.49	.90	.81
Radvansky et al. (1997), Exp. 6	972	905	1.20	0.21	0.46	.91	.85
Temporal							
Radvansky et al. (1998), Exp. 1[a]	1,817	501	1.20	0.07	0.60	.86	.62
Radvansky et al. (1998), Exp. 2	1,230	466	1.24	0.23	0.44	.98	.82
Radvansky et al. (1998), Exp. 3[a]	1,445	430	1.20	0.09	0.58	.89	.69
Similar fan effects							
Person–location							
Anderson (1974), Exp. 1	1,019	388	1.27	0.32	0.35	.84	.84
Anderson (1974), Exp. 2	933	313	1.79	0.28	0.39	.98	.97
Anderson (1974), Exp. 3[a]	1,025	478	1.20	0.25	0.42	.91	.87
Radvansky et al. (1993), Exp. 3[a]	704	1,203	1.20	0.42	0.23	.91	.88
Radvansky et al. (1993), Exp. 4[a]	739	1,193	1.20	0.42	0.25	.85	.83
Ownership							
Radvansky et al. (1997), Exp. 2	963	813	1.55	0.23	0.44	.97	.95
Radvansky et al. (1997), Exp. 3[a]	946	815	1.20	0.29	0.38	.90	.90
Radvansky et al. (1997), Exp. 4[a]	871	943	1.20	0.25	0.42	.92	.89
Radvansky et al. (1997), Exp. 5[a]	1,237	608	1.20	0.24	0.43	.84	.80

Note. I = intercept; F = latency scale; S = initial strength.
[a]Values that changed with additional constraint that all associations between concepts be positive.

the information can or should be integrated into models. According to the ACT model's differential weighting explanation, a differential fan effect should be observed either always or never, not both. A further assumption is needed that the type of verb phrase dramatically influences processing so that one concept is attended to much more than the other in one case but not the other.

Following similar logic, Radvansky et al. (1998, Experiment 2) used sentences about people doing activities that could be done at the same time (e.g., stirring the soup, checking the time, and smiling). For a given person concept, verb tense was either constant (e.g., all past tense) or varied (i.e., past, present, and future). A fan effect was observed when different verb tenses were used but not when the same verb tense was used (a differential fan effect). The situation model account is that information that refers to a common time period can be integrated into a single model; however, information that refers to different time periods is likely to be interpreted as referring to different situations, resulting in multiple models. This cannot be explained by the differential weighting account, because the same concepts were used in both conditions.

These studies demonstrate that an explanation focusing on a confounding of some factor (concreteness, length, or whatever) with concept type (within a reasonable range) does not drive the observed differential fan effect. Instead, a single consistent explanation is that people form referential representations of this information and use these representations during retrieval.

Organization

Anderson and Reder (1999) suggested that the ACT–R explanation of the fan effect is the opposite of the situation model view (see also Moeser, 1979). For ACT, the associations among concepts cause interference (i.e., the more associative links fanning off of a concept node, the greater the interference). Such interference occurs at retrieval. Although Anderson and Reder took no explicit position regarding the organization of information in storage, the simplest account would be either that the data from retrieval reflect the organization at storage or that they do not. If not, then an additional process is needed to produce the pattern observed at retrieval. Because there is no plausible reason to postulate such a process (see the Encoding Versus Retrieval section, next), an empirical demonstration is required before this possibility can be taken seriously. Thus, in this section I assume that data from recognition reflect organization at storage.

In ACT–R, associations for concepts given a high weight play a strong role in retrieval. If retrieval reflects the stored representation, this is functionally equivalent to saying that there are meaningful associations (links) between concepts in memory. They have been integrated (stored together). Conversely, associations for concepts given a low weight play a negligible role in retrieval. This is functionally equivalent to saying that there is no meaningful association among the concepts in memory. They have not been integrated. Information that has been integrated produces interference, whereas information that is not integrated does not produce interference.

In contrast, according to the situation model view there is little to no interference when information is integrated. Interference is experienced when related information is stored apart and then competes during retrieval. So, for the materials used by Radvansky et al. (1993), the ACT view is that people were organizing by object in Experiments 1 and 2 and by small location in Experiments 5 and 6. This is a plausible, if counterintuitive, interpretation of the results. However, the ACT account seems implausible when other experiments are considered.

In Radvansky et al.'s (1997) study, the experiments combined different objects and verb phrases. The objects were ones that are either typically owned (e.g., house, computer, or boat) or could be bought in a drugstore (e.g., candy, toothpaste, or magazines). The verb phrases described either a general state ("owns") or a specific event ("is buying"). The sentences were of the form "The *person* owns/is buying the *object*." A differential fan effect was observed only with drugstore objects and the "is buying" verb phrase; that is, a fan effect occurred when one object was bought by several people but not when several objects were bought by a single person. For example, knowing that the lawyer, the banker, and the writer were buying a magazine produced retrieval interference. However, knowing that the farmer is buying tissues, candy, and greeting cards did not produce interference. In contrast, fan effects were observed in both conditions for the other material types, for example, when typically owned objects were used, or when the sentences were about owning but not buying. Increased interference was observed both as more objects were associated with a person and as more people were associated with an object.

The situation model explanation is that information can be integrated when an event was clearly indicated (i.e., "is buying") and the objects were all ones that could be interacted with in the same situation, but not otherwise. In contrast, the ACT model view is that the information is integrated in all cases except when the "is buying" verb phrase was used with objects present in the same location. That is, information about a person buying several items of these types would be stored apart in memory. This seems implausible.

Similarly, Radvansky et al. (1998, Experiment 2) manipulated verb tense (as described earlier). This study focused on the idea that events occurring at the same time are more likely to be considered as part of the same situation than events occurring at different times. So, integration occurred for same-time but not different-time conditions. In contrast, for ACT there was integration when the information referred to different time periods but not if it referred to the same time period. This seems implausible.

Finally, in Radvansky et al.'s (1998) Experiment 3, a fan effect occurred for activities that could not be done at the same time but not for activities that could be done at the same time. The situation model interpretation was that when activities can be part of the same situation they can be integrated, but when they cannot they are stored apart. In contrast, the ACT model interpretation is that there is integration for activities that are not done at the same time, but there is no integration for activities that can be done at the same time. This seems implausible.

Encoding Versus Retrieval

Anderson and Reder (1999) suggested that the differential fan effect is due to factors that occur at retrieval. They listed several studies (e.g., Reder & Anderson, 1980; Reder & Ross, 1983; Reder & Wible, 1984) that show that the size of the fan effect can be shifted by factors occurring at test. The implication is that a similar sort of factor is producing the differential fan effect, but no such factor is identified. Although factors that are manipulated at retrieval can certainly produce reductions in the fan effect, they cannot be responsible for the differential fan effect that I have attributed to the use of situation models; that is, the presence and absence of fan effects observed in the studies cited by Anderson and Reder (1999) occurred under different testing conditions with different groups or in different testing blocks. There was no shift in testing conditions in the differential fan effect studies. Probes were presented in a mixed and random fashion, and the effects were within subjects. The idea that there is some unspecified process operating only at retrieval is unlikely and lacks empirical support.

Converging Evidence

The final point is whether there is converging evidence for the situation model view. Anderson and Reder (1999) wrote that "Radvansky et al. offered an explanation in terms of situation models, but the type of situation model differed from experiment to experiment. . . . They provided no converging evidence that this was the way their participants were organizing the materials" (p. 191). The types of models are location- and person-based models. It should be noted that the difference between the types of models was motivated by a distinction between state-of-affairs and course-of-events situations outlined by Barwise and Perry (1983). Basically, a state-of-affairs situation involves a single spatial–temporal framework. Our location-based situations are of this type. A course-of-events situation cuts across several spatial–temporal frameworks and is unified by a common entity—in the Radvansky et al. (1993) case, the person. However, this is a philosophical distinction. Here I address converging empirical evidence.

Organization by Location

Is there any evidence that people can organize situational information around locations? The use of spatial information in situation models has been by far the most frequently studied. For example, it has been found that people foreground information spatially in a situation model, as shown by memory probe (e.g., Glenberg et al., 1987; Morrow, Greenspan, & Bower, 1987) and reading time data for anaphoric references (Glenberg et al., 1987; Rinck & Bower, 1995). The further apart pieces of information are spatially, the longer the processing time. Also, for people familiar with a spatial layout, shifts in location during text comprehension result in increased reading times (Zwaan, Radvansky, Hilliard, & Curiel, 1998). When a set of words from a story are sorted, breaks in spatial location in the story are followed by the placement of these words into different categories (Zwaan, Langston, & Graesser, 1995), suggesting that differences in location during comprehension lead to differences in mental organization. Thus, spatial location can be an important aspect around which situational information is organized.

Organization by Person

Is there evidence that situational information can be organized around people? Again, most of the evidence comes from language comprehension studies. There is good evidence that readers organize information in a story around a person concept, such as the protagonist. When given a text, it is not unusual for people to provide continuations of a story that are structured around the main person in the story (Garrod & Sanford, 1983). When information is foregrounded in a model, this increased availability is typically oriented by the protagonist's actions (Glenberg et al., 1987; Morrow et al., 1987; Rinck & Bower, 1995). The introduction of new people into a story results in increased reading times (Zwaan et al., 1998) and the later segregation of story words into separate categories (Zwaan, Langston, & Graesser, 1995). Thus, people can be an important component around which situational information can be organized.

Multidimensionality

Why is it that people will switch from one organization to another? Situation models are multidimensional representations, and this multidimensionality needs to be taken seriously (Zwaan & Radvansky, 1998). Situations in the world are complex configurations of different types of information. A mental representation of such situations would be expected to reflect this complexity to a substantial degree.

Situation models often involve a spatial–temporal framework (Zwaan & Radvansky, 1998). As such, when location or time frame information is explicitly provided, people will be able to structure a model around it. This is evident in the object–location (e.g., Radvansky et al., 1993) and the temporal experiments (Radvansky et al., 1998). This point is further bolstered by the fact that in the ownership experiments (Radvansky et al., 1997) integration was observed only when the information could be interpreted as referring to the same spatial–temporal context, even though location and time information was not explicitly provided.

In addition to the spatial–temporal framework, each situation model contains tokens representing entities. Moreover, causal and temporal relations can be used to unite a series of spatial–temporal frameworks by means of a prominent entity, such as a protagonist. In such cases, the primary basis for organization is the person. Thus, when both person and location information are available, and not redundant, a participant would need to select between them. Over a number of participants, some would be expected to choose the location, some the person, and some a mixture (see footnote 4 of Radvansky et al., 1993). This is why strong evidence of organization was not observed by Anderson (1974) and in Experiments 3 and 4 by Radvansky et al. (1993).

The reason that this does not occur when the person–small-location materials are used (e.g., Radvansky et al., 1993) is because of people's knowledge of how situations operate in the world. Situations in which a person is in a phone booth, a dressing room, or a tanning bed are plausible. However, situations in which several people are in any one of these places are implausible—hence the person-based organization observed in those experiments.

The multidimensionality of situation models is seen in other research. Taylor and Tversky (1997) used study time, verification, and diagramming measures to assess the organization of information read from a text. They found that readers structured information along multiple dimensions. When person and location organizations were compared, they found a mixture of strategies, consistent with my interpretation of the person–location fan effect studies. Zwaan, Langston, and Graesser (1995) found that words from previously read stories are sorted into different categories on the basis of five situational dimensions: space, time, entity, causality, and intentionality—that is, a shift along any of these dimensions leads to information being stored apart in memory, whereas information between shifts is more likely to be stored together. Zwaan, Magliano, and Graesser (1995) and Zwaan et al. (1998) have found that reading times are also affected by these dimensional shifts. This illustrates that situation models are multidimensional and that people are keeping track of all of these dimensions more or less simultaneously.

Thus, the organizations differed across experiments because the nature of the information differed. The information's reference to a fictional world and people's knowledge of how situations are plausibly structured guided which aspects of a situation model would be more salient. Showing that organizations differ from experiment to experiment was one of the points of Radvansky et al.'s (1993) study.

This evidence does not address the specific materials used in the differential fan effect experiments. Such data could be gathered. However, a global perspective showing that these principles of situational structure are present in cognition across many different stimuli and experimental paradigms seems more compelling than the more narrow view of considering only one type of materials in one experimental paradigm.

Rapprochement

An attractive feature of the original fan effect article (Anderson, 1974) was that it provided evidence of interference in memory retrieval with information more complex than nonsense syllables, words, or paired associates. It showed that some thought needs to be given to how complex units of knowledge are structured, such as for sentences, to provide a more complete understanding of memory. Studying small units of information will take us only so far.

In some sense, the situation model view is a continuation in that direction. This view goes further in that it also assumes that people will draw inferences using their knowledge of the world (in this case, knowledge of how situations are typically structured) to organize information. There were some statements made in the original fan effect article (Anderson, 1974) that suggest that something like a situation model was at least momentarily considered. For example, in the instructions, people were "told to 'try to understand fully the meaning of these sentences because this is the best way to remember them' " (p. 455).[6] This suggests that the experimenter thought that more was involved in memorization than the encoding of the words in the sentences. More to the point, it was also noted that

> all subjects claimed to treat the sentences as meaning-bearing entities. There were frequent reports of imagery and semantic elaborations of the propositions. Most subjects claimed to have created for themselves a *fictional world* [italics added] of people and places. More than one subject joked after an experimental session that he felt he was leaving old friends. (p. 452)

The creation of representations based on the information in the text as well as inferences based on general world knowledge to create a mental simulation of a possible world sounds very much like the creation of a situation model.

Situation model theory provides an understanding of how event information might be structured; however, it has little or nothing to say about the processes of memory retrieval other than that situation models are involved. Thus, some insight about memory retrieval processes may be gained by acknowledging that something like situation models are used. The assumption has always been that the same sorts of processes are used to retrieve these representations as are used to retrieve other types of mental representations (see also Kintsch, 1998).

In ACT, information is stored in long-term memory as *chunks* (see Anderson, 1993, pp. 25–31). These chunks are composed of more basic elements of information along with specific relational information. As a form of invited imperialism, it should be possible for situation models to serve as chunks within the ACT framework. What is needed is for some way of stipulating how information is chunked to capture the organizations observed in the differential fan effect. This would involve incorporating some form of situation model theory into ACT.

Conclusions

Anderson and Reder (1999) suggested an ACT model explanation of the differential fan effect. Five points were made: that (a) by changing the weights of concepts in propositions, ACT can produce the obtained pattern of data; (b) there are meaningful differences in the concepts that result in these different weightings; (c) ACT can provide a view of how information is organized; (d) the organizational effects of interest likely occurred solely at retrieval; and (e) there is no converging evidence to support the situation model view.

I have tried to argue against these claims. Specifically: (a) the differential weighting leads to implausible predictions, (b) an account focused on differences between the concepts does not apply across a wide range of materials, (c) the ACT model suggests implausible organizations of information, (d) there are no manipulations at retrieval in the studies listed in Tables 1 and 2 that would influence the fan effect, and (e) there is a great deal of evidence of how information is organized in situation models.

For an ACT model explanation of the differential fan effect to work in the form proposed by Anderson and Reder (1999), it must (a) define a psychologically plausible range of concept weights and still be able to model effectively the differential fan effect, (b) explicitly identify the factor that results in the differential weighting and provide an empirical demonstration of its influence on the fan effect, and (c) provide an explanation of the organization of all types of materials showing a differential fan effect.

[6] Participants in the differential fan effect studies were typically told to try to memorize the sentences as efficiently as possible.

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Received December 31, 1997
Revision received June 2, 1998
Accepted June 2, 1998 ■