
The illusory-letters phenomenon: An illustration of graphemic restoration in visual word recognition

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Abstract. We present a demonstration of word perception in which stimuli containing very few letters (just 50% of their original number) are presented for unlimited durations and yet are seen unequivocally as complete words. The phenomenon suggests that recognition of words can be achieved even when perception of their component letters is prevented.

1 Introduction

A little over 100 years ago, Pillsbury (1897) reported a number of studies in which participants perceived incomplete stimuli as whole words. Specifically, incomplete words were formed from real words (eg chimney) in which a letter had been replaced by another letter (chimnzy), omitted altogether (chimny), or overtyped with an 'x'. These stimuli were then presented for durations of 0.2 s (or thereabouts) by an ingenious Victorian version of what is now called tachistoscopic presentation. Under these conditions, participants often reported seeing each word in its entirety, despite the very obvious nature of each omission under conditions of extended exposure. One interpretation of these findings is that recognition of words does not rely on perception of their component letters (Pillsbury 1897; see also Neisser 1967; Woodworth 1938) and this notion continues to thrive in word-recognition research (eg Allen et al 1995; Jordan 1990, 1995; Jordan and Scott-Brown 1999).

However, the observations reported by Pillsbury may have been inspired by a number of factors which, in turn, limit the generality of these findings. First, the effects relied on the predominant use of stimuli in which just one letter was replaced in words of between five and eight letters in length. Thus the actual 'restoration' of missing letters to produce complete word recognition may actually rely on perceiving the vast majority of the letters in words. Second, the effects were obtained by presenting stimuli very briefly and so may reflect temporal constraints on encoding relevant letter information which are not present in normal reading situations. Third, participants were often aware that their perception of complete words was contaminated by extraneous visual input. For example, when presented with the word 'chimney' in which the 'e' had been overtyped with an 'x', one participant commented "There are some crosses but I can't remember where they are" (Pillsbury 1897, page 377).

Here, we report a recently discovered illusion which represents a more powerful demonstration that words can be perceived in their entirety when perception of their component letters is prevented. In particular, the illusion demonstrates that the phenomenon of seeing incomplete words as complete words is obtainable when stimuli contain very few letters (just 50% of their original number), are presented for unlimited durations, and yet are seen as complete words without visual contamination. The illusion was discovered while the first author was assembling examples of exterior letter combinations from four-letter English words (eg d--k from dark). Part of this process involved temporarily replacing the interior letters of words with nonsense characters which maintained the overall dimensions of the original letters but which were composed only of diagonal lines. When embedded between the exterior letter pairs, however, the

nonsense characters produced a range of illusory contours such that the entire array now looked like a complete four-letter word (the *illusory-letters phenomenon*); that is, words were seen with all four letters in their appropriate locations. Examples of stimuli which produce this illusion are shown in figure 1. Readers can experience the illusion by placing the page vertically at an initial viewing distance of about 3 m (depending on eyesight) and moving slowly towards the stimuli. At some point, complete words (never nonwords) become visible, including distinct letters in medial positions. As viewing distance is decreased further still, the letters seen in medial positions revert to the nonsense characters actually present. The illusion was established more formally in the following way.

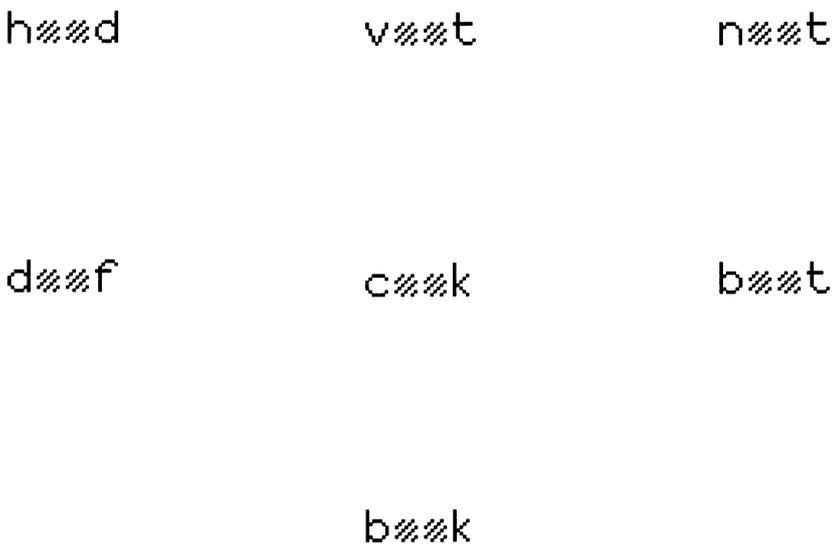


Figure 1. Examples of stimuli producing the “illusory-letters phenomenon”.

2 The experiment

2.1 Method

2.1.1 *Participants.* Twelve native speakers of British English took part in the experiment. All participants showed normal or corrected-to-normal vision and had English as their first language.

2.1.2 *Stimuli.* Four lists of different stimuli were constructed and presented to each participant. Each list was composed of 10 four-letter words printed in lowercase with both interior letters replaced by the nonsense characters which broadly matched the overall height of the original neutral letters (eg a, e, n, r, s, etc). These ‘illusory-letters’ stimuli were randomly intermingled with 10 complete four-letter words (ie words which contained all their letters) which shared none of the exterior letter combinations used for the illusory-letters stimuli. Thus, each participant was shown 40 complete words and 40 illusory-letters stimuli. All stimuli were presented horizontally, one above the other in a vertical column, in high contrast black on white paper and were viewed under bright lighting conditions. Each stimulus measured approximately 15 mm horizontally.

2.1.3 Procedure. Participants were told that the purpose of the experiment was to investigate the legibility of different words. To allow for individual differences in visual acuity, the visual angle of each stimulus was adjusted by using a test list of 20 complete four-letter words and decreasing viewing distance until accuracy of report for each list was approximately 90%. Mean viewing distance was 2.1 m. The four experimental lists were then presented one at a time in random order and participants were required to read each stimulus out loud. Responses were noted by the experimenter. At the end of each list, participants were asked to select the 10 stimuli in that list which they thought were the most legible. This forced-choice procedure provided an assessment of the legibility of illusory-letters stimuli relative to complete words. At the end of the experiment, participants were asked to comment on their perceptions of the stimuli they had been shown and were made aware of the nature of the illusory-letters stimuli used.

2.2 Results

Mean accuracy of report for complete word stimuli was 93%, indicating that the visual information encoded from each of these stimuli was sufficient for high levels of word recognition accuracy. All illusory-letters stimuli produced the illusion for all participants. Indeed, all responses provided for illusory-letters stimuli were real four-letter English words, all contained the same exterior letters as the stimulus, and all were produced without prompting and with no apparent (or reported) effort, indicating that the visual information encoded from each stimulus was sufficient to produce the phenomenological experience of 'normal' word recognition. This point is supported by the finding that the reported legibility of complete and illusory-letters stimuli did not differ: Of the 480 stimuli selected by participants as the most legible, 52% were complete words and 48% were illusory-letters stimuli ($p > 0.05$ by a binomial test). In addition, all participants reported (and showed) surprise when they were told that half of the stimuli presented in the experiment had contained two nonsense characters and all participants reported having seen 'real letters' (including a range of appropriate letter strokes) in the medial locations in every stimulus. Moreover, all reported that letters were perceived in a single, consistent typeface across each stimulus.

3 Discussion

The illusory-letters phenomenon indicates that words can be perceived in their entirety when only half of their component letters are presented. The precise nature of the phenomenon remains to be determined but two potential sources can already be identified. One potential source (which Pillsbury himself favoured) is the overall physical length and height of words. According to this notion, representations for words may be accessed with the use of coarse-scale information about the overall shape of words without recourse to fine-scale analyses of individual letters (for discussions, see Allen et al 1995; Jordan 1990, 1995; Jordan and Scott-Brown 1999; Mayall et al 1997; Paap et al 1984). The illusory-letters stimuli used in our study maintained broadly the overall shape of real words and, indeed, the words reported for each of these stimuli corresponded to these shapes. Consequently, despite the absence of medial letters, word-shape information may have helped generate sufficient lexical activation to produce the illusion of perceiving complete word stimuli composed entirely of fully formed letters.

A second source of the phenomenon may be that word recognition does involve identification of individual letters but that this requires only a cursory analysis of the physical characteristics of letters in certain positions. Indeed, this may be the case particularly when highly influential letters groups (like the exterior letter pairs present in our stimuli; Jordan 1990, 1995) can be perceived and which may constrain the identities of letters in medial locations. Consequently, despite the absence of medial letters in our illusory-letters stimuli, cursory letter information from medial positions coupled

with letter information from exterior positions may have helped generate sufficient lexical activation to produce the illusion.

However, irrespective of which explanation eventually proves the most appropriate, the phenomenon provides yet another indication that access to lexical entries can be achieved somewhat independently of physical form (eg Evett and Humphreys 1981; Humphreys et al 1990; Mayall and Humphreys 1996; Mayall et al 1997; Polk and Farah 1997; Rapp and Caramazza 1997). In particular, in the illusory-letters phenomenon, various letters are perceived in interior locations despite the use of stimuli containing just two exterior letters and two non-letter medial characters with physical characteristics which distinguish these stimuli from any written stimulus previously encountered. Thus, while the exact cause of the phenomenon remains to be determined, its existence indicates word recognition can be achieved on the basis of something other than precise visual form.

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