Word Frequency and Subliminal Perception

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Running head: Partial matches to memory

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Abstract

Subjects were presented with words to study silently while performing a secondary task. Words varied in frequency of use. When asked to later discriminate new, unstudied words from previously presented ones, subjects were shown to be susceptible to spurious, subliminal flashes of the word prior to judgment, such that judgments of old were elevated for actual old and also new words. Interestingly, the manipulation of a brief exposure to the word prior to judgment had differential effects depending on practice at the task and word frequency, such that early in the experiment a brief flash affected performance for high frequency words but not low frequency words, while later in the experiment, the opposite pattern was found. Four levels of frequency were used and four practice blocks were measured. The shift was gradual across levels of frequency and practice. This suggests that thresholds of sufficient stimulus exposure depend on the resting activation level of the stimulus items. We argue that resting activation levels vary as a function of word frequency.

Word Frequency and subliminal perception

In this brief report, we present evidence that perceptual thresholds should not be thought of in terms of *duration of stimulus exposure* , but rather in terms of absolute activation levels that reflect the summation of the stimulus word's prior activation level and the activation provided by the physical stimulation of a brief flash. Furthermore, we argue that this experiment gives evidence for the view that (a) there exist different resting activation levels for words of different frequencies (as defined by norms of the lexicon), and (b) the stimulus exposure duration required for subliminal, semantic activation (SSA), and the stimulus exposure duration for conscious perception vary as a function of the frequency of the word.

This study adapts a paradigm used by Jacoby and Whitehouse (1989). In their experiment, subjects studied a list of words and later were asked to identify which words on a test list had been studied earlier. The important result was that people's judgments of whether or not a target word was presented earlier was influenced by a brief, tachistoscopic (masked) flash that immediately preceded the presentation of the test word. Subjects were more prone to believe that the target word had been seen earlier if the briefly presented *context* word matched the target to be judged than when it mis-matched. Jacoby and Whitehouse concluded that this brief flash made the subsequent supraliminal presentation of the target word more *perceptually fluent.* According to them, subjects would interpret this *perceptual fluency* as evidence that the word had been studied earlier because they were unaware of the brief, subliminal, masked flash. In contrast, when subjects were aware of this flash, their judgments (response bias) were not affected in the same way. That is, when the exposure was supraliminal, i.e., subjects were conscious of the manipulation and no longer misattributed their perceptual fluency to a prior study, thereby eliminating the effect of the flash.

It is generally understood (for example, see Greenwald, 1992, for a review) that there are two thresholds associated with brief exposures, one allowing subliminal semantic activation (SSA), the second allowing conscious awareness. We have argued elsewhere (Reder, Nelson and Stroffolino, in preparation) that higher frequency words should have a higher resting activation level than lower frequency words and this should interact with the thresholds involved in this spurious familiarity effect. We predict that high frequency words should more easily pass the first threshold, achieving SSA, but also more easily pass the second threshold. This means that if the flash is extremely brief, higher frequency words will be subject to the spurious familiarity/recognition judgments, but not lower frequency words--the former rising above the SSA threshold, but not the latter group of words. On the other hand, if the flash is longer, the opposite should prevail. That is because the longer flash will be detected (rise above the conscious threshold) for higher frequency words such that subjects will discount what Jacoby calls the impression of greater perceptual fluency. Moreover, with the longer flash, the lower frequency words will exceed the SSA threshold, and their rate of positive responding will go up.

Prior research has also shown (e.g., Wolford, G., Marchak, F., & Hughes, H.,1988; Wolford,G. and Kim, H.Y. ,1990)) that a person's threshold for perception of subliminal flashes shifts during the course of an experiment. We suggest that thresholds should not be defined in terms of duration of stimulus exposure, but rather in terms of total activation and that these do not shift over the course of the experiment. Rather, practice at the task makes people more efficient at extracting the stimulus energy out of a presentation of any word. For this reason, the same duration of a flash will behave as a longer flash later in the experiment, yielding the pattern of responses predicted above for differing duration flashes.

From these principles and conjectures, we make the somewhat complicated prediction that spurious brief presentations of the words prior to their presentation for a recognition judgment will interact both with frequency of the word, and also experience with the task, i.e., flashes. Specifically, if the words are higher frequency, they should be more easily activated from a brief exposure than low frequency words. On the other hand, a high frequency word will exceed threshold for consciousness more easily than low frequency words. To show this, one could vary the exposure of the flash. Alternatively, one could look at effects of these variables across time, on the assumption that sensitivity to the flashes increases with practice.

Method

Subjects Twenty four Carnegie Mellon students participated either for course requirement or for pay.

Procedure. Subjects were run individually on a Mac SE. The task inolved a divided attention procedure during study for all subjects. Prior to the study phase, subjects practiced the distractor task ,used to divide attention, until they felt comfortable with it. The distractor task consisted of a steady stream of random numbers from one to ten being verbally presented via synthesized speech at a rate of one per second, with the subject instructed to press the space bar on the keyboard each time three even or odd numbers were presented in sequence. A fourth odd or even number in a row was considered the start of a new potential sequence. A beep sounded to inform subejcts when they had responded incorrectly (omission or comission).

When subjects indicated that they were comfortable with the number distractor task, the actual experiment began. Subjects were presented with a list of words, one at a time, at a rate of 1 second per word at the center of the computer screen. Subjects were instructed to read these words silently while listening (and responding to) series of three odd or even numbers.

After the words had been presented for study, subjects were put into the recognition phase, which consisted of discriminating the original words from distractors, i.e., non-studied words. For each trial, the subject would indicate readiness to respond by pressing the spacebar. After a refractory period of 750 ms, a row of ampersands (&&&&&&&&&&) would flash briefly before the word to be judged was displayed. On half of these trials, the flashing ampersands would mask a subliminal presentation of the word itself (&&&WORD&&&). On the other half of the trials, X's of the same length as the word were flashed instead (&&&XXXX&&&). The duration of the flash was 30 ms. The full row of ampersands reappeared after the flash, and before the actual presentation of the target for an ISI of 1 sec. The target word was then displayed on the screen, flanked by ampersands until the subject responded to the recognition query. Subjects were required to identify whether the words were "old" or "new" by pressing the button labeled "O" for old words and "N" for new words. They were also instructed to respond "as quickly as possible without sacrificing accuracy."

This procedure was repeated four times, except for the distractor task familiarization phase.

<u>Materials and Design.</u> The experiment used a 4 x 2 x 4 x 2, within subject factorial design: There were four blocks of study-test trials; words to be judged could have been

presented during study or be new at test; there were four levels of word frequency; and before a test trial, the target (word to be judged) could be primed or not by a brief (surreptitious) flash. Lists of equal number of words from each frequency were presented to the subjects. Each study list consisted of 32 words, eight from each frequency level. These words were randomly selected from the 150 words from that level (described below) with the restriction of non-replacement, i.e, each word was used only once per subject. The foils for each test block were likewise selected from the pool of words, eight from each frequency level. The recognition test order of words was a random permutation of the study (old) and foil (new) words yielding 64 test trials per block. This process was repeated for each of the four (4) blocks of trials (with no overlap in word use).

Each set of words from the four frequency levels contained 150 non ‘s’ plural nouns. These words were selected from The American Heritage Word Frequency Book within the following ranges:

Highest frequency noun list: (SFI: 59.0-75.1; F: 445-11215);

2nd highest frequency noun list: (SFI: 40.7-41.5; F: 9-79);

2nd lowest frequency noun list: (SFI: 27.7-30.4; F: 2-10);

Lowest frequency noun list: (SFI: 19.1-20.4; F: 1-1).

The selection criteria excluded any obsolete words, non “English” words, acronyms, compound words, or proper nouns. Words of length less than 5 or greater than 10 were also excluded. When presented, words were displayed in all capital letters.

RESULTS

Both response times and category of responses (new or old) were collected as a function of the 64 conditions. Table 1 presents the probability of responding "old" to a to-be-recognized (TBR) word, as a function of whether the word was actually presented earlier (OLD) or not (NEW), as a function of the TBR word's frequency, whether there had been a brief flash before the probe, and the block of trials during the experiment (first through fourth or last).

For simplicity, these data are schematically represented in Figure 1. The figure plots the effect due to flash (the difference between flash and no flash trials) for the highest and lowest frequency levels and the earliest and latest trial blocks. Old words and new words are plotted separately.

Insert Table 1 and Figure 1 about here

There was a significant effect of whether the word had actually been presented earlier on subjects tendency to respond "old", $\underline{F}(1, 18)=108.27$, $\underline{p}<.001$, confirming that subjects were indeed able to discriminate new from old words with some accuracy. There was also a significant effect of flash, $\underline{F}(1, 18)=34.01$, $\underline{p}<.001$, replicating Jacoby and Whitehouse's result that a brief flash prior to the judgment can give a spurious impression that the word had been studied earlier. As expected, there was a significant interaction of word frequency and whether the word had actually been studied earlier on tendency to respond "old", $\underline{F}(3, 54)=14.33$, $\underline{p}<.001$, such that subjects were much more accurate at discriminating new from old words for low frequency words. It is generally known that subjects are poorer at recognition memory for high frequency words (e.g., Glanzer & Adams, 1985, 1990; Hintzman, Caulton & Curran, 1994).

The result of special interest was the significant interaction of trial block with word frequency and flash, $F(9, 162)=2.84$, $p<.01$, such that in the early blocks, the flash manipulation had an effect on the higher frequency words, but not the lower frequency words; conversely, towards the end of the experiment, the opposite result occurred. This result can be seen schematically in Figure 1a and b. Notice that the slope declines from the first block to the last block for the function that represents the effect of flash for high frequency words, while the slope increases for the low frequency words. This interaction can be seen for both new words and old words, although the effect is less pronounced for low frequency new words.

DISCUSSION

The pattern of data showed a rather dramatic change in the effectiveness of the flash manipulation across blocks of the experiment. Most impressive was the fact that in the early blocks a constant exposure duration was sufficient to replicate a previous finding for high frequency level words, but not low frequency level words, while in later blocks the converse was true.

Our explanation for this interaction is the following. Previous research has already established that as subjects become more experienced with an experiment involving masked presentations, their ability to identify those masked stimuli increases. We interpret this as an increased ability to extract the stimulus energy from the brief flash. This extracted energy will sum with the prior activation level of the word. That total activation may or may not be sufficient to cross one of two thresholds--one for subconscious semantic activation (SSA), and the higher one for conscious awareness.

Like other theorists, (e.g.,Cheesman & Merikle, 1984; 1986; Greenwald, 1992; Merikle & Cheesman, 1986), we postulate that in order to *prime* a subsequent exposure to that same word, the brief exposure must be above the SSA threshold. Low frequency words, we claim have a lower resting activation level. Therefore, in the early blocks, the brief exposure of a low frequency word added to its resting activation level tended not to be adequate to boost activation above the SSA threshold. This meant that there was little or no impact of the flash in the early blocks on low frequency words. On the other hand, this same duration flash for a high frequency word when added to the higher resting activation level of the higher frequency word was enough to boost the total activation above the SSA threshold in the early blocks.

With practice at the task, and presumably greater facility to extract information/stimulus enery from a brief exposure, larger amounts of activation was added to words of each frequency levels. This implies that in later blocks lower frequency words would be more likely to cross the SSA threshold, i.e., show an increase in bias to respond "old" to words that had been briefly flashed. Conversely, the larger amounts of activation added to high frequency words implies that these exposures would be more likely to cross the conciousness threshold. Jacoby and Whitehouse also demonstrated that when the context words were presented for much longer exposures so that subjects were fully aware of them, the tendency to favor words preceded by a matching context word disappeared.

We take this result as evidence that visual thresholds should be thought of in terms of activation levels of the stimulus item rather than in terms of *length of exposure* to a word *per se.* Further, we believe these data provide evidence that activation levels are not simply a function of how of the duration of a stimulus flash. Rather, the probability of a word exceeding a visual threshold is determined by summing the word's long-term resting activation level (which we claim is based on word frequency) and the stimulus energy extracted from the brief flash.

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Table 1

Mean Proportion of "old" Responses as a Function of Prior Study (actual old or new), Word Frequency, Trial Block, and Flash (brief exposure to word before judgment).

Block:1

		no flash			flash		
frequency		Percent	dprime	Beta	Percent	dprime	Beta
	Old			Old			
very low	new	21			25		
	old	56	0.9703	1.3634	52	0.7405	1.2527
low	new	32			36		
	old	53	0.5419	1.0976	57	0.5352	1.0373
medium	new	30			35		
	old	71	1.0718	0.9798	72	0.9650	0.8981
high	new	27			53		
	old	42	0.3946	1.1694	64	0.2720	0.9380
Over all mean:		41.50			49.25		

Block:2

		no flash			flash		
frequency		Percent	dprime	Beta	Percent	dprime	Beta
	Old			Old			
very low	new	18			32		
	old	58	1.1524	1.3727	65	0.8862	0.9683
low	new	22			27		
	old	55	0.9157	1.2672	53	0.7206	1.1506
medium	new	16			31		
	old	55	1.1492	1.5394	62	0.8495	1.0155
high	new	26			35		
	old	48	0.6268	1.1922	48	0.3690	1.0575
Over all mean:		37.25			44.125		

Block:3

		no flash			flash		
frequency		Percent	dprime	Beta	Percent	dprime	Beta
	Old			Old			
very low	new	22			28		
	old	55	0.9495	1.2580	62	0.9597	1.0362

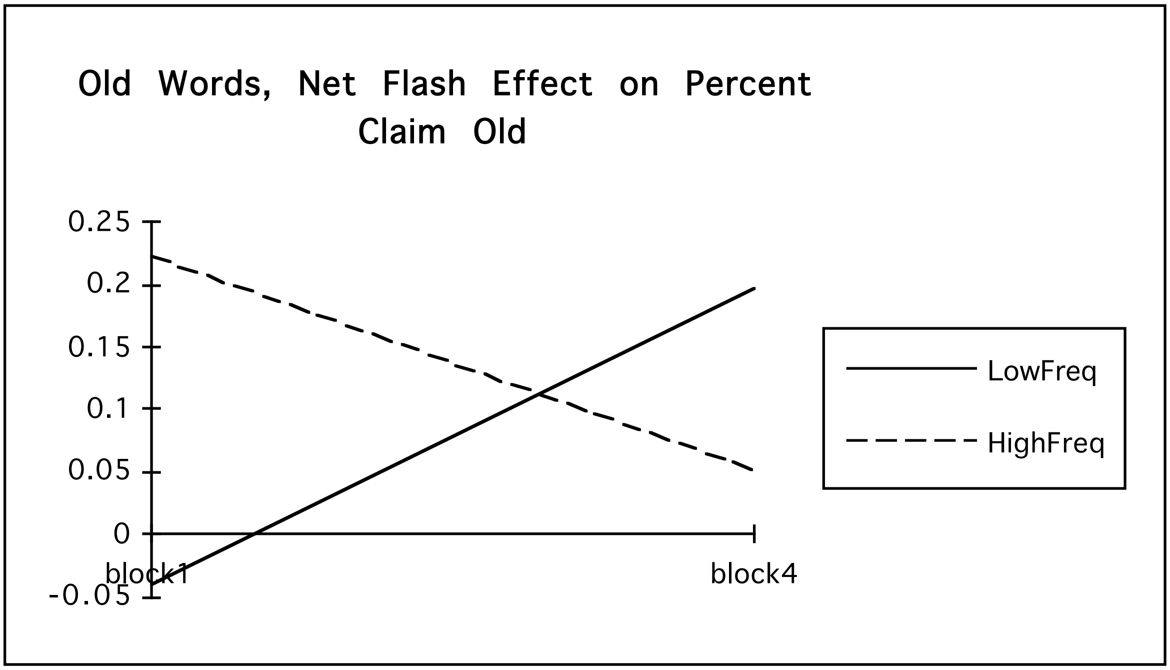
low	new	28			27		
	old	45	0.4839	1.1423	59	0.8910	1.1024
medium	new	27			33		
	old	53	0.7206	1.1506	67	0.9650	0.8981
high	new	28			38		
	old	38	0.2839	1.1123	50	0.3321	1.0225
Over all mean:		37.00			45.50		

Block: 4 (Last Trial block)

			no flash			flash	
frequency		Percent	dprime	Beta	Percent	dprime	Beta
	Old			Old			
very low	new	16			32		
	old	50	1.0491	1.5626	69	1.0404	0.8887
low	new	17			38		
	old	45	0.8664	1.4977	65	0.7498	0.8990
medium	new	32			32		
	old	59	0.7428	1.0266	58	0.7081	1.0380
high	new	28			34		
	old	41	0.3845	1.1329	46	0.3360	1.0581
Over all mean:		36.00			46.75		

Figure Caption

Figure 1. Mean net flash effect (increase in proportion of words judged to be old due to the brief flash of the target word prior to judgment), graphed as a function of word frequency (high vs. low) and experience at the task (trial block 1 vs. trial block 4). Figure 1a is for Old Words; Figure 1b is for New Words.


Old Words, Net Flash Effect on Percent Claim Old
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0.2
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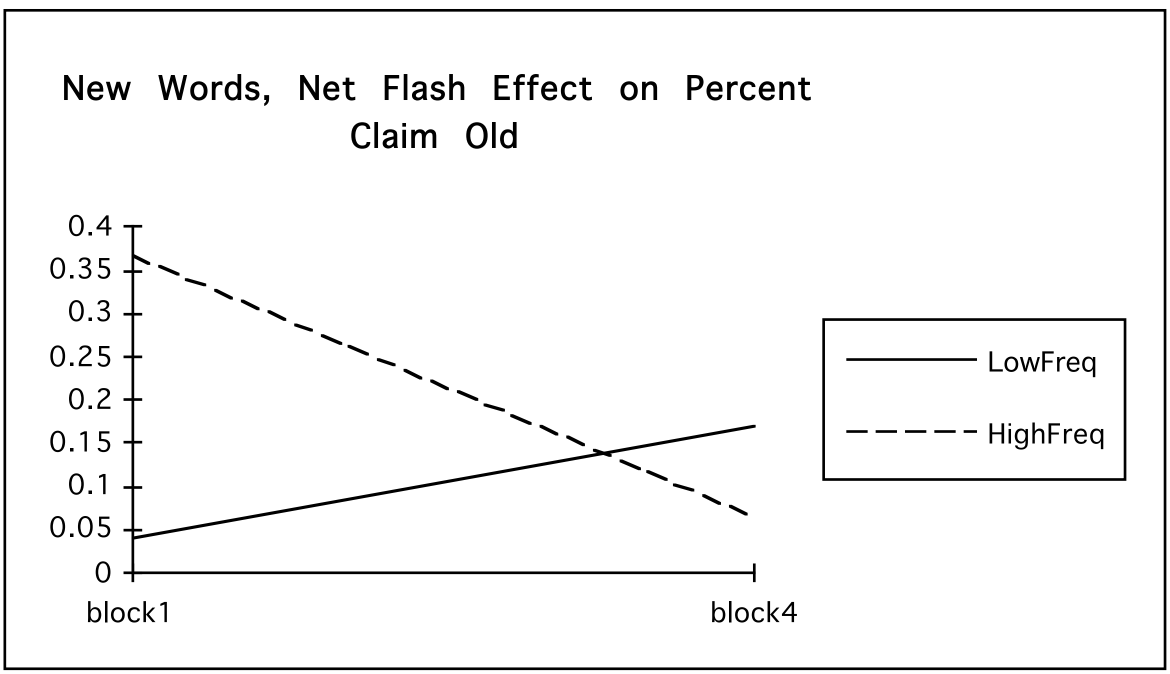
HighFreq


New Words, Net Flash Effect on Percent Claim Old
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