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A New Demonstration of the Illusory Letters Phenomenon:
Graphemic Restoration in Arabic Word Perception

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Abstract

The Illusory Letters Phenomenon (ILP) is a unique demonstration that words can be perceived as complete even when letters are physically absent. However, the ILP has only ever been reported for a Latinate language (English) and it is unknown whether the illusion occurs for alphabetic languages with fundamentally different visual properties. Here we report a demonstration of the ILP for Arabic in which stimuli containing only the exterior letters of three-letter Arabic words and a nonsense pattern in the interior position were presented to fluent Arabic readers. Despite being incomplete, participants perceived these stimuli as complete Arabic words with all letters visible in their appropriate positions, and were unable to distinguish between illusory and normal displays. This finding provides an important extension of the original ILP and suggests that alphabetic languages may be widely susceptible to the phenomenon and reading generally may occur as a process augmented by illusory percepts.

A major challenge for visual word recognition research is to determine which components of words are necessary for lexical access to occur (e.g., Grainger, 2008; Jordan, 1990). One approach to this challenge involves identifying situations in which words are perceived as complete even when letters are absent. Indeed, an early example of this phenomenon was reported by Pillsbury (1897) who described studies in which incomplete words were formed from real words (e.g., *chimney*) by letter replacement (*chimnzy*) or letter omission (*chimny*). When these incomplete words were presented briefly, participants sometimes reported seeing words in their entirety, with all letters present, despite the obvious nature of each incomplete stimulus when viewed for longer durations.

A little over 100 years later, Jordan, Thomas and Scott-Brown (1999) reported in *Perception* a demonstration that the illusory restoration of missing letters in words can occur more reliably, and when viewing time is unlimited. In this study, the two exterior letters of four-letter English words (e.g., h d) were presented with a nonsense pattern composed only of diagonal lines in each interior position (see Figure 1). When these stimuli were presented for unlimited durations, observers reported a range of illusory contours that made each stimulus appear to be a normal, complete, four-letter English word (the *Illusory Letters Phenomenon* or ILP). Indeed, participants were able to trace the outline of four letters in each stimulus, including letters in interior positions that were not actually present, and were unable to distinguish between words that were illusory and words that were physically complete.

The nature of the ILP indicates that the phenomenon is more than just a demonstration that incomplete words can produce lexical activation. For example, other studies have shown that brief presentations of incomplete word primes can improve word recognition (e.g., *apricot* preceded by *arict*; e.g., Grainger, Granier, Farioli, Van Assche, & van Heuven (2006), and that incomplete “leet” words (e.g., *R3AD*) and transposed words (e.g., *raeding*) allow some form of reading to take place despite the obvious disruption of normal orthographic content in these stimuli (e.g., Perea, Duñabeitia, & Carreiras, 2008; Rayner, White, Johnson, & Liversedge, 2006; see also Fang & Wu, 1989). But

while these effects provide important evidence that lexical activation can happen when incomplete words are presented, the paradigms used do not provide clear evidence that the illusory perception of complete words has actually occurred. For example, it is unclear in the brief priming paradigm that incomplete word primes are perceived as complete words, and when reading leet words and transposed words, the disrupted orthographic content of these stimuli is frequently apparent to participants. In contrast, in the ILP, the observer's subjective experience is of actually perceiving complete words, with all letters fully-formed and in their appropriate locations, even though the normal physical bases for these complete perceptions are not present in the display. Thus, the effect is truly an illusion, where perception is clearly separated from sensation.

However, the ILP has only ever been reported for English, and it may be that printed English (and other Latinate languages) lends itself unusually well to producing the phenomenon. In particular, letters in English have a constant size and shape within a typeface and, when printed, are spatially separable and distinct (like the words on this page). Under these conditions, therefore, word recognition processes for Latinate languages may be unusually adept at using cues from the letters that are present in a stimulus to produce the ILP.

hzzzd vzzzt

Figure 1. Examples of stimuli producing the ILP in English (after Jordan et al., 1999). Readers can experience the illusion by placing the page at a viewing distance of 3m (depending on eyesight) and moving slowly towards the stimuli. At some point, complete words become visible, including distinct letters in interior positions.

To address the generalisability of the ILP, therefore, we investigated the phenomenon using a language with very different characteristics from English and other Latinate languages; Arabic. Arabic has the second most used alphabet in human societies, after the Latin alphabet. However, in addition to

being read from right to left, printed Arabic, unlike Latinate languages, is formed in cursive script in which the visual appearance of letters varies considerably within the same typeface, and spaces between letters seldom exist. These characteristics contrast strongly with those of Latinate languages and so Arabic provides a powerful assessment of the generalisability of the ILP across different alphabetic systems. Indeed, if the ILP occurs for Arabic, this would suggest that alphabetic languages generally are susceptible to the phenomenon and reading these languages may be augmented by illusory percepts.

Twelve illusory stimuli were formed from twelve, three-letter Arabic words in which the middle letter was replaced by a nonsense pattern composed only of dots (see Figure 2). Following the procedure of the original study (Jordan et al., 1999), illusory stimuli were randomly intermingled with other, complete three-letter Arabic words (i.e., words that contained all their letters). All stimuli were presented one above the other in a vertical column in high contrast black on white and were viewed under bright lighting conditions. Each stimulus measured approximately 25 mm horizontally.

Figure 2. Examples of illusory stimuli used in the present study.

Participants were 20 fluent, native Arabic readers from Dubai, aged between 18 and 21 years. To accommodate individual differences in visual acuity, the visibility of stimuli was adjusted by using a separate set of 10 complete three-letter Arabic words and altering viewing distance until accuracy of word report for these items was approximately 90%. The experimental items were then presented and participants read out loud what they saw for each stimulus. In addition, participants were required at regular intervals to identify which stimuli were the most legible.

Mean accuracy of report for complete (i.e., normal) word stimuli was 97%, indicating that the visual information encoded from these stimuli was sufficient for high levels of accurate word recognition. Moreover, 100% of responses made to illusory stimuli showed the ILP, and responses were produced with no apparent (or reported) effort by participants, indicating that the visual information encoded from each illusory stimulus was sufficient to produce the phenomenological experience of “normal” word content. Indeed, when requested during each session, participants were unable to distinguish between normal and illusory stimuli, and traced the outline of all three letters in illusory stimuli with their fingers even though no letter was physically present in any interior position. This point is supported by the finding that when asked to name the most legible stimuli, 49% were complete words and 51% were illusory-letters stimuli ($p > 0.05$ by a binomial test).

These findings indicate that the ILP is not restricted to English, and that the phenomenon is a characteristic common across very different alphabetic systems. As Jordan et al. (1999) argue, one source of the ILP may be that representations for words are accessed using coarse-scale information without fine-scale analyses of individual letters (for discussions, see Allen, Smith, Lien, Kaut, & Canfield, 2009; Jordan, McGowan, & Paterson, 2012; Jordan et al., 1999). Thus, even when letter content is physically incomplete, overall shape information (in Arabic and other alphabetic systems) may generate sufficient lexical activation to produce the illusion of complete words containing all their component letters. An additional source may be the identification of individual letters that requires only a cursory analysis of their physical characteristics, and this process may be assisted by interactive influences that feedback from the word level to reinforce the perception of a complete array of letters (e.g., Rumelhart, & McClelland, 1982; Smith, Jordan, & Sharma, 1991). Indeed, both these sources of influence may be particularly effective when prominent letters groups (like exterior letter pairs; Jordan, 1990; Jordan, Thomas, Patching, & Scott-Brown, 2003) are present in the stimulus to constrain the identities of letters in other positions. But irrespective of which explanation ultimately proves most

appropriate, the indication now is that the ILP occurs in a language very different from English (Arabic), suggesting that alphabetic languages generally are likely to be susceptible to the phenomenon and that reading these languages may often occur as a process augmented by illusory percepts.

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