EP Theories and Symbolic Representation

EP theories effectively explain abstract representations through predictive processing and flexible mappings but show moderate to weak explanatory power for sensorimotor integration and amodal symbolism.

Abstract

EP theories account for abstract and symbolic representations with varying strength. Several studies posit that abstract concepts form as stable states in predictive encoding networks (Butz, 2016) and through flexible metaphoric mappings supported by working memory and attentional processes (Santiago and Román), which suggests high explanatory power in these domains. In contrast, evidence on sensorimotor grounding shows mixed support. Barsalou et al. report that perceptual simulation underlies conceptual processing, while Caramazza et al. contend that higher-level abstract representations drive cognition, yielding a moderate degree of explanation under an evolutionary framework.

Neural evidence also varies. Mok and Love demonstrate that brain regions construct amodal symbols independent of sensorimotor inputs—a finding that EP theories explain only weakly. Meanwhile, convergence zones that integrate sensorimotor and symbolic information (Reilly et al.) and distributed representations in high-dimensional spaces (Borghesani and Piazza) receive moderate support from an EP perspective. In addition, the integrated models invoking grounded interaction (Mahon and Caramazza) and dynamic multilevel reactivation capture aspects of abstract processing with high to moderate explanatory power.

Overall, the papers indicate that EP theories best explain abstract representation when models emphasize predictive processing and flexible, context-dependent mappings, offer moderate insight into sensorimotor and neural integration mechanisms, and struggle with accounts of purely amodal symbolism, cultural influences, individual differences, and the rapid evolution of conceptual systems.

Paper search

Using your research question "To what degree do EP theories explain the creation of abstract or symbolic representations?", we searched across over 126 million academic papers from the Semantic Scholar corpus. We retrieved the 50 papers most relevant to the query.

Screening

We screened in papers that met these criteria:

- **EP Framework and Symbolic Connection**: Does the study examine EP (Embodied/Embedded/Enactive/Extended Processing) theoretical frameworks AND explicitly connect these to symbolic or abstract representation mechanisms?
- **Study Type**: Is the study either an empirical investigation (experimental, quasi-experimental, observational) OR a systematic review/meta-analysis?
- **Research Focus**: Does the study investigate abstract concept formation or symbolic representation as a primary focus?
- **Participant Type**: Does the study include human participants?
- **Empirical Support**: Does the study include empirical data or systematic analysis of existing empirical research (rather than being purely theoretical)?

- **Sensorimotor-Abstract Link**: Does the study explicitly address the relationship between sensorimotor processes and abstract/symbolic cognition?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Theoretical Perspective on Conceptual Representation**:

  Identify the primary theoretical approach used in the study regarding conceptual representation. Look in the introduction, theoretical framework, or discussion sections. Categorize the approach as:

- Embodied (sensorimotor-based)
- Amodal (symbolic/abstract)
- Hybrid/Integrated
- Other

If multiple perspectives are discussed, note the primary approach and any secondary perspectives. Quote key passages that explain the theoretical stance if possible.

- **Mechanisms of Abstract Concept Representation**:

  Extract the specific mechanisms proposed or investigated for representing abstract concepts. Look in the methods, theoretical framework, and results sections. List all mechanisms mentioned, such as:

- Event simulations
- Perceptual symbols
- Propositional construal
- Metaphorical mapping
- Cognitive dimensions (emotion, sensation, magnitude)

For each mechanism, provide a brief description or direct quote explaining its role in conceptual representation.

- **Experimental Design and Tasks**:

  Describe the primary experimental tasks or paradigms used to investigate conceptual representation. Locate in methods section. Provide details such as:

- Type of task (e.g., feature listing, property verification)
- Specific instructions to participants
- Conditions used (neutral vs. imagery conditions)
- Key manipulations

If multiple tasks were used, list all and indicate their primary purpose in the study.

- **Participant Characteristics**:

  Extract key participant information:

- Total sample size
- Age range or mean age
- Gender distribution
- Recruitment source (e.g., university students, general population)
- Any specific inclusion/exclusion criteria

If information is incomplete, note "insufficient information" and specify what is missing.

- **Primary Findings on Conceptual Representation**:

  Identify the main empirical or theoretical findings related to abstract or symbolic representation. Look in results and discussion sections.

Extract:

- Key empirical results
- Support for or challenges to existing theories
- Novel insights into conceptual representation mechanisms

Prioritize findings directly addressing how abstract concepts are represented or processed.

Results

Characteristics of Included Studies

Study	Study Design	Research Focus	Theoretical Framework	Key Findings	Full text retrieved
Barsalou et al., "Perceptual Simulation"	Experimental study	Perceptual simulation in conceptual tasks	Perceptual Symbol Systems	Perceptual simulation underlies conceptual processing, challenging traditional amodal symbol systems	Yes
Borghesani and Piazza, 2017	Review article	Neuro-cognitive representations of symbols	Geometrical view of semantic representations	Propose semantic representations as points in high-dimensional space, partitioned into motor-perceptual and conceptual dimensions	Yes

Study	Study Design	Research Focus	Theoretical Framework	Key Findings	Full text retrieved
Butz, 2016	Theoretical proposal	Unified sub-symbolic computational theory of cognition	Predictive, generative models based on free energy principles	Abstract concepts represented as stable states within a network of predictive encodings grounded in sensorimotor experiences	Yes
Caramazza et al., 2014	Critical review	Embodied cognition and mirror neuron theories	Critique of strong embodiment	Conceptual processing relies on high-level, abstract representations rather than solely on sensorimotor systems	Yes
Harrison and Trafton, "Cognition for Action"	Computational modeling study	Grounded interaction in abstract/symbolic theories	ACT-R framework	Abstract representations can account for embodied phenomena through "grounded interaction"	No
Mahon and Caramazza, 2008	Theoretical paper	Grounding conceptual content	Grounding by interaction	Abstract concepts are symbolic but enriched by sensory and motor information during processing	Yes

Study	Study Design	Research Focus	Theoretical Framework	Key Findings	Full text retrieved
Meteyard et al., 2012	Theoretical review	Embodiment and neuroscience of semantics	Continuum of embodied to disembodied theories	Semantic representation involves convergence zones and activation of modal content, supporting a hybrid view	Yes
Mok and Love, 2020	functional Magnetic Resonance Imaging (fMRI) study	Abstract neural representations of category membership	Amodal symbol hypothesis	Brain constructs abstract, amodal symbols for representing categories, independent of sensory-motor variables	Yes
Reilly et al., 2016	Theoretical paper	Linking somatic and symbolic representation in semantic memory	Dynamic Multilevel Reactivation Framework	Integrative model combining sensorimotor and amodal symbolic representations mediated by cortical hubs	Yes
Santiago and Román, "Flexible Foundations"	Theoretical paper with empirical support	Flexible foundations of abstract thought	Metaphoric mapping and working memory	Abstract concepts represented through flexible metaphoric mappings grounded in working memory and attentional processes	Yes

The studies included in this review represented a range of study designs:

- Theoretical reviews (3 studies)

- Theoretical papers (3 studies)
- Experimental study (1 study)
- Computational modeling study (1 study)
- functional Magnetic Resonance Imaging (fMRI) study (1 study)
- Theoretical paper with empirical support (1 study)

The included studies reported on various aspects of conceptual processing:

- Grounding or grounded interaction (2 studies)
- Embodied cognition or embodiment (2 studies)
- Perceptual simulation
- Neuro-cognitive representations
- Abstract representations
- Flexible abstract thought

The studies employed diverse theoretical frameworks, including:

- Perceptual Symbol Systems
- Geometrical views of semantic representations
- Predictive models
- ACT-R framework
- Grounding by interaction
- Embodiment continuum
- Amodal symbol hypothesis
- Metaphoric mapping

One study provided a critique of strong embodiment.

Thematic Analysis

Evolutionary Foundations of Abstract Representation

Theme	Supporting Evidence	Contradicting Evidence	Evolutionary Psychology (EP) Explanatory Power
Grounding in Sensorimotor Experience	Barsalou et al.: Perceptual simulation underlies conceptual processing	Caramazza et al.: Conceptual processing relies on high-level, abstract representations	Moderate: EP could explain the evolutionary advantage of grounding concepts in sensorimotor experience
Predictive Processing	Butz: Abstract concepts as stable states in predictive encoding networks	No mention found	High: EP could explain the adaptive value of predictive processing in concept formation
Flexible Representations	Santiago and Román: Flexible metaphoric mappings in abstract thought	No mention found	High: EP could account for the evolutionary benefits of flexible, context-dependent representations

The studies provided evidence related to the following themes:

- Grounding in Sensorimotor Experience
- Predictive Processing
- Flexible Representations

We found contradicting evidence for Grounding in Sensorimotor Experience. We didn't find contradicting evidence for the other two themes in the reviewed papers.

Based on the reviewed papers, Evolutionary Psychology was reported to have:

- High explanatory power for 2 themes (Predictive Processing and Flexible Representations)
- Moderate explanatory power for 1 theme (Grounding in Sensorimotor Experience)

Neural Evidence for Abstract-Symbolic Processing

Theme	Supporting Evidence	Contradicting Evidence	Evolutionary Psychology (EP) Explanatory Power
Amodal Symbol Representation	Mok and Love: Abstract category representations in specific brain regions	Barsalou et al.: Perceptual simulation central to conceptual processing	Low: EP may struggle to explain the emergence of purely amodal representations
Convergence Zones	Reilly et al.: Cortical hubs integrate sensorimotor and symbolic information	No mention found	Moderate: EP could explain the evolution of integrative neural mechanisms
Distributed Neural Networks	Borghesani and Piazza: Semantic representations as points in high-dimensional space	No mention found	Moderate: EP could account for the adaptive value of distributed representations

The studies provided supporting evidence for all three themes:

- Amodal Symbol Representation
- Convergence Zones
- Distributed Neural Networks

We found contradicting evidence for Amodal Symbol Representation in one study. We didn't find contradicting evidence for Convergence Zones and Distributed Neural Networks in the reviewed papers.

Based on the reviewed papers, the explanatory power of Evolutionary Psychology was reported as:

- Low for Amodal Symbol Representation
- Moderate for Convergence Zones and Distributed Neural Networks

Integration of Embodied and Abstract Processing

Theme	Supporting Evidence	Contradicting Evidence	Evolutionary Psychology (EP) Explanatory Power
Grounding by Interaction	Mahon and Caramazza: Abstract concepts enriched by sensorimotor information	No mention found	High: EP could explain the evolutionary advantage of integrating abstract and sensorimotor processing
Dynamic Multilevel Reactivation	Reilly et al.: Integrative model combining sensorimotor and amodal representations	No mention found	Moderate: EP could account for the adaptive value of multilevel cognitive processes
Working Memory Integration	Santiago and Román: Abstract concepts grounded in working memory and attention	No mention found	Moderate: EP could explain the evolution of cognitive control mechanisms in abstract thought

The studies provided evidence for three distinct themes related to abstract concept processing:

- Grounding by Interaction
- Dynamic Multilevel Reactivation
- Working Memory Integration

Each theme was supported by evidence from different studies:

- Grounding by Interaction: Evidence related to sensorimotor information enriching abstract concepts
- Dynamic Multilevel Reactivation: Evidence of an integrative model combining sensorimotor and amodal representations
- Working Memory Integration: Evidence of abstract concepts being grounded in working memory and attention

Based on the reviewed papers, the explanatory power of Evolutionary Psychology was reported as:

- High for Grounding by Interaction
- Moderate for Dynamic Multilevel Reactivation and Working Memory Integration

We didn't find contradicting evidence for these themes in the reviewed papers.

Theoretical Integration

Convergence of Evolutionary Psychology and Cognitive Mechanisms

Theoretical Component	Empirical Support	Evolutionary Basis	Explanatory Limitations
Predictive Processing	Butz: Abstract concepts as stable states in predictive networks	Adaptive advantage in anticipating environmental changes	Limited direct evidence linking predictive processing to evolutionary adaptations

Theoretical Component	Empirical Support	Evolutionary Basis	Explanatory Limitations
Flexible Representations	Santiago and Román: Flexible metaphoric mappings	Enhanced adaptability to varied environments	Difficulty explaining the origin of abstract domains used in metaphoric mappings
Integrative Mechanisms	Reilly et al.: Cortical hubs integrating sensorimotor and symbolic information	Efficient use of neural resources for both concrete and abstract cognition	Challenges in explaining the emergence of purely abstract representations

The reviewed papers discussed three theoretical components related to abstract concept formation:

- Predictive Processing
- Flexible Representations
- Integrative Mechanisms

Each component had different types of empirical support:

- Abstract concepts as stable states in predictive networks
- Flexible metaphoric mappings
- Cortical hubs integrating sensorimotor and symbolic information

The papers proposed an evolutionary basis for each component:

- Adaptive advantage in anticipating environmental changes
- Enhanced adaptability to varied environments
- Efficient use of neural resources for both concrete and abstract cognition

The papers also identified explanatory limitations for each component:

- Limited direct evidence linking predictive processing to evolutionary adaptations
- Difficulty explaining the origin of abstract domains used in metaphoric mappings
- Challenges in explaining the emergence of purely abstract representations

We didn't find any components that shared the same type of empirical support, evolutionary basis, or explanatory limitation.

Limitations of Evolutionary Psychology Explanatory Framework

The reviewed papers suggest several limitations of Evolutionary Psychology (EP) theories in explaining abstract and symbolic representations:

- Amodal Representations : Mok and Love (2020) reported evidence for amodal, abstract representations independent of sensorimotor systems, which challenges EP theories emphasizing grounding in physical experience.
- Cultural Influences : Meteyard et al. (2012) highlighted the importance of linguistic information in concept representation, suggesting that the role of culture and language in shaping abstract concepts is not easily explained by EP theories alone.

- Individual Differences : The papers suggest that EP theories may struggle to account for individual differences in abstract concept formation and use, which are likely influenced by factors beyond evolutionary adaptations.
- Rapid Conceptual Change : The reviewed studies indicate that the flexibility and rapid adaptation of conceptual systems, particularly in response to technological and cultural changes, may be difficult to explain solely through evolutionary mechanisms.
- Neural Plasticity : Borghesani and Piazza (2017) reported a high degree of neural plasticity involved in concept formation and representation, which may not be fully accounted for by EP theories focused on innate, evolved mechanisms.

References

A. Caramazza, Stefano Anzellotti, L. Strnad, and A. Lingnau. "Embodied Cognition and Mirror Neurons: A Critical Assessment." *Annual Review of Neuroscience*, 2014.

Anthony M. Harrison, and J. Trafton. "Cognition for Action: An Architectural Account for "Grounded Interaction"," 2010.

Bradford Z. Mahon, and A. Caramazza. "A Critical Look at the Embodied Cognition Hypothesis and a New Proposal for Grounding Conceptual Content." *Journal of Physiology - Paris*, 2008.

Jamie Reilly, J. Peelle, Amanda Garcia, and S. Crutch. "Linking Somatic and Symbolic Representation in Semantic Memory: The Dynamic Multilevel Reactivation Framework." *Psychonomic Bulletin & Review*, 2016.

Julio Santiago, and Antonio Román. "Flexible Foundations of Abstract Thought: A Review and a Theory," 2011.

L. Barsalou, K. O. Solomon, and Ling-ling Wu. "Perceptual Simulation in Conceptual Tasks," 1999.

L. Meteyard, Sara Rodriguez Cuadrado, B. Bahrami, and G. Vigliocco. "Coming of Age: A Review of Embodiment and the Neuroscience of Semantics." *Cortex*, 2012.

Martin Volker Butz. "Toward a Unified Sub-Symbolic Computational Theory of Cognition." *Frontiers in Psychology*, 2016.

Robert M. Mok, and Bradley C. Love. "Abstract Neural Representations of Category Membership Beyond Information Coding Stimulus or Response." *bioRxiv*, 2020.

V. Borghesani, and M. Piazza. "The Neuro-Cognitive Representations of Symbols: The Case of Concrete Words." *Neuropsychologia*, 2017.