Formal Methods for Interactive Systems

Part 7 — Task Failure and Behavioural Patterns

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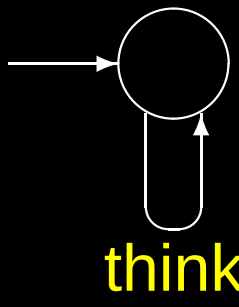
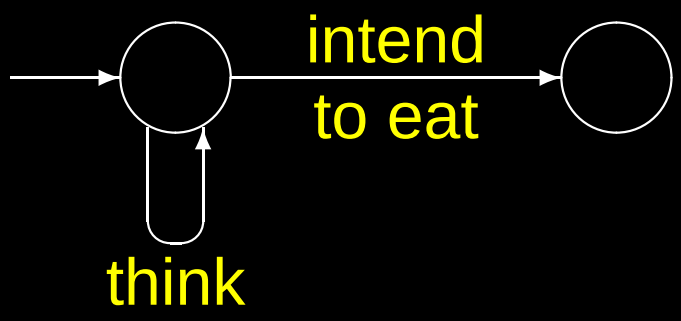
Dining Philosopher

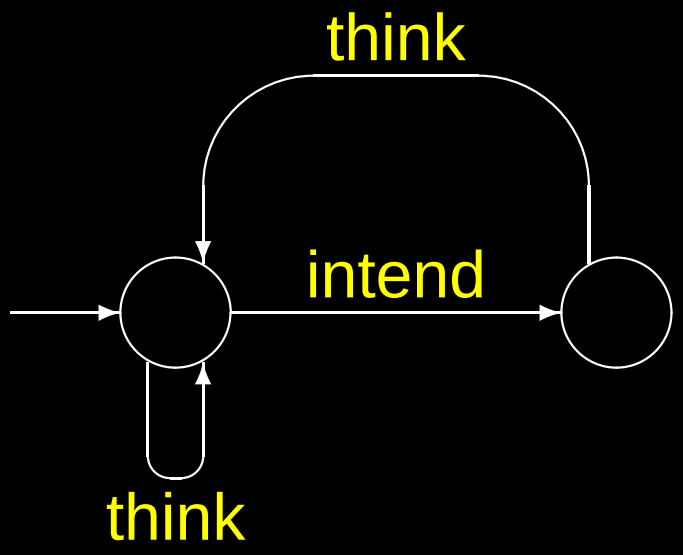
chopstick version



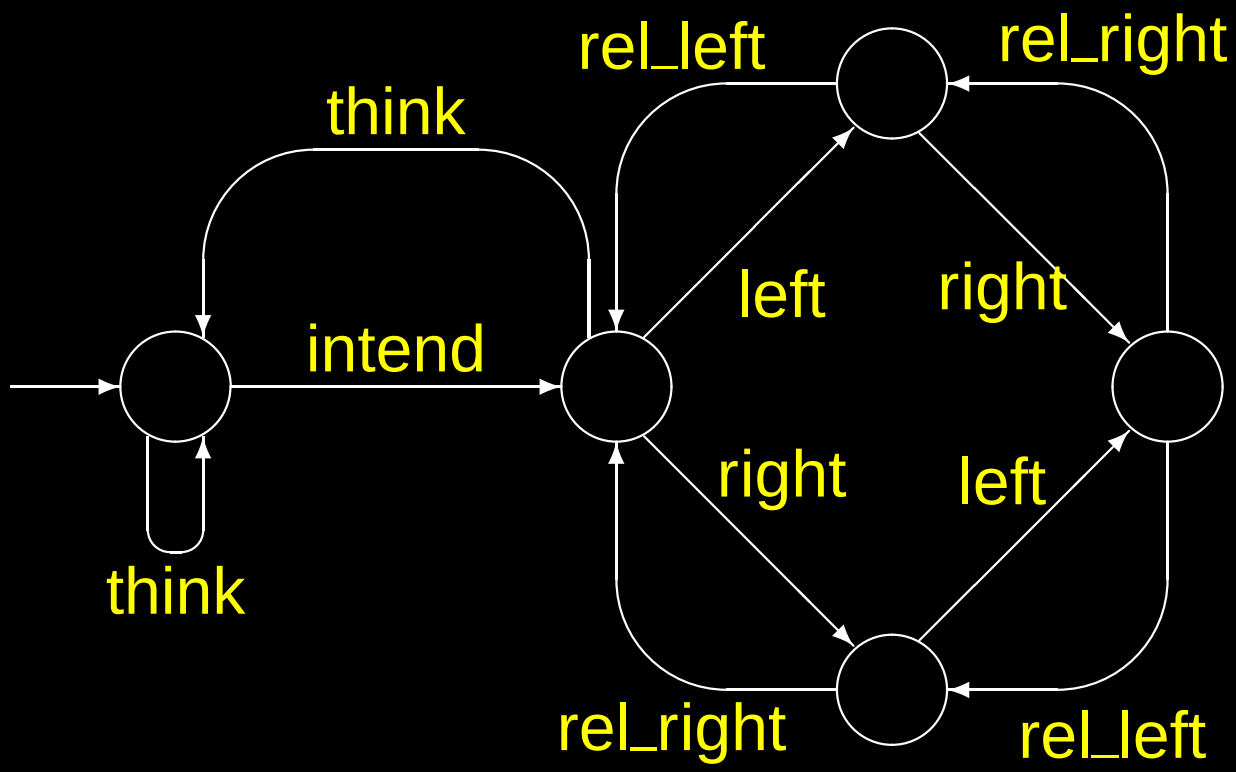
Dining Philosopher



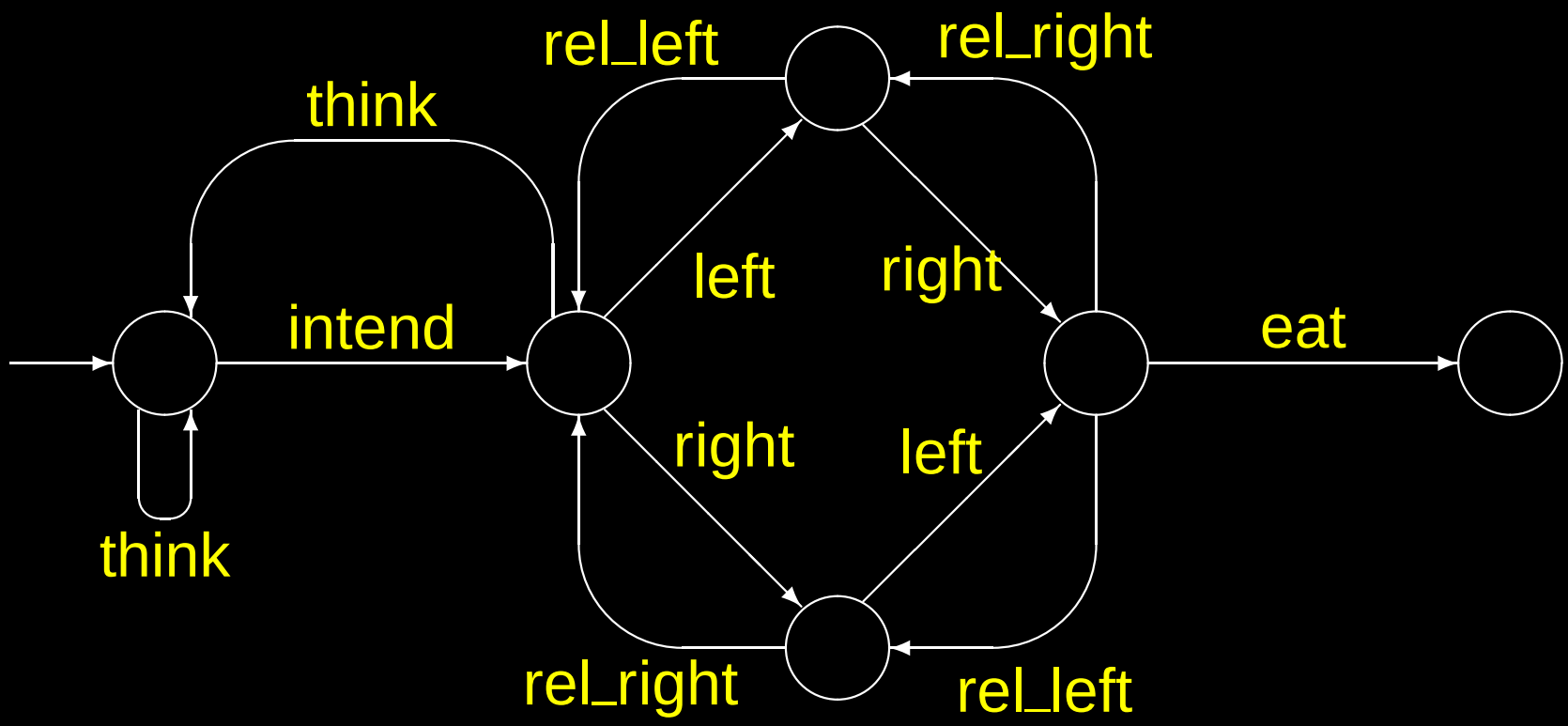
Dining Philosopher



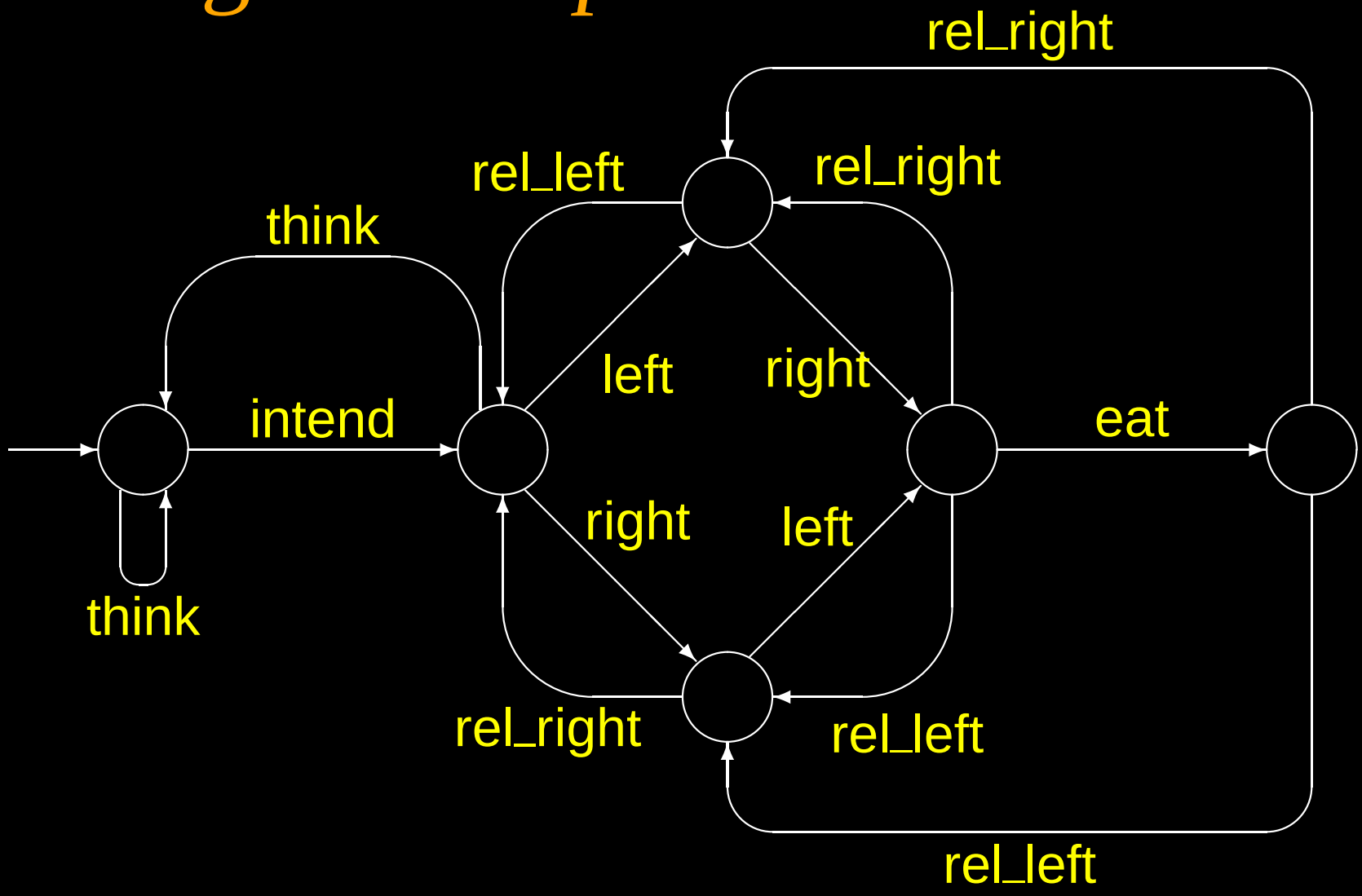
Dining Philosopher



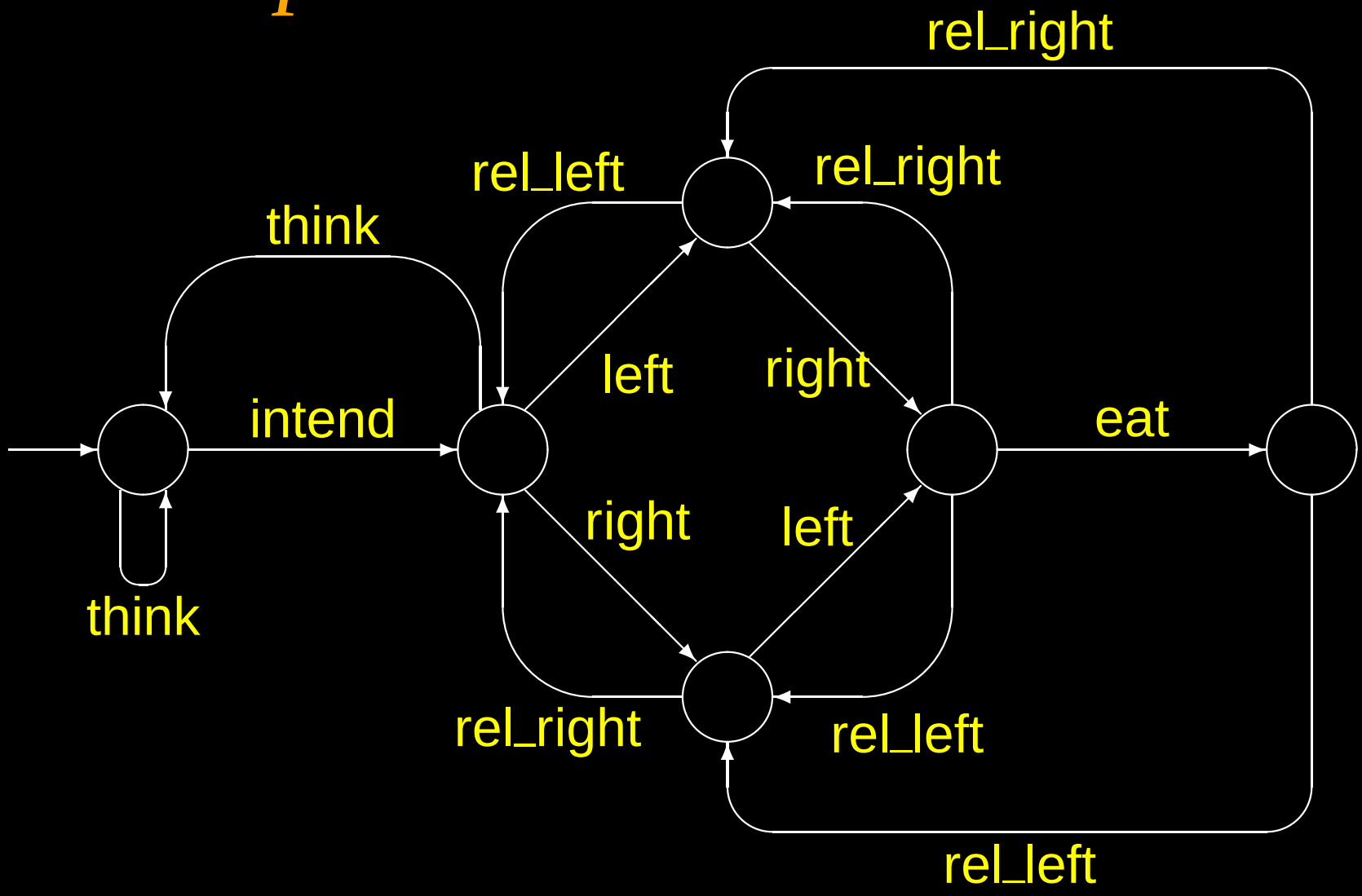
Dining Philosopher



Dining Philosopher



Philosopher's Goal and Task



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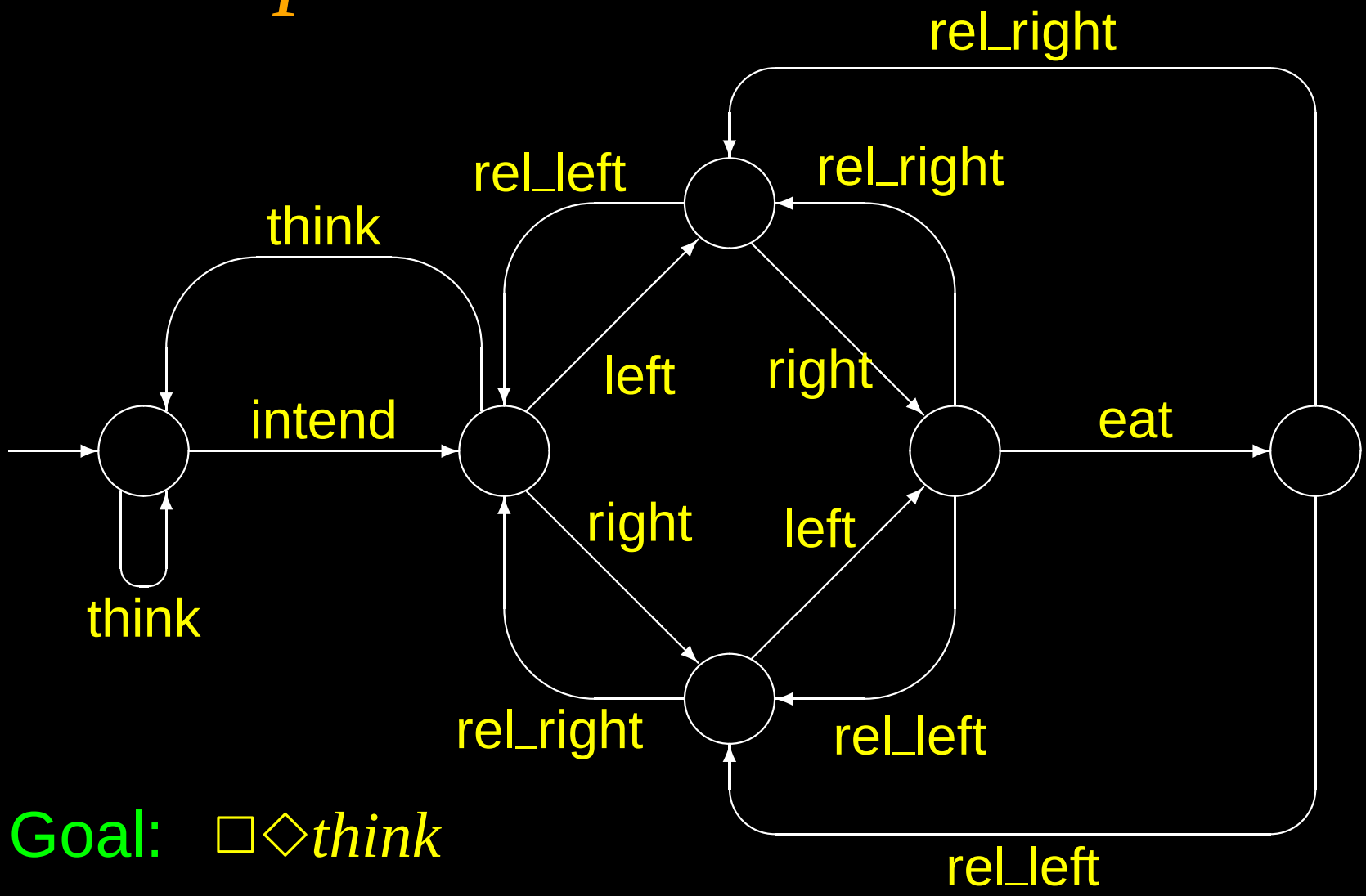
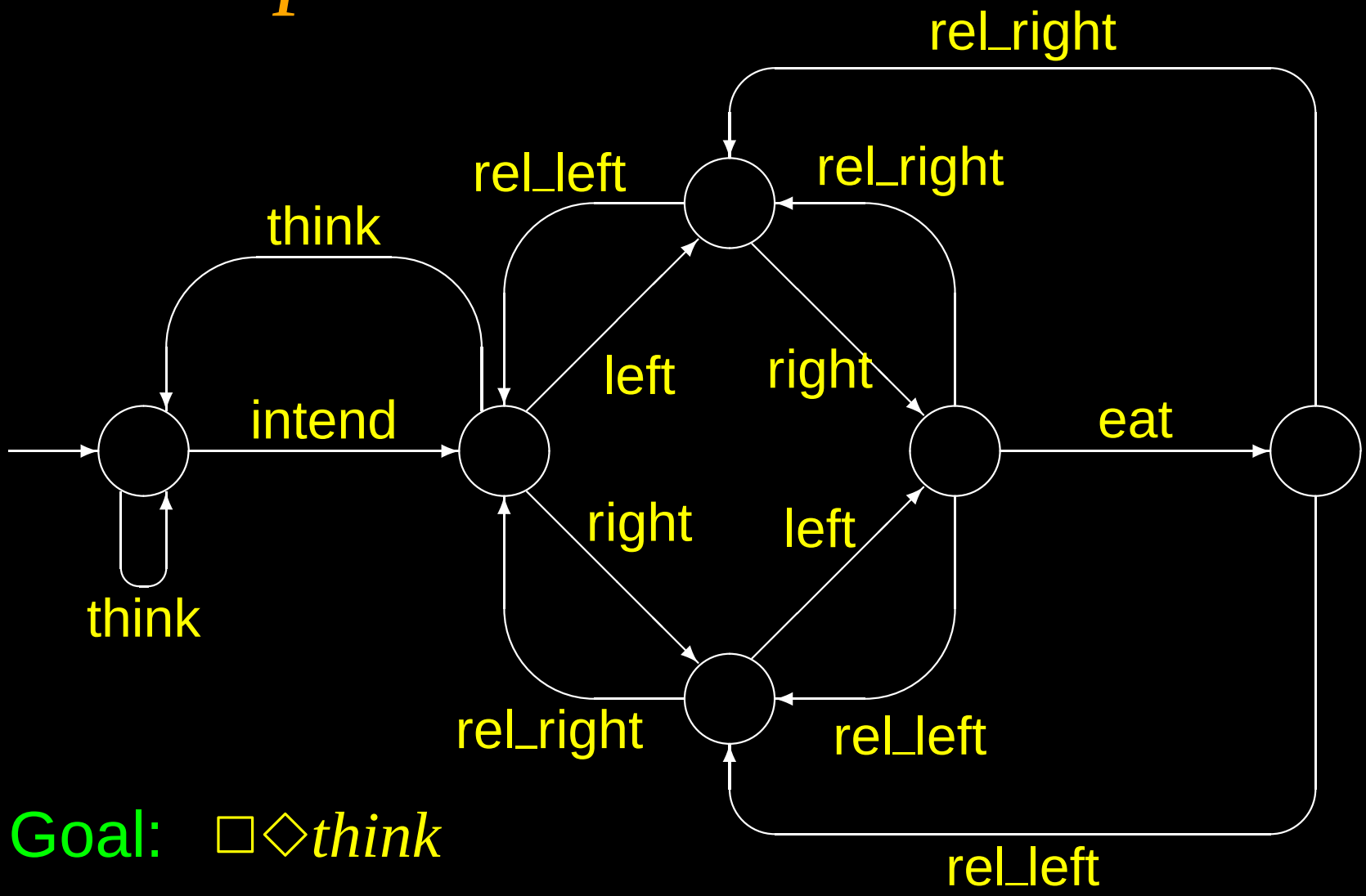


Goal: $\Box\Diamond think$

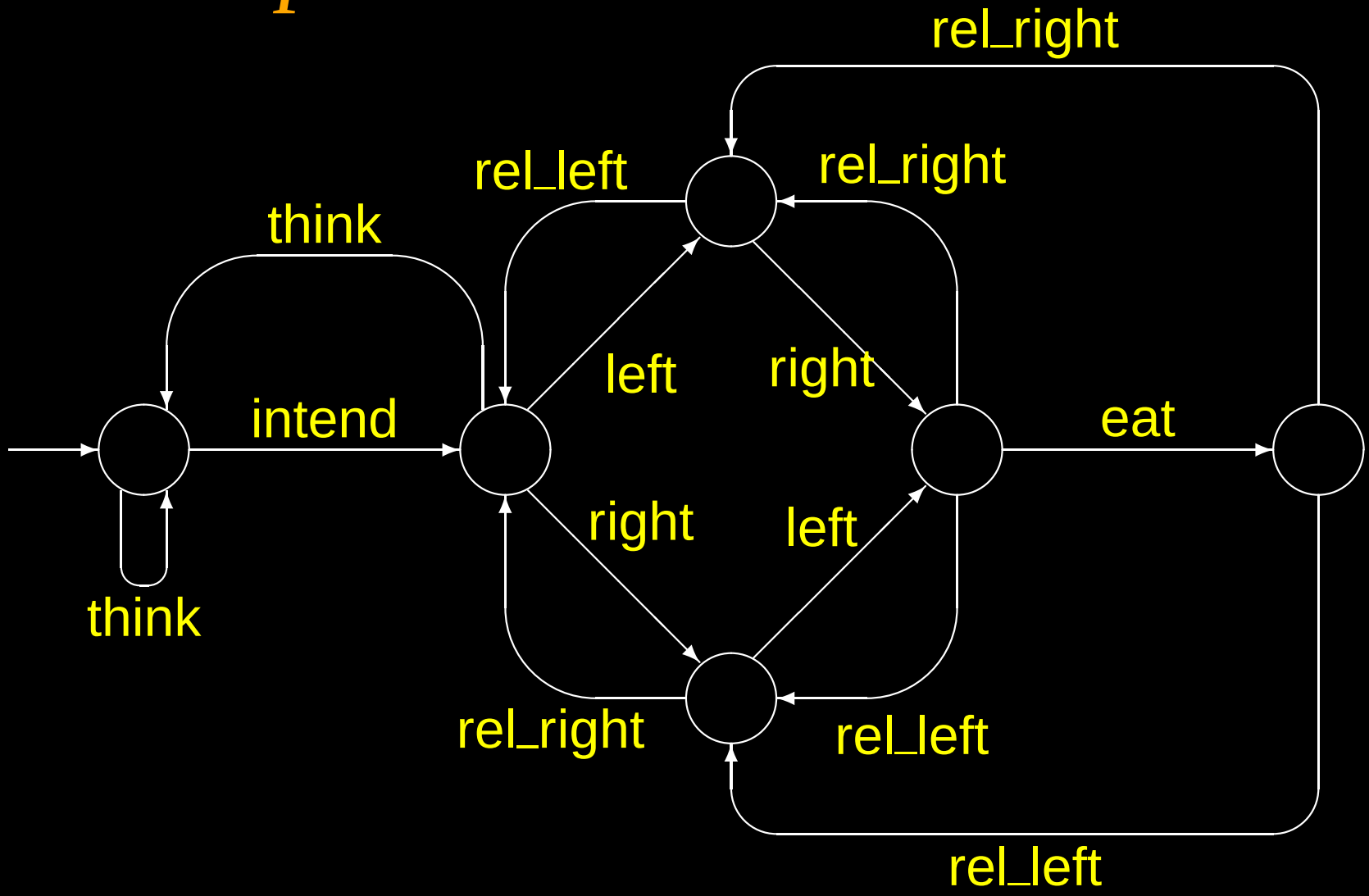
Philosopher's Goal and Task



Goal: $\Box\Diamond think$

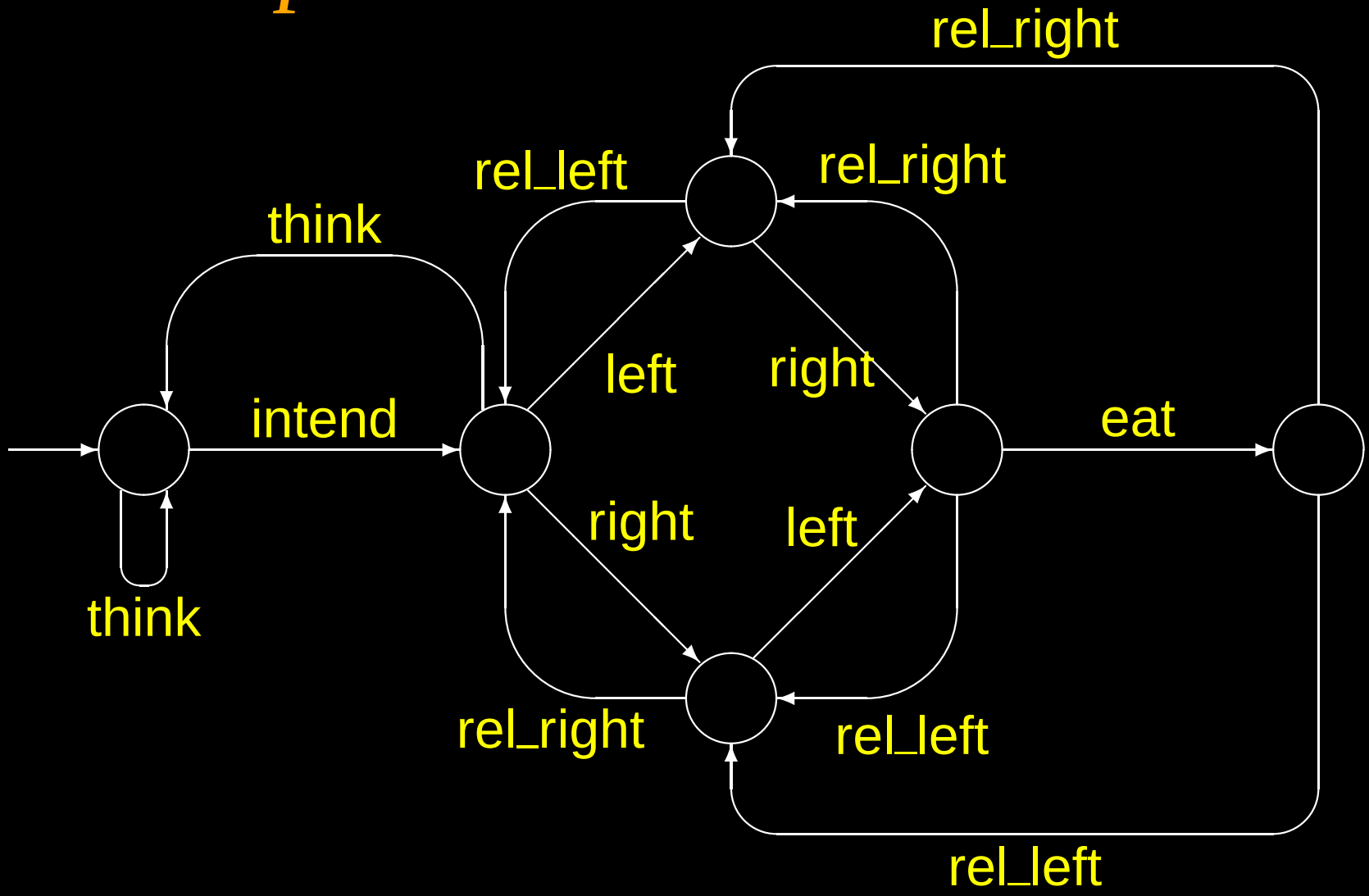
Task: $\Box((\Diamond think) \wedge (\Diamond eat))$

Philosopher's Task Failure



Task: $\Box((\Diamond think) \wedge (\Diamond eat))$

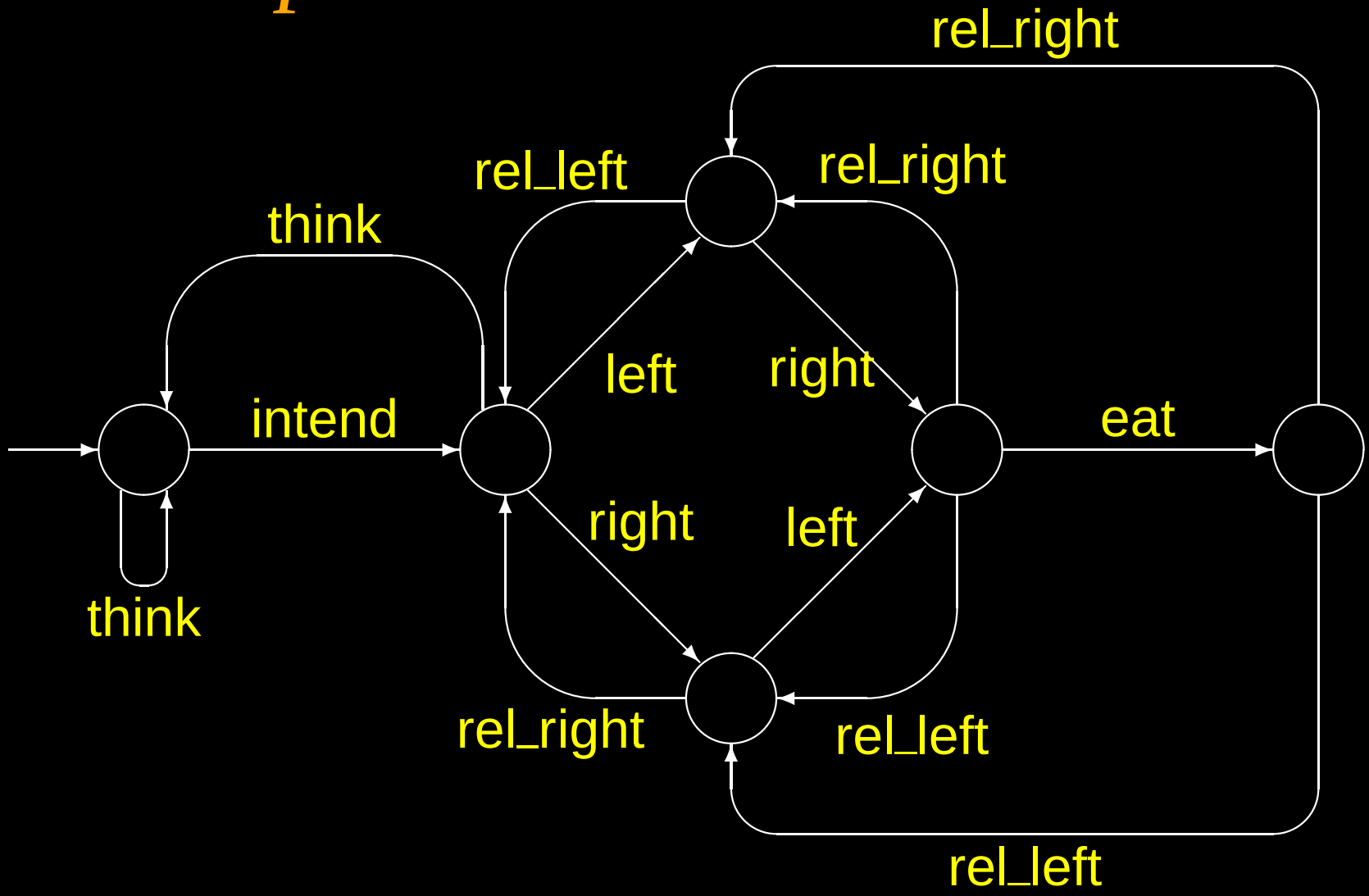
Philosopher's Task Failure



Task: $\Box((\Diamond think) \wedge (\Diamond eat))$

Task Failure: $\neg \Box((\Diamond think) \wedge (\Diamond eat))$

Philosopher's Task Failure



Task: $\Box((\Diamond think) \wedge (\Diamond eat))$

Task Failure: $\Diamond((\Box\neg think) \wedge (\Box\neg eat))$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$

$(\Diamond think) \wedge (\Box\neg\, eat)$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

$(\Diamond intend) \wedge \Box(\neg\, left \wedge \neg\, right)$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

$(\Diamond intend) \wedge \Box(\neg\, left \wedge \neg\, right)$

distracted by thoughts

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

$(\Diamond intend) \wedge \Box(\neg\, left \wedge \neg\, right)$

distracted by thoughts

$(\Diamond((left \wedge \bigcirc right) \vee (right \wedge \bigcirc left))) \wedge \Box\neg\, eat$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

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cannot use chopstics

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

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distracted by thoughts

$(\Diamond((left \wedge \bigcirc right) \vee (right \wedge \bigcirc left))) \wedge \Box\neg\, eat$

cannot use chopstics

$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg\, left \vee \neg\, right)$

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

$(\Diamond intend) \wedge \Box(\neg\, left \wedge \neg\, right)$
distracted by thoughts

$(\Diamond((left \wedge \bigcirc right) \vee (right \wedge \bigcirc left))) \wedge \Box\neg\, eat$
cannot use chopstics

$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg\, left \vee \neg\, right)$
unable to get two chopstics

Philosopher's Behaviour

leading to task failure $(\Box\neg\, think) \wedge (\Box\neg\, eat)$

$(\Box\neg\, think) \wedge (\Diamond eat)$ not a philosopher

$(\Diamond think) \wedge (\Box\neg\, eat)$ further decomposed

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$(\Diamond((left \wedge \bigcirc right) \vee (right \wedge \bigcirc left))) \wedge \Box\neg\, eat$
cannot use chopstics

$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg\, left \vee \neg\, right)$
unable to get two chopstics
further decomposed

Philosopher's Behaviour

$$((\Diamond \mathit{left}) \vee (\Diamond \mathit{right})) \wedge \Box(\neg \mathit{left} \vee \neg \mathit{right})$$

unable to get two chopstics

further decomposed

Philosopher's Behaviour

$$((\Diamond \mathit{left}) \vee (\Diamond \mathit{right})) \wedge \Box(\neg \mathit{left} \vee \neg \mathit{right})$$

unable to get two chopstics

further decomposed

$$(\Diamond \mathit{left}) \wedge \Box \neg \mathit{right}$$

Philosopher's Behaviour

$$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg\, left \vee \neg\, right)$$

unable to get two chopstics

further decomposed

$$(\Diamond left) \wedge \Box \neg\, right$$

physical problem

Philosopher's Behaviour

$$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg\, left \vee \neg\, right)$$

unable to get two chopstics

further decomposed

$$(\Diamond left) \wedge \Box\neg\, right$$

physical problem

$$(\Diamond right) \wedge \Box\neg\, left$$

physical problem

Philosopher's Behaviour

$$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg left \vee \neg right)$$

unable to get two chopstics

further decomposed

$$(\Diamond left) \wedge \Box \neg right$$

physical problem

$$(\Diamond right) \wedge \Box \neg left$$

physical problem

$$(\Diamond left) \wedge (\Diamond right) \wedge \Box(\neg left \vee \neg right)$$

Philosopher's Behaviour

$((\Diamond left) \vee (\Diamond right)) \wedge \Box(\neg left \vee \neg right)$

unable to get two chopstics

further decomposed

$(\Diamond left) \wedge \Box \neg right$

physical problem

$(\Diamond right) \wedge \Box \neg left$

physical problem

$(\Diamond left) \wedge (\Diamond right) \wedge \Box(\neg left \vee \neg right)$

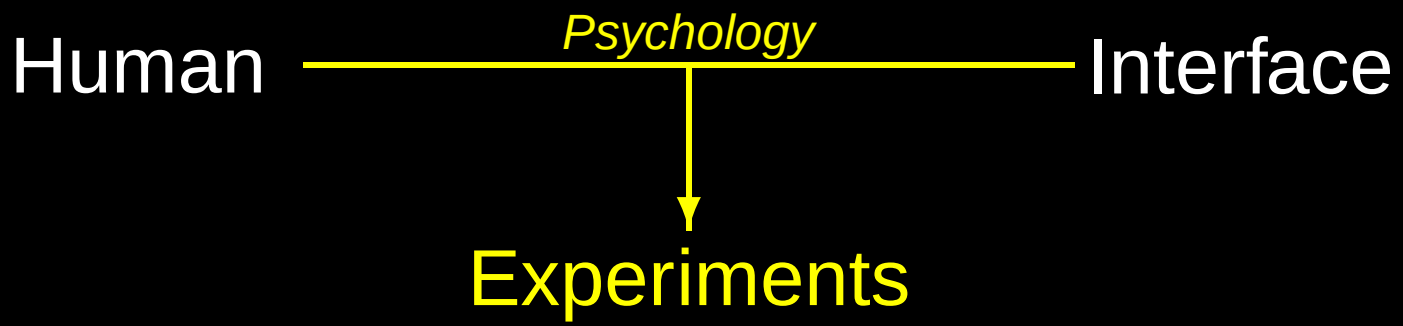
does not understand

Big Picture

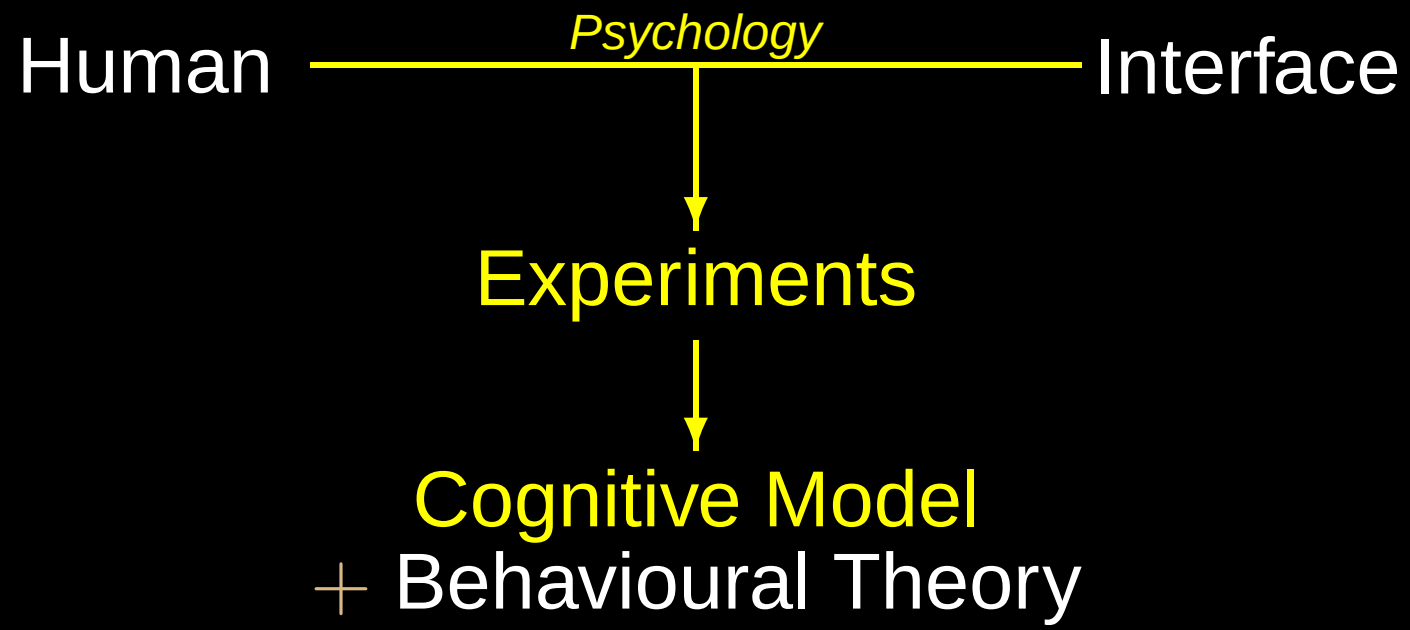
Human

Interface

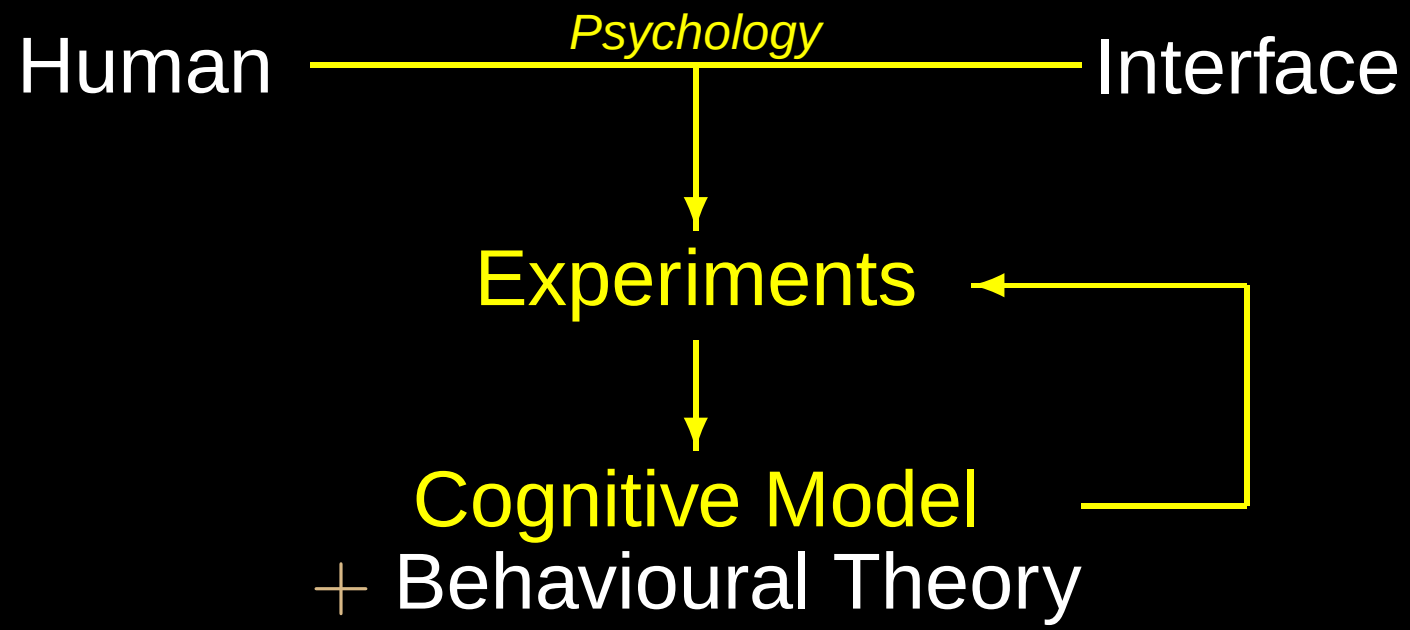
Big Picture



Big Picture


Human
Psychology
Interface
Experiments
Cognitive Model
+ Behavioural Theory

Big Picture


Human
Psychology
Interface
Experiments
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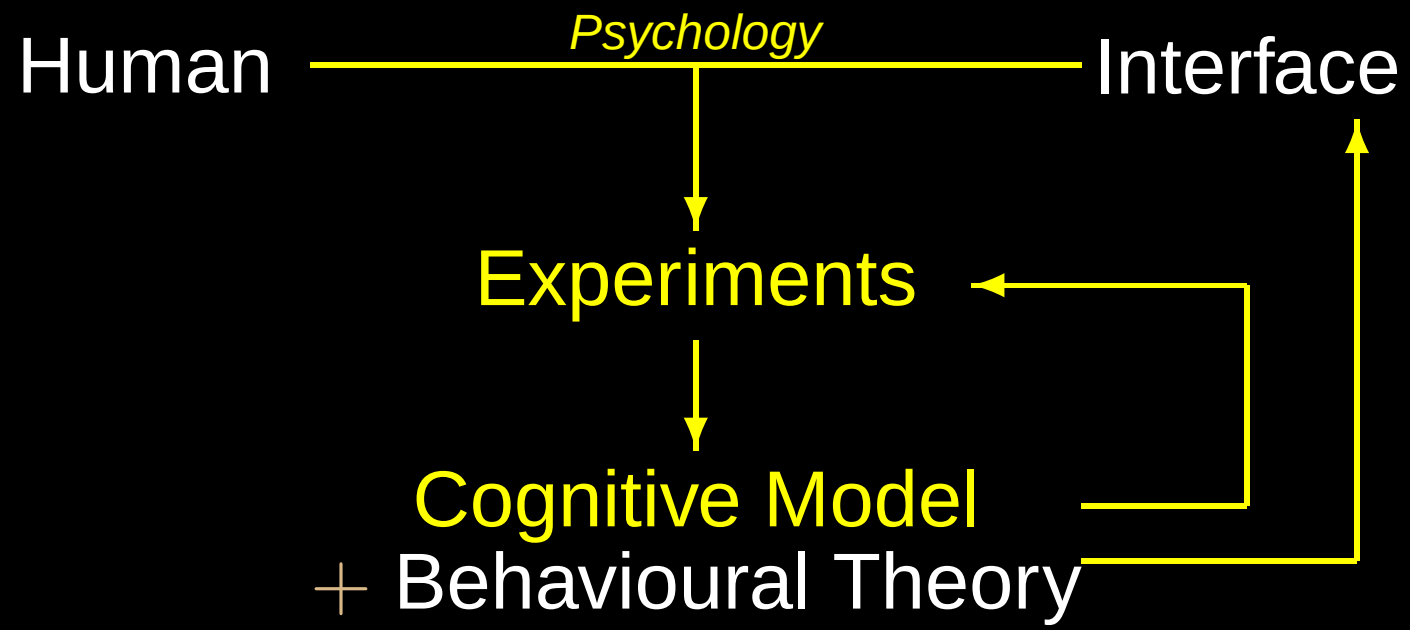
+ Behavioural Theory

Big Picture


Human
Psychology
Interface
Experiments
Cognitive Model
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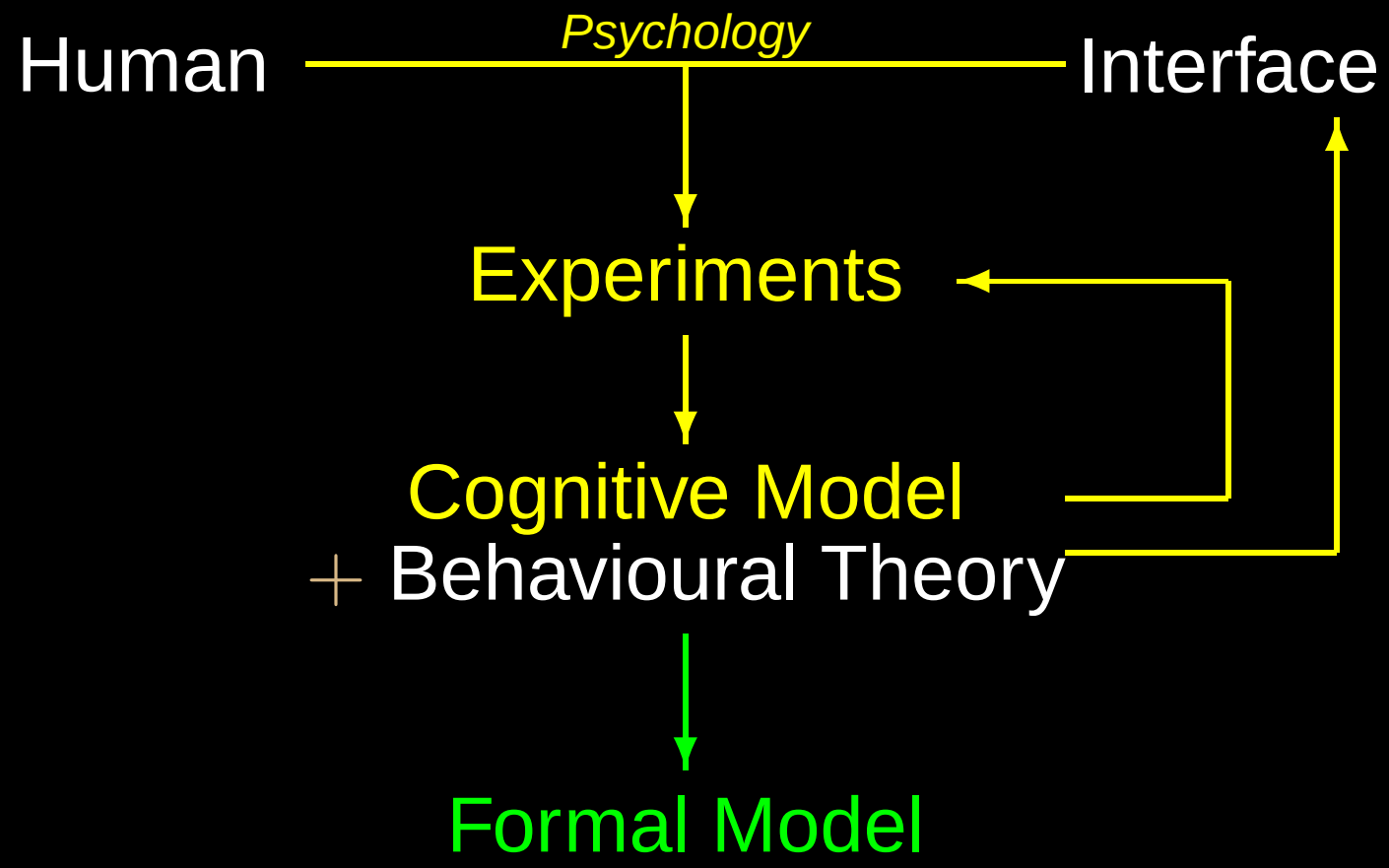
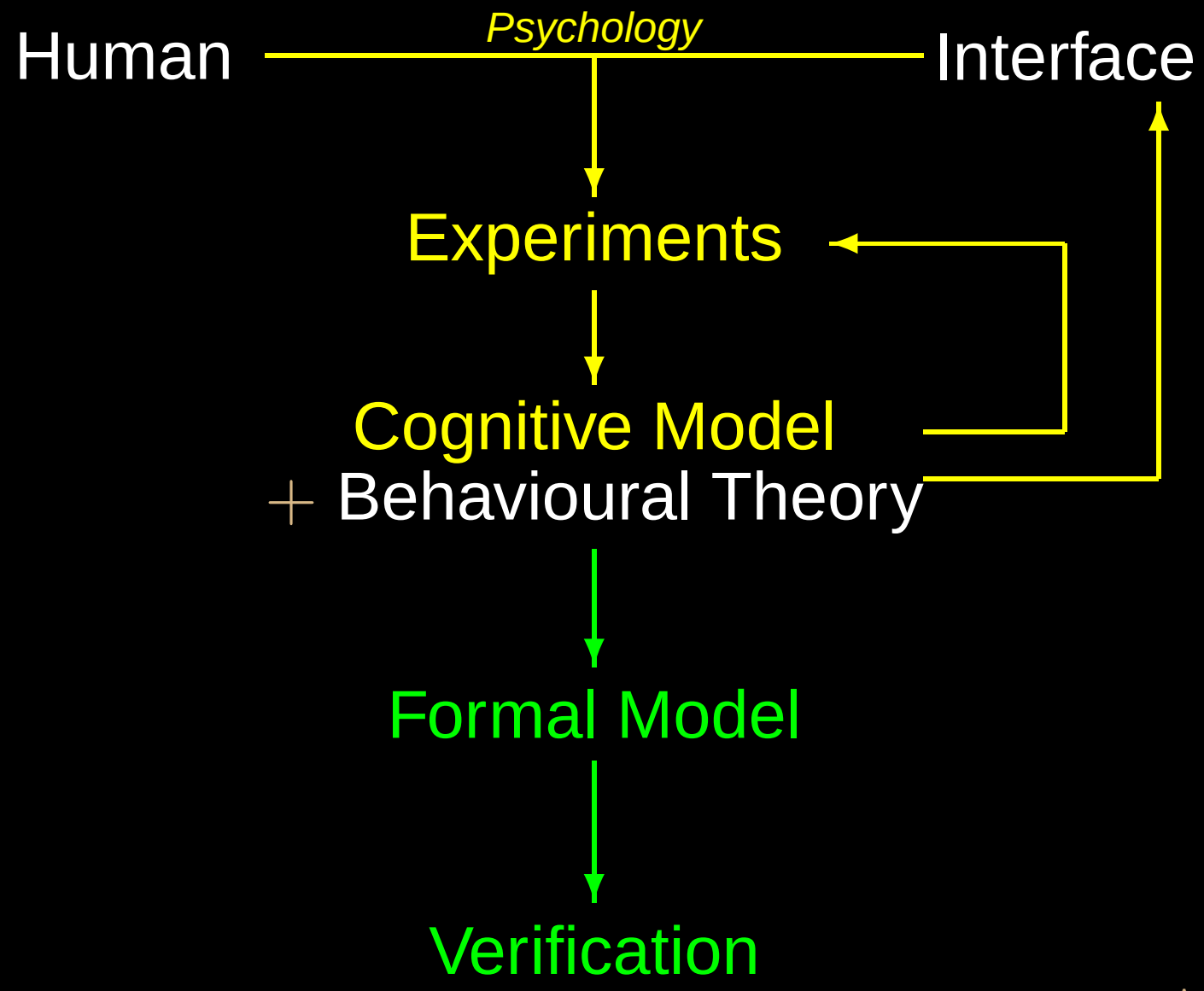
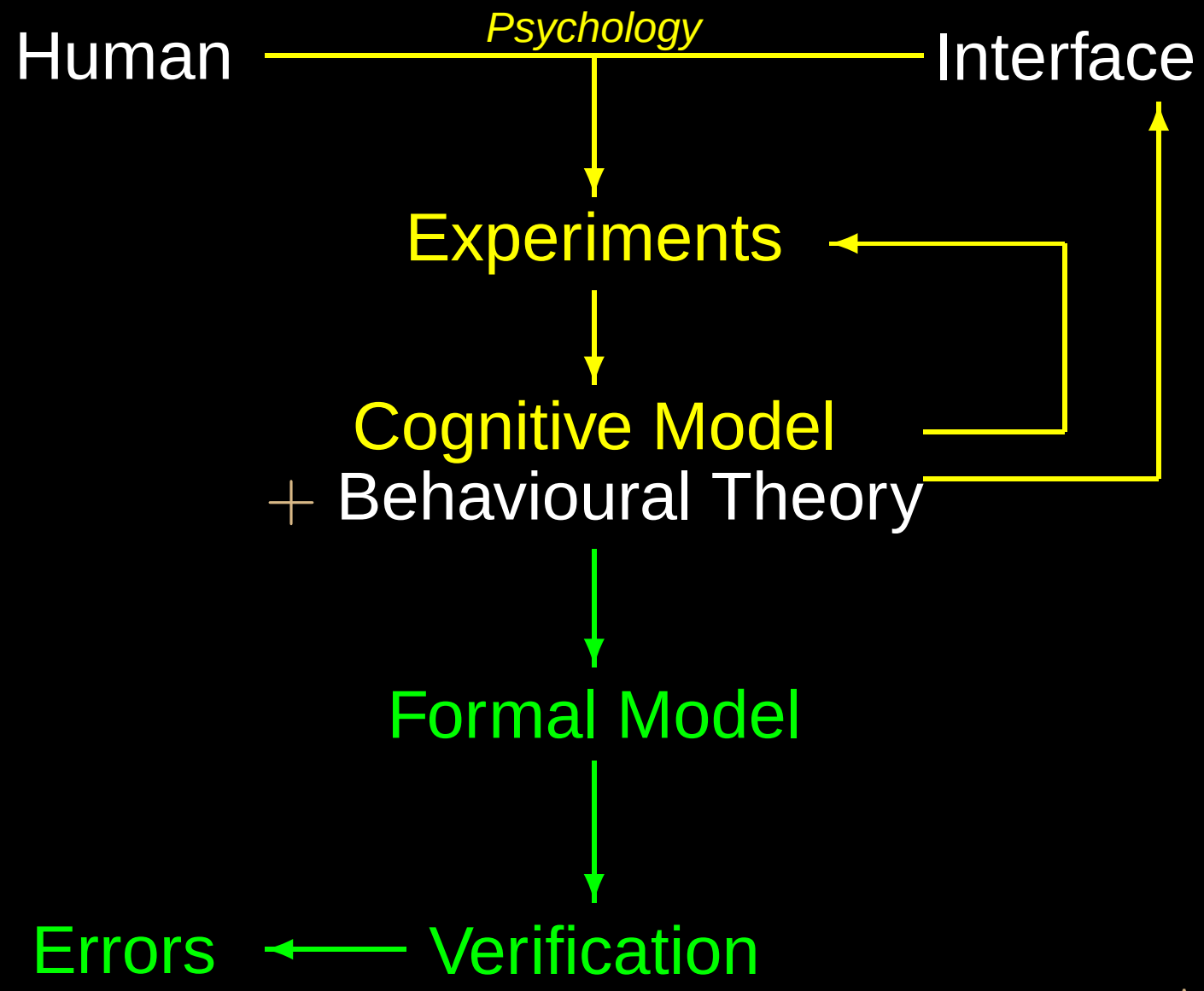
Big Picture


Human
Psychology
Interface
Experiments
Cognitive Model
+ Behavioural Theory
Formal Model

Big Picture


Human
Psychology
Interface
Experiments
Cognitive Model
+ Behavioural Theory
Formal Model
Verification

Big Picture


Human
Psychology
Interface
Experiments
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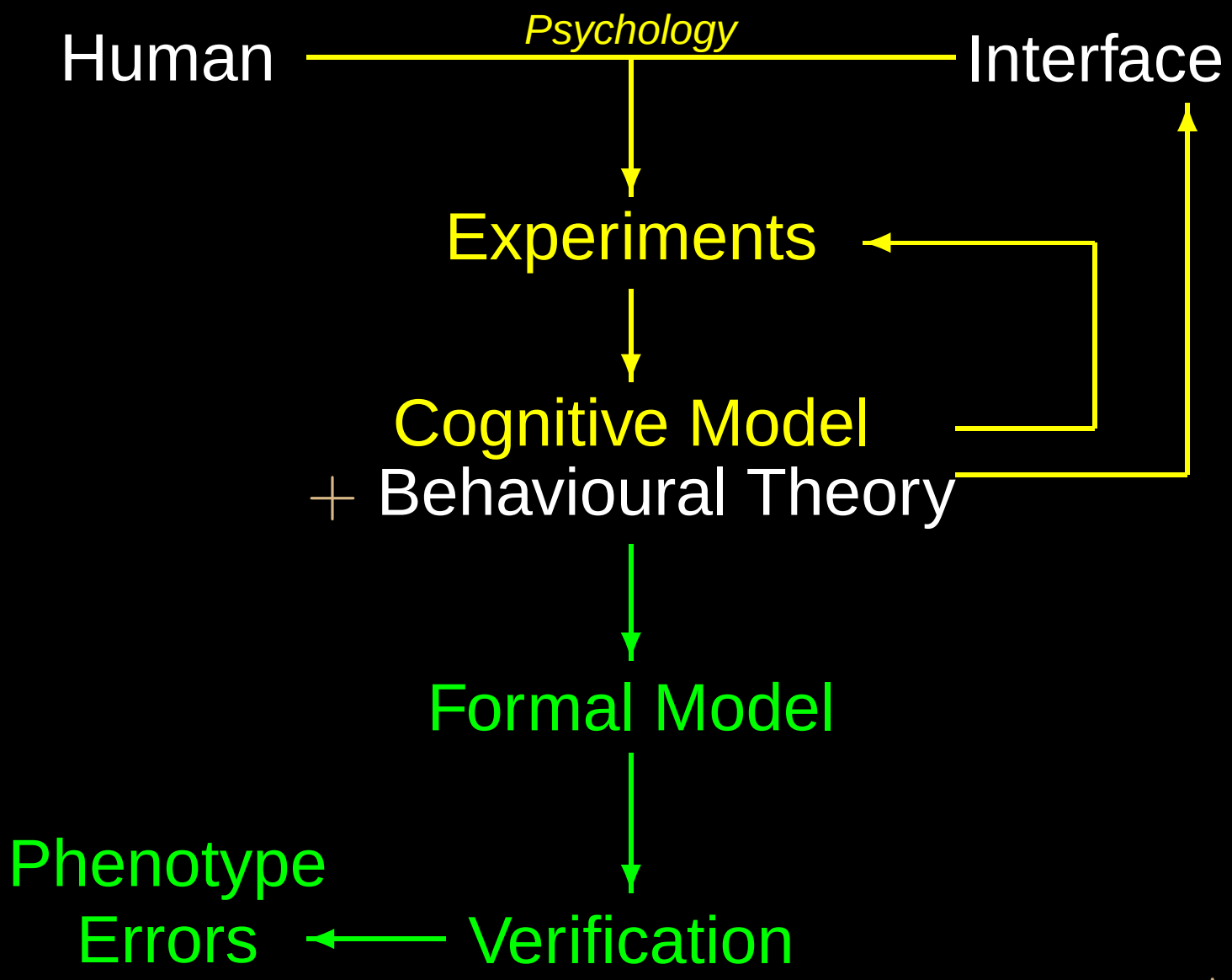
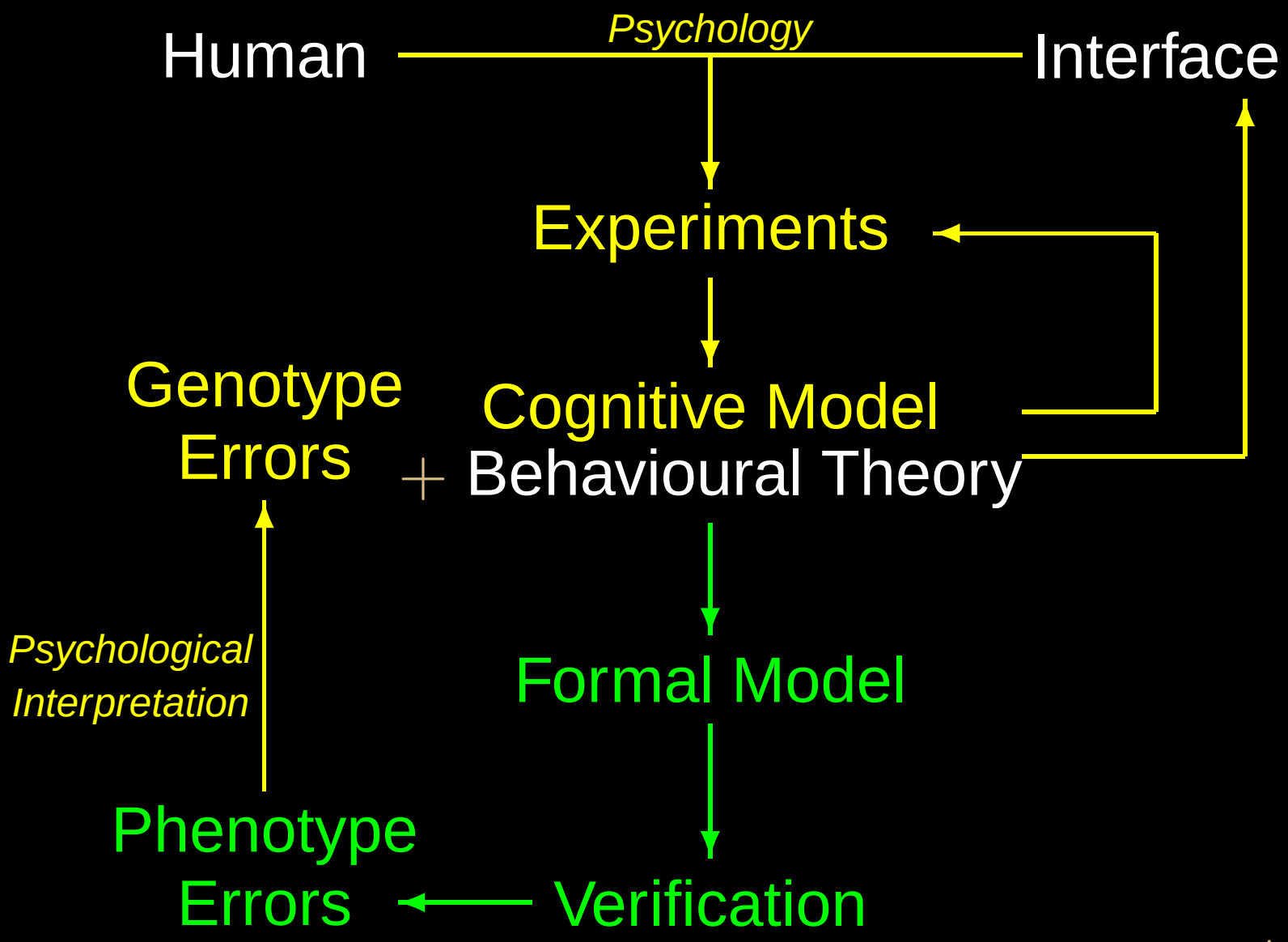
Formal Model
Errors
Verification

Big Picture


Human
Psychology
Interface
Experiments
Cognitive Model
+ Behavioural Theory
Formal Model
Phenotype
Errors
Verification

Big Picture


Human
Psychology
Interface
Experiments
Genotype
Errors
Cognitive Model
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Psychological
Interpretation
Formal Model
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Errors
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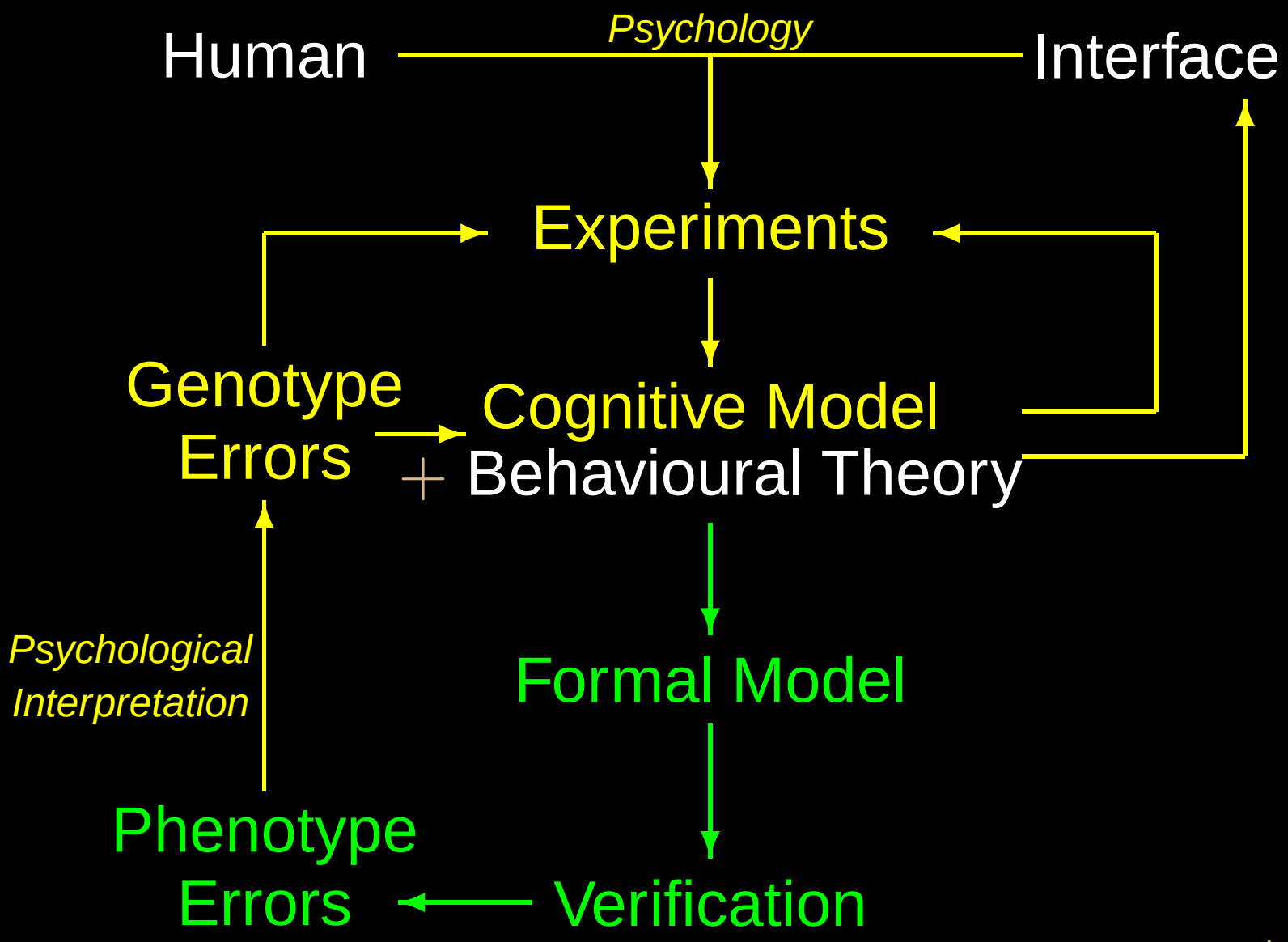
Human
Psychology
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History of Model-checking

- 1980s: Model-checking

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  - *[Emerson and Clarke]*

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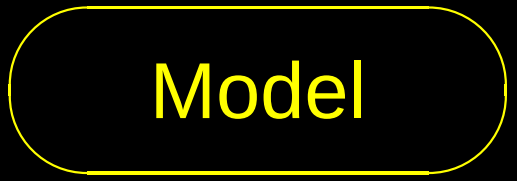
  - Software Verification

Model-checking

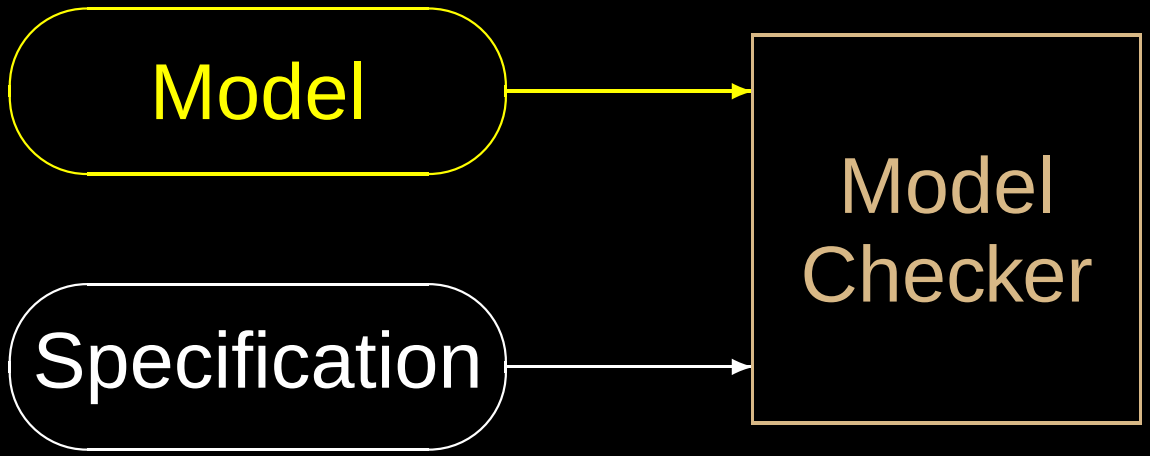


Model-checking

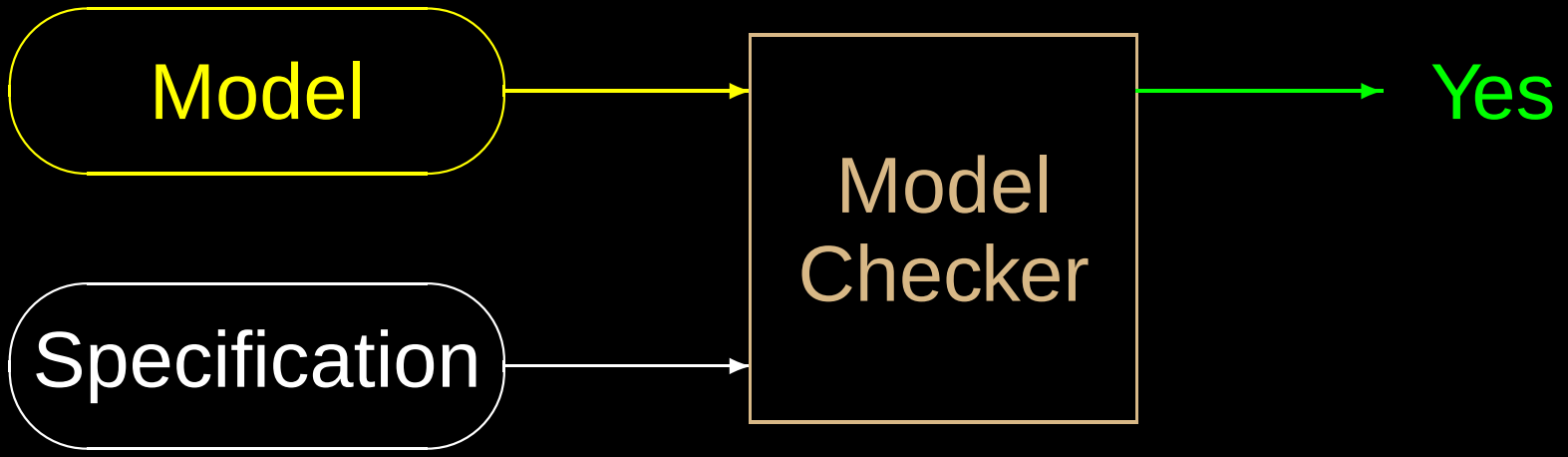
Model

Specification

Model-checking



Model-checking



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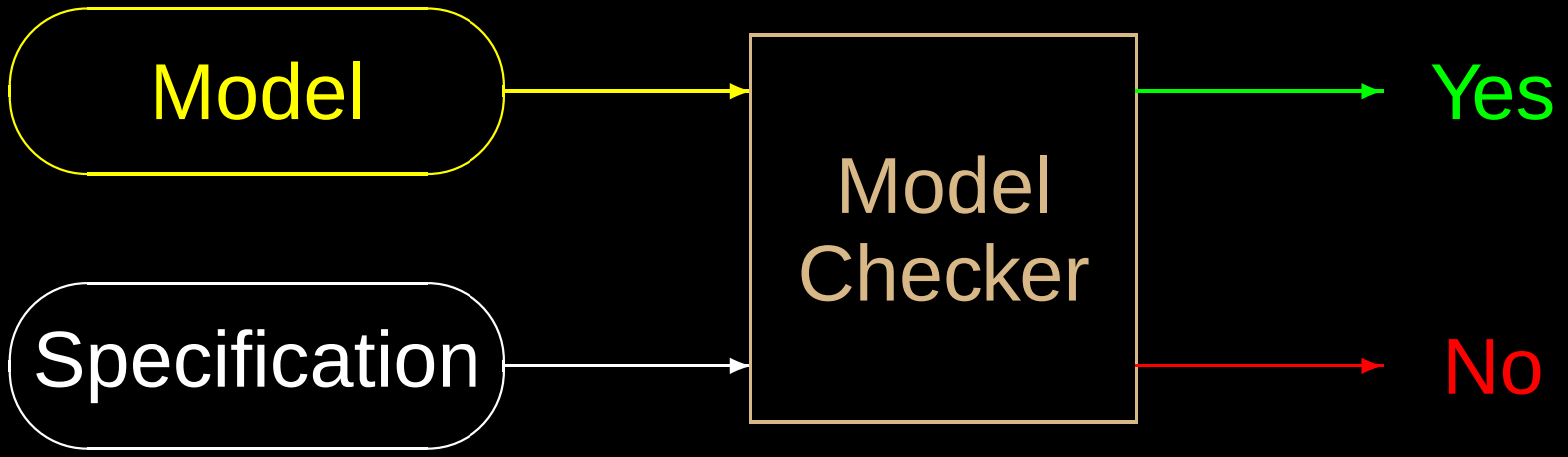
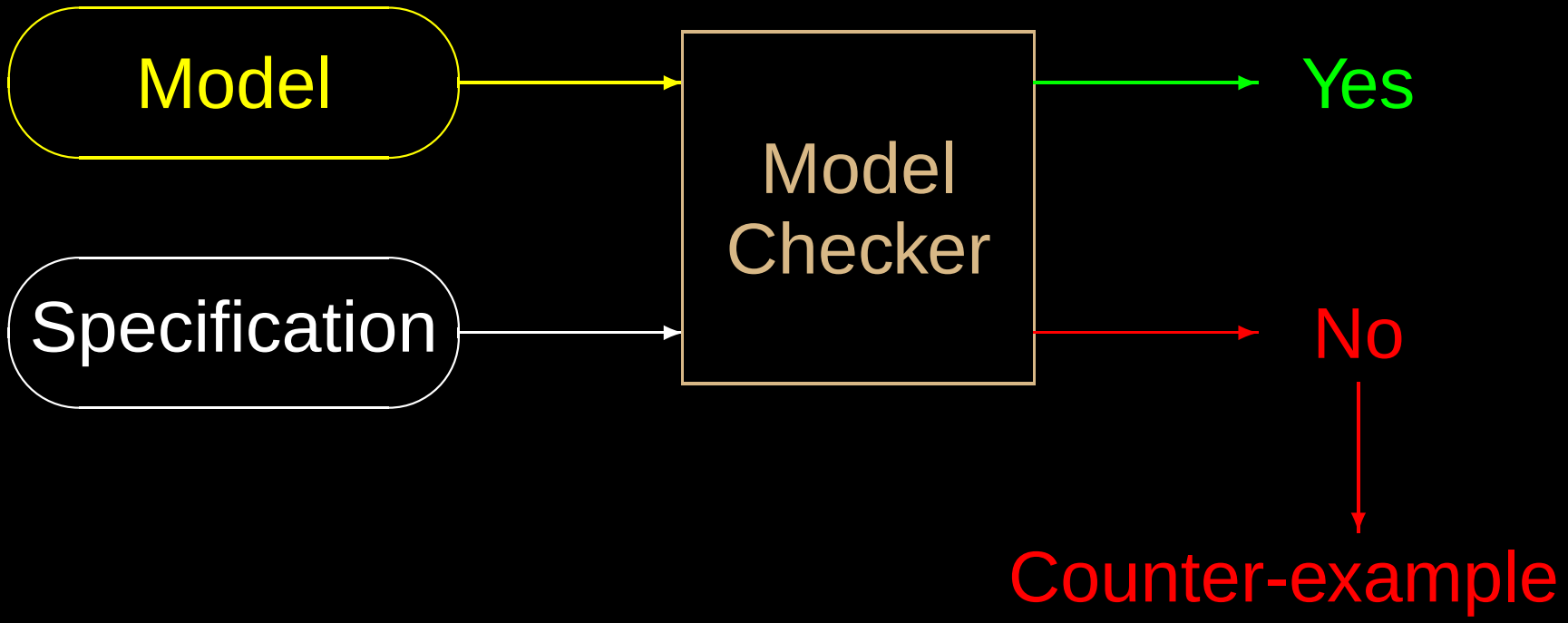
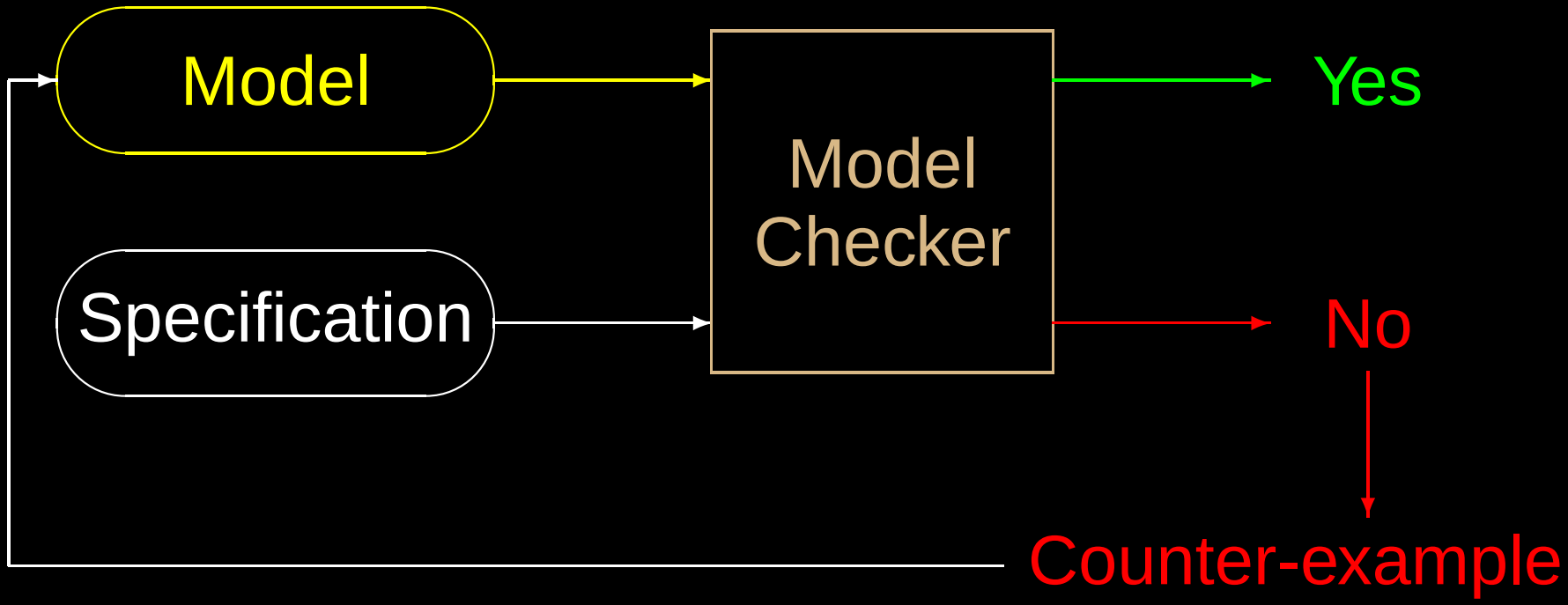


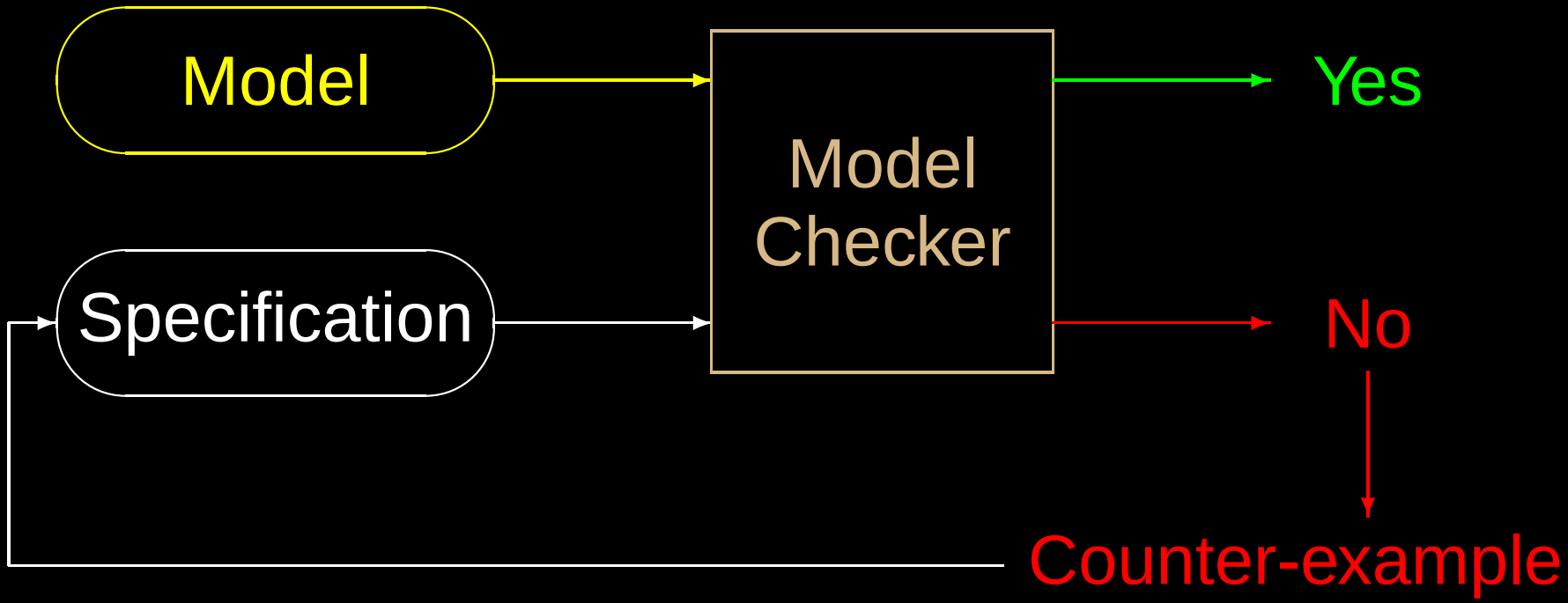
Model-checking



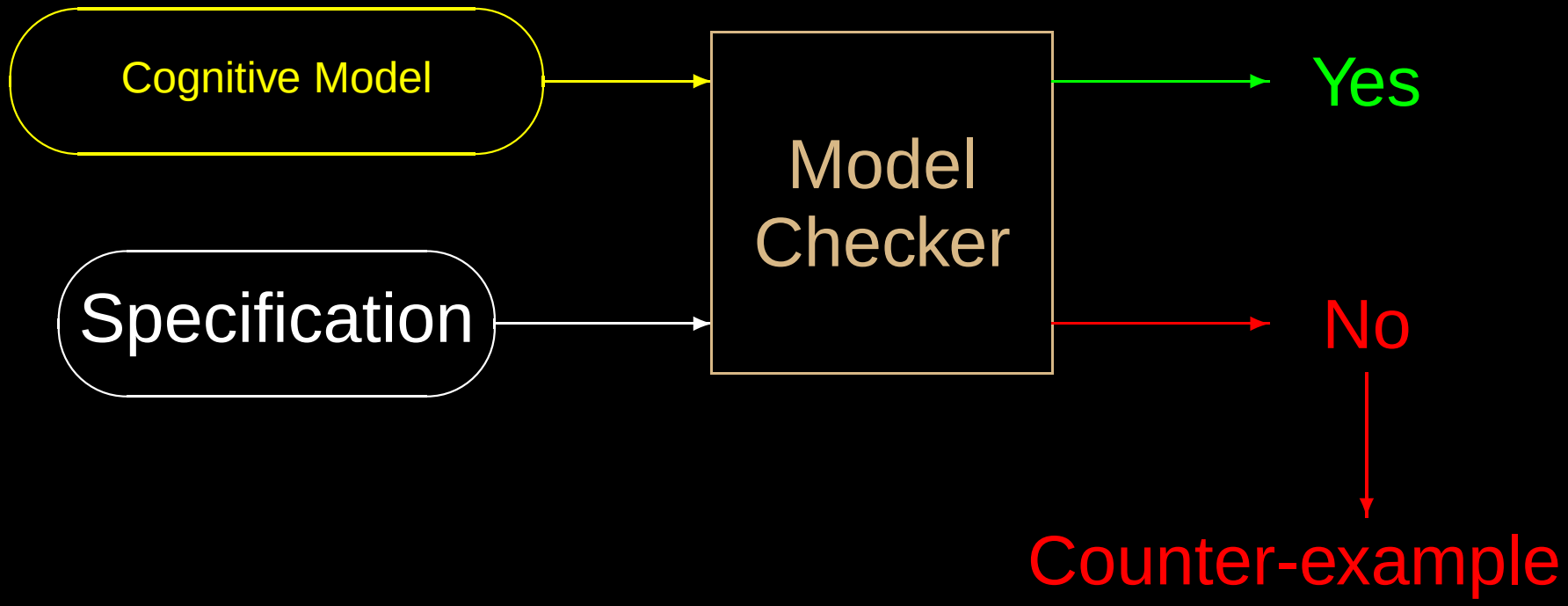
Model-checking



Model-checking



MC and Cognitive Psychology



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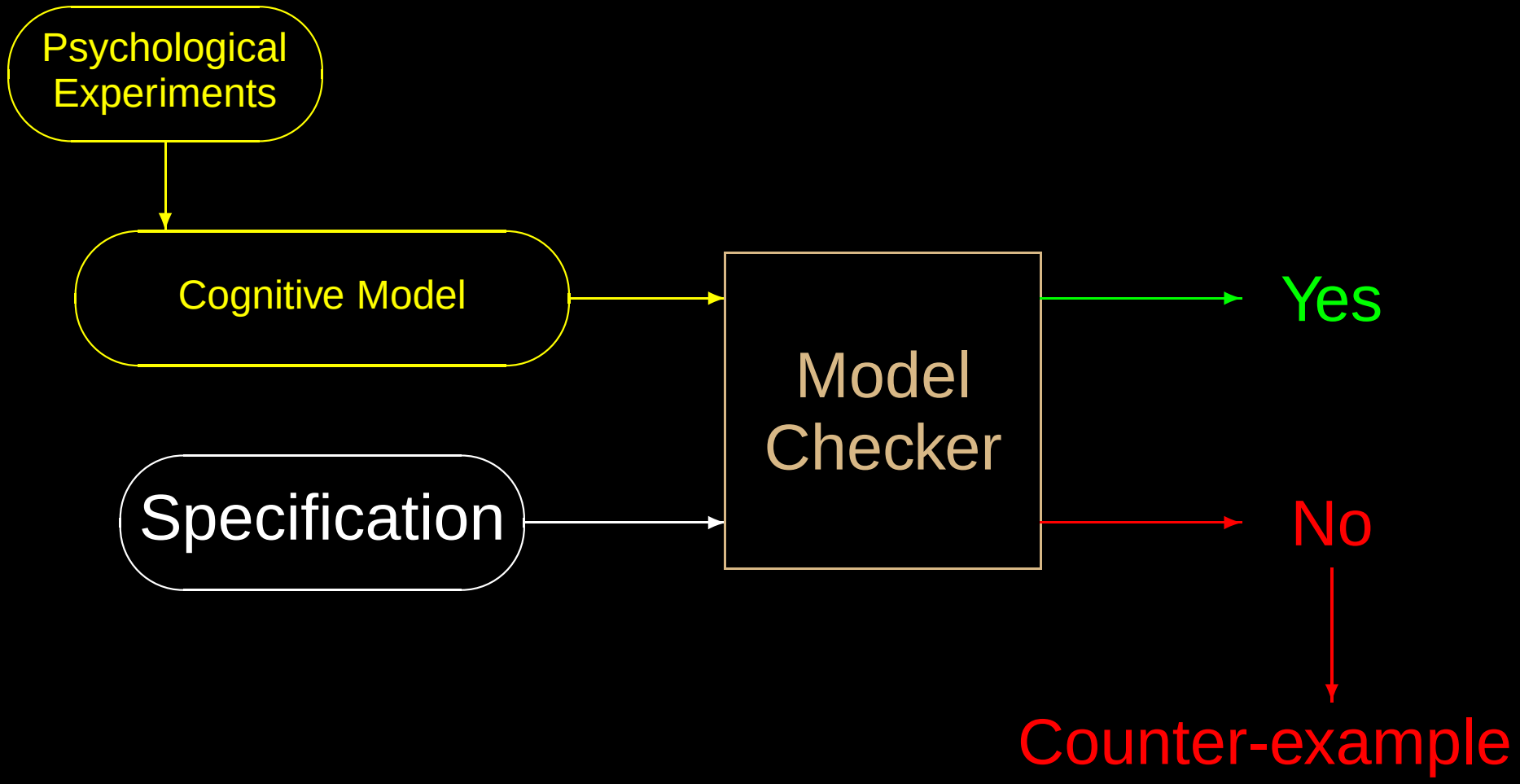

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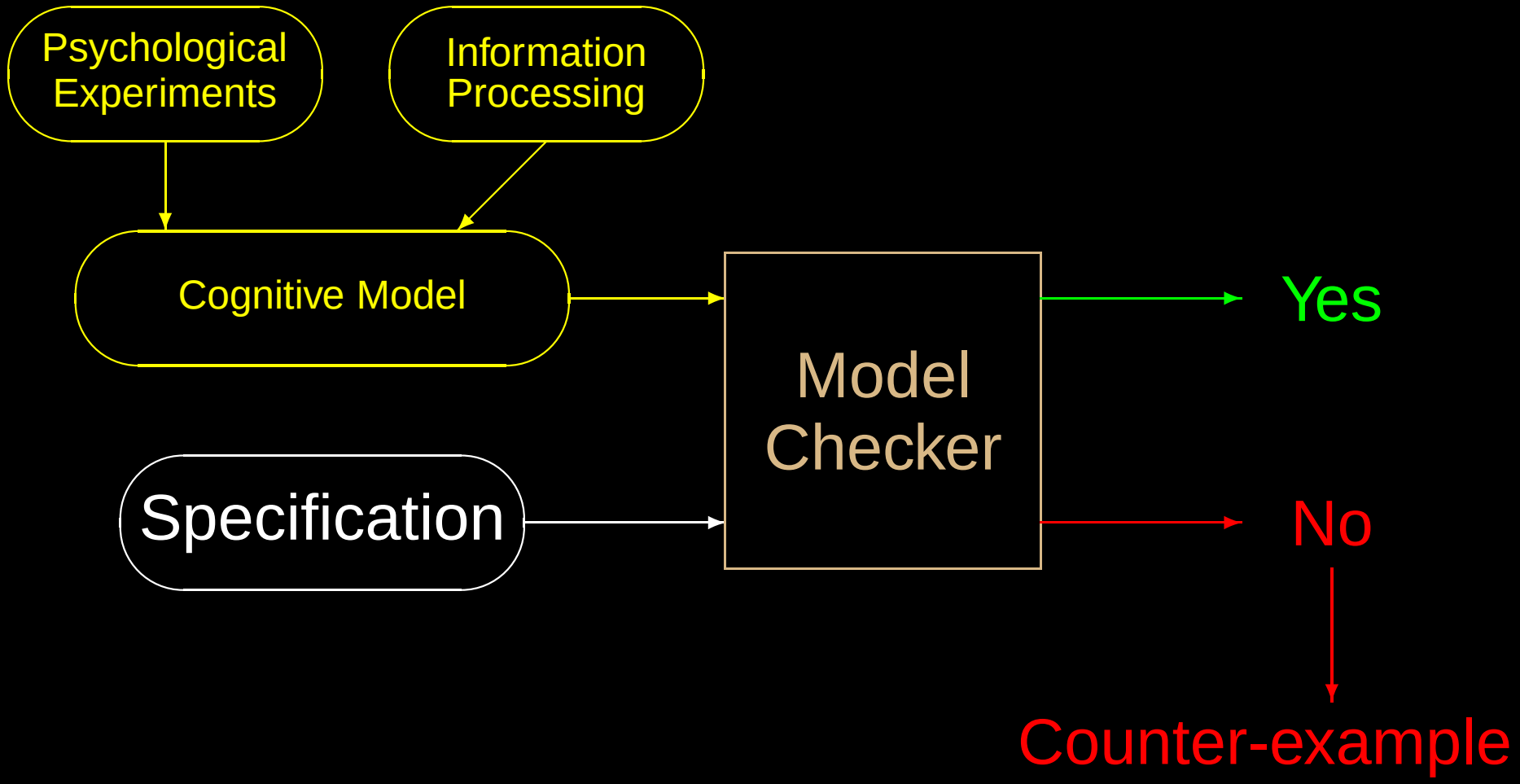

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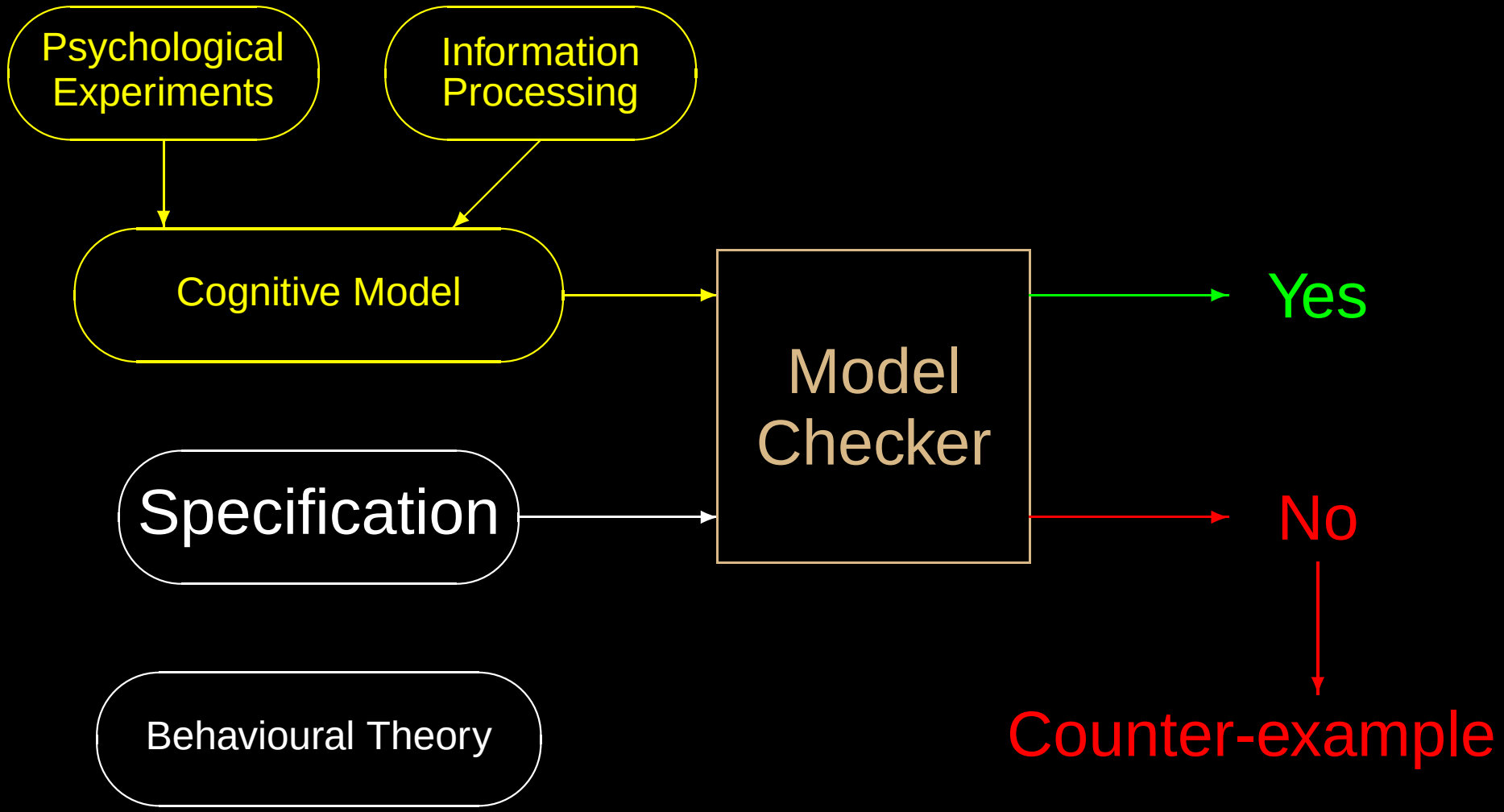

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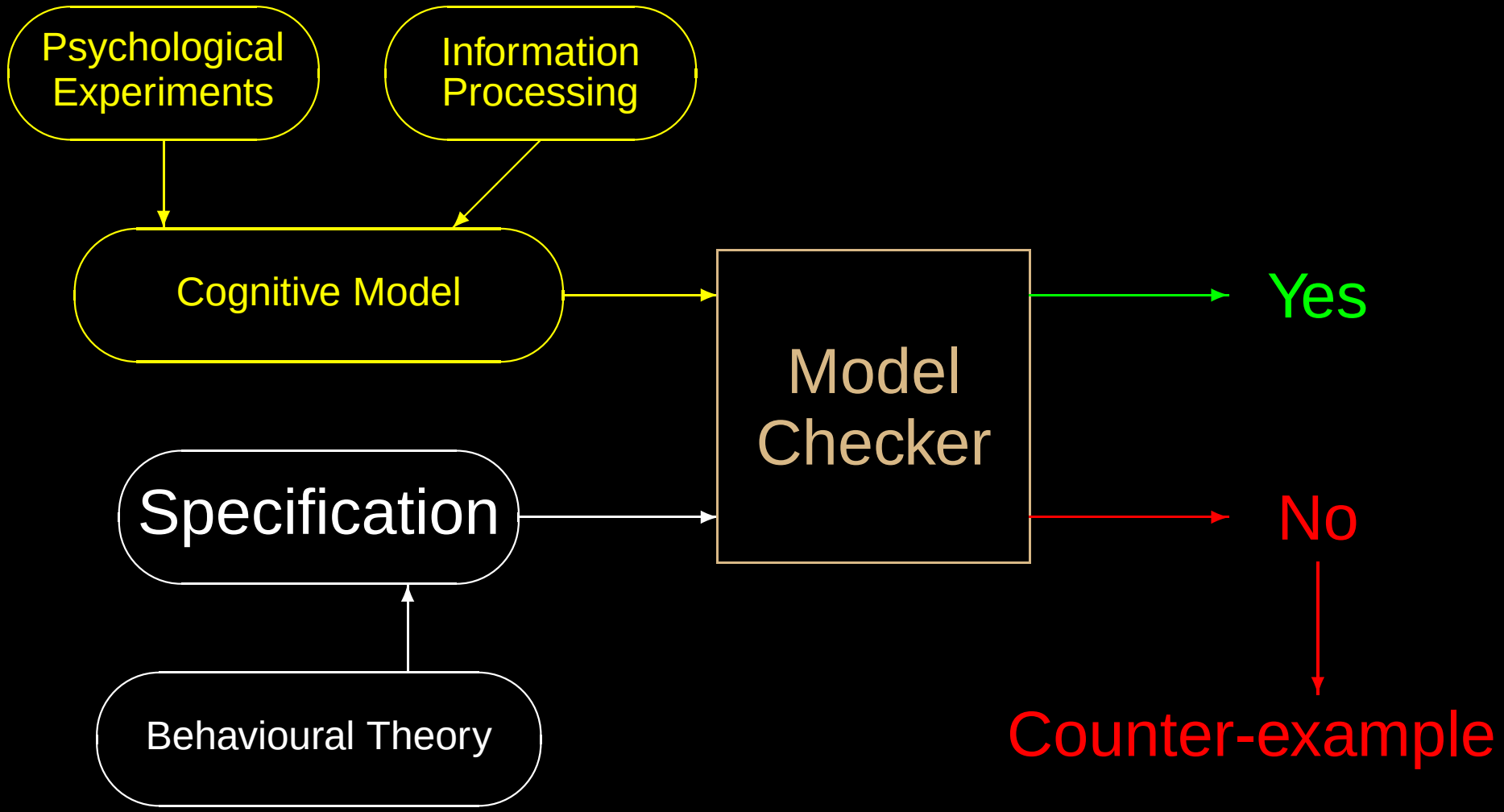

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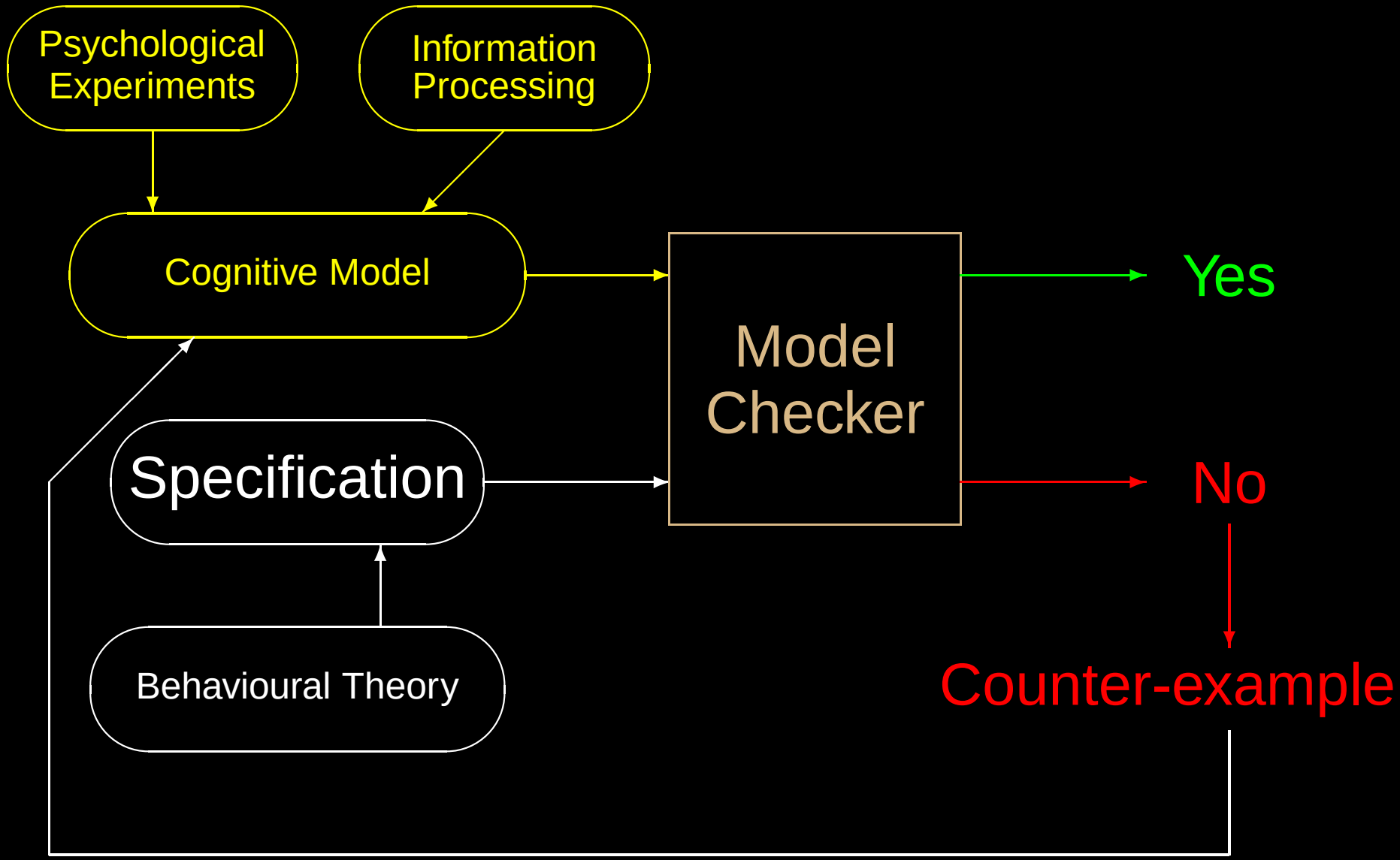

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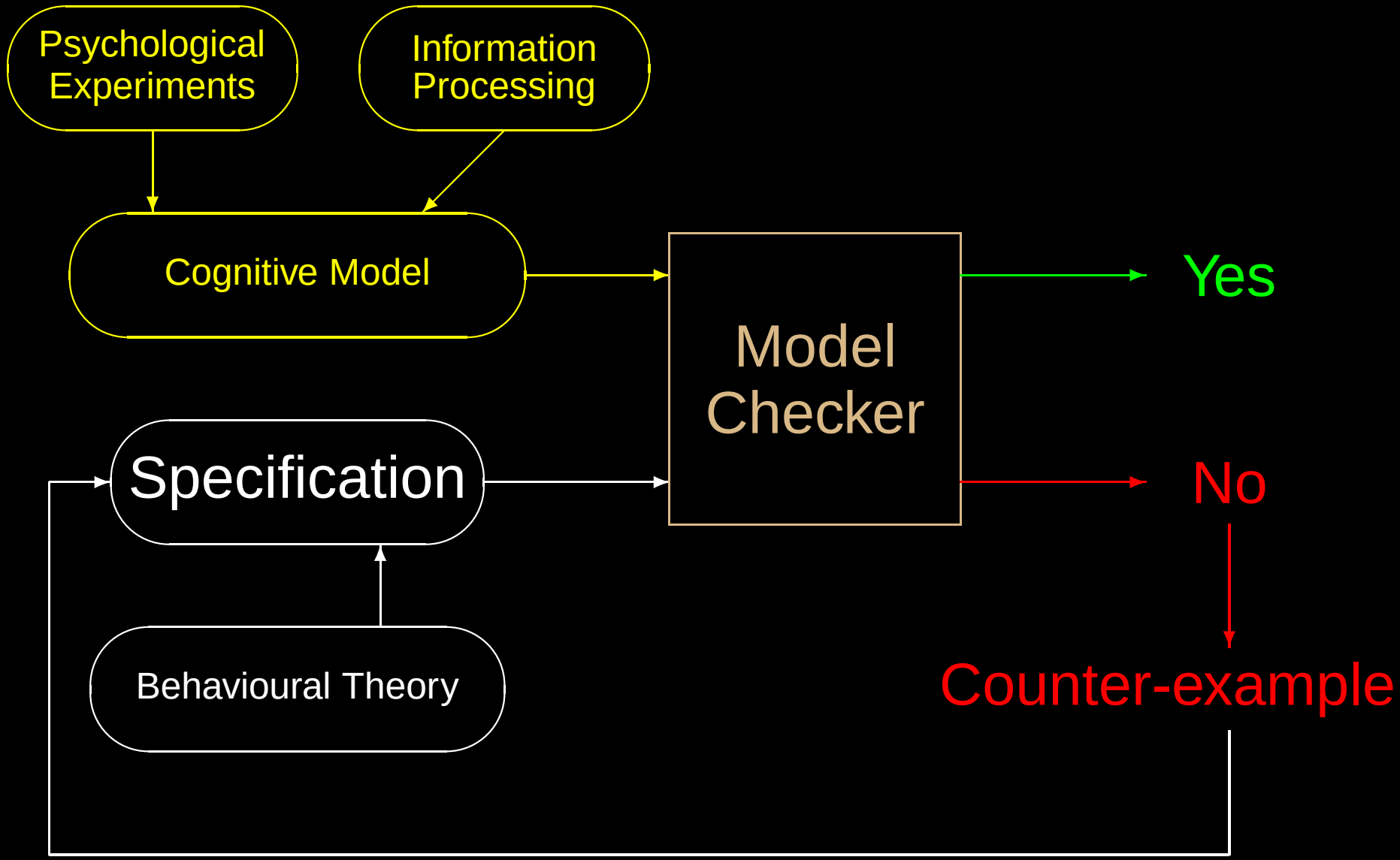

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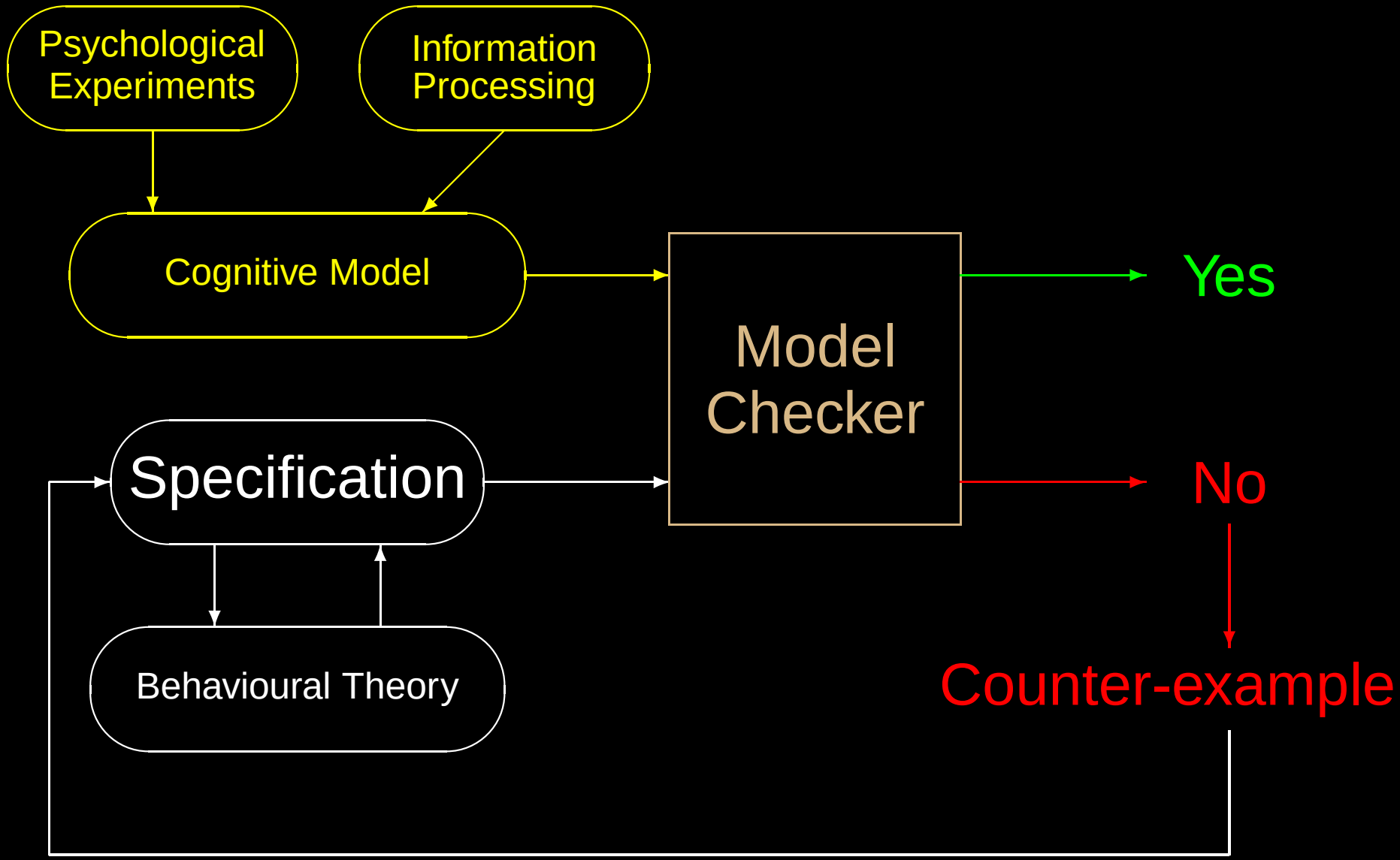

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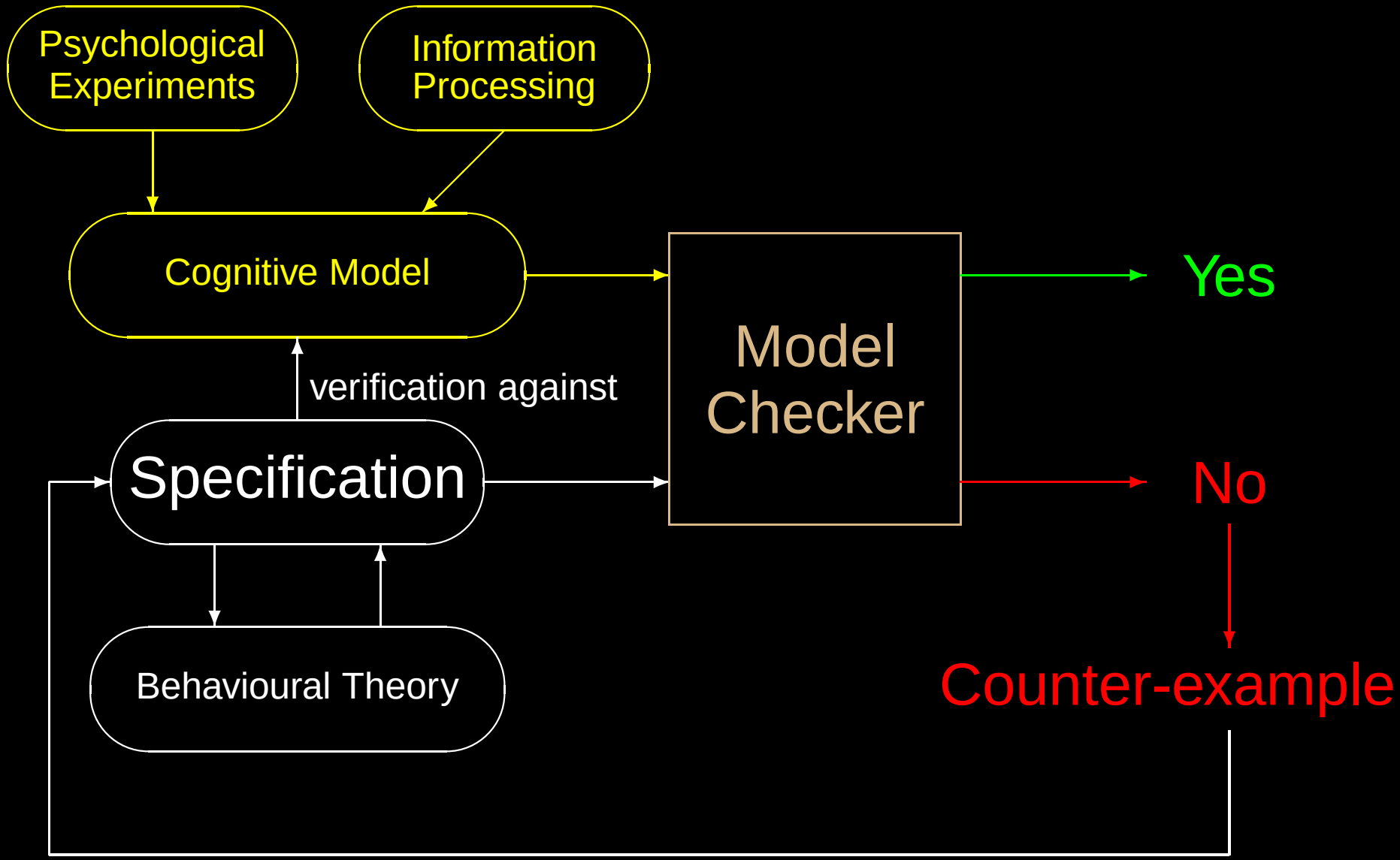

Air Traffic Control (ATC)

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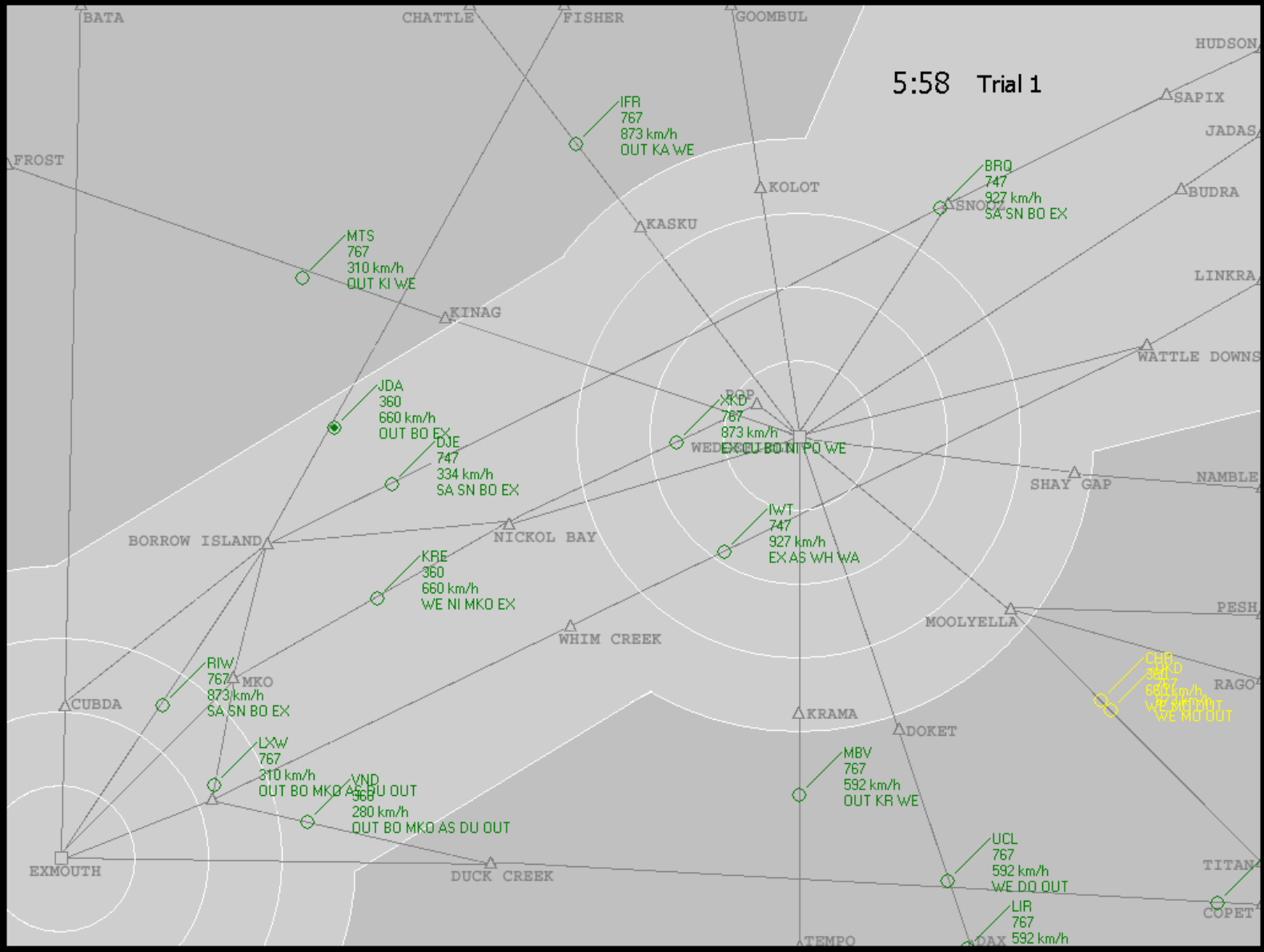
- We have a task failure when separation is violated.

ATC Simulator Screenshot



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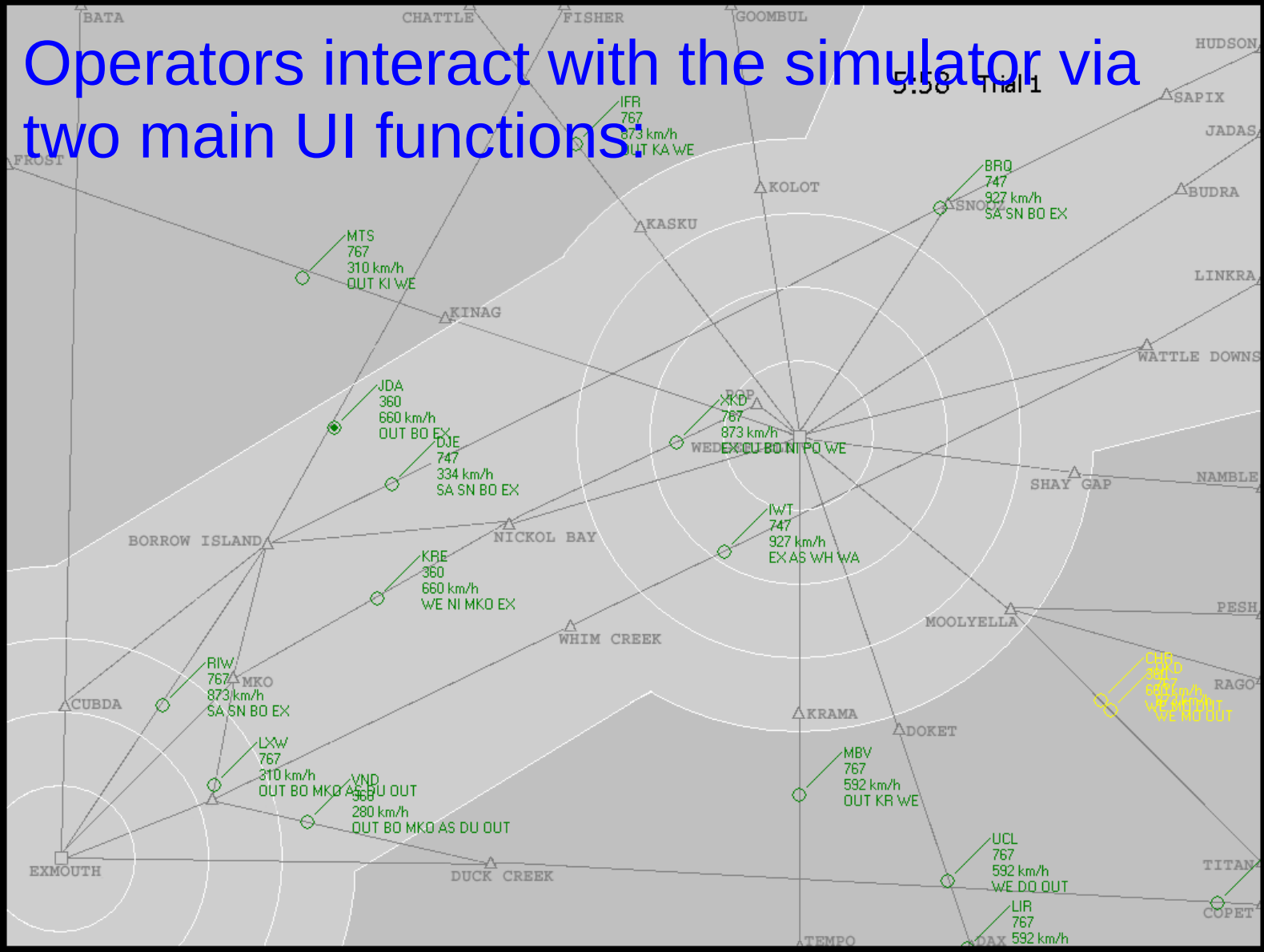

ATC Simulator Screenshot

Operators interact with the simulator via two main UI functions:

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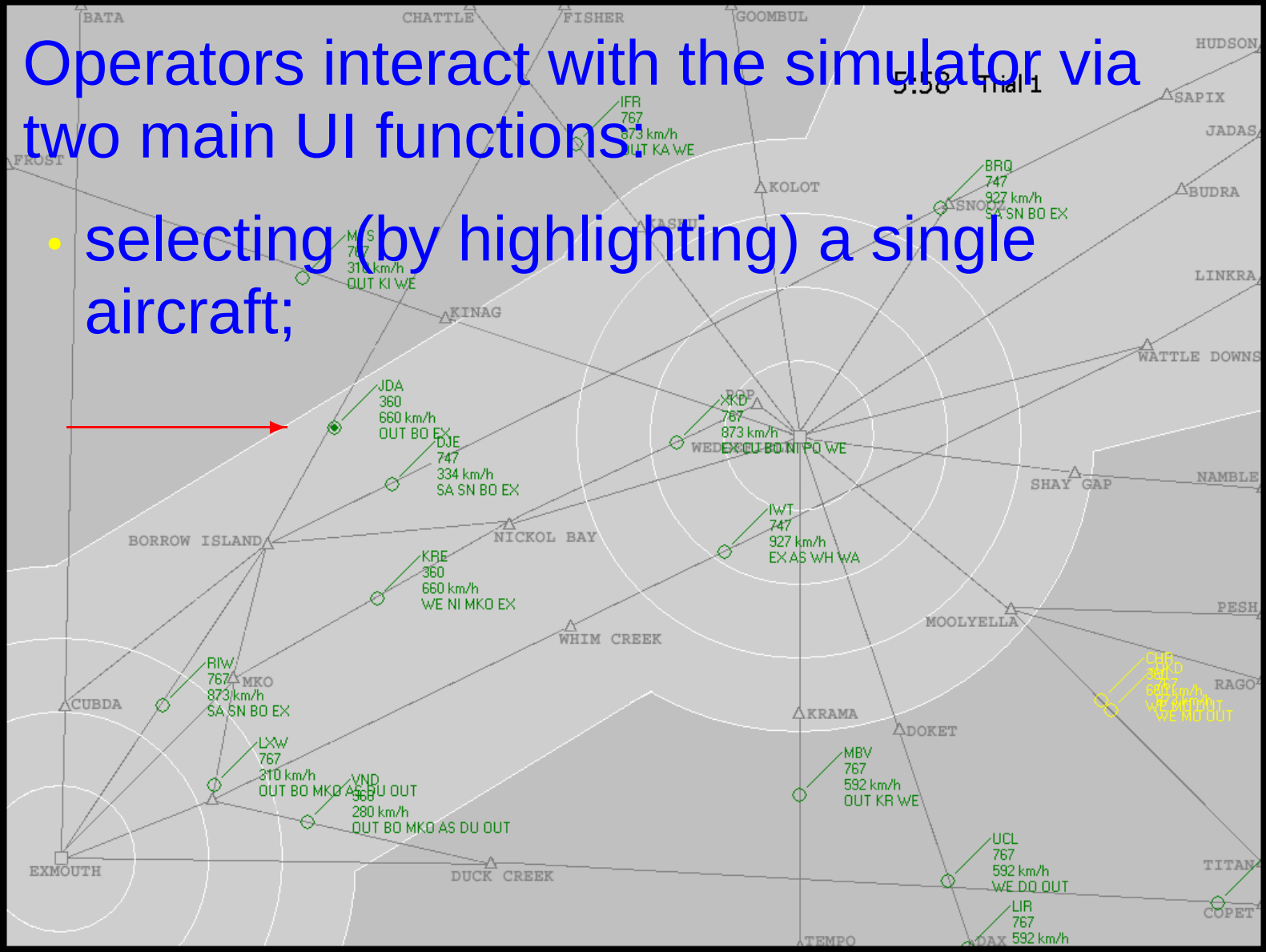

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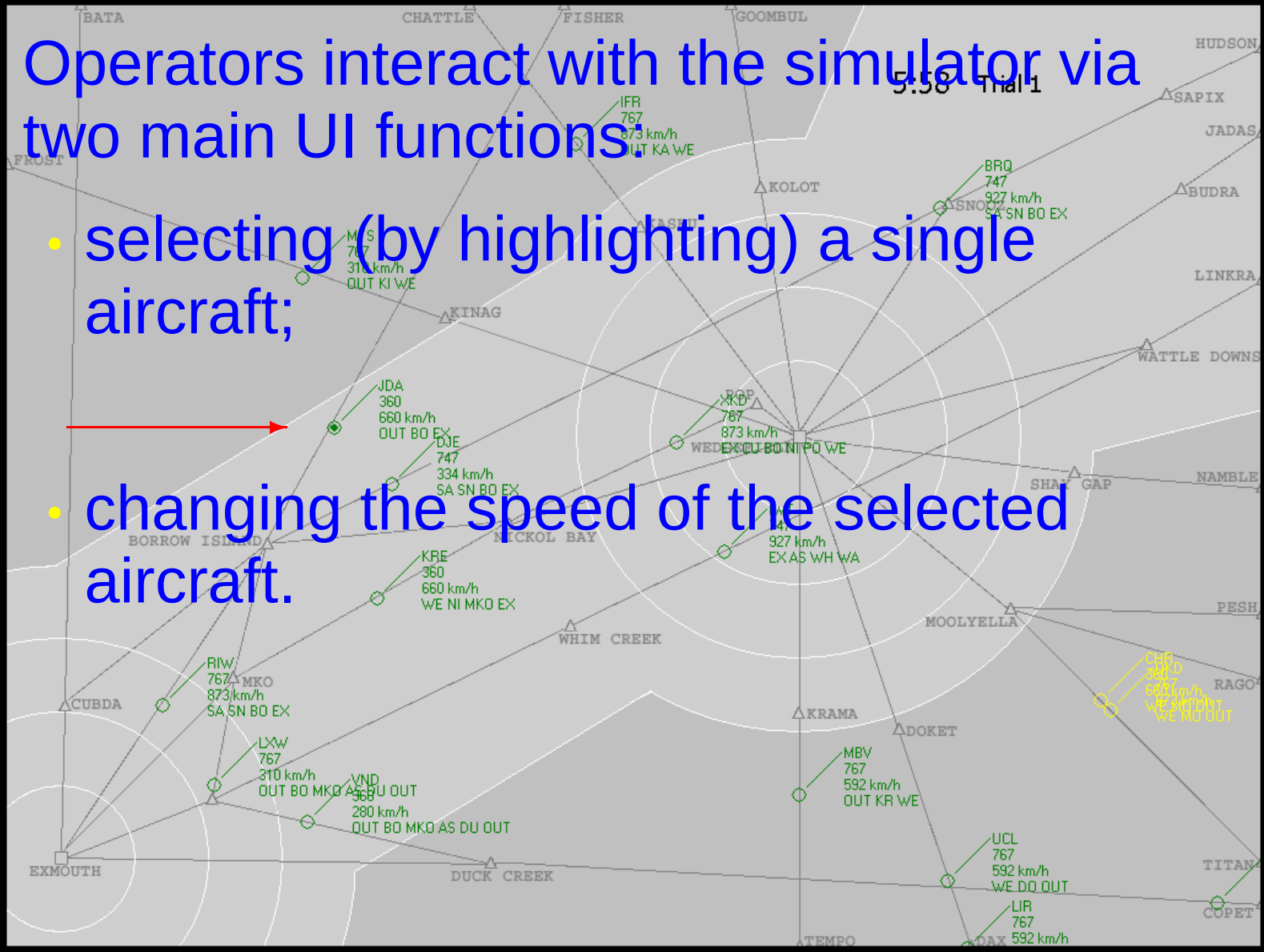

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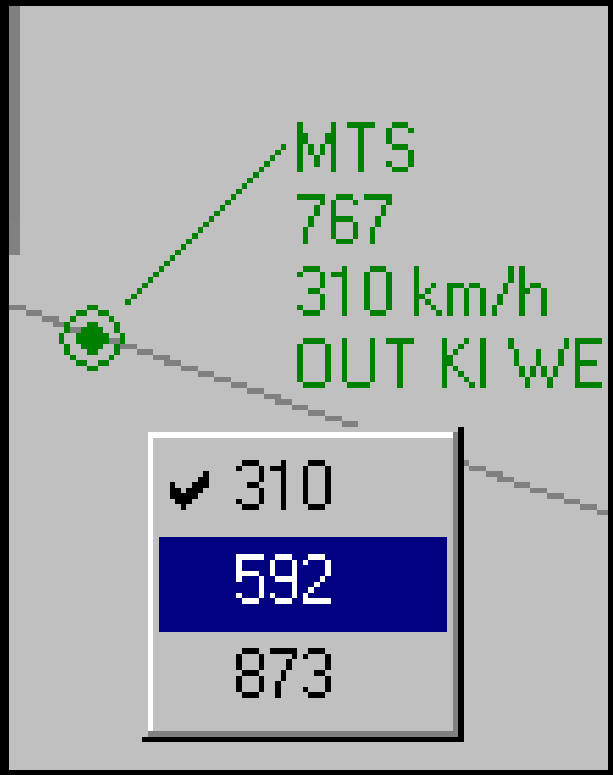
Speed Menu



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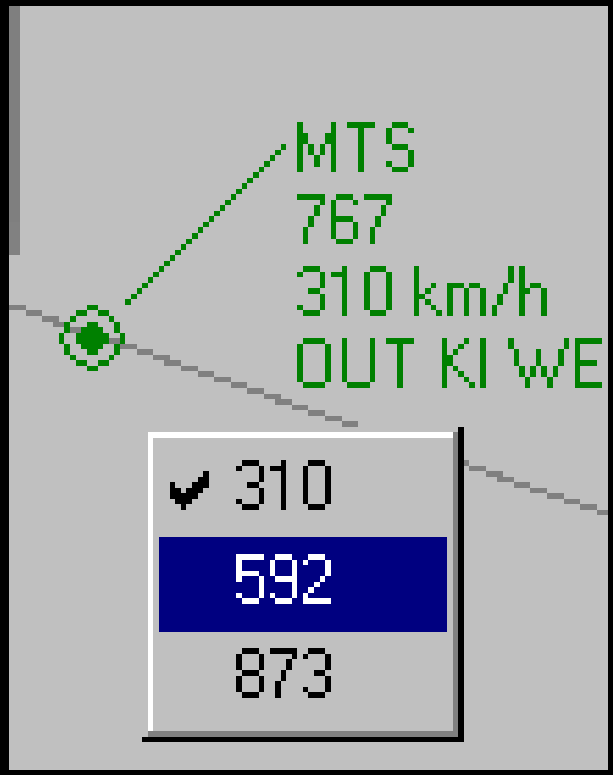
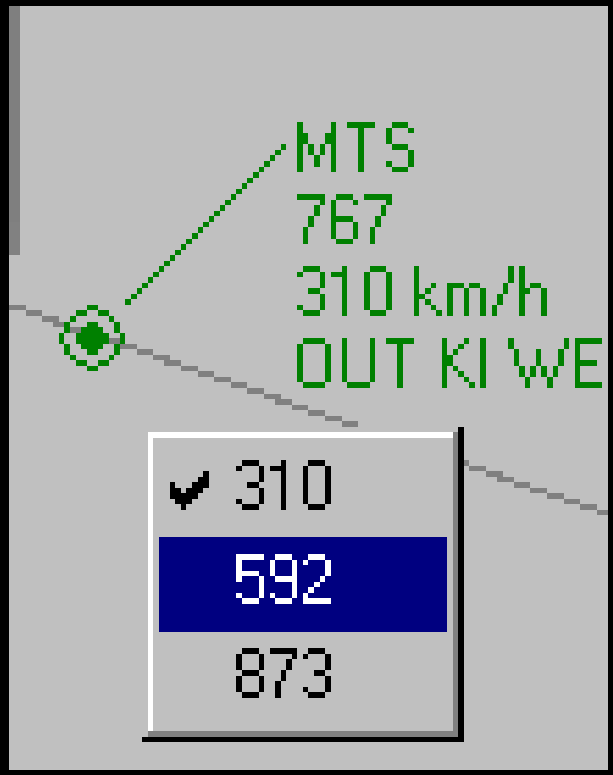


Open the menu by clicking the right button.

Speed Menu



Open the menu by clicking the right button.
The menu appears at the position of the cursor.

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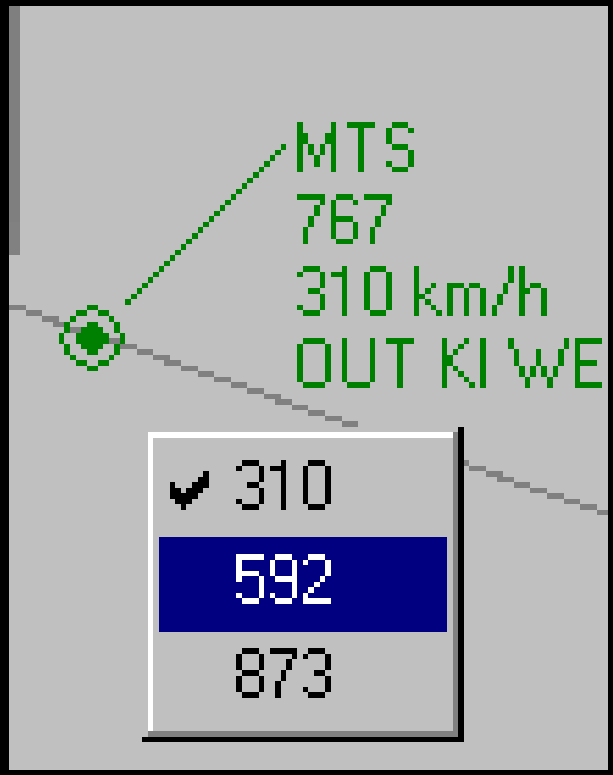

Open the menu by clicking the right button.
The menu appears at the position of the cursor.
Selected the speed by left clicking on the desired menu entry.

Operator Erros

- slip: inadvertedly select a wrong or the current speed

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The operator can recover from these errors without causing separation violation (task failure)

OCM for Air Traffic Control

Scanning: The operator scans among each pair of aircraft searching for a pair that may violate separation.

Identification: The operator identifies a pair of aircraft.

Classification: The operator

- assesses whether the identified pair of aircraft will eventually violate separation (in conflict) or not (not in conflict);
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Decision on how to resolve the conflict.

Action to be performed as a series of interaction with the interface.

Model Interpretation for ATC

$$S = s \rightarrow (([]_{p:Part}(s_p \rightarrow C_p))[]S)$$
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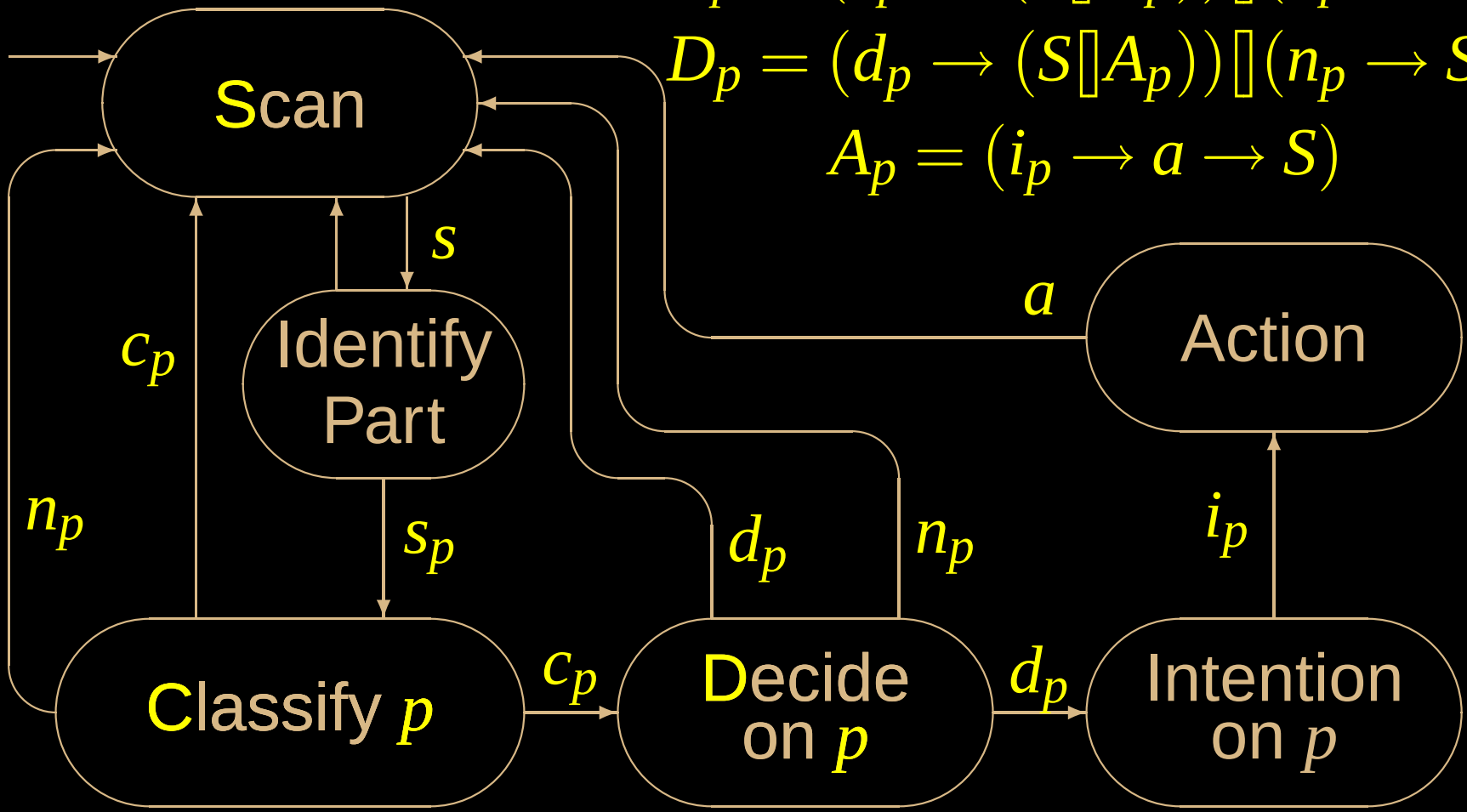

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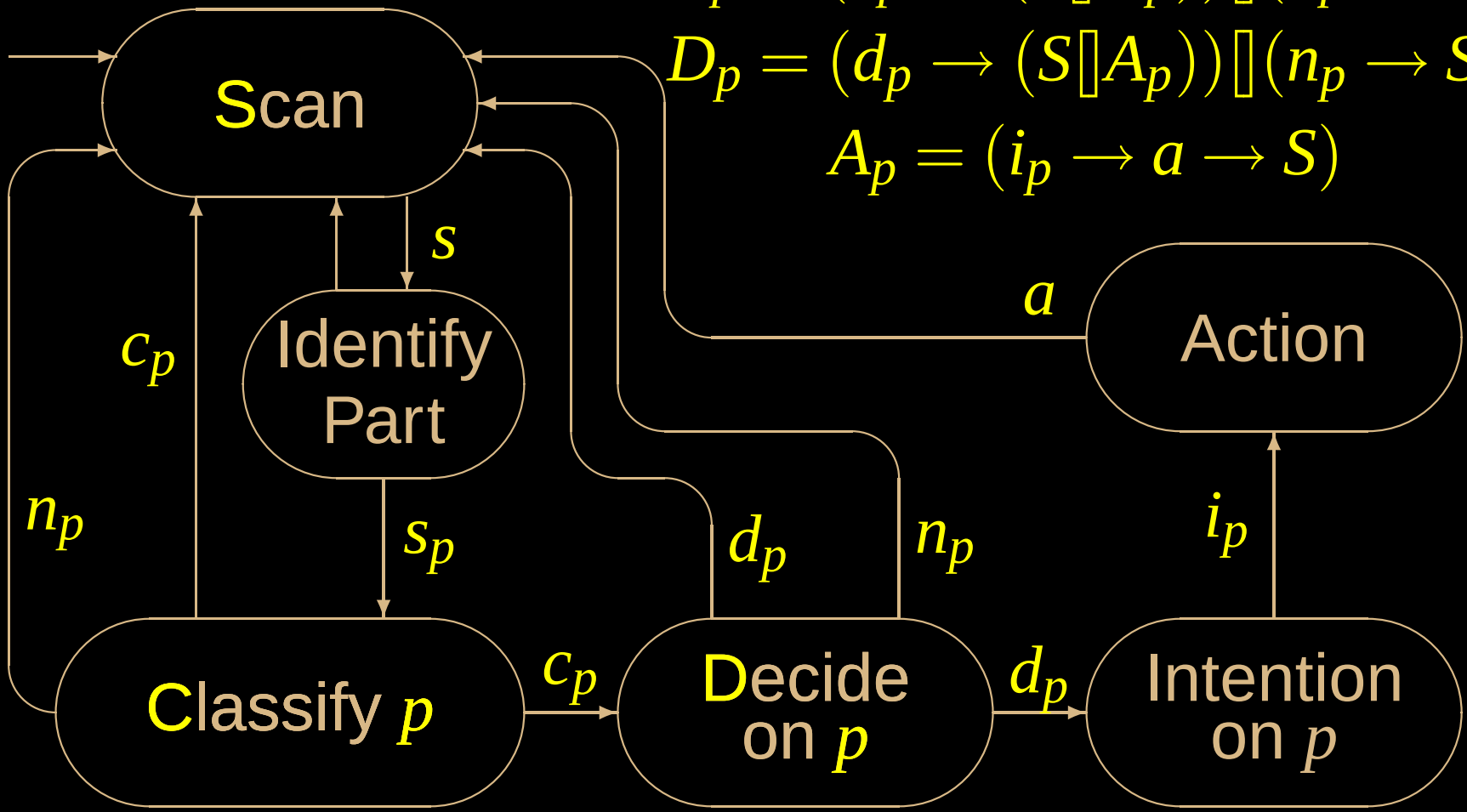

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The pair is classified
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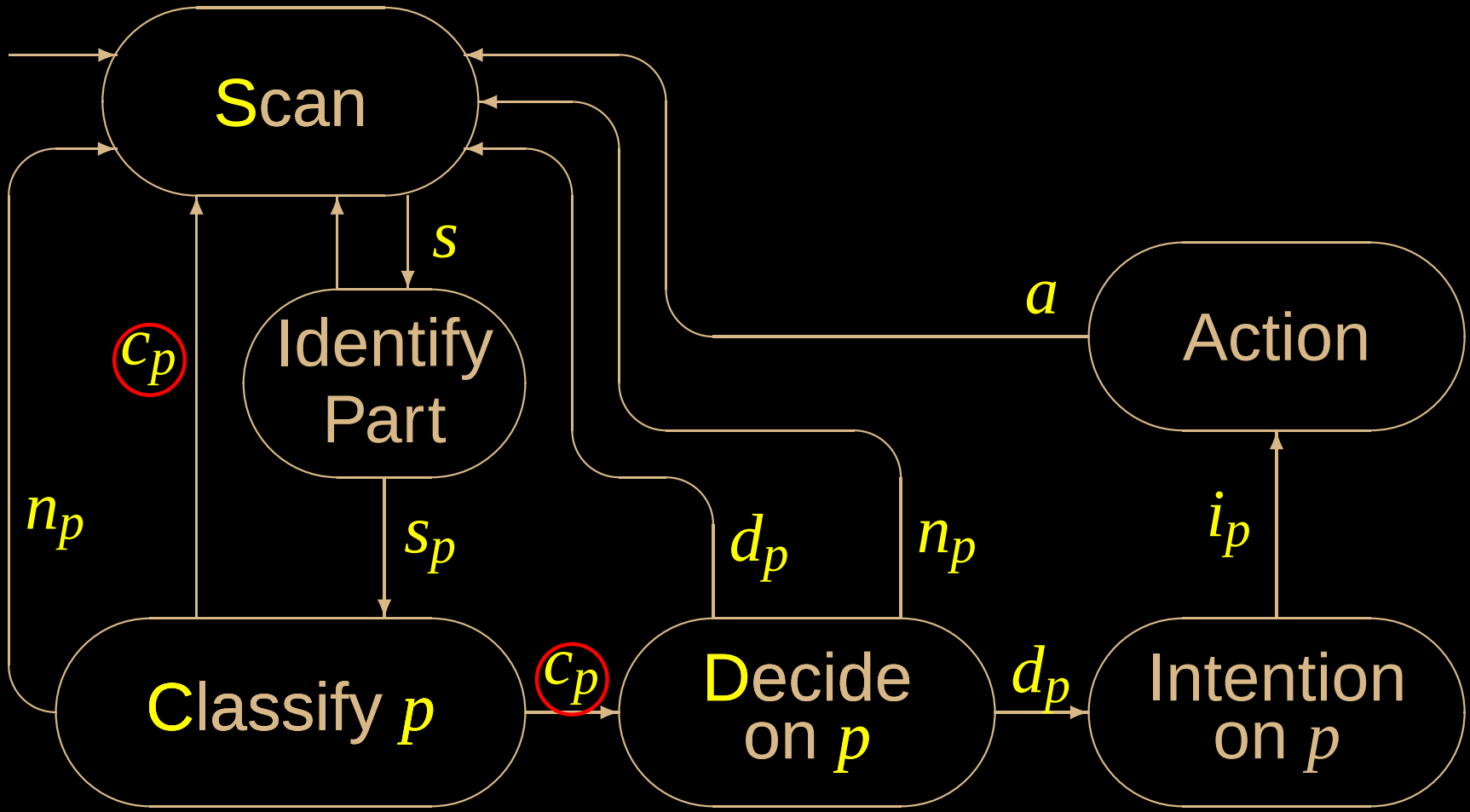

Model Interpretation for ATC

$p =$ Pair of aircraft

The pair is classified
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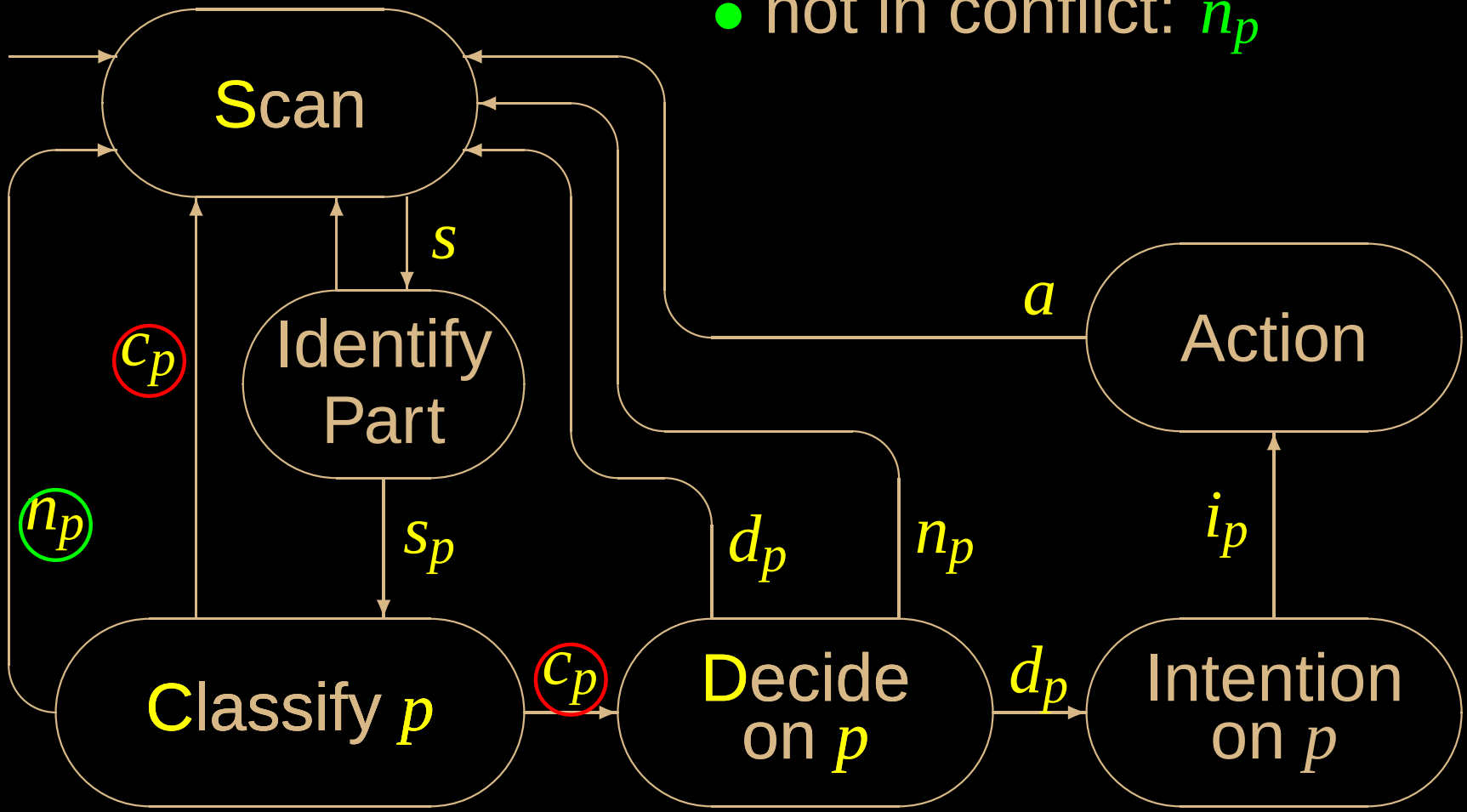
- not in conflict: n_p



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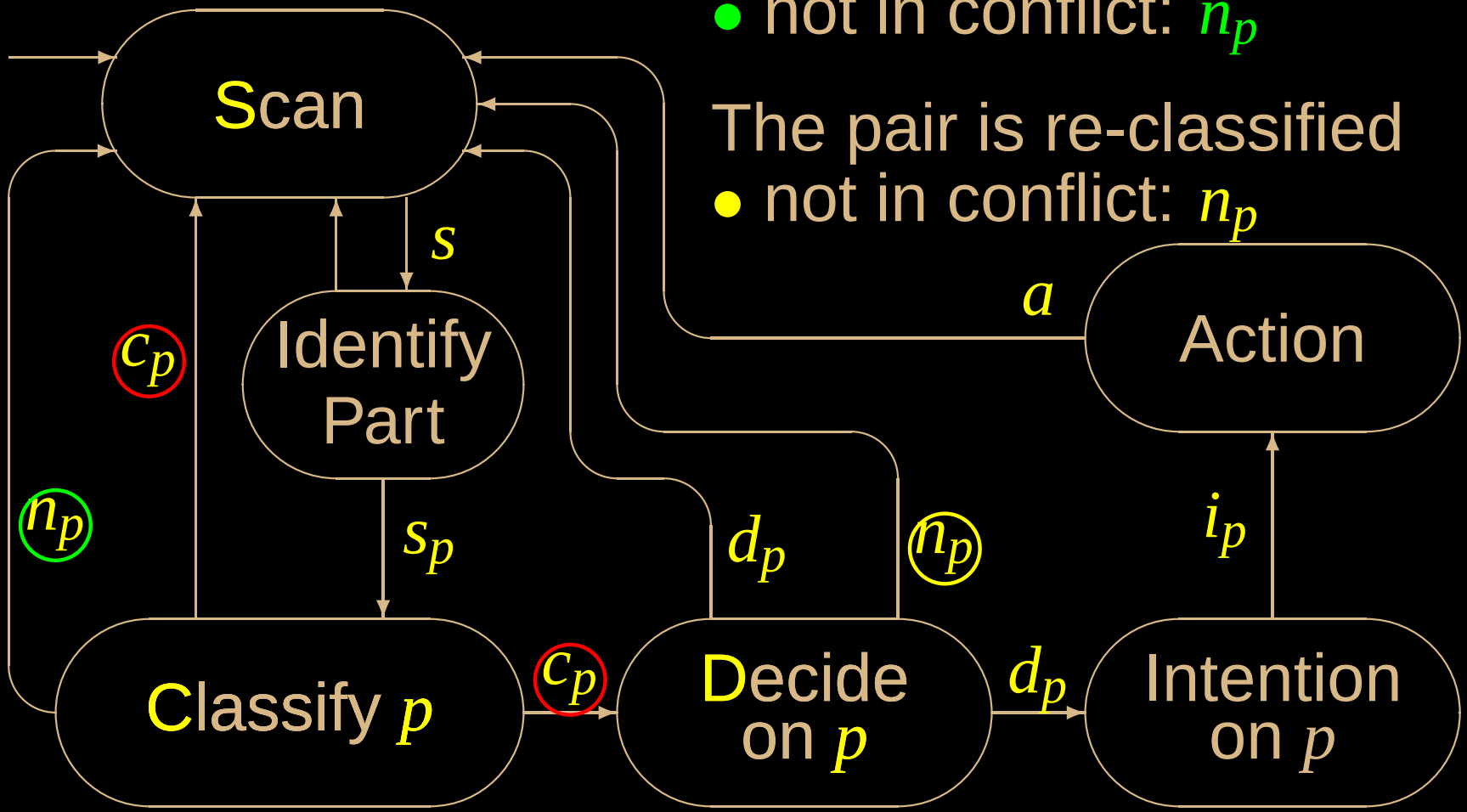
The pair is classified
- in conflict: c_p
- not in conflict: n_p

The pair is re-classified
- not in conflict: n_p



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$$OCM = S \parallel (\parallel_{p:Init_I} I_p) \parallel (\parallel_{p:Init_N} N_p)$$

Task Failure Analysis

Three levels of decomposition of task failures.

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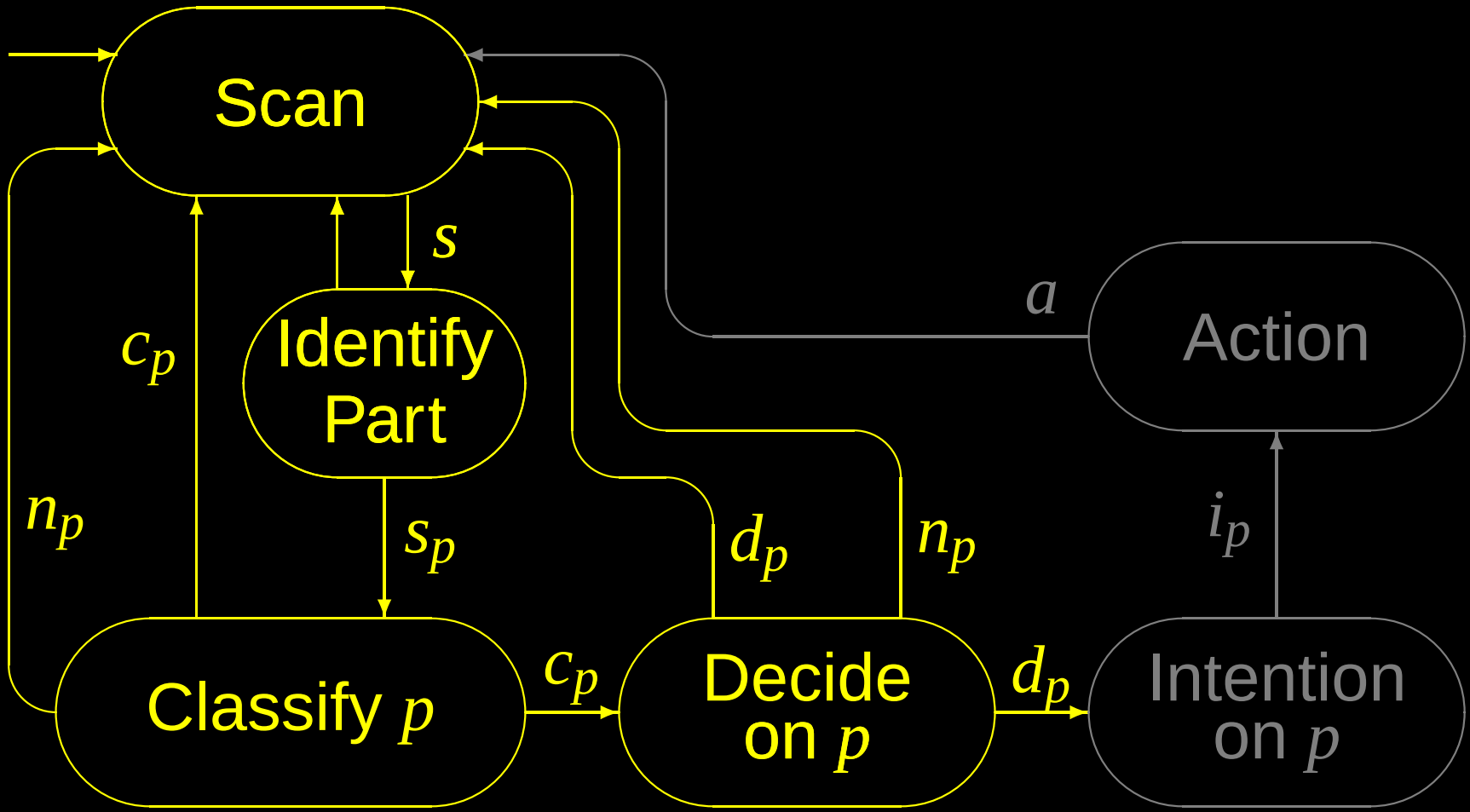
- the fact that in absence of initial conflict (N_p) a new conflict is created ($adverse_p$).

Failure of Scanning

no_intended_response$_p$:



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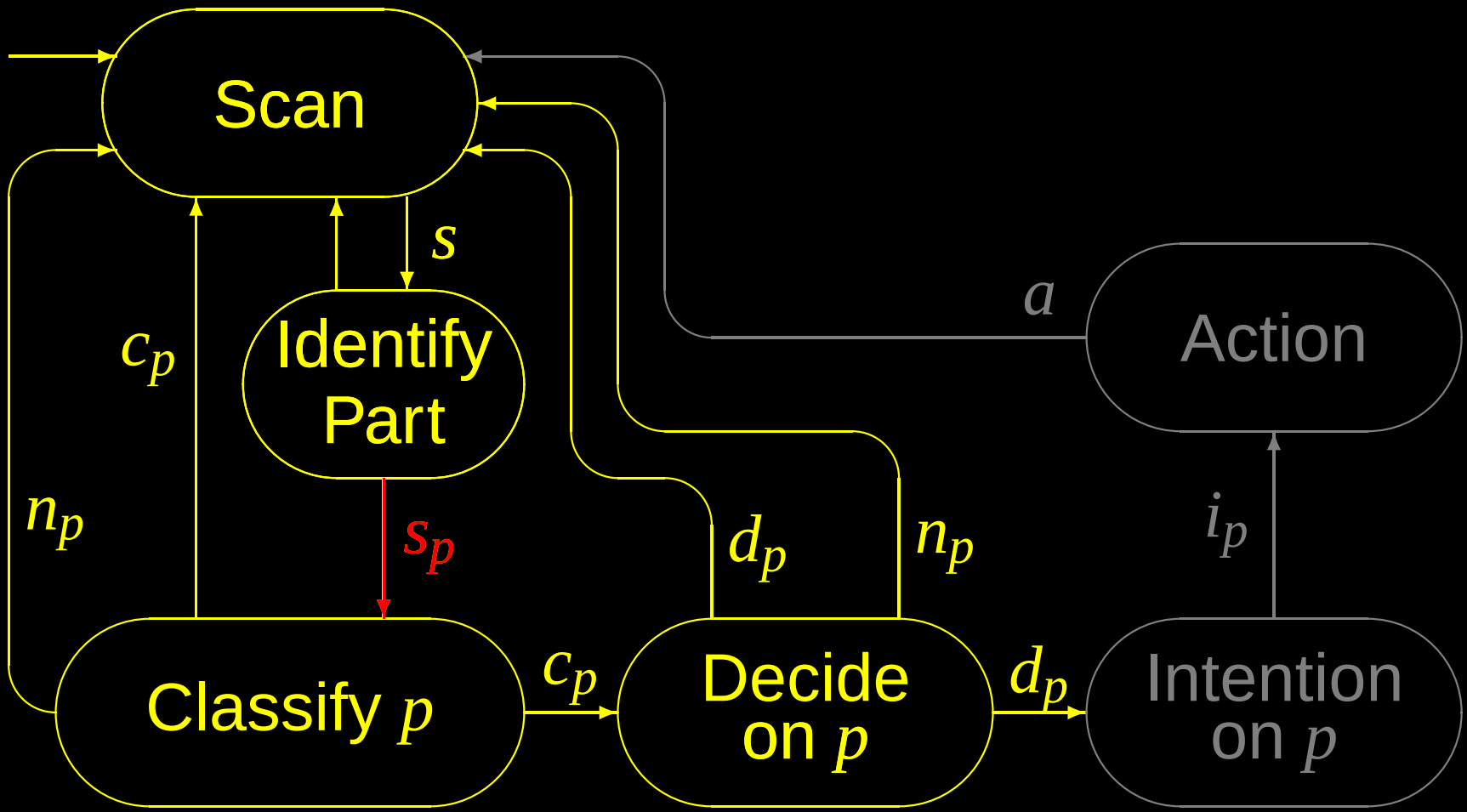

Failure of Making Decision

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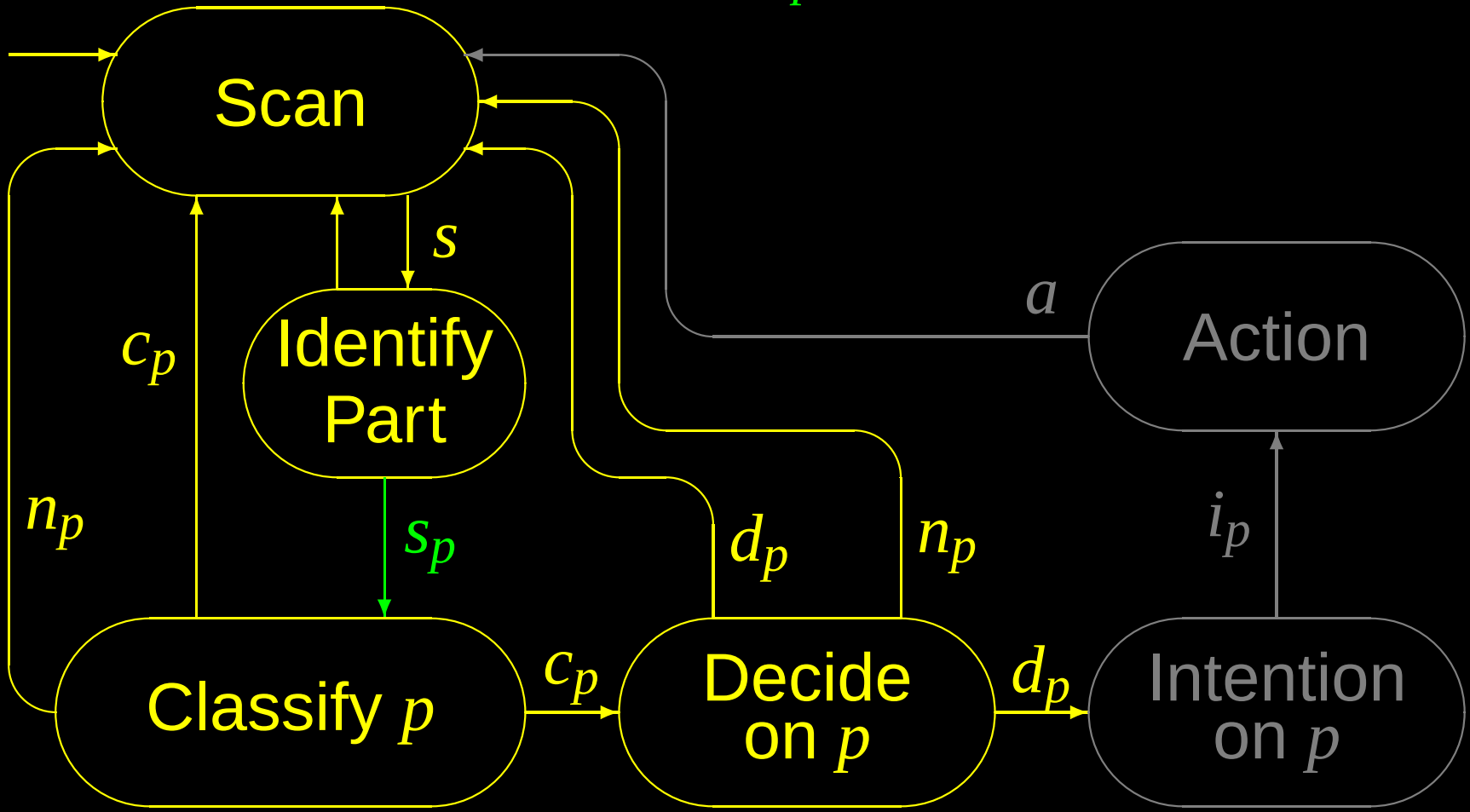

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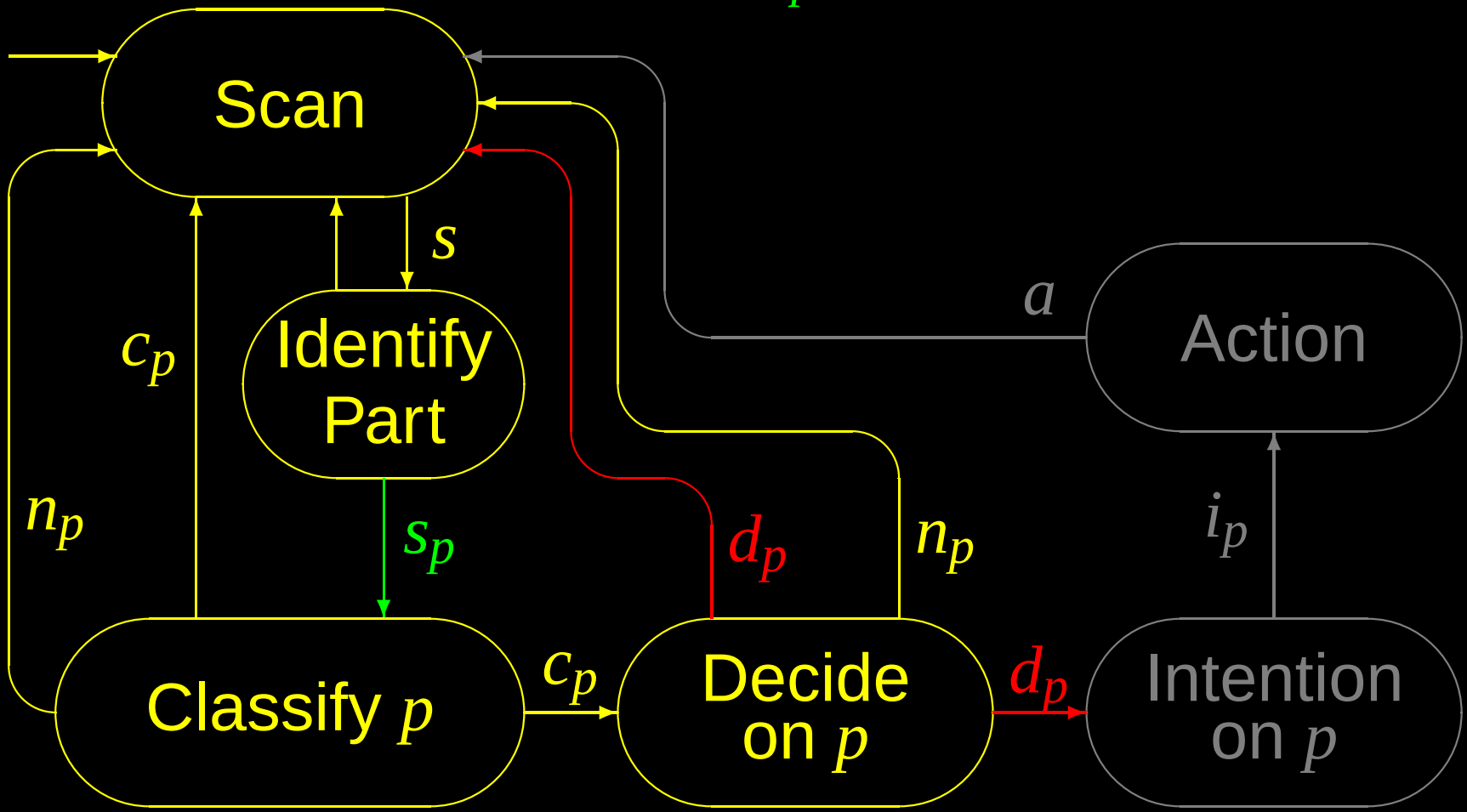

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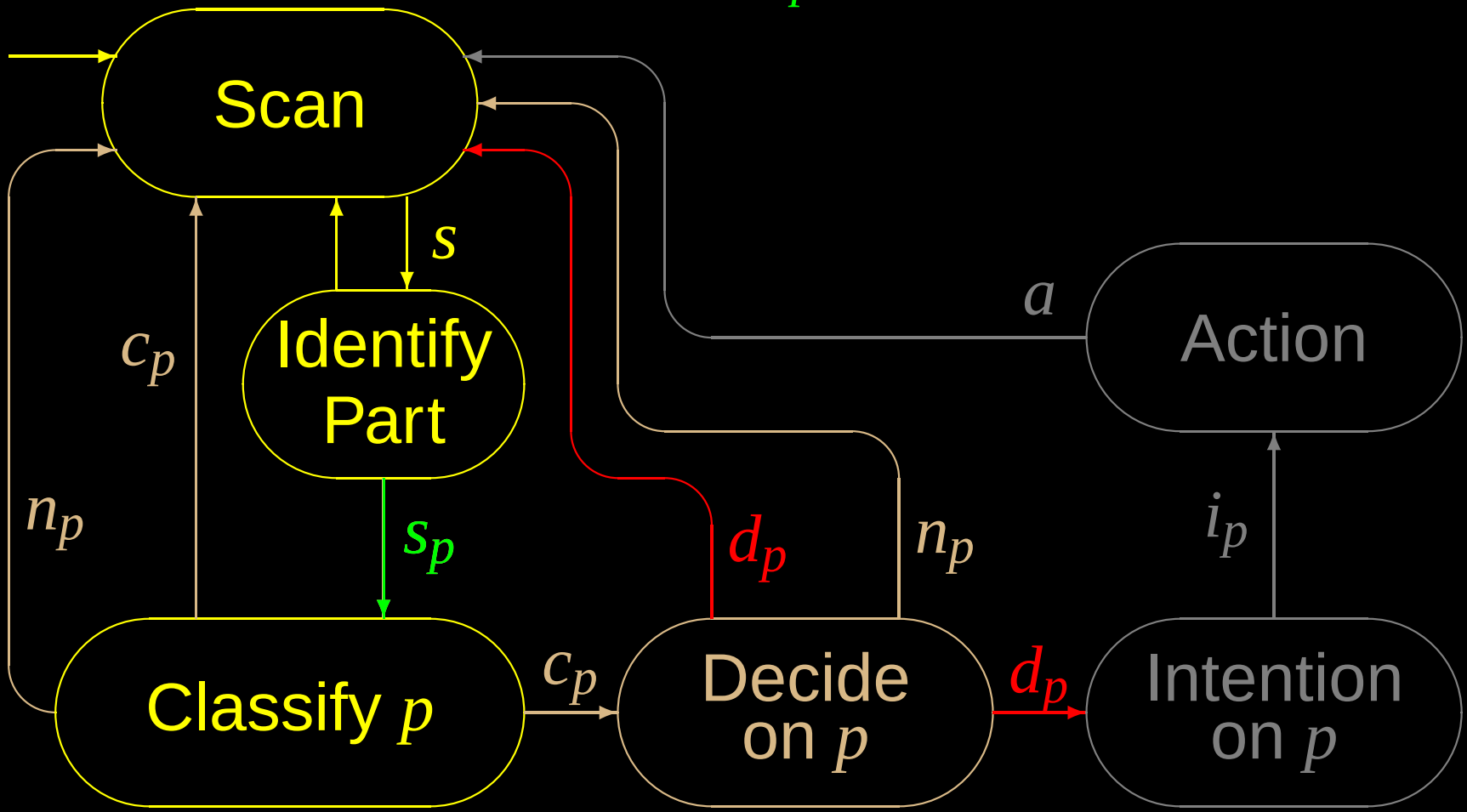

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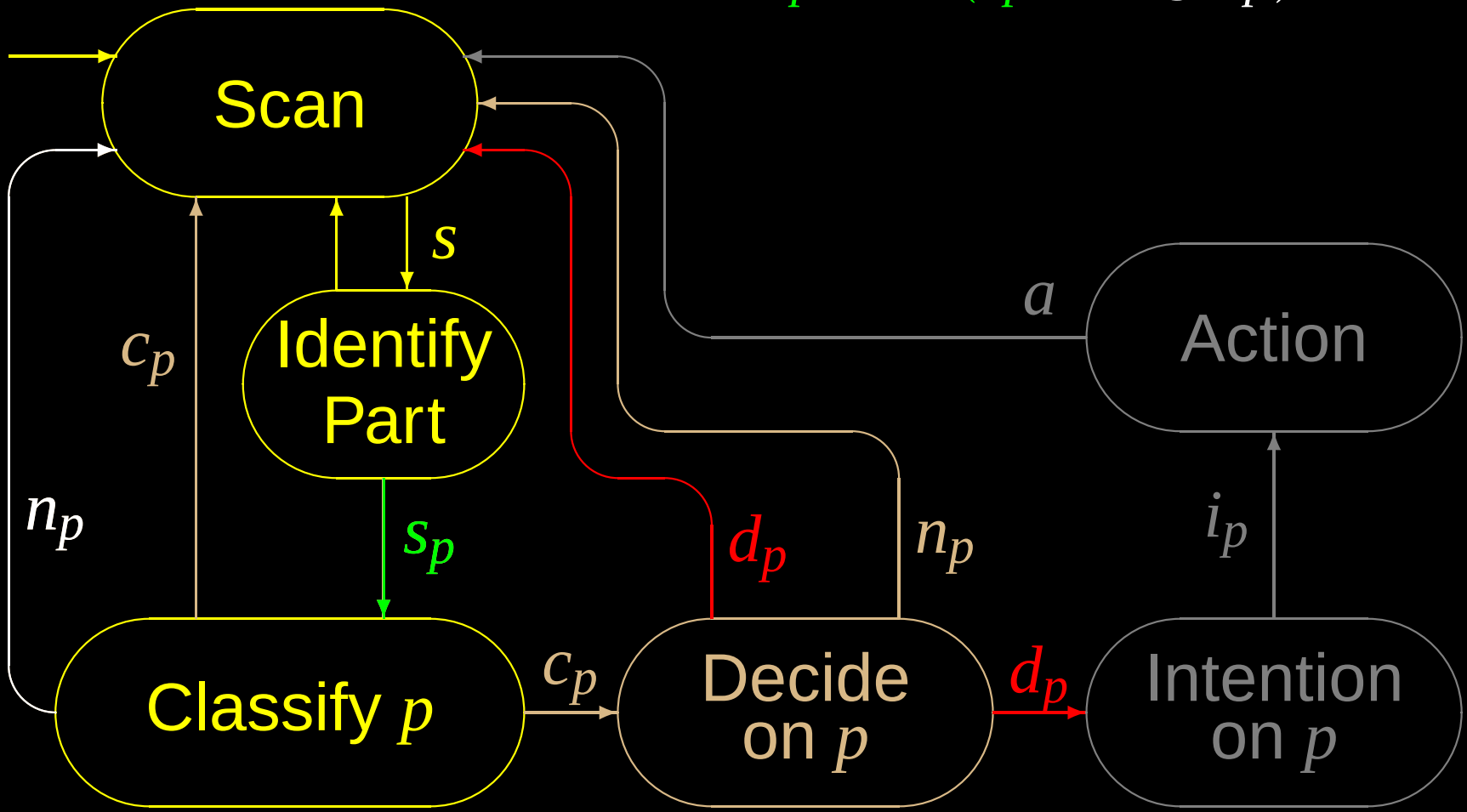

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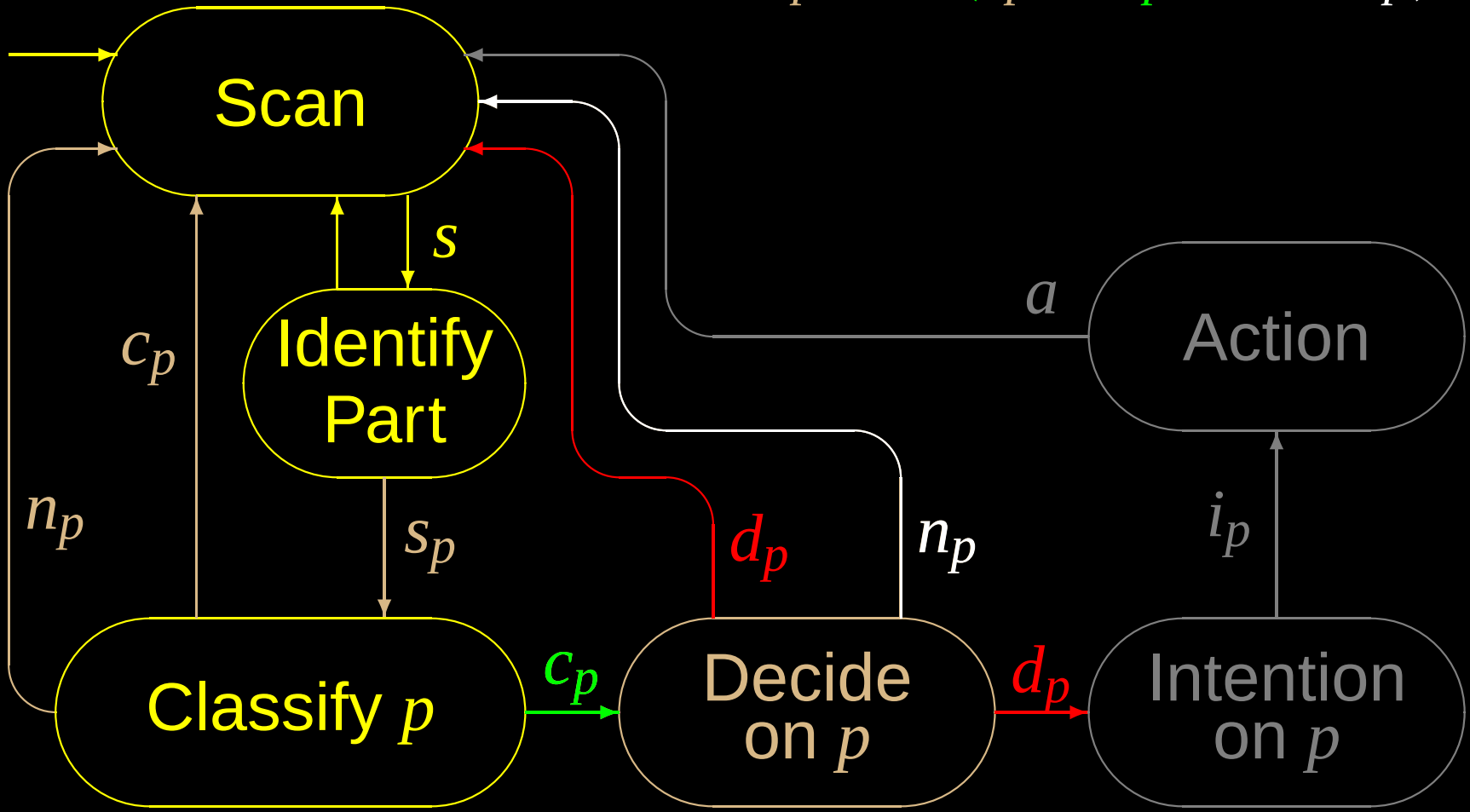

Persistent Mis-prioritisation

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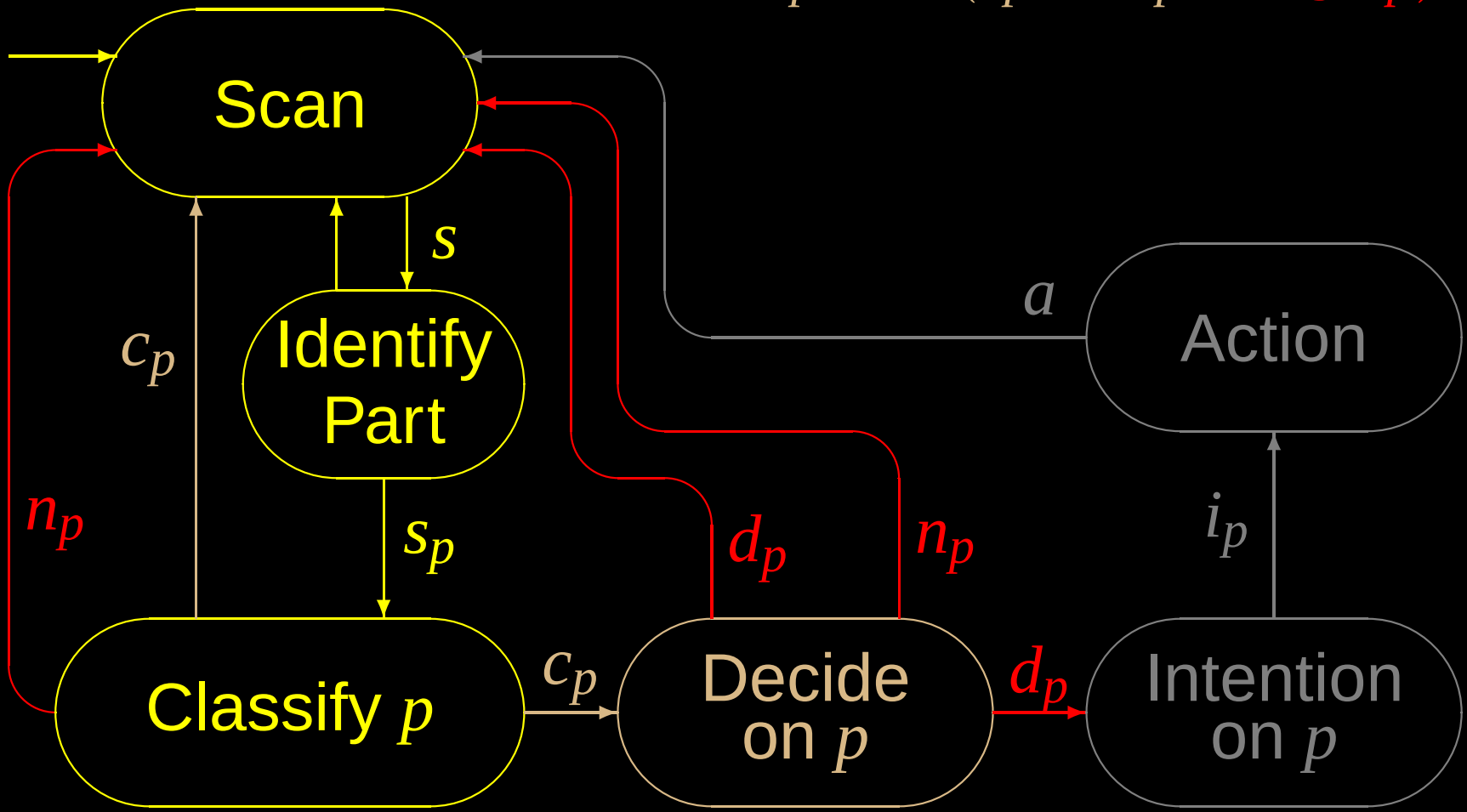

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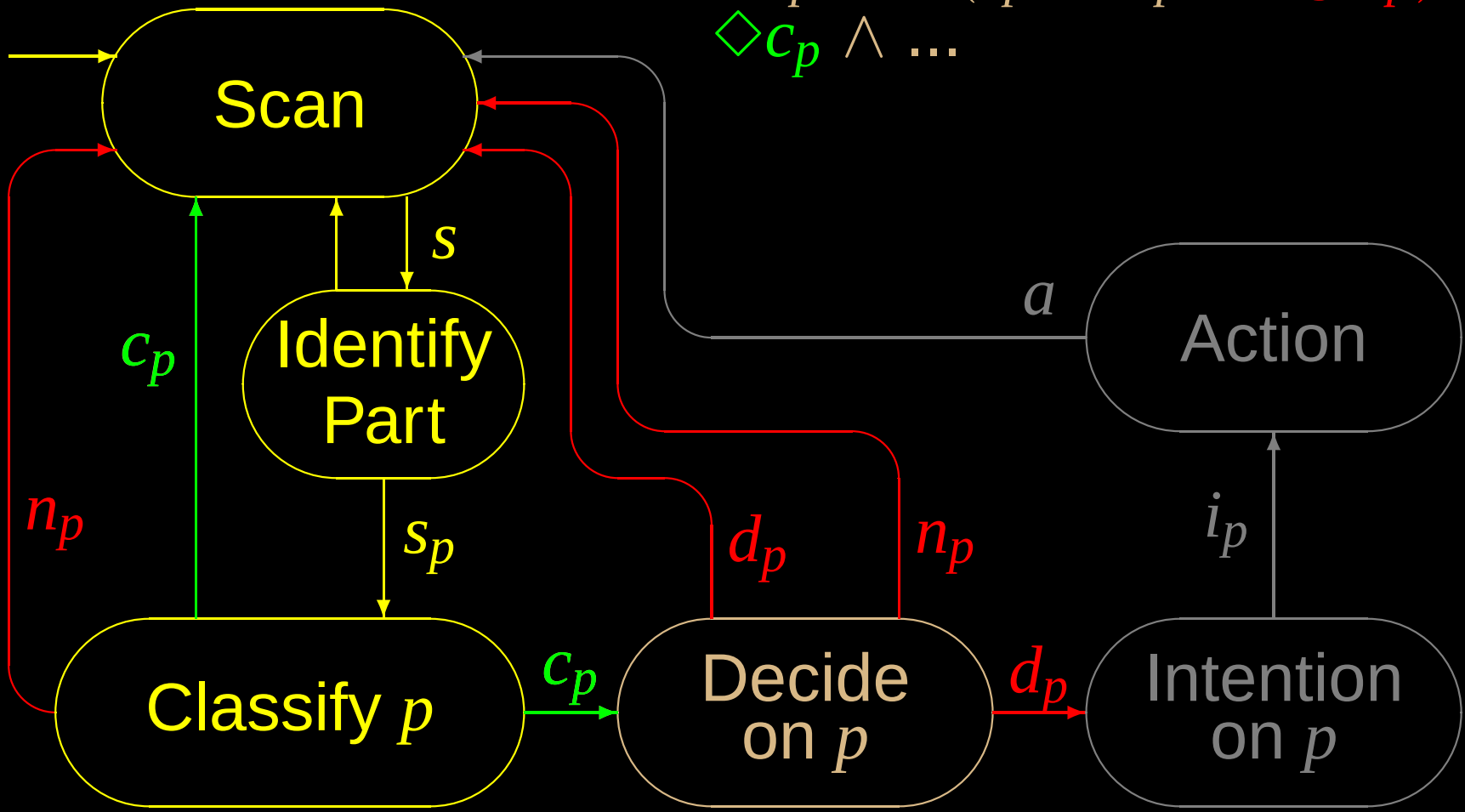

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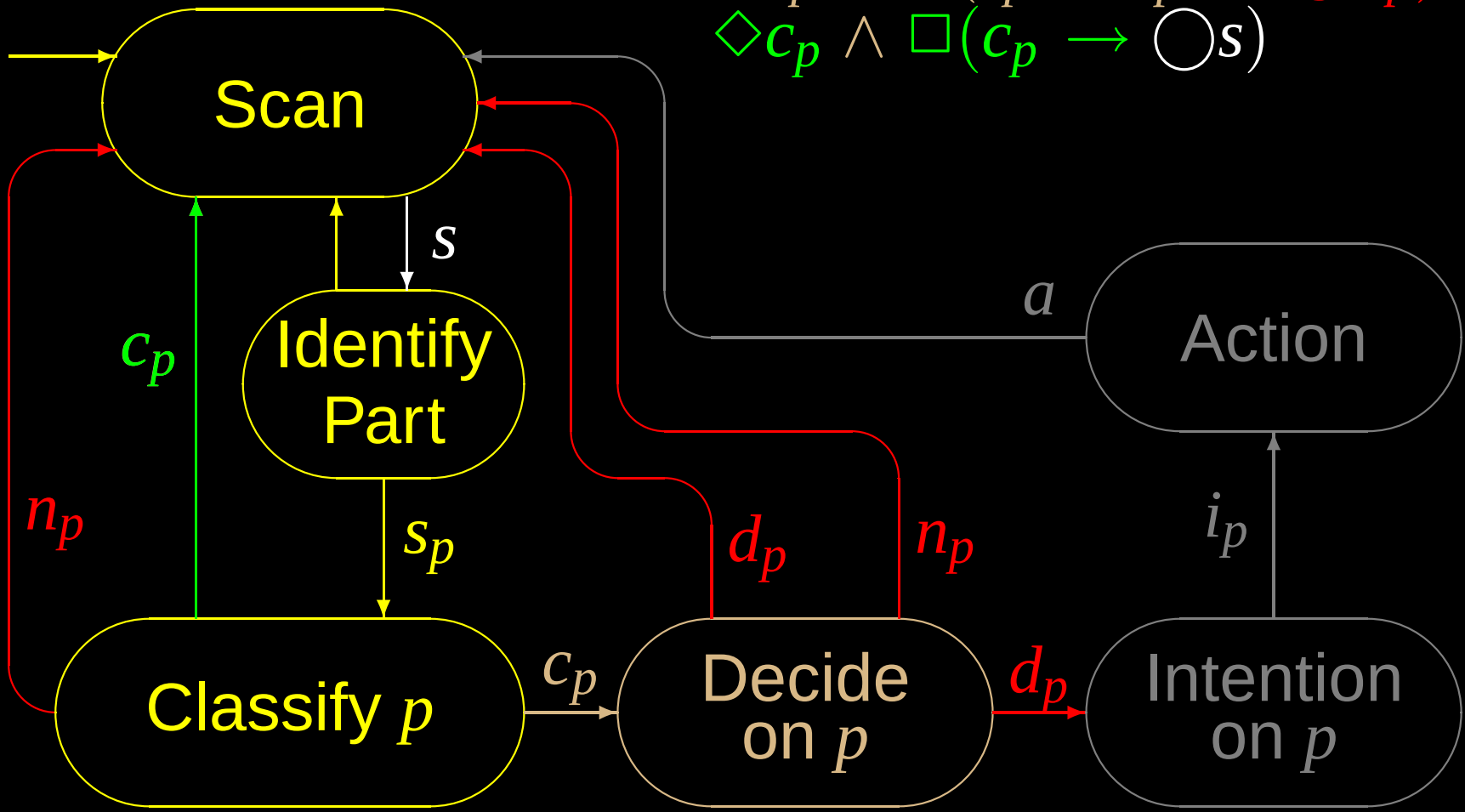

Defer Action for Too Long

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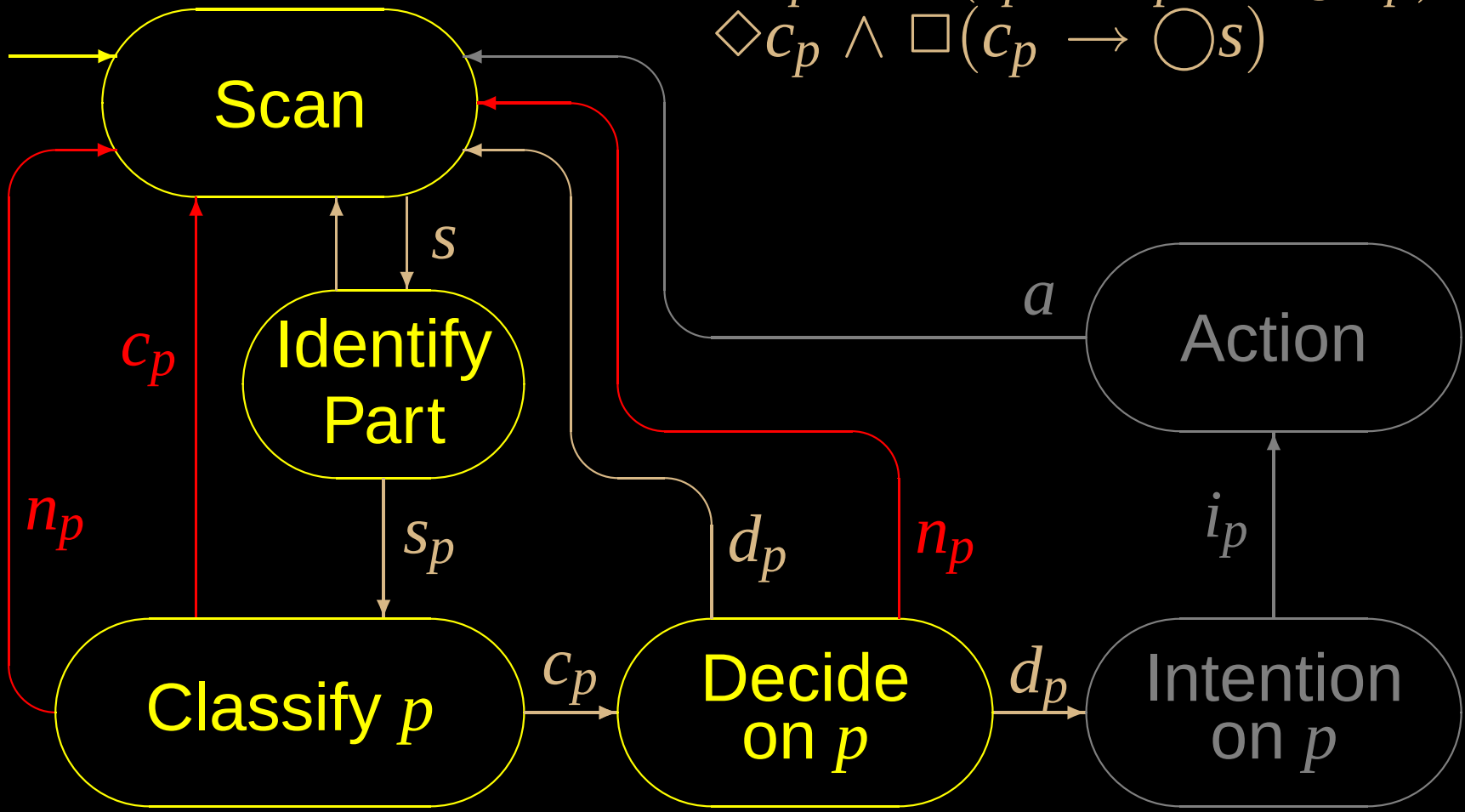

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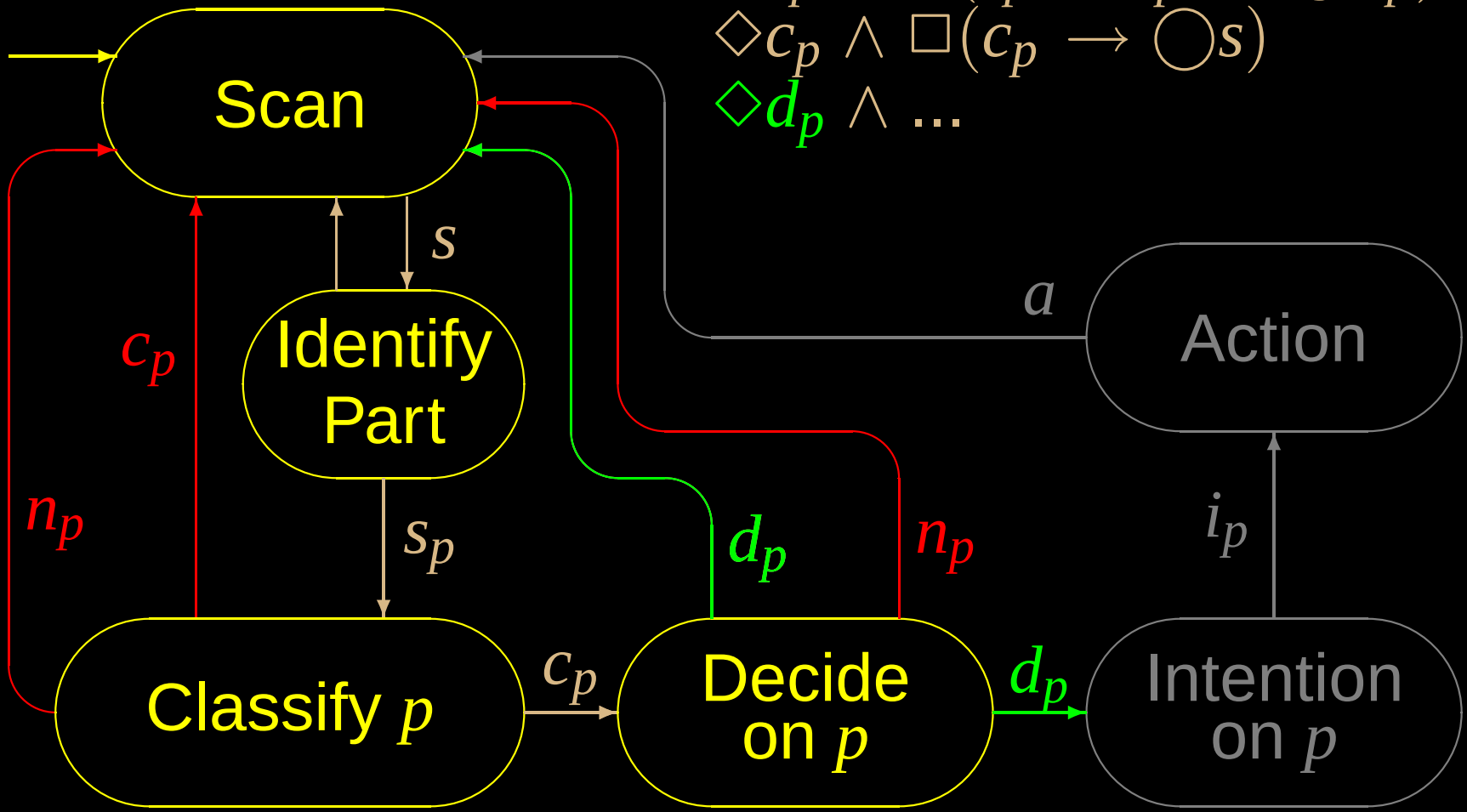

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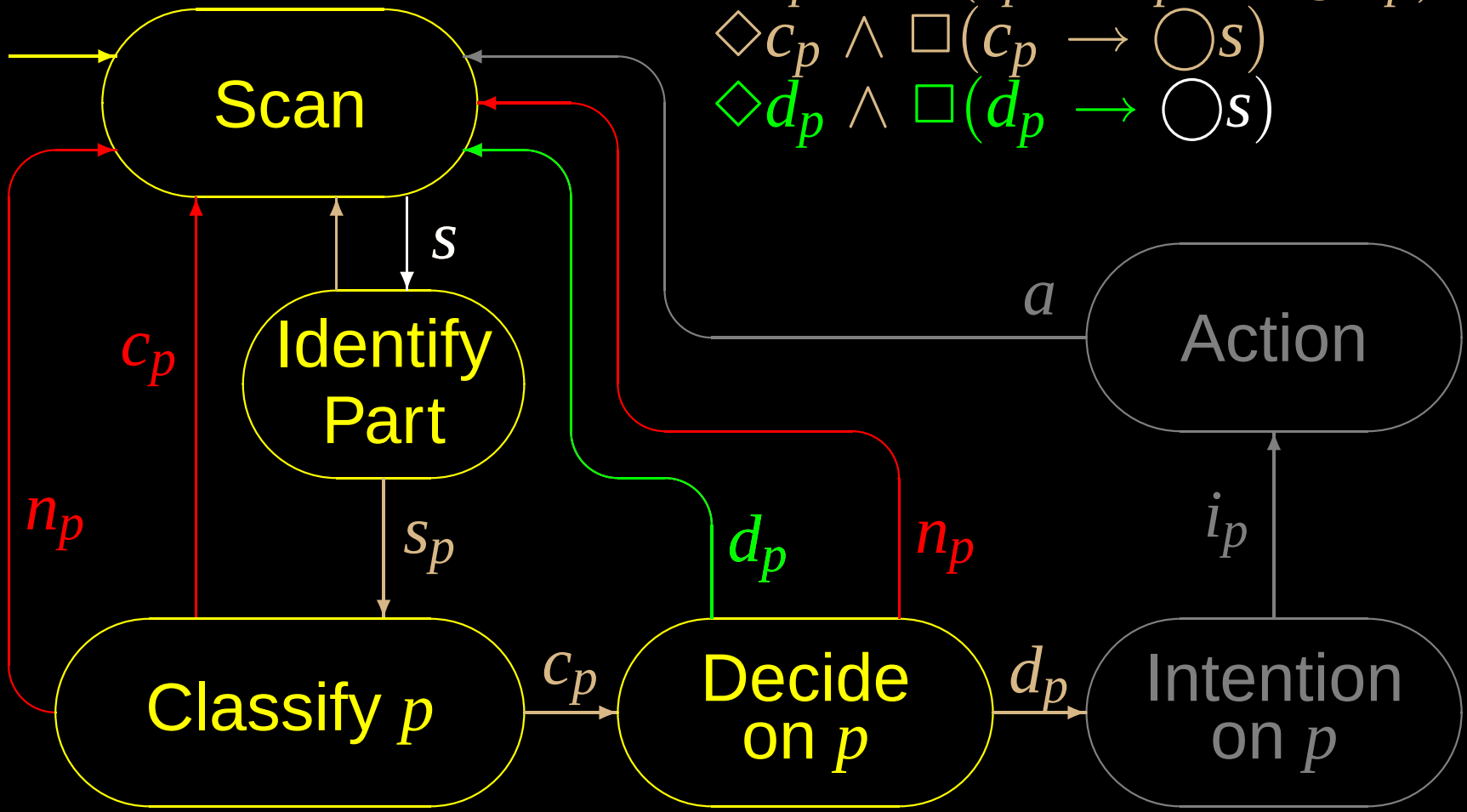

Final Decomposition

$$\mathcal{D}\ (\mathit{no\_intended\_response}_p) = \{\Box\neg\ s_p\ ,$$
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$$\begin{aligned}
&\mathcal{D}\ (\mathit{non_response}_p)\\
&= \{f \wedge \mathit{non_resolved}_p \mid f \in \mathcal{D}\ (\mathit{no_intended_response}_p)\}\\
&= \{\Box\neg\ s_p \wedge \mathit{non_resolved}_p,\\
&\quad \Diamond s_p \wedge \Box(s_p \vee c_p \rightarrow \bigcirc n_p\ ) \wedge \mathit{non_resolved}_p,\\
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\end{aligned}$$

Proofs

- Existence of the Task Failures.
- Disjunction of the Task Failures.
- Soundness of the Decomposition.
- Completeness of the Decomposition.

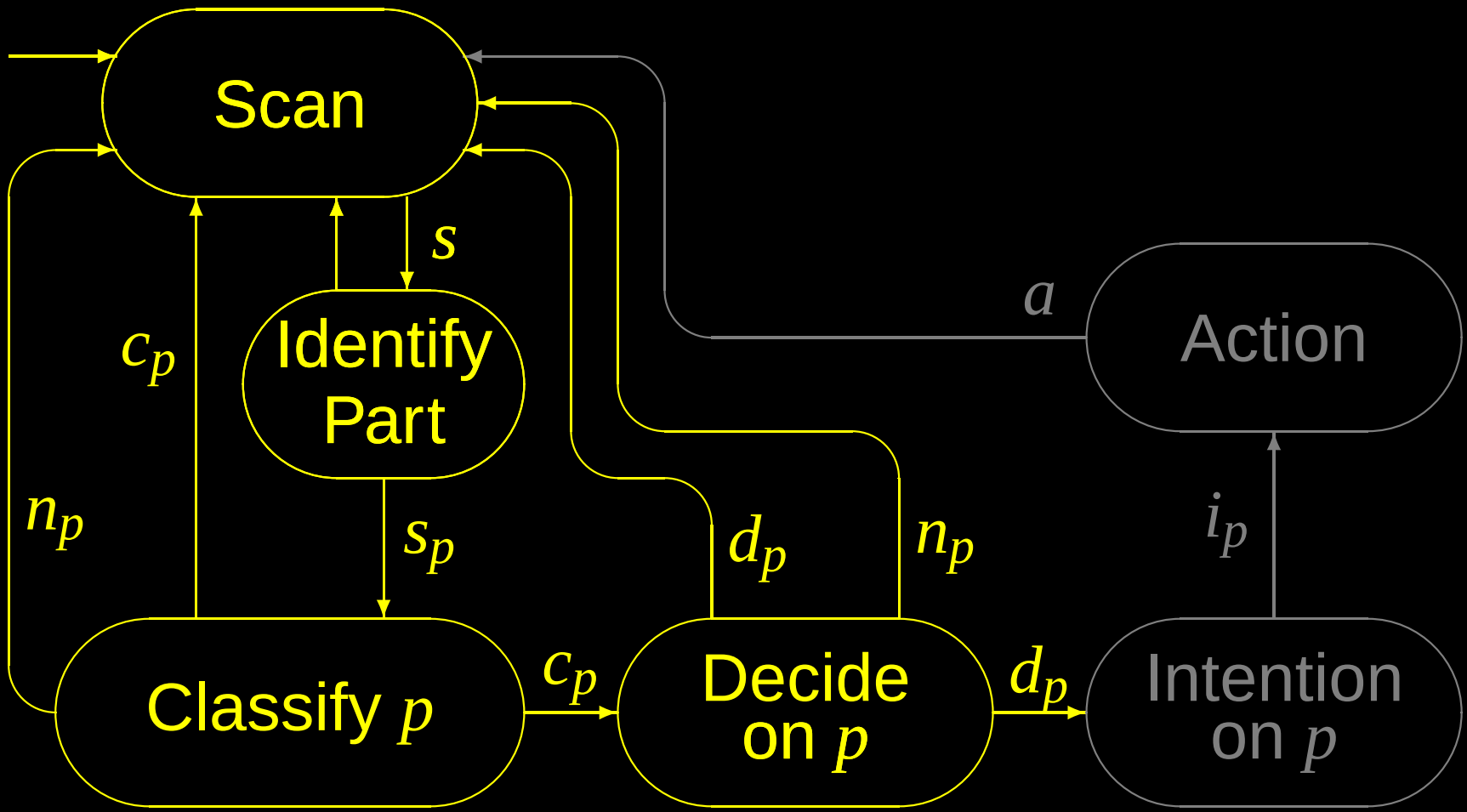
$$OCM \models (\Box \neg\, i_p) \rightarrow \bigvee_{f \in \mathcal{F}} f,$$

where

$$\mathcal{F} = \{fail\_scan_p, pers\_mis\_clas_p, pers\_mis\_prio_p \\ cont\_dec\_proc_p, def\_too\_long_p\}$$

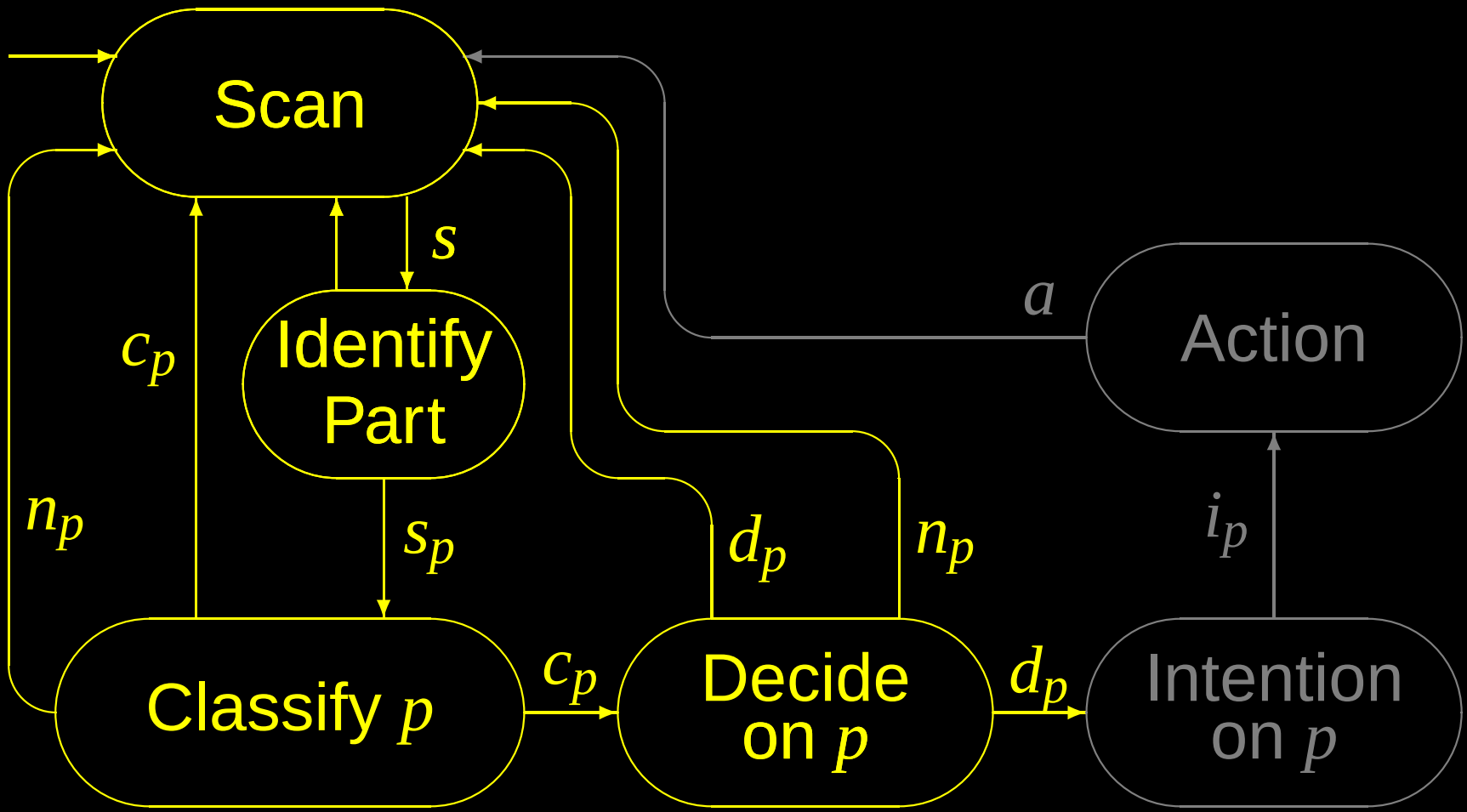
Soundness

Soundness


Scan
Identify Part
Classify p
Decide on p
Action
Intention on p
s
c_p
n_p
s_p
d_p
n_p
a
i_p
c_p
d_p

Soundness

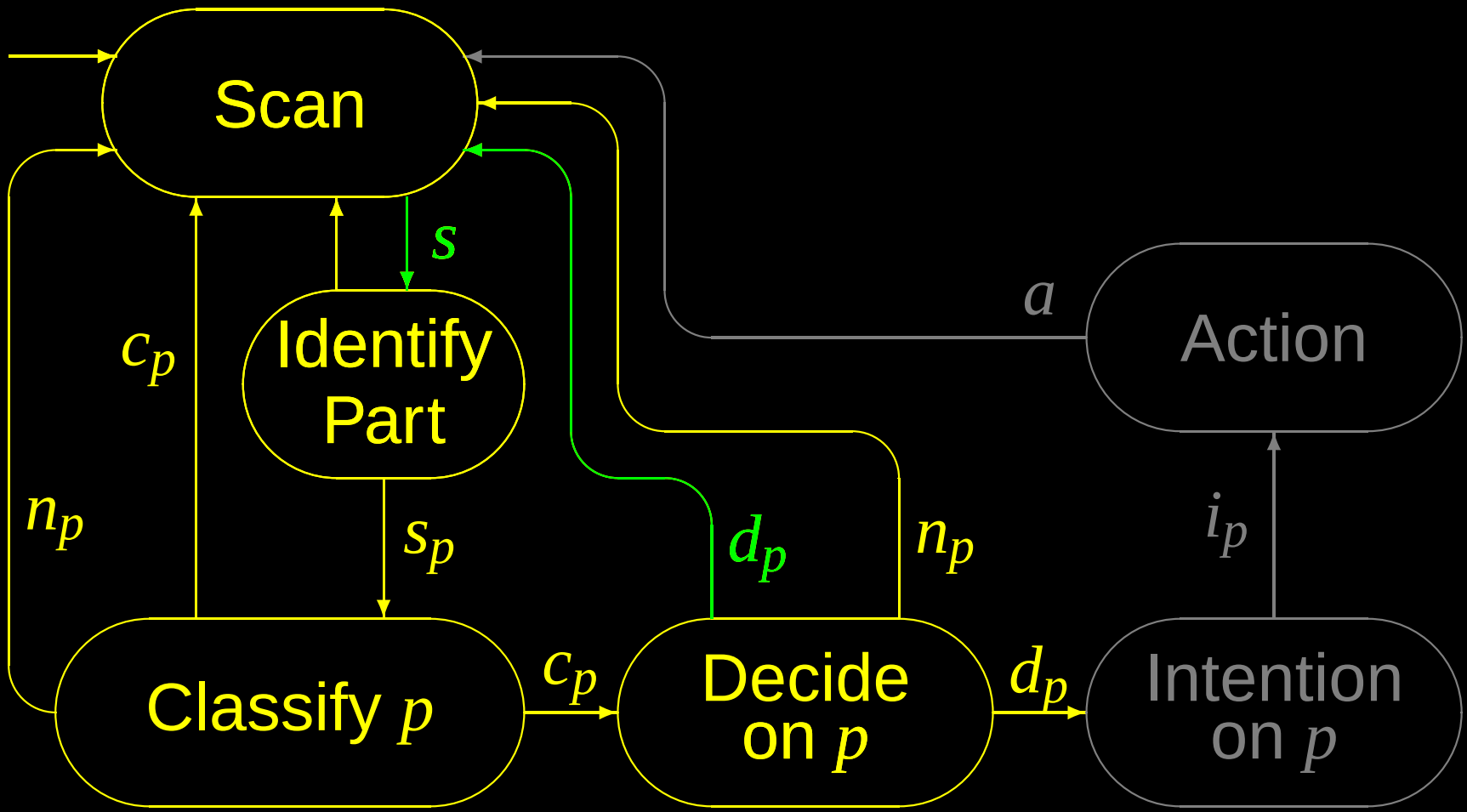
Example: Defer action for too long



Soundness

Example: Defer action for too long

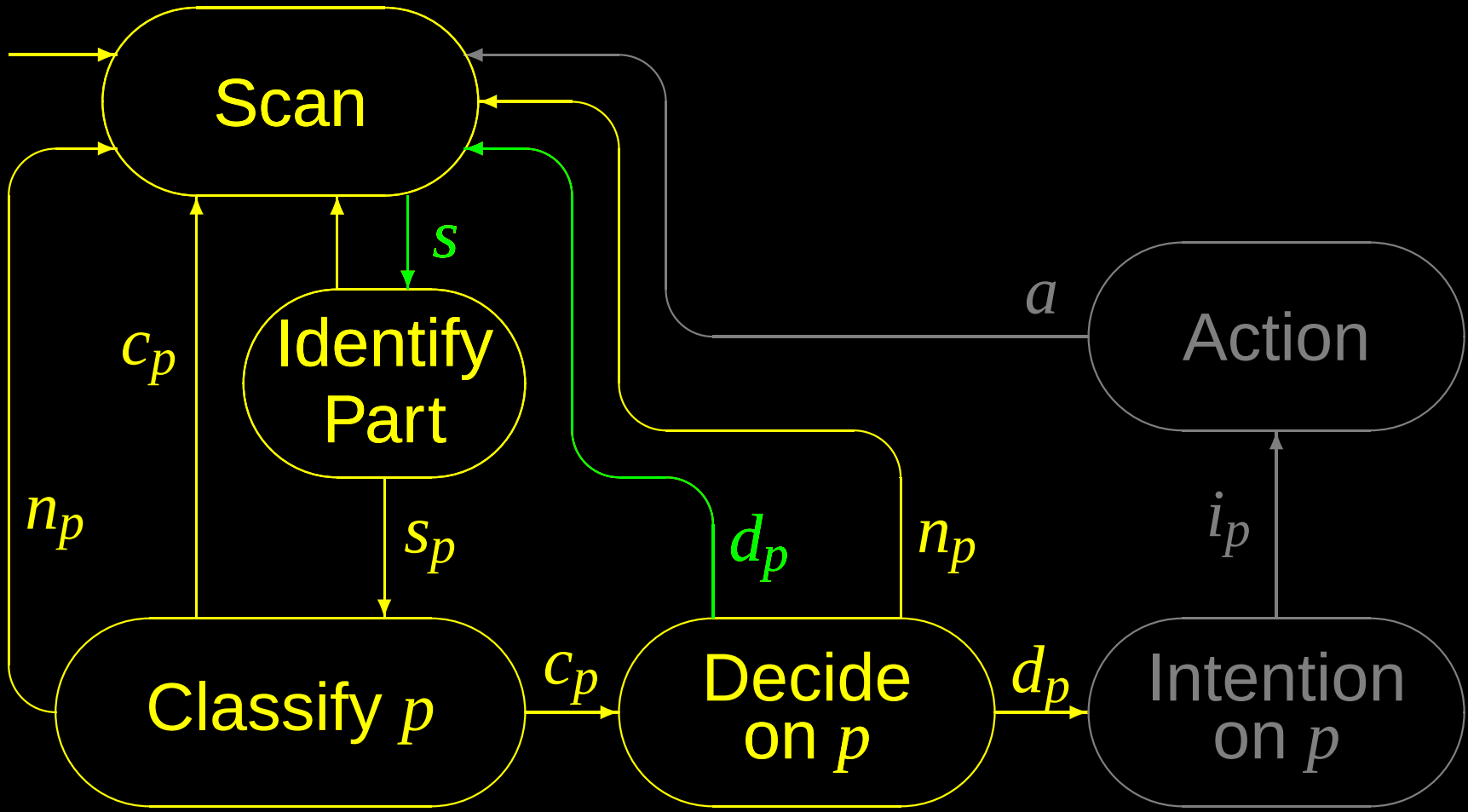
$$\Diamond d_p \wedge \Box(d_p \rightarrow \bigcirc s)$$



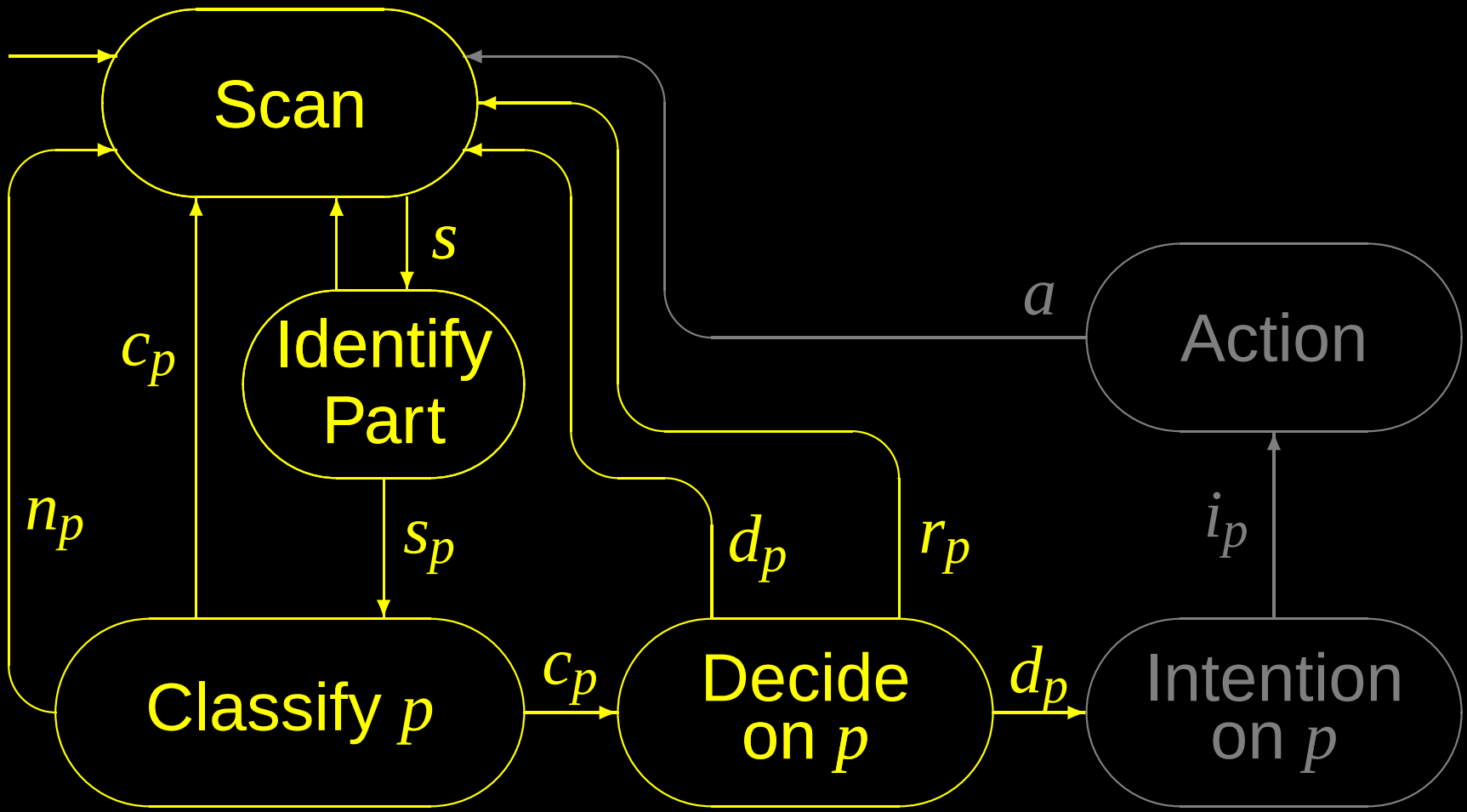
Soundness

Example: Defer action for too long

$$(\Diamond d_p \wedge \Box(d_p \rightarrow \bigcirc s)) \rightarrow \Box\neg\, i_p$$

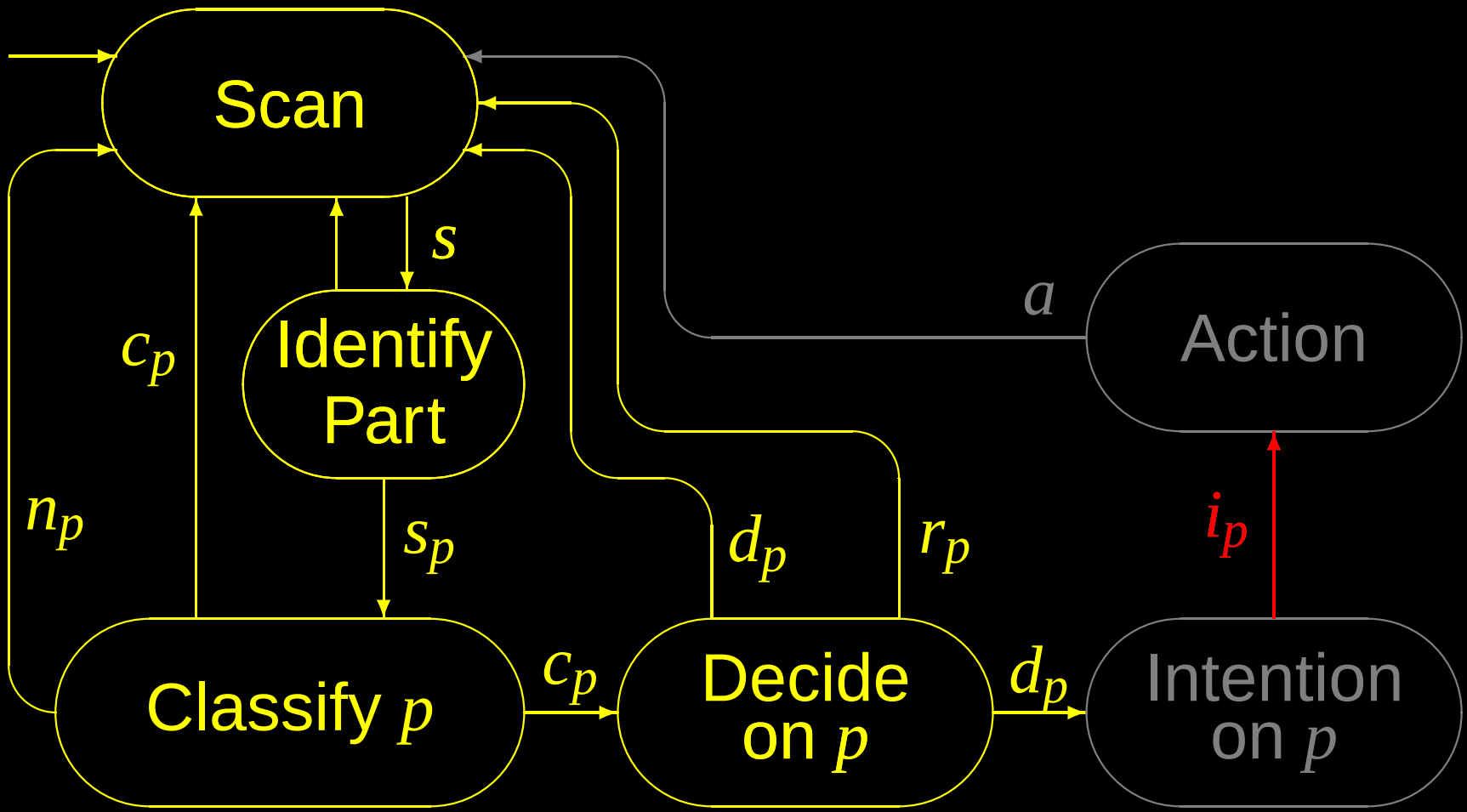


Completeness



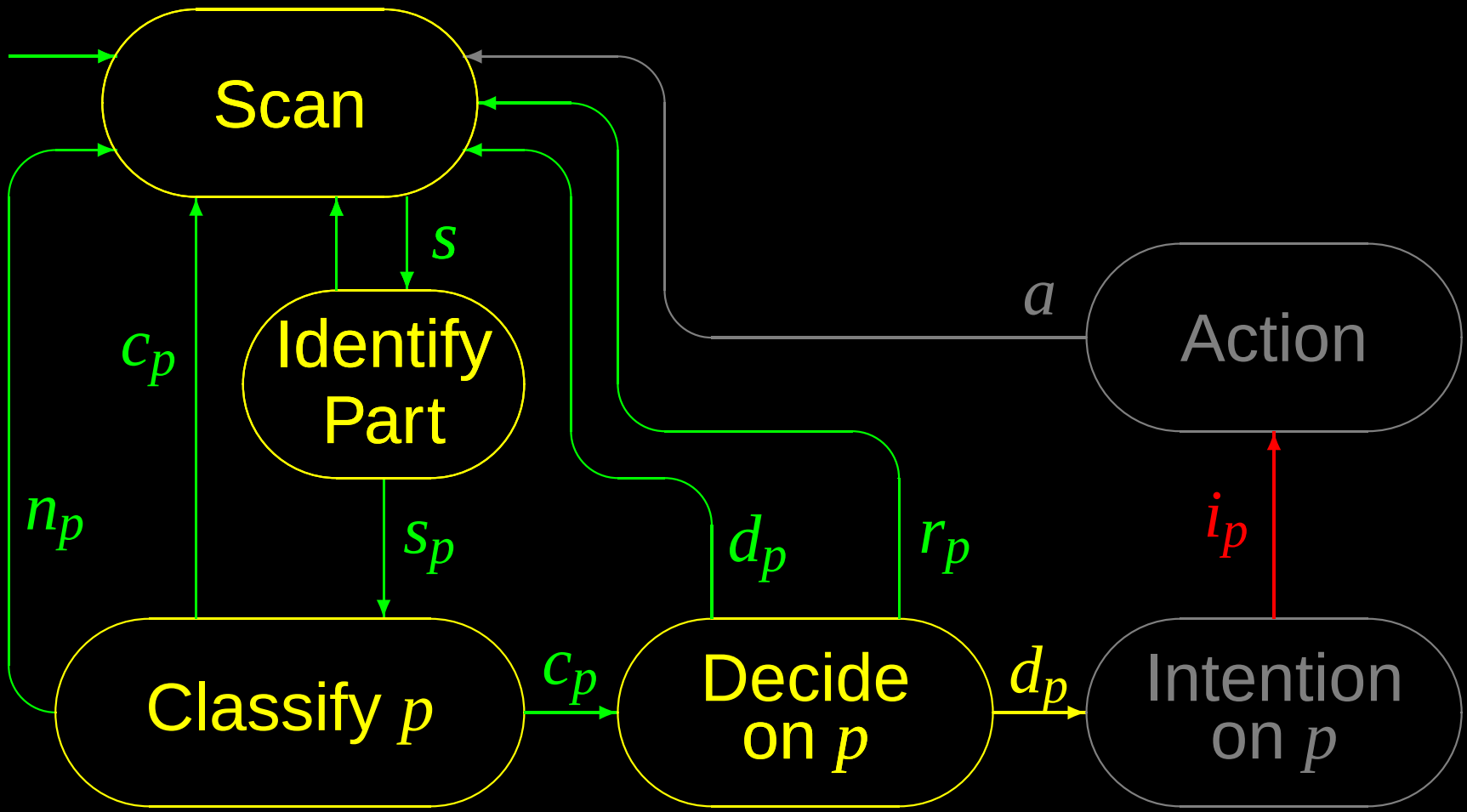
Completeness

$\Box\neg\, i_p \ \ldots$



Completeness

$\Box\neg\, i_p \rightarrow \ldots$



Completeness

$$\Box\neg\, i_p \;\rightarrow \bigvee_{f\in\mathcal{F}} f$$

where

$$\mathcal{F} \;= \mathcal{D}\;(\Box\neg\, i_p) = \mathcal{D}\;(no\_intended\_response_p) =$$

Completeness

$$\Box\neg\, i_p \;\rightarrow \bigvee_{f\in\mathcal{F}} f$$

where

$$\mathcal{F} \;= \mathcal{D}\;(\Box\neg\, i_p) = \mathcal{D}\;(no\_intended\_response_p) =$$
$$\{\, \Box\neg\, s_p\;,$$
$$\Diamond s_p \wedge \Box(s_p \vee c_p \rightarrow \bigcirc n_p)\;,$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)\;,$$
$$\Diamond d_p \wedge \Box(d_p \rightarrow \bigcirc s)\;\}$$

Model-checking Properties

using The Concurrency Workbench of the New Century

http://www.cs.sunysb.edu/∼cwb/

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- Soundness $\Longrightarrow$ YES

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- Soundness $\Longrightarrow$ YES
- Completeness $\Longrightarrow$ NO

Model-checking Properties

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- Soundness $\Longrightarrow$ YES
- Completeness $\Longrightarrow$ NO
  $\Longrightarrow$ counterexample

Exercise

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- Which error did I (deliberately) make while explaining the decomposition?

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- Does the model need to be modified?
- Does the decomposition need to be modified?
- Modify model and/or decomposition to achieve completeness

Exercise

- Which error did I (deliberately) make while explaining the decomposition?
- What caused such an error?
- Find and analyse the counterexample which falsifies completeness
- Does the model need to be modified?
- Does the decomposition need to be modified?
- Modify model and/or decomposition to achieve completeness
- Give a psychological interpretation to the task failure in the correct decomposition

Any Solution?

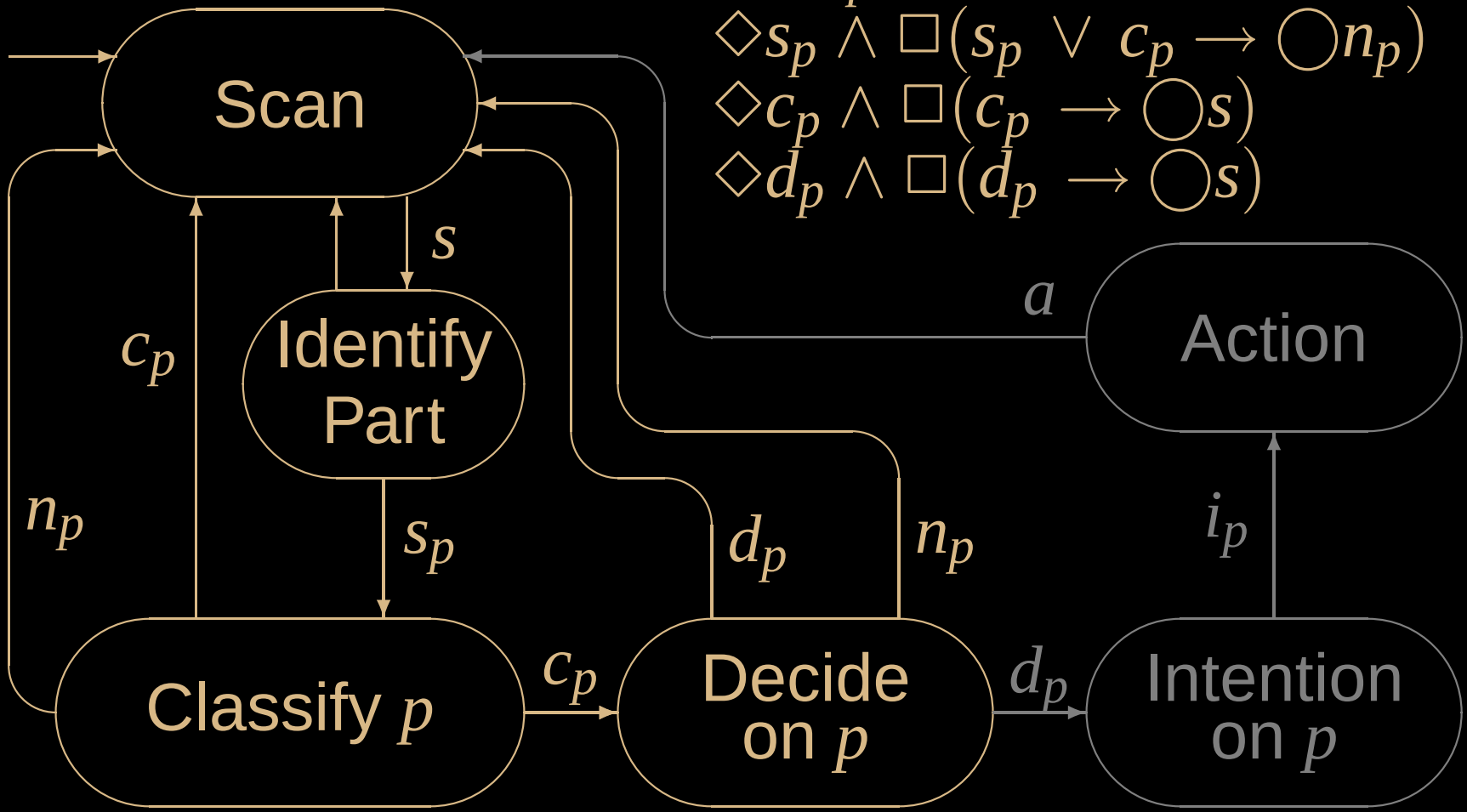
$no\_intended\_response_p$:

$\Box \neg s_p$

$\Diamond s_p \wedge \Box(s_p \vee c_p \rightarrow \bigcirc n_p)$

$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)$

$\Diamond d_p \wedge \Box(d_p \rightarrow \bigcirc s)$

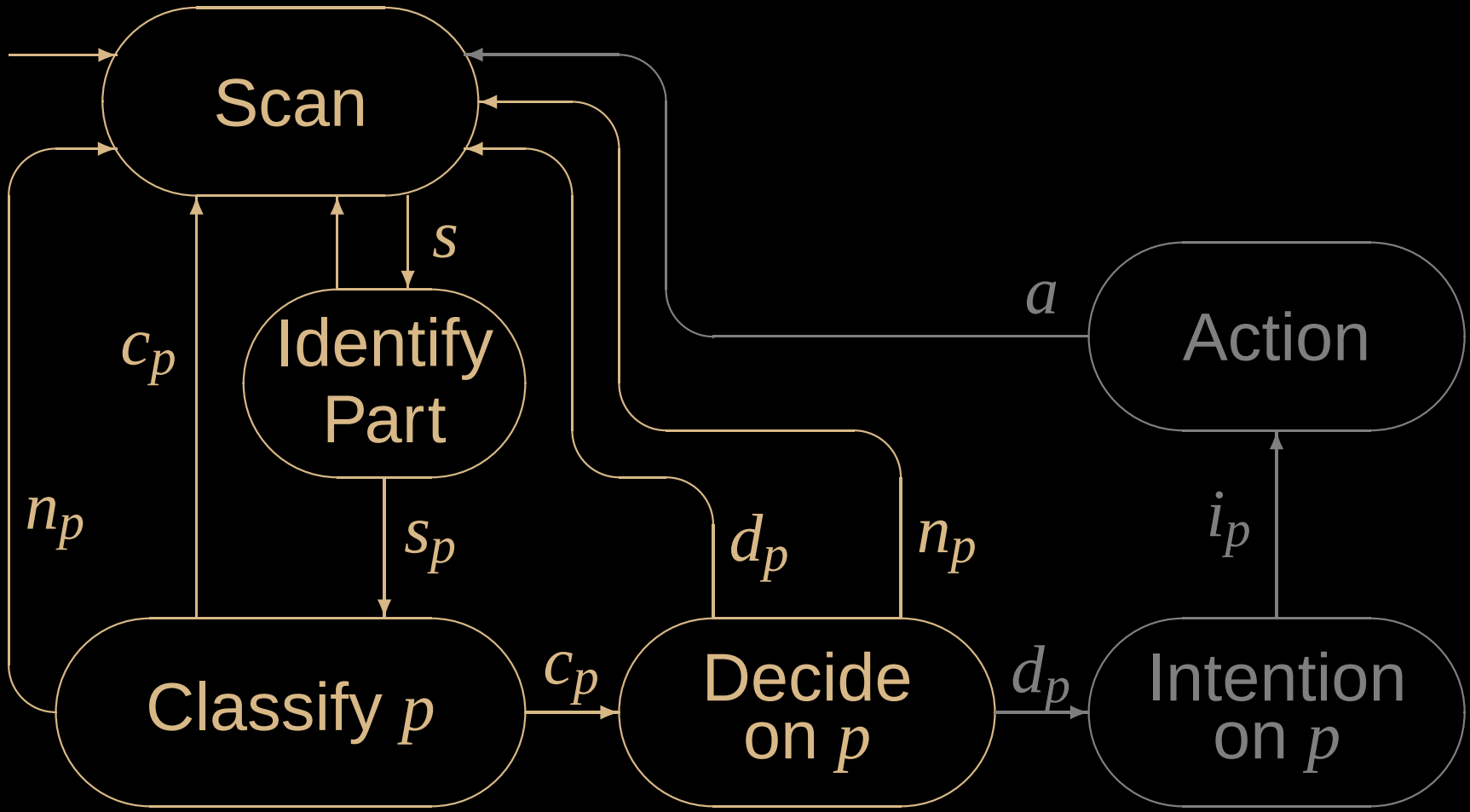


Solution: Counterexample

Find and analyse the counterexample which falsifies completeness

Solution: Counterexample

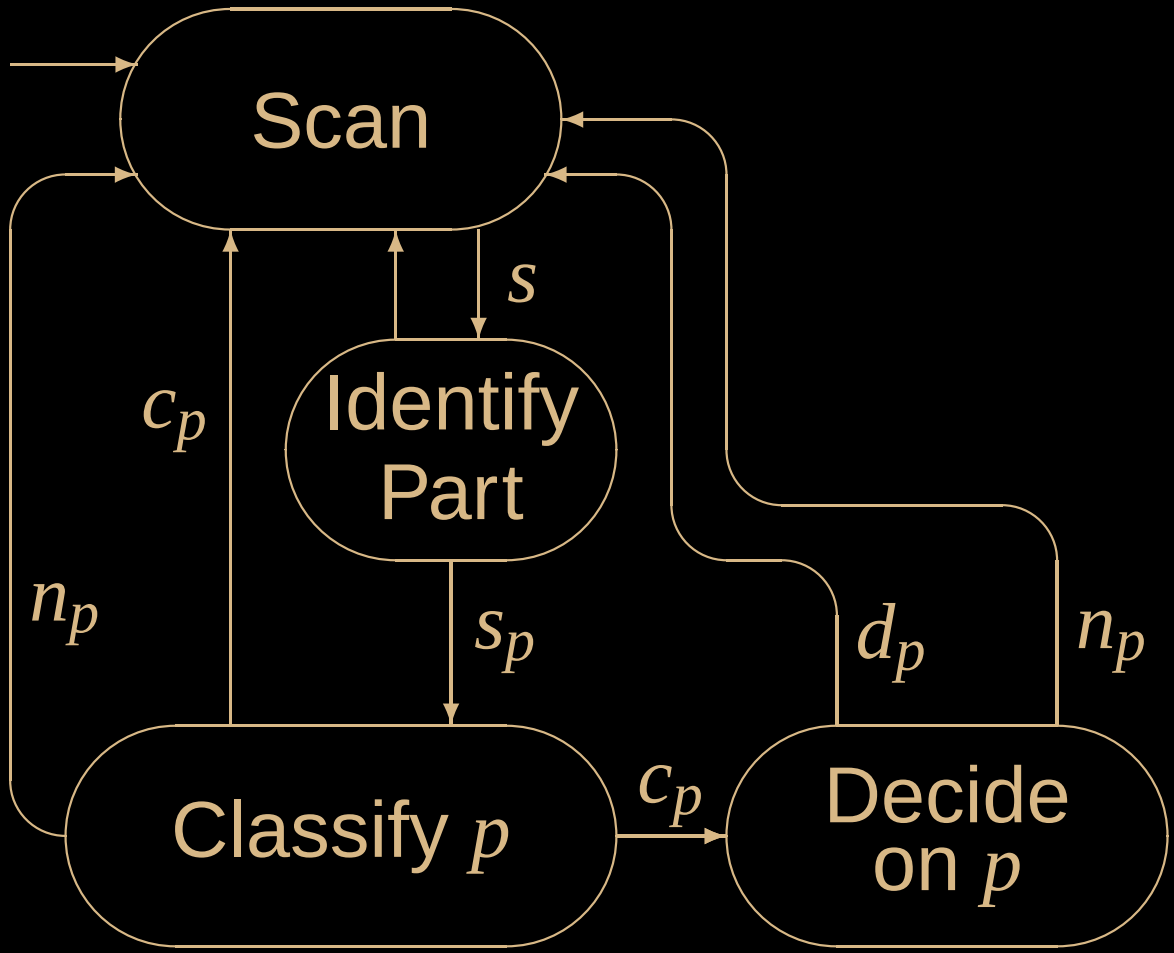
Find and analyse the counterexample



Solution: Counterexample

Find and analyse the counterexample

$$s \longrightarrow s_p \longrightarrow c_p \longrightarrow s \longrightarrow s_p \longrightarrow c_p \longrightarrow n_p \longrightarrow s \longrightarrow \ldots$$



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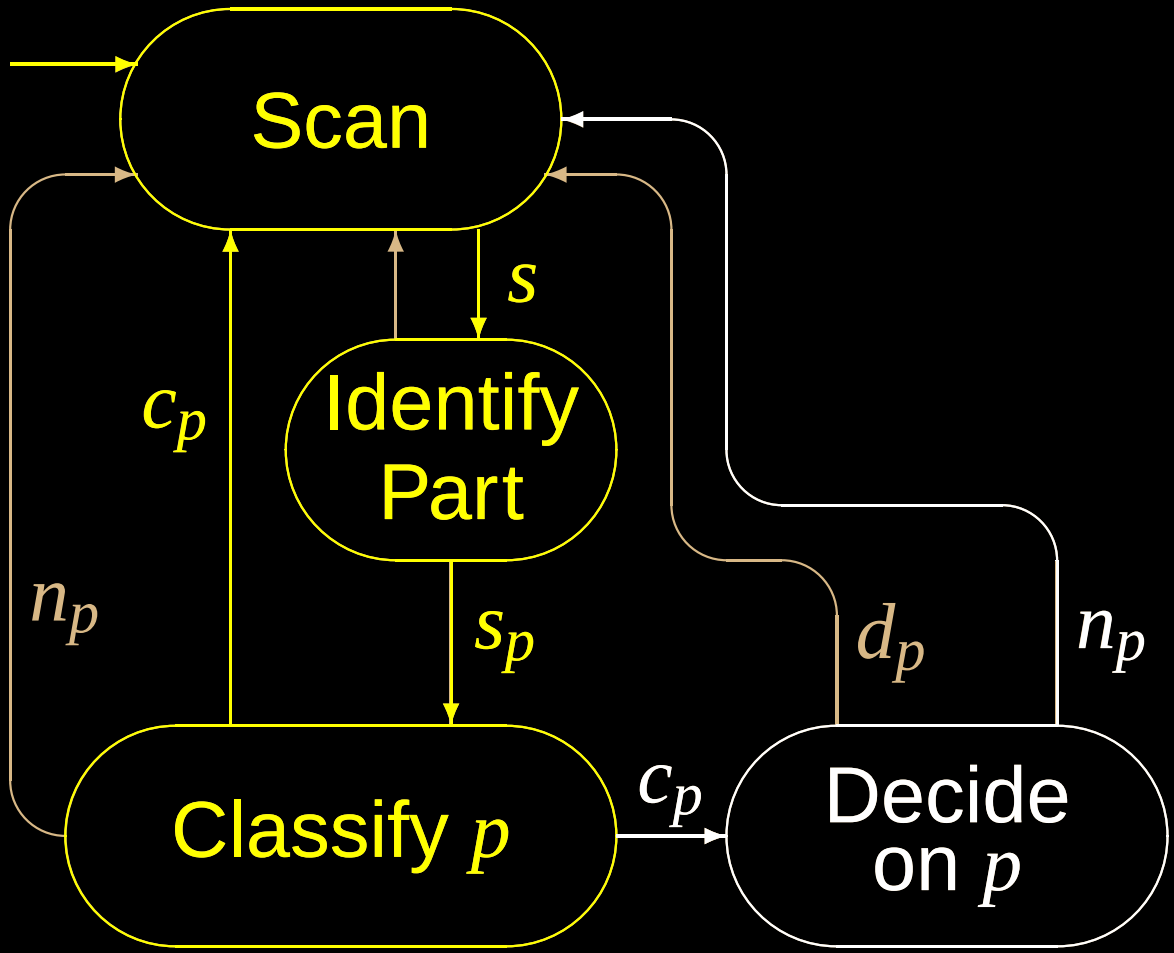

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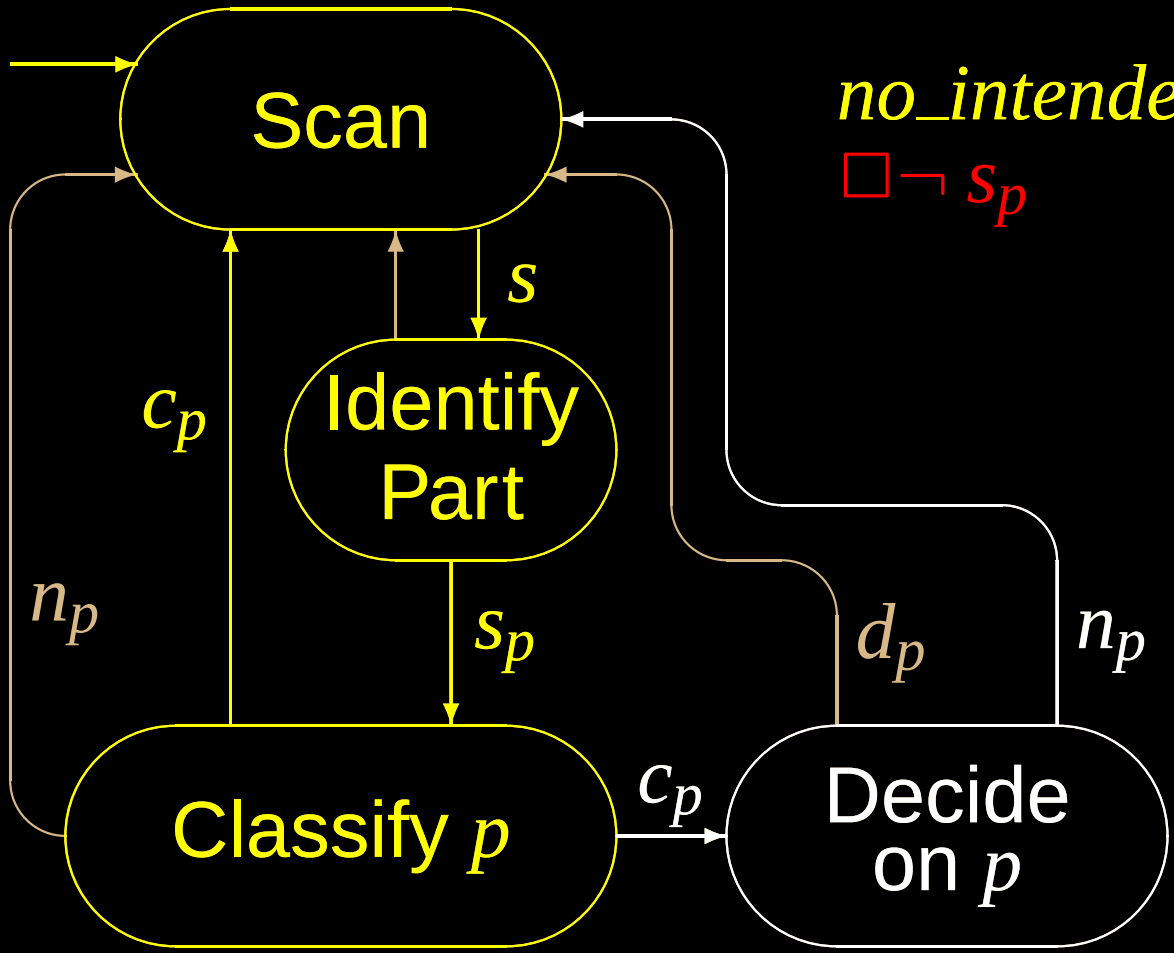

$no\_intended\_response_p$:

$\Box \neg s_p$

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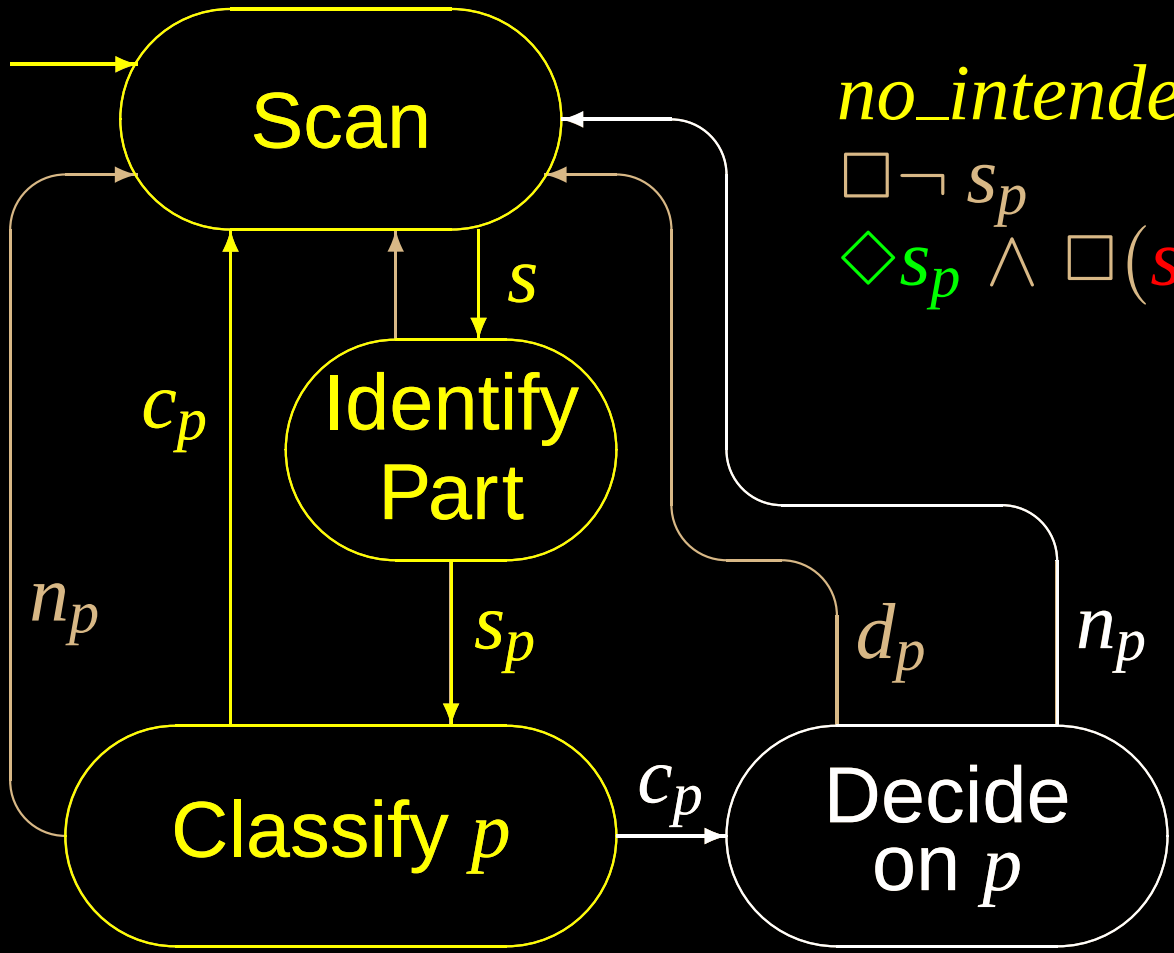

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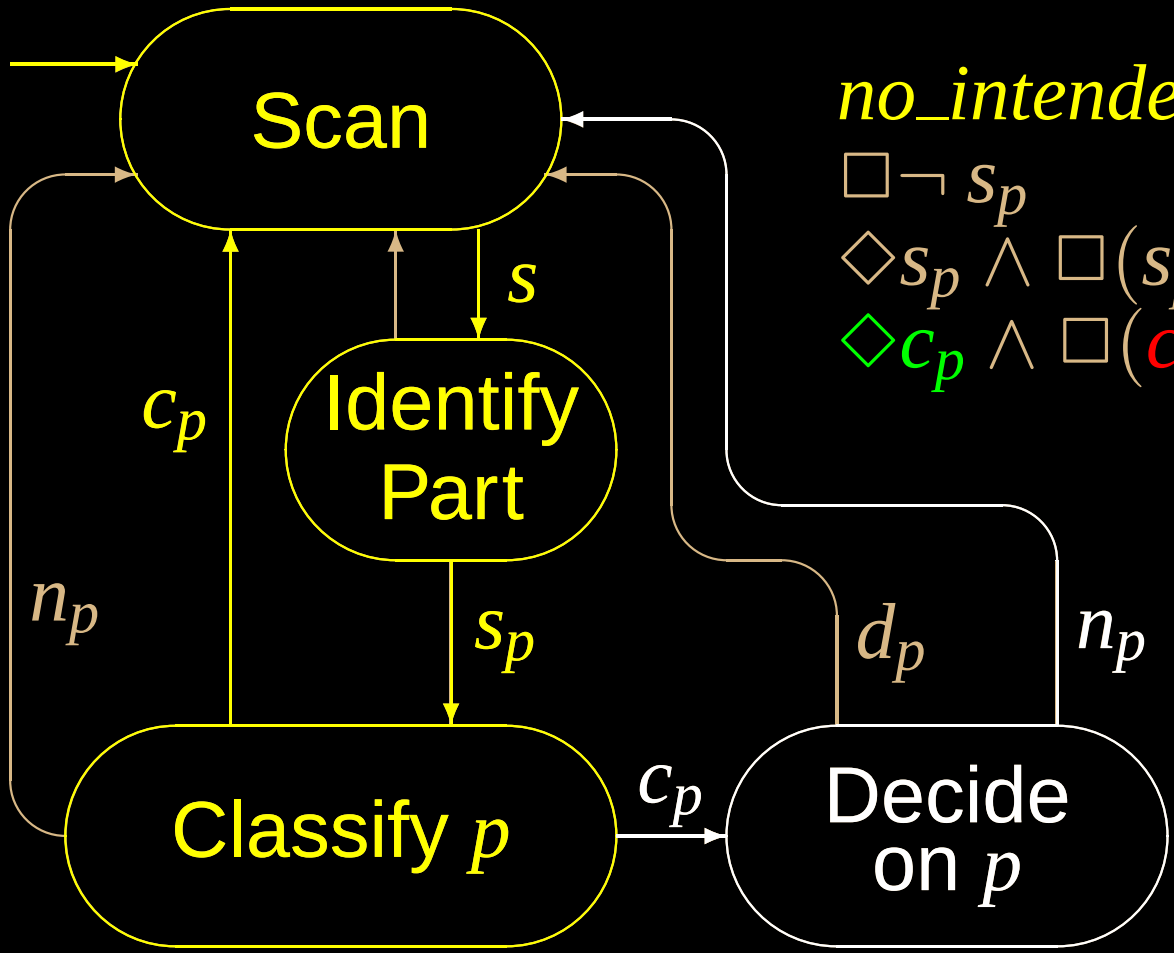

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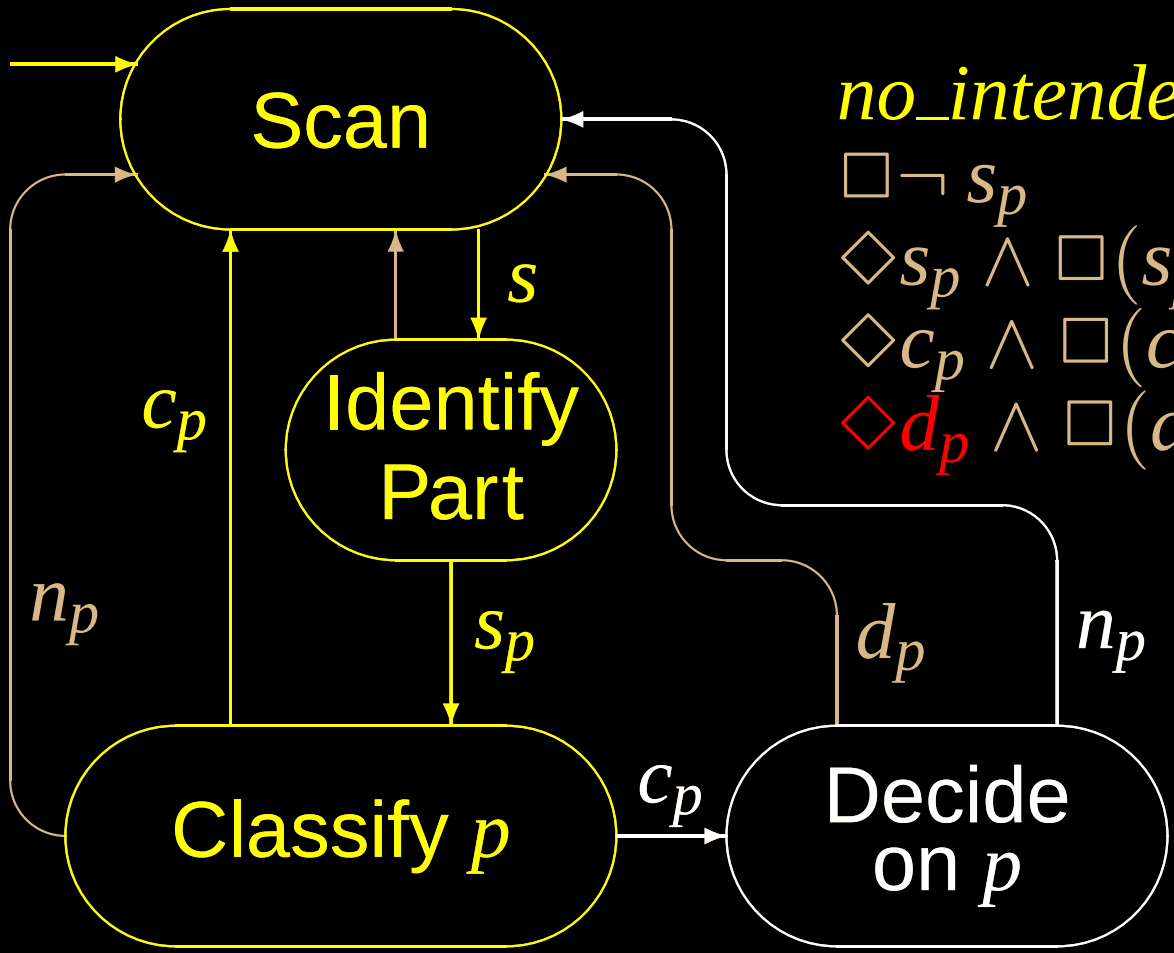

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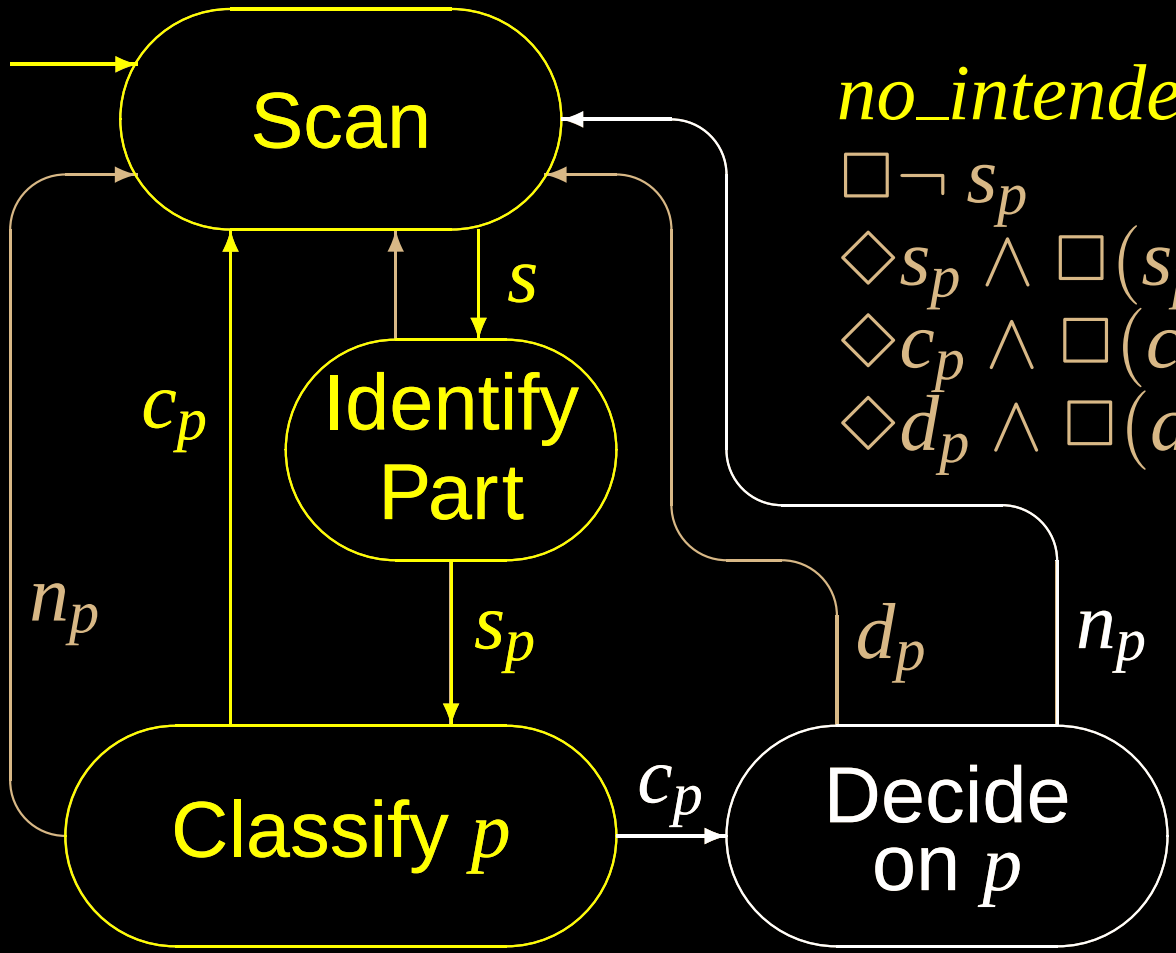

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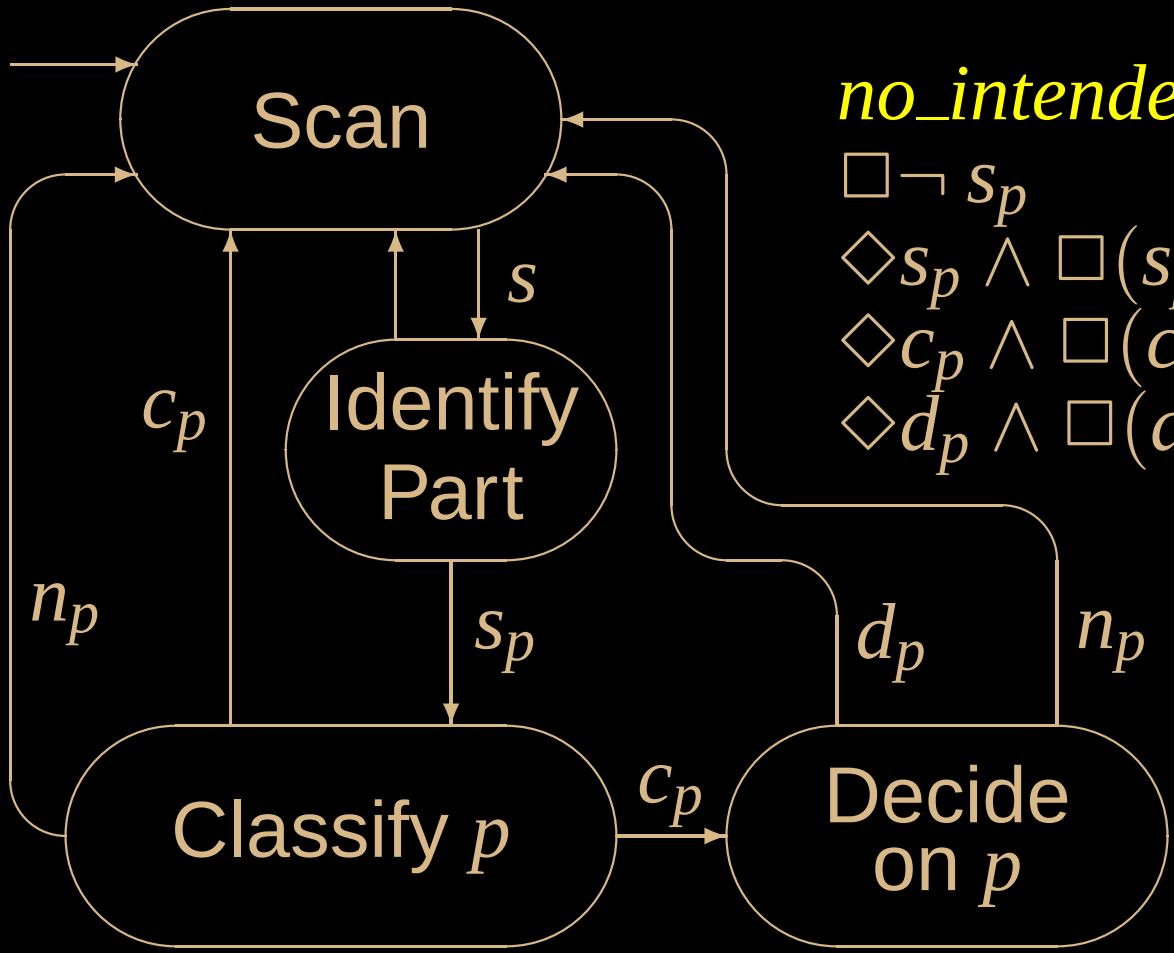
Solution: Error

Which error did I (deliberately) make while explaining the decomposition?



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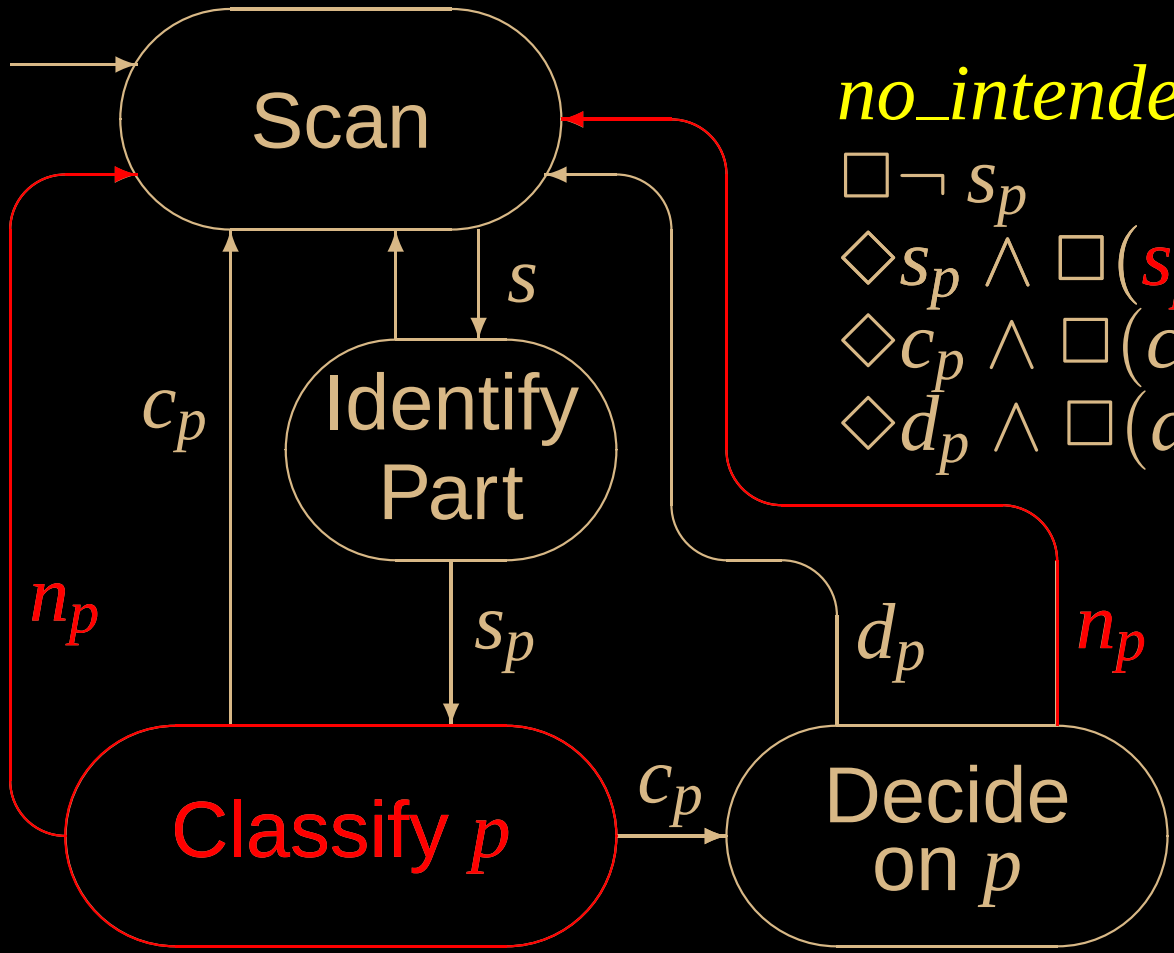
Solution: Error

Persisten Mis-classification $\Longleftarrow$ repeated classification as a non conflict causes a perception distorted by the mistaken belief that p is not in conflict



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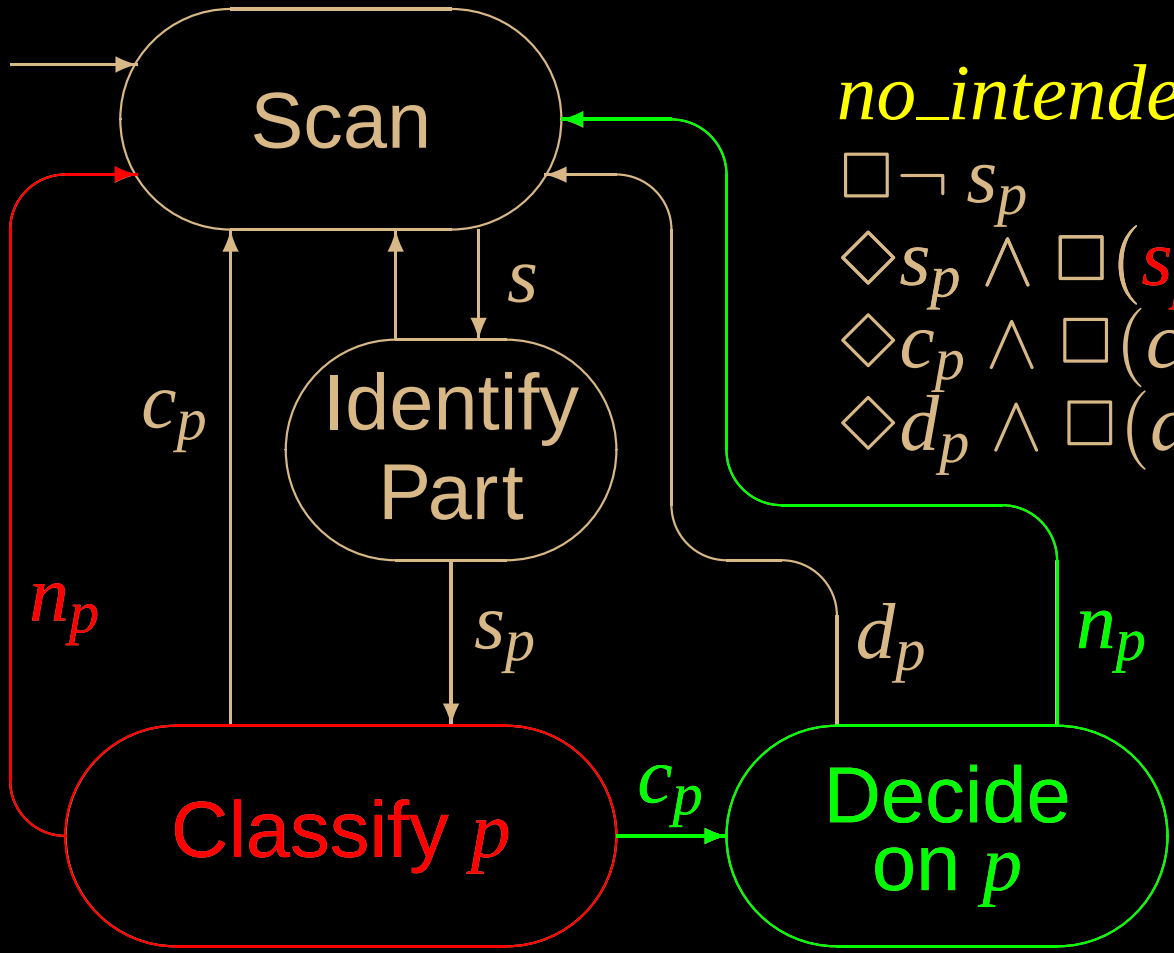

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Contrary Decision Process $\Longleftarrow$ previous decisions on similar pairs

Solution: Error Cause

What caused such an error?

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- use of the same action name n to denote the results of two cognitive processes

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Solution: Error Cause

What caused such an error?

- use of the same action name n to denote the results of two cognitive processes
- aim at an elegant and easy to understand (to psychologists) formal model
  $\Longrightarrow$ focus on syntactical look of formulae
  rather than on their interpretation on the model

Solution: Model?

Does the model need to be modified?

Solution: Model?

Does the model need to be modified?

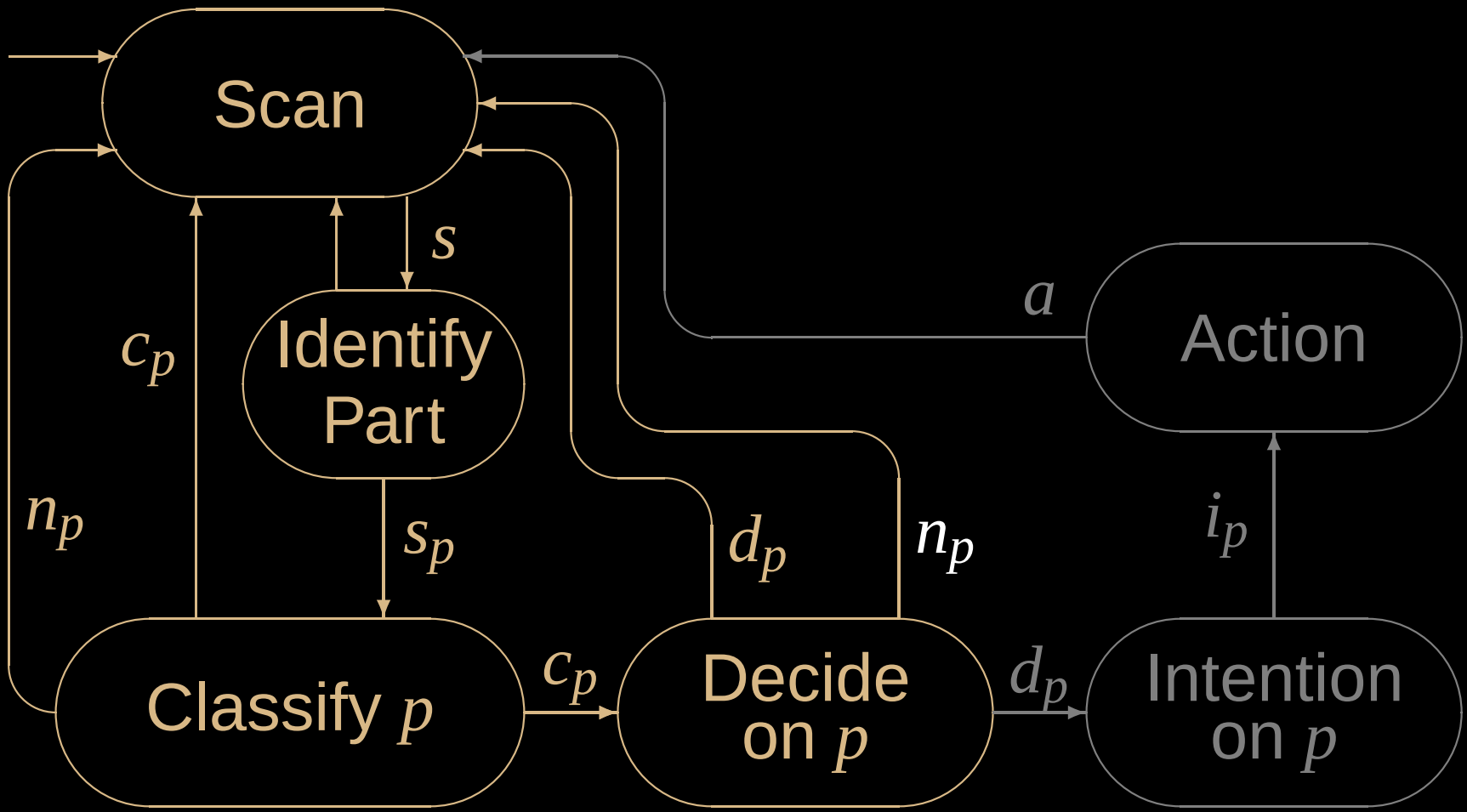
- Error Cause: use of the same action name n to denote the results of two cognitive processes

Solution: Model?

Does the model need to be modified?

- Error Cause: use of the same action name n to denote the results of two cognitive processes
- Change to the model: use action r_p to replace some of the n_p actions.

Solution: New Model



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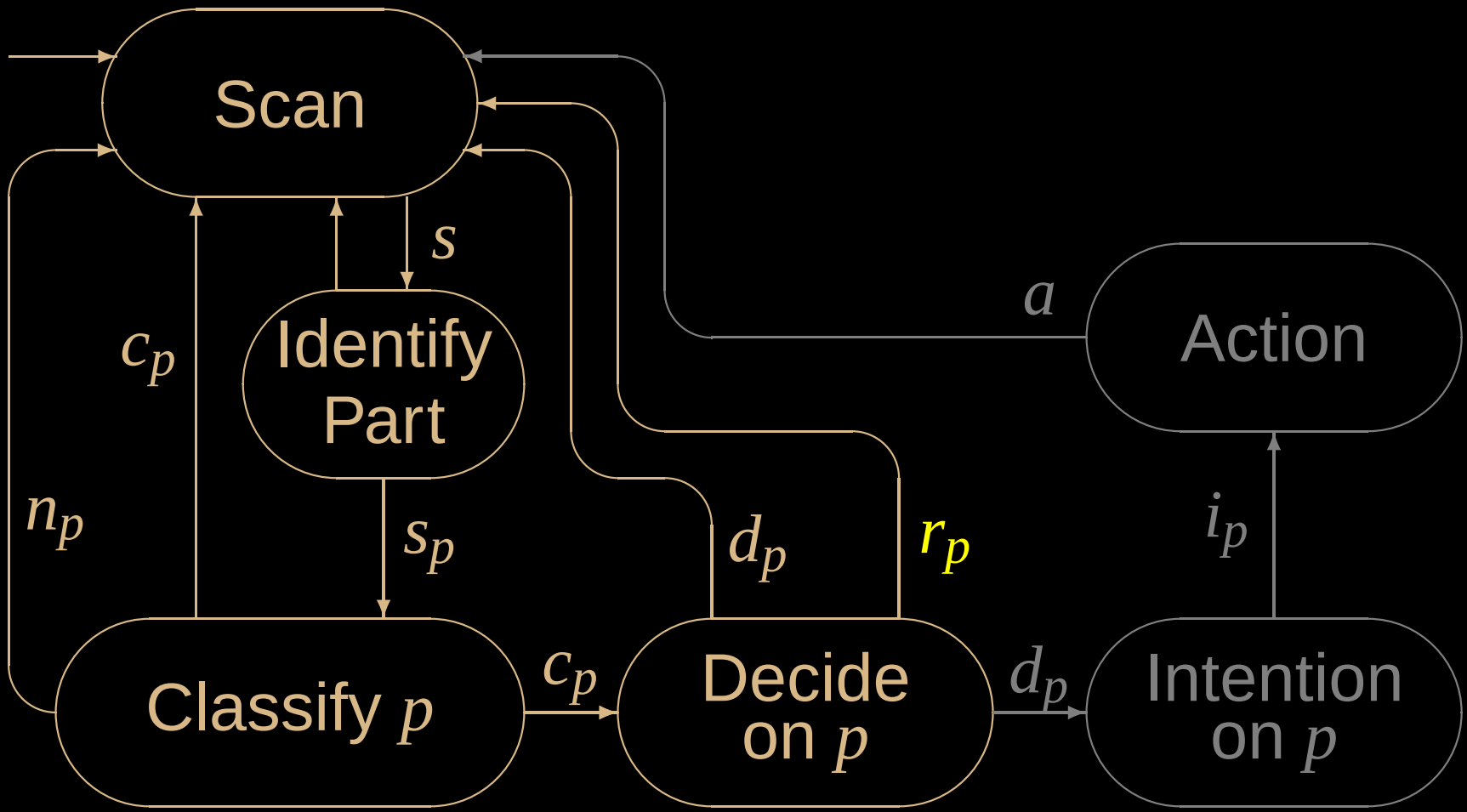


Solution: Decomposition?

Does the decomposition need to be modified?

Solution: Decomposition?

Does the decomposition need to be modified?

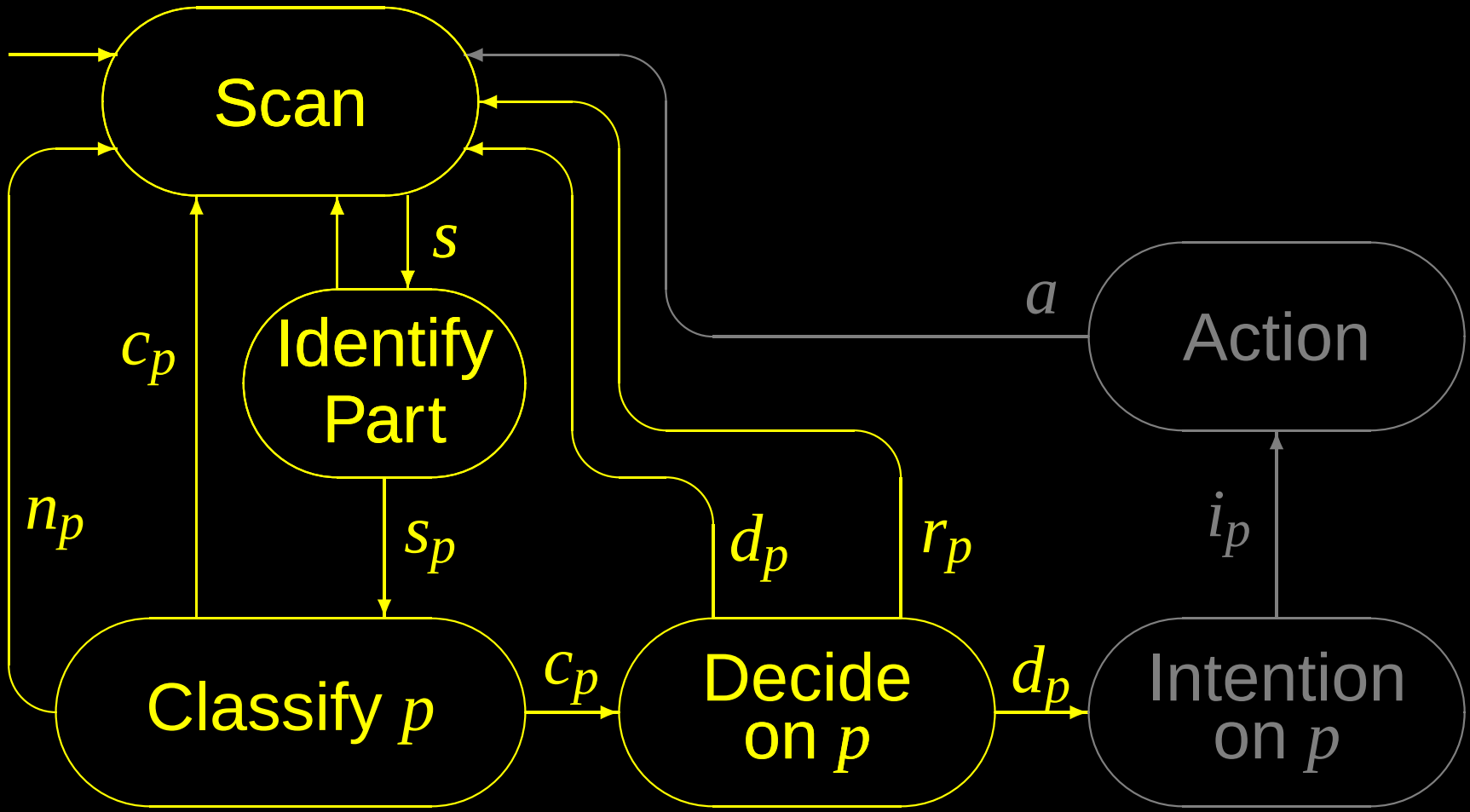
YES!
The decomposition need to cover the counterex-ample

Solution: Completeness

Modify model and/or decomposition to achieve completeness

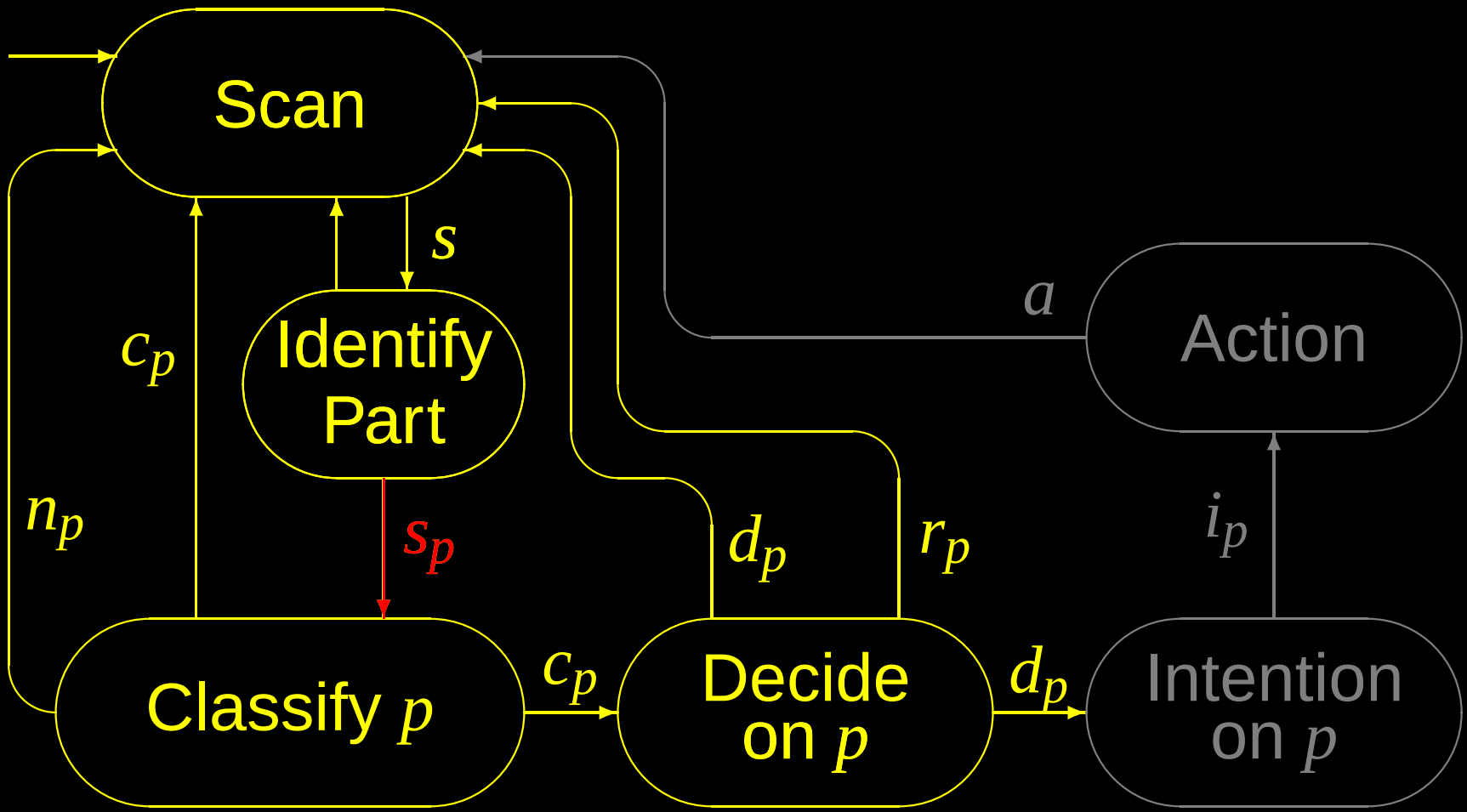
Failure of Scanning

$no\_intended\_response_p$:



Failure of Scanning

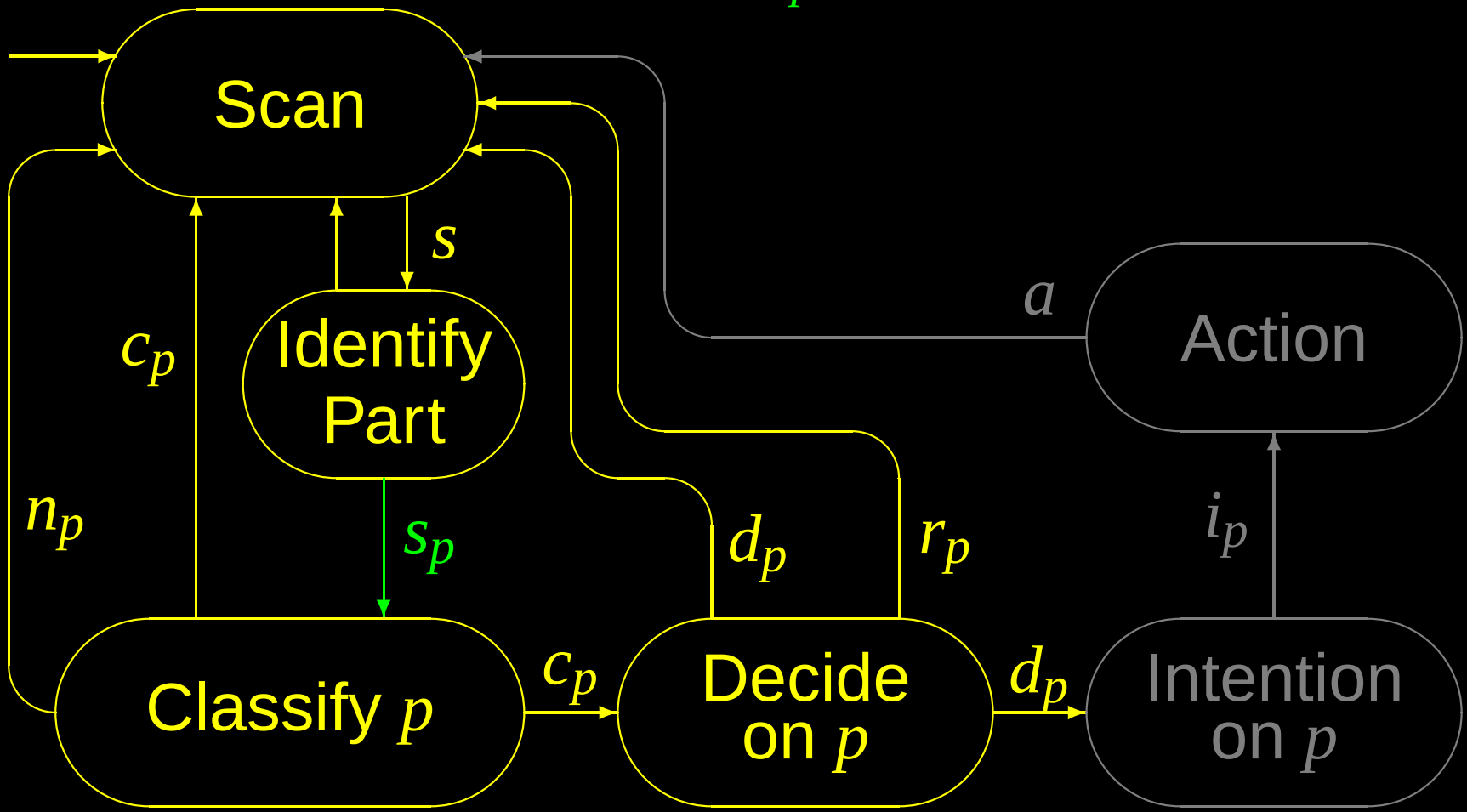
$no\_intended\_response_p$: $\Box \neg s_p$



Failure of Making Decision

$no\_intended\_response_p$: $\Box \neg s_p$

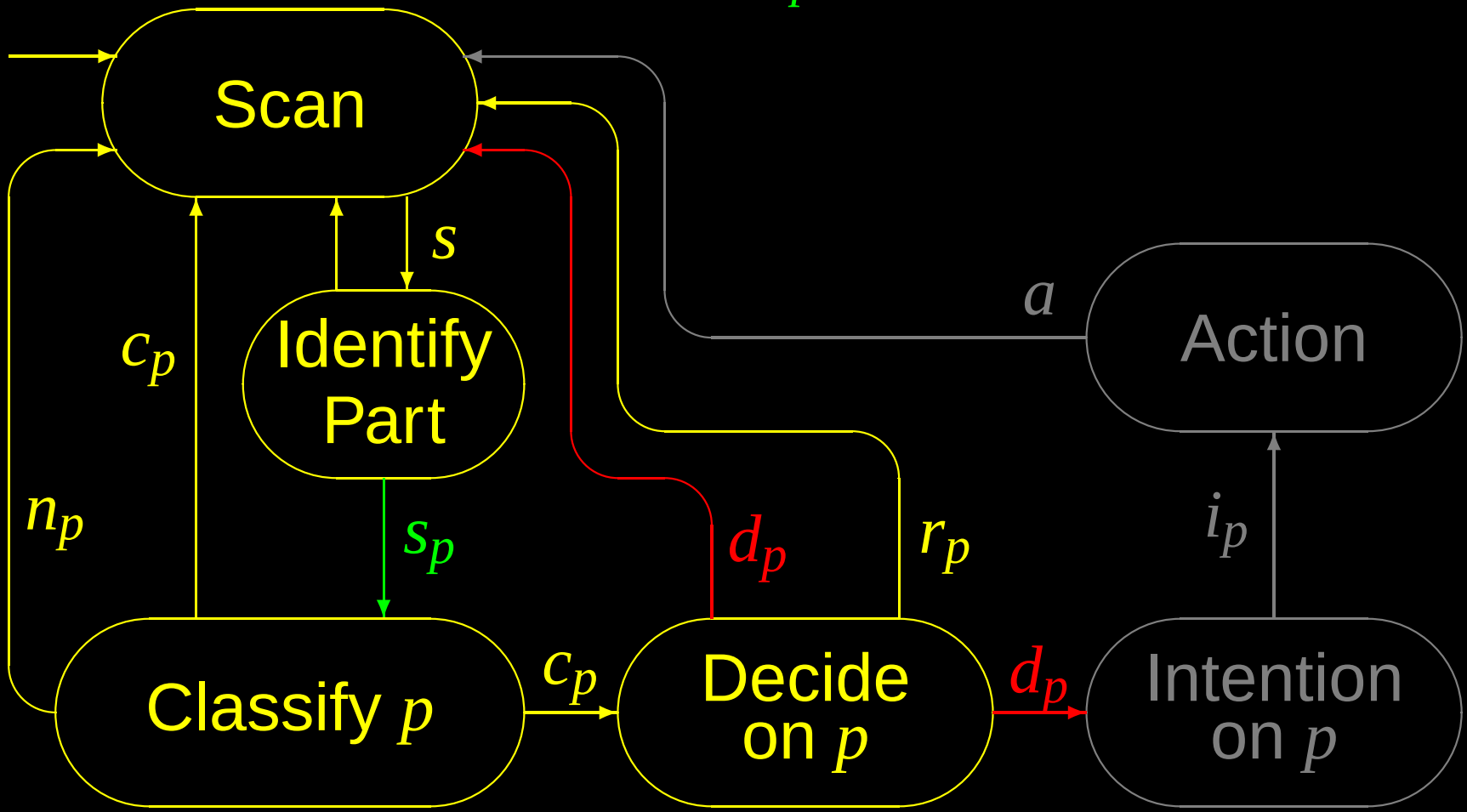
$\Diamond s_p \wedge \ldots$



Failure of Making Decision

$no\_intended\_response_p$: $\Box\neg\, s_p$

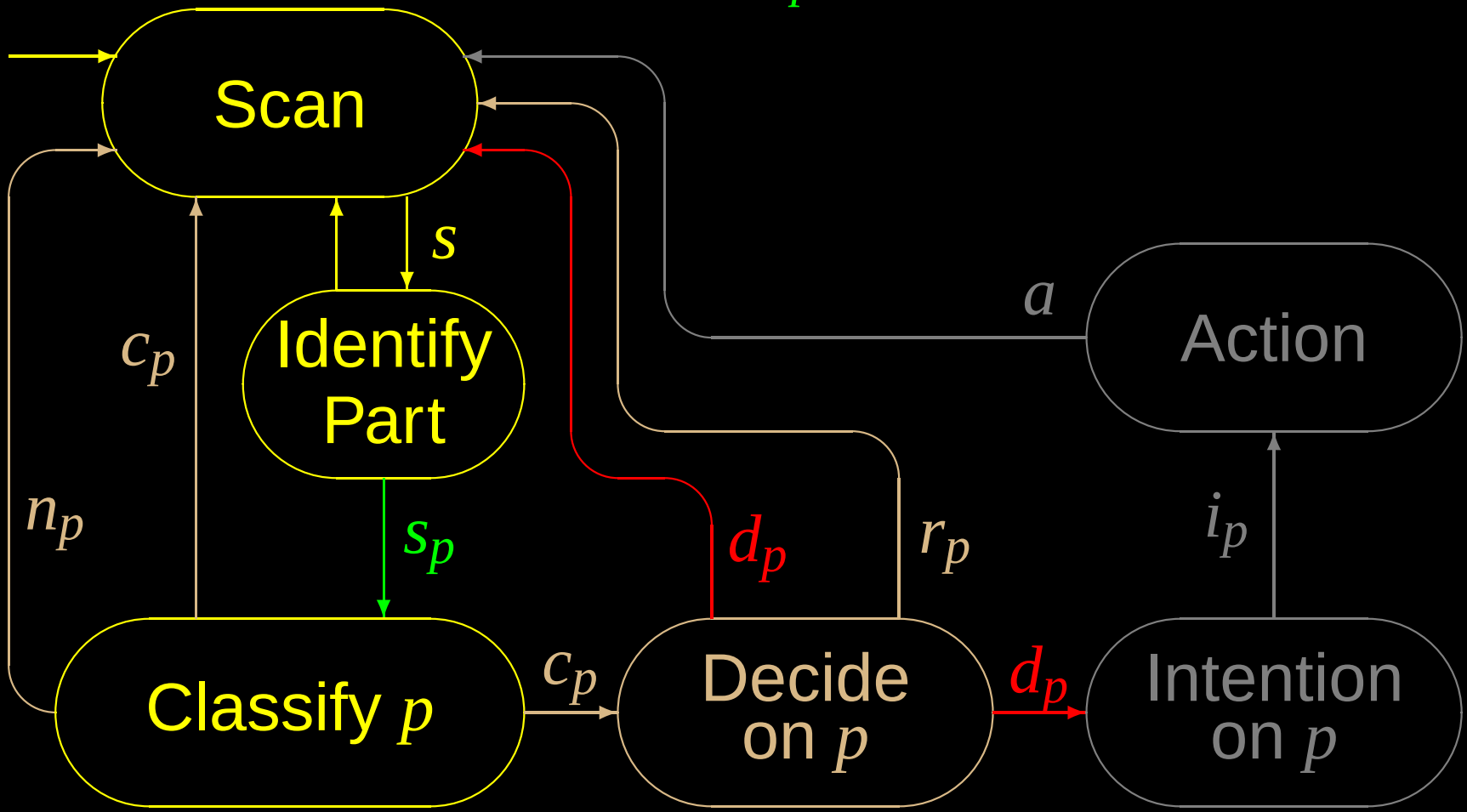
$\Diamond s_p \wedge \ldots$



Persistent Mis-classification

no_intended_response$_p$: $\Box\neg\, s_p$

$\Diamond s_p \wedge \ldots$



Persistent Mis-classification

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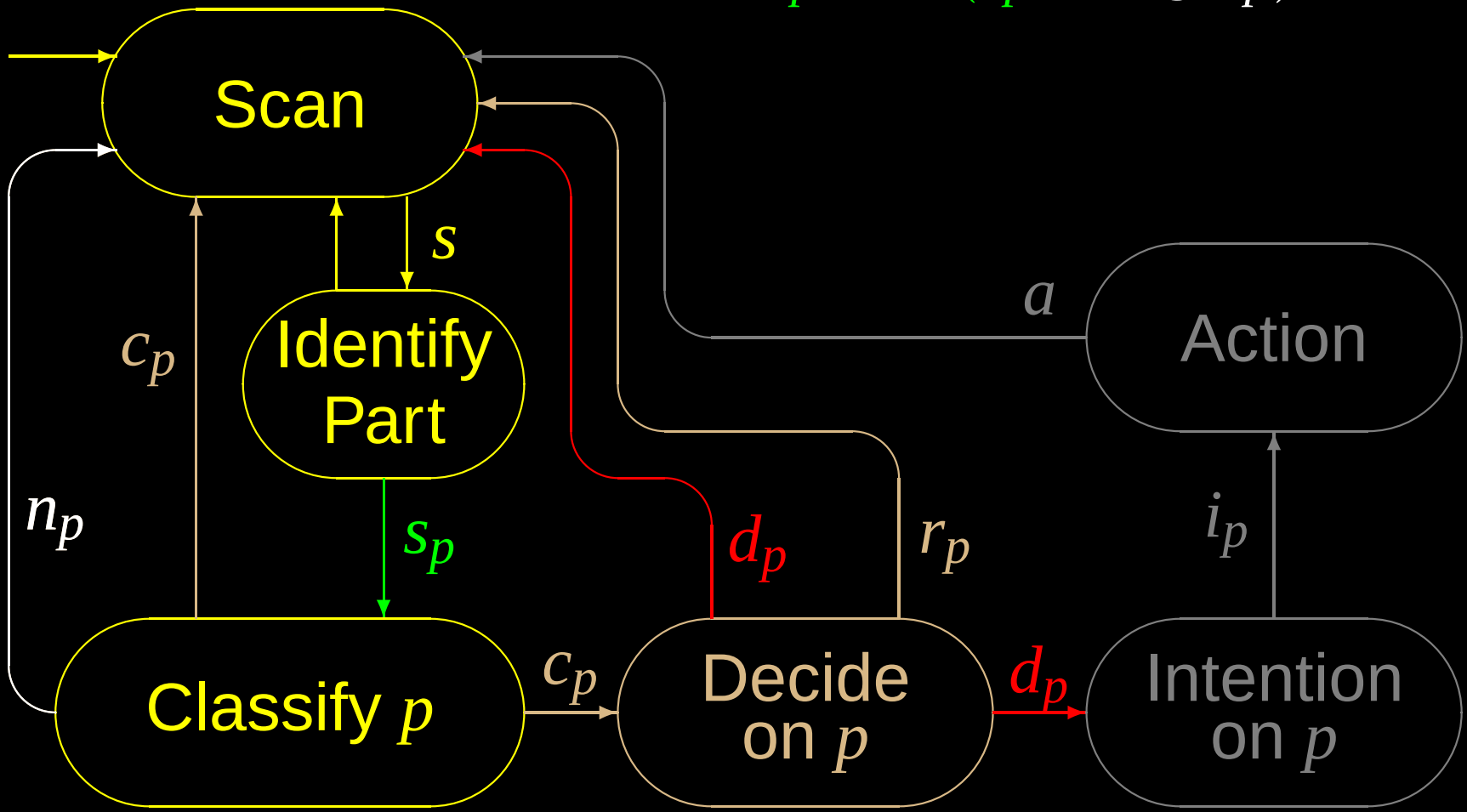
$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p)$



Persistent Mis-prioritisation

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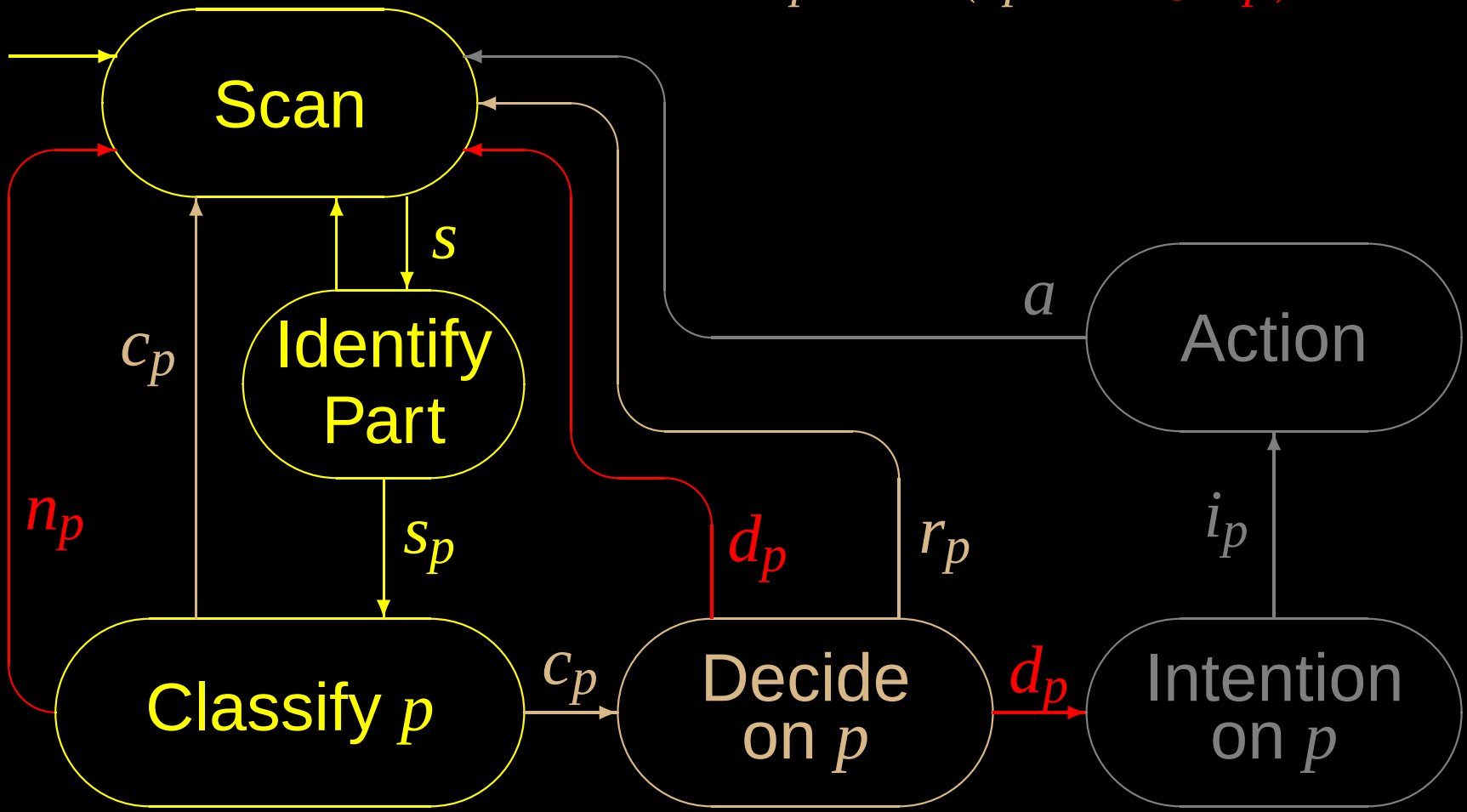

Persistent Mis-prioritisation

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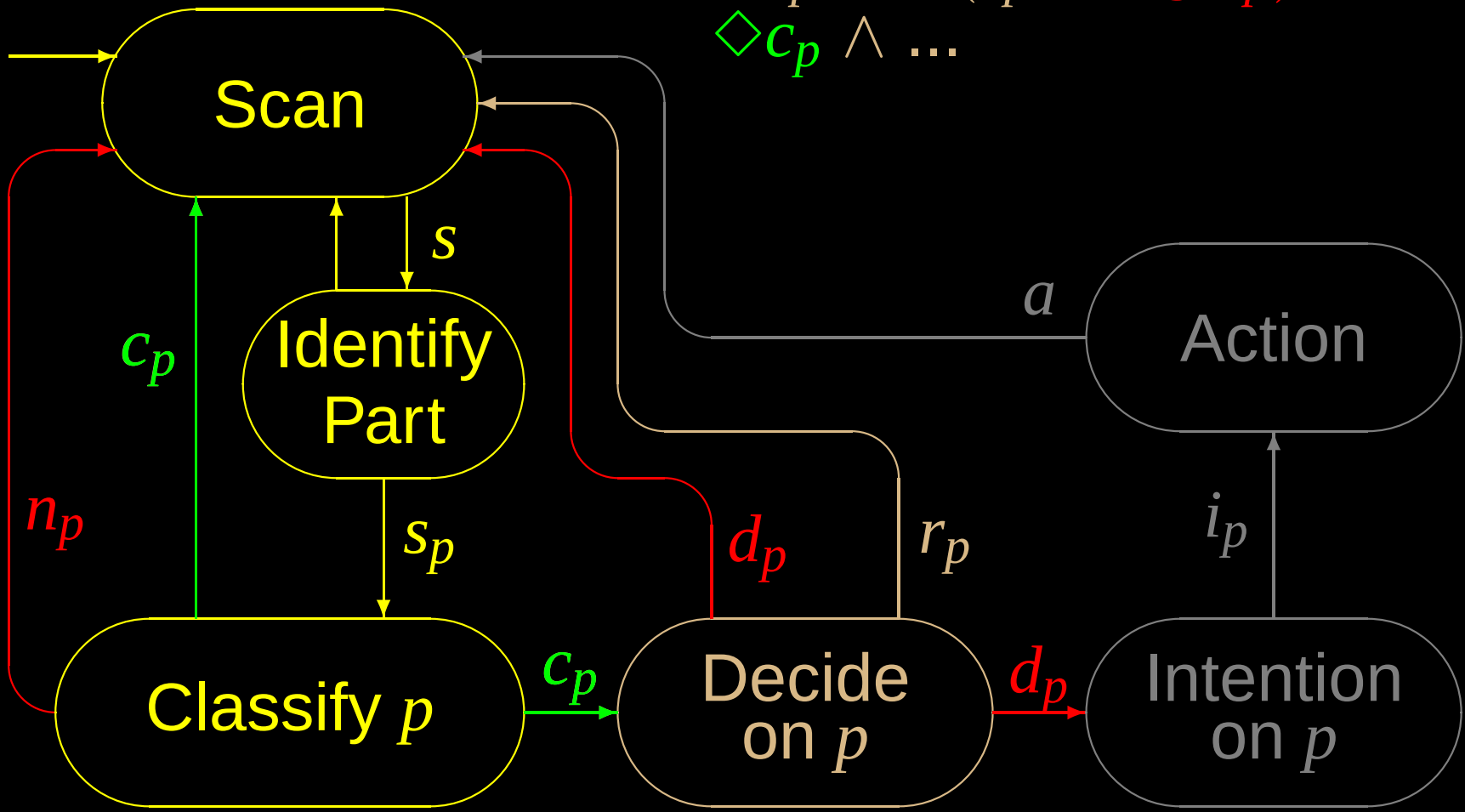

Persistent Mis-prioritisation

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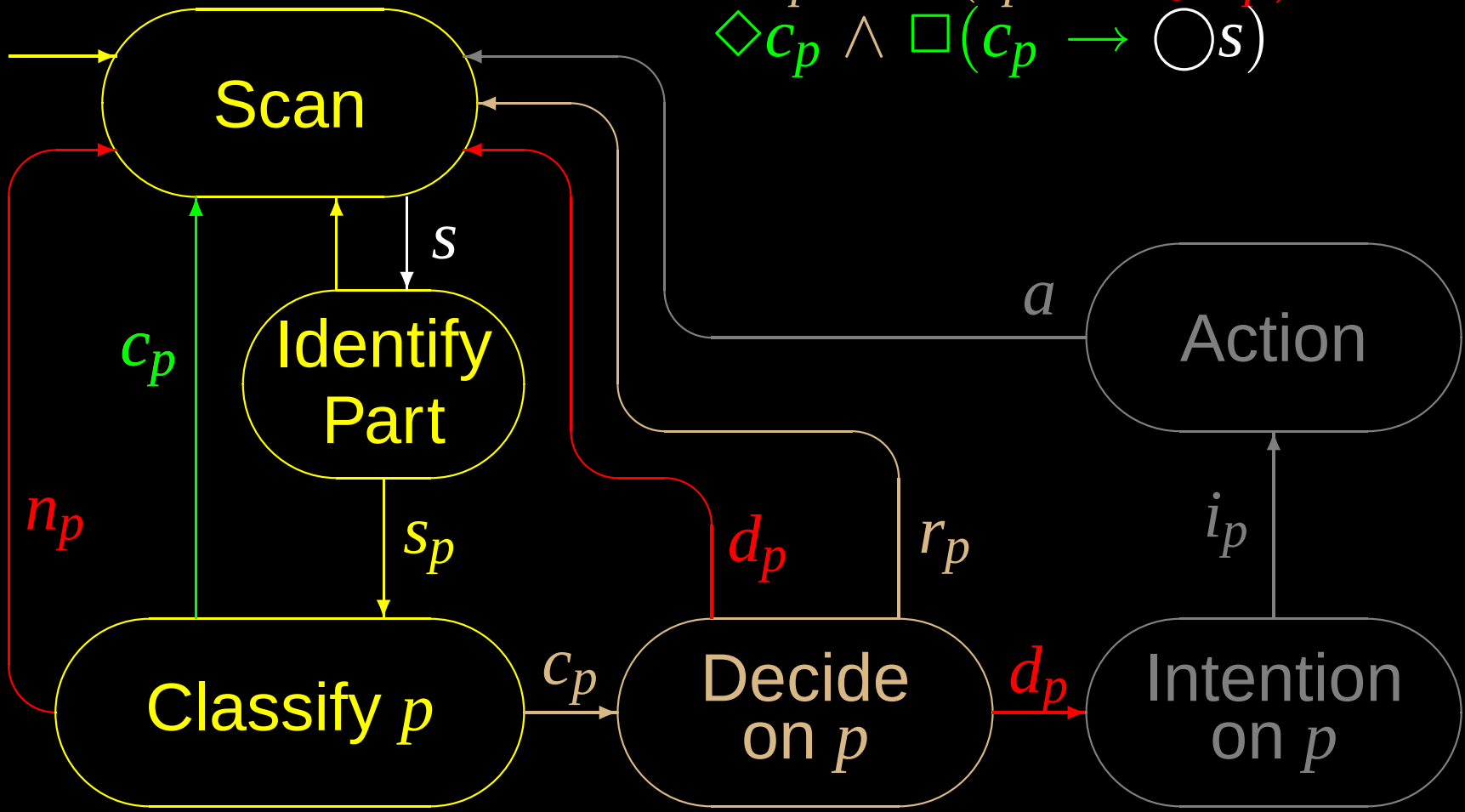

Contrary Decision Process

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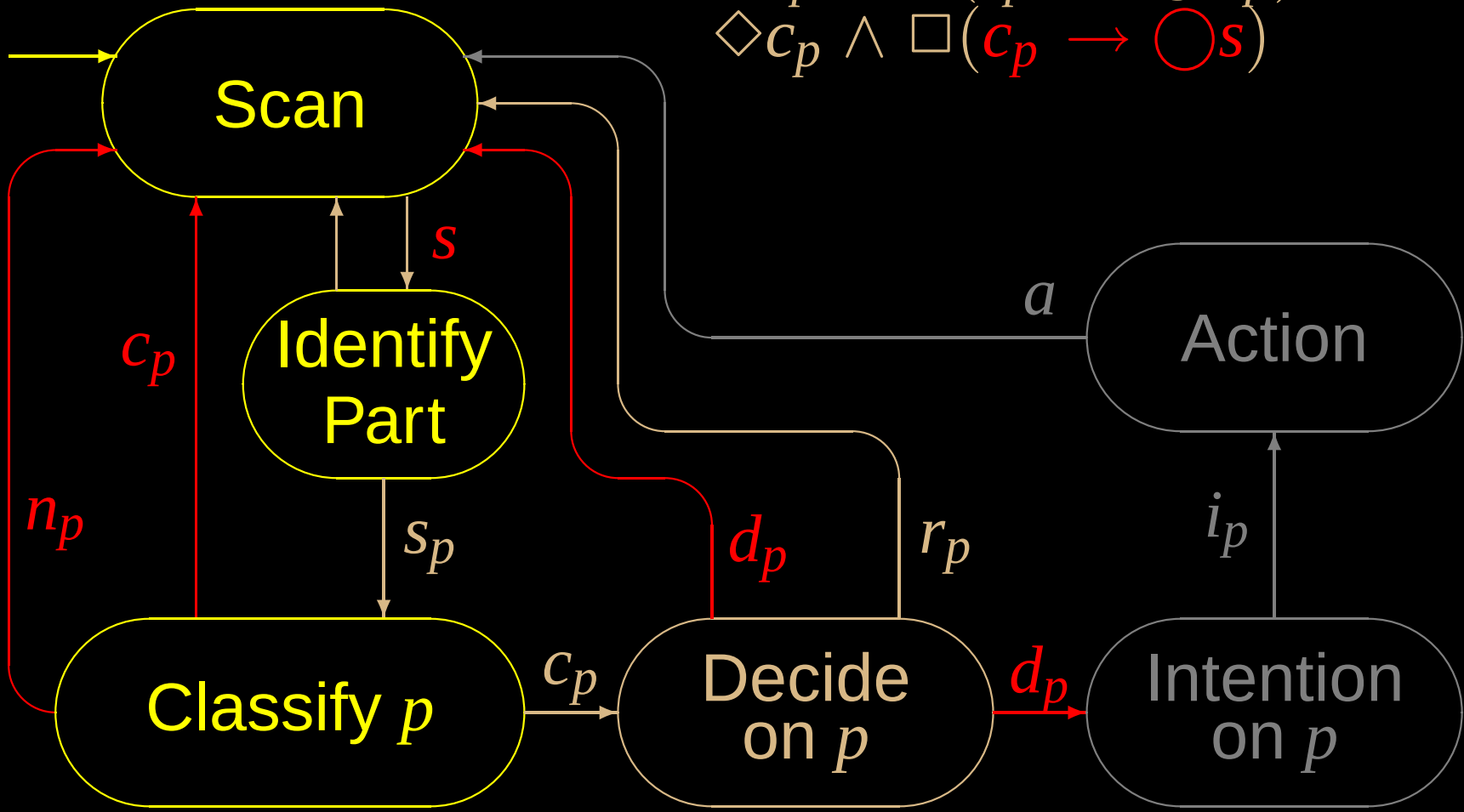
$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)$



Contrary Decision Process

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$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)$$
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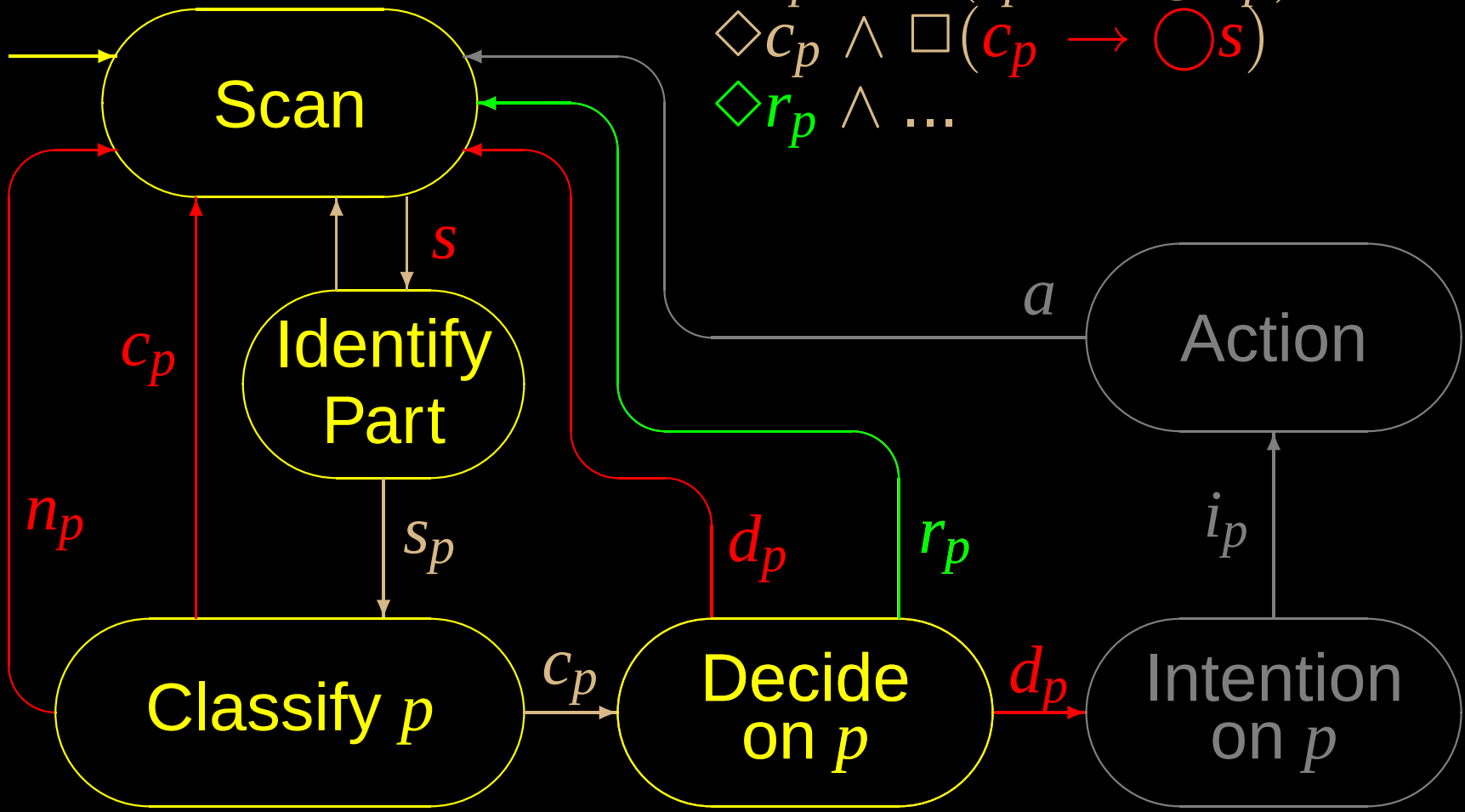

Contrary Decision Process

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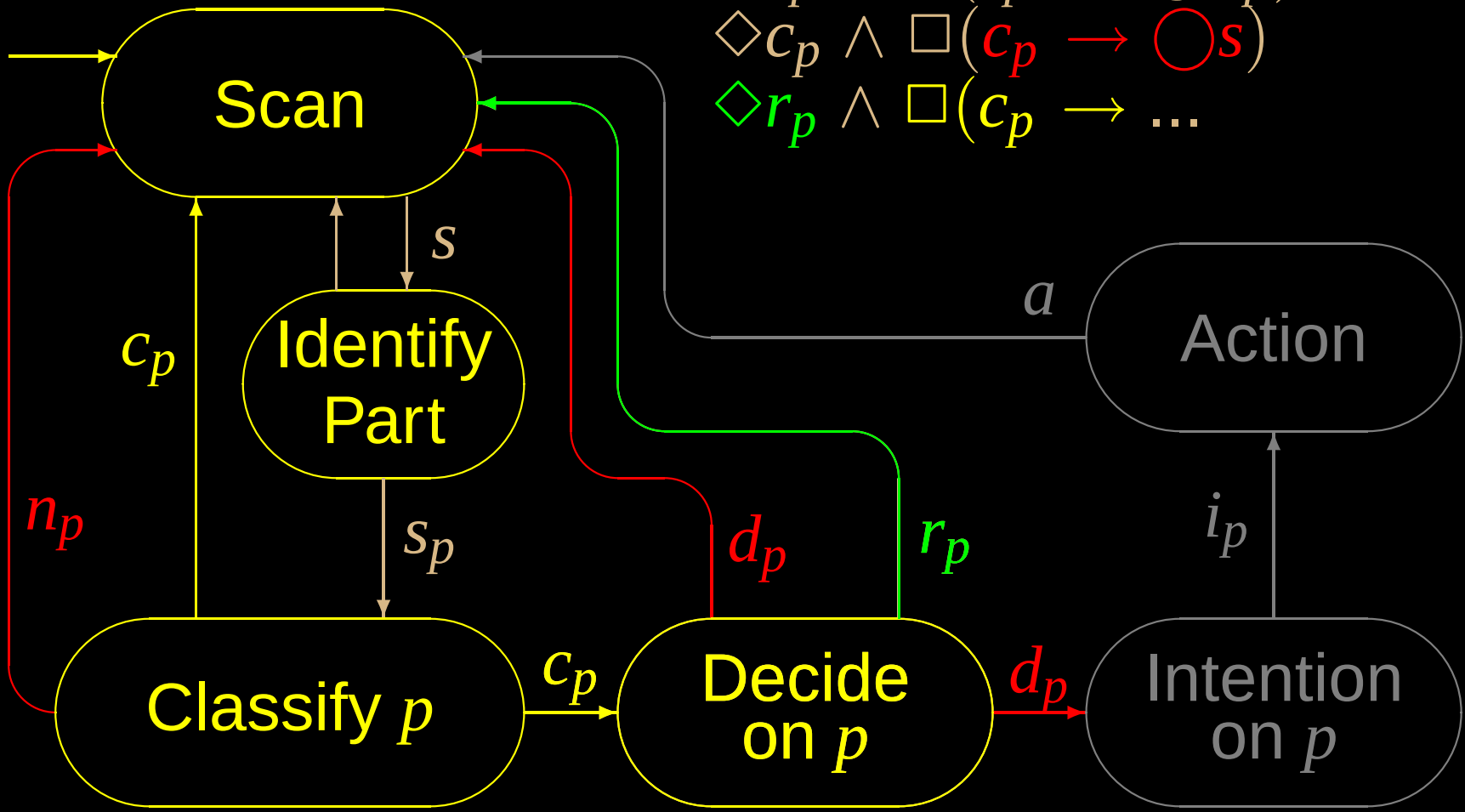

Contrary Decision Process

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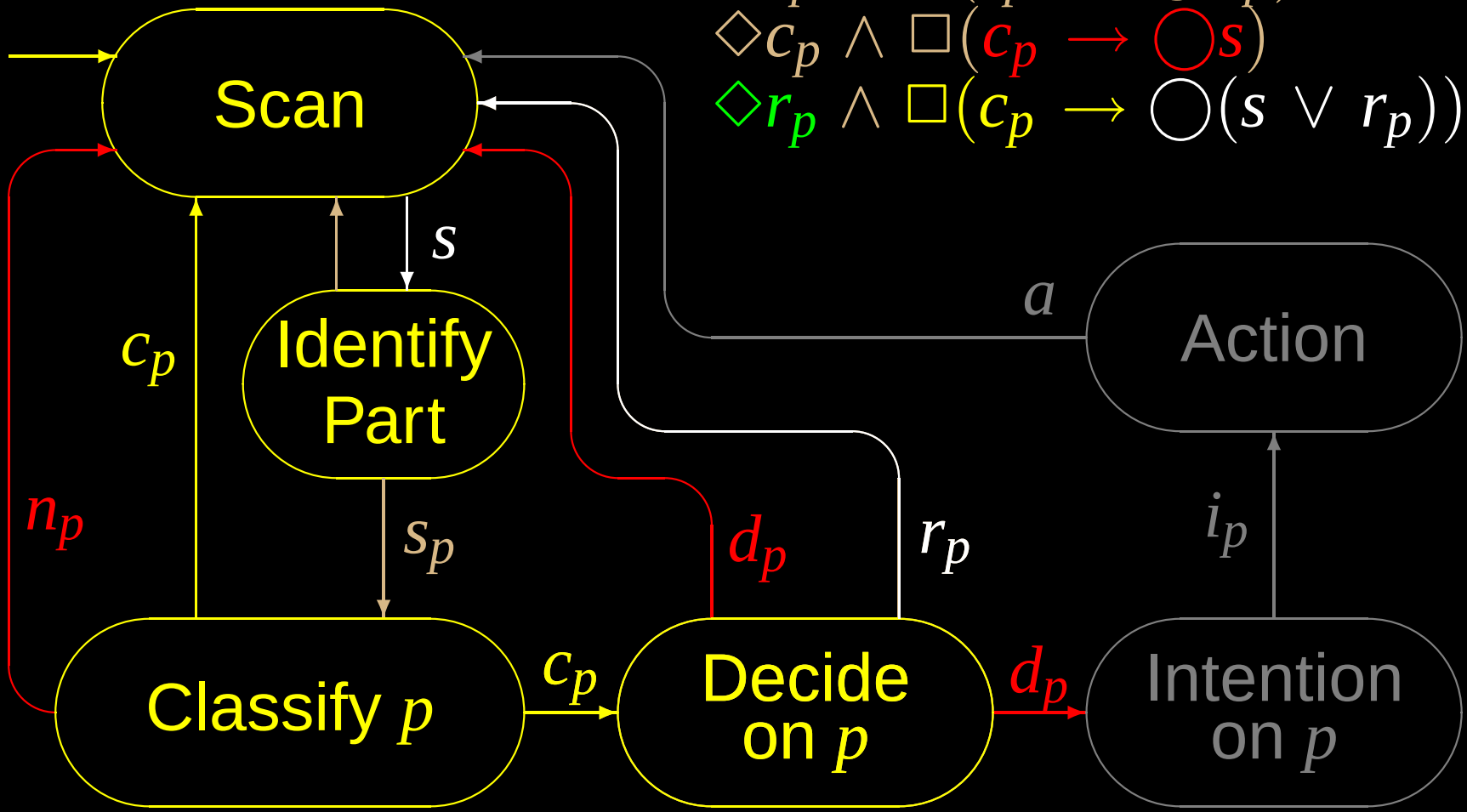
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p))$$



Defer Action for Too Long

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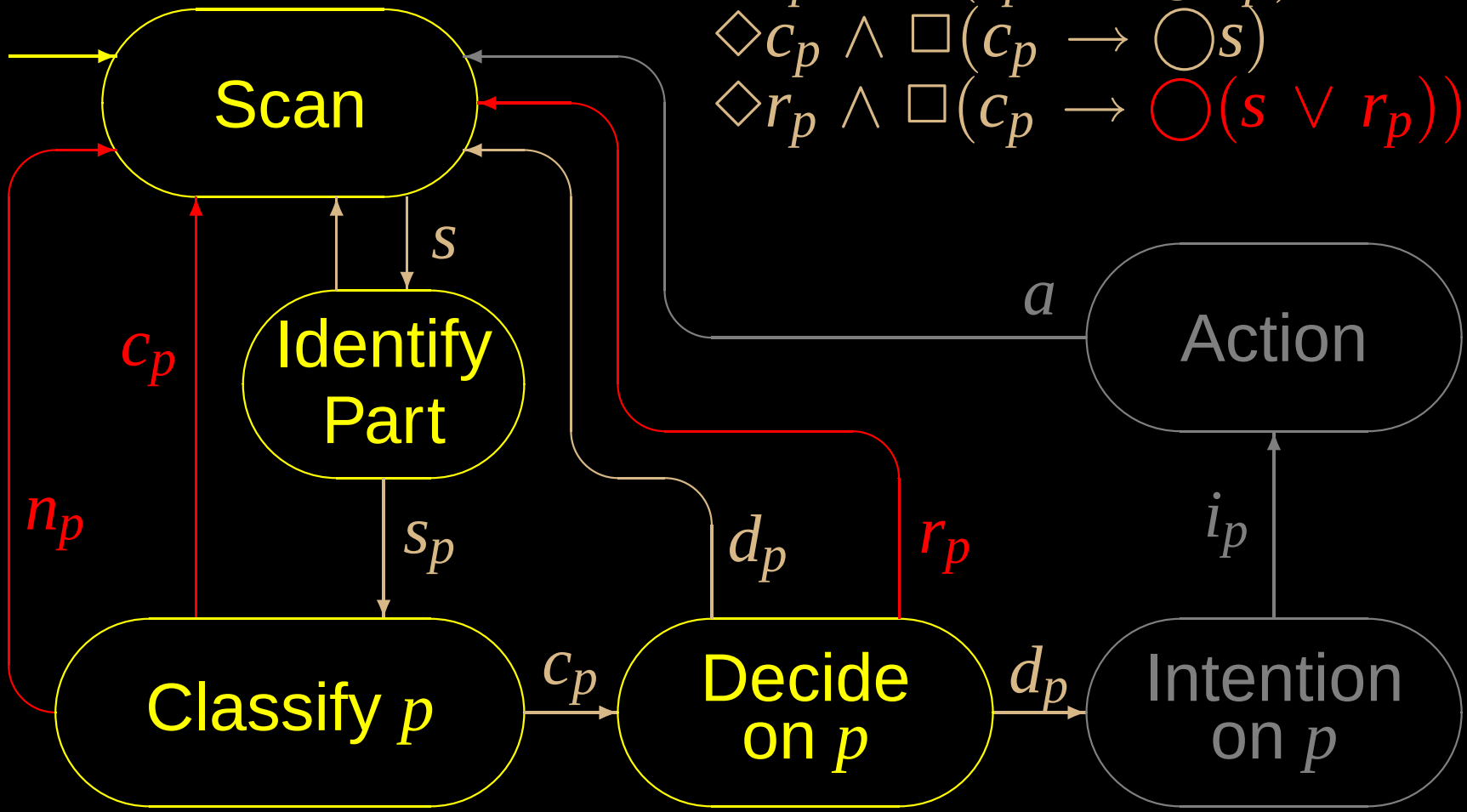
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p))$$



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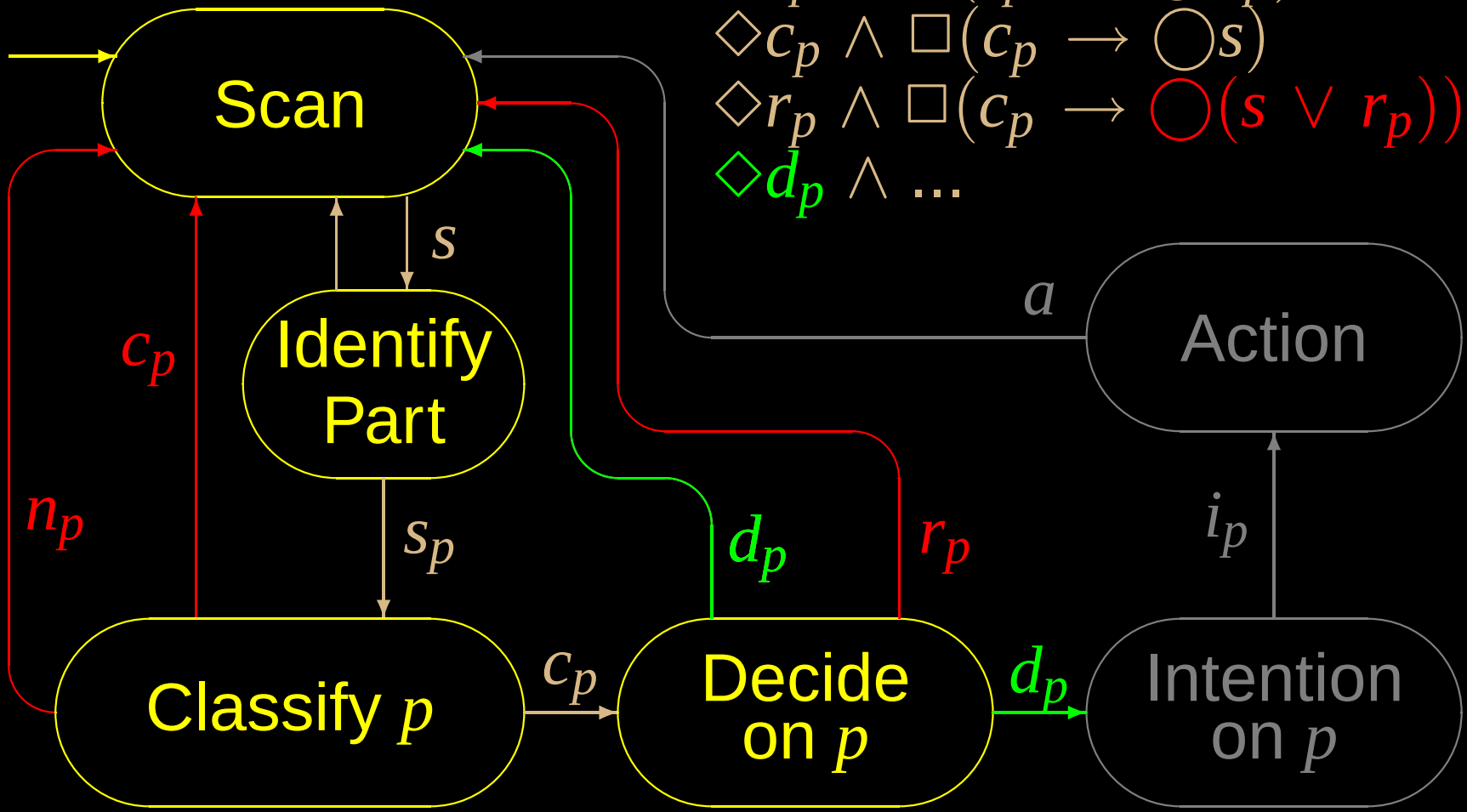
$$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p)$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)$$
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p))$$
$$\Diamond d_p \wedge \ldots$$



Defer Action for Too Long

$no\_intended\_response_p$:

$$\Box\neg\, s_p$$
$$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p)$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)$$
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p))$$
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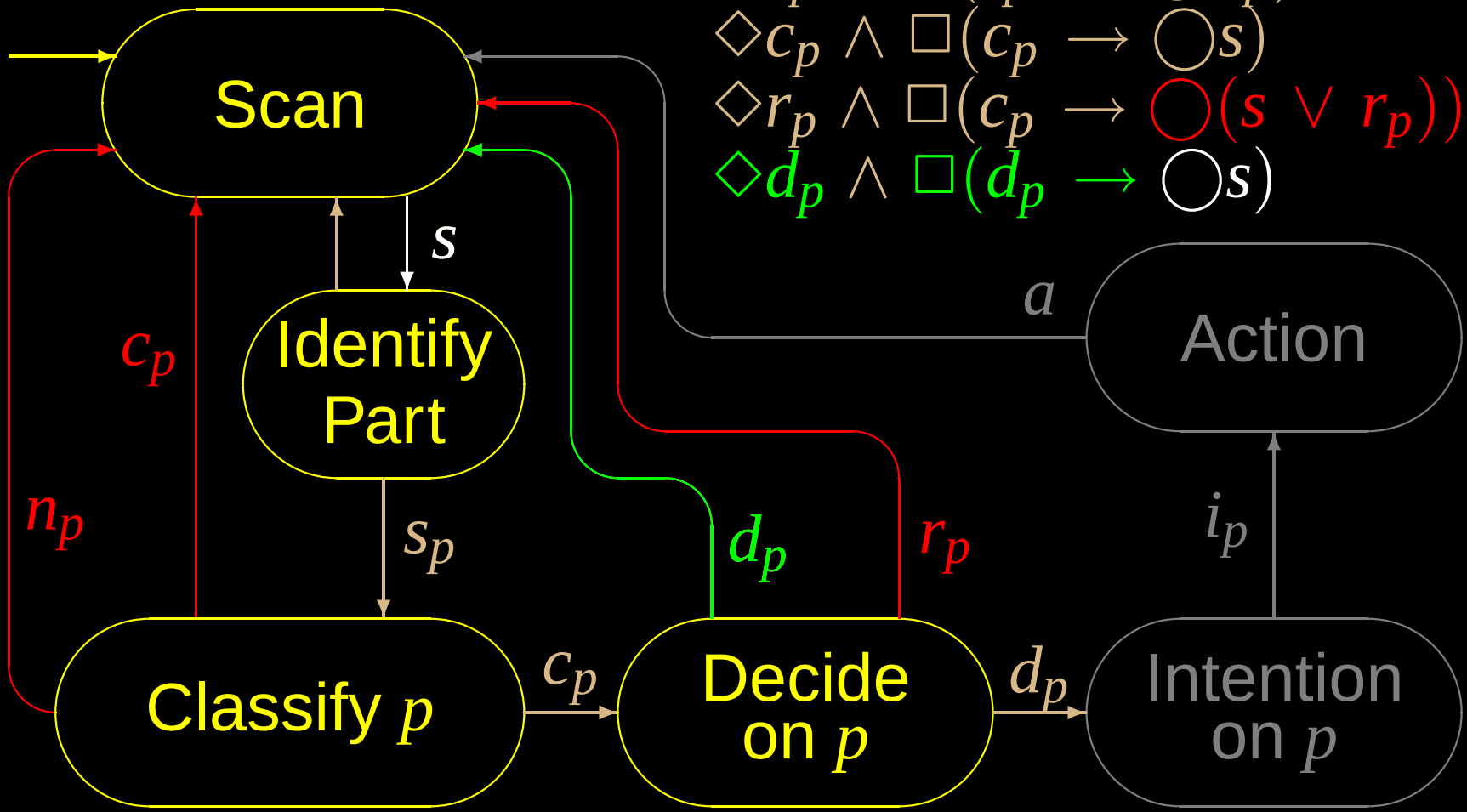

Final Decomposition

$$\mathcal{D}\ (\mathit{no\_intended\_response}_p) = \{\Box\neg\ s_p\ ,$$
$$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p)\ ,$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)\ ,$$
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$$\mathcal{D}\ (\mathit{non\_response}_p)$$
$$= \{f \wedge \mathit{non\_resolved}_p \mid f \in \mathcal{D}\ (\mathit{no\_intended\_response}_p)\}$$
$$= \{\Box\neg\ s_p \wedge \mathit{non\_resolved}_p,$$
$$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p\ ) \wedge \mathit{non\_resolved}_p,$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s) \wedge \mathit{non\_resolved}_p,$$
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p)) \wedge \mathit{non\_resolved}_p,$$
$$\Diamond d_p \wedge \Box(d_p \rightarrow \bigcirc s) \wedge \mathit{non\_resolved}_p\}$$

Proofs

- Existence of the Task Failures.
- Disjunction of the Task Failures.
- Soundness of the Decomposition.
- Completeness of the Decomposition.

$$OCM \models (\Box \neg\, i_p) \rightarrow \bigvee_{f \in \mathcal{F}} f,$$

where

$$\mathcal{F} = \{fail\_scan_p, pers\_mis\_clas_p, pers\_mis\_prio_p \\ cont\_dec\_proc_p, def\_too\_long_p\}$$

Completeness

$$\Box\neg\, i_p \;\rightarrow\; \bigvee_{f\in\mathcal{F}}\; f$$

where

$$\mathcal{F} \;=\; \mathcal{D}\;(\Box\neg\, i_p) = \mathcal{D}\;(\mathit{no\_intended\_response}_p) =$$
$$\{\; \Box\neg\, s_p\;,$$
$$\Diamond s_p \wedge \Box(s_p \rightarrow \bigcirc n_p)\;,$$
$$\Diamond c_p \wedge \Box(c_p \rightarrow \bigcirc s)\;,$$
$$\Diamond r_p \wedge \Box(c_p \rightarrow \bigcirc(s \vee r_p))\;,$$
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Solution: Interpretation

Give a psychological interpretation to the task failure in the correct decomposition

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Give a psychological interpretation to the task failure in the correct decomposition

- Failure of Scanning
- Failure of Making Decision
  - Persistent Mis-classification
  - Persisten Mis-prioritisation
  - Contrary Decision Process
- Defer Action for Too Long

Solution: FS Interpretation

phenotype error: Failure of Scanning

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Possible genotype errors are

- tunnel vision: operator looks only at a small portion of the display at a time
- encystment: operator focuses on a single problem and ignores everything else
- vagabonding: operator skipping from problem to problem without spending enough time on each

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- tunnel vision: operator looks only at a small portion of the display at a time
- encystment: operator focuses on a single problem and ignores everything else
- vagabonding: operator skipping from problem to problem without spending enough time on each ($\Longrightarrow$ high workload)

Possible design errors:
low resolution or ambiguous display

Solution: PMC Interpretation

- phenotype error: Single Mis-classification

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- phenotype error: Single Mis-classification
  Possible genotype errors
  - failure to project forward correctly
  - mistaken identity
  - belief to have already dealt with the problem

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  Possible genotype errors

  - failure to project forward correctly
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  $\Longrightarrow$ likely recovery

  (project forward eventually wins on memory)

Solution: PMC Interpretation

- phenotype error: Single Mis-classification
  Possible genotype errors
  - failure to project forward correctly
  - mistaken identity
  - belief to have already dealt with the problem

  $\Longrightarrow$ likely recovery
  (project forward eventually wins on memory)
- phenotype error: Persistent Mis-classification
  Possible genotype errors
  - memory may be strengthened $\Longrightarrow$ perception distorted

  due to distraction, similarity with observed non-conflicts, high workload

Solution: PMP Interpretation

- phenotype error: Single Mis-prioritisation

Solution: PMP Interpretation

- phenotype error: Single Mis-prioritisation
  Possible genotype errors are
  - mis-calculation
  - mis-storage
  - mis-retrival

  of the time planned for corrective actions

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- phenotype error: Single Mis-prioritisation
  Possible genotype errors are
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  - mis-retrival

  of the time planned for corrective actions $\Longrightarrow$
  possible recovery
  (through new calculation at a next scan)

Solution: PMP Interpretation

- phenotype error: Single Mis-prioritisation
  Possible genotype errors are
  - mis-calculation
  - mis-storage
  - mis-retrival

  of the time planned for corrective actions $\Longrightarrow$
  possible recovery
  (through new calculation at a next scan)
- phenotype error: Persistent Mis-prioritisation
  Possible genotype errors
  - memory of result of previous mis-calculation keeps emerging

Solution: CDP Interpretation

- phenotype error: Single Mis-reclassification

Solution: CDP Interpretation

- phenotype error: Single Mis-reclassification

  Possible genotype errors are

  - mis-calculation
  - mis-storage
  - mis-retrival

  during the decision process

Solution: CDP Interpretation

- phenotype error: Single Mis-reclassification
  Possible genotype errors are
  - mis-calculation
  - mis-storage
  - mis-retrival

  during the decision process $\Longrightarrow$ possible recovery
  (through new calculation at a next scan)

Solution: CDP Interpretation

- phenotype error: Single Mis-reclassification
  Possible genotype errors are
  - mis-calculation
  - mis-storage
  - mis-retrival

  during the decision process $\Longrightarrow$ possible recovery
  (through new calculation at a next scan)
- phenotype error: Contrary Decision Process
  Possible genotype errors
  - memory of previous decisions on similar pairs resulting in unnecessary actions

  due to fear, high workload

Solution: DATL Interpretation

- phenotype error: Single Mis-deferring Action

Solution: DATL Interpretation

- phenotype error: Single Mis-deferring Action
  Possible genotype errors are
  - mis-calculation of time
  - mis-retrival of intention
  - slip

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  Possible genotype errors are
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  - mis-retrival of intention
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Solution: DATL Interpretation

- phenotype error: Single Mis-deferring Action
  Possible genotype errors are
  - mis-calculation of time
  - mis-retrival of intention
  - slip

  $\Longrightarrow$ possible recovery
  (through new decision process at a next scan)
- phenotype error: Defer Action for Too Long
  Possible genotype errors
  - persistent mis-retrival of intention and closure of the decision process

  due to very high workload

Model-checking Results

- Negative result of the validity checking on the completeness of an initially attempted decomposition.

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- Negative result of the validity checking on the completeness of an initially attempted decomposition.
- Changes to the Model: in particular, it has been enriched with r_p.
- Changes to the Specification: in particular, the the newly defined *contrary decision process* task failure has been added to the decomposition.
- Psychological interpretation of the new task failure.

Examination — ATC

Operator Choice Model and Mode Confusion

- Seminars
  - Full OCM model for the ATC
  - Formal analysis of mode confusion
- Reports
  - Formal model of the full OCM for ATC
  - Formal analysis of Cooperative Task Models

Examinations

Seminar 1 — Full OCM for ATC

Topic: Operator Choice Model for ATC

Full OCM model for the ATC

- D. Leadbetter, P. Lindsay, A. Hussey, A. Neal and M. Humphreys Towards Towards Model Based Prediction of Human Error Rates in Interactive Systems, 2000
- A. Hussey, D. Leadbetter, P. Lindsay, A. Neal and M. Humphreys Modelling and Hazard Identification in an Air-Traffic Control User-Interface, 2000
- S. Connelly, P. Lindsay, A. Neal and M. Humphreys A formal model of cognitive processes for an Air Traffic Control Task, 2001

Seminar 2 — Mode Confusion

Topic: Mode Confusion

Formal analysis of mode confusion

- S. P. Miller and J. N. Potts
  Detecting Mode confusion Through formal Modelling and Analysis, 1999
- N. Leveson, L. D. Pinnel, S. D. Sandys, S. Koga and J. D. Reese
  Analysing Software Specification for Mode Confusion Potential, 1998
- R. W. Butler, S. P. Miller, J. N. Potts and V. A. Carreno
  A Formal Methods Approach to the Analysis of Mode Confusion, 1998

Report 1 — FM of Full ATC

Topic: Operator Choice Model

Formal model of the full OCM for ATC

using CSP or other formalism, possibly running simulation using a tool

- D. Leadbetter, P. Lindsay, A. Hussey, A. Neal and M. Humphreys
  Towards Model Based Prediction of Human Error Rates in Interactive Systems, 2000
- S. Connelly, P. Lindsay, A. Neal and M. Humphreys
  A formal model of cognitive processes for an Air Traffic Control Task, 2001
- Antonio Cerone, Simon Connelly and Peter Lindsay.
  Formal Analysis of Operator Behavioural Patterns in Interactive Systems, submitted

Report 2 — Cooperative TM

Topic: Task Models

Formal Analysis of Cooperative Task Models

Discussion of the papers' differences and limitations and propose possible extensions

- F. Paternò, C. Santoro and S. Thamassebi
  Formal models for Cooperative Tasks: Concepts and an Application for En-route Air Traffic Control
- V. M. R. Penichlet, F. Paternò, J. A. Gallud and M. D. Lozano
  Collaborative Social Structures and Task Modelling Integration
- D. Pinelle and C. Gutwin
  Task Analysis for Groupware Usability Evaluation: Modeling Shared Workplace Tasks with Mechanics of cCllaboration

Demo

References