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**Article:**

Barnard, P.J., Scott, S., Taylor, J. et al. (2 more authors) (2004) Paying attention to meaning. *Psychological Science*, 15 (3). pp. 179-186. ISSN 0956-7976

<https://doi.org/10.1111/j.0956-7976.2004.01503006.x>

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## Research Article

## Paying Attention to Meaning

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**ABSTRACT**—Several paradigms show that responses to one event compromise responses to a second event for around 500 ms. Such effects are generally attributed to attentional capacity limitations associated with processing information in the first event. In a task in which targets could be distinguished only by their meaning, we varied the semantic relationship between distractors and targets following at different lags. Semantic relatedness alone produced a classic attentional blink. We conclude by discussing how attention theory might best accommodate these new effects.

Attention mechanisms select salient events. People selectively attend to their names (Moray, 1959), and anxious individuals show increased sensitivity to threat words (MacLeod, Mathews, & Tata, 1986). Mostly, people attend to things that matter for their current goals (Duncan, 2000), and what “matters” in laboratory paradigms is determined by experimental instructions about how to respond to particular stimulus properties, either in static arrays or as events dynamically unfold over time.

Several paradigms show that responses to one event compromise responses to a second event. These paradigms include the psychological refractory period (Pashler & Johnson, 1998), task switching during rapid word sequences (Allport, Styles, & Hsieh, 1994), and the attentional blink (AB). In the latter paradigm, participants watch items presented at a rate of around 10 items/s. It is a divided-attention task, involving two targets, each requiring a different response. For example, participants might have to report a white letter (T1) embedded in a stream of black letters, and then report whether a probe (T2), such as the letter *X*, occurs subsequently. Given correct report of T1, detection of T2 is impaired for about 500 ms (Raymond, Shapiro, & Arnell, 1992). There are now several accounts of this effect (e.g., see Shapiro, Arnell, & Raymond, 1997). All assume that allocating attention to T1 leaves less attention for T2, although the various theories differ in the precise mechanisms, stages, or storage components proposed.

Attention to meaning is also selective. When asked, “How many animals of each type did Moses take into the Ark?” respondents frequently answer, “Two,” apparently failing to access their knowledge that the agent was really Noah (Erickson & Mattson, 1981). They do not make this mistake when “Nixon” is substituted for “Moses.” The effect occurs because both Moses and Noah fit the generic schema

“male Old Testament figure with two-syllable name.” The question focuses attention on number rather than agent identity. Because “Moses” is compatible with the evolving biblical schema, “Ark” can pass along the conveyor belt of semantic interpretation without detailed scrutiny of its antecedent. Its occurrence following “Nixon” requires attention.

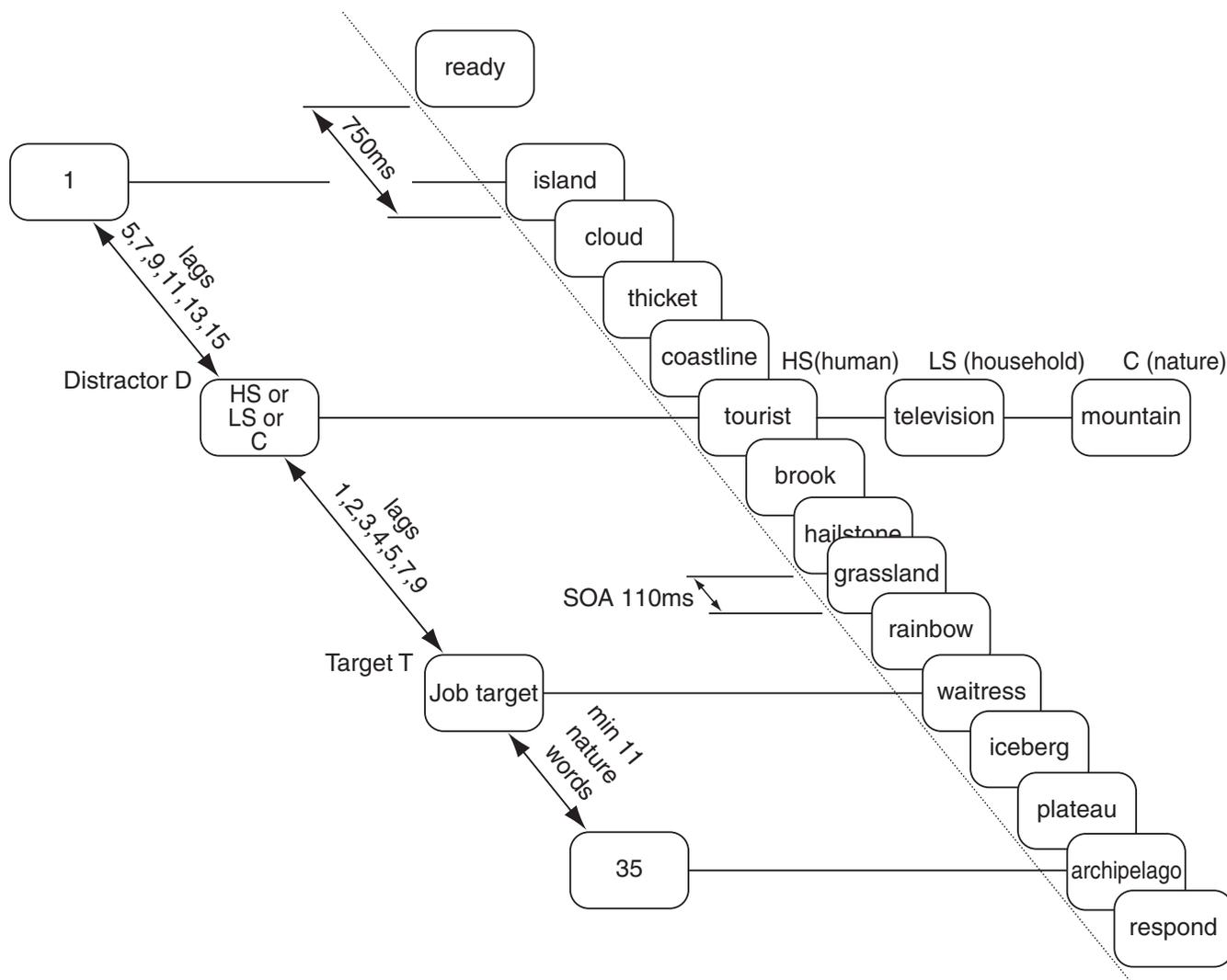
Selective attention to events and to meaning may be connected. Whatever the task, incoming information must be evaluated against some mental representation of relevant knowledge. In classic visual attention tasks, that knowledge is given by task instruction that specifies how to respond to particular contingencies. The mental representations for contingencies in dual-task paradigms such as the AB would be more elaborate than the representations of tasks requiring the detection of a single target with a particular physical property. Given that physical properties can be mapped onto their semantic counterparts, capacity limitations in visual attention need not necessarily arise from a classic bottleneck. As with the Moses effect, they may be determined in the natural course of matching the semantic representations of incoming items to semantic representations of the relevant response contingencies.

Although associative meaning (Maki, Frigen, & Paulsen, 1997) and personal salience (Shapiro, Caldwell, & Sorensen, 1997) influence report of T2 in the AB paradigm, research has overwhelmingly relied on using perceptual attributes, such as color, to distinguish at least one of the targets from other presented items. Hence, task-salient items have been directly tied to perceptual features. The idea that the effects might be underpinned by processing task- and stimulus-related meaning suggests that the blink itself should require neither distinguishing perceptual features nor dividing attention between two responses. All that should be required are conditions in which the semantic properties of one event are salient to the response contingency for a subsequent event.

## METHOD

In the present study, lists of 35 words were presented at a rate of 110 ms/item, with one word replacing another with no interstimulus interval (ISI). Most words referred to things or events occurring in natural environments (e.g., island, snowstorm). Participants were instructed to report a single target, a word that referred to a job or profession that people engage in for pay (e.g., banker, shepherd, waitress). On test trials, these targets were preceded at varying serial positions by a potential distractor word, and the semantic relationship between distractor and target was varied (see Fig. 1).

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**Fig. 1.** Schematic illustration of the task. C = control condition; HS = high-salience condition; LS = low-salience condition; SOA = stimulus-onset asynchrony.

In the high-salience condition, distractors conformed to the schema “property of human agent,” but referred to things for which people are not paid (e.g., shopper, coward, witness). These distractors were expected to attract attention and compromise target detection. In a second condition, household items (e.g., freezer, cupboard, wireless) were the distractors. This condition was included so we could assess any effects of category change from the stream of nature words, but with distractors having lower salience to targets. Although associated with human activity, these distractors were expected to attract less attention because they are inanimate. To maximize impact, we presented each distractor only once, whereas nature words occurred many times across lists. In the control condition, distractors were a subset of nature words, each occurring once only, so we could assess any effects of distractor novelty.

There were 42 distractors of each type and 42 targets. The four sets were matched for word frequency ( $Mdn = 3$ ), and length ( $M = 7.8$  letters). To eliminate superficial cues, we used a variety of word

endings, and all sets had comparable distributions of endings. Distractors were presented at one of six positions (5, 7, 9, 11, 13, 15). Targets occurred at one of seven positions after the distractor (1, 2, 3, 4, 5, 7, 9). At least 11 items followed the target.

There were 42 trials in each condition, representing every combination of distractor position and lags to target. Another 42 trials assessed performance when no distractor was presented. On 21 of these trials, neither a distractor nor a target occurred; on the other 21 trials, a target occurred, with no distractor, at Position 6, 12, or 24 of the list. Trial order was randomized, as was the selection of distractors and targets.

Thirty participants (23 female; mean age = 33.1 years) gave informed consent. They were asked to respond by reporting the identity of the job in each list; they were told to say “no” when they did not see a job and to say “yes” when they were confident they saw a job but could not report its identity. There were 19 practice trials using different distractor words and targets.

At the end, participants completed a questionnaire, followed by an unexpected recognition test. For the test, 60 words were presented in random order, and participants were asked to judge whether each word had occurred in the earlier lists. There was no time limit for response. The test included 10 old and 10 new items for each distractor type.

## RESULTS

On trials with no distractor, correct report of the target's identity averaged 67%. Correct report of no job seen averaged 85% when no target occurred. False positive reports that a job was seen accounted for 11% of responses. The error rate, report of words that were not targets, was 3% in the control and low-salience conditions. In the high-salience condition, the error rate was 6%, the increase due to reports of the distractor itself.

The percentage of correct report of targets is shown in Figure 2. There were main effects of condition,  $F(2, 60) = 30.9, p < .001$ , and position,  $F(6, 180) = 9.8, p < .001$ , and an interaction between the two,  $F(12, 360) = 3.5, p < .001$ . The control condition showed no blink effect (i.e., no effect of serial position) at all,  $F(6, 180) = 1.75, p > .1$ . A shallow blink followed low-salience distractors,  $F(1, 30) = 12.6, p < .01$ , for quadratic fit. Accurate report in this condition ( $M = 61%$ ) was at a similar level to that following novel nature words (i.e., control condition,  $M = 64%$ ). A substantial blink followed high-salience distractors,  $F(1, 30) = 39.0$  for quadratic fit and  $F(1, 30) = 23.4$  for

cubic fit, both  $ps < .001$ . The presence of a deeper blink for the high-salience than the low-salience distractors was confirmed by the presence of a significant Serial Position  $\times$  Condition interaction when these two conditions were compared directly,  $F(6, 180) = 2.29, p < .05$ .

In addition to correctly reporting a target's identity, participants could report total unawareness ("no") or awareness of presence but not identity ("yes"). For both these measures, there were reliable effects of condition,  $F(2, 60) = 14.5, p < .001$ , for "no" responses and  $F(2, 60) = 10.9, p < .01$ , for "yes" responses, as well as position,  $F(6, 180) = 4.3, p < .001$ , for "no" responses and  $F(6, 180) = 6.2, p < .01$ , for "yes" responses. In addition, the condition-by-position interaction was significant for both "no" responses,  $F(12, 360) = 2.9, p < .01$ , and "yes" responses,  $F(12, 360) = 2.02, p < .05$ . Figure 3 suggests that the deeper blink Figure 2 shows for the high-salience condition is mostly due to a greater lack of awareness for high-salience than low-salience distractors across Positions 2, 3, and 4.

In the recognition test (Table 1), nature words were equally likely to be judged old or new. There was a bias toward judging high- and low-salience distractors as new. Signal detection analysis showed that detection was higher with high-salience than low-salience distractors,  $t(29) = 3.4, p < .01$ . There was no difference in bias for these conditions,  $t(29) = 1.04, p = .5$ . These results corroborate more extensive processing of the high-salience than the low-salience distractors.

Just as threatening material attracts attention, so human agents might inherently be more salient than inanimate distractors. To

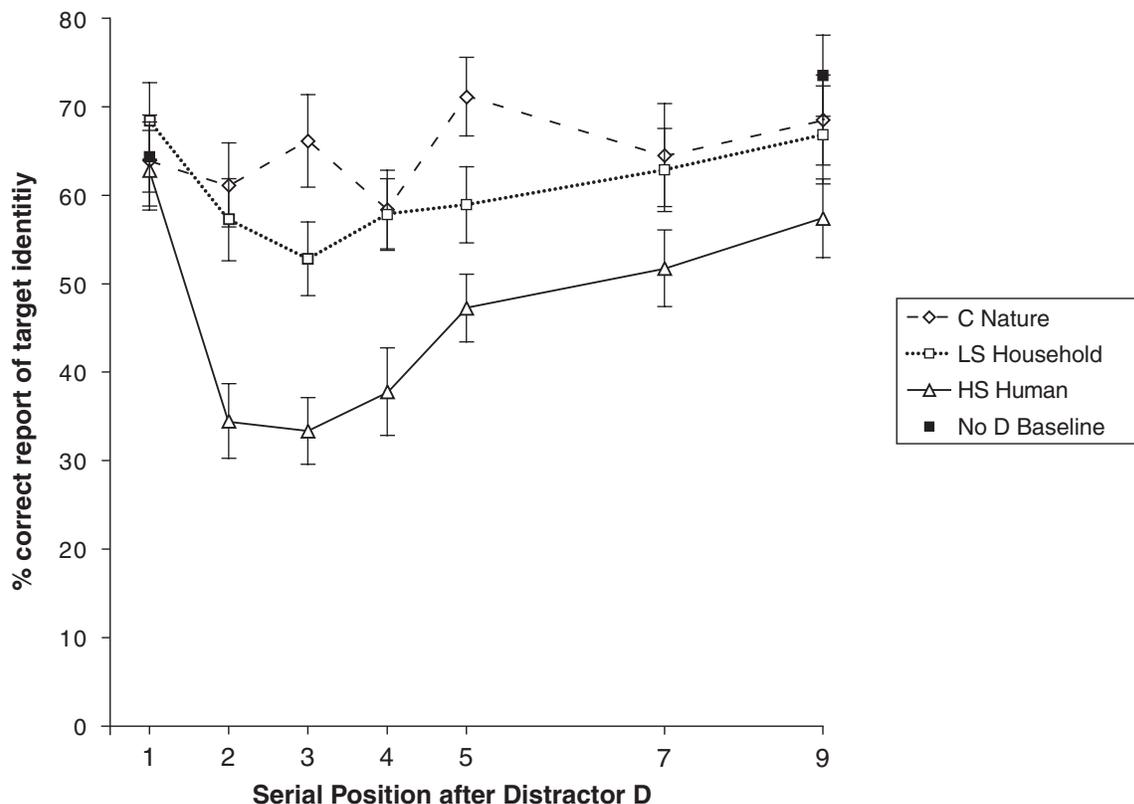
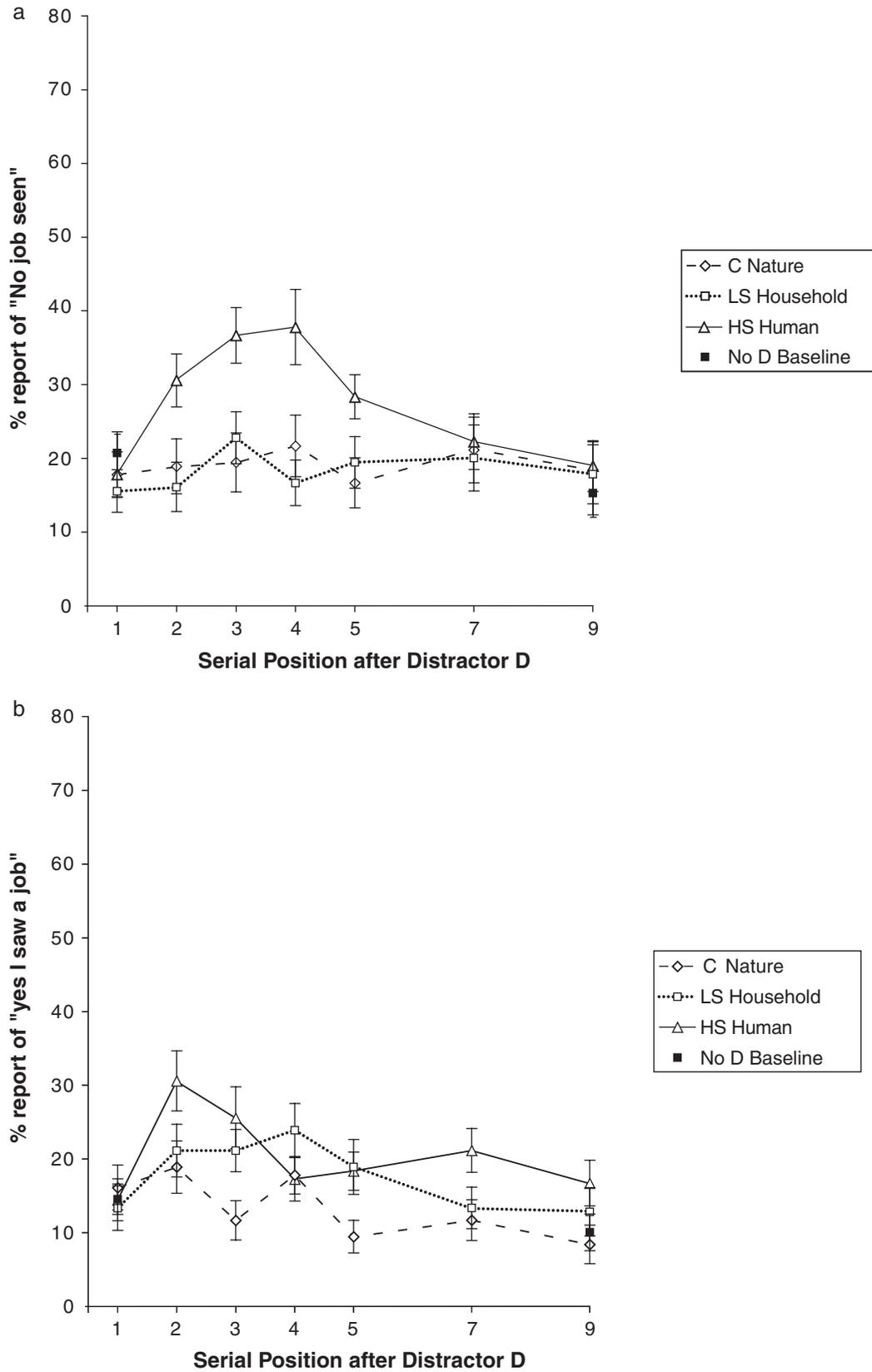


Fig. 2. Percentage of correct report of a target's identity across serial positions. The two points for the no-distractor baseline are for early (average of absolute serial positions 6 and 12) and late (absolute position 24) targets. C = control condition; HS = high-salience condition; LS = low-salience condition.



**Fig. 3.** Percentage of reports of “no job seen” (a) and “yes, I saw a job” (b) across serial positions. C = control condition; HS = high-salience condition; LS = low-salience condition.

**TABLE 1**  
*Recognition Memory for Distractors*

Condition	Detection sensitivity ( $d'$ )	Bias ( $\beta$ )
Control (nature)	0.17	1.02
Low-salience (household)	0.17	1.59
High-salience (human)	0.69	1.34

eliminate this explanation, we repeated the procedure with 30 new participants. The same distractor categories were used, but targets were animals, again matched for length, frequency, and word endings. Accurate report in all three conditions (Fig. 4) was at a level comparable to the level of the control and low-salience conditions of the first experiment. There was no differential effect of the type of distractor,  $F(12, 360) = 0.81, p = .64$ , for the interaction of condition and position. Thus, the effect obtained in the main experiment can be attributed to the semantic relationship between distractors and targets.

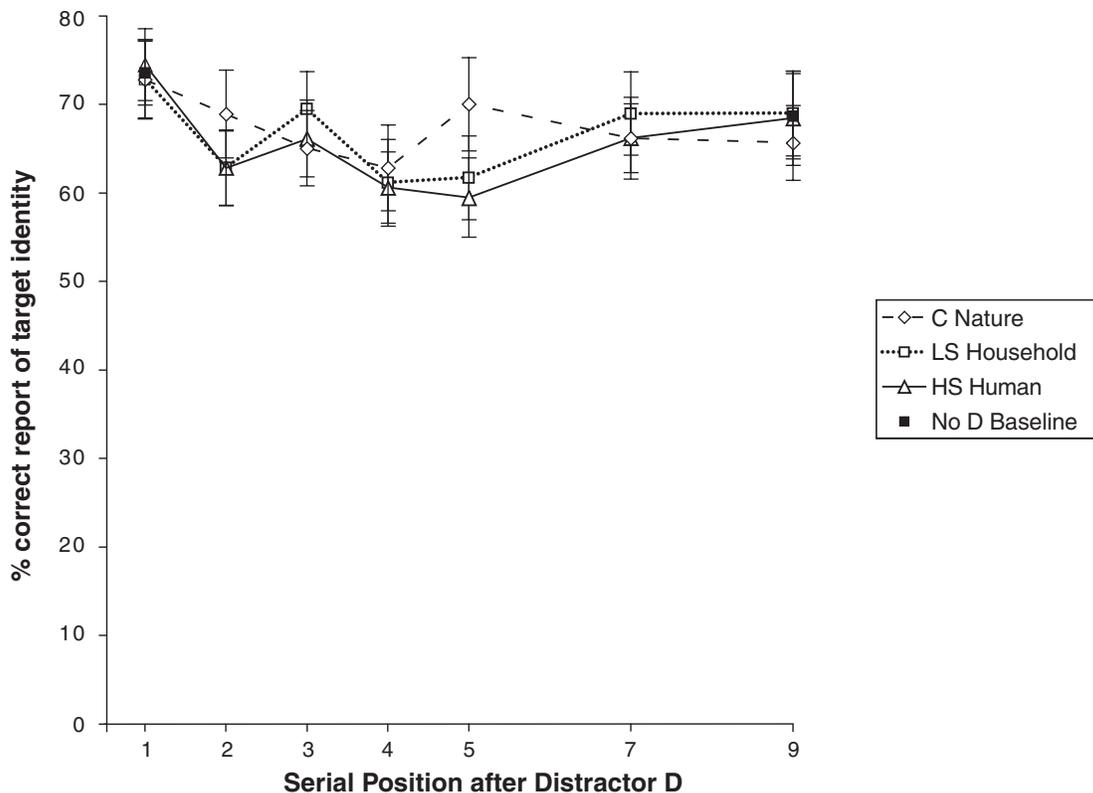
### MODELING MEANING

The blink we found followed a time course similar to that for standard effects, but in a paradigm in which perceptual features do not identify distractors and there is no requirement for two responses. Distractors belonging to a salient category were processed more extensively than

distractors from a less salient one. One issue to resolve is whether influences such as lexical priming played a part in determining the effect, or whether it can be explained by semantic and executive mechanisms alone, and if so, how?

Priming effects could have operated during word recognition. Positive priming of targets occurs when their meaning is associated with earlier items, though reported effects are of short duration (Maki, Frigen, & Paulsen, 1997). Our instructions might have lowered thresholds for all words associated with jobs or occupations. The human distractors would then have been more likely than household items to rise above threshold, gain access to central mechanisms, and thus cause a blink. Alternatively, it could be argued that processing of distractors, which do not require a response, made the task analogous to settings in which negative priming occurs (Tipper & Driver, 1988). According to this reasoning, human distractors would have inhibited subsequent job words, reducing the likelihood of their rising above threshold. Both arguments would predict that lack of awareness would rise with increasing semantic relatedness between distractors and targets.

Similar predictions would be made by other theories. If transient conceptual storage (Potter, 1999) and capacity-limited processing are required to consolidate incoming information for report (Chun & Potter, 1995), then the higher the semantic relatedness between the distractor and target category, the greater the likelihood a distractor would progress toward consolidation for report or interfere in conceptual storage.



**Fig. 4.** Percentage of correct report of animal targets across serial positions in the follow-up experiment. C = control condition; HS = high-salience condition; LS = low-salience condition.

**TABLE 2**  
*Cosines Obtained in the Latent Semantic Analysis*

Category	Generic human (n = 10)	Generic occupation (n = 10)	Generic payment (n = 10)	Generic household (n = 10)	Target jobs (n = 41)	High-salience (human) (n = 40)	Low-salience (household) (n = 36)	Control (nature) (n = 40)
Generic occupation	.32	1						
Generic payment	.11	.38	1					
Generic household	.30	.23	.08	1				
Target jobs	.36	.47	.15	.30	1			
High-salience (human)	.50	.29	.12	.25	.47	1		
Low-salience (household)	.34	.28	.06	.44	.43	.35	1	
Control (nature)	.22	.10	.01	.09	.14	.17	.18	1

**Note.** One target, 2 human, 6 household, and 2 nature words had no entry in the analysis.

Latent semantic analysis (LSA; Landauer & Dumais, 1997) can be used to evaluate whether the explanations discussed in the preceding paragraphs are viable explanations of our results. LSA is based on word occurrence in huge corpora. Words with similar meaning occur in similar contexts. LSA uses this fact to index the association of the constructs underlying word use by creating a high-dimensional mathematical space onto which individual words, groups of words, or texts can be mapped. LSA approximates similarity in meaning by computing how far apart items or texts are in semantic space. The closer they are, the more similar they are in meaning or in their associations to related knowledge. Similarity is indexed by the cosine of their relationship coded on 300 dimensions, a measure that ranges between  $-1$  and  $+1$ . There is good evidence that this measure has considerable validity. It systematically relates to many behavioral effects that depend on similarities in meaning (Landauer & Dumais, 1997).

Using LSA, we examined similarity relations among the distractor categories and between the categories and their exemplars. Similarities were computed by taking all items in a category as a pool. We included four additional pools of 10 words to capture generic schema that might be required in response selection. One pool represented human agents (human, people, mankind, womankind, someone, mortal, fellow, sentient, folk, soul). The second represented work at a more generic level than the individual target words (occupation, profession, job, trade, employment, work, business, career, livelihood, vocation). The third represented getting paid for work (payment, fee, remuneration, recompense, bribe, salary, honorarium, income, earnings, wages). The final pool included generic references to household goods (ornament, device, utensil, gadget, tool, possession, decoration, fitting, fixture, furnishing).

The matrix obtained made sense (Table 2). Distractors and targets all showed low similarities to nature words. Human (high-salience) and household (low-salience) distractors showed high similarities to their superordinate schema pools. However, high- and low-salience distractors showed rather strong and equal levels of association to the job targets, as well as a lower and equal level of association with generic occupation words. These results are understandable because LSA captures knowledge through the occurrence of concepts across a wide range of contexts, and these pools are all related to human activity. All distractors and targets had low levels of association with generic payment words. Payment was closely associated only with generic occupation words. More extensive processing of the high-salience than the low-salience distractors may have been related not simply to a “human” feature, but to the ease of accessing knowledge about occupations and payment.

To further explore relationships between LSA cosines, we conducted a by-item analysis. We identified which of the high-salience distractors were associated with above-, on-, and below-median use of each type of response (correct identity, “no,” and “yes”). The numbers of distractors in each range and their associated levels of usage are shown in Table 3. We then calculated the cosines to generic categories and specific targets for the pools of distractors with above-, on-, and below-median usage (Table 4). The similarities revealed two striking patterns. First, similarities were lower for above-median correct report than for below-median correct report. The cosines for household (low-salience) distractors in Table 2 are .34 for the human category, .28 for the occupation category, and .43 for job targets. Human distractors with the highest levels of correct report of targets had the same level of similarity, or lower similarity, compared with the pooled household items. The implication is clear: Those human distractors most likely to result in accurate report would have been unlikely to stand out as salient in terms of either their generic semantic properties or their similarities to specific targets.

Second, use of “yes” and “no” responses showed different patterns on the human and occupation dimensions. Above-median use of “yes” was linked to a profile of high similarities and below-median use to a profile of lower similarities. This would be expected if failure to report were simply the opposite of the pattern for accurate report. However, the profiles for above- and below-median use of “no” were not unlike those for accurate report. Examination of the words in each pool confirmed that this was due to differential migration of distractors from one range to another. Of the 19 words in the pool for above-median use

**TABLE 3**  
*Numbers of Human High-Salience Distractors Giving Rise to Above-, Below-, and On-Median Use of Each Type of Response to the Targets*

Range of use	Response to target		
	Correct identity	“No”	“Yes”
Above median	15 (56)	16 (36)	19 (28)
Median	7 (47)	10 (27)	7 (20)
Below median	18 (38)	14 (19)	14 (11)

**Note.** The numbers in parentheses show the percentage use of each response type for distractors in a given usage category.

TABLE 4

*Latent Semantic Analysis Cosines for Pools of Human (High-Salience) Distractors With Above-, On-, and Below-Median Use of Each Response*

Range of use	Response to target											
	Correct identity				"No"				"Yes"			
	Human	Occupation	Pay	Jobs	Human	Occupation	Pay	Jobs	Human	Occupation	Pay	Jobs
Above median	.35	.19	.06	.32	.38	.23	.11	.37	.52	.27	.09	.48
On median	.41	.17	.08	.39	.40	.16	.08	.33	.37	.25	.13	.37
Below median	.46	.30	.14	.45	.45	.29	.10	.47	.33	.20	.09	.33

of "yes," only 4 were in the pool of 16 showing above-median use of "no." To test the significance of the asymmetry, we computed an LSA cosine for each word in relation to a semantic specification of the target profile, this time defined by the exact text of the experimental instructions describing the target category, and corrected the cosines for vector length. Excluding the 4 shared items, words with above-median use of "yes" were more similar to the generic description of targets than were words with above-median use of "no,"  $\chi^2(1, N = 27) = 6.24, p = .013$ .

## DISCUSSION

LSA revealed that participants, when unable to report identity, were more aware of target presence (indexed by "yes" responses, Table 4) following human distractors with relatively high similarity to the targets than following distractors with relatively low similarity to targets. However, participants were also more unaware of target presence (indexed by "no" responses, Table 4) following human distractors with relatively low similarity to the targets than following distractors with high similarity to targets. Arguments based on lexical priming, or on simple interference effects in conceptual storage, do not have ready-made explanations for this pattern. Similarities should have been higher for "no" responses than for "yes" responses, and above-median use of "no" should have been linked to higher similarities between distractors and targets than below-median use of "no."

The results appear more readily explicable in terms of two stages of semantic interpretation in which rapidly extracted generic properties of the incoming stream are being monitored. In this specific case, if the generic meaning of an item was discrepant with the schema of "stuff in natural environments," then that item was examined in relation to a generic schema for "human occupation with possible remuneration associations." An item whose meaning was similar to this schema was marked as salient, and this triggered a second stage to establish its specific referential meaning and whether that meaning involved paid work. The first stage is rather like taking a "glance" at generic meaning, and the second stage is like taking a closer "look" at the more precise semantic relationship between a distractor and the semantic specification of targets. If semantic processes cannot glance at incoming items while looking at another, a blink would result. Neither household items nor human distractors with low similarities to the target schema would have stood out as salient in the initial glance. Like the occurrence of "Ark" after "Moses," they would have passed along the conveyor belt of semantic interpretation without detailed scrutiny.

Having reached the second stage, any human distractors that are highly similar to targets would again have an advantage. The semantic profile for these words most clearly signposts the way to occupation relatedness, and Table 2 shows that knowledge about payment needed to reject a distractor as a "job" is closely associated only with occupation relatedness. Hence, in the present experiment, the subset of human distractors with high similarities should have been rejected rapidly, allowing relatively fast return to monitoring for targets. For distractors with lower similarities, access to pertinent knowledge about payment would have been poorly signposted in semantic space, the process of rejection would have been more protracted, and target detection would have been compromised for a longer duration. This more protracted process would be associated with greater unawareness of targets, indexed by the use of "no" responses, while those human distractors of lower similarity to targets underwent detailed scrutiny.

Our results show accurate report of a target when it immediately follows a distractor, a characteristic known as lag-1 sparing. This usually occurs in AB studies in which no attentional switch is required or the switch is unidimensional (Visser, Bischof, & Di Lollo, 1999). Think of a semantic analogue of glancing over objects in a dynamically changing visual scene. A distractor may be the topic of a glance while a subsequent item that also has a salient semantic profile moves onto the contemporaneous semantic scenery, enabling an immediate switch from glancing at one item to looking at the temporally adjacent item, and hence lag-1 sparing. Awareness that a probable target has just co-occurred—something more like a temporal analogue of peripheral vision—could instead precipitate successive glances rather than a glance followed by a look. With successive glances, the wider cognitive system might well, on some occasions, reconfigure its processes to access a current representation of the visual form of a distractor rather than relying on its meaning. The initial glance would lead to a sense of knowing that a target had been present, and hence the association of imprecise awareness with failed attempts to recover visual form fits the pattern of "yes" responses following human distractors. "Yes" was more frequently used in response to distractors with high similarity to targets than in response to those with low similarities, a result consistent with the proposed mechanism of glancing. "Yes" responses also contributed to accurate identification falling short of baseline levels at the longest lags. Any extensive reconfigurations of processing that fail to recover the actual visual form of the target would be linked to more protracted diversions of attention than those required for a closely coupled semantic glance and look.

Few current models focused specifically on mechanisms of visual attention have much to say about the exact part played by representations

of meaning and task knowledge. Those that do make reference to such concerns are typically those that address the wider architectural picture in cognition (Meyer & Kieras, 1997; Potter, 1999; Shallice, 1988). Barnard (1999) proposed that executive functions are fulfilled by two subsystems specialized to process generic and specific types of meaning. These two types of meaning can be linked directly to the glance-and-look explanation of blink effects offered here, as well as to analogous effects in question answering (Scott, Barnard, & May, 2001). We thus conclude that semantic representations can play a substantial role in the allocation of visual attention over time.

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(RECEIVED 10/20/01; REVISION ACCEPTED 4/11/03)