test-based modeling in an **ultrametric space**

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test-based modeling

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active automata learning

"[The advent of systems theory] was achieved by viewing a system not via its internal structure, but via the mathematical laws which govern its observable behavior."

–Arthur Gill, Introduction to the theory of finite-state machines, 1962

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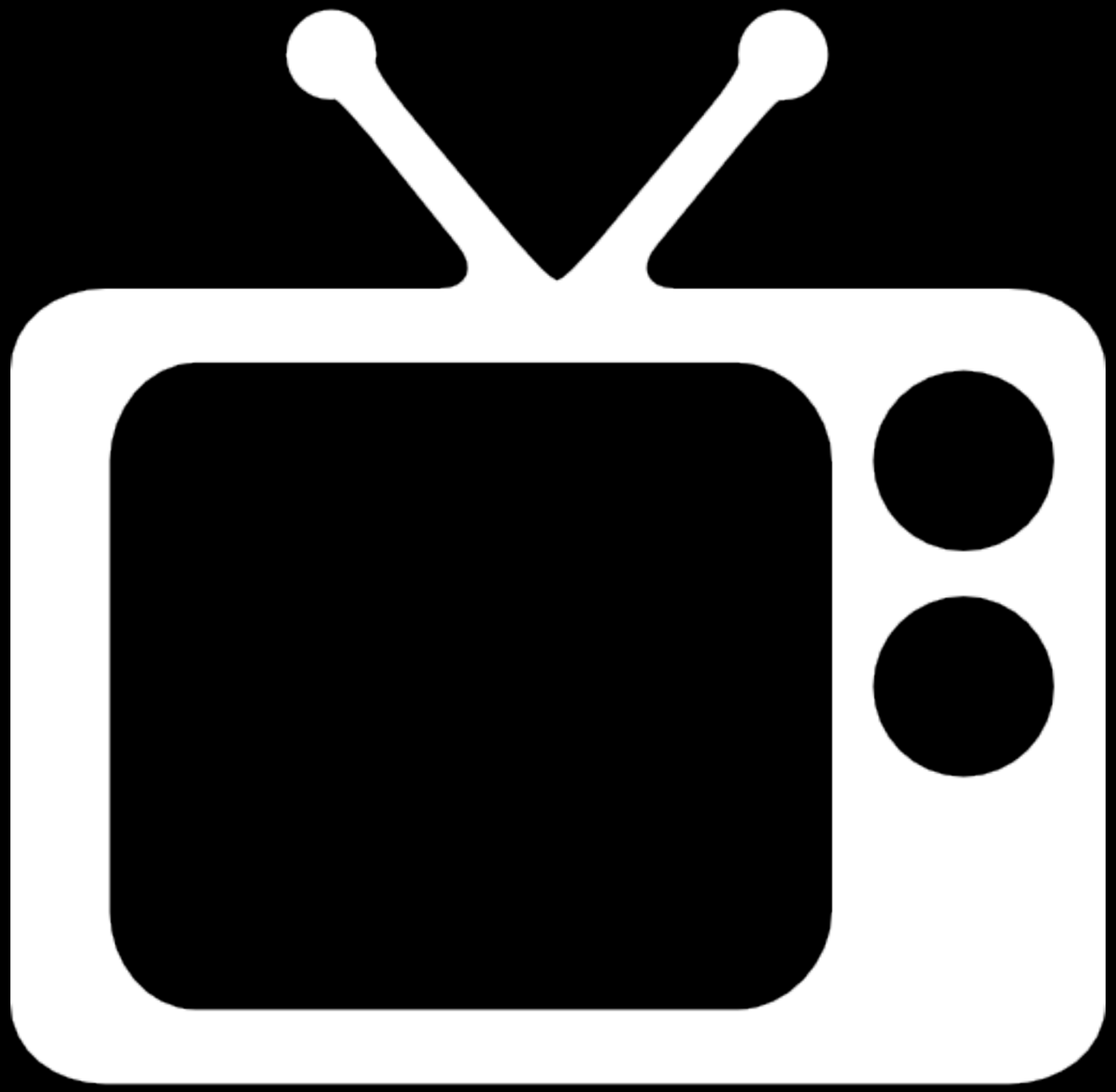
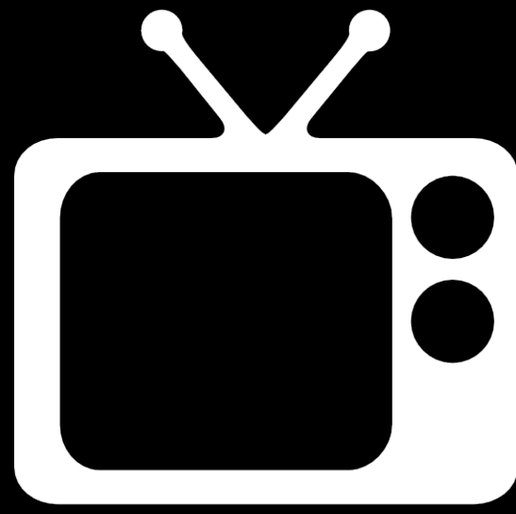
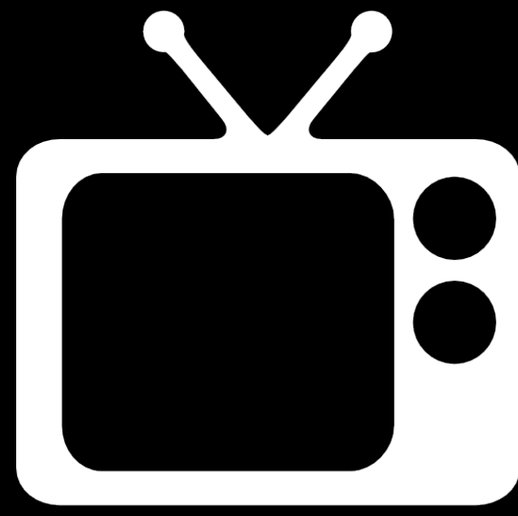
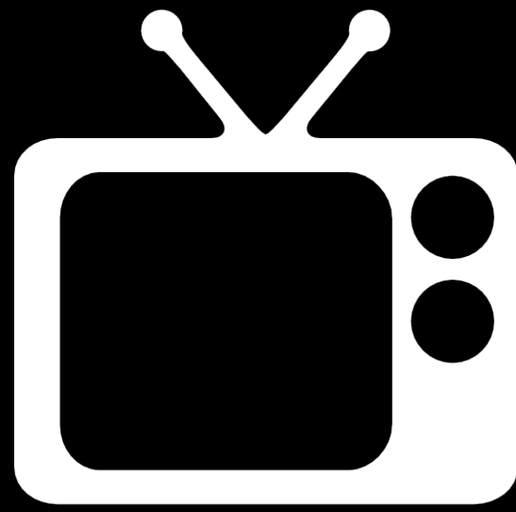


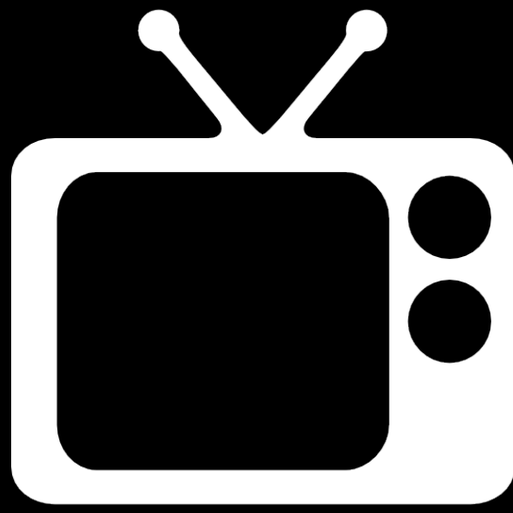
system under test (SUT)



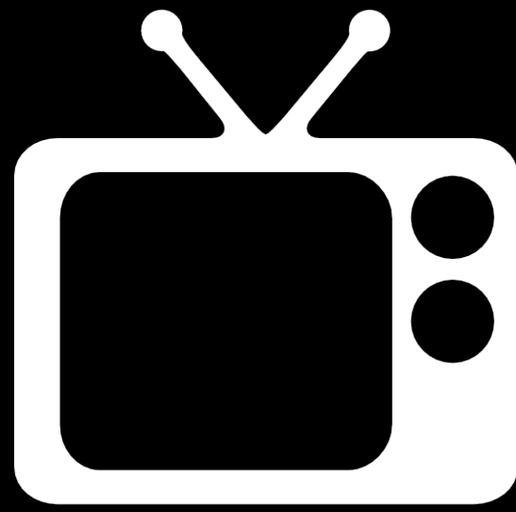


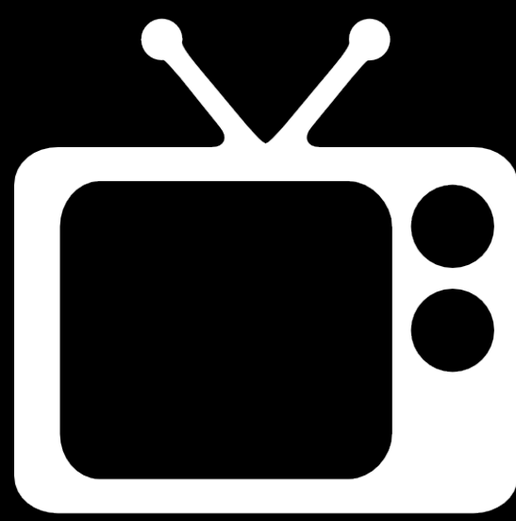
learning algorithm (*us*)



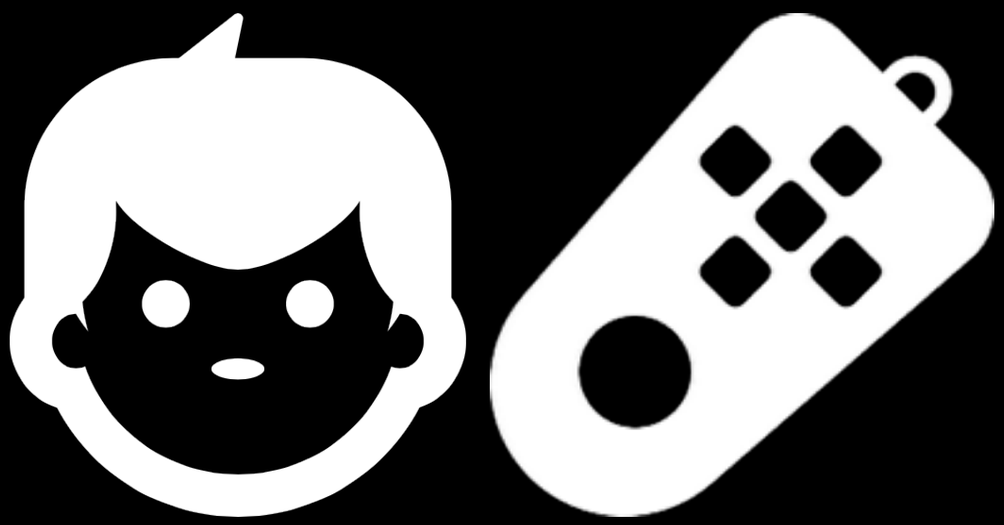


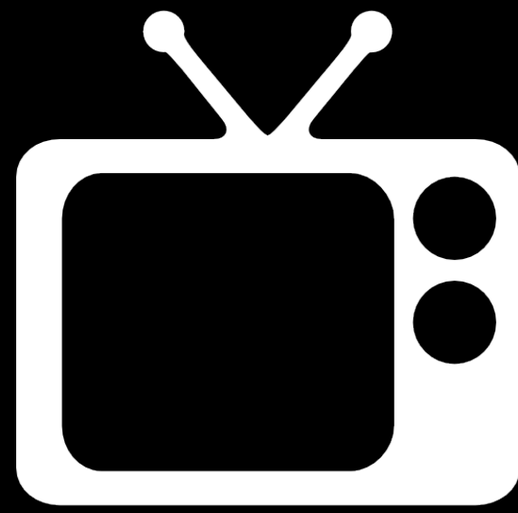
no formal specification





testing





oracle (model-based testing)

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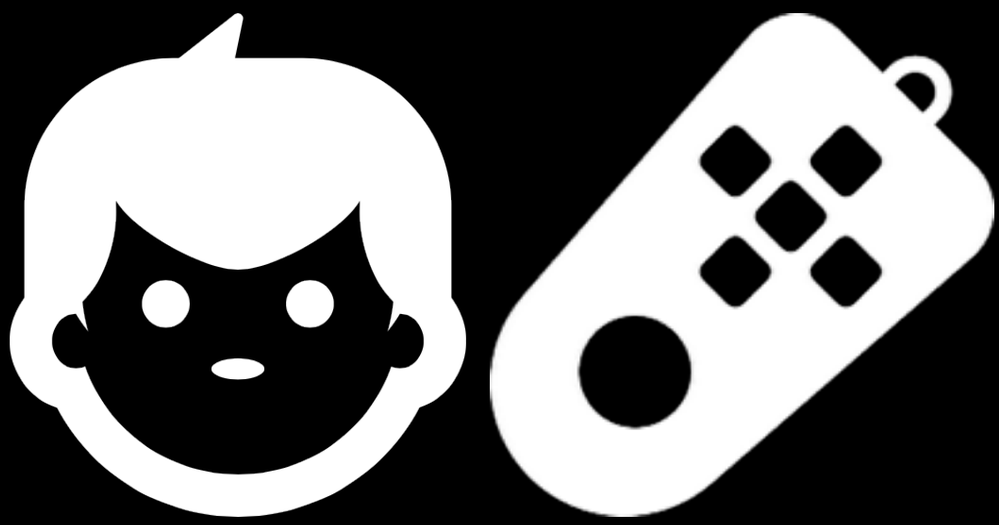

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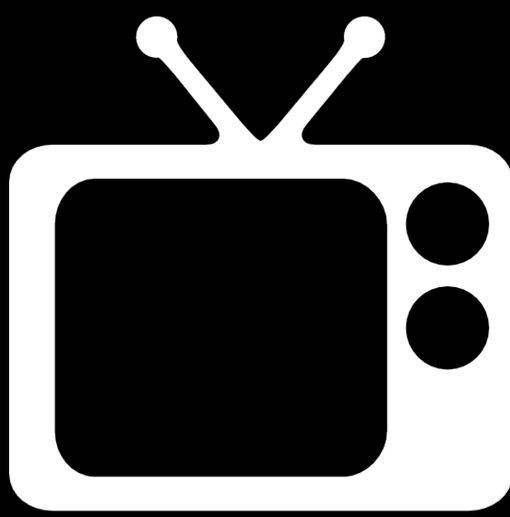

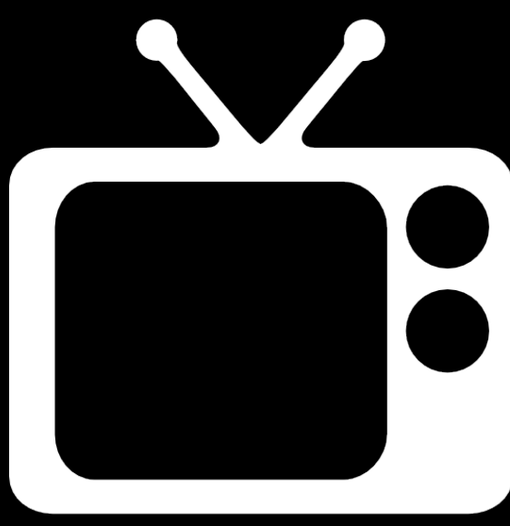

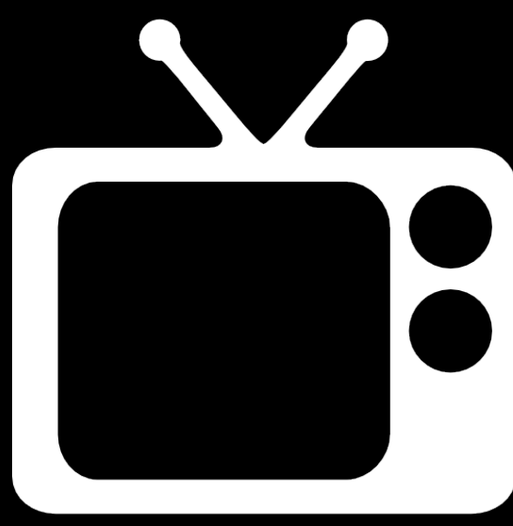

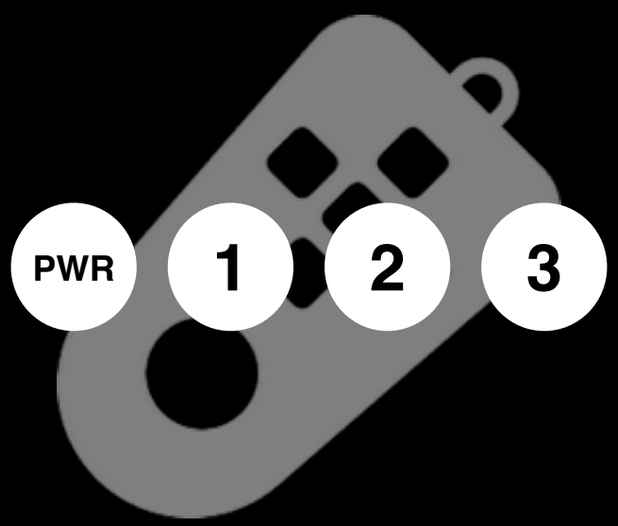
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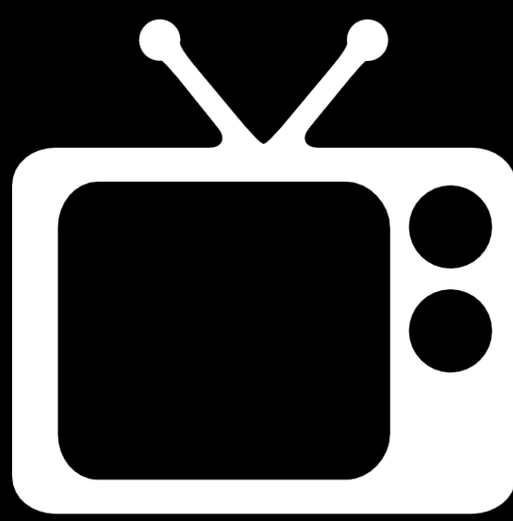

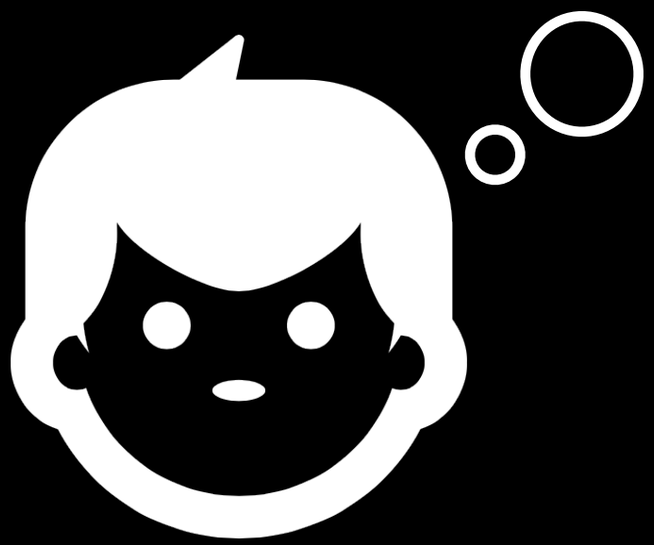

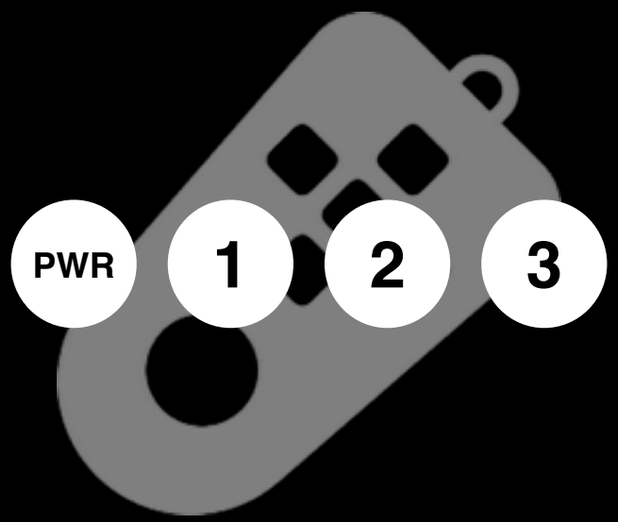
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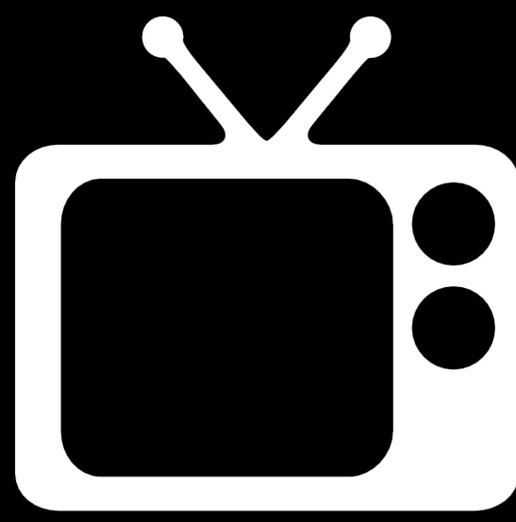

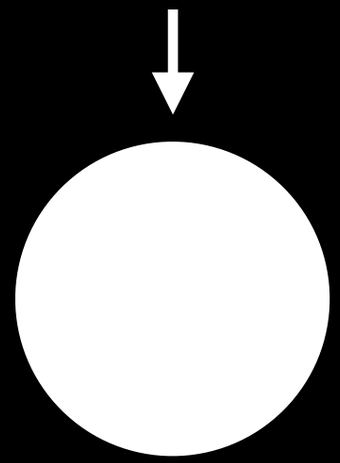

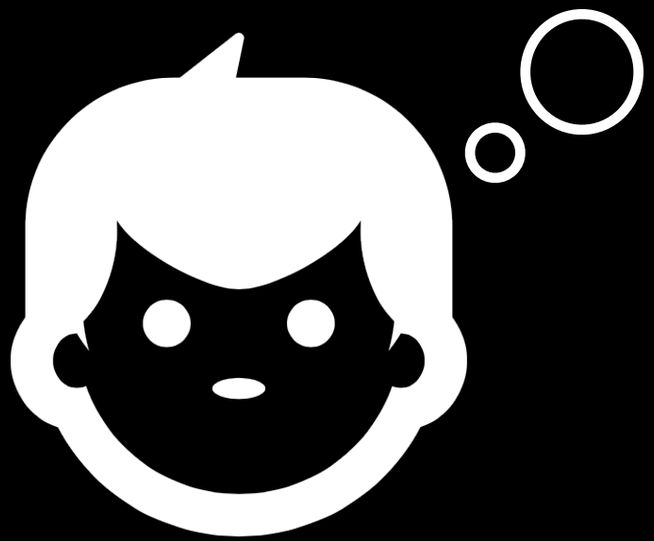

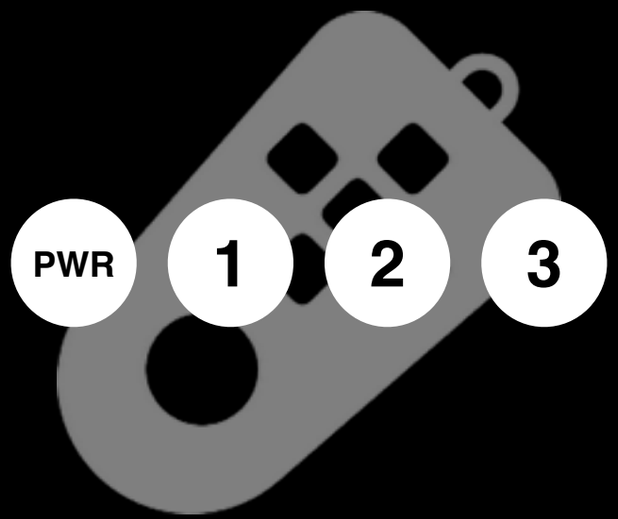
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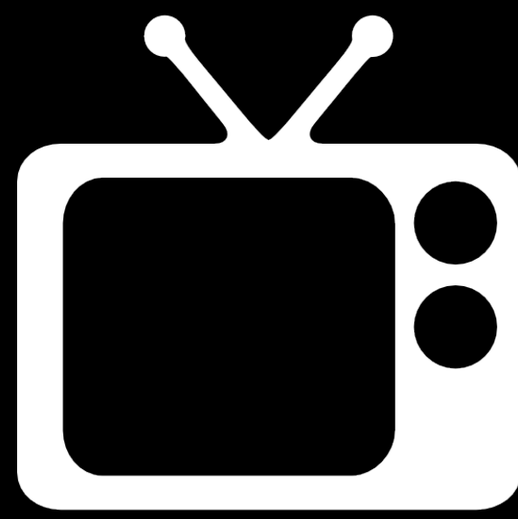

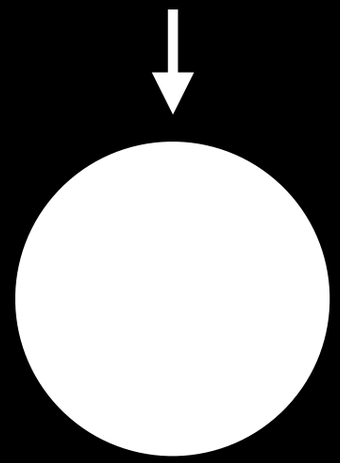

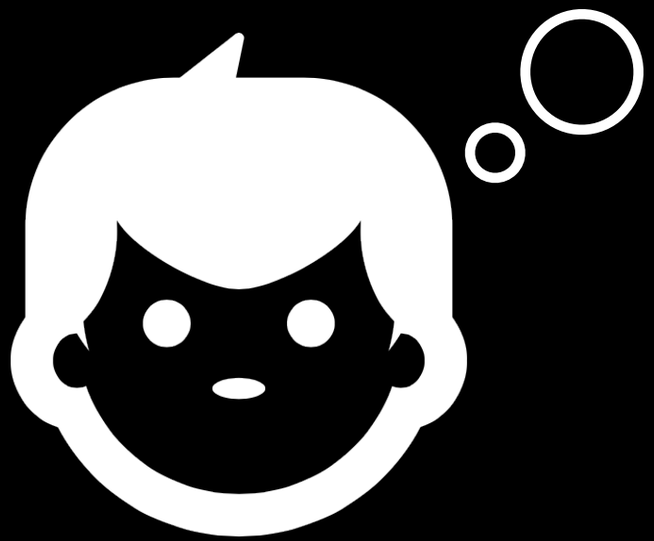

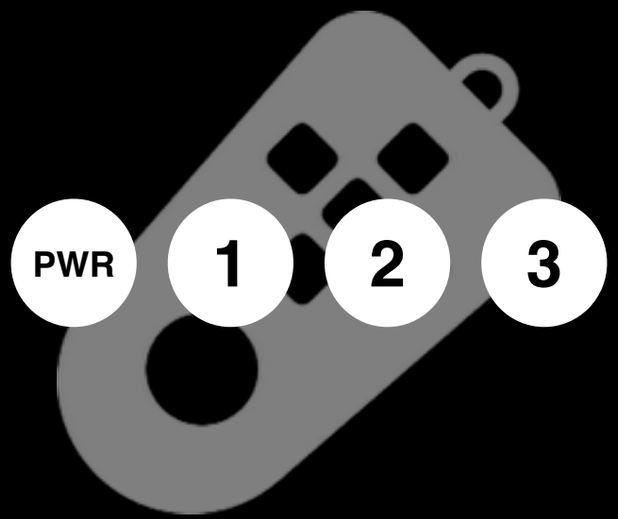
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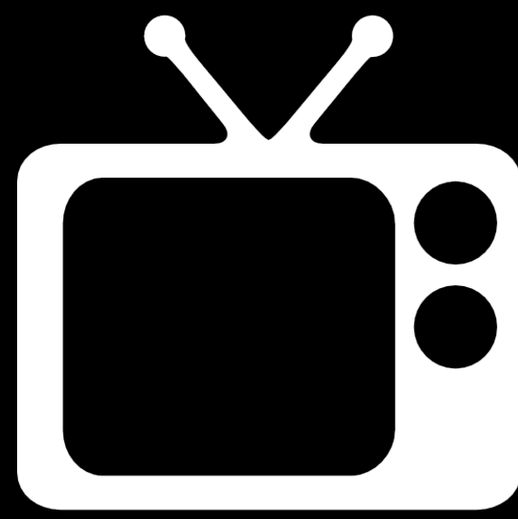

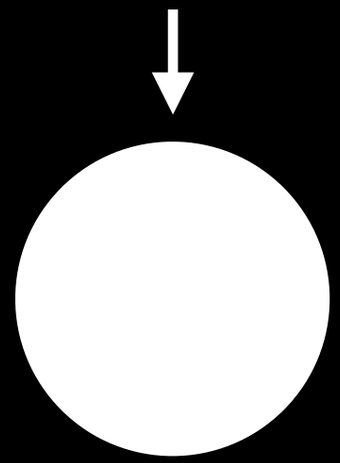

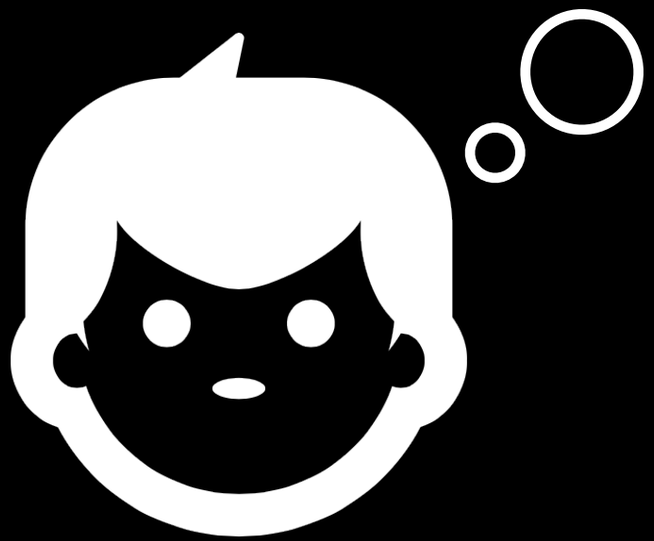

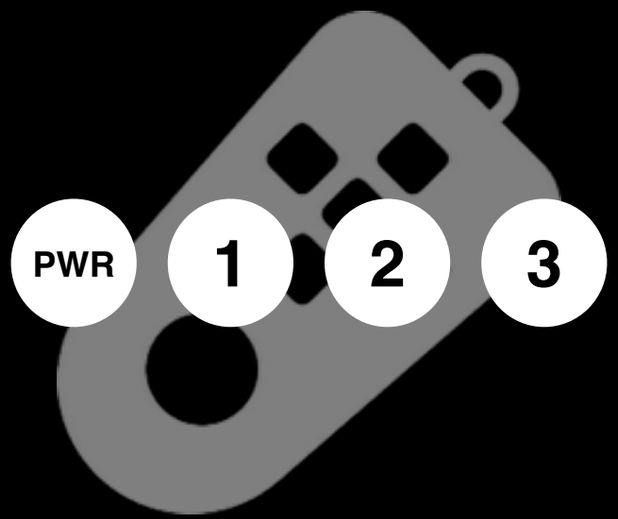
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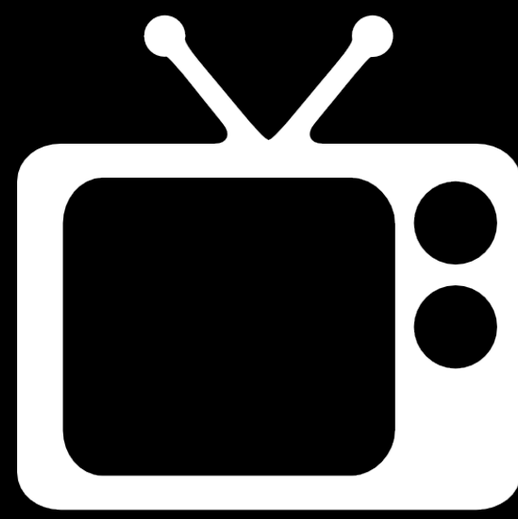

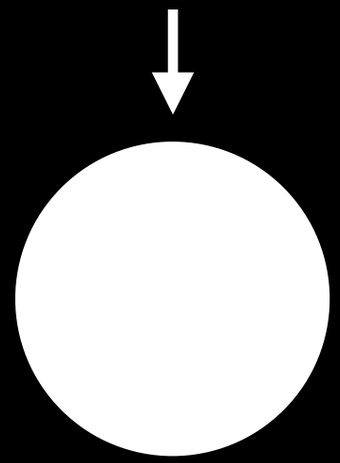

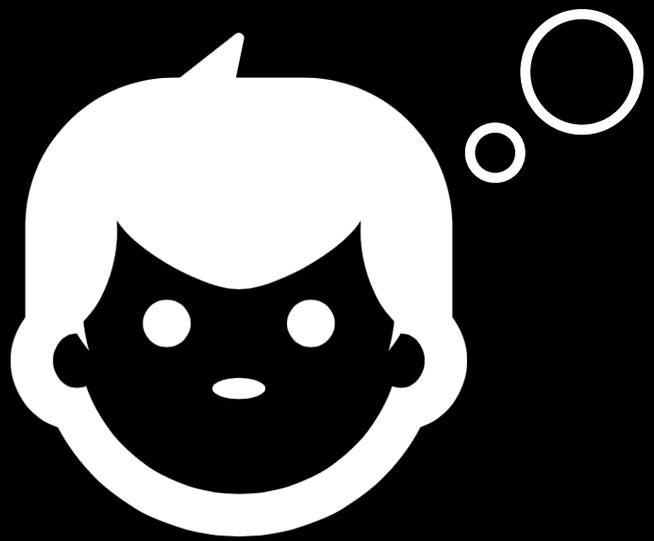

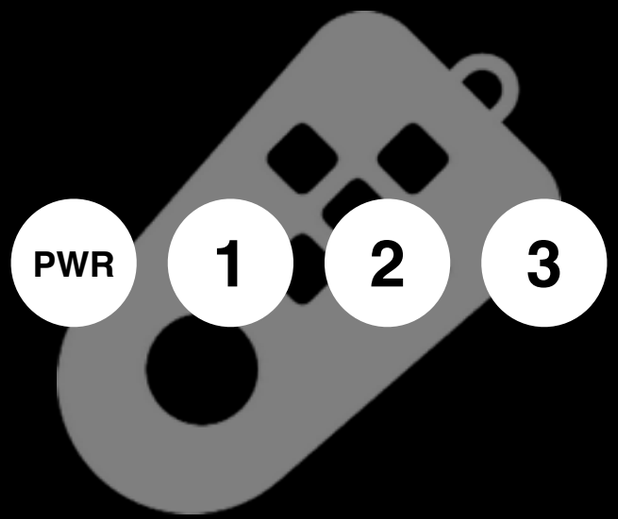
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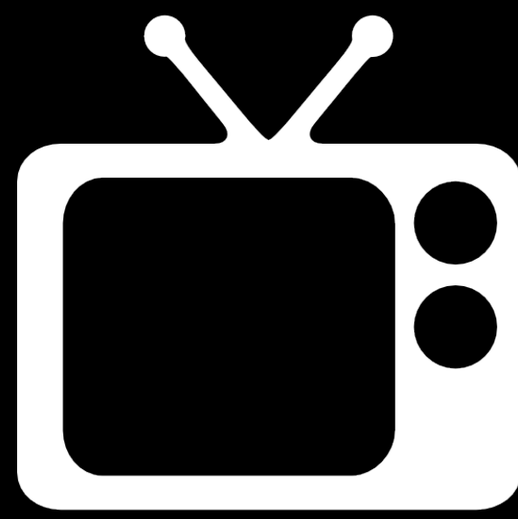

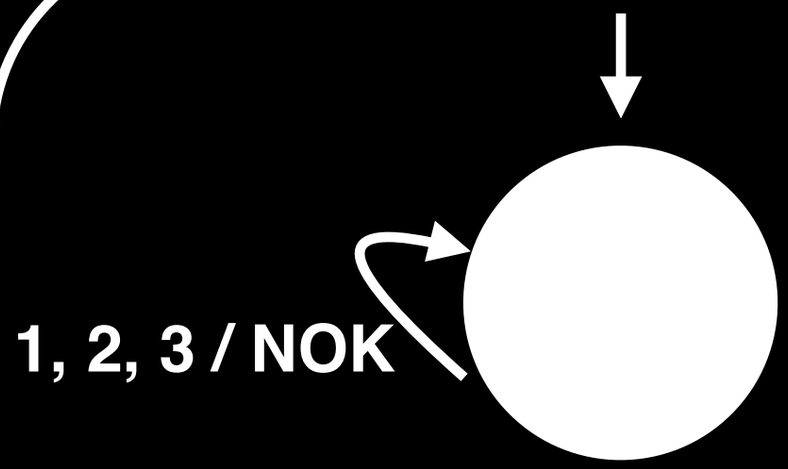
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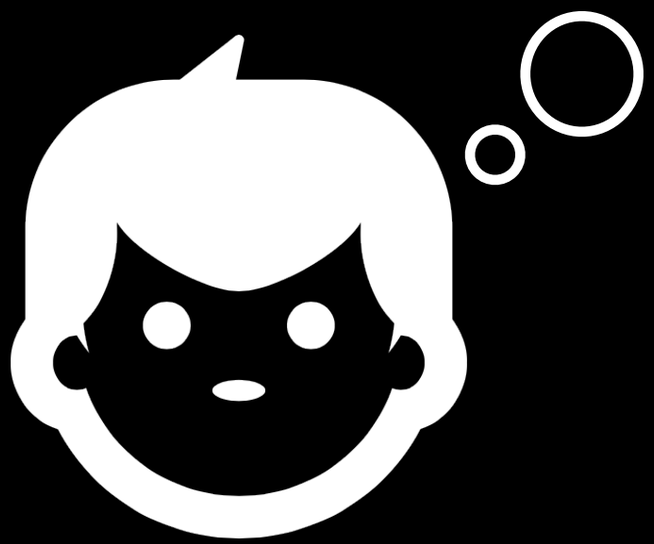

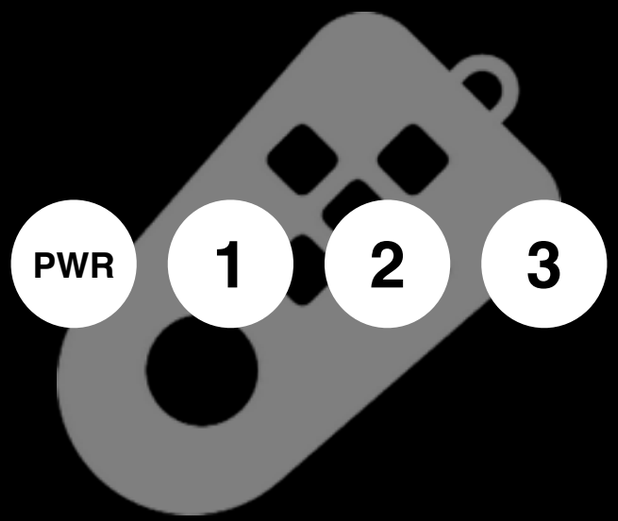
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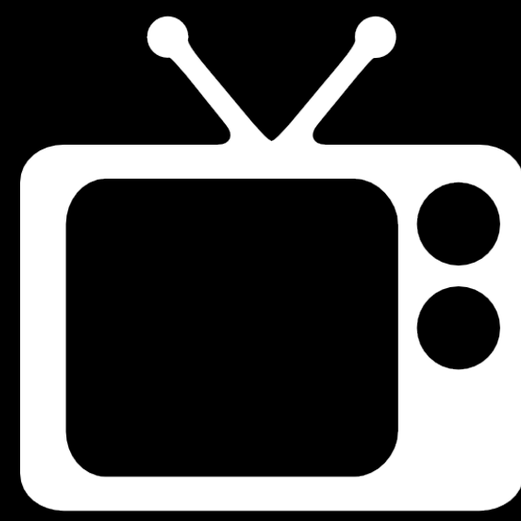

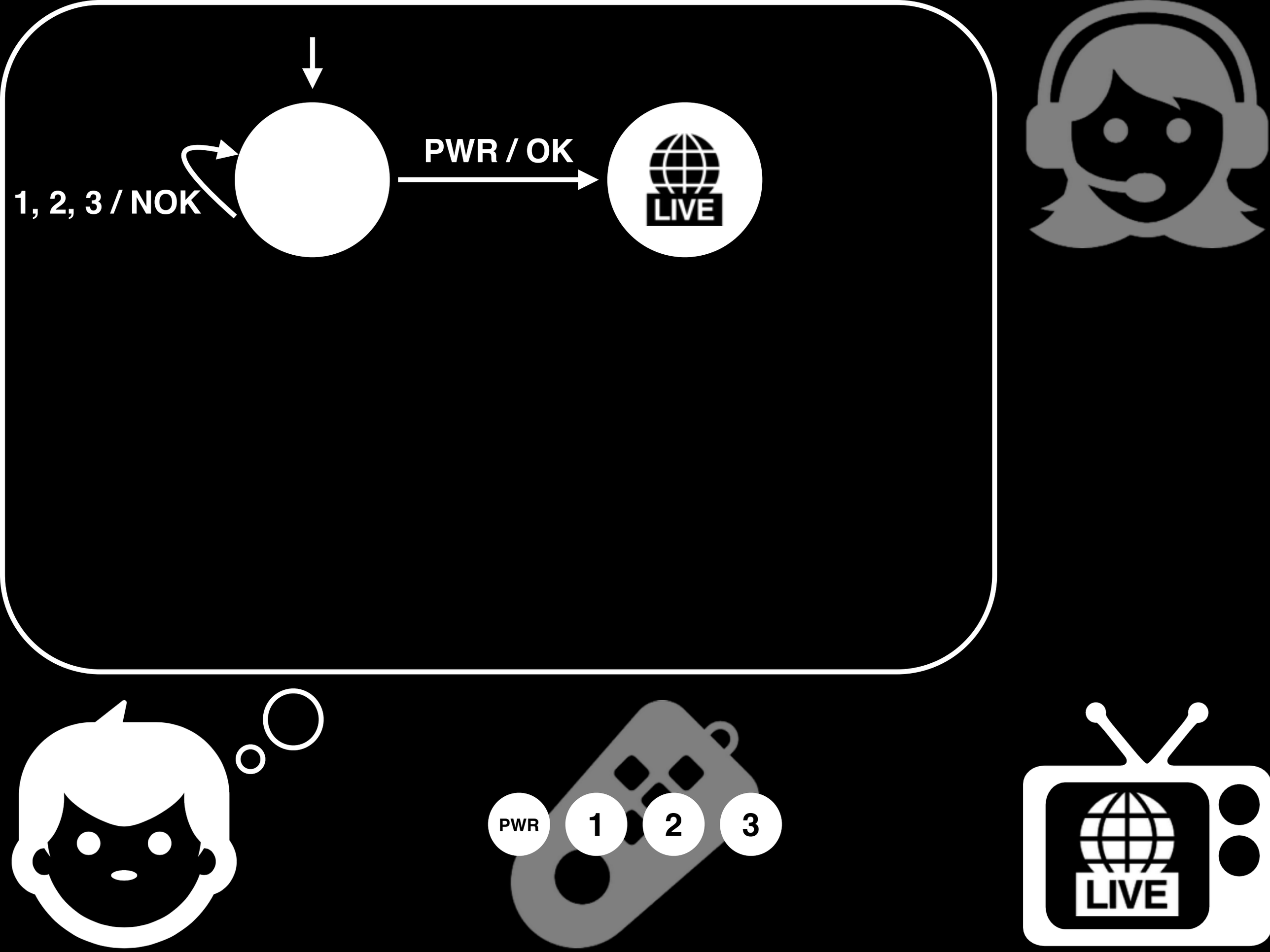
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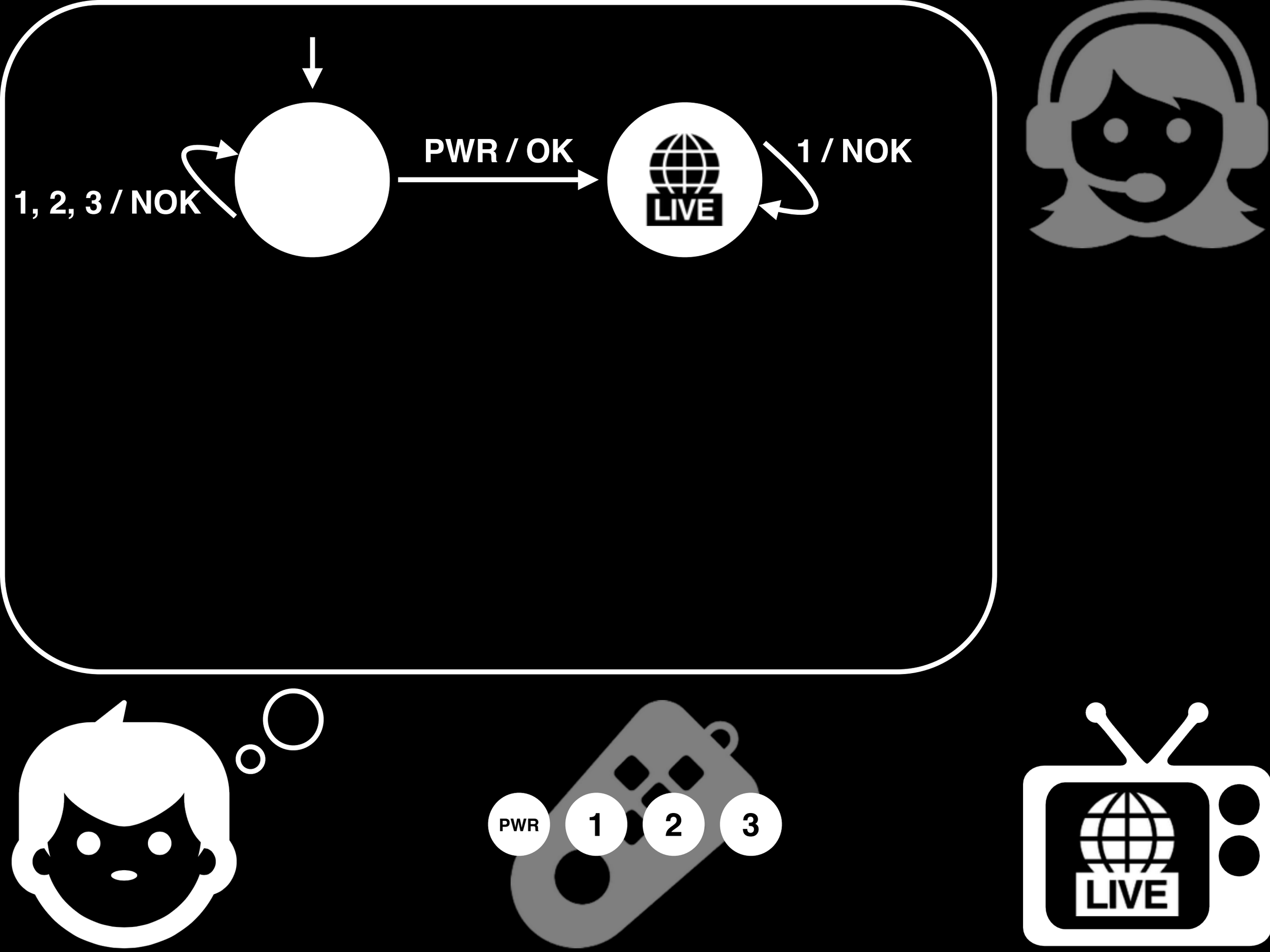
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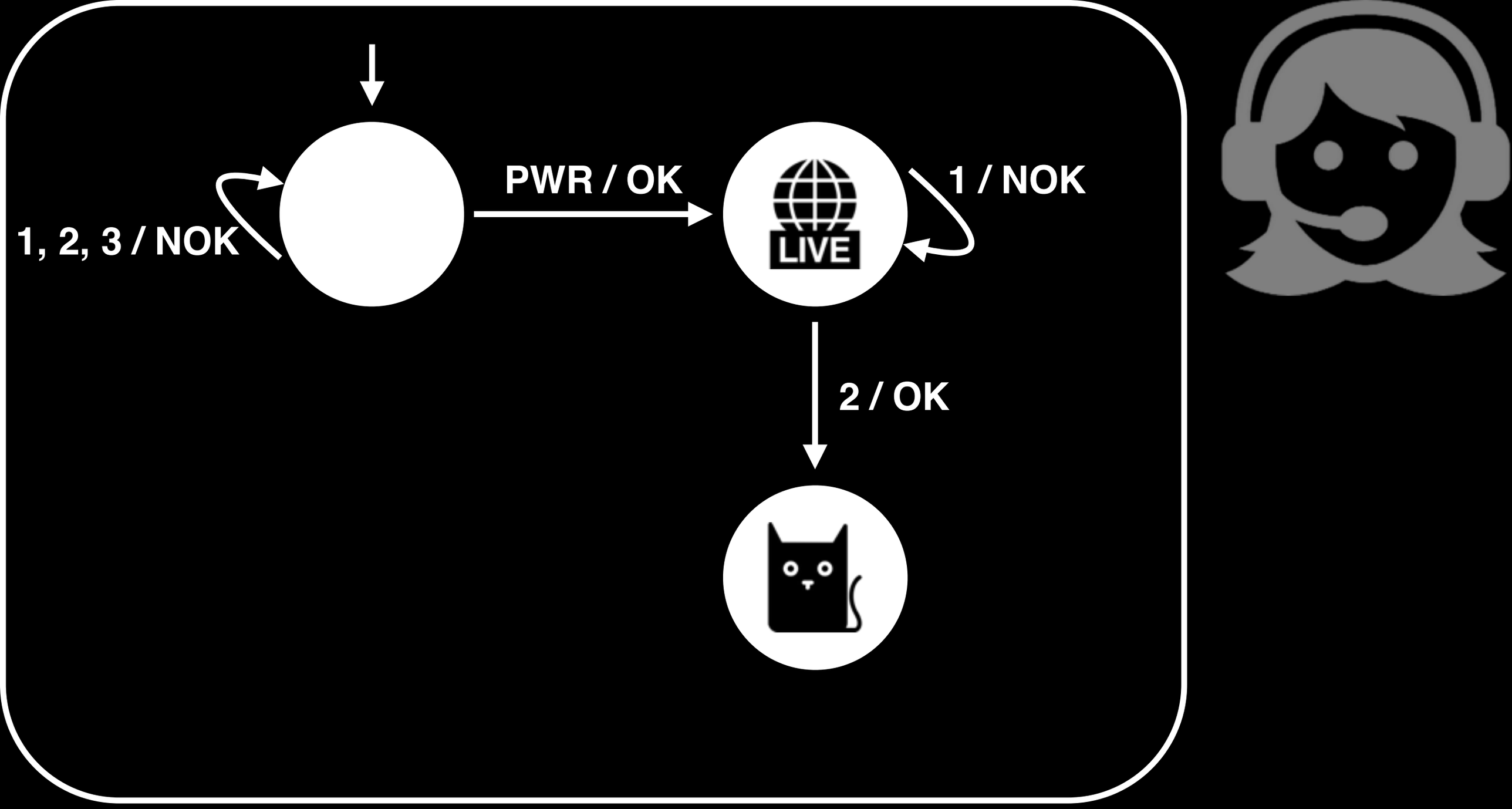
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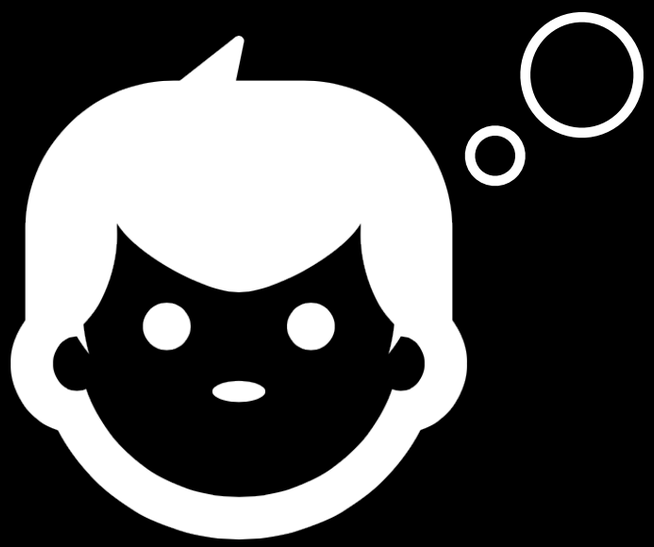

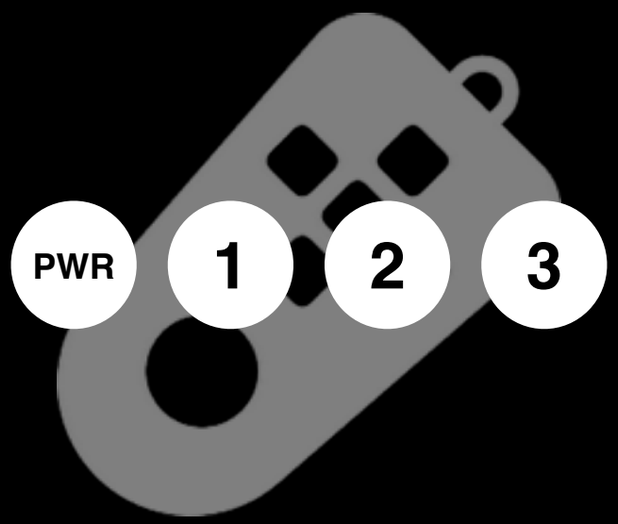
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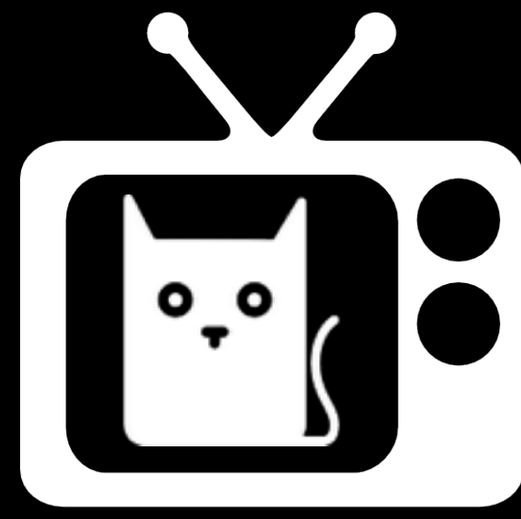

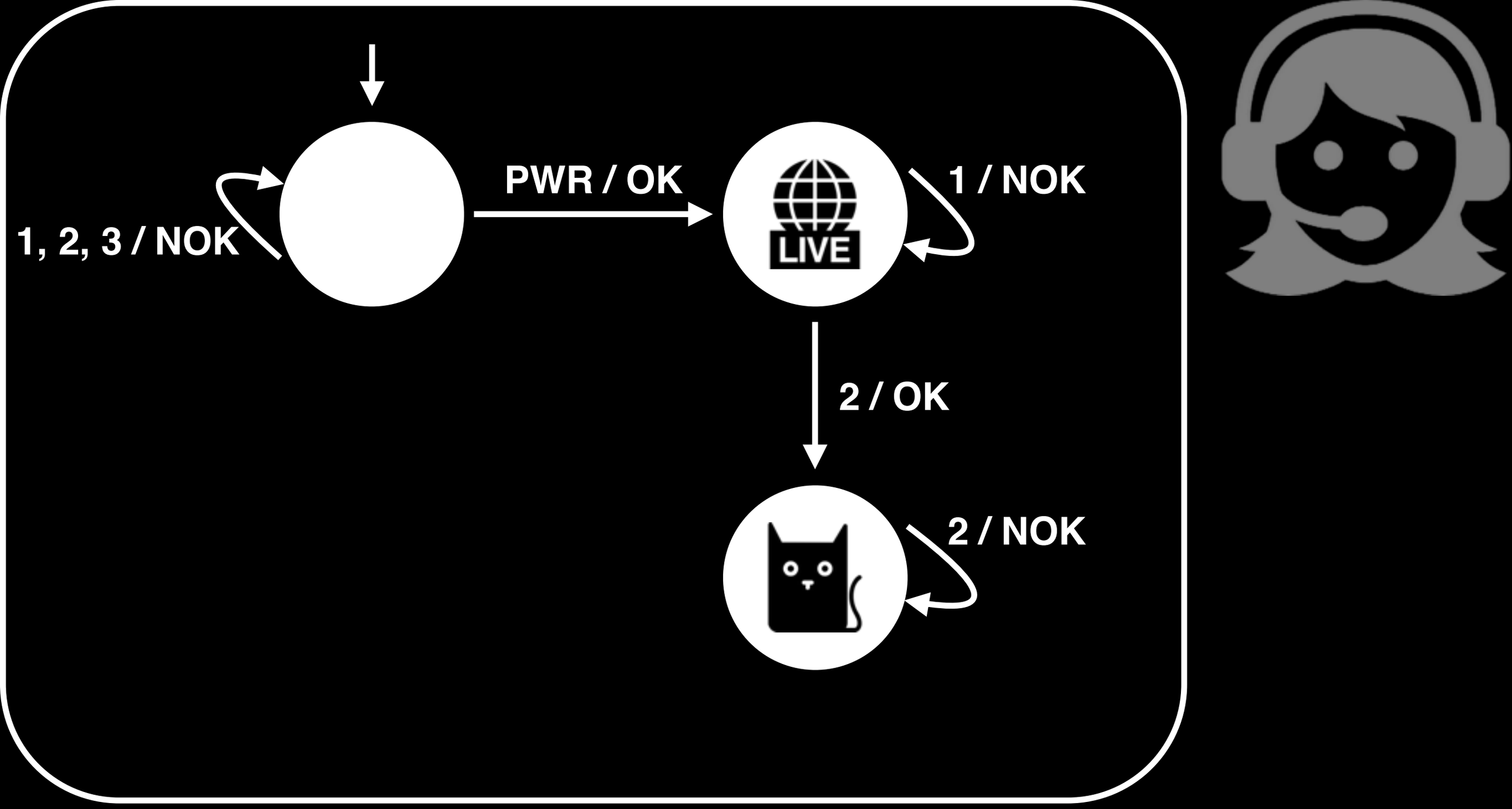
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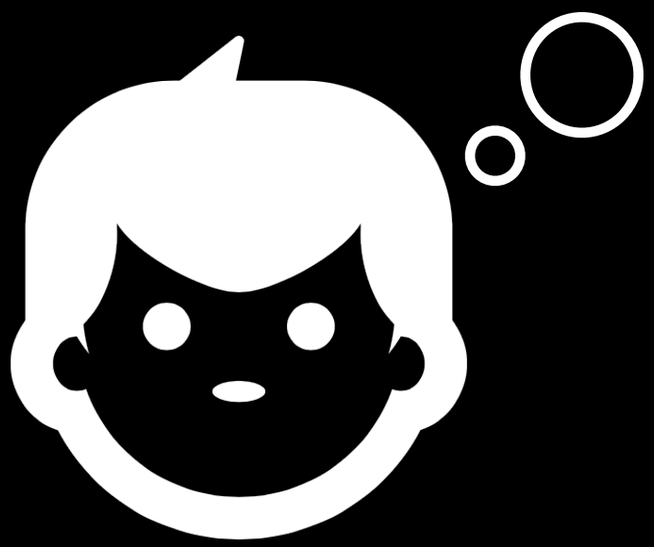

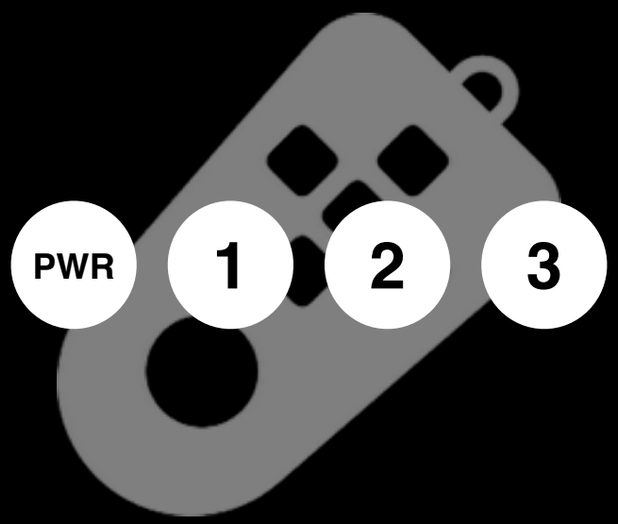
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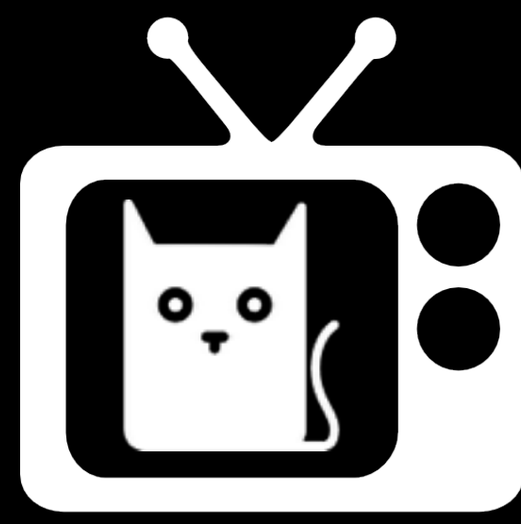

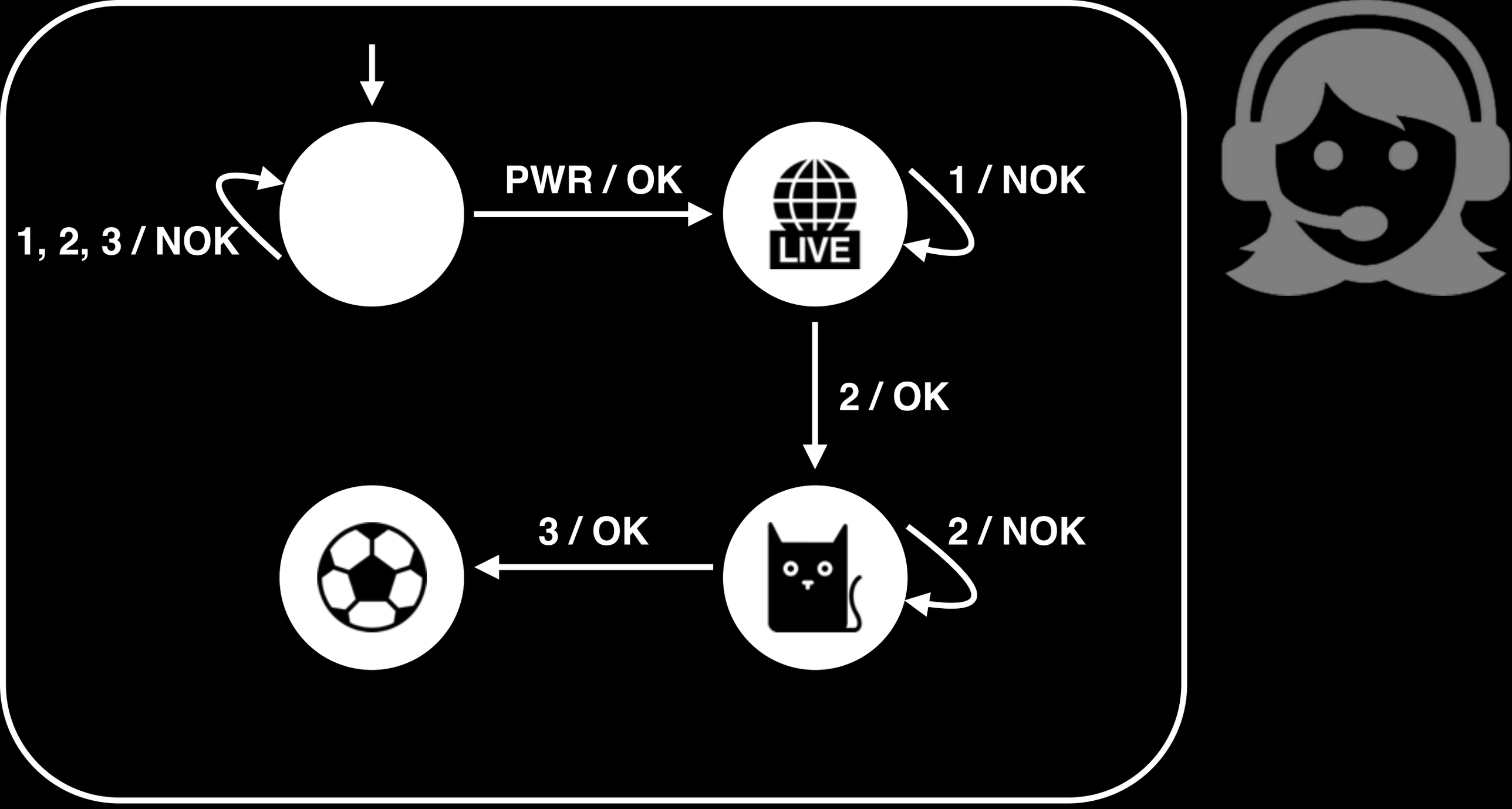
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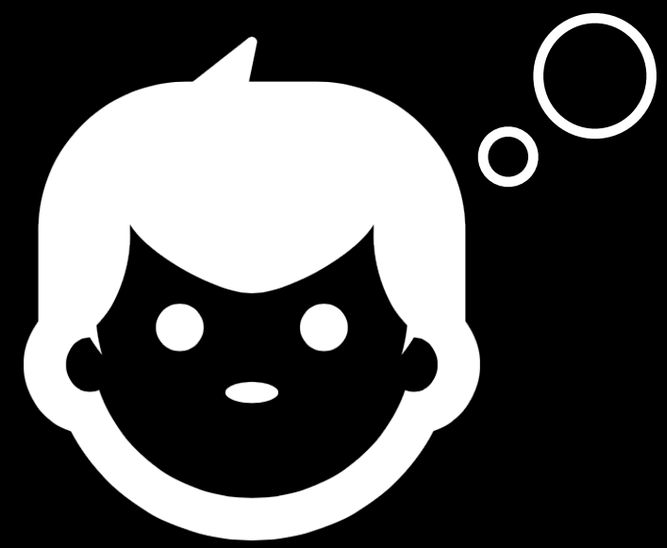

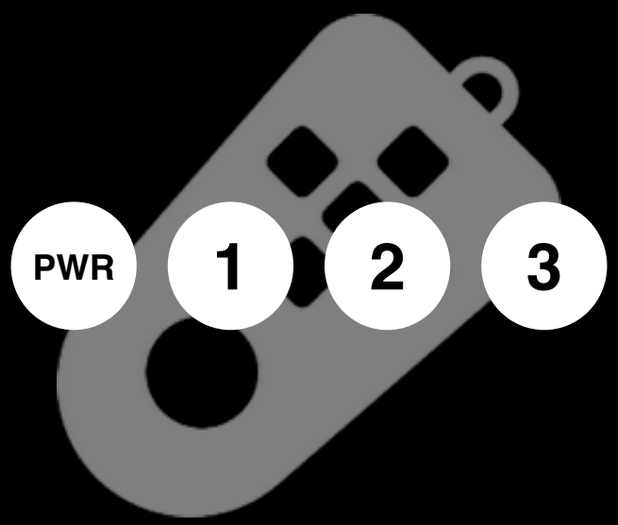
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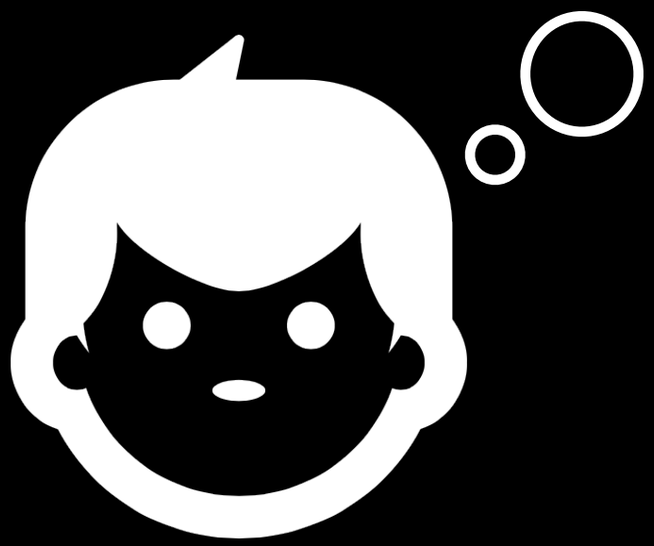

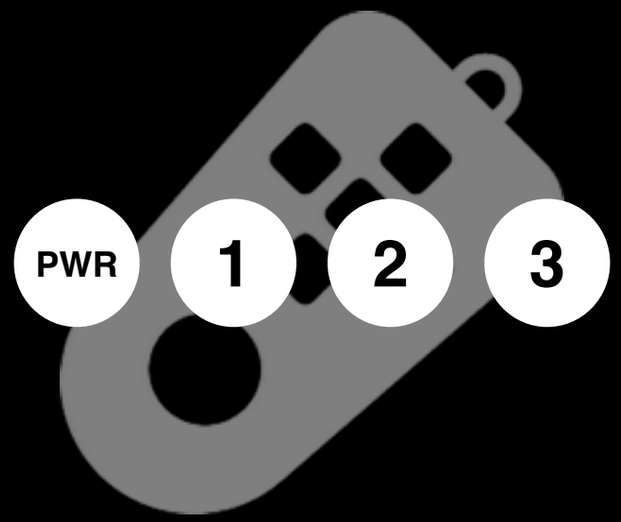

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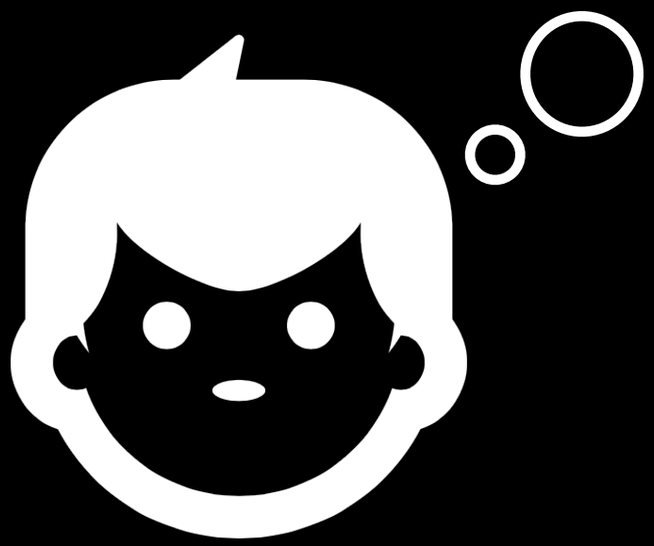

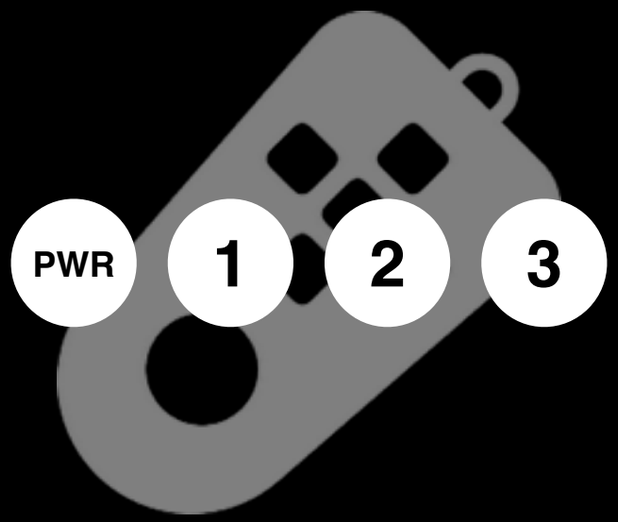

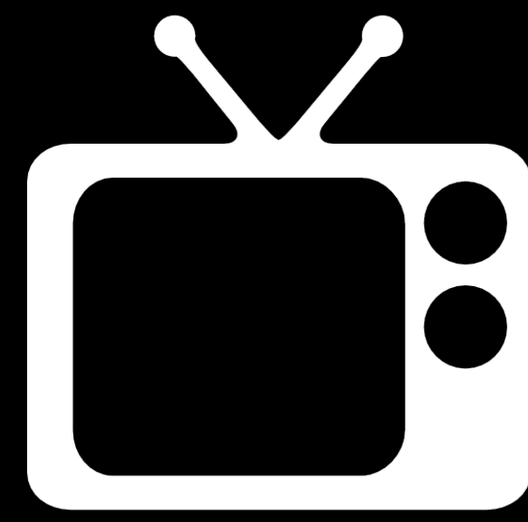

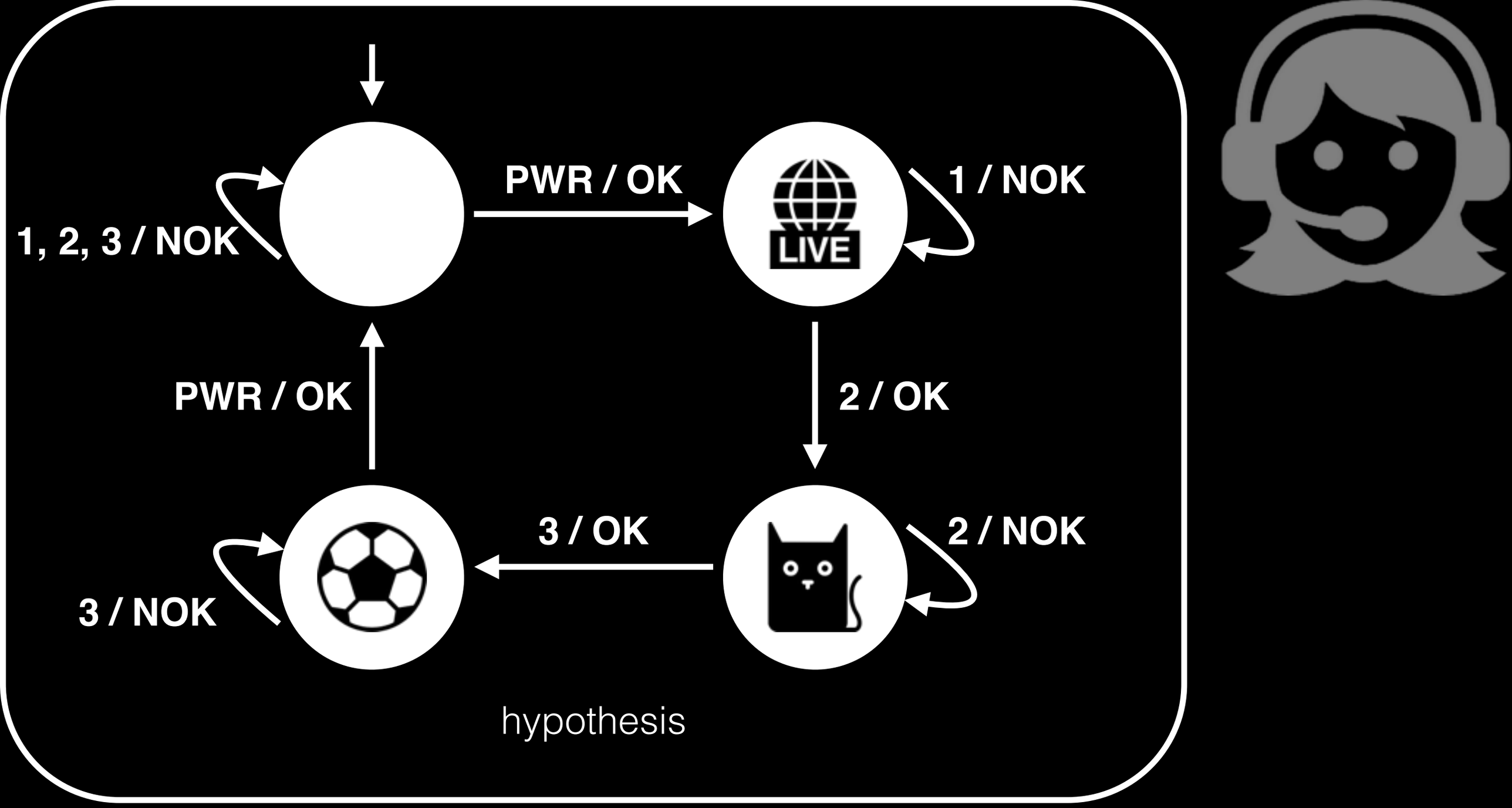
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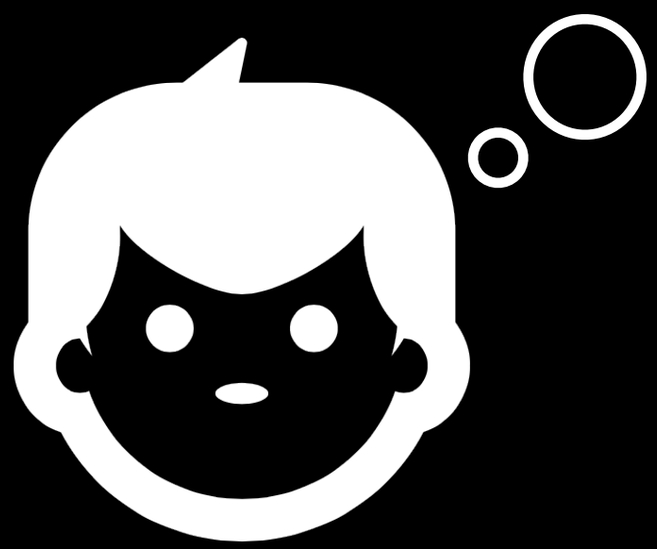
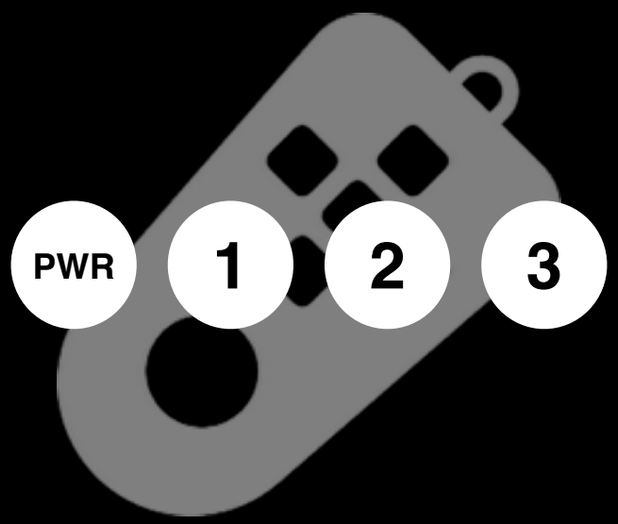
hypothesis

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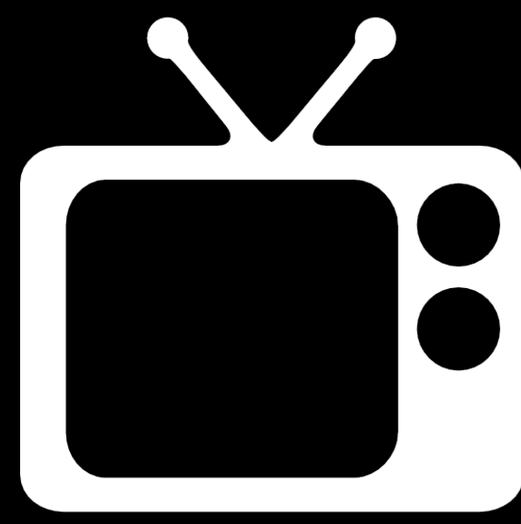

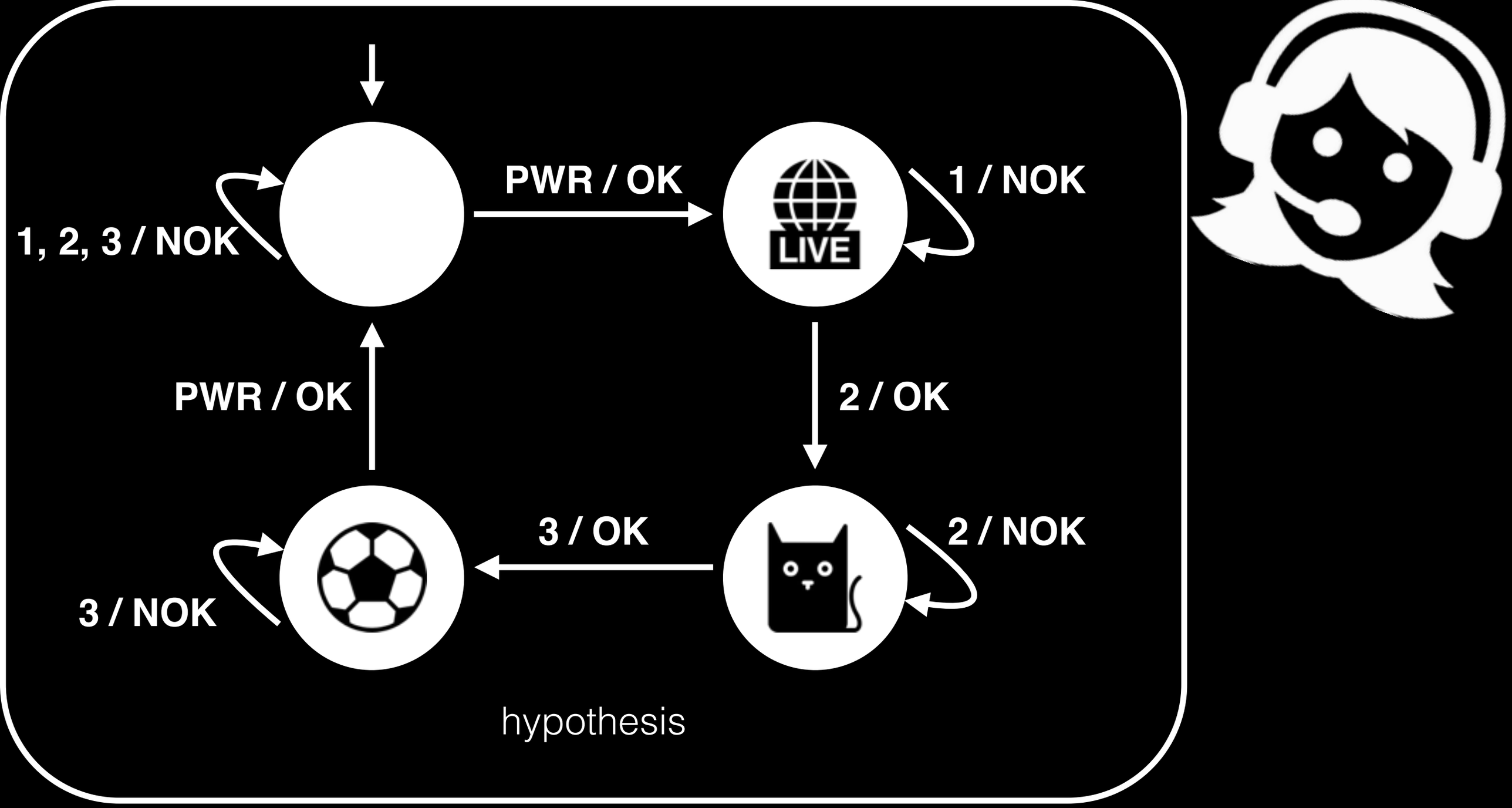
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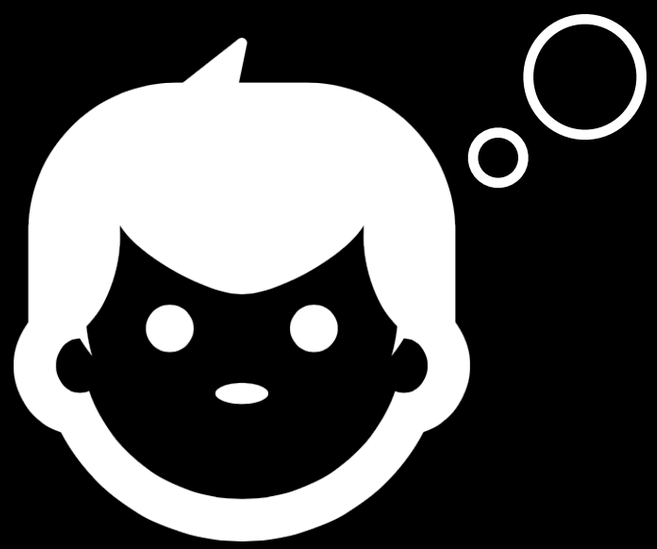

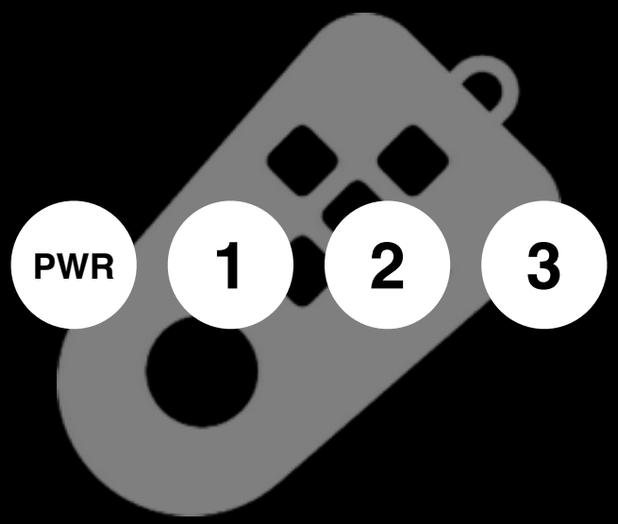
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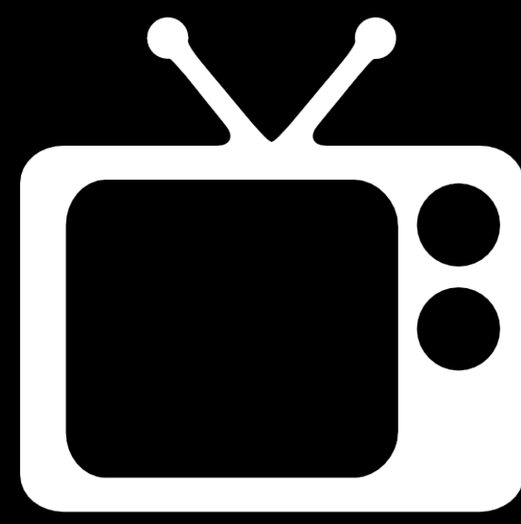

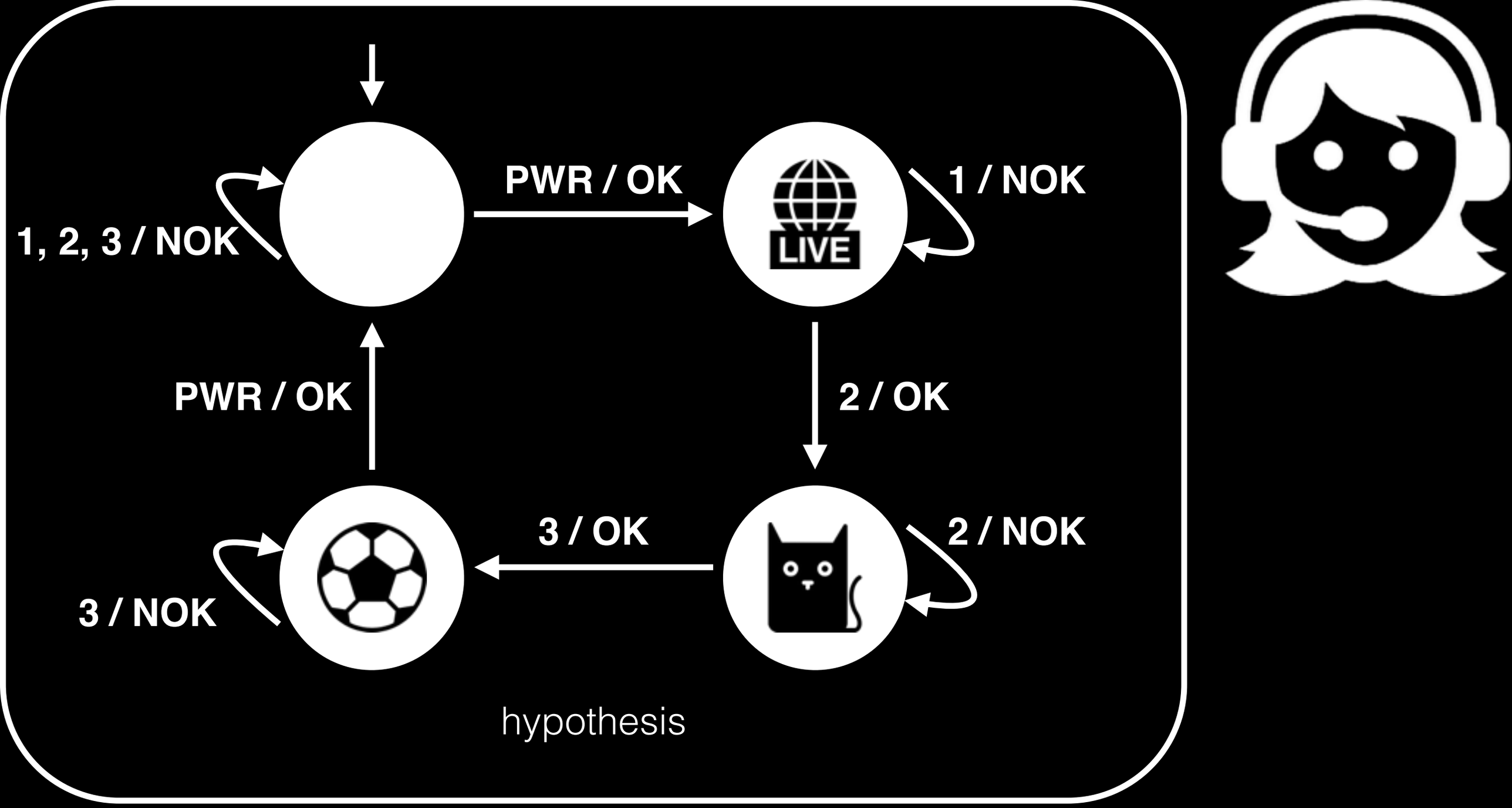
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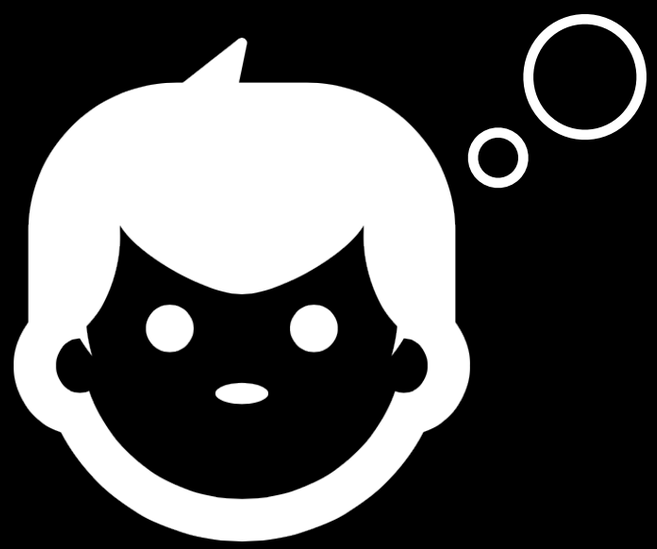

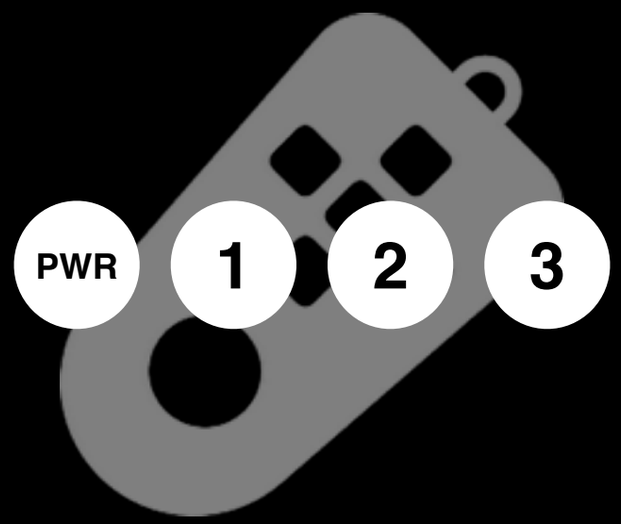
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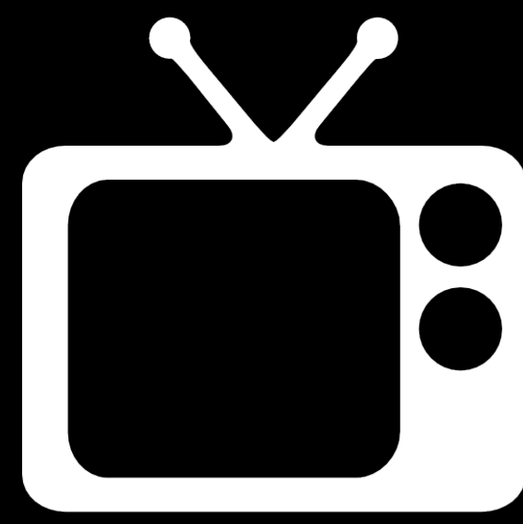

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hypothesis

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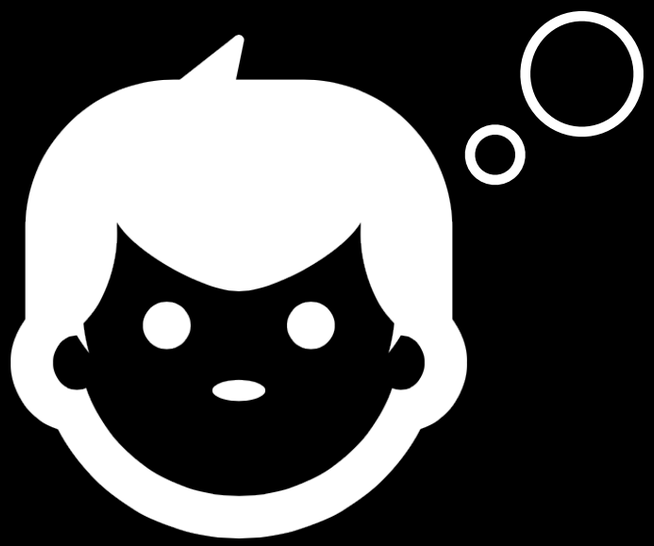
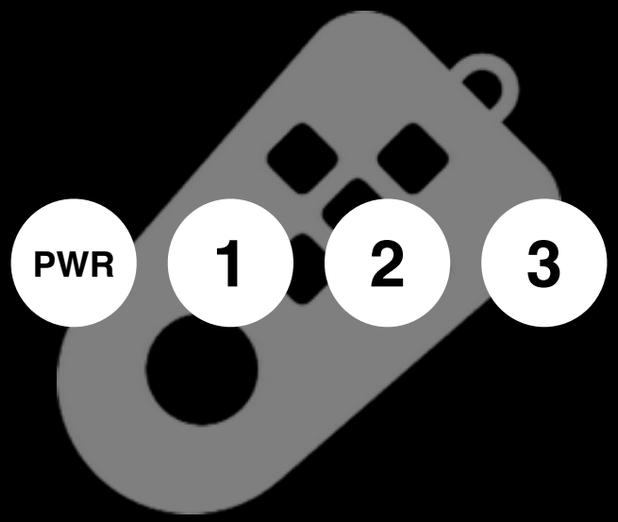
hypothesis

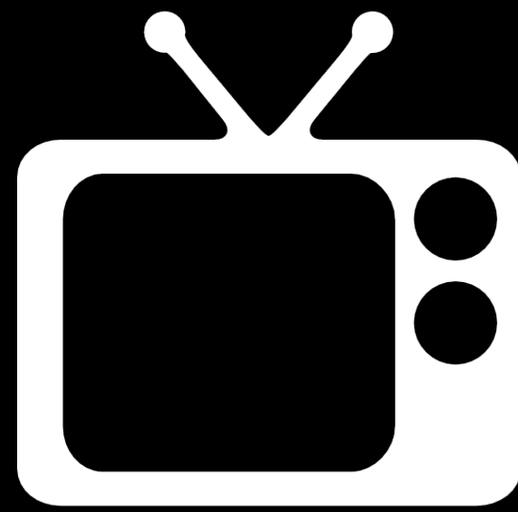
PWR 3

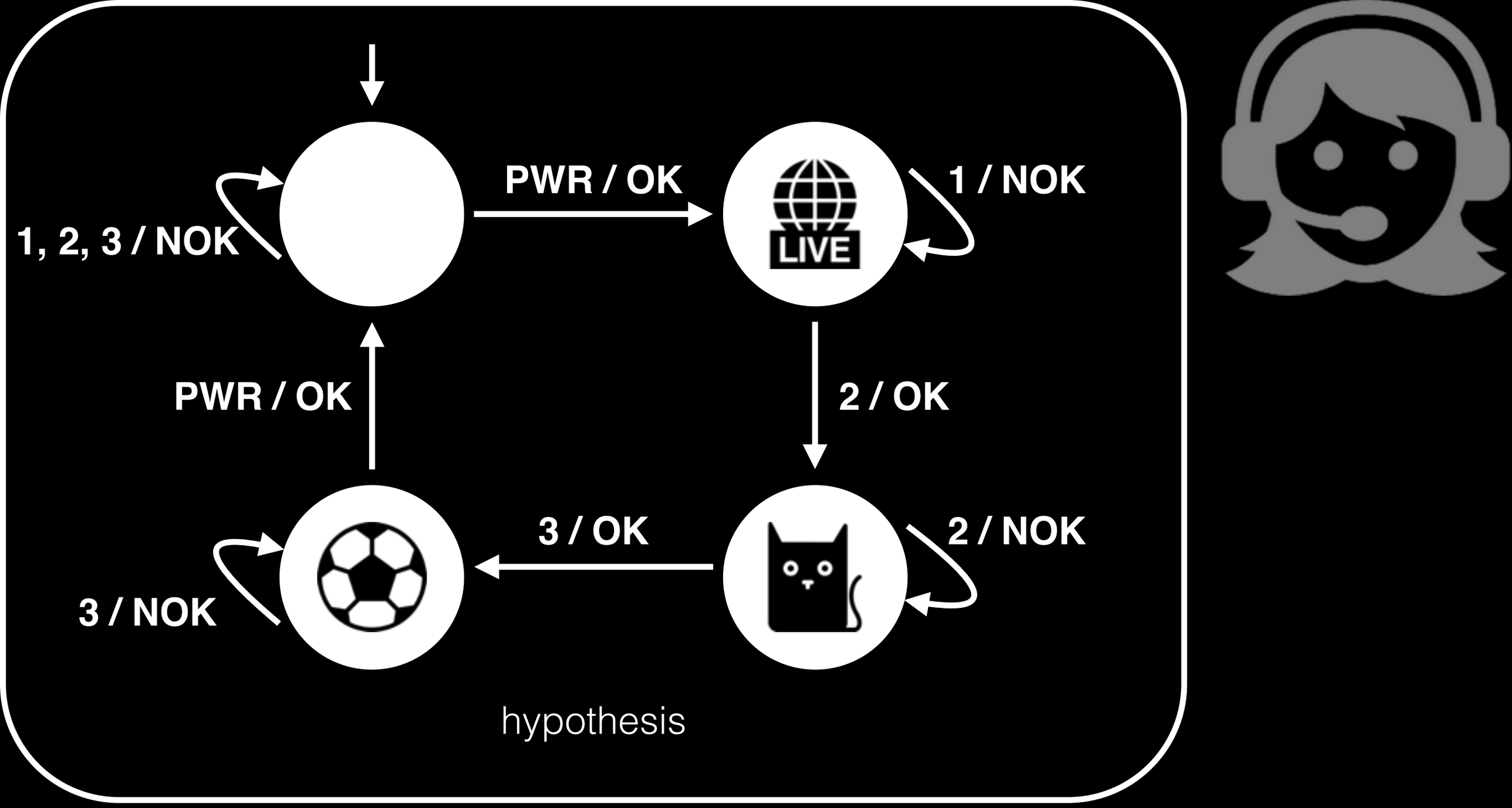
OK

counterexample





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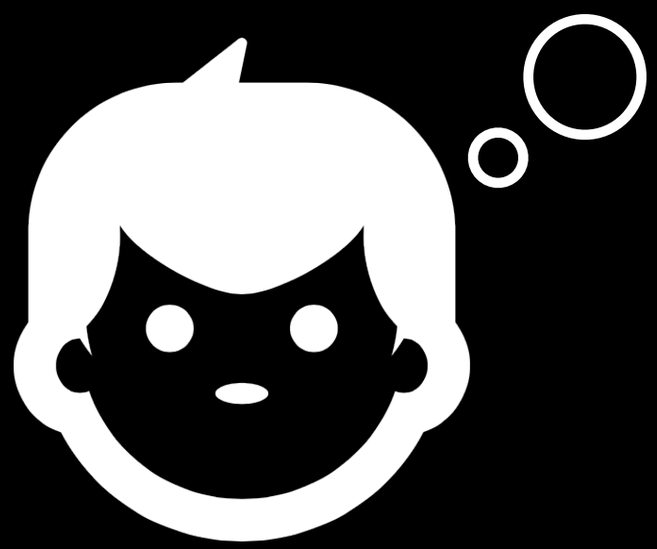

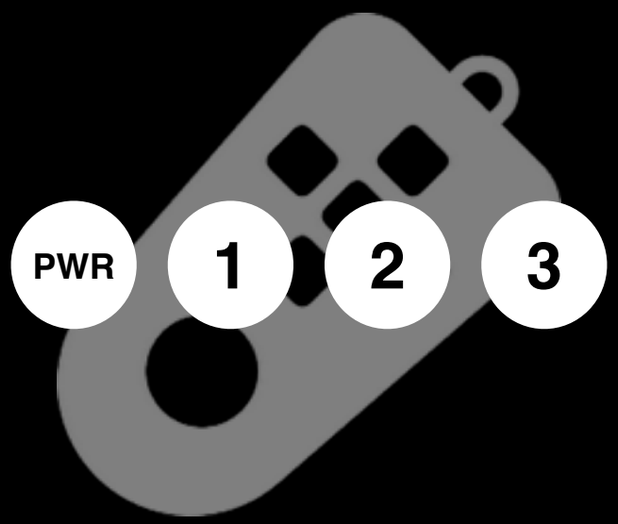
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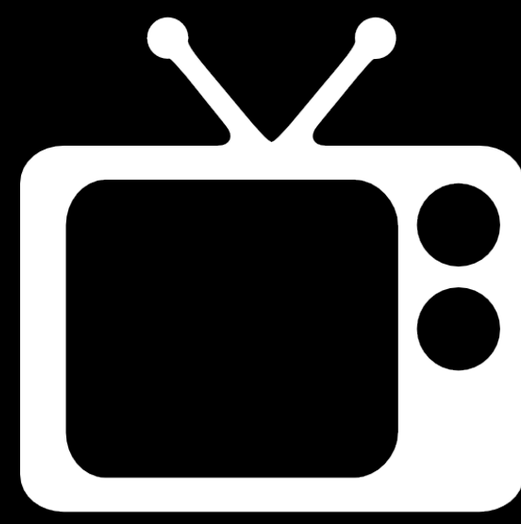

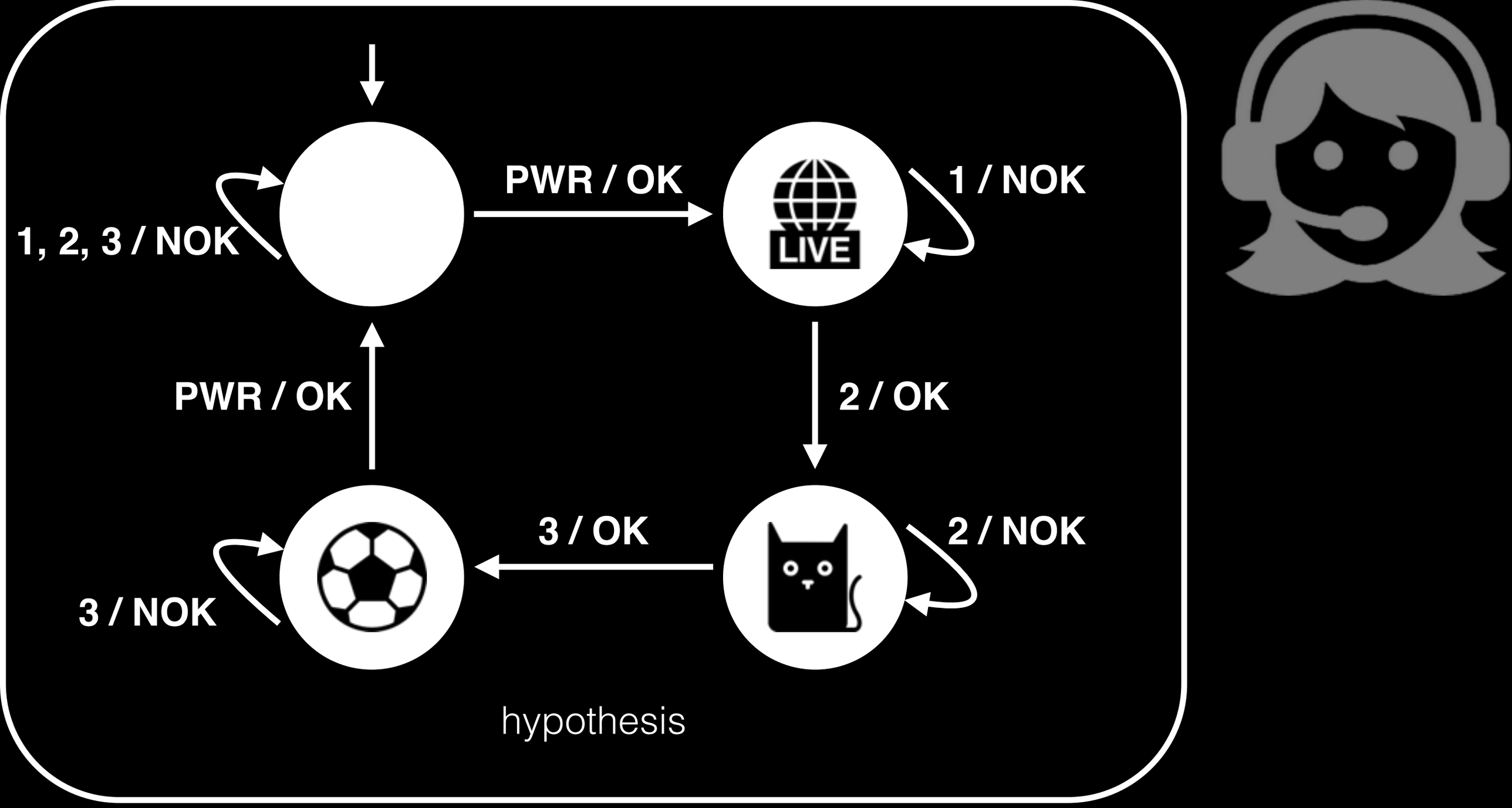
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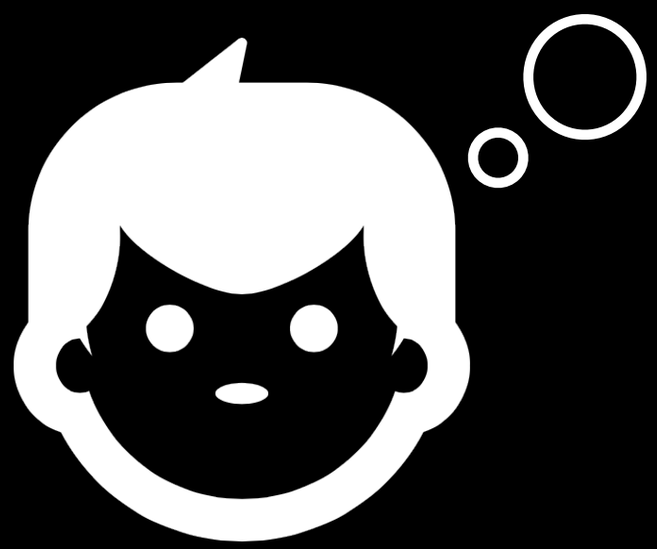

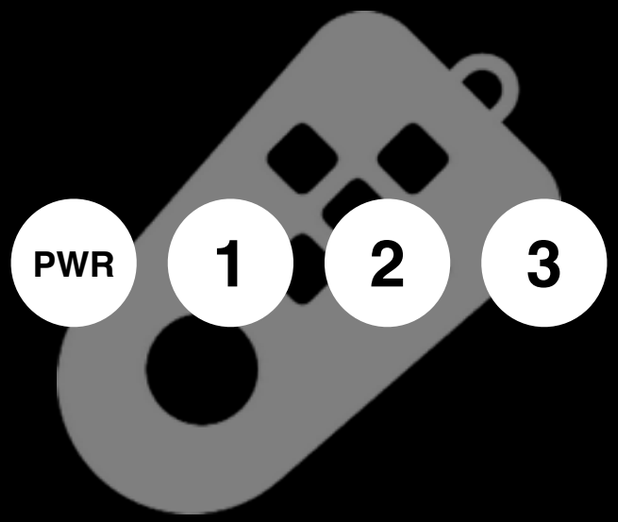
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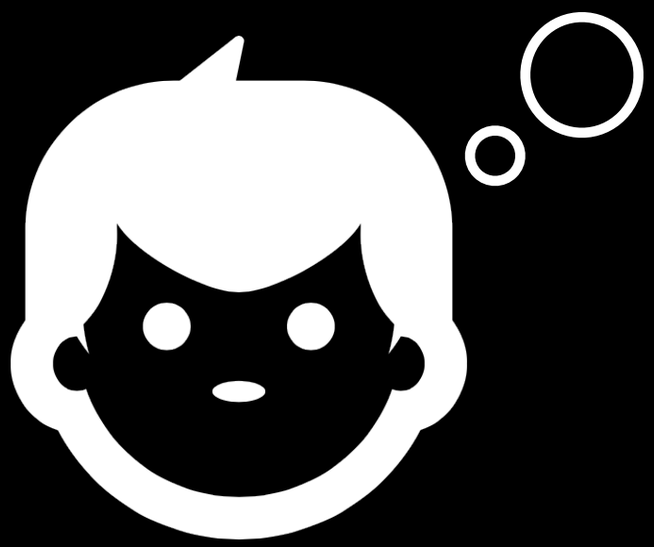
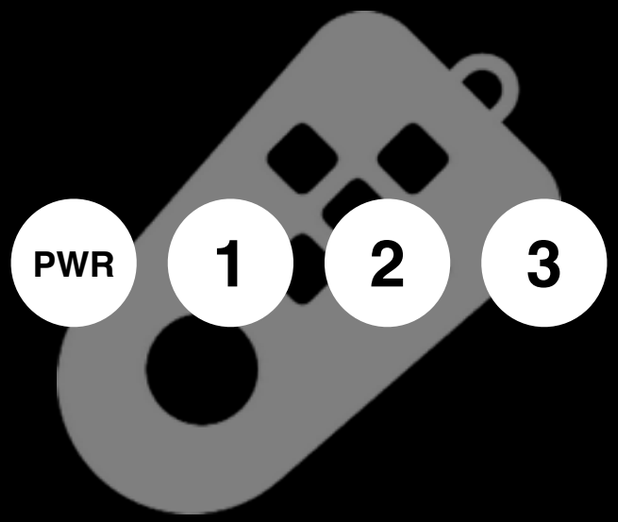
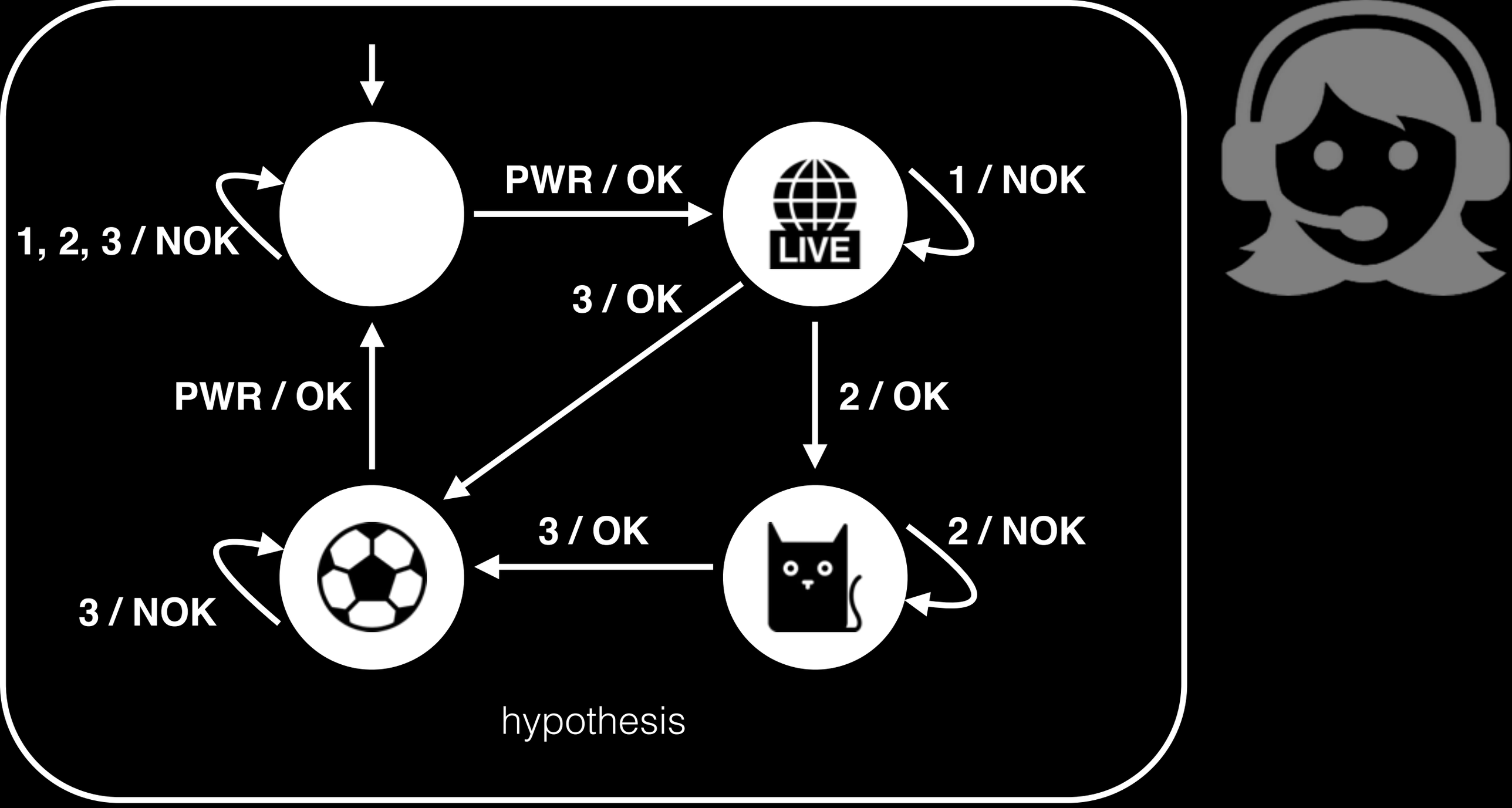
hypothesis







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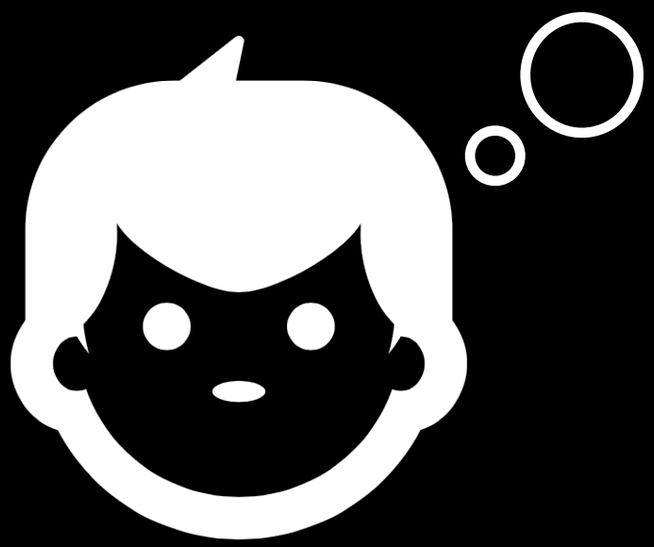

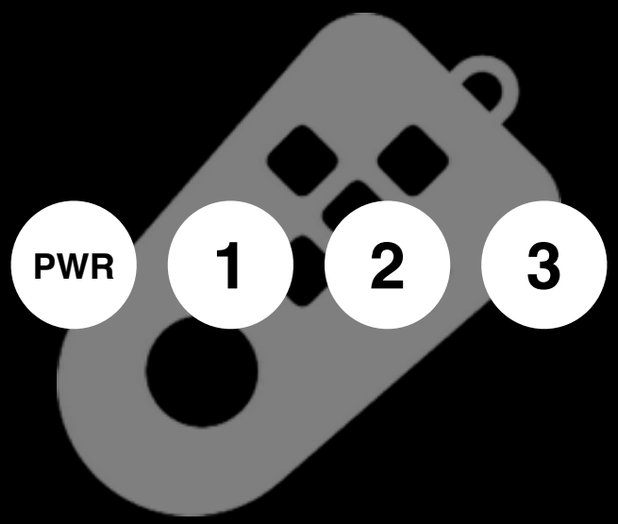

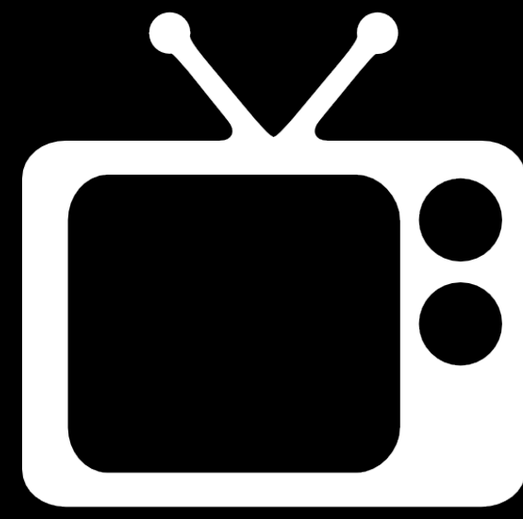

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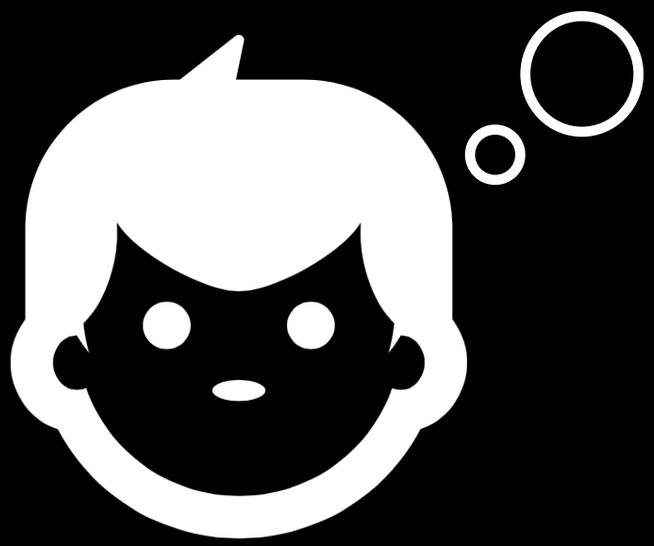
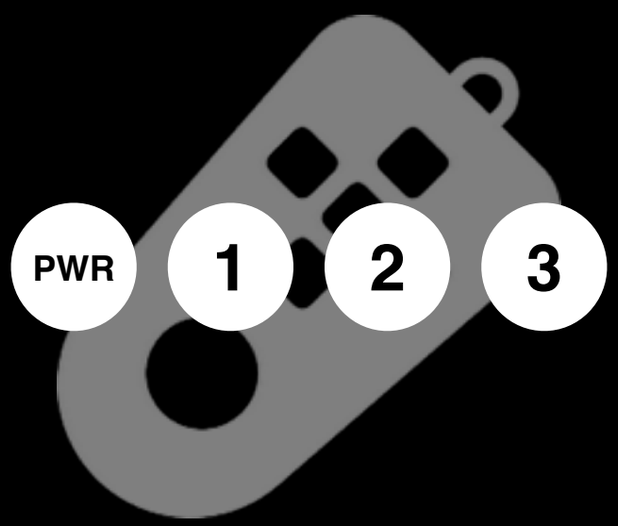
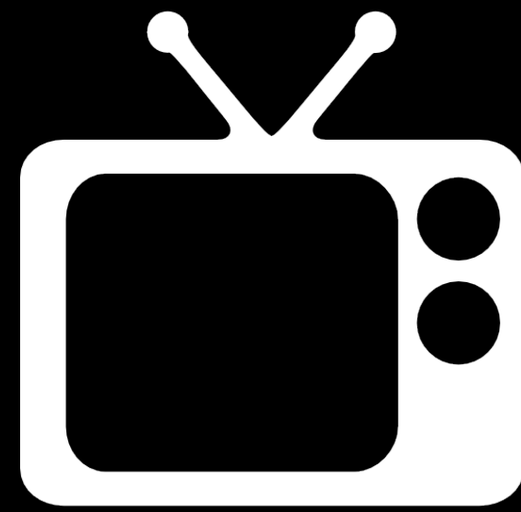
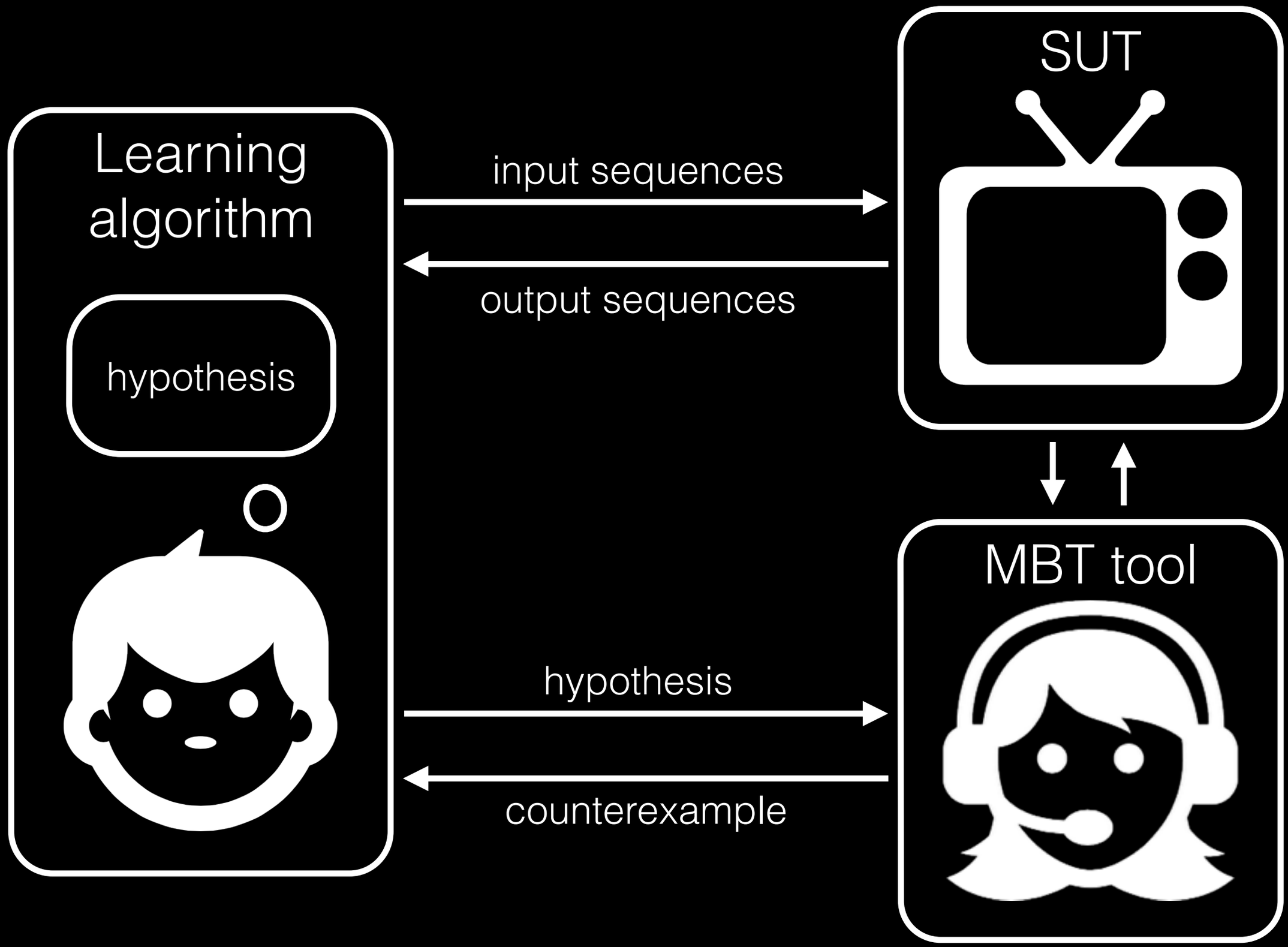







Learning algorithm
hypothesis
input sequences
output sequences
SUT
MBT tool
hypothesis
counterexample

hypotheses in an ultrametric space

ultrametric for hypothesis quality

$d(\text{👦}, \text{📺}) = 2^{-n}$

n is the length of a minimal-length counterexample

“In systems engineering, a potential bug in the far-away future is less troubling than a potential bug today.”

–Luca de Alfaro et. al., Discounting the future in systems theory, 2004

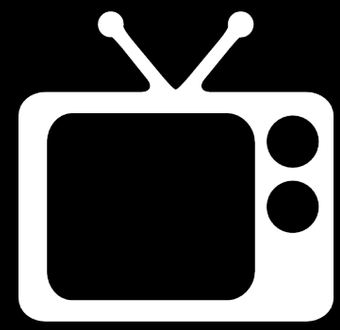
quality (relative to SUT)

progress (number of states)

original algorithm

our improvement

(quality increases monotonically)



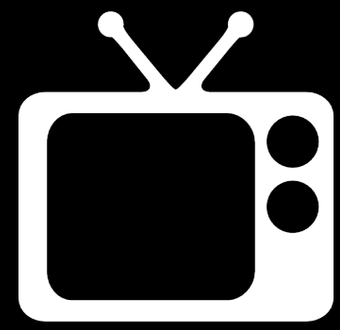
quality (relative to SUT)

····· original algorithm

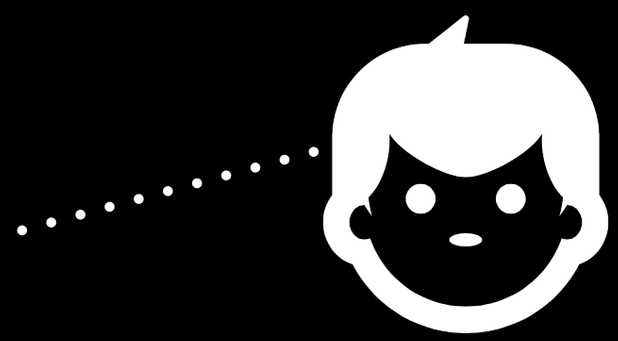
——— our improvement

(quality increases monotonically)

progress (number of states)



quality (relative to SUT)



original algorithm

our improvement

(quality increases monotonically)

progress (number of states)

quality (relative to SUT)

progress (number of states)

original algorithm

our improvement

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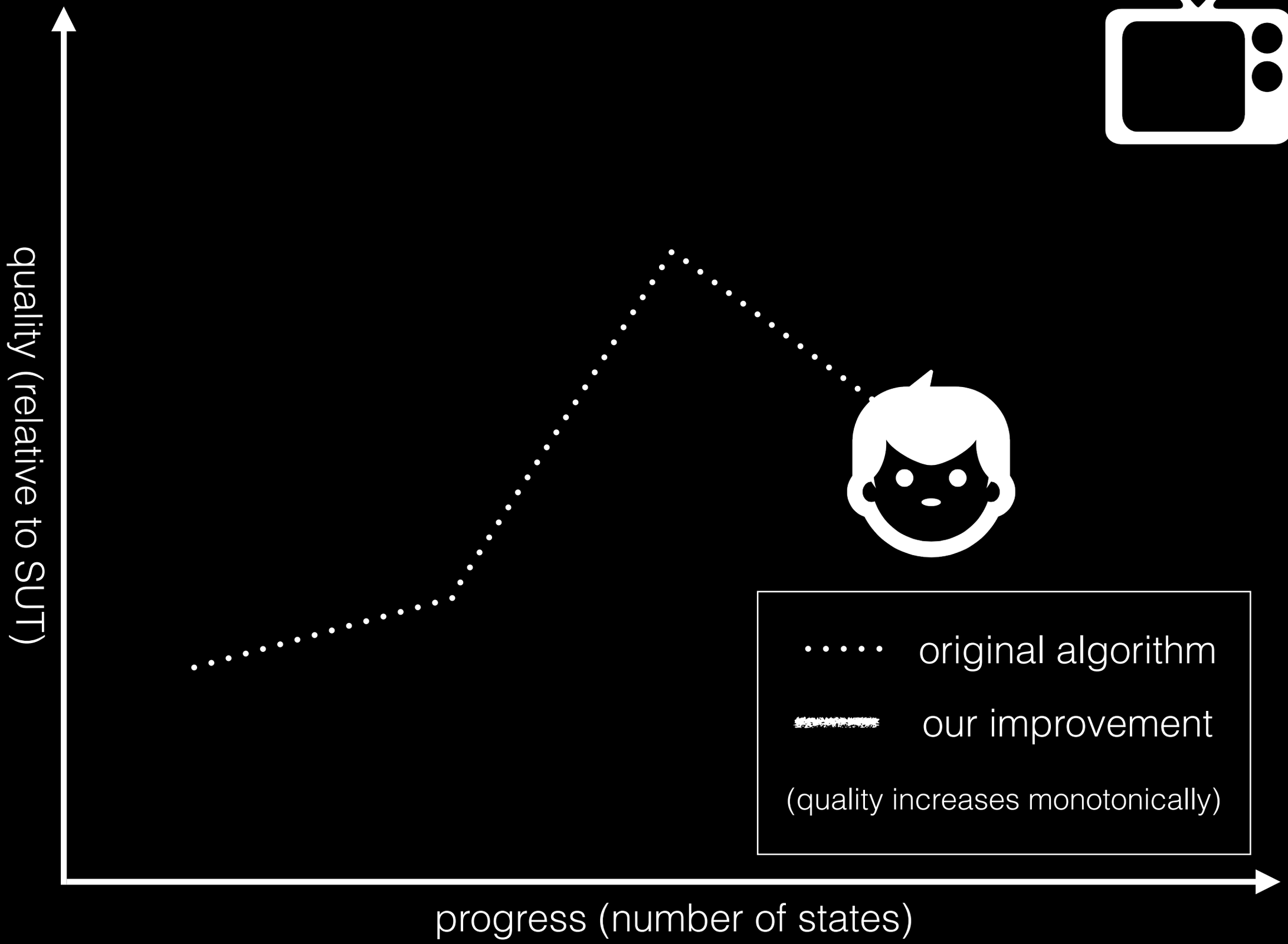
quality (relative to SUT)
progress (number of states)
original algorithm
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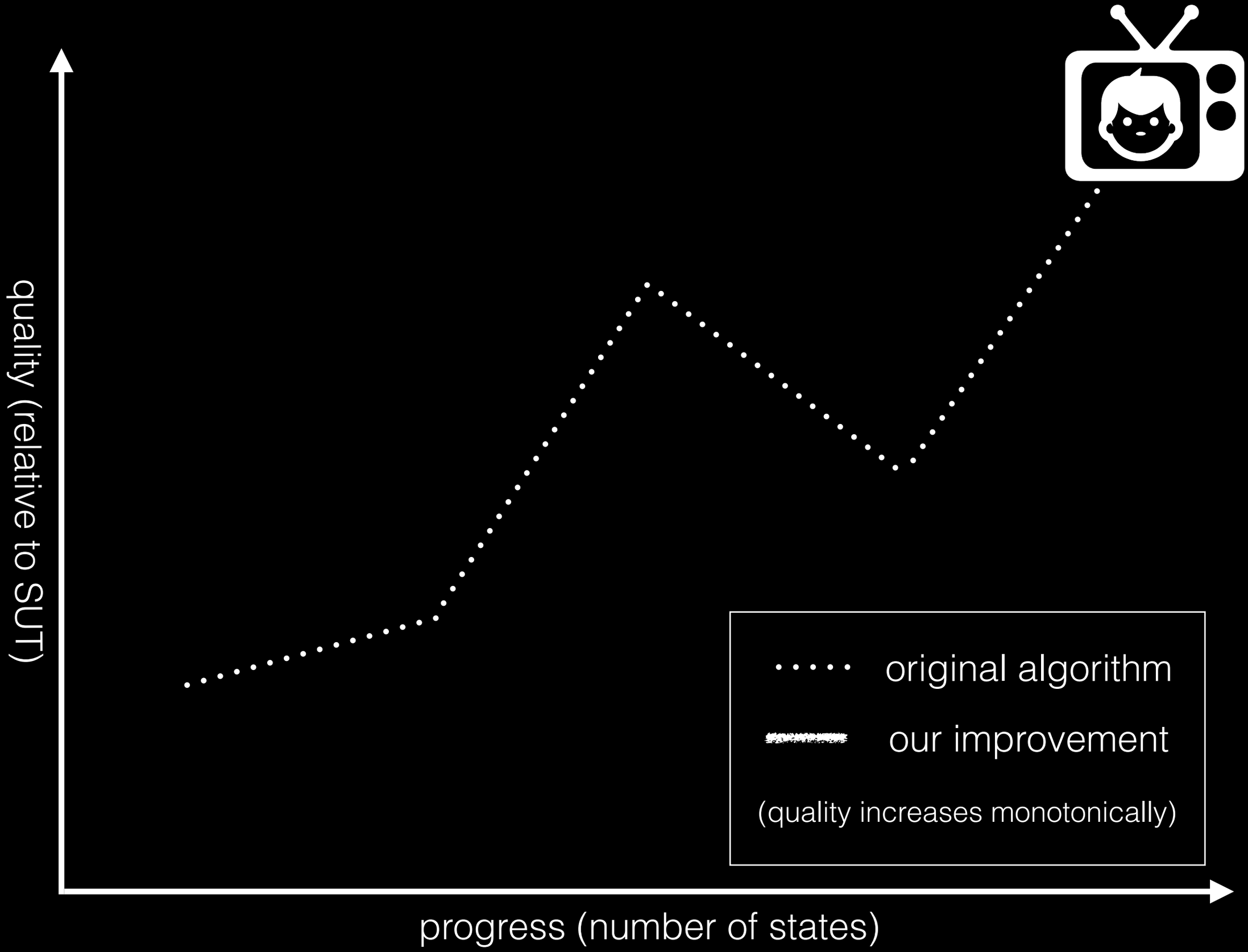
(quality increases monotonically)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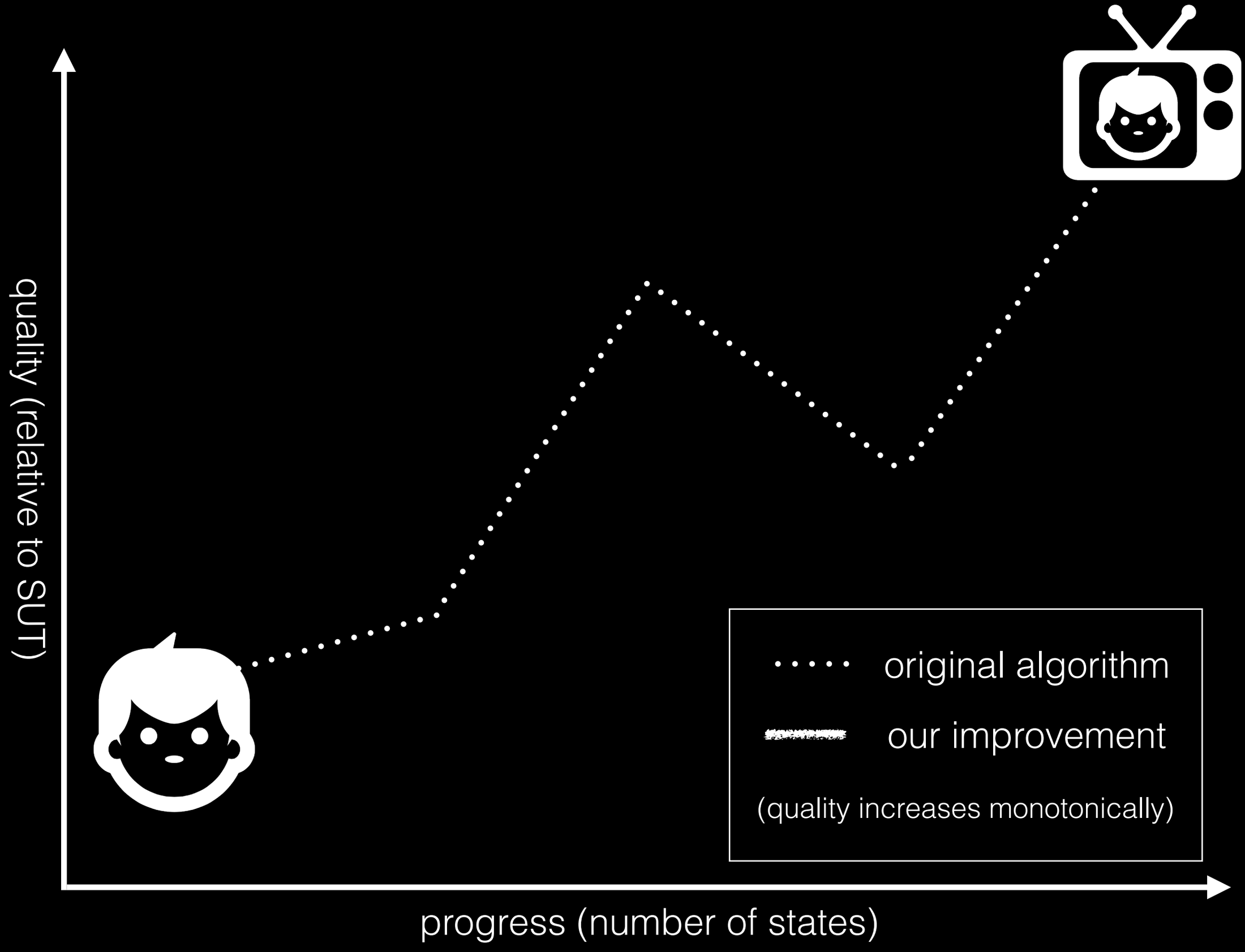
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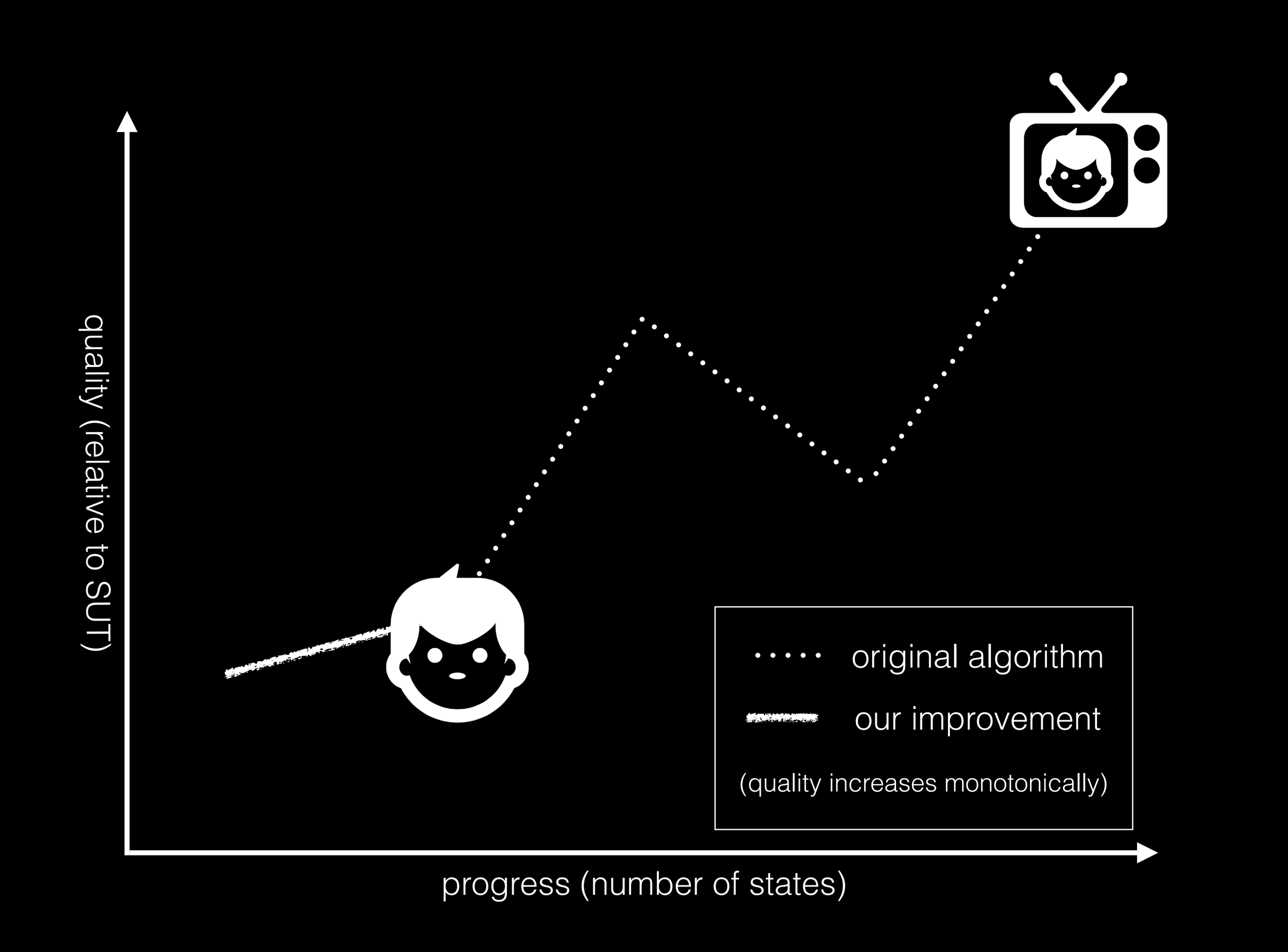
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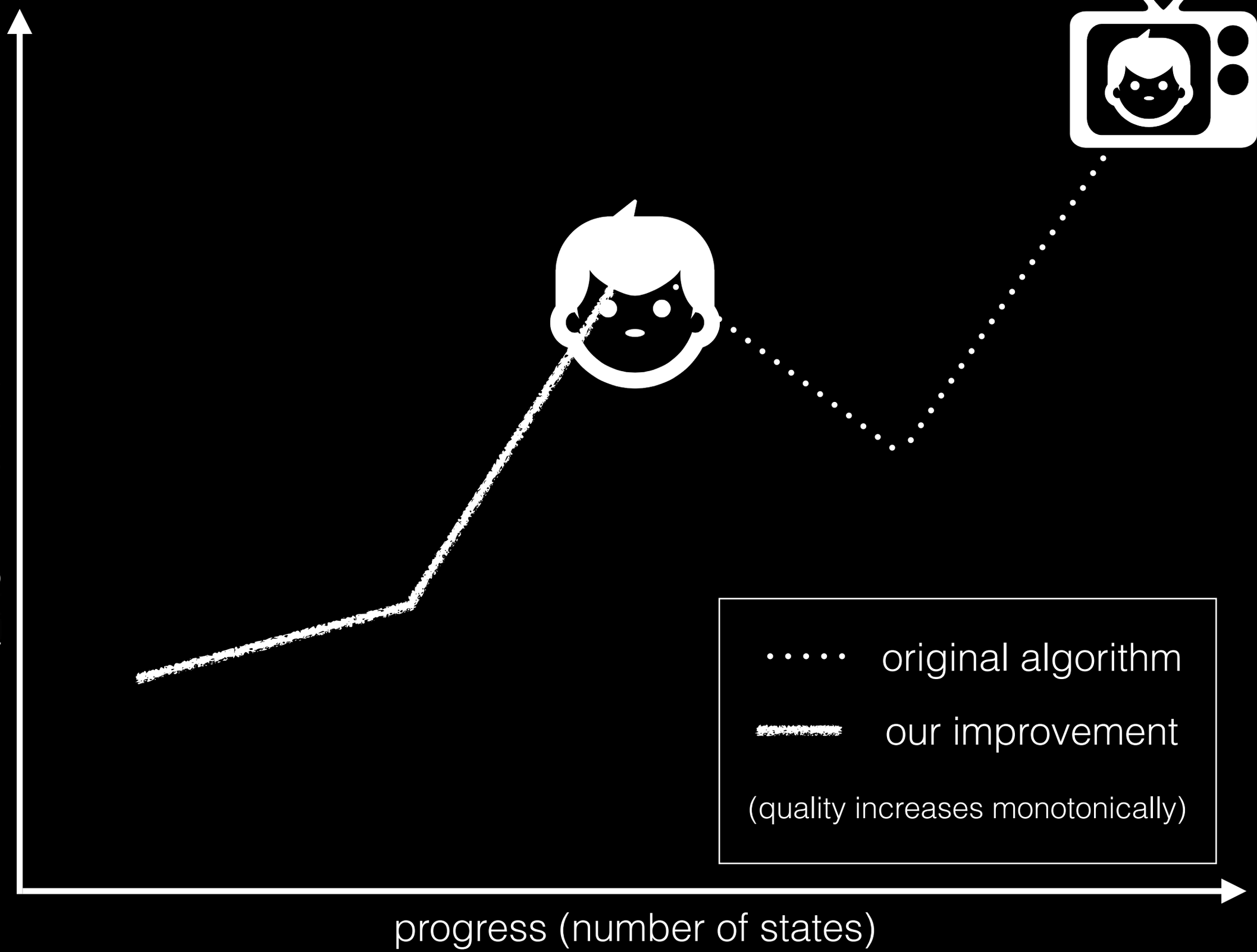
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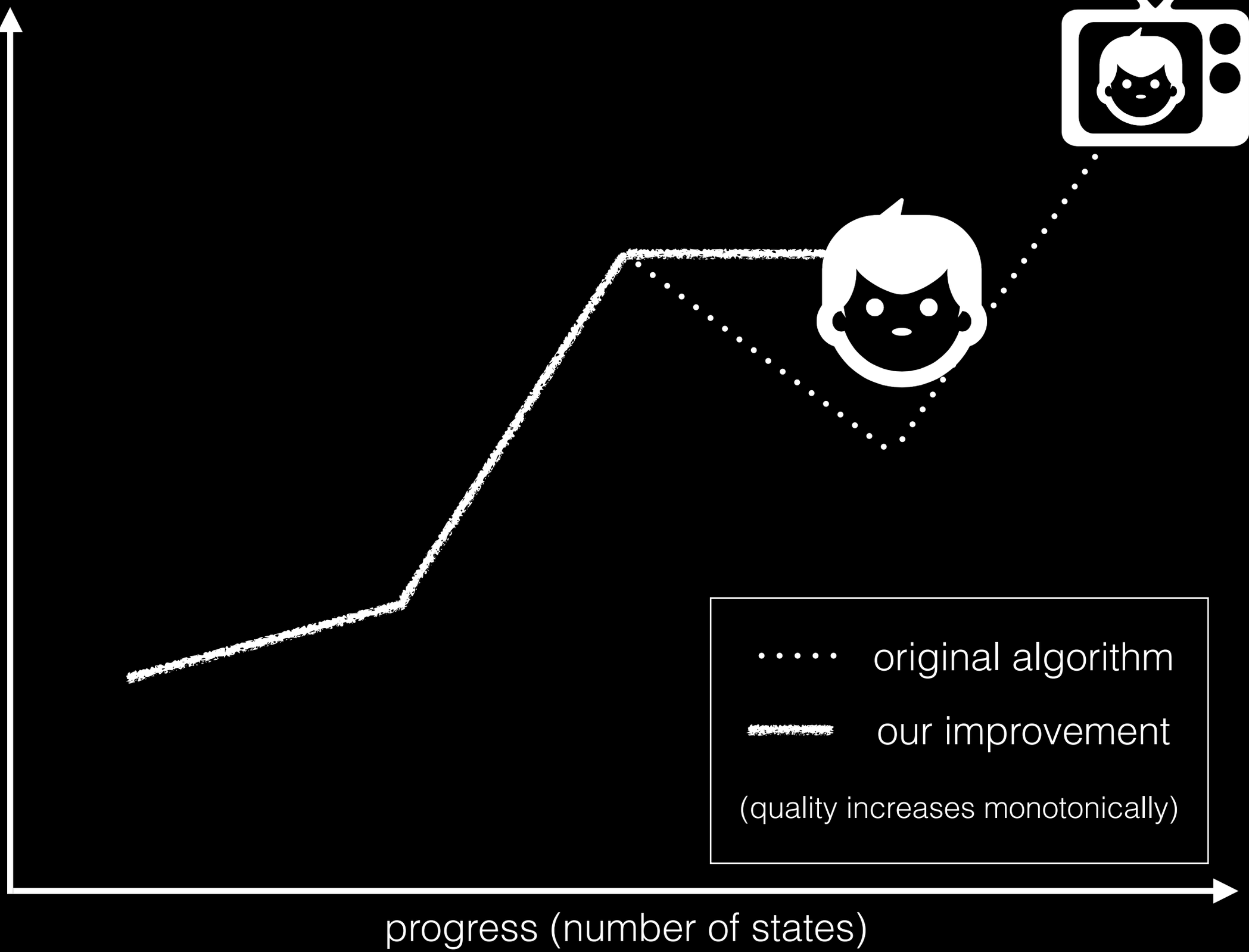
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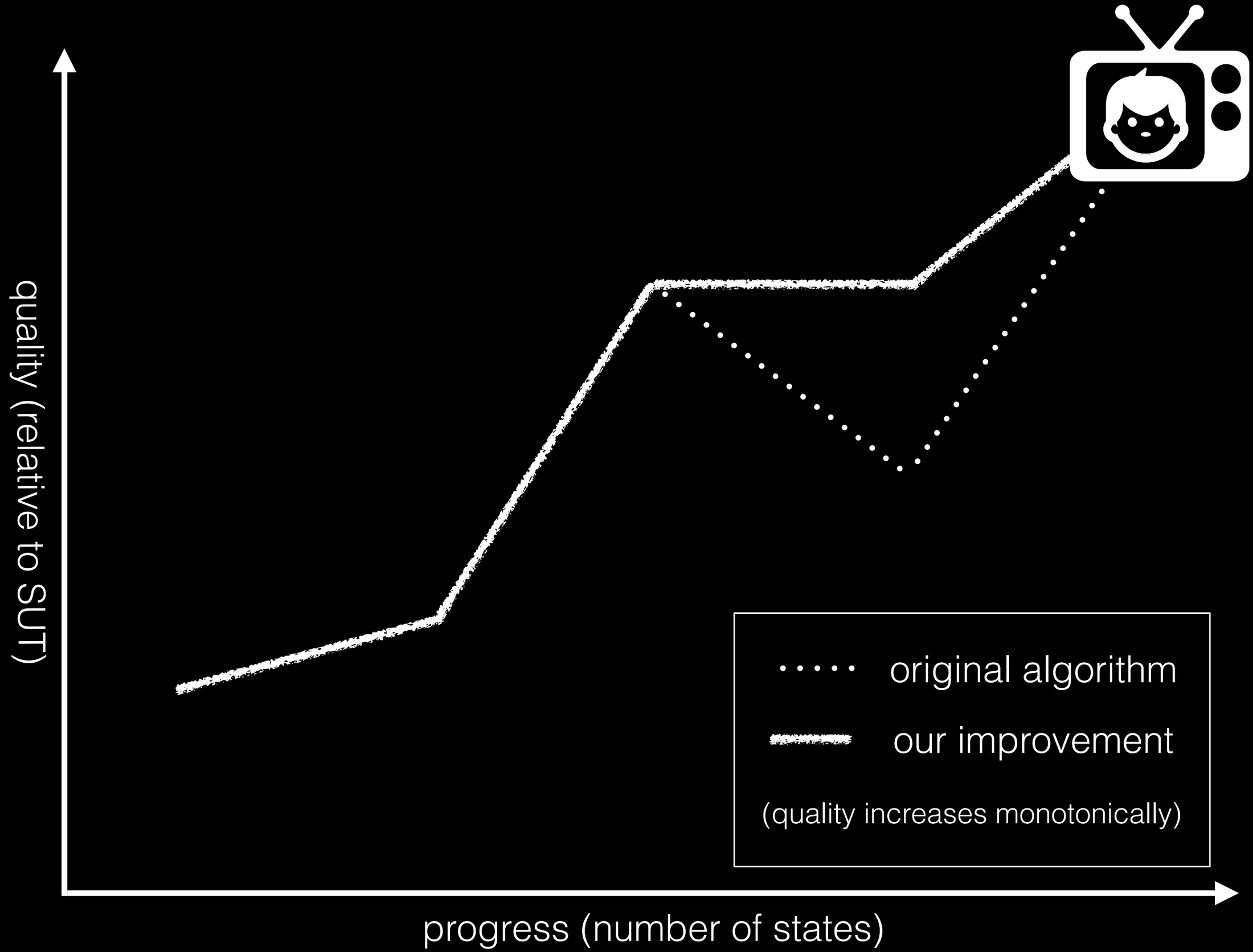
quality (relative to SUT)
progress (number of states)
original algorithm
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(quality increases monotonically)

Why?

Océ engine status manager

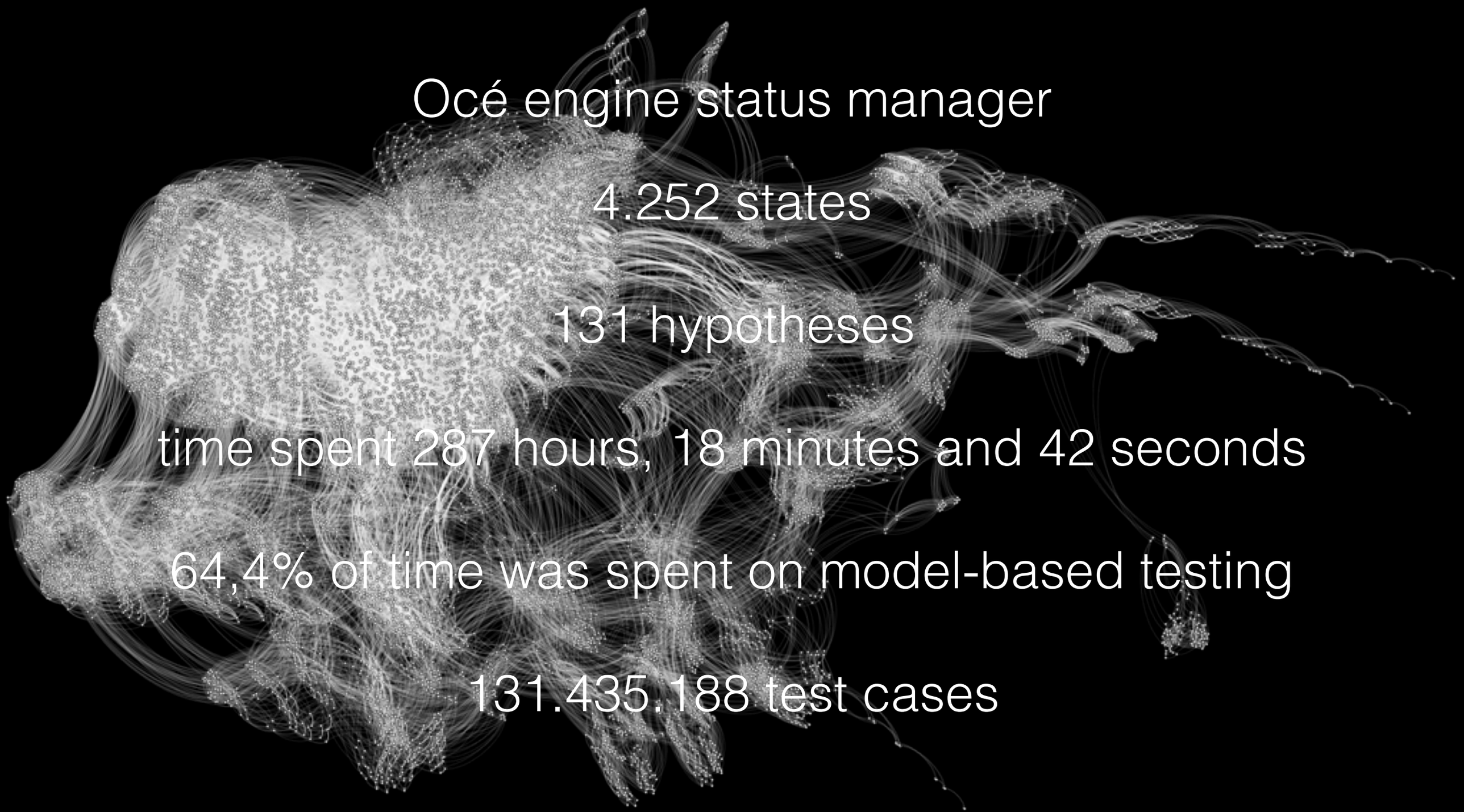
4.252 states

131 hypotheses

time spent 287 hours, 18 minutes and 42 seconds

64,4% of time was spent on model-based testing

131.435.188 test cases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4.252 states
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Proceedings of the 12th International Conference on Grammatical Inference
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Bigger is Not Always Better: on the Quality of Hypotheses in Active Automata Learning

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Abstract

In Angluin's L^* algorithm a learner constructs a sequence of hypotheses in order to learn a regular language. Each hypothesis is consistent with a larger set of observations and is described by a bigger model. From a behavioral perspective, however, a hypothesis is not always better than the previous one, in the sense that the minimal length of a counterexample that distinguishes a hypothesis from the target language may decrease. We present a simple modification of the L^* algorithm that ensures that for subsequent hypotheses the minimal length of a counterexample never decreases, which implies that the distance to the target language never increases in a corresponding ultrametric. Preliminary experimental evidence suggests that our algorithm speeds up learning in practical applications by reducing the number of equivalence queries.

Keywords: Active learning, automata learning, distance metrics

1. Introduction

Automata learning techniques have become increasingly important for their applications to a wide variety of software engineering problems, especially in the analysis and testing of complex systems. Recently, they have been successfully applied for security protocol testing (Shu and Lee, 2007), for the analysis of botnet command and control protocols (Cho et al., 2010), in regression testing of telecommunication protocols (Hungar et al., 2003), and in

Reference

- Smetsers, R., Volpato, M., Vaandrager, F., & Verwer, S. (2014). Bigger is not always better: on the quality of hypotheses in active automata learning. In A. Clark, M. Kanazawa, & R. Yoshinaka (Eds.), JMLR: W&CP 34; Proceedings of the 12th ICGI (pp. 167–181).