The Integrated Warning Experience (IWE):

A Theoretical Framework for Visual Warning Design Based on Biological Warning Signs

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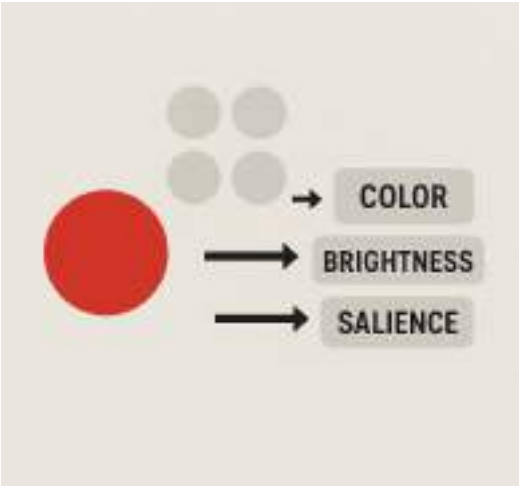
This work **reframes warnings as perceptual events**, integrates **distance-based** visibility and recognisability, and **derives a biologically grounded architecture** for **visual-warning design**

Content

Introduction

Background: Limitations of Current Visual Warnings



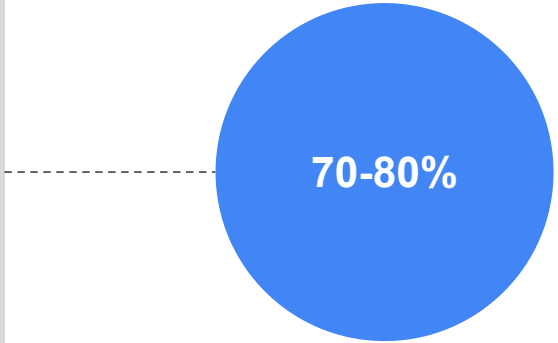
Current systems rely heavily on
Conspicuity—color, brightness, and salience.

In complex environments
(HRI, high-noise industries, autonomous driving),
Users often **see the warning but fail to interpret it**.

Visibility does not guarantee understanding.

Background: Limitations of Current Visual Warnings

Why did this research prioritise visual warnings before other sensory channels?

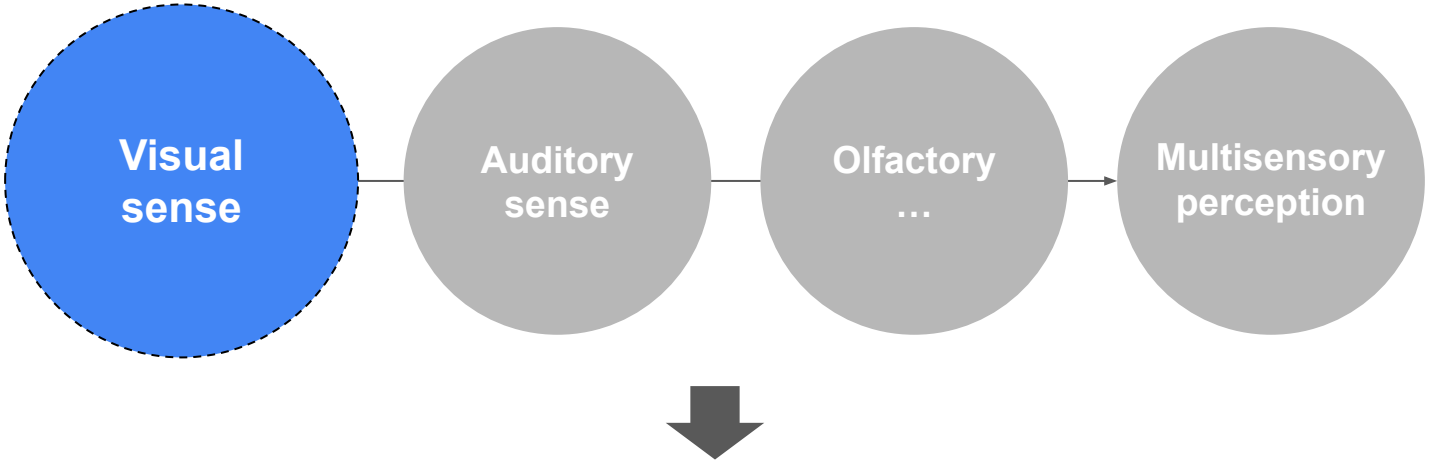


Vision accounts for the majority of human perceptual intake—often cited as around 70–80%—making it the dominant channel for rapid warning perception

Goldstein, E. Bruce. (2010). *Sensation and Perception*. Cengage

Background: Limitations of Current Visual Warnings

This study examines the limitations of the sensory channel most used in current warning systems.



‘IWE model’ as a <u>first step</u>
before expanding to multisensory warning design.

Key Terms

The following are the key terms central to this study

Term	Definition
Conspicuity[1)]	Ability to attract attention from a **distance**
Distinctiveness[2)]	Ability to be semantically **differentiated**

Recognition–Interpretation–Response cycle -> 'IWE’

1)Stevens, M., &Cuthill, I. C. (2006). Disruptive coloration, crypsis and edge detection in early visual processing. Proceedings of the Royal Society B: Biological Sciences, 273(1598), 2141–2147.
2)Ruxton, G. D., Franks, D. W., Balogh, A. C. V., &Leimar, O. (2008). Evolutionary implications of the form of predator generalization for aposematic signals and mimicry in prey. Evolution, 62(11), 2913–2921.

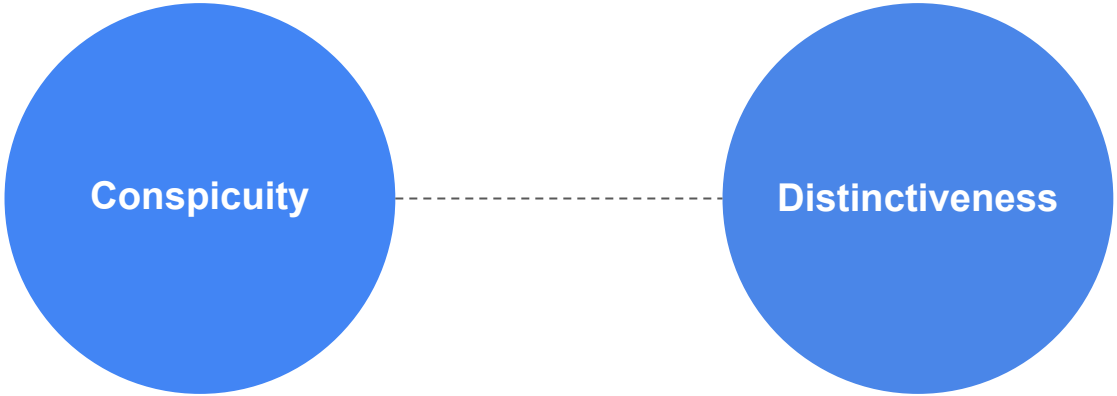
Key Terms

Conspicuity

Distinctiveness

1) 3M 983-326 6" Red/ 6" White Diamond Grade Conspicuity Reflective Tape for Trailers, DOT-C2
2) Photo by Jeremy Richards, Shutterstock

Why Biological Models?



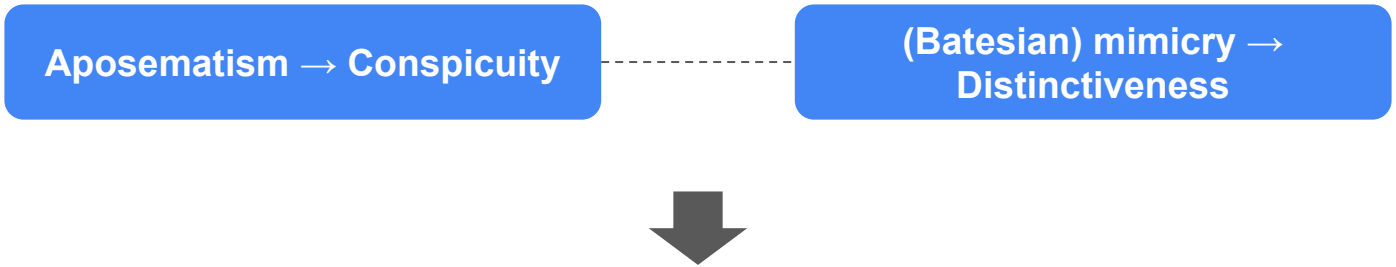
Making the signal **seen first**

Making the signal **understood correctly**
Biological systems reveal this dual structure in its purest form.

Warning design hinges on two perceptual factors

Why Biological Models?

Biological signalling offers a strong reference for warning design.
Aposematism maps onto conspicuity, and Batesian mimicry illustrates why distinctiveness matters.



Together, they form the theoretical basis
for the **Conspicuity–Distinctiveness dual structure** in visual warning design.

Examples

Aposematism → Conspicuity

- **Example:** High-chroma coloration in poison dart frogs
- Instantly captures attention from a distance
- **Insight:** Prototype of “being seen first”

Mimicry → Distinctiveness + Learned Recognition

- **Example:** Hoverflies mimicking wasp patterns
- Avoidance occurs only after learning “this pattern = danger”
- **Insight:** Meaning arises from **pattern-based distinctiveness + learning**

Halpin, C. G., Skelhorn, J., & Rowe, C. (2008). Being conspicuous and defended: Selective benefits for the individual. Behavioral Ecology, 19(5), 1012–1017.

Examples

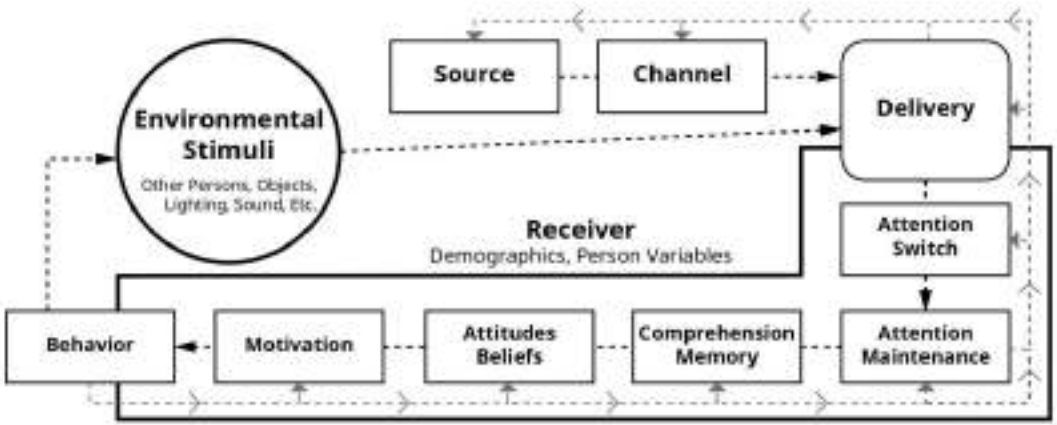
Batesian mimicry occurs when a harmless species imitates the warning signal of a harmful one, exploiting the predator's past aversive learning to induce avoidance.

Stuckert, A. M., Venegas, P. J., & Summers, K. (2013). Experimental evidence for predator learning and Müllerian mimicry in Peruvian poison frogs (Ranitomeya, Dendrobatidae). Evolutionary Ecology, 28(4). x

Theoretical Background

Existing Models (C-HIP, ISO)

C-HIP(Wogalter, 2012)



Signal → Attention → Comprehension → Behavior

Wogalter, M. S., Laughery, K. R., &Mayhorn, C. B. (2012). Warnings and hazard communications. In G. Salvendy (Ed.), Handbook of human factors and ergonomics (4th ed., pp. 868–894). Wiley.

Existing Models (C-HIP, ISO)

ISO, Other Standards

Standard	Core Components	Color and Meaning	Characteristics	Organization / Country (Year)
ISO 3864	Safety colors, shapes, symbols	Red (Prohibition), Yellow (Warning), Blue (Mandatory), Green (Safe)	Global standard; clear color–meaning correspondence	ISO / International (1984)
ANSI Z535	Signal words, safety colors, symbols	Red (Prohibition), Yellow (Warning), Blue (Mandatory), Green (Safe)	Text-focused; legal compliance; industrial use	ANSI / USA (1991)
KS A ISO 3864	Color, shape, pictogram	Red (Prohibition), Yellow (Warning), Blue (Mandatory), Green (Safe)	Korean national standard based on ISO 3864	KATS / Korea (2007)
JIS Z9103	Safety colors, shapes, text	Red (Danger), Yellow (Caution), Blue (Instruction), Green (Safety)	Factory-focused; ISO-compatible	JISC / Japan (1993)

ISO/ANSI focus on fixed color/shape parameters.

Limitations of Existing Models (C-HIP, ISO)

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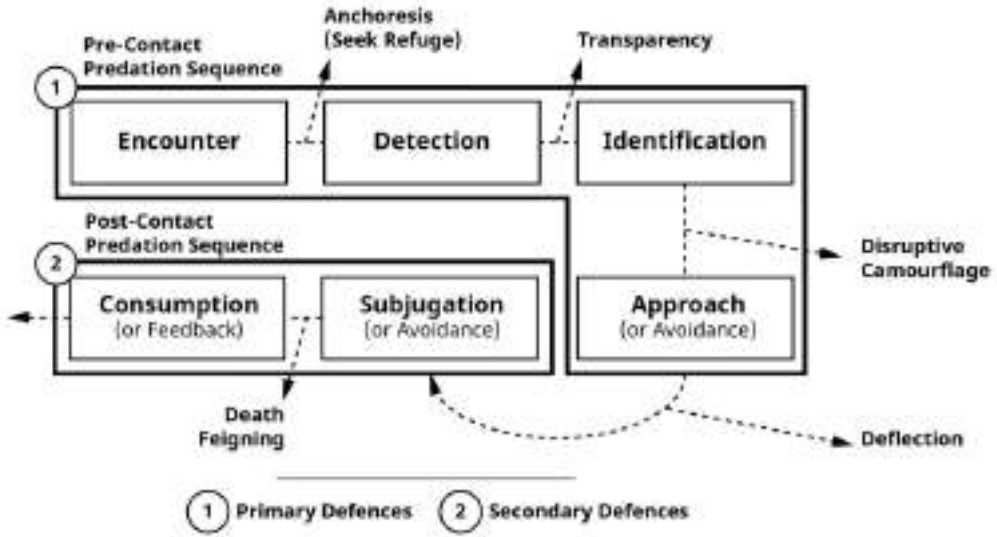
Biological Warning Structure: The Predation Sequence

Biological Model(Endler, 1991; Caro, 2005)

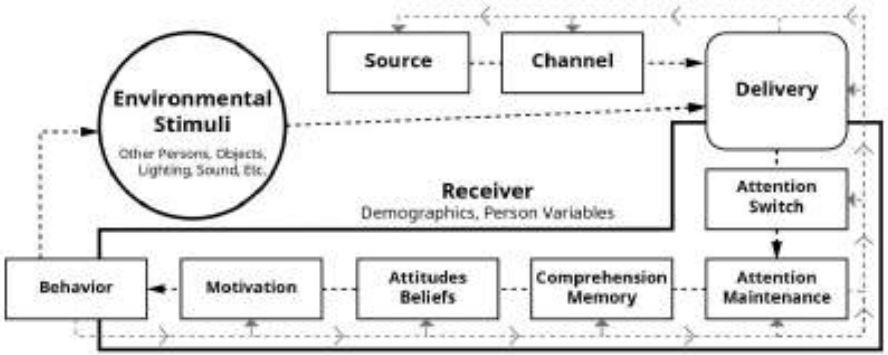
Detect → Identify → Avoid



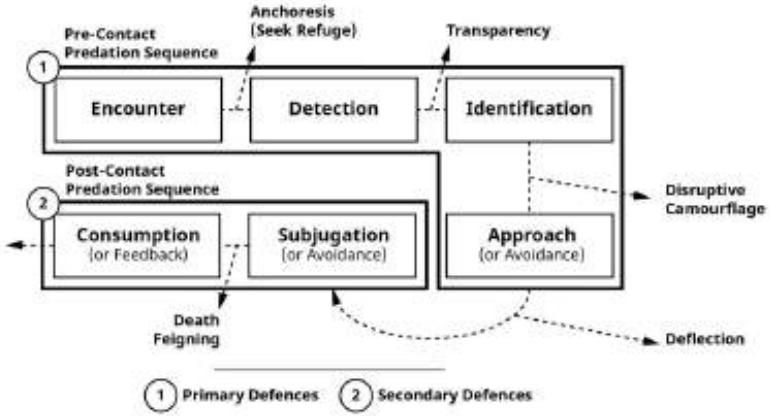
Endler, J. A. (1991). Interactions between predators and prey. In J. R. Krebs &N. B. Davies (Eds.), Behavioural Ecology (3rd ed., pp. 169–196). Blackwell.
Caro, T. (2005). Antipredator defenses in birds and mammals. University of Chicago Press.

Comparative Structure (C-HIP vs. Predation Sequence)

Both share a **recognition** → **interpretation** → **action** logic.



C-HIP Model

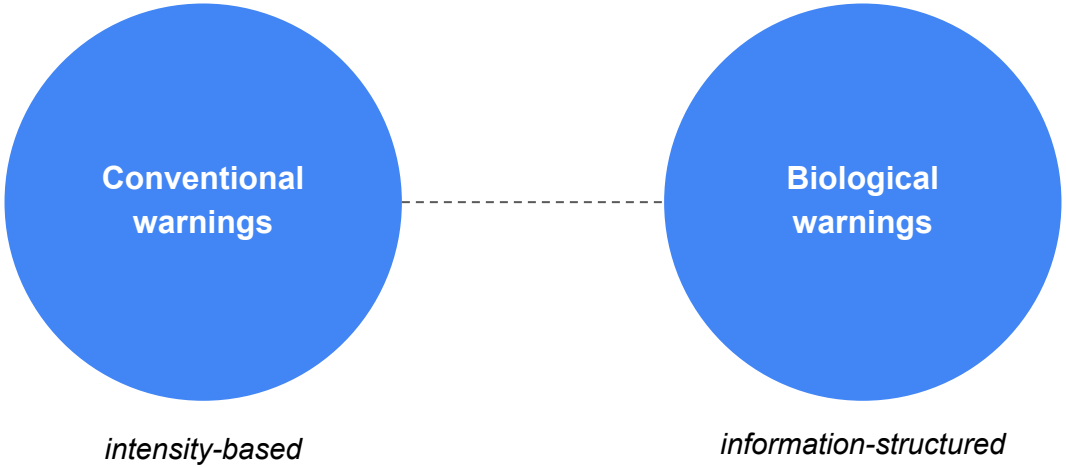


Biological Model

However, Biological systems provide the **distance-based specification** missing in human-centered systems.

Theoretical Gap

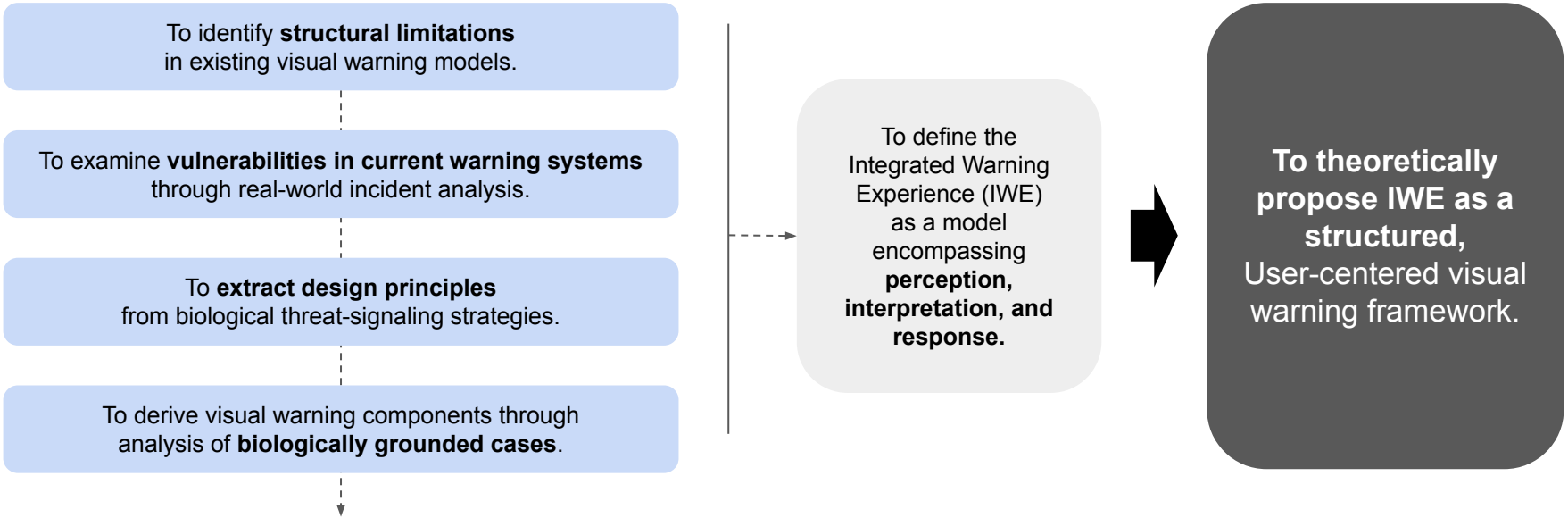
Lack of a model integrating conspicuity and distinctiveness across distance



‘IWE’ addresses this gap.

Analysis

Methodology Overview

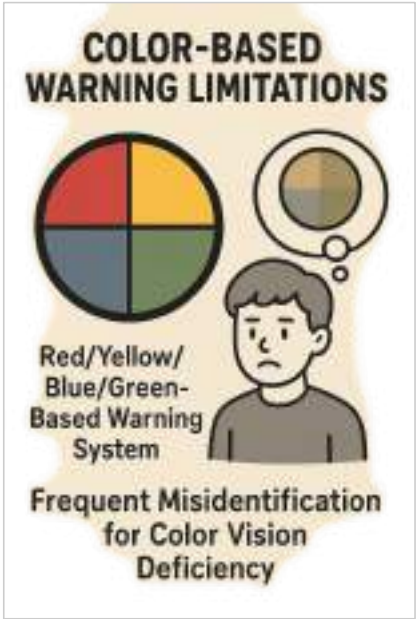


Accident Case Findings

Auditory Inaccessibility

Poor Contrast

Single-Modality Dependence



Color-Based Warning Limitations

Bae, D. W. (2021, May). Dramatic rescue of deaf people after 6 hours of fire. UBC. http://web.ubc.co.kr/wp/archives/89131
Dong-A Science. (2017, December 14). Fatal track worker accident at Onsu Station. https://dongascience.com/news.php?idx=20809

Accident Case Findings

Perceptual Dynamics

Existing standards define colours and contrast, but perception is a distance-based, dynamic process.

Meaning vs Visibility

Colour ensures visibility, but not meaning or distinctiveness.

Recognition Failure

Most failures occur at the point of recognition, not detection.

IWE reframes warnings as perceptual events, not static visual signals.

Model Proposal

From C-HIP to IWE

Encounter – Detection

Enhance *Conspicuity*
– Facilitate rapid detection and visual attention

Identification – Approach

Enhance *Distinctiveness*
– Support accurate interpretation of warning content

Core Principle

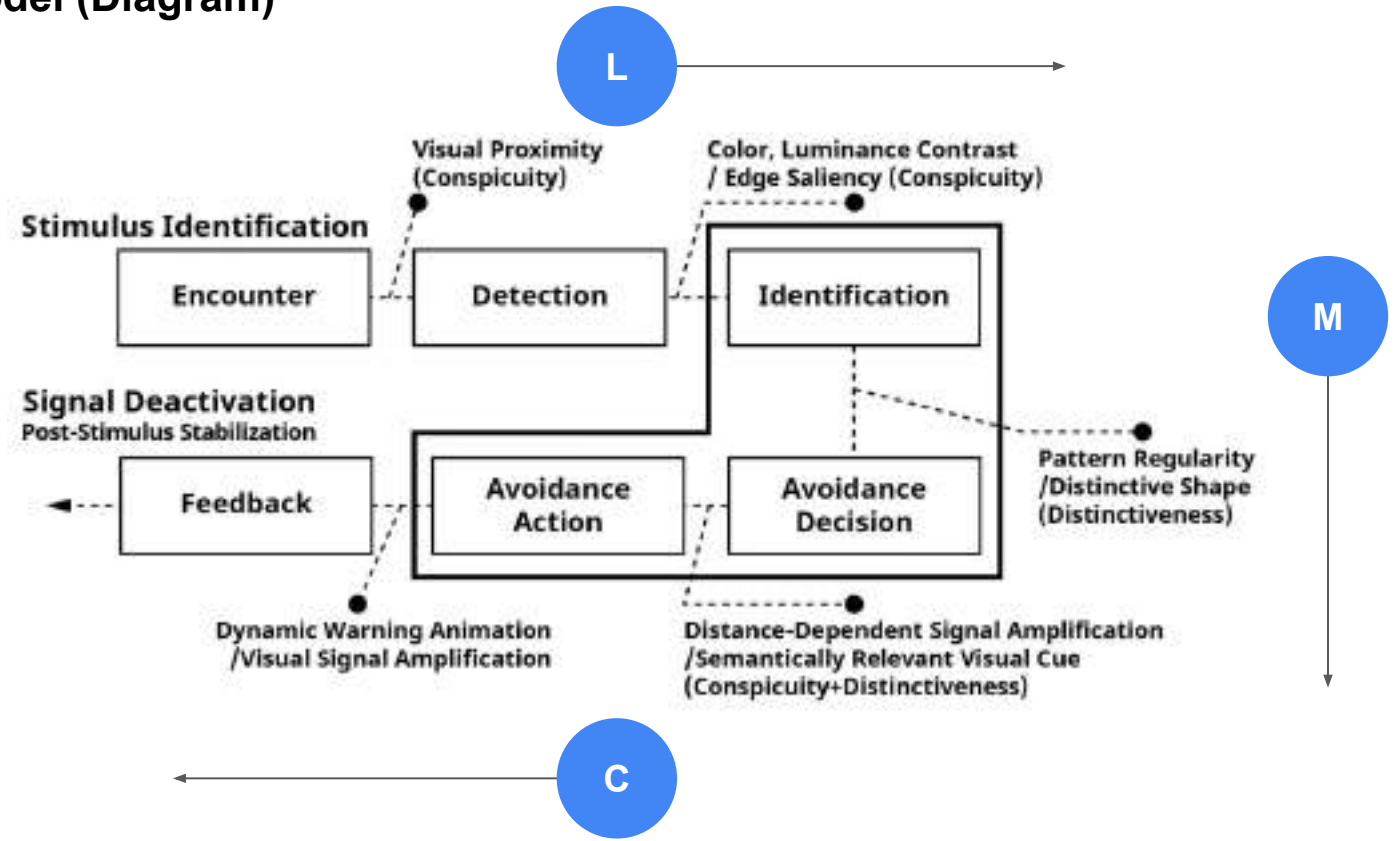
Warnings must dynamically shift from conspicuity to distinctiveness as distance decreases.

Distance-Based Perceptual Roles & Design Features

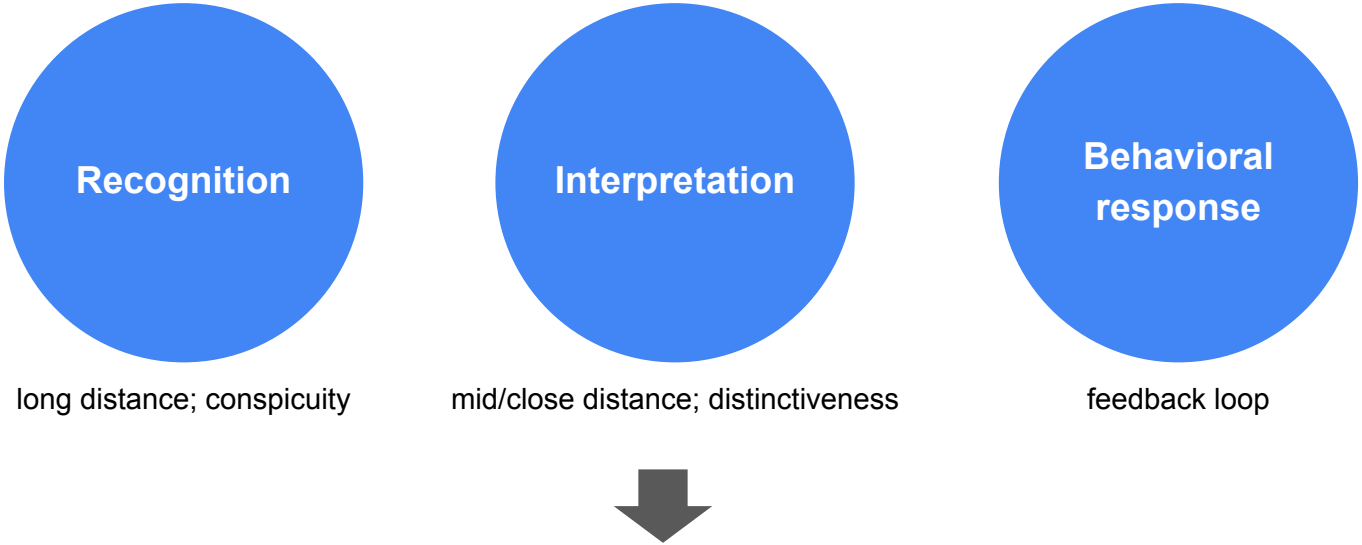
Distance	Primary Perceptual Goal	Conspicuity	Distinctiveness	Design Features
Long	Fast detection	High	Low	High contrast, large forms, flashing
Mid	Transition & differentiation	Medium	Medium	Mixed cues (contrast + pattern)
Close	Semantic interpretation	Low	High	Patterns, colour modulation, detail

Visual warnings are not static signals
but a continuous perceptual spectrum shaped by distance.

The IWE Model (Diagram)



The IWE Model (Diagram)



Includes contextual modulation (background, luminance, motion, task).

Conclusion

Key Contributions

- Redefines visual warnings as perceptual processes rather than intensity-based cues.
- Introduces a structured, distance-based integration of conspicuity and distinctiveness.
- Shows how biological signalling systems can inform the perceptual architecture of human warning design.

Closing & Future Work

- Eye-tracking validation of distance-based perceptual transitions.
- Empirical determination of approximate long–mid–close distance ranges (adjusted by contextual settings).
- Luminance-sensitivity modelling for users with Colour-Vision Deficiency.
- Multimodal extension of the IWE framework (visual + tactile + auditory).

“IWE moves visual warnings from mere visibility toward meaningful, interpretable, and inclusive perceptual experiences.”