

Hierarchical Temporal Intentionality

John Thornton

Institute for Integrated and Intelligent Systems
and School of Humanities
Griffith University Gold Coast

The Basic Message

- Phenomenology has a central role to play in the development of a correct theory of brain function, not just in providing empirical observational data to test a given theory, but in **guiding the process of theory formation in the first place**
- For, if certain processes in the brain are absolutely (i.e. immediately) given to consciousness, and there is a **lawful mapping** between the abstract structure inherent in those processes and the structure of conscious experience, it should be possible to characterise the structure of those physical processes on the basis of a **proper phenomenological analysis**

The Temporal Structure of Experience

- The unified overarching structure of conscious experience is that of a **temporal flow** within which **enduring** self-identical **objects** appear
- Each moment of temporal experience appears within a **temporal horizon** of the immediate past and future
- It is an **experience of succession** (**flowing continuity**) **not** a point like succession of experiences

A Phenomenological Example

The Crow Call



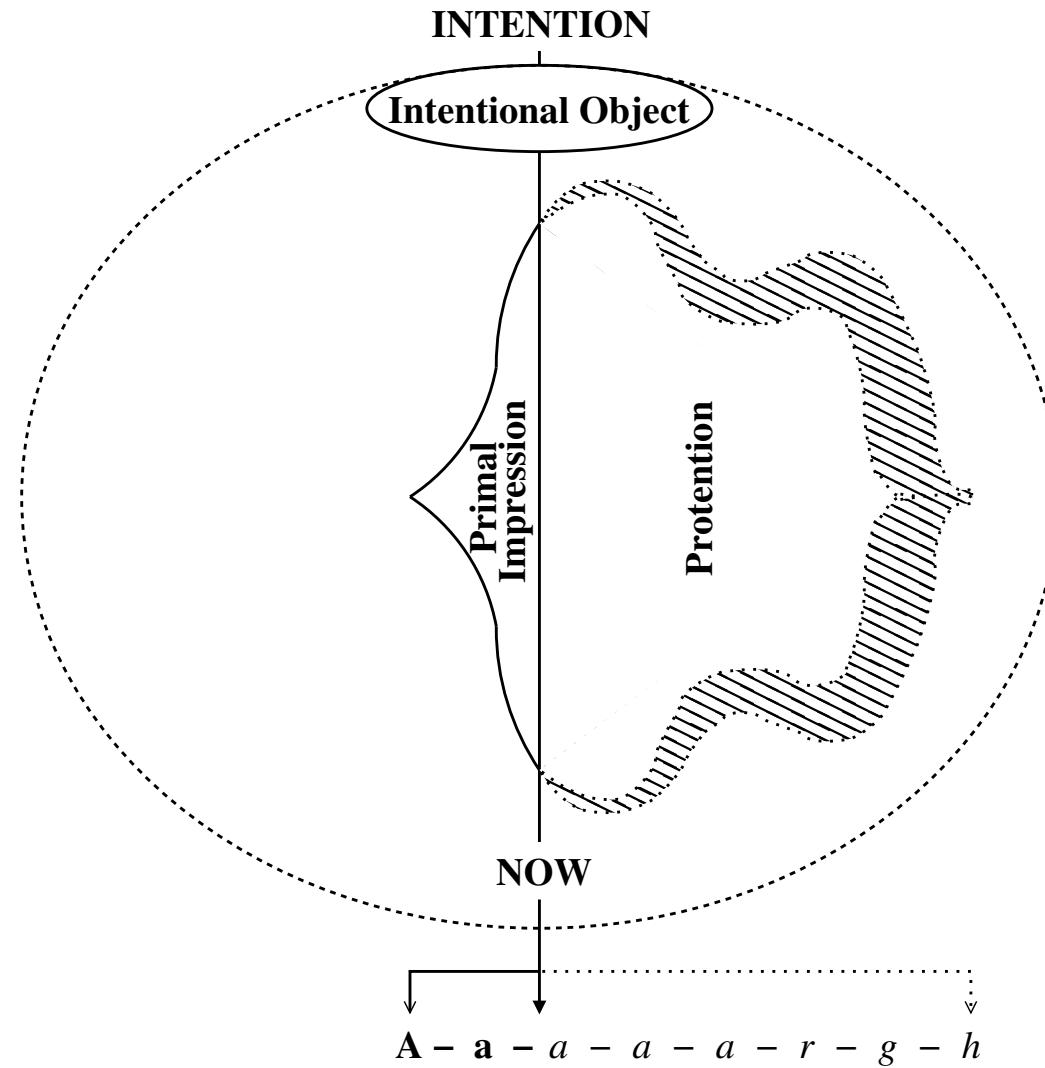
Phase 0

INTENTION

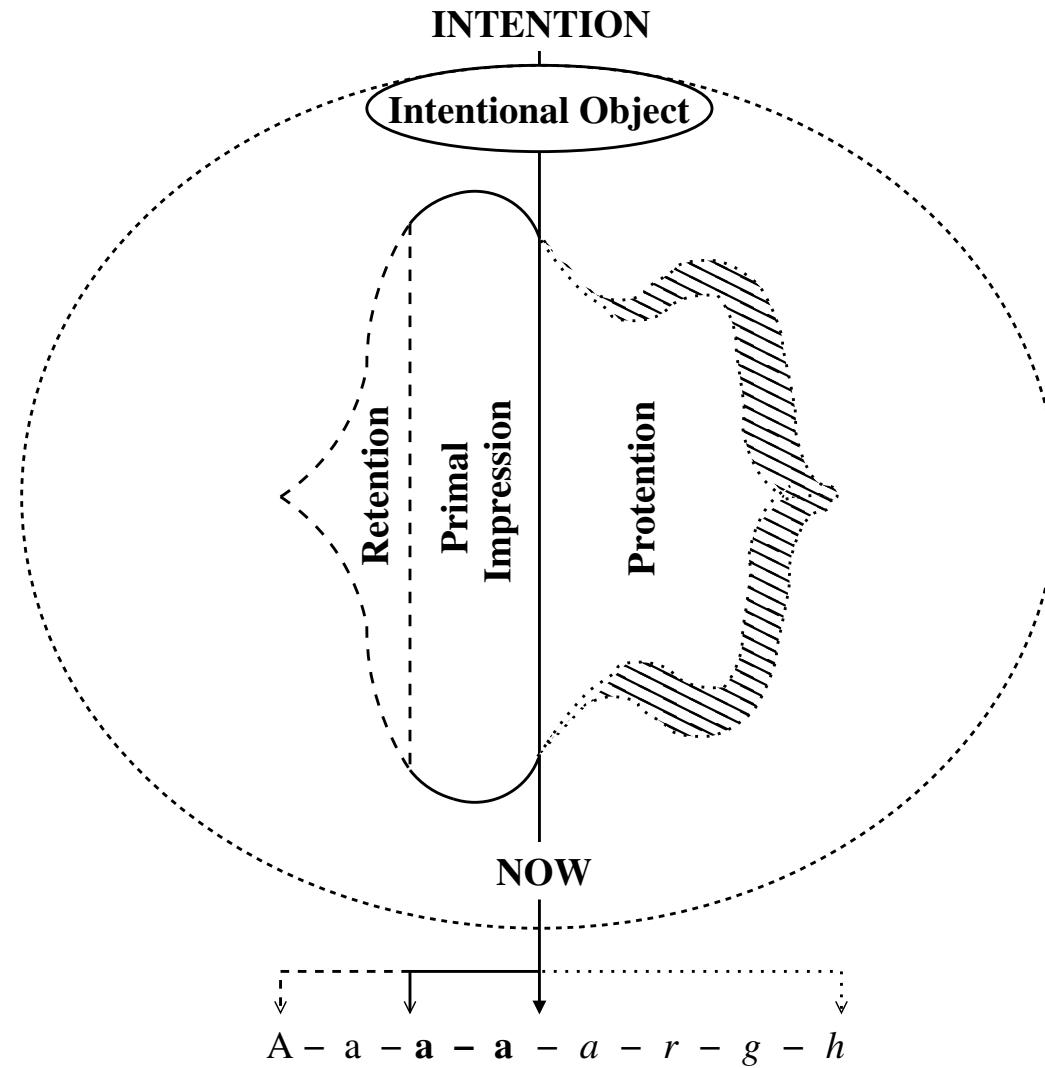


NOW

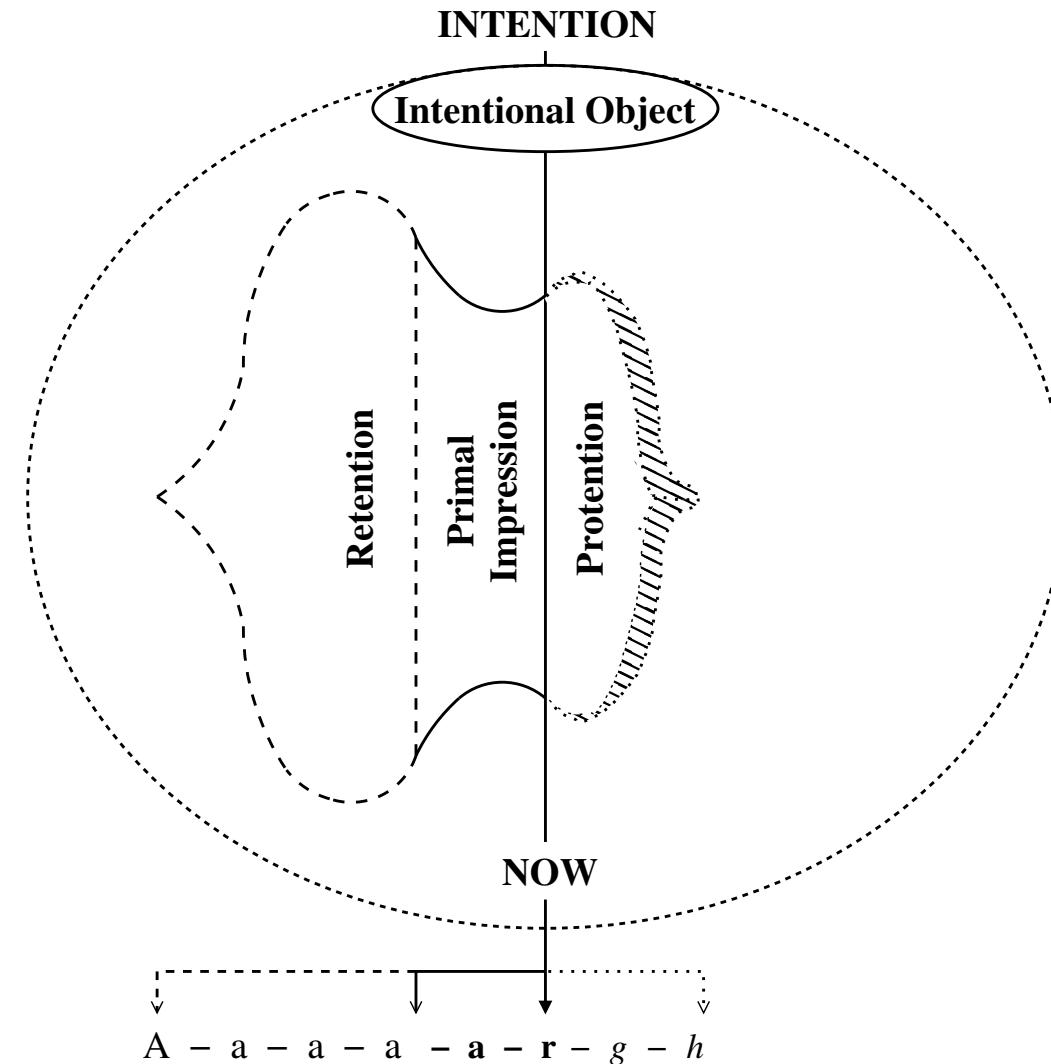
Phase 1



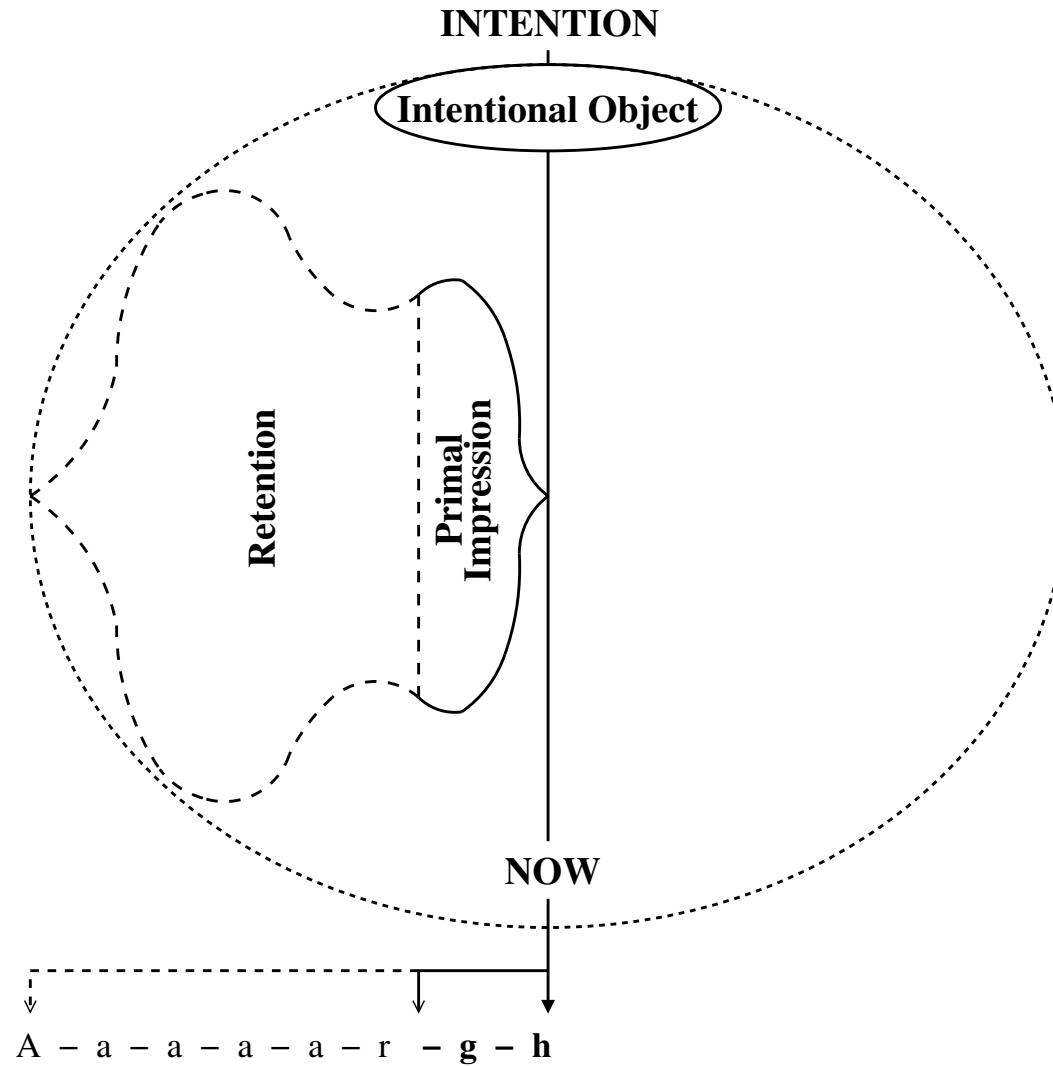
Phase 2



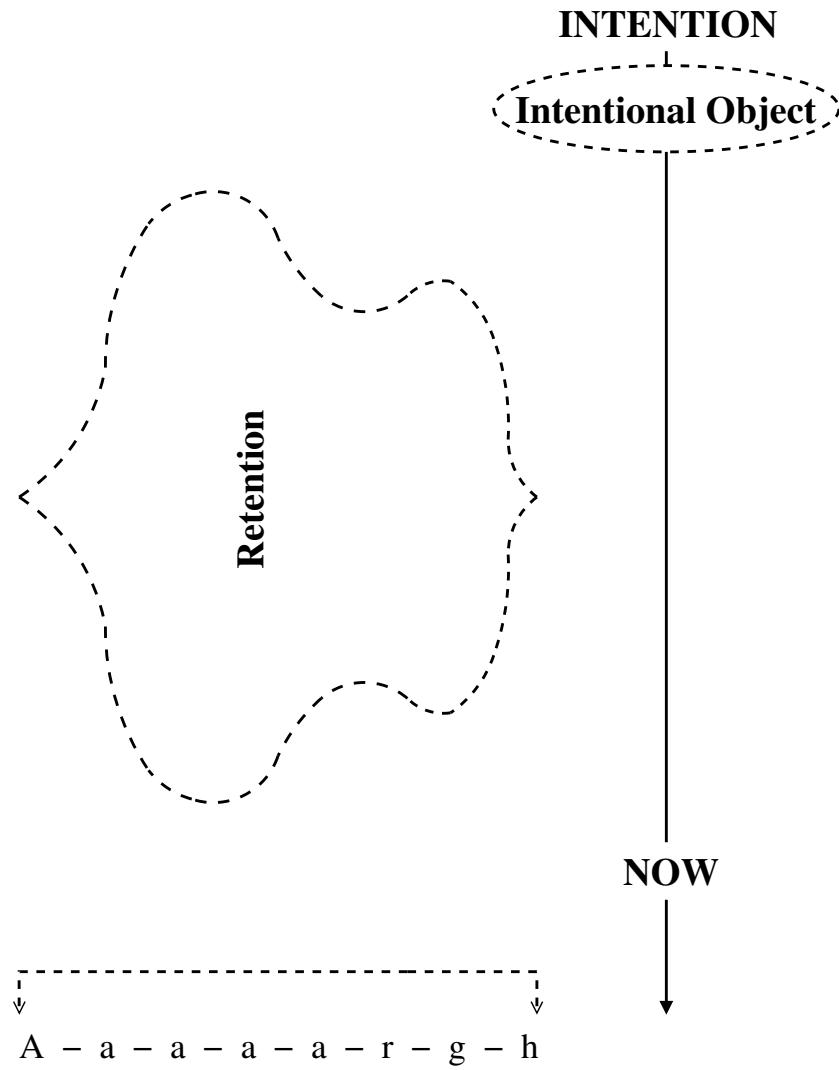
Phase 3



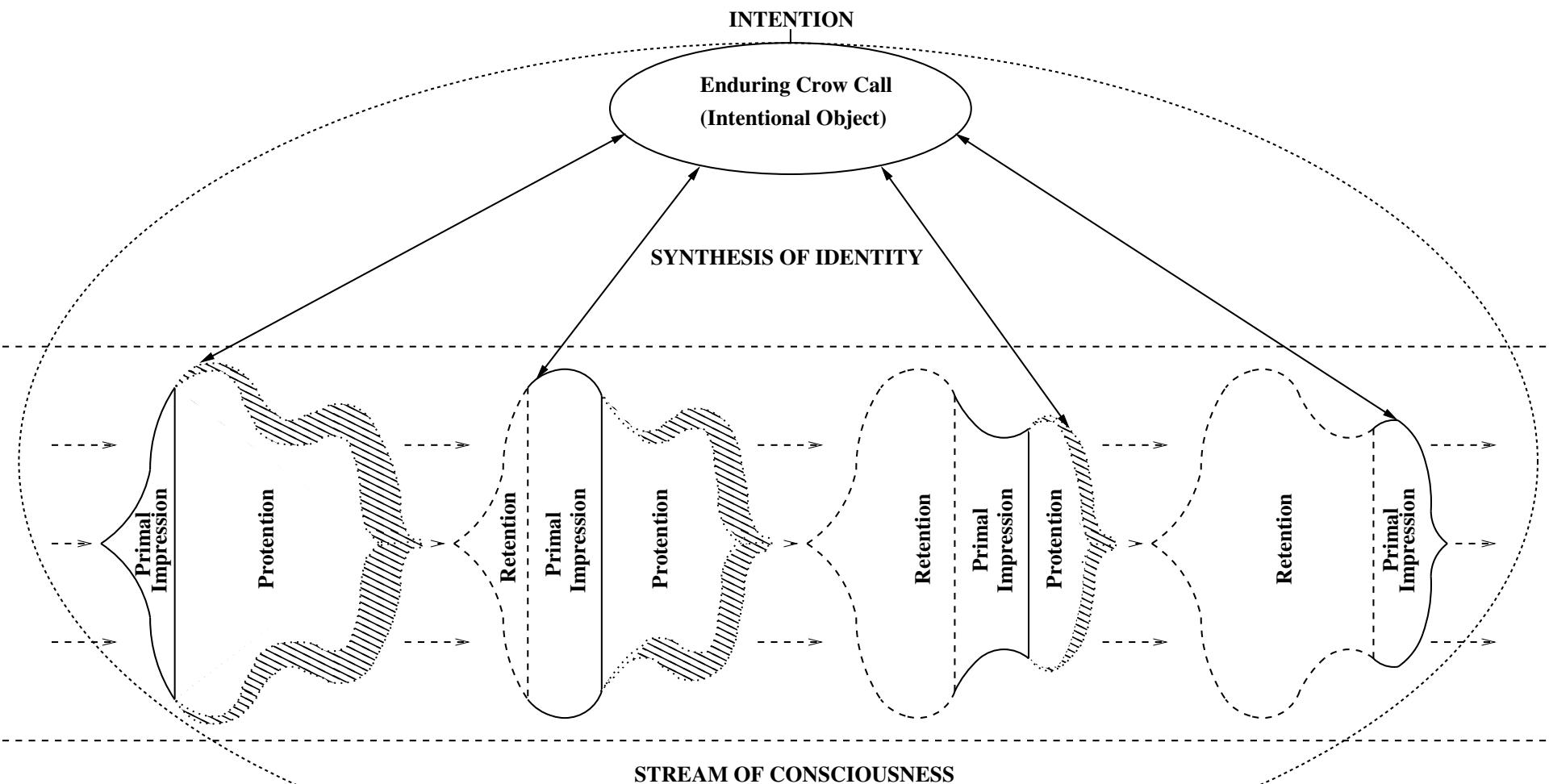
Phase 4



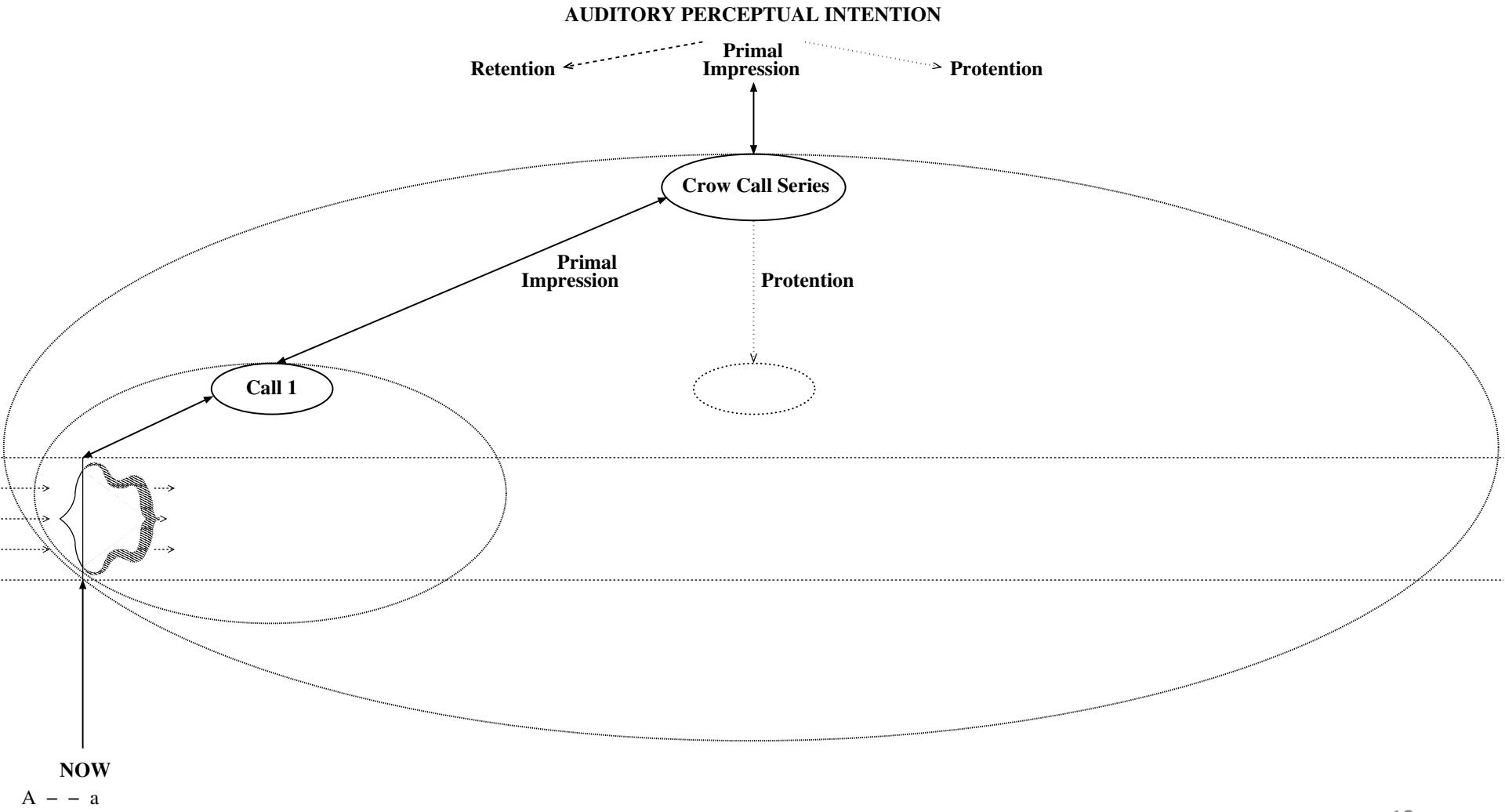
Phase 5



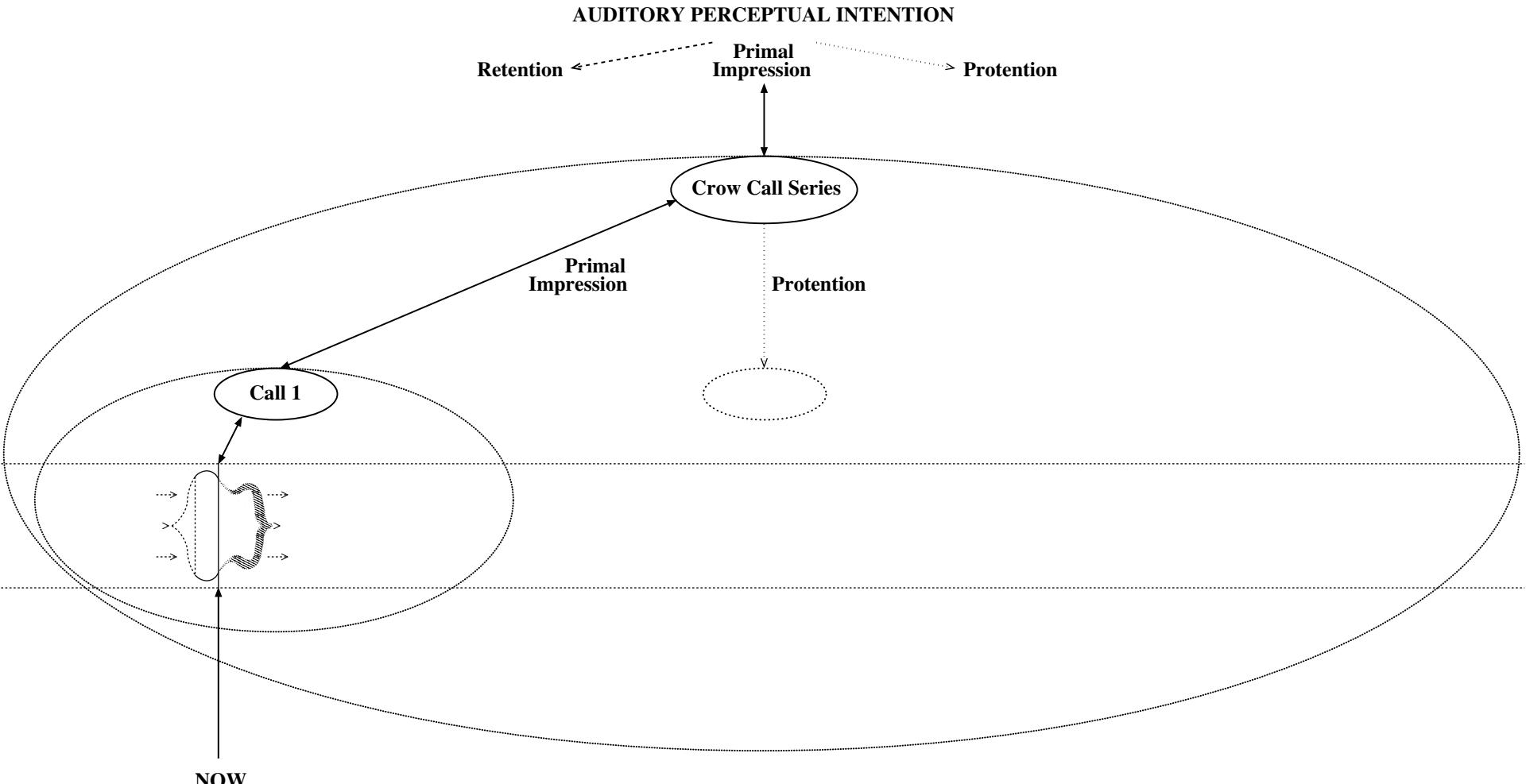
Intentional Object



Hierarchical Intentionality

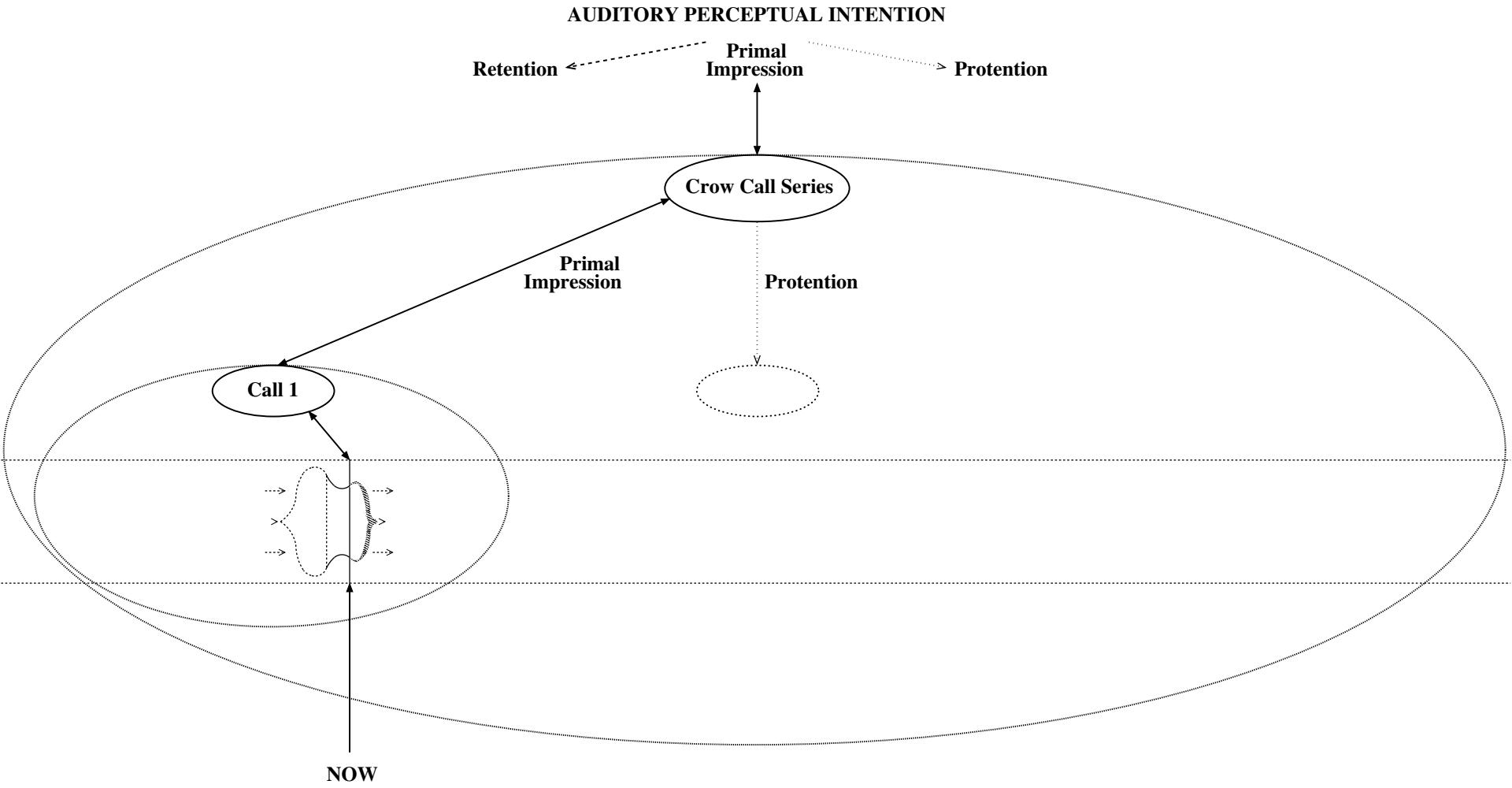


Hierarchical Intentionality



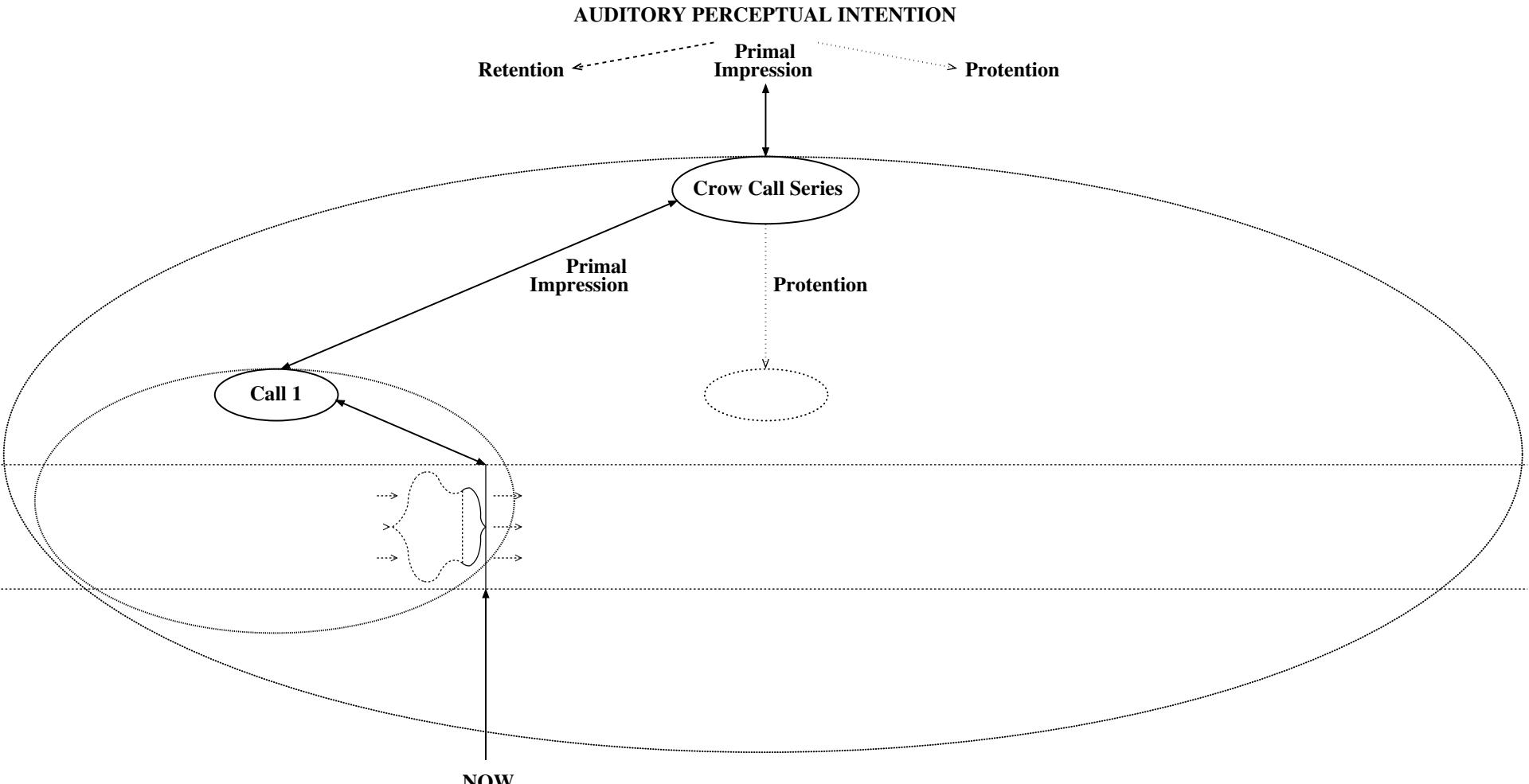
A — a — a — a

Hierarchical Intentionality



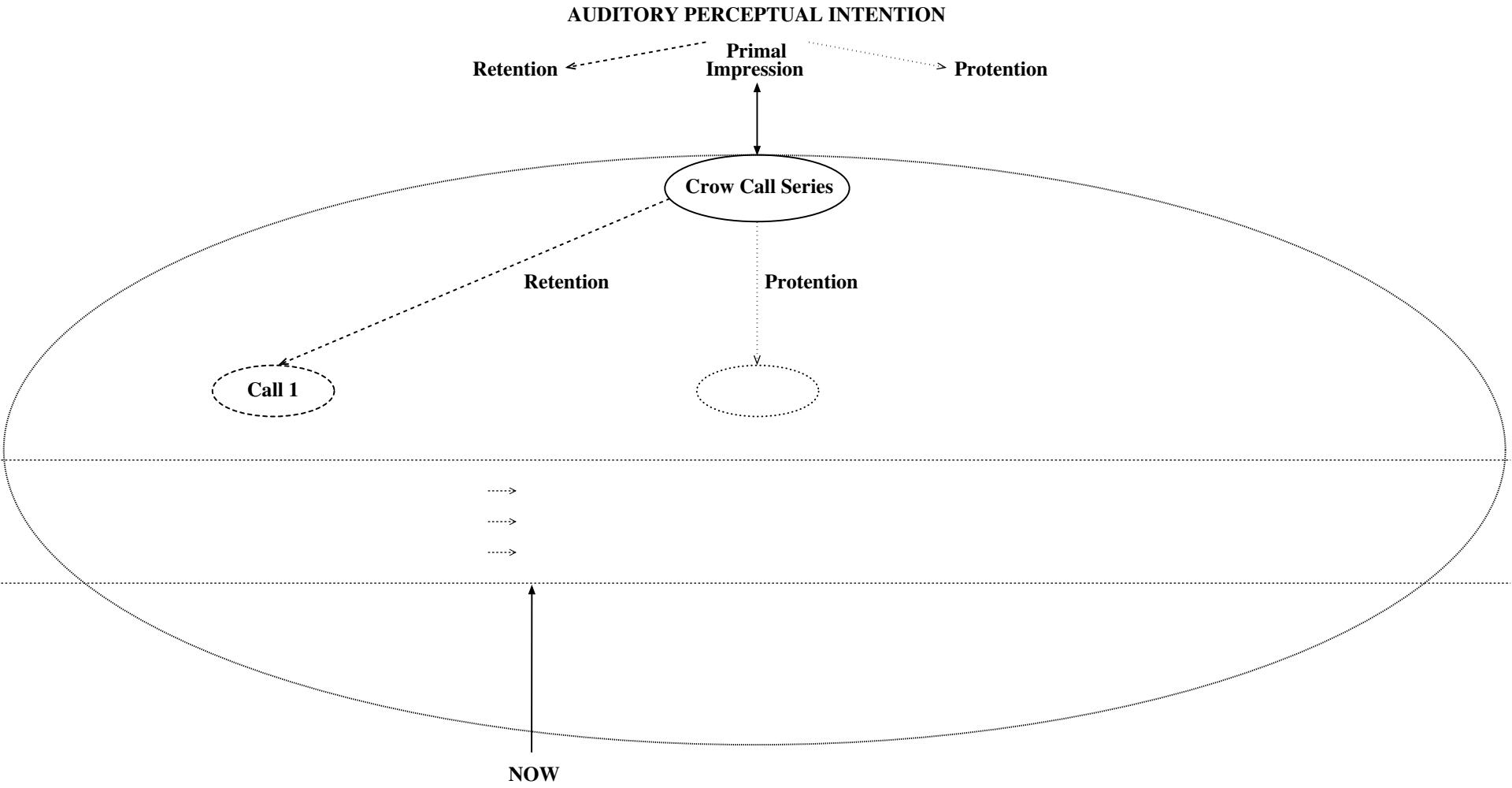
A - - a - - a - - a - - a - - r

Hierarchical Intentionality



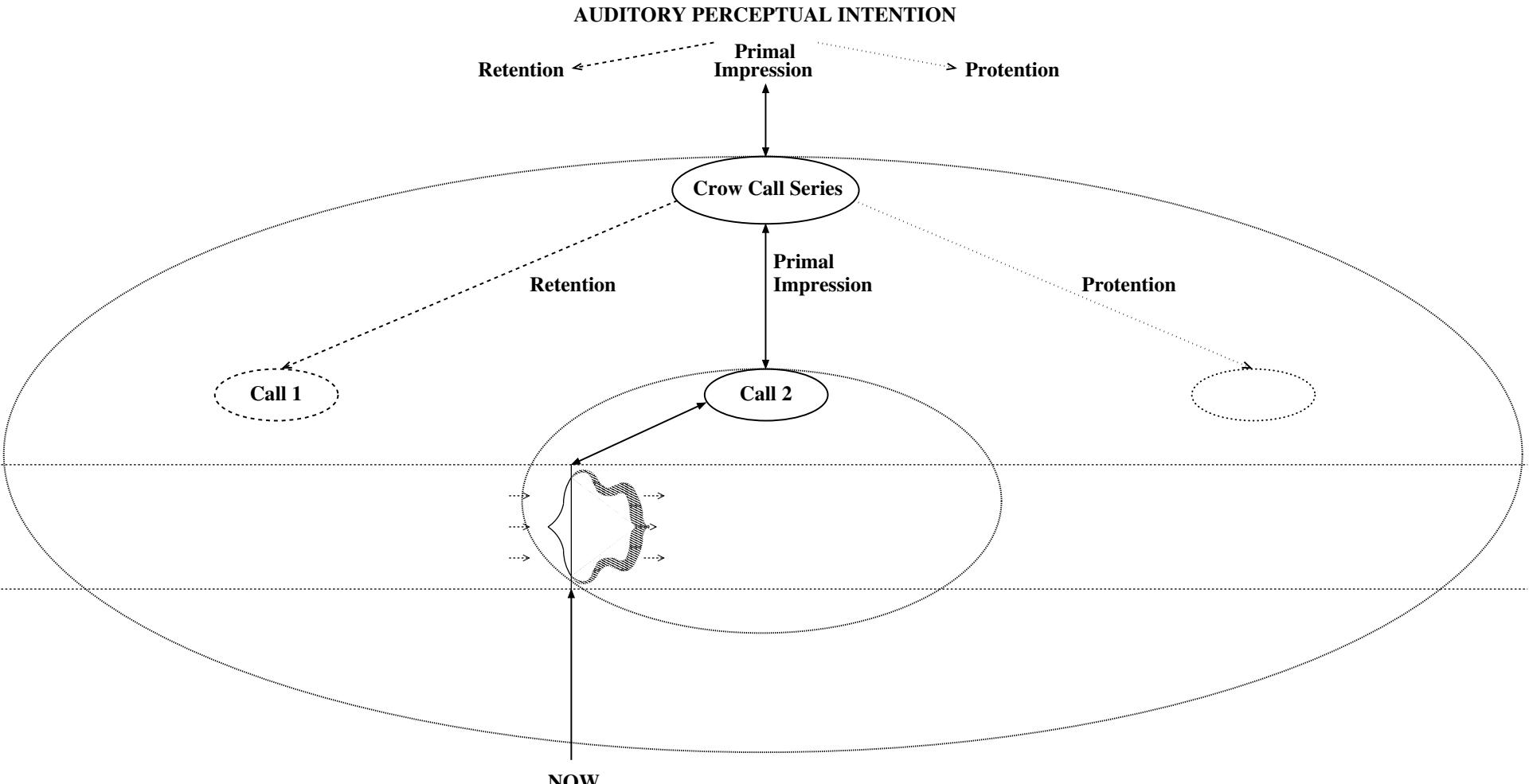
A — a — a — a — a — r — g — h

Hierarchical Intentionality



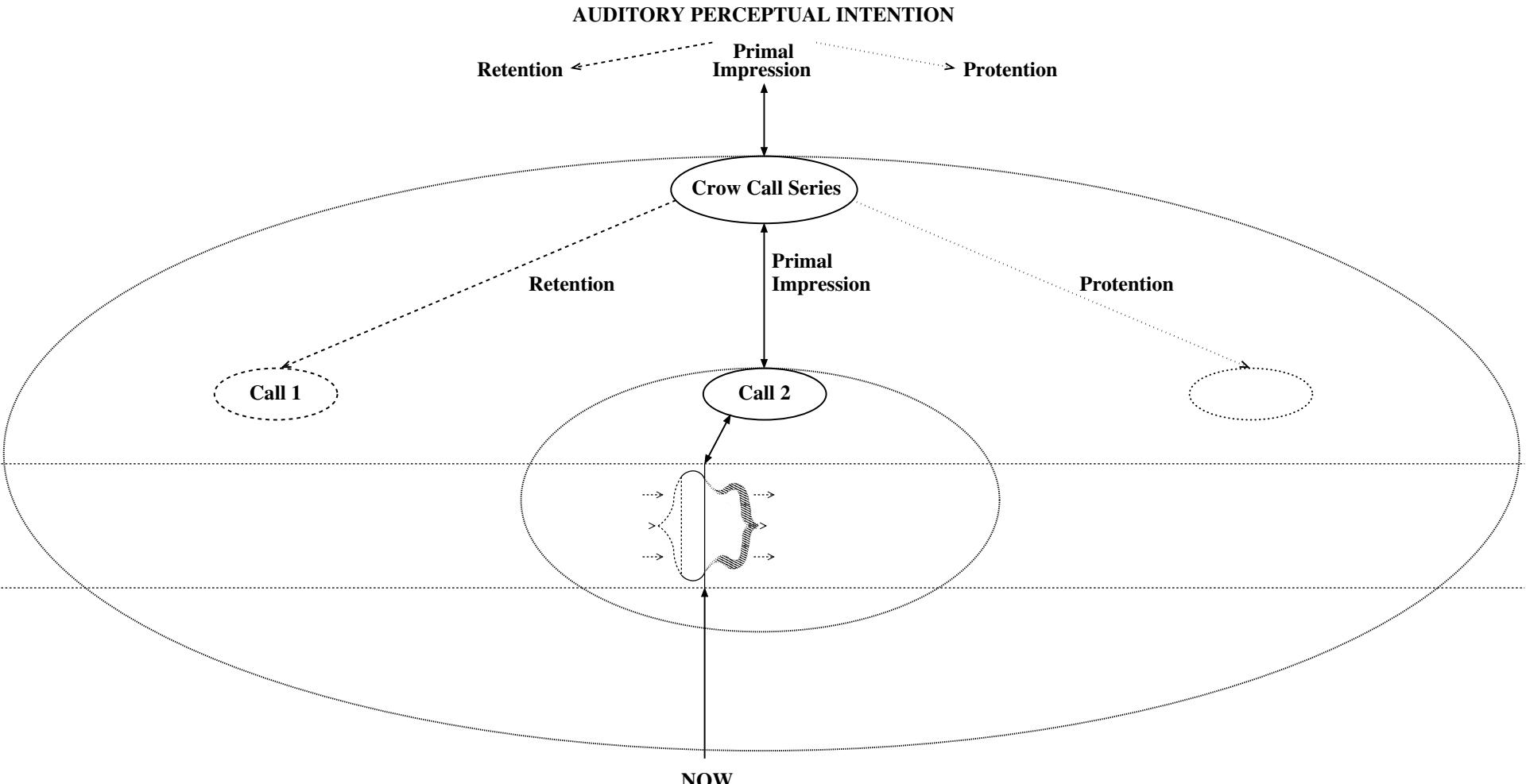
A - - a - - a - - a - - r - - g - - h

Hierarchical Intentionality



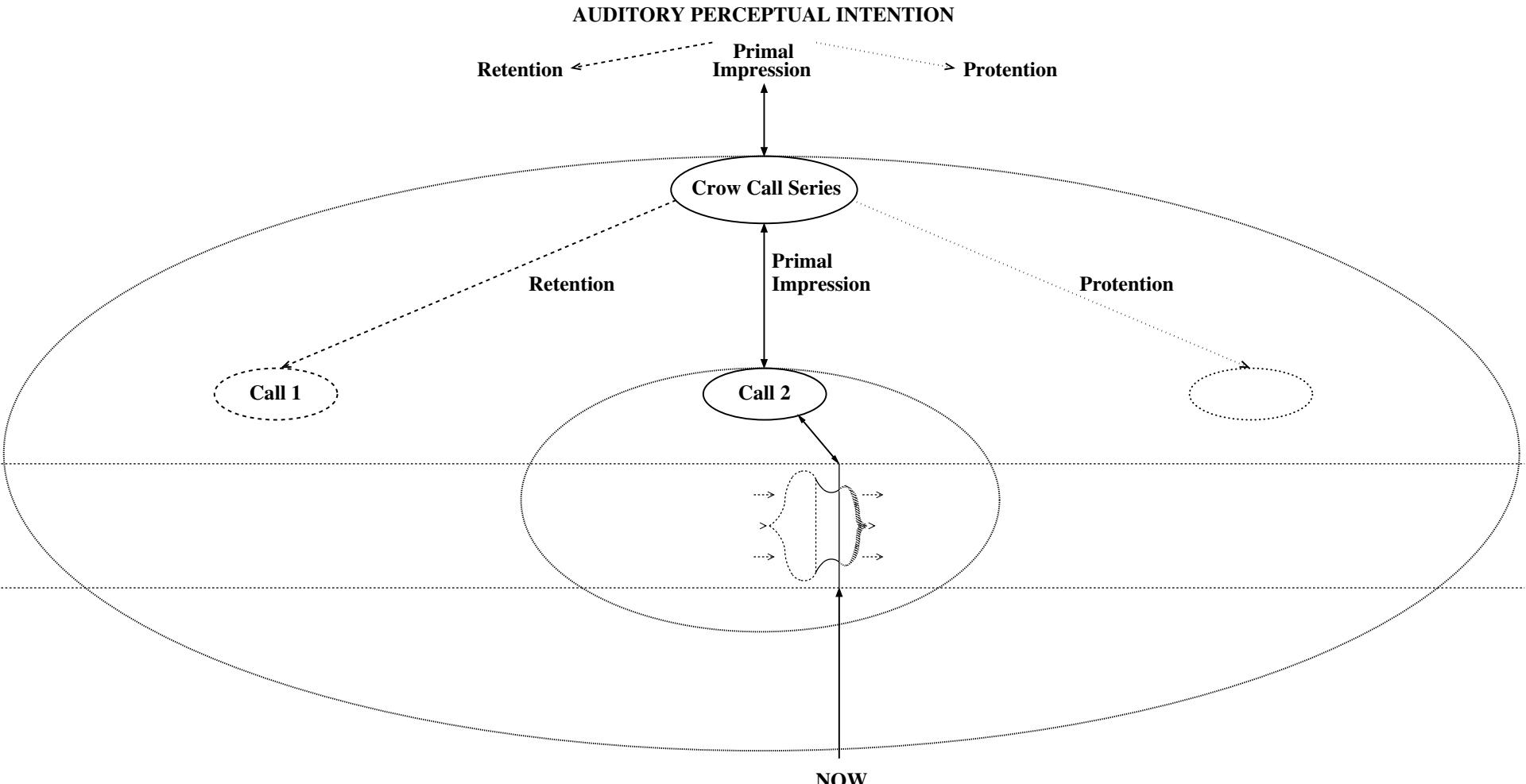
A - - a - - a - - a - - r - - g - - h A - - a

Hierarchical Intentionality



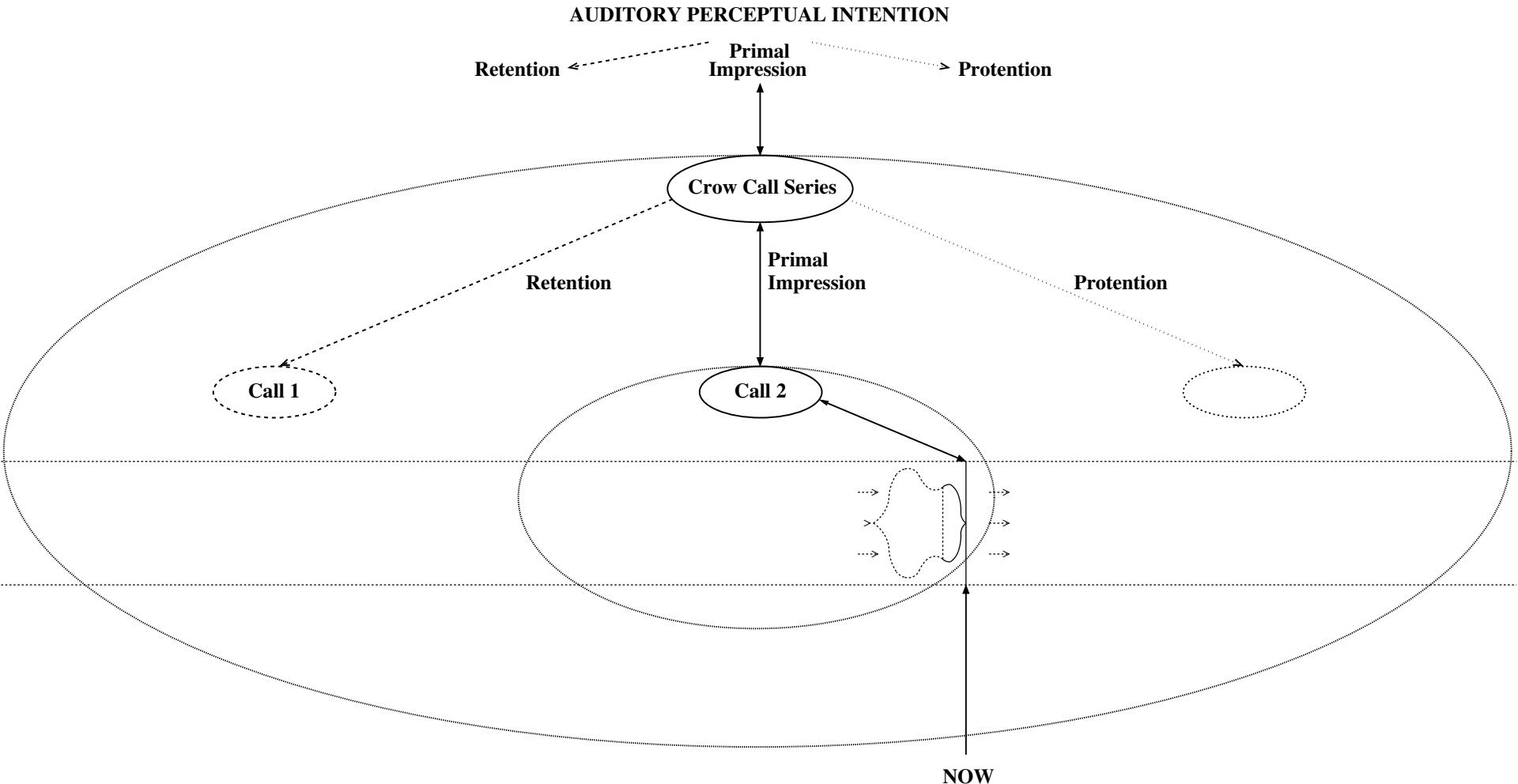
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a

Hierarchical Intentionality



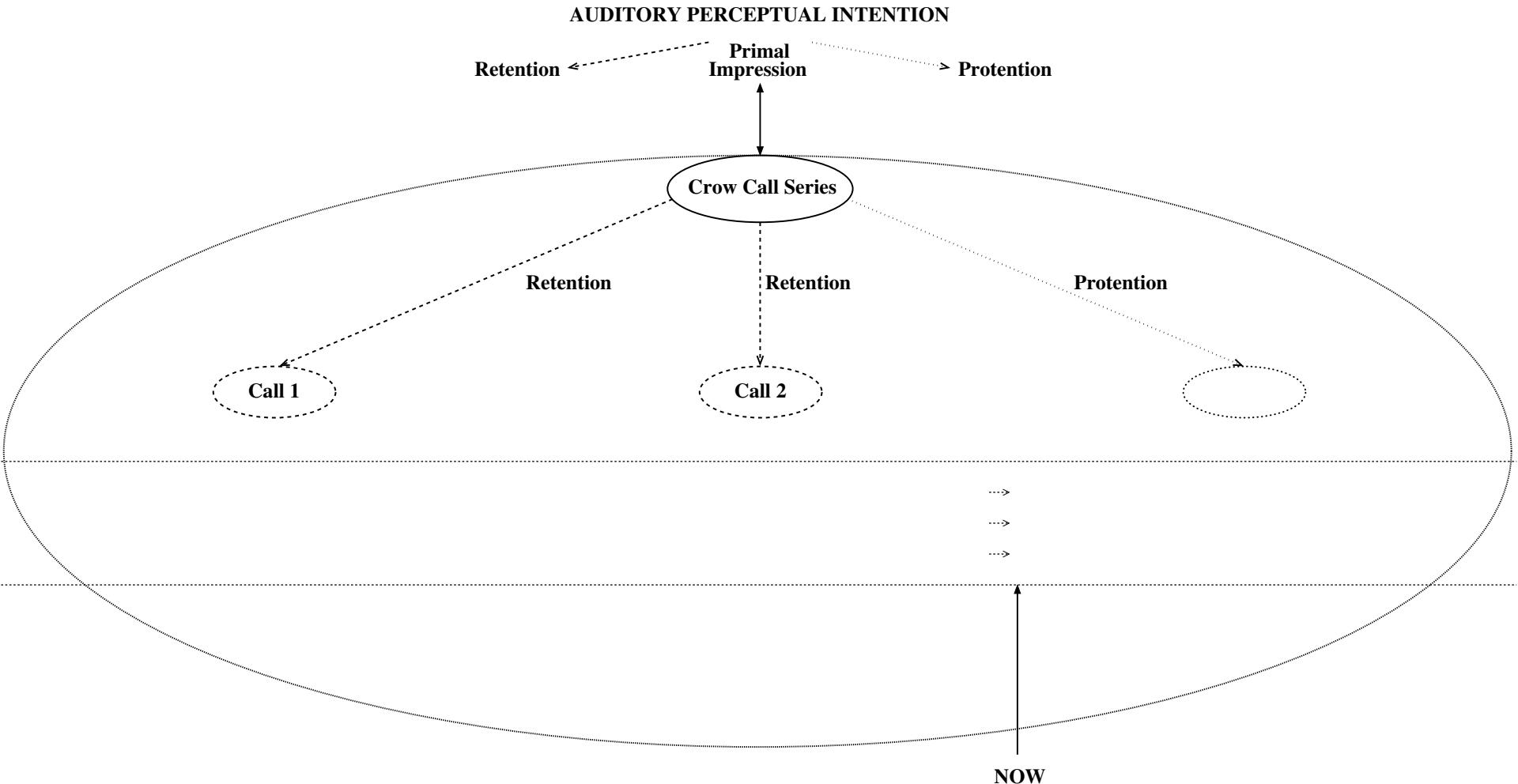
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r

Hierarchical Intentionality



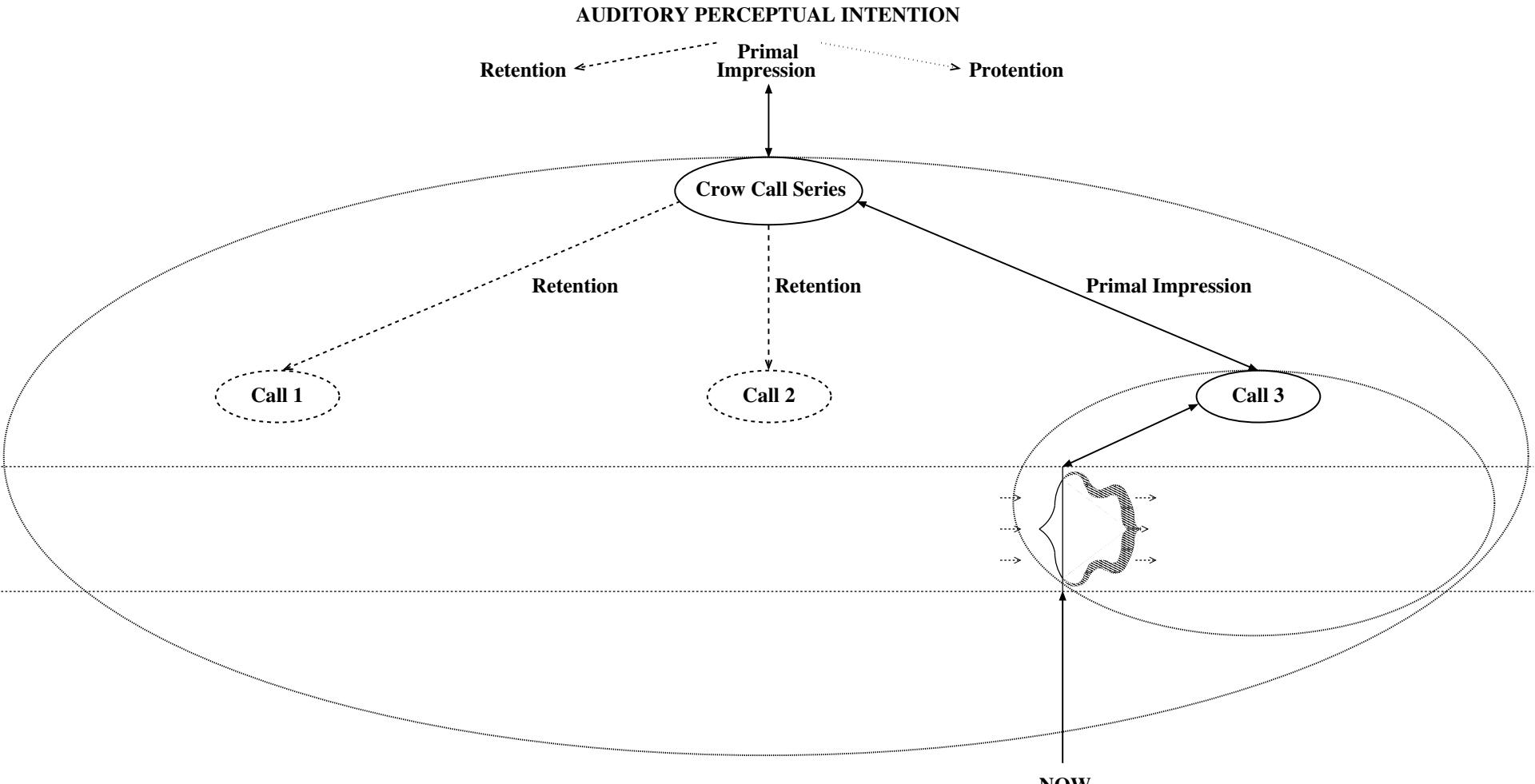
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r - - g - - h

Hierarchical Intentionality



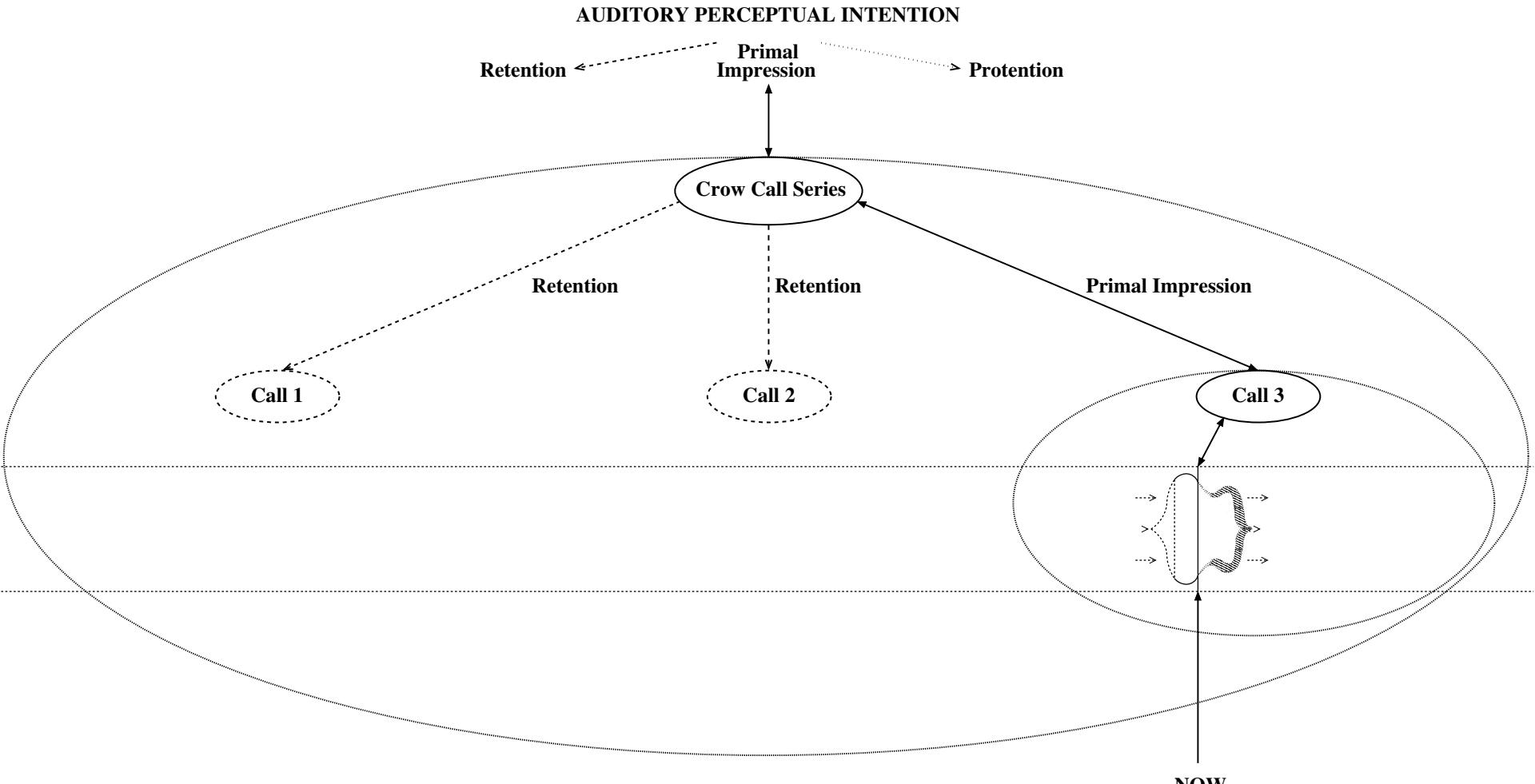
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r - - g - - h

Hierarchical Intentionality



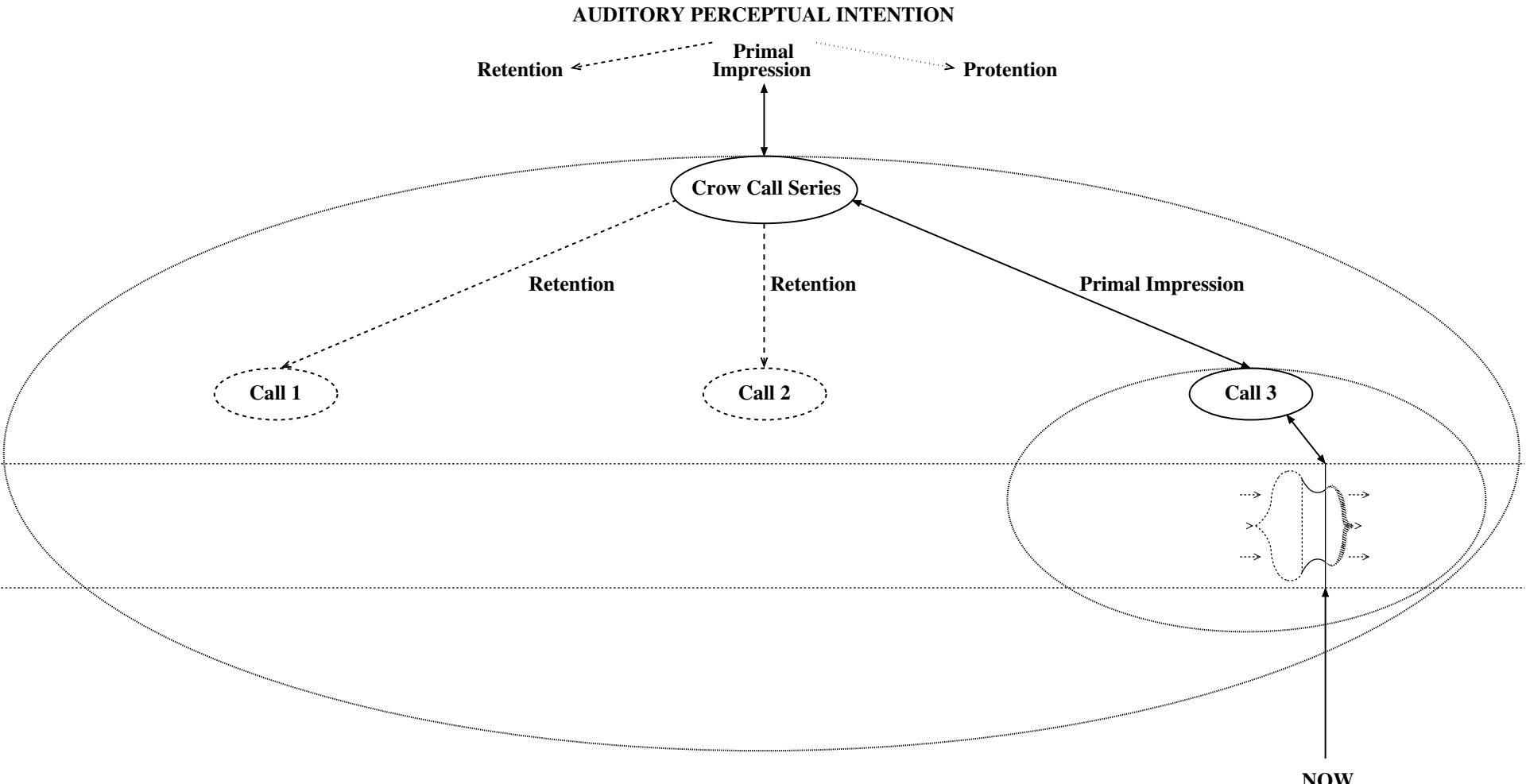
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r - - g - - h A - - a

Hierarchical Intentionality



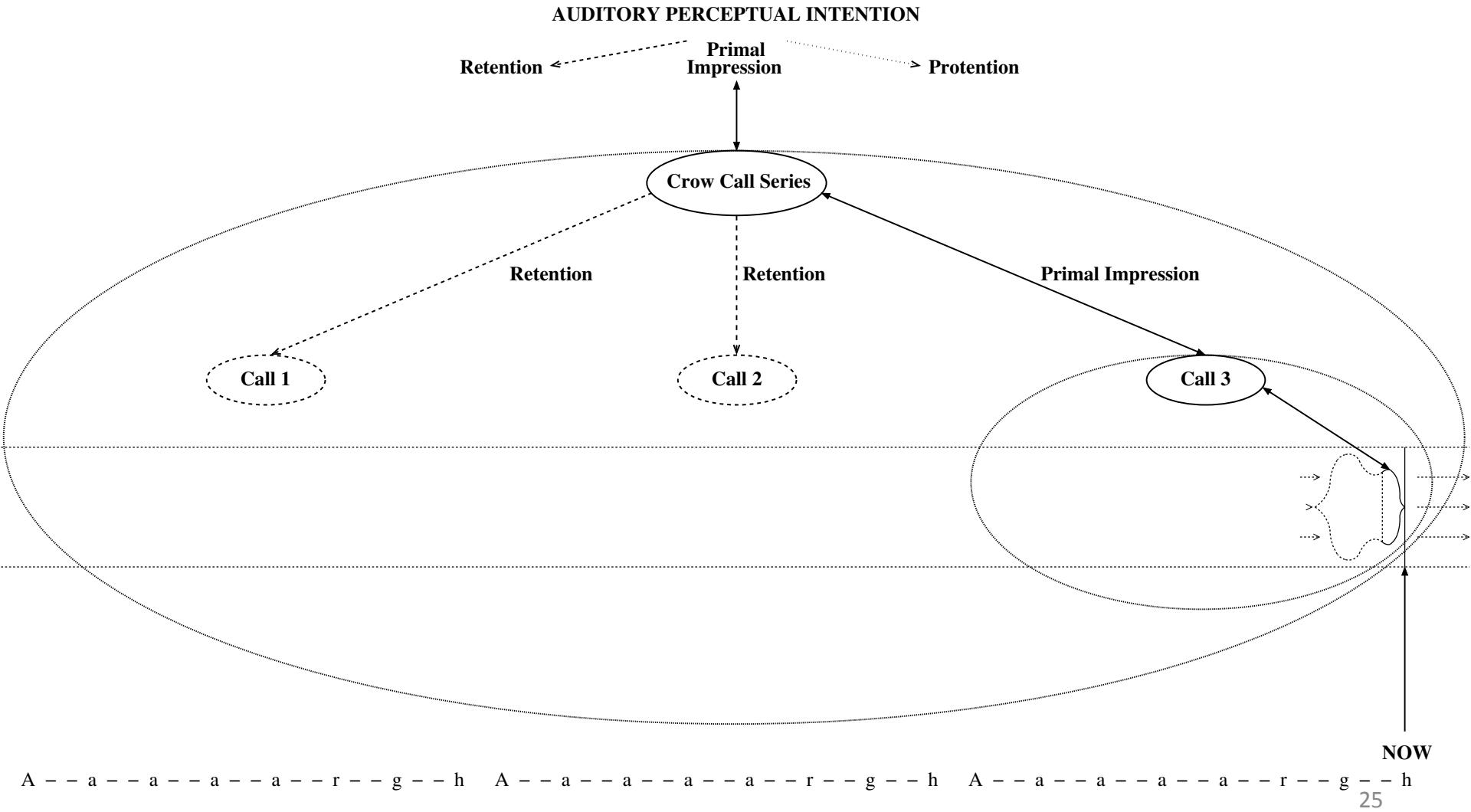
A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r - - g - - h A - - a - - a - - a

Hierarchical Intentionality

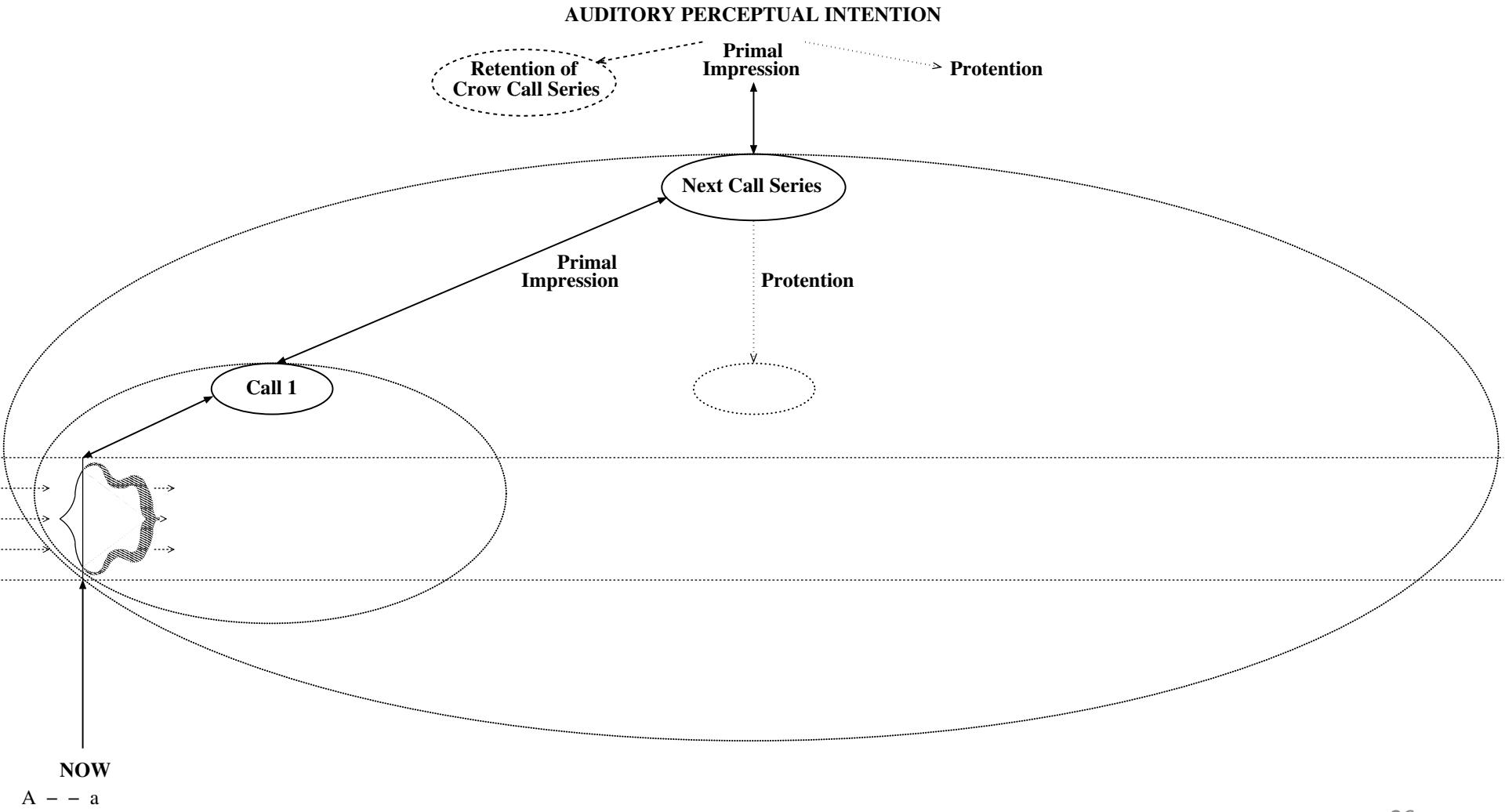


A - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r - - g - - h A - - a - - a - - a - - a - - r

Hierarchical Intentionality



Hierarchical Intentionality



Hierarchical Temporal Memory

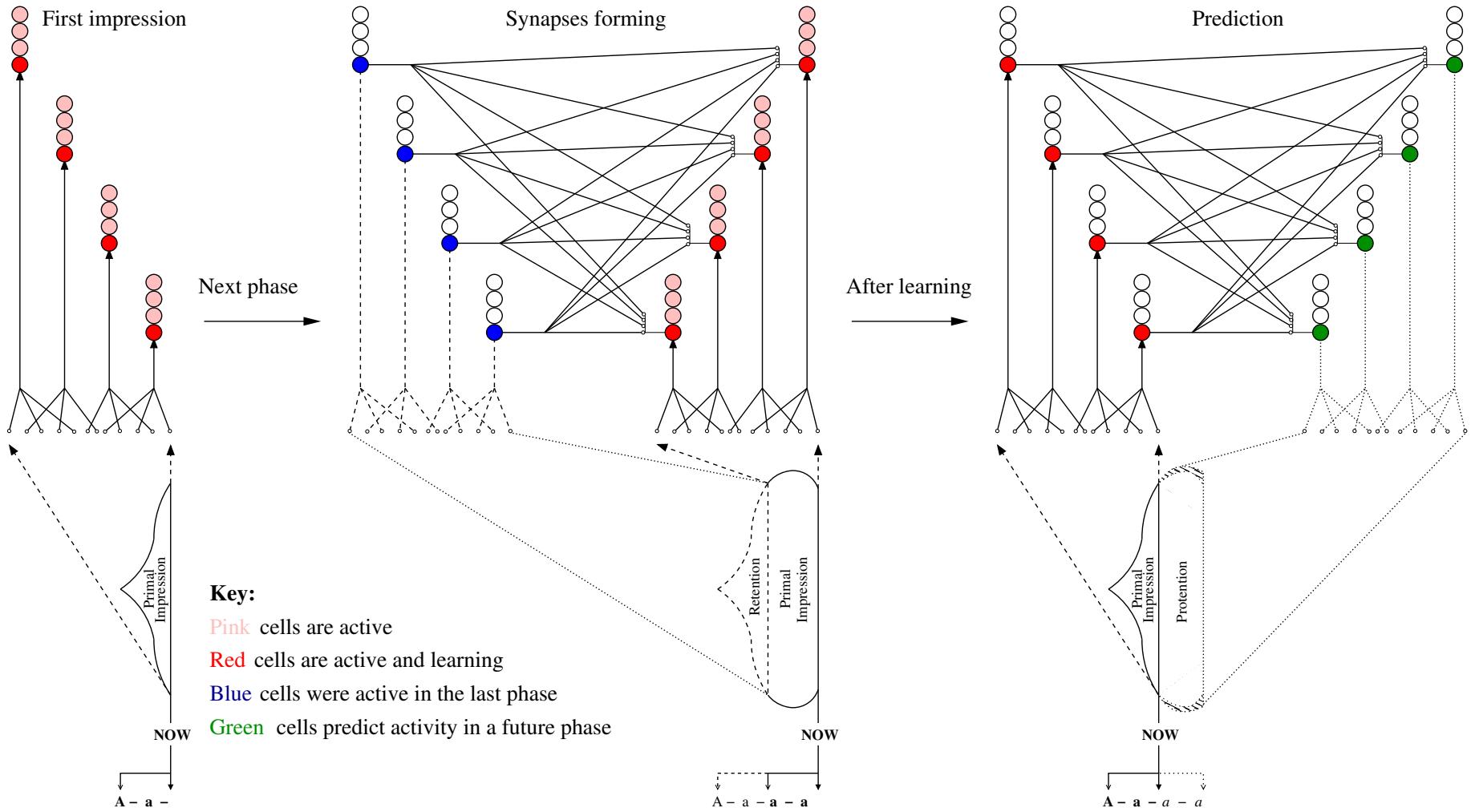
- Hierarchical Temporal Memory (HTM) is a model of neocortical function developed by Jeff Hawkins and colleagues from 2004 up to the present
- It shares many key ideas from the hierarchical predictive coding model:
 - Neocortical processing is **hierarchically structured error minimisation** that **infers causes** from sensory input
 - The neocortex implements the **same underlying process** across its entire area
 - Stored ‘knowledge’ extracted from past experience is used to make **predictions** concerning future actions and perceptions
 - Perception and action are determined via a process of **reciprocal predictive feedback** between regions within dynamically activated hierarchies

HTM's Innovation

- The function of **neocortical minicolumns** is not only to resolve mismatches between bottom-up input and top-down feedback but also to learn **temporal sequences** in the input via the formation of short range lateral connections
 - Hierarchical **predictive coding** learns a generative model of the world in order to predict what will happen **now** – producing a **succession of experiences**
 - An **HTM** encodes patterns of column activation that **retain** past activity and **predict** future activity – producing an **experience of succession** that **agrees with the phenomenology**

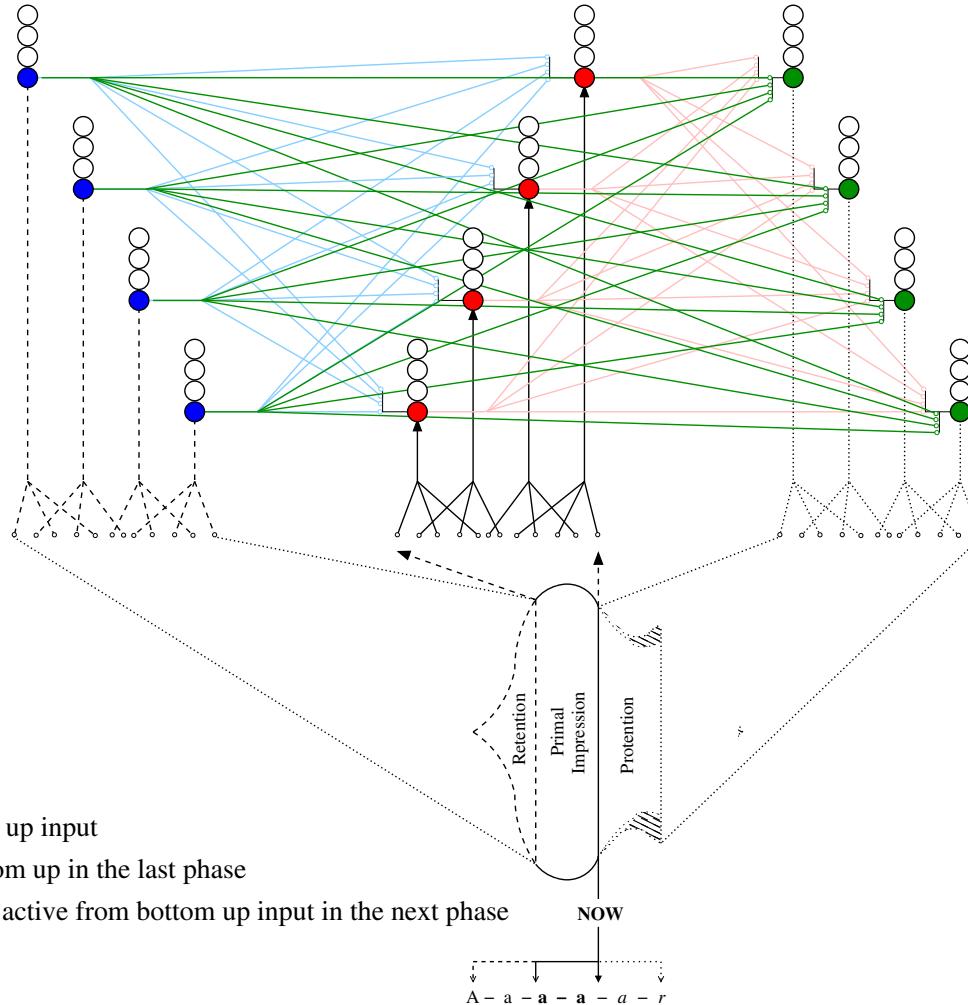
Example HTM Implementation: The Cortical Crow Call

Hebbian Learning



Hebbian Sequence Learning

Green axons connect cells active in the last phase with cells predicting activity in a future phase – thereby extending the sequence one step further back into the past



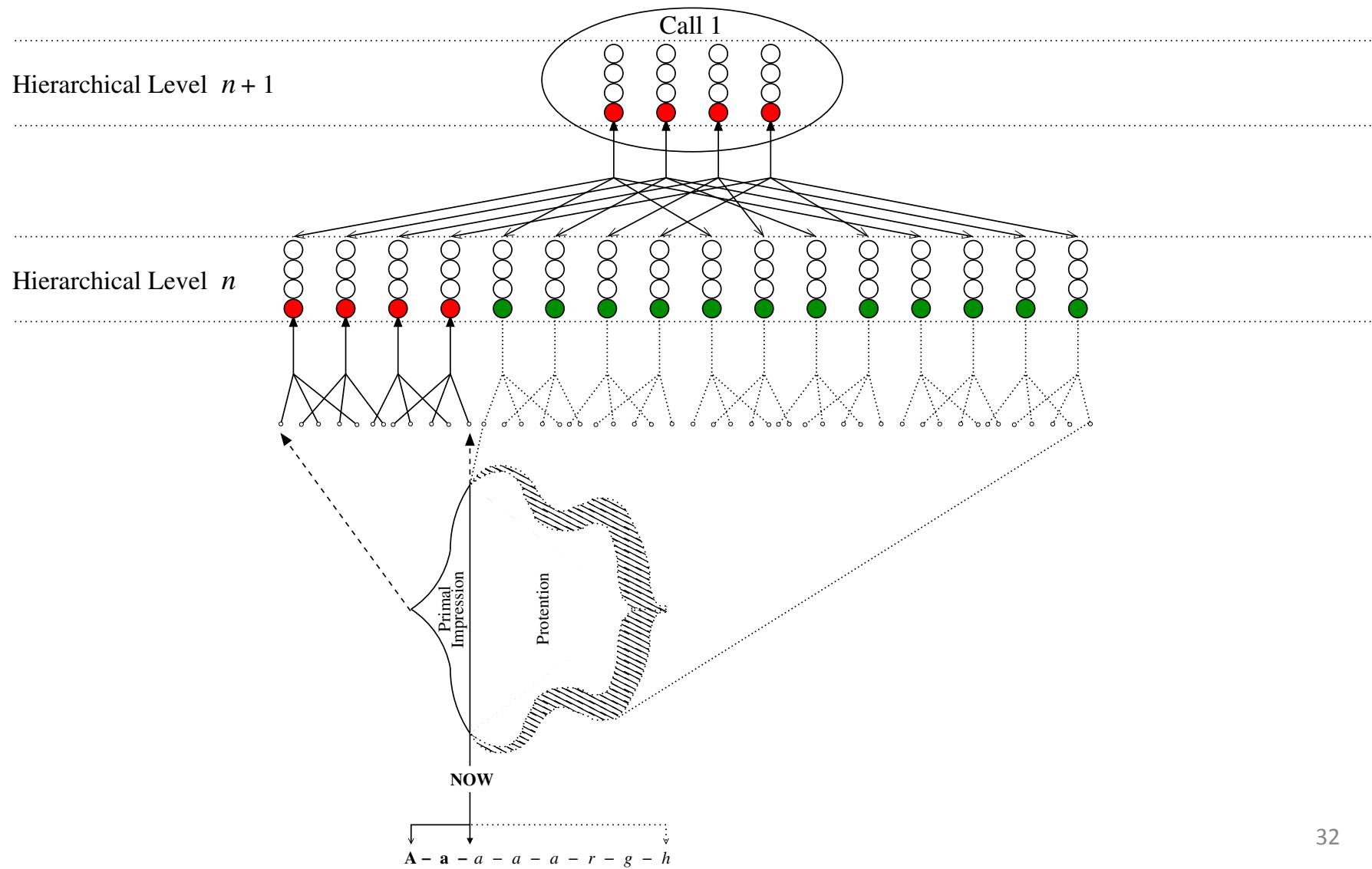
Key:

Red cells are active from bottom up

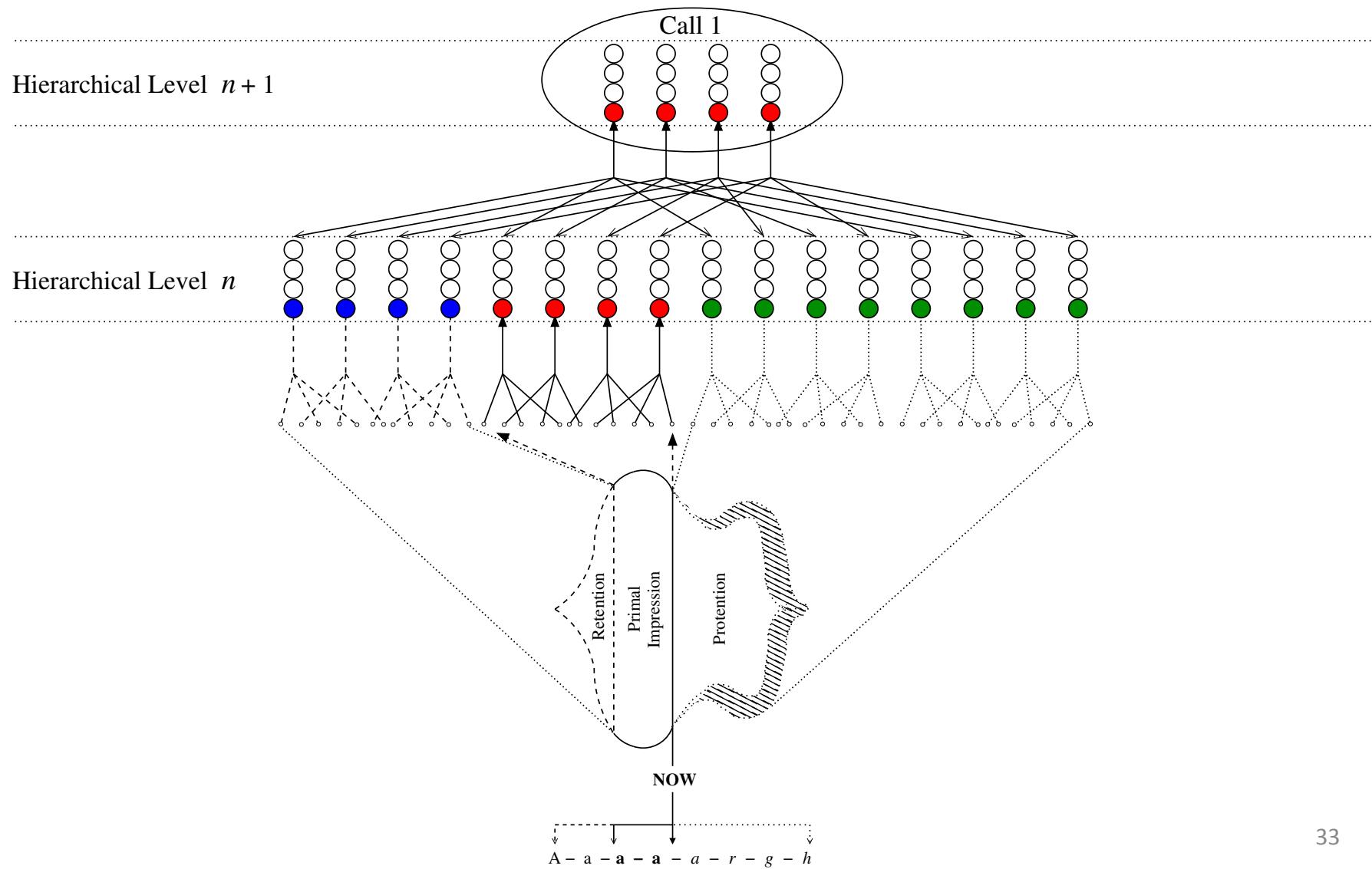
Blue cells were active from bottom up in the last phase

Green cells are predicting being active from bottom up input in the next phase

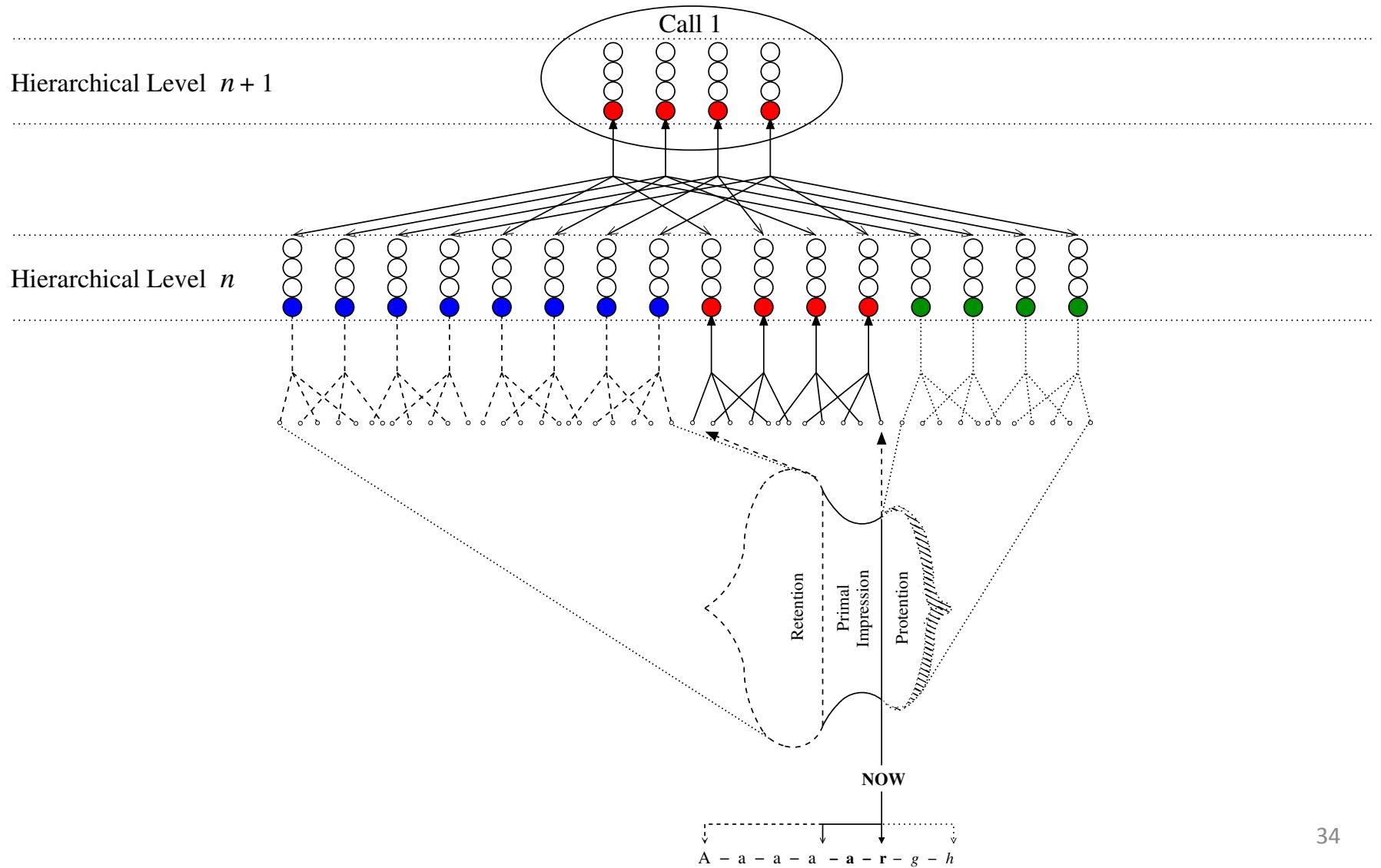
Hierarchical Synthesis



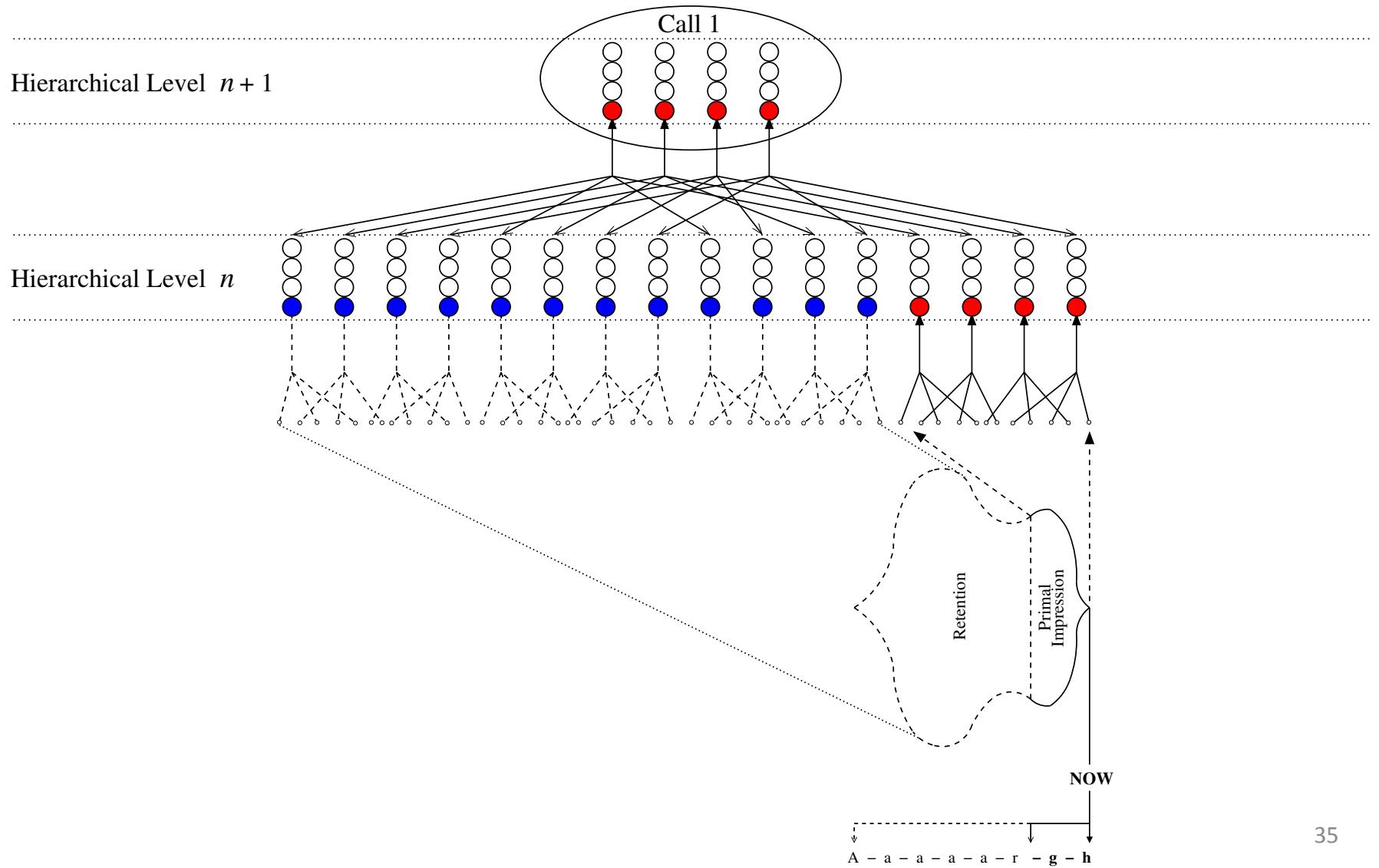
Hierarchical Synthesis



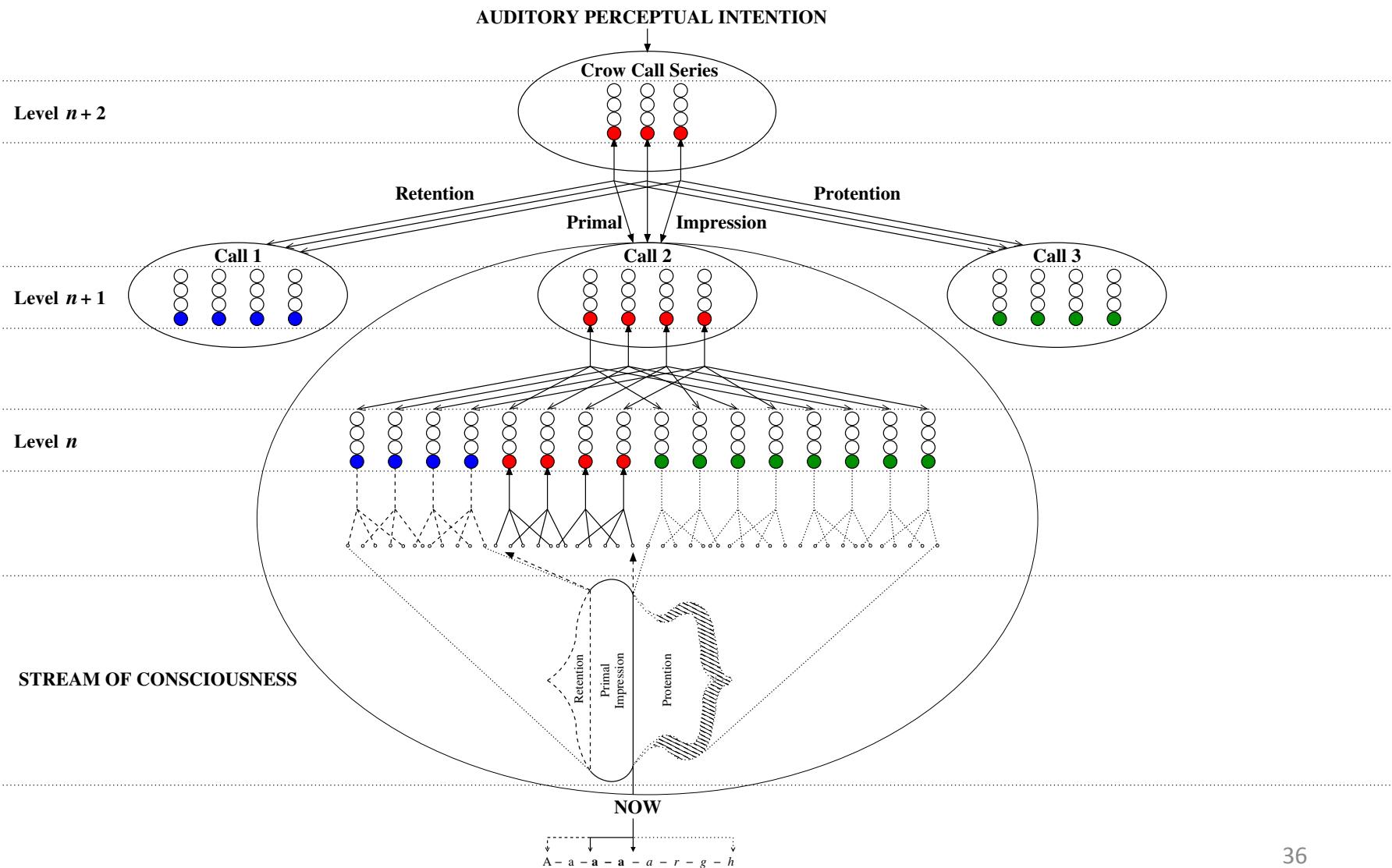
Hierarchical Synthesis



Hierarchical Synthesis



Hierarchical Levels



Mapping to Temporal Structure

- Blue cortical column activity is the intersection of recent feed-forward activity with top-down feedback = retention
- Red cortical column activity is the intersection of current feed-forward activity with top-down feedback = primal impression
- Green cortical column activity is the intersection of lateral excitation with top-down feedback = protention
- In this way, the tripartite Husserlian structure of temporal consciousness can be mapped to the various activity states of the cortical columns that comprise a currently active intention-process
- This mapping occurs at every level of the neocortex – forming a unified hierarchical structure of temporal consciousness

Mapping to Intentionality

- Intentionality corresponds with the entire top-down process that specifies (at each level) the higher level temporally extended form of what is unfolding at the lower level
- Intentionality is **hierarchically temporally structured**:
 - At level n I intend **birdsong**, at $n - 1$ the **crow call series**, at level $n - 2$ **crow call 2**, at level $n - 3$ **phase 2 of crow call 2**
 - For the intentional objects at each level I intend the same structure of retention/primal impression/protention
 - The higher the level, the less the detail, and the greater the temporal scope

Mapping to Perception

- Perceptual experience corresponds with the meeting of top down feedback (intentionality) with bottom up (synthesised) sensory input
- The temporally enduring harmonious fulfillment of the predictions of top down and bottom up processes specifies that these processes correspond with something actual
- This correspondence is a correspondence of forms: it is one and the same crow-call-form expressed in the column activity and in the activity of the air molecules

Summary

- Hierarchical Temporal Memory extends Hierarchical Predictive Coding by proposing that the **basic encoding units** of the neocortex are **temporal sequences** – and not spatial instants ‘strung together’ by neocortical activity to form sequences *over* time
- In this talk we have shown how the HTM model can be mapped onto the basic structures disclosed by Husserl’s phenomenological analysis of temporal consciousness
- Hence we have renamed the model **Hierarchical Temporal Intentionality**
- We take this correspondence of the phenomenology of temporal consciousness with the neuroscience of cortical functioning to be evidence that the **basic principles of neocortical function** are beginning to emerge...