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Illusory Conjunctions in the Perception of Chinese Characters

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A Chinese compound character consists of a radical component and a stem component. When compound characters were presented briefly, Ss often reported seeing illusory recombinations of radicals and stems. A series of 5 experiments suggested that the probability of seeing illusory characters is not under the direct influence of lexicality, pronounceability, or character frequency, but depends on 2 factors: (1) familiarity defined in terms of unit frequency, i.e., the frequency of occurrence of a unit either by itself or as part of a larger unit, and (2) the context-dependent perceptual distinctiveness of the components of a given character. It is suggested that the seemingly unreliable lexicality effect obtained in English studies may be reduced to a familiarity effect, and that what McClelland and Mozer (1986) referred to as the surround-similarity effect may be better characterized as an effect of perceptual distinctiveness.

This study intends to find out whether and why some Chinese characters are perceptually more cohesive than others by using the illusory conjunction paradigm developed by Shallice and McGill (1978) and by Treisman and her colleagues (Treisman & Gelade, 1980; Treisman & Schmidt, 1982; Treisman, Sykes, & Gelade, 1977). This is mainly an attempt to show how graphemic migrations might reflect orthographic structure.

Treisman and Gelade (1980) proposed a feature integration theory of attention, which states that the bottom-up processing of object identification involves two stages: an early stage of feature registration that is independent of attention and a later stage of feature integration that requires focused attention. Illusory conjunctions are said to occur when attention is diverted or overloaded so that features detected in the early stage are incorrectly recombined in the later stage.

It has been shown that the size of units of migration varies from simple features such as color or line segments (Treisman & Schmidt, 1982) to feature conjunctions such as letters or letter clusters (Mozer, 1983; Prinzmetal & Millis-Wright, 1984; Treisman & Souther, 1986). For example, given a brown triangle and a blue circle, a subject might perceive a brown circle; or given *hark* and *live*, a subject might perceive *lark*.

In the study of letter migrations, one much debated issue is how strongly higher level structural knowledge may affect lower level encoding. Attempts have been made to examine the effects of lexicality and pronounceability on the rate of illusory conjunctions, and seemingly inconsistent results have been obtained. Some researchers claimed that pronounceable items were perceptually more cohesive than unpronounceable nonwords (Prinzmetal & Millis-Wright, 1984). Some reported more letter migrations between pseudowords than between words (McClelland & Mozer, 1986). Other researchers obtained neither a pronounceability effect nor a lexicality effect on the rate of illusory conjunctions (Treisman & Souther, 1986).

One difficulty in studying English words is that the possible units of perception vary in size from single letters to entire words. In comparison, the Chinese compound character, which is made up of a radical and a stem, has a simpler structure and, therefore, might present a clearer view of the nature of illusory conjunctions. This study intends to offer an explanation for the inconsistency described in the preceding paragraph: The unreliable lexicality and pronounceability effects obtained in English language studies may be reducible to a frequency effect.

The majority of Chinese characters are compound characters consisting of one radical component and one stem component. For example, the character for *do* is made up of a radical meaning *human* and a stem that is the character for *suddenly* (Figure 1a). In most cases, the stem by itself can serve as a simple character, whereas the radical is derived from a simple character and is not used in isolation.

In some cases, the stem component of a compound character is itself a compound character. For example, the character for *flower* (Figure 1b) consists of a radical indicating *flora* on top and a stem, *transform*, which in turn is a character consisting of a radical indicating *human* and a stem, *dagger*.

Not all compound characters, however, can form parts of more complex compounds. The character for *do*, for example, cannot join any radical to form new compounds. It represents a unique stem–radical pairing within the repertoire of Chinese characters and is referred to as a *unique compound*.

The character for *transform*, on the other hand, can be combined with various stroke patterns to form new characters (Figure 1b). It thus serves as the core of a family of characters and is referred to as a *stem compound*.

Suppose there is a three-component compound m(xA), where m represents a radical, xA represents a compound stem, made up of a radical, x, and a stem, A. Intuitively, the

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	Radical (x)	Stem (A)	Compound (xA)	Derived Characters m(xA)			
a.	unique	character					
	亻 (human)	乍[zha] suddenly	作[zuo] do 2,168	(none)			
b.	stem	character					
	亻 (human)	匕[bi] dagger	化[hua] transform 602	花[hua] flower 675	货[huo] goods 73	靴[xue] boots 3	訛[e] erroneous 1
c.	stem	component					
	NA	NA	殳[shu] (a bamboo spear) 0	没[mei] not 1,322	投[tou] throw 206	殺[sha] kill 216	般[ban] sort 188

Figure 1. Example of three types of two-component Chinese compound characters, their components, and some of the multicomponent compounds derived from them. (The general meaning indicated by a radical is shown in the parentheses below it. The pronunciation of each character is shown in the brackets, according to the Pinyin system of romanization. The character's English meaning is given below it, its frequency of usage below that.)

bond between the components within the stem, (i.e., x and A) would be stronger than that between the radical and the stem within the character (i.e., m and xA). If such intuition does reflect one facet of psychological reality, one can predict that, given two compound characters m(xA) and n(yB), an illusory m(yB) is more likely to occur than an illusory n(xB). In other words, component migrations might reflect the structural relationship of character components. These migrations might even serve as a tool for studying the structural properties of Chinese orthography. Unfortunately, the actual distribution of radical–stem combinations in three-component compounds makes it difficult to verify this prediction. That is, in most cases, given a probe m(yB) or n(xB), neither m(xA) or n(yB) exists. One can only tackle the problem indirectly by comparing the rates of illusory conjunctions yielded by unique compounds and by stem compounds.

If the compound stem xA within m(xA) is treated as a unitary whole by the perceptual system, one can conceptualize the bond between m and xA as equivalent to that between the two components of a unique compound, mC, where m is the radical and C the stem, other things being equal. In other words, the radical–stem association in a stem compound should approximate the x–A type of association within a three-component compound, whereas the radical–stem association in a unique compound should approximate the m–xA type of association within a three-component compound. One would predict that the cohesiveness of components within stem compounds is stronger than that within unique compounds. Therefore, unique compounds should yield more illusory conjunctions than stem compounds. (Note that characteristics consisting of four or more components are rare, resulting in a low chance for a three-component character to be perceived as a unitary whole.)

One possible reason why stem compounds are expected to be perceptually more cohesive than unique compounds is that stem compounds not only appear by themselves but also appear as part of larger units, as shown in Figure 1b. Stem compounds might in general appear more frequently than unique compounds and consequently are more likely to be treated as unitary wholes by the perceptual system at the stage of feature registration. Thus, components of a stem compound are less likely to join those of another compound to yield illusive characters at the stage of feature integration. Unique compounds, on the other hand, are more likely to be treated as a set of separable units at the stage of feature registration. Components of unique compounds, thus, are more likely to float around and to form illusory conjunctions at the stage of feature integration.

Experiment 1 was conducted to verify that single strokes and stroke clusters can be subject to conjunction errors in the perception of Chinese characters. Experiment 2 then demonstrated that unique compounds are more likely to yield conjunction errors than stem compounds. Experiment 3 replicated similar results by using familiar compounds that have no lexical entry. Experiment 4 compared the rates of conjunction errors between compounds and pseudocompounds. Experiments 1 and 5 examined how a character's surroundings might affect its components' separability.

Experiment 1: Stroke and Radical/Stem Migrations

Experiment 1 was designed for two purposes: to demonstrate the basic phenomenon of illusory conjunctions among Chinese characters, and to investigate the effect of context on the likelihood of conjunction errors.

The general experimental procedures in this and each of the succeeding experiments were basically the same. The subject was asked to perform a target detection task. Each trial consisted of the following sequence: a verbal "ready" signal given by the experimenter, a 1-s presentation of a probe character, a 1-s presentation of a black rectangle outlining the area within which the test characters would appear, the test display for a variable duration, and finally a "checkerboard" noise mask for 200 ms.

The test display consisted of two digits with either two or three test characters in between. The subject was instructed to report the digits and then to state whether or not the preceding probe exactly matched one of the test characters.

According to a pattern-unit model of word perception (Johnson, 1977, 1981), features that are physically contiguous are fused into a higher order pattern and are consequently more difficult to detect in a target detection task than features that are not touching one another. For example, a slash (/) in the letter *V* took longer to detect than that in a display consisting of two separate slants: \ /. Such a prediction was also confirmed by using Chinese characters as test stimuli (Fang, et al., 1985). A stroke cluster contiguous with the rest of the character took longer to detect than a discrete part of a character (840 ms, as compared with 700 ms).

Would a stroke segment in a simple character be more resistant to entering into illusory conjunctions than a radical/stem in a compound character? To answer this question, Experiment 1 examined the occurrence of illusory conjunctions at two levels: the stroke level and the radical/stem level. The unit of potential migration at the stroke level was a single stroke that is contiguous with another stroke, or a segment of a stroke. For example, the left-falling stroke at the top of the character for *grass* might migrate to the character for *ancient* and form an illusory character for *tongue* (Figure 2a); or the hook feature at the bottom of *eaves* might replace the turning stroke at the bottom of *hair* and form an illusory *hand* (Figure 2b).

Migration Level		Source Characters		Illusory Character
Stroke	a.	禾 grass	古 ancient	舌 tongue
	b.	宇 eaves	毛 hair	手 hand
Radical/ Stem	c.	波 wave	役 service	沒 not

Figure 2. Illustration of possible migrations at the stroke level and the radical/stem level. (A character's English meaning is given below it.)

The unit of potential migration at the *radical/stem level* was a stem or a radical of a compound character whose two parts did not touch each other. For example, a shift of parts between the two characters *wave* and *service* might generate an illusory *not* (in the context of *there is not*) (Figure 2c).

In a pilot study, each of the test displays consisted of two characters (the source characters of illusory conjunctions), the parts of which could recombine to form new characters and a third character (the context character) that was unrelated to the other two. The experimenter tried to maintain a 30% error rate. It was found that when the subject made errors at the desired percentage, the subject was hardly ever sure of her or his judgments. When the exposure duration lengthened so that the subject could sometimes be sure, she or he hardly ever saw illusory characters. The dilemma was solved by modifying the neutral context character into a composite context character. While the neutral context character was unrelated to the source characters, the composite context character was a conjunction of components of the two source characters. As a consequence, Experiment 1 also examined whether migrations occurred more frequently in a composite context than in a neutral context.

In the stroke-level condition, the composite context character differed from one of the two source characters by one stroke. For example, given two simple characters, *tongue* and *wood*, as the source characters, the composite context character would be *ancient*, the neutral context character would be *sweet*, and the probe conjunction, *grass* (Figure 3). In the radical/stem condition, the composite context character shared one component with each of the two source characters. The question of interest is whether *wave* and *service*, for example, would be more likely to generate an illusory *not* when the context character was *that* (i.e., in a composite context) than when it was *absorb* (i.e., the neutral context; Figure 3).

Displays	Migration Levels: Stroke			Radical/Stem			Symbolic Form
Probe	禾 grass			没 not			pP
Composite Context	舌 tongue	木 wood	古 ancient	波 wave	役 service	彼 that	pA aP aA
Neutral Context	舌 tongue	木 wood	甘 sweet	波 wave	役 service	吸 absorb	pA aP bB
Control	木 wood	古 ancient	甘 sweet	投 throw	彼 that	吸 absorb	cP aA bB
Identical	禾 grass	古 ancient	甘 sweet	没 not	彼 that	吸 absorb	pP aA bB

Figure 3. Example of the two types of characters and the four types of test displays used in Experiment 1. (Small letters denote the radicals, capital letters the stem.)

The composite context is expected to enhance the separability of source character components and thus the likelihood of conjunction errors whenever illusory conjunctions are possible. Plausible explanations of the context effect will be offered later.

Method

Stimuli. Twenty probe displays and 80 test displays were made for this experiment. The probe display consisted of one black Chinese character located 0.94° above the center point of the screen, subtending a visual angle of 1.88° horizontally and vertically. The test display consisted of three black Chinese characters arranged in a row positioned at the center of the screen between two blue digits. The subtended angles were 1.88° horizontally and vertically for the characters, and 0.75° horizontally and 1.50° vertically for the digits. The row of characters subtended an angle of 5.65°. For the entire row, including the digits, the subtended angle was 8.20°.

The 20 probe characters and their corresponding test displays were evenly divided into two conditions, determined by the level at which illusory conjunctions might occur: the stroke–level condition and the radical/stem–level condition, as previously illustrated.

Each probe was presented four times, each time followed by one of its four corresponding test displays: the composite-context conjunction display, the neutral-context conjunction display, the control display, and the identical display. Take the probe *not* as an example (Figure 3). The composite-context conjunction display included *wave* and *service* as source characters, which would allow the illusion of the probe to occur, and *that* as the context character. The neutral-context conjunction display included the same source characters and *absorb*, an unrelated character, as the context character. The identical display included the probe character and two unrelated characters (i.e., *that* and *absorb*). The control display included the same two unrelated characters and one character that was similar to the probe (i.e., *throw*). The control condition served to estimate the proportion of false detection due to intrusion or guessing. In each of these display conditions, the character types occurred equally often in each of the three display positions.

Procedure. A 2 × 4 × 10 (Conjunction Level × Probe Condition × Trial) within-group design was adopted, totaling 80 trials. The 80 trials were separated into four blocks of 20 trials, each block containing the 20 probe characters, with the display conditions divided evenly among composite-context conjunction displays, neutral-context conjunction displays, control displays, and identical displays. The order of probes was randomized within blocks and remained the same across blocks. The order of blocks was randomized across subjects.

The stimuli were presented in a Gerbrands four-field tachistoscope. The sequence of events for each trial was as previously described: a verbal "ready" signal, a probe character presented for 1 s, a rectangle presented for 1 s, a test display of variable duration, and a noise mask for 200 msec.

The subject was instructed to report the digits on the test display and then to state whether or not the preceding probe exactly matched any one of the three test characters. Four response categories were used to reflect the confidence of the subject's judgment. The four categories were *sure yes*, *think yes*, *think no*, and *sure no*. The importance of accuracy on naming the digits was emphasized. Feedback was provided for digit naming but not for probe detection. The mean digit-naming error rate across subjects was .03, with a range of .00–.12.

The initial exposure duration of the test display was determined during practice trials. Each practice trial consisted of a test display (used for practice purposes only) followed by a noise mask for 200 ms. The exposure duration was set at 200 ms for the first few trials. The subject was asked to give a whole report of the two digits and then the three characters. The duration was increased or reduced by the steps of 10 ms until the subject could accurately report both digits but no more than two characters.

During the experimental trials, the experimenter tried to elicit an overall error rate (including false detection and miss of probes) of about 30% for each subject by increasing or reducing the exposure duration of the test display. The number of errors was calculated every 10 trials. If a subject made more than three errors, the exposure duration was increased by 10 ms. If a subject made less than three errors, the exposure duration was reduced by 10 ms. The median exposure duration across all the trials was 140 ms, with a range of 30–210 ms.

Subjects. Twenty students, 10 men and 10 women, at National Tsing Hua University, Hsinchu, Taiwan, volunteered to participate in this experiment.

Results

Table 1 gives the mean probabilities of each of the four responses, *sure yes*, *think yes*, *think no*, and *sure no*. The proportion of illusory conjunctions was estimated by subtracting the *sure yes* response rate in the control condition from that in each of the two conjunction conditions. As the *sure yes* responses were generally prompt, the latencies for the *think yes* responses were unduly long. The latter were not included for analysis, because we were only interested in illusory conjunctions as subjectively real perceptual experience. The estimated percentages of illusory conjunctions at the stroke level were .08 (.30 − .22) for the composite context and −.01 (.20 − .22, with rounding error taken into account) for the neutral context. Those at the radical/stem level were .13 (.34 − .21) for the composite context and .04 (.24 − .21) for the neutral context. An analysis of variance (ANOVA) for repeated measurements revealed the following results.

First, as expected, the nature of the context played an important role in the generation of illusory conjunctions. The composite context significantly enhanced the proportion of illusory conjunctions, $F(1, 19) = 11.76$, $p < .005$. In fact, illusory conjunctions tended to concentrate in the composite-context condition, and the rate of illusory conjunctions was generally negligible for the neutral context.

Second, neither the main effect of the conjunction level nor the interaction between the level of conjunction and the type of context was significant ($Fs < 1$). Illusory conjunctions were equally likely to occur at both the stroke level and the radical/stem level.

Experiment 2: Stem Compounds Versus Unique Compounds

Experiment 1 showed that components of Chinese characters were subject to illusory conjunctions and that this tendency was stronger in a composite context than in a neutral context. Experiment 2 was designed to examine the distribution of illusory conjunctions among stem compounds and unique compounds in a composite context. It was predicted that unique compounds would yield more illusory conjunctions than stem compounds. Migrations observed in this and succeeding experiments were exclusively at the radical/stem level.

It should be mentioned here that a majority of unique compound characters are pictophonetic characters, with the radical indicating meaning and the stem indicating sound. Nowadays the pronunciation of a pictophonetic character might not be consistent with that of its stem, due to historical variations of the spoken language. In Experiments 2–5, a precaution was taken in the selection of unique compounds to avoid possible confounding between the uniqueness of the radical–stem pairing and the character–stem congruency in pronunciation.

Method

Stimuli. One hundred twenty probe displays and 120 test displays made up a total of 120 trials. A new set of characters was selected but the display cards were made in the same way as in Experiment 1. Each test display consisted of three characters between two digits. Two of the characters served as source characters of illusory conjunctions and one served as the context character, which was composed of one component of each of the two source characters. Half of the test displays consisted of stem compounds, and the other half, unique compounds. The frequency counts of the source characters in the two conditions were matched as closely as possible. According to a grade-school-level norm established by the National Institute for Compilation and Translation (1967), the frequency counts of stem compounds ranged from 0 to 3,404 with a mean of 243, and those of unique compounds ranged from 0 to 2,079 with a mean of 164.

The 120 trials were made up of 60 conjunction-probe trials, 30 control-probe trials, and 30 identical-probe trials. Examples are shown in Figure 4. In a conjunction probe trial, the probe pP was a

Table 1
Proportion of Responses Receiving Each Confidence Rating for Each Conjunction Level and Display Condition in Experiment 1

Conjunction level	Identical				Composite context				Neutral context				Control			
	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2
Stroke	.22	.04	.09	.64	.53	.10	.08	.30	.64	.11	.05	.20	.64	.08	.06	.22
Stem	.16	.06	.14	.64	.46	.08	.12	.34	.54	.12	.10	.24	.58	.09	.12	.21

Note. −2 = *sure no*, −1 = *think no*, +1 = *think yes*, +2 = *sure yes*.

	Unique Compound		Stem Compound		Symbolic Form	
Probe Condition	Probe	Test Display	Probe	Test Display	Probe	Test Display
Conjunction	村	核 討 該	跛	路 波 洛	pP	pA aP aA
Control	桂	娃 妙 秒	恥	耶 郎 朗	pP	pA aA aB or aP aA bA
Identical	虹	虹 蜕 脱	視	視 親 新	pP	pP aP aB or pP pA bA

Figure 4. Example of the two types of compounds and the three types of probe conditions used in Experiment 2. (Small letters denote the radicals, capital letters the stem.)

complementary conjunction to the context character aA, and the test display could be denoted as pA aP aA. In an identical-probe trial, the probe (pP) was present on the test display (pP pA bA or pP aP aB). And in a control-probe trial, the probe (*pP*) shared one component with one and only one character on the test display (aP aA bA or pA aA aB). The character types occurred equally often in each of the three display positions.

Procedure. A 2 × 3 (Compound × Probe) within-group design was adopted. For each type of compound, there were 30 conjunction-probe trials, 15 identical-probe trials, and 15 control-probe trials. The percentage of *sure no*, *think no*, *think yes*, and *sure yes* judgments served as the response measure. The general procedure was the same as in Experiment 1. The median exposure duration of the test display across all the trials was 160 ms, with a range of 70–270 ms.

Subjects. Twenty students at National Tsing Hua University received course credit for participating in this experiment. None had participated in Experiment 1.

Results

Data were analyzed in the same way as in Experiment 1. The results are shown in Table 2. The estimated proportions of illusory conjunctions were .05 (.16 − .11) for the stem compound and .17 (.20 − .03) for the unique compound. A two-tailed *t* test showed that stem compounds generated fewer conjunction errors than unique compounds, $t(19) = 4.26$, $p < .01$.

Experiment 3: Stem Components Versus Unique Components

The purpose of Experiment 3 was to examine whether the difference between stem and unique compounds observed in Experiment 2 would still hold if the compounds were character components whose meaning and pronunciation are unknown to the subject. For example, as shown in Figure 1c, the item representing *a bamboo spear-like ancient weapon* is not presently in use as a character. Not even a sinologist is expected to be able to identify its meaning or pronunciation without consulting a dictionary. But it is frequently seen because it serves as a component in a number of characters (e.g., *not*, *throw*, *kill*, *sort*). A component of this kind is

Table 2
Proportion of Responses Receiving Each Confidence Rating for Each Type of Compound and Probe Condition in Experiment 2

	Probe condition											
	Identical				Conjunction				Control			
Compound	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2
Stem	.09	.10	.23	.58	.48	.21	.16	.16	.58	.20	.10	.11
Unique	.12	.14	.21	.54	.39	.21	.20	.20	.65	.23	.08	.03

Note. −2 = *sure no*, −1 = *think no*, +1 = *think yes*, +2 = *sure yes*.

referred to as a *stem component.* A component that appears only in one particular character is referred to as a *unique component.*

Four types of compounds were used in Experiment 3: stem components, stem characters, unique components, and unique characters. Parallel results for compound components and compound characters would exclude the possibility that lexicality plays an essential role in the generation of illusory characters. Stem and unique components served as a better control for character frequency (as opposed to *unit frequency,* the frequency of occurrence of a unit either by itself or as part of a larger unit) than stem and unique compounds. In Experiment 3, stem compound characters inevitably ranked higher in character frequency than unique compound characters, due to the fact that all selected items were vertical compounds, the components of which were arranged in top–bottom formation. But the character frequency was 0 for both stem and unique compound components.

Method

Stimuli. Thirty-two probe displays and 96 test displays (including 32 cards each for the identical trials, conjunction trials, and control trials) were made in the same way as in Experiment 1, except that the test displays consisted of only two characters (see Figure 5). The row of characters subtended an angle of 3.82° and the entire row, including the digits, subtended an angle of 6.11°. There were four types of test displays (stem components, stem characters, unique components, and unique characters), with eight probes for each type of test display (six compound characters and two compound components).

The character frequency of the stem characters ranged from 0 to 3404, with a mean of 719 and a median of 156. Those of the unique characters ranged from 0 to 889, with a mean of 128 and a median of 38. Those of the stem and the unique components were all 0. (The unit frequency counts of the stem components ranged from 46 to 2,250 with a mean of 500, and those of the unique components ranged from 0 to 313 with a mean of 71.)

Procedure. Experiment 3 adopted a 4 × 3 × 8 (Compound × Probe × Trial) within-group design, totaling 96 trials. The general procedure was the same as in Experiments 1 and 2. The median exposure duration of the test display across all the trials was 78 ms, with a range of 40–190 ms.

Subjects. Twenty Tsing Hua University students, 7 men and 13 women, received course credit for participating in this experiment. None had participated in Experiment 1 or 2.

Results

The results are shown in Table 3. The estimated proportions of true conjunctions for the stem and the unique characters were .11 (.14 − .02, with rounding error taken into account) and .16 (.19 − .04), respectively. Those for the stem and unique components were .09 (.12 − .04) and .18 (.21 − .04), respectively. The relative importance of lexicality and compound type was assessed by carrying out an ANOVA for a 2 × 2 repeated measurement design.

The ANOVA showed, first of all, that there was no significant main effect of lexicality, $F(1, 19) < 1$. Compound components and compound characters were equally likely to yield illusory conjunctions. Second, as previous experiments showed,

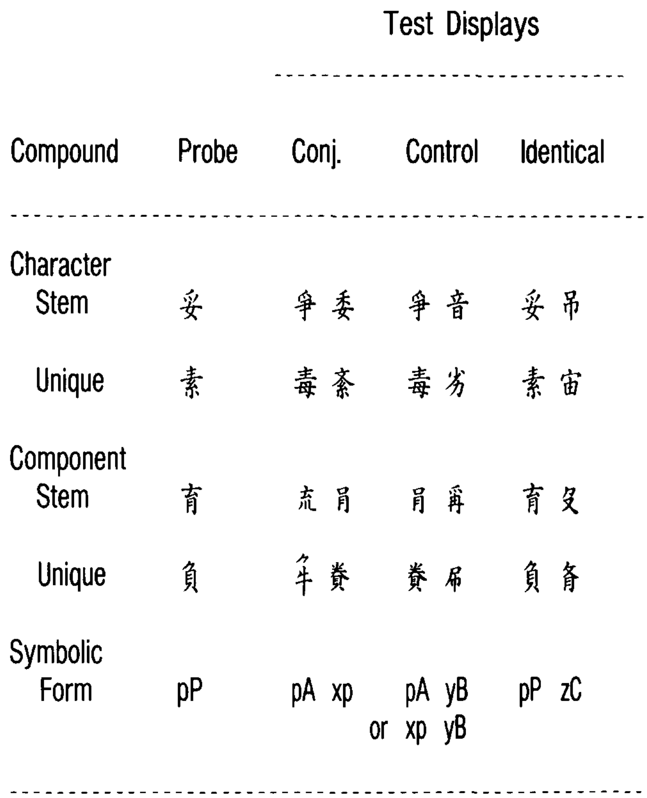

Figure 5. Example of the four types of compounds and the three types of test displays used in Experiment 3. (Small letters denote the radicals, capital letters the stem.)

unique compounds gave rise to significantly more illusory conjunctions, $F(1, 19) = 12.72$, $p < .005$. Third, there was no significant interaction between lexicality and compound type, $F(1, 24) < 1$.

Experiment 4: Pseudocompounds

Experiments 2 and 3 consistently showed that stem compounds generated fewer illusory conjunctions than unique compounds, suggesting that components of stem compounds were perceptually more cohesive. The results of Experiment 3 also suggested that lexicality and pronounceability played only a minor role in the generation of illusory conjunctions; compound components, which had no lexical entries or pronunciations, were as likely to generate illusory conjunctions as were compound characters. Nor could character frequency account for the observed differences between stem and unique compounds, since stem components generated fewer illusory conjunctions than unique components even though neither ever appeared as a character by itself.

Although lexicality and pronounceability have little effect on the rate of illusory conjunctions, familiarity, defined in terms of unit frequency, seemed to play a dominant role, suggesting that frequently encountered patterns are most likely to be adopted by the perceptual system as an integral unit and are therefore less likely to enter into illusory conjunctions than rarely seen items.

Table 3
Proportion of Responses Receiving Each Confidence Rating for Each Type of Compound in Experiment 3

	Probe											
	Identical				Conjunction				Control			
Compound	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2
Character												
Stem	.04	.06	.24	.66	.45	.29	.12	.14	.76	.14	.07	.02
Unique	.06	.13	.17	.64	.48	.19	.13	.19	.73	.14	.09	.04
Component												
Stem	.10	.08	.12	.69	.65	.15	.08	.12	.75	.16	.05	.04
Unique	.16	.06	.15	.63	.39	.26	.14	.21	.72	.14	.10	.04

Note. −2 = *sure no*, −1 = *think no*, +1 = *think yes*, +2 = *sure yes.*

According to the familiarity account, English words and pseudowords may or may not differ in the proportions of conjunction errors they generate, depending on the unit frequency counts of pseudowords selected (cf. Treisman & Souther, 1986; McClelland & Mozer, 1986). However, the familiarity account predicts a higher rate of illusory conjunctions for Chinese pseudocompounds than for compound characters; the unit frequency of a character, however low, is higher than that of a pseudocharacter, which is an absolute zero.

Experiment 4 was designed to verify this prediction. The pseudocompound characters were made up of one commonly seen radical and one commonly seen stem (see Figure 6 for examples). In addition to the character-versus-pseudocharacter manipulation, the compound characters in Experiment 4 were divided into three types: stem compounds, high-frequency unique compounds, and low-frequency unique compounds. This arrangement served as a back-up design to double-check the effect of unit frequency. The characters were chosen so that the unit frequency of the high-frequency unique compounds matched those of the stem compounds, and therefore the previously obtained differences between the stem and the unique compounds should not be observed between these two categories. The low-frequency unique compounds, on the other hand, should produce more illusory conjunctions than the other two types of characters.

In Experiment 1, which included both the composite and the neutral context conditions, true illusory conjunctions seldom occurred in the neutral context condition. Experiment 4 was designed to elicit illusory conjunctions in a neutral context. Stem compounds whose components cannot form characters with the source-character components were chosen as the context characters, so that context characters would add to the subject's attention load but would neither enter into illusory conjunctions nor lower the subject's chance of seeing the illusory probe.

Method

Stimuli. A new set of characters was selected for this experiment. One hundred twelve probe displays and 56 test displays (including 14 cards each for the stem compound, the high-frequency unique compound, the low-frequency unique compound, and the pseudocompound conditions) were made in the same way as in Experiment 1. Each test display was presented twice, preceded once by a conjunction probe and once by either an identical probe or a control probe. Each test display consisted of two source characters and one context character unrelated to the source characters. The unit frequency counts of the source characters on the stem compound displays ranged from 101 to 10,125, with a mean of 925. Those of the source characters on the high-frequency unique compound displays ranged from 79 to 26,872 with a mean of 1,626. Those of the low-frequency unique source characters ranged from 0 to 43 with a mean of 7. Those of the pseudocompounds were all 0. All of the context characters were stem compounds. The mean unit frequency counts of the context characters in the stem, the high-frequency unique, the low-frequency unique, and the pseudocompound conditions were 1,050, 861, 650, and 758, respectively. In each condition, half of the conjunction probes were stem compounds and half were unique compounds. The mean unit frequency count of the probes in the stem, the high-frequency unique, the low-frequency unique, and the pseudocompound conditions were 995, 919, 906, and 845, respectively. Examples are given in Figure 6.

Procedure. A 4 × 3 (Compound × Probe) within-group design was adopted. The general procedure was the same as in Experiments 1, 2, and 3. The median exposure duration across all the trials was 130 ms, with a range of 30–230 ms.

Subjects. Twenty-six Tsing Hua students, 9 men and 17 women, volunteered to serve as subjects. None of them had participated in any of the previous experiments.

Results

The results are shown in Table 4. The estimated percentage of true conjunctions was .04 (.07 − .03) for the stem compounds, .06 (.15 − .09) for the high-frequency unique compounds, −.01 (.22 − .23) for the low-frequency unique compounds, and .24 (.39 − .15) for the pseudocompounds. An ANOVA for repeated measurements revealed a significant main effect, $F(3, 75) = 22.00$, $p < .001$. A multiple comparison showed that the main effect was mainly due to the higher rate of illusory conjunctions of the pseudocompounds, $F(3, 75) = 31.34$, $p < .001$. Illusory conjunctions tended to concentrate in the pseudocompound conditions. The conjunction rates in the other conditions were negligible and did not differ from one another.

In order to allow the differences between the three types of characters to surface, Experiment 4 was replicated with the pseudocompound condition removed. As a routine practice in this study, an entirely different set of characters was selected. The mean unit frequencies of the source characters in

	Probe Condition					
	Conjunction		Control		Identical	
Compound	Probe	Test Display	Probe	Test Display	Probe	Test Display
Stem	村	松 付 將	科	利 加 化	胡	胡 敬 制
Unique Hi Freq	約	給 的 新	待	特 昨 張	復	陽 清 復
Lo Freq	好	姣 籽 於	粗	沮 怯 付	鈾	鈾 拙 快
Pseudo	級	紴* 极* 俟	呢	柅* 粘* 切	此	⿰木夬* ⿰阝交* 此
Symbolic Form	pP	pA aP lL	qQ	xQ bB mM or qX bB mM	rR or nN	rR cC nN

Figure 6. Example of the four types of compounds and the three types of test displays used in Experiment 4. (Small letters denote the radicals, capital letters the stem. Pseudocompounds are marked with an asterisk [*]. l, m, n, L, M, N = components of context characters.)

the stem, the high-frequency unique, and the low-frequency unique conditions were 565, 552, and 15, respectively. The mean unit frequencies of the context characters in the stem, the high-frequency unique, and the low-frequency unique conditions were 798, 905, and 798, respectively. Those of the probes in these three conditions (given in the same order) were 325, 318, and 356. The obtained percentage of true conjunctions was .03 for the stem compounds, .00 for the high-frequency unique compounds, and .16 for the low-frequency unique compounds. An ANOVA for repeated measurements revealed a significant main effect, $F(2, 50) = 12.74$, $p < .001$. A multiple comparison showed that the main effect was mainly due to the higher rate of illusory conjunctions of the low-frequency compounds, $F(2, 50) = 13.91$, $p < .005$. In other words, when unit frequency was held constant, stem compounds and unique compounds were equally likely (or

Table 4
Proportion of Responses Receiving Each Confidence Rating for Each Type of Probe and Compound in Experiment 4

	Probe											
	Identical				Conjunction				Control			
Compound	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2
Stem	.08	.04	.09	.79	.66	.18	.09	.07	.71	.20	.05	.03
Unique												
Hi freq	.12	.09	.12	.67	.58	.19	.09	.15	.74	.15	.02	.09
Lo freq	.13	.09	.09	.68	.51	.16	.11	.22	.58	.11	.09	.23
Pseudo	.13	.08	.09	.70	.35	.16	.11	.39	.54	.19	.12	.15

Note. Hi freq = high frequency; Lo freq = low frequency. −2 = *sure no*, −1 = *think no*, +1 = *think yes*, +2 = *sure yes*.

unlikely) to yield illusory conjunctions. Thus, the results of both sets of data supported the familiarity account of illusory conjunctions.

Experiment 5: Context Again

In the process of designing and conducting Experiment 1, we had the impression that illusory conjunctions occurred more frequently when the context character was a conjunction of two components, one from each of the two source characters (the composite context condition), than when the context character shared no part with either of the two source characters (the neutral context condition). The overall similarity of the test display was higher in the composite context condition than in the neutral context condition. Generally, subjects are more likely to mistake a neighboring item for the target when the target–distractor similarity is high (e.g., Estes, 1982; McClelland & Mozer, 1986; Mozer, 1983; Shallice & McGill, 1978), providing the basis for a *similarity account* to explain the context effect obtained in Experiment 1.

However, there is a possible confusion of similarity and *distinctiveness*. Although the overall similarity of a composite-context display (pA aP aA) is higher than that of a neutral-context display (pA aP bB), the aA in the composite-context display can also serve a distinctive function that the bB in the neutral-context display cannot. For example, the concurrent display of pA and aA might enhance the distinctive value of p_ and a_ in the process of identification, but the concurrent display of pA and bB would not yield such an effect.

The purpose of Experiment 5 was to assess the relative importance of similarity and distinctiveness in the context effect by comparing the rates of illusory conjunctions in two types of context: the composite context and the *duplicate context*. Given the probe character pP, the composite context display would contain pA and aP as source characters and aA as the context character; the duplicate context display would contain the same source characters (pA and aP), but the context character, pA, would be identical to the source character that shares the radical with the probe. The three characters in each test display were made up of four units at the radical/stem level, two of which appeared twice: a_ and _A in the composite context display, and p_ and _A in the duplicate context display. Thus, while similarity was high at the radical/stem level in the composite context condition, it was high at both the radical/stem level and the character level in the duplicate context condition.

If conjunction errors are due to a loss of positional information caused by the overall similarity in a display (Estes, 1982), the duplicate context display would be at least as likely to generate illusory conjunctions as the composite context display. If, however, conjunction errors are due to partial activations of character (word) units (McClelland & Mozer, 1986), the duplicate context display would be more likely to favor the occurrence of an illusory probe pP, since the probe might be partially activated by the duplicate context character pA but could not possibly be activated by the composite context character aA. Thus, the similarity account predicts as many or more illusory conjunctions in the duplicate context condition as in the composite context condition.

One might argue that the difference between the duplicate context and the composite context is more than one of the degree of similarity. For example, given a duplicate-context display (pA pA aP), the two identical characters might form a perceptual group separate from the other character. Prinzmetal (1981) found that feature integration followed the perceptual group principle, in that features from the same perceptual group are more likely to form illusory conjunctions than those from different groups. Would possible perceptual grouping lead to fewer migrations in the duplicate context and thus lower the chance of perceiving an illusory pP? We assume not. First, as each of the four experiments in Prinzmetal's study showed, features between different perceptual groups did yield a good number of true illusory conjunctions. Therefore, given that the two pA's in a duplicate context display form a perceptual group, there is no reason to assume that their parts should become inert in relation to parts of the third character, aP. Between-group migrations do occur. Second, given that when a fixed error rate is maintained more conjunction errors occur within a perceptual group than between different groups, the within-group migrations in Experiment 5 would not be recorded as conjunction errors, because the two within-group characters and the possible illusory characters they might generate are all identical (pA) and different from the probe (pP). The error rate obtained in the current experiment would therefore only reflect the rate of between-group migrations. Thus, the operation of the perceptual group principle should not hinder potential illusory pPs from surfacing in the duplicate context condition.

It should be mentioned here that the number of possible illusory probes generated by the duplicate context display could be twice as great as that generated by the composite context display. Treisman and Schmidt (1982, Experiment 3) observed a higher rate of false positive matches for a display in which 8 out of 20 possible feature exchanges would produce an identical pair of items than for a display in which 4 out of 20 would (40.0% vs. 25.4%). Prinzmetal, Treiman, and Rho (1986) found that the rate of letter-color conjunctions doubled when the number of the odd-colored letter increased from one to two. The number of possible illusory probes obviously affects the rate of conjunction errors, and a direct comparison between the two context conditions is not fair. In addition to using the normal procedure of data analysis performed in Experiments 1–4, we also analyzed the case where the estimated proportion of illusory conjunctions in the duplicate context condition was reduced by half to present a picture of less bias.

Method

Stimuli. Forty probe displays (including 20 conjunction probes, 10 identical probes, and 10 control probes) and 40 test displays (including 20 composite-context and 20 duplicate-context displays) were prepared in the same way as in Experiment 1. Each of the 40 probes was presented twice, once followed by a composite-context display and once followed by a duplicate-context display. Each of the 40 test displays was presented twice, once preceded by a conjunction probe and once preceded by either an identical probe or a control probe.

Procedure. A 2 × 3 × 20 (Context × Probe × Trial) within-group design was adopted. The general procedure was the same as in

Experiments 1–4. The median exposure duration of the test display across all the trials was 160 ms, with a range of 40–320 ms.

Subjects. Twenty-one students at National Tsing Hua University, 8 men and 13 women, volunteered to serve as subjects. None had participated in any of the previous experiments.

Results

The results are shown in Table 5. Data were analyzed once in the same manner as in each of the previous experiments and once with the estimated proportion of illusory conjunctions in the duplicate context condition reduced by half. The percentage of illusory conjunctions before correction was .17 for the composite context and .13 for the duplicate context. A two-tailed t test suggested that the composite context gave rise to more illusory conjunctions than the duplicate context, $t(20) = 1.75$, $p < .10$. (The difference would reach statistical significance if a one-tailed t test were performed, $p < .05$.) The corrected percentage of illusory conjunctions for the duplicate context condition was .07. A two-tailed t test showed that the composite context displays gave rise to significantly more illusory conjunctions than the duplicate context displays, $t(20) = 5.28$, $p < .0005$, contrary to the prediction made by the similarity account.

General Discussion

We began with the questions of whether and why components of stem compounds were perceptually more cohesive than those of unique compounds. The degree of cohesiveness or separability was inferred from the percentage of illusory conjunctions. Experiment 1 demonstrates that local components of Chinese characters, whether single strokes or more complicated stems, can serve as primitive, separable units of character perception and give rise to illusory conjunctions when focused attention is diverted. Experiments 2 and 3 show that, when character frequencies match closely, stem compounds indeed give rise to fewer illusory conjunctions than unique compounds, in accordance with the general impression that stem compounds are more "compact" than unique compounds. A grasp of the cause of differential conjunction rates as such should lead to better understanding of illusory conjunctions.

Experiment 3 also shows that character frequency has little effect on the rate of conjunction errors, because compound components and compound characters differ tremendously in character frequency but do not differ in the rate of conjunction errors. Experiments 3 and 4 show that unit frequency can adequately explain the differential conjunction rates observed in Experiments 2, 3, and 4. Lower unit frequency consistently results in a higher rate of illusory conjunctions. Moreover, stem and unique characters do not differ in the rate of conjunction errors when their unit frequencies are matched. Stem compound characters give the impression of being more compact than unique compound characters mainly because the unit frequency of stem compounds is generally high, whereas that of unique compounds has a wider distribution.

Experiment 3 also suggests that lexicality and pronounceability play a minor role in the generation of illusory conjunctions. First, unique compounds yield more illusory conjunctions than stem compounds, regardless of their lexical status. Second, meaningless, unpronounceable compound components are just as likely to yield illusory conjunctions as are compound characters. One can therefore infer that, given a multicomponent character, some components are psychologically closer and form a perceptual unit separate from the other components, and that the emergence of the perceptual unit is on distributional grounds and is independent of meaning.

Unit Frequency and the Familiarity Effect

There have been inconsistent findings concerning the roles lexicality and pronounceability play in letter migrations between English words. While Treisman and Souther (1986) obtained neither a lexicality nor a pronounceability effect on the rate of illusory conjunctions, other researchers have reported such effects (McClelland & Mozer, 1986; Prinzmetal & Millis-Wright, 1984). We suggest that the seemingly conflicting findings might be reconcilable if the unit frequency of the items selected by individual researchers is taken into account.

Unit frequency refers to the total frequency counts of an item either by itself or as part of a larger unit (e.g., a syllable). According to Kucera & Francis (1967), the word frequency of *bank*, for example, is 83, but its unit frequency would be at least 162 (taking into account *banked*, *banker*, *bankers*, *banking*, *bankrupt*, *bankruptcy*, *banks*, etc.). Similarly, the word frequency of the pseudoword *sev* is 0, but its unit frequency would be at least 593 (taking into account *seven*, *seventeen*, *seventeenth*, *seventh*, *sever*, *several*, etc.). For the sake of convenience, the estimation of unit frequency in this article is limited to single syllables and excludes cross-bound-

Table 5
Proportion of Responses Receiving Each Confidence Rating for Each Type of Context in Experiment 5

	Probe											
	Identical				Conjunction				Control			
Context	−2	−1	+1	+2	−2	−1	+1	+2	−2	−1	+1	+2
Duplicate	.11	.12	.21	.58	.30	.25	.18	.26	.53	.24	.10	.13
Composite	.10	.11	.14	.65	.42	.22	.14	.21	.58	.27	.11	.04

Note. −2 = *sure no*, −1 = *think no*, +1 = *think yes*, +2 = *sure yes.*

ary patterns such as *cade* in the word *decade* or *wove* in the word *woven*, since color–letter conjunction errors are more likely within the same syllable of a word than between syllables (Prinzmetal et al., 1986).

Consider the results obtained by Prinzmetal and Millis-Wright (1984). They found that unpronounceable nonwords (e.g., *hnf, hrf*) produced far fewer color–letter conjunction errors than words (e.g., *ant, art*), pseudowords (e.g., *rec, nec*), or abbreviations (e.g., KGB, EKG), and concluded that pronounceable items were more likely to be processed as multiletter perceptual units than unpronounceable nonwords. If this was the case, however, one would need to explain why abbreviations are more pronounceable than nonwords. It seems that a familiarity account based on unit frequency can handle the data easily. The unit frequency of the pseudowords chosen in their study was obviously comparable with that of their high-frequency words. For example, the pseudoword *rec* can form the first syllable in such high-frequency words as *recognize, recommend, reconcile, record, recreation, rectangle,* etc. But the nonwords they chose probably never appear by themselves or as part of a word. In other words, the unit frequency counts of the nonwords were far lower than those of the other three types of stimuli. The familiarity account would correctly predict a higher degree of perceptual separability and thus a lower rate of color–letter conjunctions for letters in nonwords than for letters in items of the other three groups.

Likewise, unit frequency might have been confounded with lexicality in McClelland and Mozer's (1986) study. Unlike other researchers, they found more letter migrations between pseudowords (e.g., *cose, cuze*) than between words (e.g., *wake, wise*), and they argued that lexical status can affect the likelihood of letter migrations. Although the words and the pseudowords they selected matched in approximation-to-English ratings, none of the five pseudoword examples given in their Table 4 form a syllable in a word contained in the Kucera and Francis (1967) corpus. Thus, the word–pseudoword difference in migration rates obtained in their Experiment 3 might be attributable to the difference in the mean unit frequency between the words and the pseudowords used in that particular experiment.

McClelland and Mozer (1986), in their discussion of Mozer's earlier (1983) study (in which, given the display *sand lane* or *sand bank*, subjects were cued to report the item on the left), noted that

> the probability of reporting LAND or SANE instead of SAND was considerably reduced when SAND was presented in the context of BANK, indicating that some of the migration errors were indeed a result of the presence of the letters L and E in the context word LANE. (p. 19)

Interestingly, the unit frequency of *bank* is 162 and that of *lane* is 38. (The word frequencies of *bank* and *lane* are 83 and 30, respectively.) It may have been the lower-frequency context instead of the letters *L* and *E* that gave rise to higher probability of letter migrations.

Treisman and Souther (1986) compared words (e.g., *pen, sew*) with pseudowords (e.g., *len, sev*) but failed to obtain differences in the rate of conjunction errors (Experiments 1 and 3). They also compared consonant-vowel-consonant (CVC) strings (e.g., *wop*) with consonant-consonant-consonant (CCC) strings (e.g., *wzp*) and found no difference in the risk of letter migrations (Experiment 2). The limited number of stimulus examples given in their report showed no sign of differential unit frequency, so little can be said here in that regard. The effect of unit frequency should be systematically examined with English stimuli and the importance of lexical status or pronounceability should be reassessed when unit frequency is held constant.

Taking unit frequency into account might also solve the puzzling fact that lexical information about morphology affects illusory conjunctions but that such information about phonology has no effect (Prinzmetal et al., 1986). We agree with McClelland and Mozer (1986) that there is a strong relation between familiarity and migrations. However, we do not think that familiarity implies pronounceability or lexical knowledge. For example, letters in CCC strings such as *THR* and *GHT* may well be as cohesive as letters in high-frequency words (cf. Miller, Bruner, & Postman, 1954). Previous studies examined the effect of familiarity by manipulating lexicality and pronounceability, but ignored word frequency and unit frequency. Future research should pay more attention to the frequency effect on illusory conjunctions.

Perceptual Distinctiveness and the Context Effect

The present study also deals with the questions of whether and how context affects the rate of illusory conjunctions. Experiment 1 showed that the composite context, as opposed to the neutral context, enhanced the perceptual separability of components of both simple and compound characters. Experiment 5 compared the conjunction rate in the composite context condition with that in the duplicate context condition. The result showed that the composite context yielded more illusory conjunctions regardless of the fact that the duplicate context allowed twice as many possible illusory conjunctions as the composite context.

That the composite context gave rise to more illusory conjunctions than the duplicate context cannot be reduced to a familiarity effect. The composite and the duplicate context conditions were identical in all aspects except that they had different sets of context characters. The unit frequency of the composite-context characters ranged from 0 to 1,389 with a mean of 146.5, and that of the duplicate-context characters ranged from 0 to 870 with a mean of 208. Although the composite-context characters were in general less common than the duplicate-context characters, and the components of the former might therefore be more likely to float freely, a familiarity account cannot explain why, given the composite-context display (pA aP aA), a less stable context character (aA) should enhance the probability of reporting an illusory probe (pP). What, then, could have contributed to the context effect?

Our study shows that the presence of a composite context consistently prolongs the required exposure duration of test displays for maintaining a 30% error rate. The test displays in Experiment 3 contained no context character and the exposure duration averaged 78 ms. The replicated Experiment

4 (in which the pseudocharacter conditions were removed) used a neutral context, and the exposure duration averaged 80 ms. In contrast, the average duration was 160 ms for both Experiment 2 (which used a composite context) and Experiment 5 (which used a mixture of composite and duplicate contexts). The increase in exposure duration is in line with the notion that the demand of making distinctions increases with similarity among items. A similarity account further argues that, with other variables held constant, a higher rate of illusory conjunctions implies a higher degree of overall similarity. However, the results of Experiment 5 challenge this account: More illusory conjunctions occurred in the composite context even though the general similarity of the duplicate context closely matched that of the composite context. The similarity account would survive if we can attribute the composite- versus duplicate-context difference to the fact that one of the source characters occurred twice in the duplicate-context display.

That repeated contexts lead to fewer illusory conjunctions seems to be supported by McClelland and Mozer's (1986) study, as their Experiments 1 and 2 showed that letters in repeated digits (e.g., *2J22 5K55*) yielded fewer migration errors than letters in words (e.g., *lamp hint*). However, a closer examination makes this assertion questionable. First, the letter-in-digit (LID) strings were consistently given more time to process than the letter-in-word (LIW) strings. Second, in the LIW condition the subject needed to pay attention to the identity of all eight letters in the display, whereas in the LID condition he or she could ignore the identity of the digits and concentrate on the letters as long as he or she could tell letters from digits. Therefore, the lower rate of illusory conjunctions in the LID condition may well have been due to a lower attentional load in this condition (and the lack of a "surround-similarity effect" may have been the result of a floor effect). Stronger supports are needed to claim that the composite- versus duplicate-context difference reflects a repeated context effect.

Although Experiment 5 does not rule out similarity in favor of a context effect, it poses serious problems for the similarity account. We propose a *distinctiveness account* as an alternative explanation for the context effects obtained in Experiments 1 and 5. According to this account, when two objects share components in common and thus look similar, the components that they do not share serve a distinctive function so that these two objects can be distinguished from each other. The cohesiveness or separability of an object's components thus depends on their value of perceptual distinctiveness, which is determined by the context. An object's surroundings can bias the object into either a unitary whole or a conjunction of simpler units. For example, although components of a character tend to blend into a unitary whole, the presence of a composite-context character would highlight the role of a component as a distinctive unit, and hence enhance its chance of floating freely. That is, given a composite-context display, pA aP aA, the concurrent display of the two similar compounds, pA and aA, might enhance the distinctive value of P_ and a_ in the process of identification, and thus enhance the separability of the components of these two compounds. Likewise, the concurrent display of aP and aA might enhance the distinctive value of _P and _A, and thus enhance the separability of the components of these two compounds. If the composite-context character, aA, is replaced with a duplicate-context character, pA, resulting in a new display, pA aP pA, the general similarity should remain at a comparable level, but the context character (pA) no longer serves any distinctive function.

In studies using English words, the probability of reporting illusory words (e.g., *sane*) is lower when the two words in a test display do not share letters in common (e.g., *sand love*) than when they do (e.g., *sand lane*) (McClelland & Mozer, 1986; Mozer, 1983; Shallice & McGill, 1978). This phenomenon is referred to as the surround-similarity effect by McClelland and Mozer (1986), and they take it as evidence that migrations are a product of interactions between higher level word representations. Mozer (1983) points out explicitly that

> Because migrations of one letter in a word are dependent on the identities of the other letters, words must not be coded as collections of independent letters at the level of visual information processing in which migrations occur. That is, migrating letters do not behave as separable 'features' of a word in the sense of feature-integration theory. Thus, feature-integration theory does not seem to be the appropriate framework for the study of letter migrations. (p. 540)

But he then says that "Surprisingly, although letter migrations could not be accounted for within the framework of feature-integration theory, it does seem like feature-integration theory may be appropriate for explaining word migrations" (p. 541). This lack of parsimony is unnecessary from the point of view of perceptual distinctiveness.

We suggest that the surround-similarity effect can be reduced to a perceptual distinctiveness effect. The *an* string in *sand* and *lane*, for example, might have enhanced the perceptual distinctiveness, and hence the separability, of the letters s, l, d, and e, resulting in a higher migration rate. Therefore, the so called surround-similarity effect does not necessarily imply the participation of higher level word representations in letter migrations. The feature integration theory may well be appropriate for explaining feature migrations, letter migrations, word migrations, and migrations at levels in between or higher.

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