



A Fuzzy Logic Approach to Semantic Ambiguity in English Idiomatic Expressions

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ABSTRACT

Idiomatic expressions occupy a notoriously unstable region of the English lexicon: they resist the binary logic of literal versus figurative meaning that underlies much of classical semantic theory. This article proposes a fuzzy-logic framework for modelling the graded, context-sensitive nature of idiomatic meaning. Drawing on Zadeh's theory of fuzzy sets and the compositional and non-compositional accounts of idiomaticity developed in cognitive and phraseological linguistics, the study constructs a membership-function model in which idioms are assigned degrees of idiomaticity, transparency, and compositionality along the [0,1] interval rather than being sorted into discrete categories. A corpus-informed sample of forty English idiomatic units is analysed using linguistic criteria — semantic transparency, syntactic flexibility, and substitutability — that are then converted into fuzzy membership scores through a simple triangular membership function and aggregated using a weighted fuzzy-mean operator. The resulting continuum reproduces linguistic intuitions that categorical models flatten, such as the difference between highly opaque idioms (*kick the bucket*) and partially transparent ones (*spill the beans*), while also predicting gradient acceptability judgments reported in the psycholinguistic literature on idiom processing. The article argues that fuzzy logic offers linguistics a formally precise, computationally implementable alternative to ad hoc scalar labels such as “more” or “less” idiomatic, with direct applications for lexicography, second-language pedagogy, and natural language processing systems that must resolve idiomatic ambiguity automatically. The article closes by outlining how the proposed model can be extended into a fuzzy inference system for automatic idiom detection.

Keywords: Fuzzy logic, Semantic ambiguity, Idiomaticity, Phraseology, Membership function, Cognitive linguistics, Natural language processing

1. Introduction

Natural languages are built on the assumption, inherited largely from classical logic, that a linguistic expression either means X or it does not. Idiomatic expressions expose the limits of that assumption more sharply than almost any other class of lexical unit. An idiom such as *kick the bucket* is fully non-compositional: its meaning cannot be derived from the meanings of its constituent words, and native speakers process it as a single semantic unit [1]. Yet an expression such as *spill the beans* retains a residue of its literal imagery — spilling something suggests an uncontrolled release, and beans metaphorically stand for secrets — so that speakers experience it as only partially opaque [2]. Between these two poles lies a large population of idioms whose degree of transparency, flexibility, and compositionality varies continuously rather than falling into a small number of discrete classes.

Traditional phraseological classification, following Vinogradov's tripartite division into fusions, unities, and combinations, and later refined by Western phraseologists such as Cowie [3] and Fernando [4], has long recognised this gradience in principle. In practice, however, most pedagogical grammars and even many computational lexicons continue to treat idiomaticity as a binary property: an expression is either “listed” as idiomatic in a dictionary or it is not. This article argues that the mathematical apparatus of fuzzy logic, introduced by Zadeh [5] precisely to formalise categories with unsharp boundaries, offers linguistics a more faithful and more useful model of idiomatic meaning than either strict binary classification or unsystematic scalar description.

The relevance of this approach extends well beyond theoretical elegance. Foreign-language learners routinely misjudge the degree of flexibility an idiom tolerates, over-literalising opaque idioms or under-recognising the figurative potential of transparent ones [6, 7]; dictionary compilers must decide how much semantic commentary an idiom entry requires; and natural language processing systems — from machine translation engines to sentiment analysis pipelines — routinely fail on idiomatic input because their underlying semantic representations assume compositionality [8]. A formal model capable of assigning a continuous idiomaticity score to any given expression would therefore have direct applications across applied linguistics, lexicography, and computational linguistics alike.

This article makes three contributions. First, it reviews the linguistic evidence for treating idiomaticity as a graded rather than categorical property. Second, it develops a fuzzy-logic model in which three linguistically motivated criteria — semantic transparency, syntactic flexibility, and lexical

substitutability — are formalised as fuzzy membership functions and combined into a composite idiomaticity index. Third, it applies the model to a sample of English idioms and discusses how the resulting continuum aligns with, and refines, existing phraseological classifications.

2. Literature Review

2.1. Idiomaticity as a Graded Phenomenon

The classical structuralist view treated the idiom as a fixed multi-word unit whose meaning was stored and retrieved as a whole, in opposition to the freely generated phrase [9]. Cognitive linguists subsequently challenged the sharpness of this opposition [10]. Lakoff and Johnson's theory of conceptual metaphor [11] showed that many idioms are not arbitrary but motivated by underlying conceptual mappings — *spill the beans* is transparent once the learner recognises the container metaphor for the mind and the container-release metaphor for disclosure. Gibbs and Nayak [12] demonstrated experimentally that idioms differ systematically in their syntactic productivity: decomposable idioms such as *pop the question* permit internal modification and passivisation (*the question was finally popped*), while non-decomposable idioms such as *kick the bucket* strongly resist such operations. These findings converge on the same conclusion: idiomaticity is not a single categorical property but a cluster of correlated, independently gradable dimensions.

Phraseological theory has proposed several classificatory clines to capture this gradience, notably Fernando's distinction between pure, semi-, and literal idioms [4], and Cowie's continuum from pure idioms to open collocations [3]. These typologies are linguistically informative but remain ordinal: an expression is assigned to one of three or four bins rather than to a continuous value, and the criteria for bin membership are rarely made explicit enough to be applied consistently by different analysts. This is precisely the situation fuzzy logic was designed to address.

2.2. Fuzzy Set Theory and Its Extension to Linguistics

Zadeh [5] introduced fuzzy set theory to model categories whose membership is a matter of degree rather than a sharp yes/no distinction. In a fuzzy set A , every element x of the universe of discourse is assigned a membership value $\mu_A(x)$ in the interval $[0,1]$, where 0 signifies total non-membership and 1 signifies full membership; intermediate values represent partial membership. Zadeh's own later work on "fuzzy semantics" and linguistic hedges [13] explicitly proposed that natural-language predicates such as *tall*, *warm*, or *expensive* are fuzzy categories, and that hedges such as *very*, *somewhat*, or *rather* can be modelled as mathematical operators (concentration, dilation) acting on membership functions. Beyond linguistics, fuzzy-logic models have been applied successfully to a wide range of decision problems under uncertainty, including lighting assessment in interior and workplace design [14–16], agricultural price regulation [17], and smart environmental management [18].

Linguists have since applied fuzzy set theory to lexical semantics (on hedges, see Lakoff [19]), to prototype-based category structure (Rosch [20], whose prototype theory is compatible with, though not identical to, fuzzy-set formalisation), and to sociolinguistic variation. Applications to phraseology specifically remain comparatively rare, despite the evident fit between the fuzzy-set formalism and the graded phenomena that phraseologists have long described in prose. This article extends the fuzzy-set paradigm to idiomaticity by treating each of the three criteria identified in Section 2.1 — transparency, flexibility, and substitutability — as an independent fuzzy variable and combining them into a composite fuzzy index.

2.3. Idiom Processing and Gradient Acceptability

Psycholinguistic research on idiom comprehension provides independent motivation for a graded model. Reaction-time studies show that more transparent idioms are processed faster and their literal meaning remains more available during comprehension than that of opaque idioms [21]. Acceptability-judgment studies similarly report that native speakers do not divide manipulated idiom variants (e.g., syntactically altered forms) into acceptable and unacceptable categories but instead rate them along a continuous scale [12]. A model that outputs a single continuous idiomaticity score is therefore better positioned to predict these gradient behavioural results than a model that outputs a categorical label.

3. Theoretical Framework and Methodology

3.1. Selecting the Fuzzy Variables

Three linguistically motivated criteria were selected as the input variables for the fuzzy model, each corresponding to an established diagnostic in the phraseological literature.

- (i) Semantic transparency (T): the degree to which the figurative meaning of the idiom can be inferred from the literal meanings of its parts, following the metaphor-motivation criterion of Lakoff and Johnson [11] and Gibbs [2].
- (ii) Syntactic flexibility (F): the degree to which the idiom tolerates internal grammatical operations such as passivisation, internal modification, and topicalisation without loss of idiomatic meaning, following the decomposability diagnostics of Gibbs and Nayak [12].
- (iii) Lexical substitutability (S): the degree to which near-synonymous lexical substitution of a component word preserves the idiomatic meaning (e.g., *spill the beans* vs. *spill the secret*), following the collocational-restriction criterion discussed by Cowie [3].

Each criterion was rated by three independent raters (postgraduate students of English linguistics) on a seven-point scale for each of forty idioms sampled from the *Oxford Dictionary of English Idioms* and cross-checked against the Corpus of Contemporary American English (COCA) for frequency and collocational range. Inter-rater agreement was calculated using Krippendorff's alpha, which exceeded 0.75 for all three variables, indicating acceptable reliability for the subsequent fuzzification procedure.

3.2. Fuzzification: From Ordinal Ratings to Membership Values

The mean seven-point rating for each criterion was converted into a fuzzy membership value using a triangular membership function, a standard choice in applied fuzzy-logic systems for its computational simplicity and interpretability [22]. For a criterion with mean rating r on the scale [1,7], the membership value μ was computed as:

$$\mu(r) = (r - 1) / 6 \quad (1)$$

This linear mapping places a rating of 1 (fully literal / fully rigid / fully substitutable) at $\mu = 0$ and a rating of 7 (fully idiomatic / fully rigid against variation / fully non-substitutable) at $\mu = 1$, so that higher membership values consistently indicate greater idiomaticity across all three variables.

3.3. Aggregation: The Composite Idiomaticity Index

The three fuzzy membership values were aggregated into a single composite Idiomaticity Index (II) using a weighted fuzzy-mean operator:

$$II = w_1 \cdot \mu_T + w_2 \cdot \mu_F + w_3 \cdot \mu_S \quad (2)$$

with weights $w_1 = 0.4$, $w_2 = 0.3$, and $w_3 = 0.3$ ($\Sigma w = 1$), reflecting the primacy assigned to semantic transparency in the phraseological literature while still allowing syntactic and lexical behaviour to modulate the final score. The weighting scheme was validated by comparing model output against the ordinal classifications independently assigned by Fernando-style [4] category judgments from the same raters; a Spearman correlation of $\rho = 0.86$ was obtained between the composite index and the raters' holistic ordinal judgments, supporting the construct validity of the aggregation procedure.

4. Analysis and Results

Table 1 presents the fuzzy membership values and composite Idiomaticity Index for a representative subset of ten idioms drawn from the full sample of forty. The complete continuum reproduces several theoretically expected contrasts while also revealing gradience that binary classification would obscure.

Table 1 – Fuzzy membership values and composite Idiomaticity Index for a representative sample of English idioms.

Idiom	μ_T	μ_F	μ_S	Idiomaticity Index (II)	Category
<i>kick the bucket</i>	0.95	0.90	0.92	0.92	Pure idiom
<i>spill the beans</i>	0.55	0.60	0.65	0.59	Semi-idiom
<i>break the ice</i>	0.60	0.55	0.50	0.56	Semi-idiom
<i>pop the question</i>	0.65	0.45	0.55	0.56	Semi-idiom
<i>a piece of cake</i>	0.70	0.75	0.72	0.72	Pure idiom
<i>under the weather</i>	0.68	0.80	0.85	0.77	Pure idiom
<i>let the cat out of the bag</i>	0.58	0.62	0.60	0.60	Semi-idiom
<i>make a decision</i>	0.10	0.15	0.20	0.14	Open collocation
<i>take a break</i>	0.08	0.20	0.25	0.16	Open collocation
<i>burn the midnight oil</i>	0.72	0.68	0.70	0.70	Pure idiom

Three patterns are worth highlighting. First, the model correctly separates open collocations such as *make a decision* and *take a break* — expressions that are lexically frequent but semantically compositional — from genuine idioms, assigning them Idiomaticity Index values below 0.2. Second, the model captures the traditionally recognised distinction between pure idioms ($II > 0.65$) such as *kick the bucket* and *under the weather* and semi-idioms ($0.4 \leq II \leq 0.65$) such as *spill the beans* and *break the ice*, while representing the boundary between these categories as a continuum rather than a

discrete cut-off, so that borderline cases such as *pop the question* ($\mu = 0.56$) are not forced into an artificially confident classification. Third, and most importantly, the model exposes internal disagreement among the three fuzzy variables that a single ordinal rating would conceal: *pop the question* has comparatively high transparency ($\mu_T = 0.65$) but low flexibility ($\mu_F = 0.45$), correctly reflecting the fact that speakers readily infer its figurative meaning yet judge some syntactic manipulations of it as marginal.

These results are consistent with the gradient acceptability judgments reported by Gibbs and Nayak [12] and with the processing-time asymmetries between transparent and opaque idioms reported by Titone and Connine [21]: idioms with higher μ_T values in the present model correspond to the idioms independently reported in that literature as showing faster access to figurative meaning and greater literal-meaning interference during processing.

5. Discussion

5.1. Theoretical Implications

The fuzzy-logic model developed here formalises an intuition that phraseologists have expressed informally for decades: idiomaticity is not a property an expression either has or lacks, but a bundle of correlated, independently variable dimensions that jointly determine a graded outcome. By making the criteria, the fuzzification procedure, and the aggregation rule fully explicit, the model offers a level of methodological transparency and replicability that impressionistic ordinal classification cannot match. It also allows for principled comparison across studies: two researchers using the same membership functions and weighting scheme, even with different rater pools, should converge on comparable Idiomaticity Index values, whereas two researchers using Fernando's [4] or Cowie's [3] categorical schemes may disagree about which bin a borderline idiom belongs to without any formal mechanism for resolving the disagreement.

5.2. Applications

Three applied domains stand to benefit directly from this framework. In lexicography, a continuous idiomaticity score could supplement dictionary entries to indicate how much figurative-meaning scaffolding a given idiom requires, allowing editors to allocate explanatory space more efficiently. In second-language pedagogy, teachers could use the transparency component of the index specifically to sequence idiom instruction, introducing semantically motivated idioms (high μ_T) before opaque ones, in line with the cognitive-linguistic teaching approach advocated by Boers and Lindstromberg [6], and could be complemented by the AI-supported tools now increasingly used in ESL classrooms [23]. In computational linguistics, the model offers a lightweight, interpretable alternative to purely statistical idiom-detection methods: rather than treating idiomaticity as a binary classification target learned from annotated corpora, a system could compute transparency, flexibility, and substitutability scores automatically — for instance by measuring the cosine distance between the literal and contextual word-embedding representations of an expression as a proxy for μ_T — and feed these into the same fuzzy-mean aggregation rule proposed here, producing a continuous confidence score for downstream tasks such as machine translation or sentiment analysis.

5.3. Limitations

Several limitations should be acknowledged. The sample of forty idioms, while sufficient to demonstrate the feasibility of the model, is too small to support strong generalisations about the distribution of Idiomaticity Index values across the English idiom inventory as a whole; a corpus-scale replication is needed. The weighting scheme (0.4/0.3/0.3) was validated against holistic rater judgments from the same rater pool that produced the input ratings, which introduces a degree of circularity that an independent validation sample would remove. Finally, the triangular membership function, while standard in applied fuzzy systems, is a simplifying choice; trapezoidal or Gaussian membership functions might better model the plateau of full idiomaticity observed for expressions such as *kick the bucket*, where further increases in opacity are not linguistically meaningful.

5.4. Toward a Fuzzy Inference System for Idiom Detection

The composite index proposed in Section 3.3 can be extended, in principle, into a full Mamdani-style fuzzy inference system [24]. Instead of a fixed linear weighting rule, such a system would define a bank of fuzzy IF–THEN rules of the form: *IF transparency is low AND flexibility is low AND substitutability is low, THEN idiomaticity is very high*. Each linguistic label (low, medium, high) would itself be represented by an overlapping membership function over the [0,1] interval, and the output would be defuzzified — for instance via the centroid method — to yield a single crisp idiomaticity score suitable for ranking or thresholding. The advantage of a rule-based inference system over the simple weighted mean used in this study is that it can capture non-linear interactions among the three criteria: for example, an idiom that is highly opaque but also highly flexible syntactically (a combination that is empirically rare but not impossible) could be assigned a different output than the linear model predicts, since the rule base can specify exceptions explicitly rather than averaging them away. Implementing and validating such a rule base against a held-out sample of idioms is identified here as the most immediate direction for future research.

5.5. Cross-Linguistic Perspective

Although the present study is confined to English, the three criteria underlying the model — transparency, flexibility, and substitutability — are not language-specific and could in principle be applied to idiomatic inventories in typologically different languages, including Azerbaijani, where contrastive Azerbaijani–English studies of lexical and stylistic phenomena are already well established [25]. Azerbaijani phraseology, like English, distinguishes fully fused idioms (*frazoloji birləşmələr*) from more transparent figurative combinations, and a parallel fuzzy analysis could test whether the same triangular membership function and weighting scheme yield comparable Idiomaticity Index distributions, or whether language-specific morphological richness (for instance, the agglutinative marking of Azerbaijani, which affects syntactic flexibility judgments) requires the weights w_1 – w_3 to be recalibrated. Such a comparison would also bear on the more general theoretical question of whether idiomaticity gradience is a language-universal cognitive phenomenon, as the conceptual-metaphor literature suggests [26], or whether its distribution is shaped by language-particular morphosyntactic constraints.

6. Conclusion

This article has argued that fuzzy logic provides a formally precise and empirically well-motivated alternative to the binary and ordinal classification schemes that have traditionally been used to describe idiomaticity in English. By modelling semantic transparency, syntactic flexibility, and lexical substitutability as fuzzy variables and aggregating them into a composite Idiomaticity Index, the proposed framework reproduces established phraseological categories as regions along a continuum rather than as discrete, non-overlapping classes, and it does so in a way that is transparent, replicable, and extensible. The model's fit with independently reported psycholinguistic gradience further suggests that fuzzy logic is not merely a convenient mathematical metaphor for graded meaning but a genuinely apt formalism for it. Future work should extend the model to a full-scale fuzzy inference system — incorporating fuzzy IF–THEN rules and defuzzification for automatic idiom classification — and should test the framework against a substantially larger and typologically more diverse idiom inventory, including comparison with idiomatic expressions in Azerbaijani, in order to assess the cross-linguistic generality of the proposed criteria.

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