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Fast Pairs: A visual word recognition paradigm for measuring entrenchment, top-down effects, and subjective phenomenology ☆

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ABSTRACT

When word pairs having a familiar order are sequentially flashed on a computer in their non-familiar order, (*code zip*), observers have a strong phenomenology of seeing them in familiar order (*zip code*). Reversal errors remained frequent even when participants obtained perceptual experience of reverse-display items by beginning with a block of longer-duration trials. A forced-choice order-detection procedure reduced but did not eliminate reversal errors, showing that "fast pairs" is a robust perceptual illusion. Even adjective + noun pairs (*green skirt*) showed reversal errors, and reversal errors increased with the log frequency of the word pair, consistent with a strong role for statistical processing at the level of multi-word units.

1. Introduction

Everyday observation leads us to expect that the order in which we perceive events is the order in which they occur (Reeves & Sperling, 1986). Exceptions to this are phenomenologically interesting and also a scientific puzzle to be solved (Dennett, 1991).

In this paper we introduce a new paradigm for exploring discrepancies between perceived and actual order. We call our paradigm "Fast pairs." Pairs of words are briefly flashed on a computer screen, one word immediately after the other, with the second word followed by a pattern mask. Observers are asked to report the words they saw, in the order in which they saw them. For exposure durations ranging from 30 to 90 ms, observers spontaneously reversed word pairs having a familiar order, such as *fees legal* and *step next*. Observers denied that they were purposely reporting words in their familiar order or that they were unsure of the order and thus simply guessed that the order was the familiar order. Instead they claimed they perceived the words in their familiar order.

It is well known that rapid visual displays lead to errors in reporting order (Lawrence, 1971; Norman, 1967; Reeves & Sperling, 1986). For example, in the "attention shift paradigm" (Reeves & Sperling, 1986), observers monitored letters displayed via RSVP. When a target was detected (for example, the letter "U"), observers were to report which number was current being displayed in a separate RSVP stream to the right to the right. When the numbers appearing after the target U were "6 2 1 7 3 4" observers frequently reported "7 3 1 4 2", along with other less frequent incorrect orders. Reeves and Sperling's explanation was that the attentional shift triggered by detection of the target letter ramps attention up to a maximum value, and the number that receives the peak of attention is then perceived as occurring first. The order of the numerals in visual short term memory is thus determined by the amount of attention allocated to each position in the numeral stream.

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Table 1
Word pair examples in the four conditions and percentages of response types[a] in Experiment 1

Word pair type	Examples	Frequency (3 million word corpus, HAL)	Frequency (Google, November 2007)	Familiarity rating (6 pt scale)	Percentage nonsense ratings	Fully veridical	Incorrect word identification	Reversals[b] (canonical, reversed display)
Hi Freq Colloc	Money order, thank you, worry about	3737	180 million	4.17	1.6%	43%	23%	34% (4%, 62%)
Lo Freq Colloc	Face value, mere fact, back yard	206	24 million	3.82	3.0%	42%	32%	25% (4%, 47%)
Adj+Noun Pair	Such space, new table, size three	0	3 million	2.21	13.1%	35%	50%	15% (3%, 27%)
Random	Since never, hey wing, cold off	0	56 thousand	0.56	58.6%	28%	64%	7% (7%, 8%)

[a] The three categories of fully veridical, incorrect word identification and reversals report sum to 100%.
[b] The mean percentage of reversals is shown in parentheses for canonical and reversed display; the average of these values is the average percentage of reversals.

Another approach to studying errors in perceiving order are temporal-order-judgment (TOJ) tasks (e.g., Stolz, 1999), such as those used to investigate the "doctrine of prior entry" which states that attended stimuli are perceived prior to unattended stimuli (Boring, 1929; Nicole & Shore, 2007; Page & Norris, 1998; Shore & Spence, 2001). Despite this long-standing and on-going interest in TOJ tasks and their obvious relevance to questions of conscious perception (Libet, 1985), no researchers have investigated how familiar order influences perceptions of temporal order of words (for pictures in RSVP, see Intraub, 1989). Do highly familiar word pairs bias perception of temporal order more strongly than word pairs that are less familiar? To systematically manipulate familiarity, we studied two-word collocations. Collocations are frequently co-occurring word sequences that are generally recognized as familiar by fluent speakers of the language (Bybee & Hopper, 2001; Harris, 1998; Jackendoff, 1995; Makkai, 1993; Wray, 2002). We compared high frequency collocations (e.g., *thank you*), low frequency collocations (e.g., *gold medal*), word pairs that were merely legal adjective + noun combinations (*green skirt*), and random combinations (*pigs troops*; see Table 1).

Following Langacker (1987), we will use the terms "entrenchment" and "entrenched" to refer to hypothetical mental processes of routinization and over-learning resulting from repeated exposure to meaningful stimuli. Compared to other patterns, entrenched patterns have robust long term memory representations and mental processing advantages, such as ease of recognition and recall. Entrenched patterns are frequently encountered, but frequency is a fact of the external world, while entrenchment describes the mental representations which may result from frequent exposure. Some highly frequent patterns may not become as entrenched as less frequent patterns if they lack conceptual coherence. For example, the phrase *child abuse* may be highly entrenched due to specificity of meaning and emotional impact, compared to highly frequent word pairs which don't refer to a familiar concept, such as *rather than* or *since you*. In the current paper, participants' familiarity ratings and text frequency counts are used as indications of entrenchment.

We first report a series of studies to document the effect of familiar order on word-pair recognition and the role of entrenchment on the temporal order illusion. We then discuss the two major questions that arise from these findings: Why do observers incorrectly perceive order, and how does their phenomenology compare to other order illusions? We will also describe the relevance of the fast-pair paradigm for Bayesian theories of word representation, and how it could be used for quantifying individual differences in susceptibility to top-down vs. bottom-up information sources.

2. Experiment 1: Measuring accuracy, reversals, and guessing

In the fast pairs paradigm, our (authors' and lab assistants') subjective phenomenology was that we were not uncertain about the temporal order: It was simply the order we experienced. It was disconcerting to learn that a stimulus had actually been *fees legal* when one had the experience of seeing *legal fees*. Study 1 verified our own experiences using controlled laboratory procedures. We examined whether participants were sometimes uncertain about the order by giving half of the participants the option of reporting their uncertainty.

2.1. Methods

2.1.1. Participants

Participants were 22 Boston University students who participated for Introductory Psychology course credit. All had acquired English from birth.

2.1.2. Design

The design included four categories of word pairs (high-frequency and low-frequency collocations, syntactically legal word combinations, and random word combinations) and two display orders (familiar order, *zip code* and reversed order, *code zip*). Both factors were varied within-participant, and the display order was also varied within-item. Half the