Semantic Similarity as Partial Cue-Match: EEG Evidence From the Fan Effect

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Cue-based retrieval accounts of memory and language processing propose that retrieval requires matching cues to items in memory. Multiple items matching a cue causes inhibitory interference ([5, 7]). This effect has originally been established in cognitive science: in fan experiments, people had to recall concepts that are associated with a varying number of facts. As the number of associations increases, retrieval difficulty, as measured in reaction times (RTs) and accuracy, increases as well ([2, 3]). Importantly, there is a gap between what fan effects established and how the model of these effects (ACT-R, [1]) is re-interpreted in the cue-based retrieval account of sentence processing: fan effect studies only considered inhibitory interference due to *exact word* match (e.g., word repetition), while cue-based retrieval accounts only consider inhibitory interference due to *word similarities* (e.g., multiple semantically similar words should slow down retrieval in sentence processing). To really link the ACT-R model and cue-based retrieval, we need to close this gap by showing that fan effects arise also when the number of associations to *semantically similar words* increase. To date, only a single study establishes the existence of such semantic inhibitory interference in fan effects ([6]). That study, however, is limited to behavioral data. We provide the first evidence that semantic inhibitory interference in fan effects is also found in neural mechanisms.

We conducted an EEG fan experiment with 50 participants. In a learning phase, participants studied 24 target person-location word pairs. Fan was manipulated by associating each target concept with either two (fan 2) or four (fan 4) semantically related concepts (Table 1). In a subsequent testing phase, participants decided via button press whether a presented word pair had been studied (target) or not (foil), while EEG was recorded.

Hierarchical Bayesian linear mixed models fitted to behavioral results revealed longer RTs and lower accuracy for fan 4 relative to fan 2 conditions, consistent with a behavioral fan effect driven by semantic similarity (see summary in Figure 1). For the EEG analyses, we defined times and regions of interest based on the Early Effect reported in a previous study on EEG in classical (word identity) fan effects, [4]. We averaged the signal by-trial within each window and fitted hierarchical Bayesian linear mixed models. For foils, the credible interval for the fan effect in the Early Effect window was predominantly positive but included zero (fan: -0.071, 1.135), with 96% of the posterior above zero. Higher fan conditions were thus associated with greater positivity, consistent with findings by [4]. Because our stimuli were selected to fit semantic categories, they were less controlled for word length and included lower-frequency words. Therefore, we expect any effect to emerge somewhat later than those in [4]. Visual inspection of the grand averages (Figure 2) supports this interpretation. When the Early Effect window is shifted by 50 ms, a positive fan effect emerges for targets and foils (fan: 0.024, 1.038), with 98% of the posterior above zero.

Together, these results suggest that semantically induced interference engages neural mechanisms similar to those underlying the classical fan effect. This is consistent with the idea that semantic similarity constitutes partial cue matching. These findings provide crucial evidence that the use of ACT-R model in sentence processing, as in cue-based retrieval, is justified in modeling inhibitory interference due to semantic similarity.

Fan size	Person	Location	Word pair
2	a_1	A_1	*admiral - abyss*
	b_1	A_2	*thinker - ravine*
2	a_2	B_1	*colonel - factory*
	c_1	B_2	*doctor - workshop*
4	e_1	E_1	*lawyer - town*
	f_1	E_2	*designer - village*
4	e_2	F_1	*councilman - faculty*
	f_2	F_2	*painter - university*
4	e_3	G_1	*notary - synagogue*
	g_1	G_2	*artist - temple*
4	e_4	H_1	*solicitor - warehouse*
	g_2	H_2	*singer - supermarket*
Re-paired foils:		*lawyer - abyss*	
		councilman - factory	

Table 1: Person and location refer to stimulus categories and are semantically related when they share the same letter, e.g., a_1 and a_2. In this example, person fan is varied (e.g., a = fan 2, e = fan 4) while location fan remains at fan 2. Stimulus sets were randomly generated and each participant received a unique set. All stimuli are translated from Dutch.

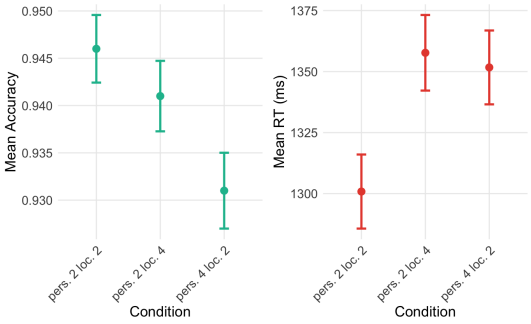

Figure 1: Behavioral results: mean accuracy (green) and reaction times (red) across conditions.

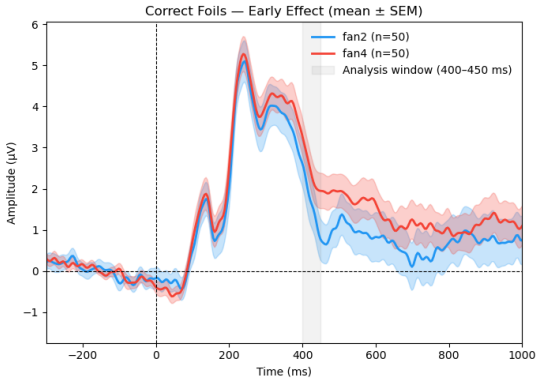

Figure 2: Grand average of the Early Effect (incl. SE of the mean, SEM), averaged over FC3, FC4, T7, C3, Cz, C4, CPz, CP4, P3, Pz, P4, POz, O1, Oz, O2. Different colors indicate the signal in response to different fan conditions. The time window of interest is indicated in gray.

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