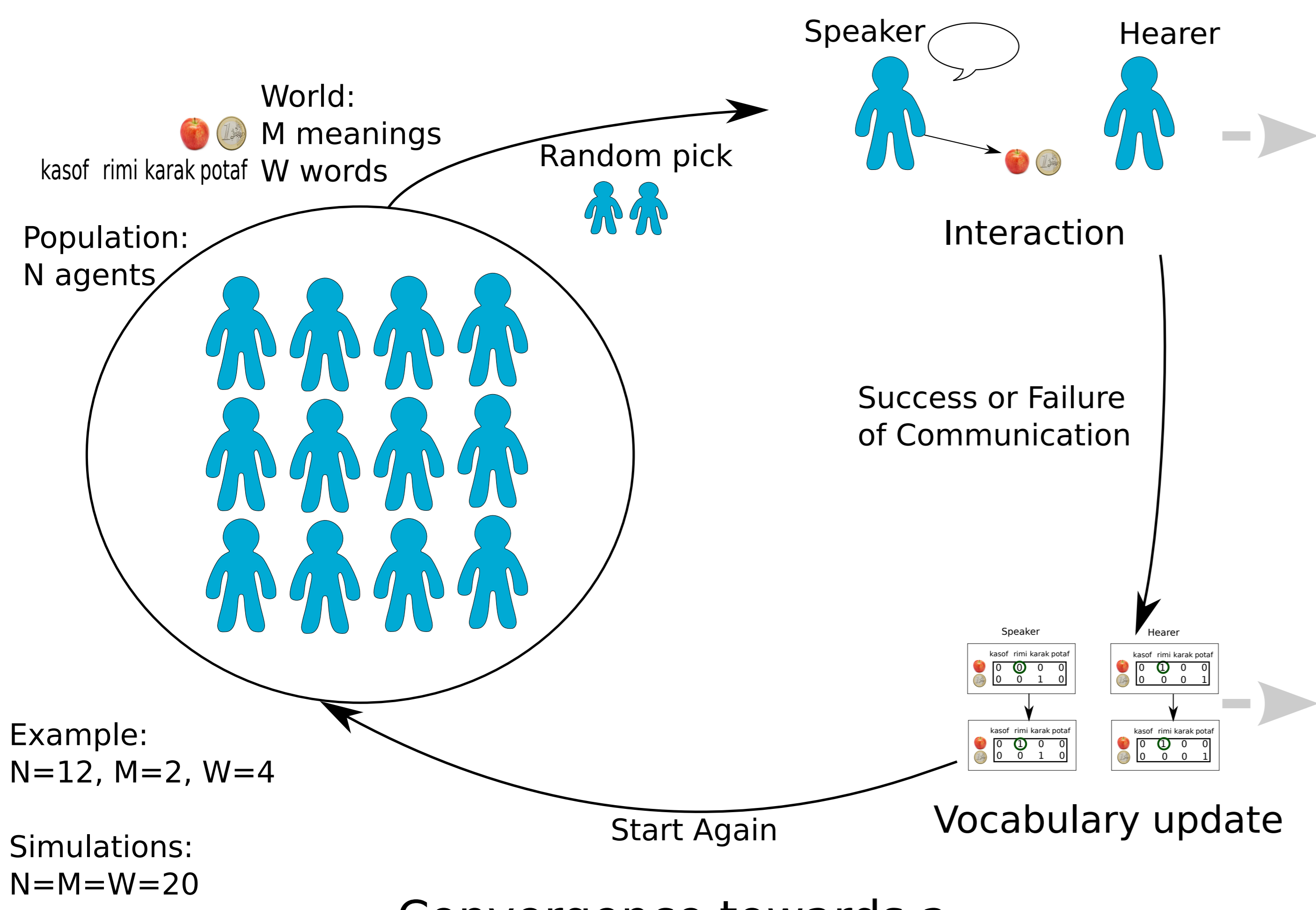
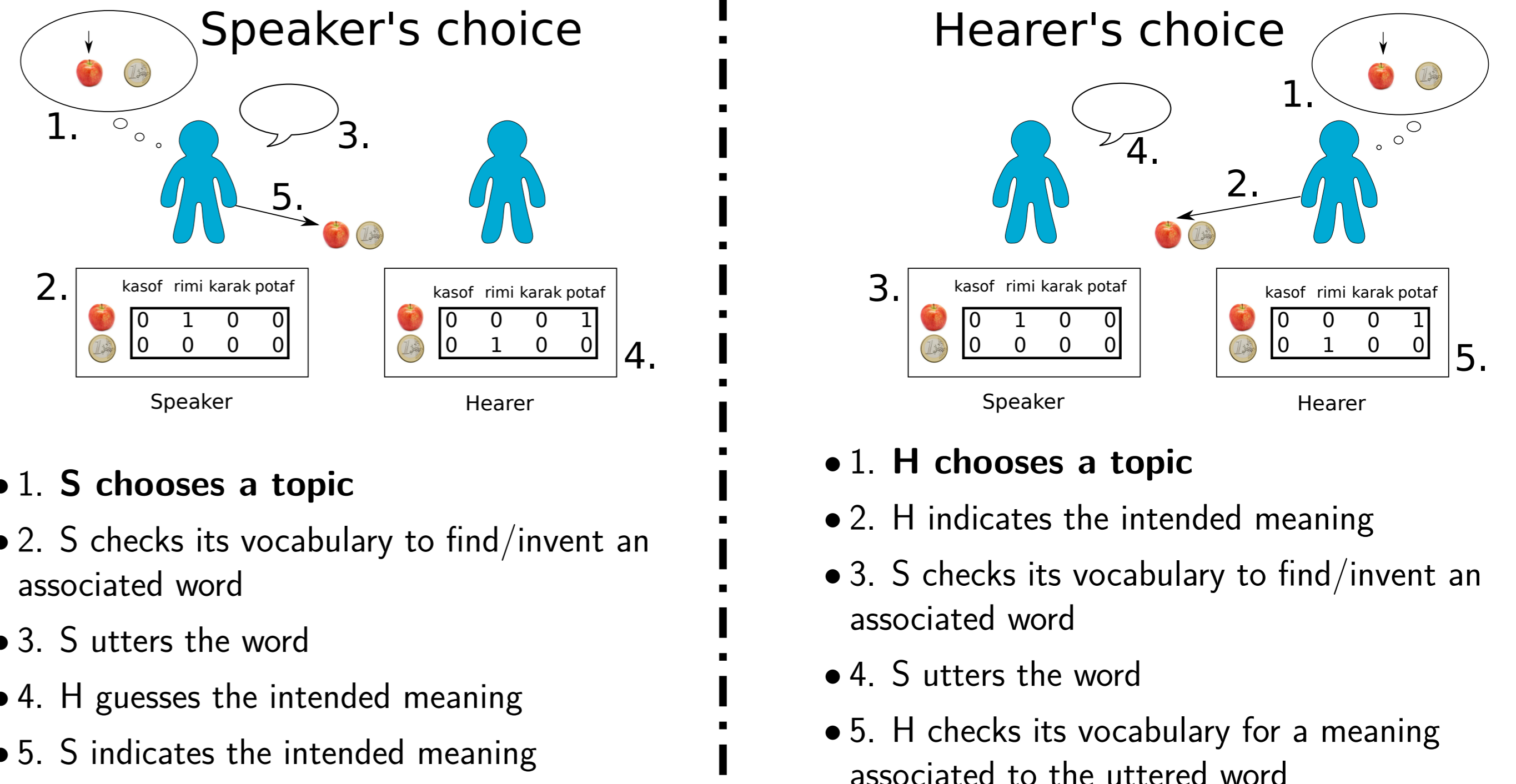


## Naming Games

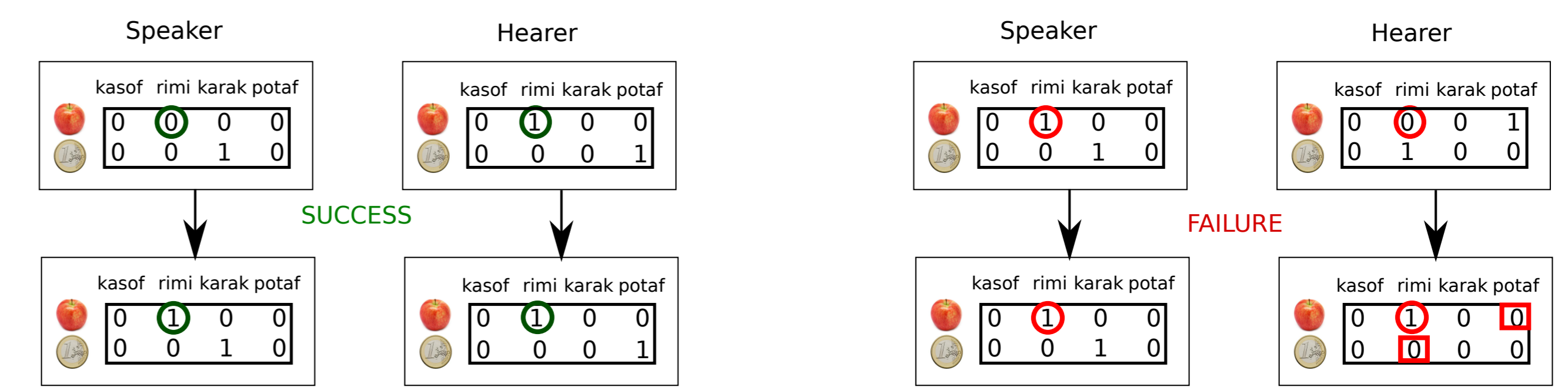


Convergence towards a **stable global pattern** (shared lexicon) through repeated **local interactions**

## Interaction scenarios



## Vocabulary update policy (from [1])



In the two distinct interactions described here, topic was the object apple, and uttered word was *rimi*. When the speaker is referring to an unlabeled (for him) meaning, it creates an association during the update. When an interaction fails, the hearer adds the used association, and erases any conflicting homonym or synonym.

## MAIN QUESTION

Self-organisation dynamics of the Naming Game [2] are greatly improved when Speaker is choosing actively the topic [3, 4]. What about Hearer choosing?

## Strategies for active topic choice

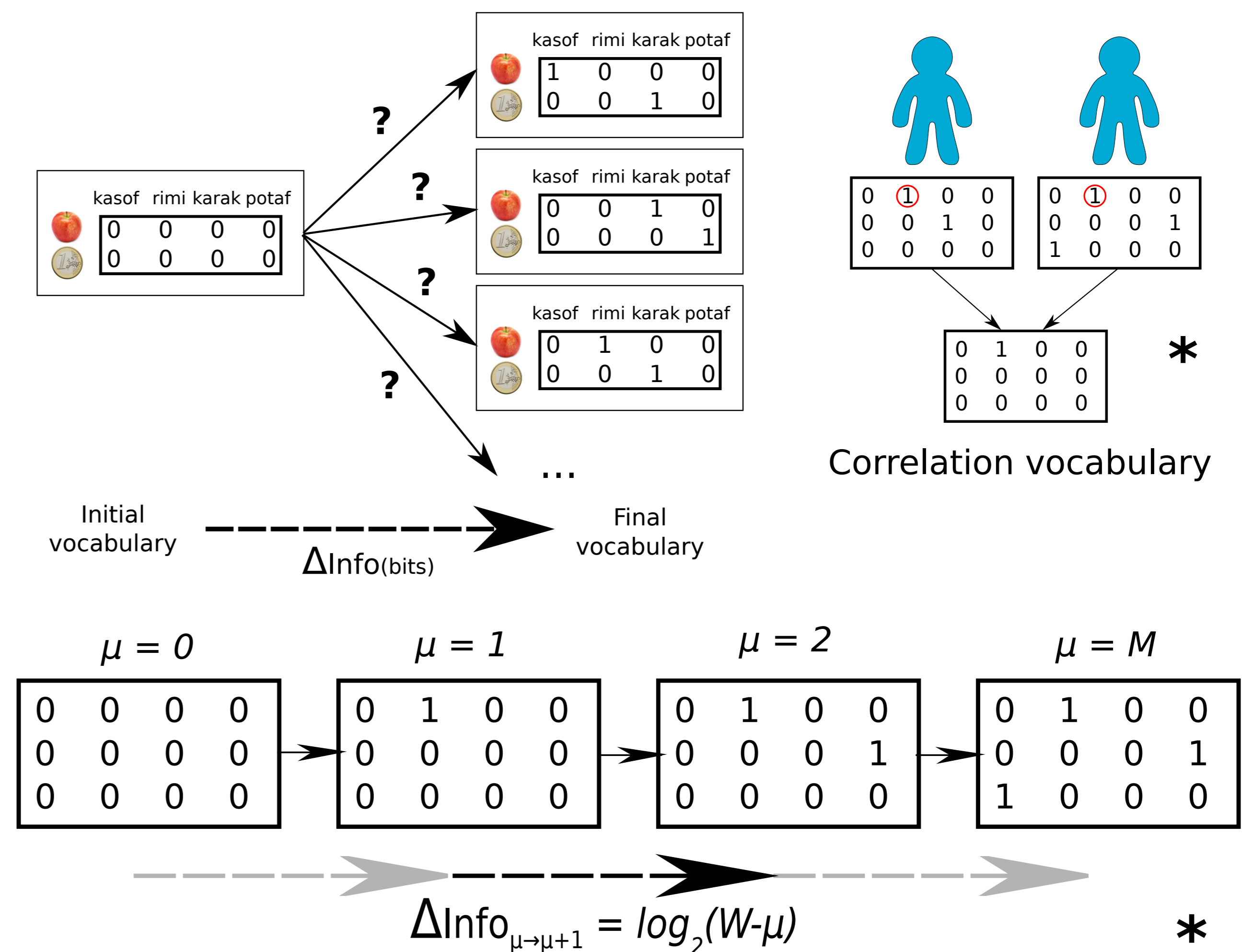
Naive (random)	Success threshold (active)	Minimal counts (active)	Info. gain softmax (active)
$m \leftarrow \text{random}(\mathcal{M})$	if $\text{mean}_{i \in \mathcal{L}\mathcal{M}} \left( \frac{\text{succ}(i)}{\text{succ}(i) + \text{fail}(i)} \right) \geq \alpha$ : $m \leftarrow \text{random}(\mathcal{L}\mathcal{M})$ else: $m \leftarrow \text{argmin}_{i \in \mathcal{L}\mathcal{M}} \left( \frac{\text{succ}(i)}{\text{succ}(i) + \text{fail}(i)} \right)$	if $\forall i \in \mathcal{L}\mathcal{M} \text{ succ}(i) > n$ : $m \leftarrow \text{random}(\mathcal{L}\mathcal{M})$ else: $m \leftarrow \text{argmin}_{i \in \mathcal{L}\mathcal{M}} (\text{succ}(i))$	if $P_{\text{exp}}(\mu, \beta) \geq \text{random}([0, 1])$ : $m \leftarrow \text{random}(\mathcal{L}\mathcal{M})$ else: $m \leftarrow \text{random}(\mathcal{L}\mathcal{M})$
<small>M: all meanings, L<math>\mathcal{M}</math>: labeled meanings, U<math>\mathcal{M}</math>: unlabeled meanings, <math>\mu</math>: vocabulary size (# word-meaning associations) succ: # successful interactions per meaning, fail: # failed interactions per meaning</small>			

Speaker's choice			Hearer's choice		
$\Delta\mu$	Info. Gain $G_\mu$ (bits)	Probability $p_\mu$	$\Delta\mu$	Info. Gain $G_\mu$ (bits)	Probability $p_\mu$
+1	$\log_2(W - \mu)$	$\frac{(M - \mu)(W - \mu)}{MW}$	+1 (explore)	$\log_2(W - \mu)$	$\frac{W - \mu}{W}$
0	0	$\frac{\mu(1 + M + W - 2\mu)}{MW}$	0 (explore)	0	$\frac{\mu}{W}$
-1	$-\log_2(W - \mu + 1)$	$\frac{\mu - 1}{MW}$	0 (check)	0	$\frac{W - \mu + 1}{W}$
			-1 (check)	$-\log_2(W - \mu + 1)$	$\frac{\mu - 1}{W}$

$P_{\text{exp}}(\mu, \beta) = \frac{e^{-\frac{G(-1)p(-1)}{\beta}}}{e^{-\frac{G(+1)p(+1)}{\beta}} + e^{-\frac{G(-1)p(-1)}{\beta}}}$

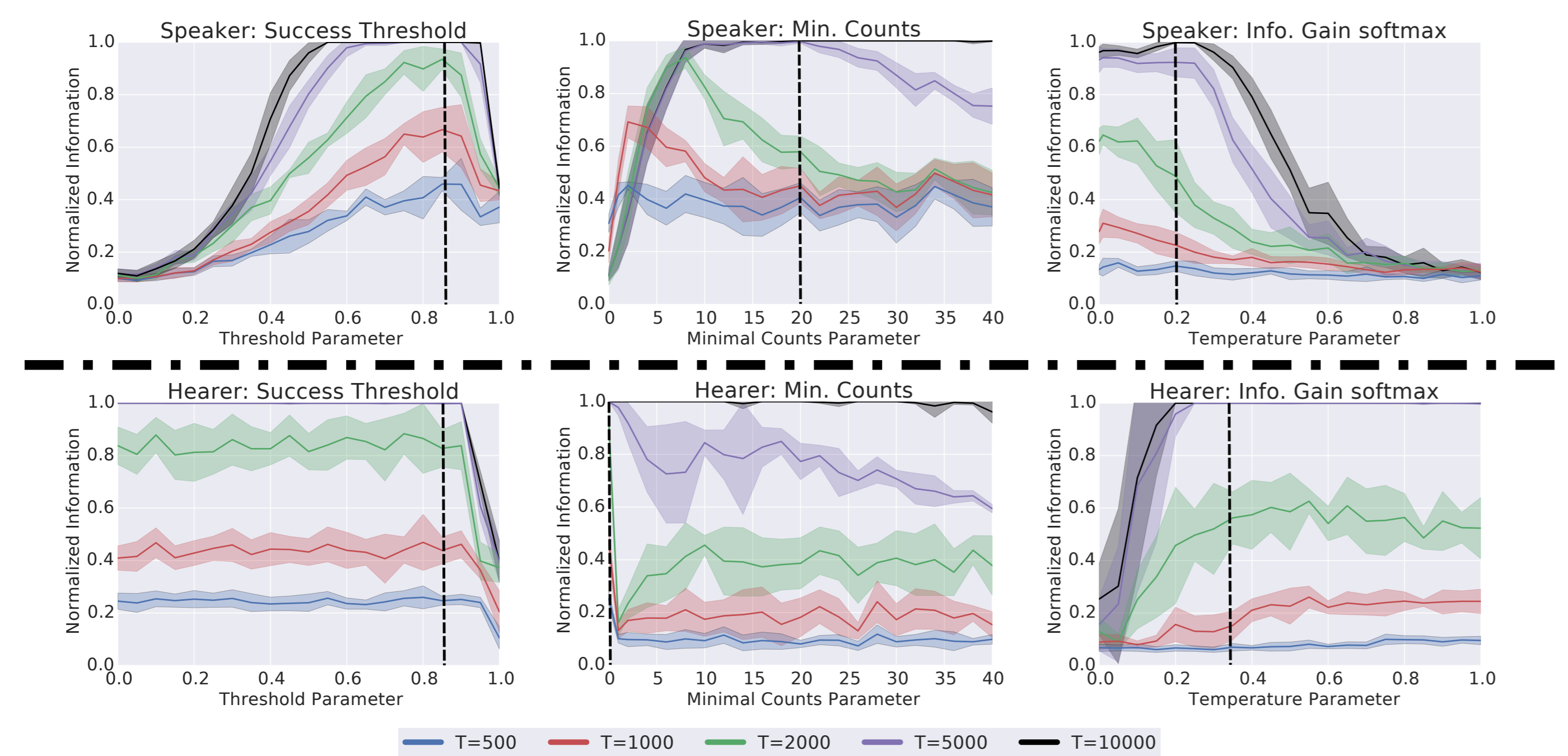
$\Delta\text{Info}_{\mu \rightarrow \mu+1} = \log_2(W - \mu)$

## Information measure (from [4])



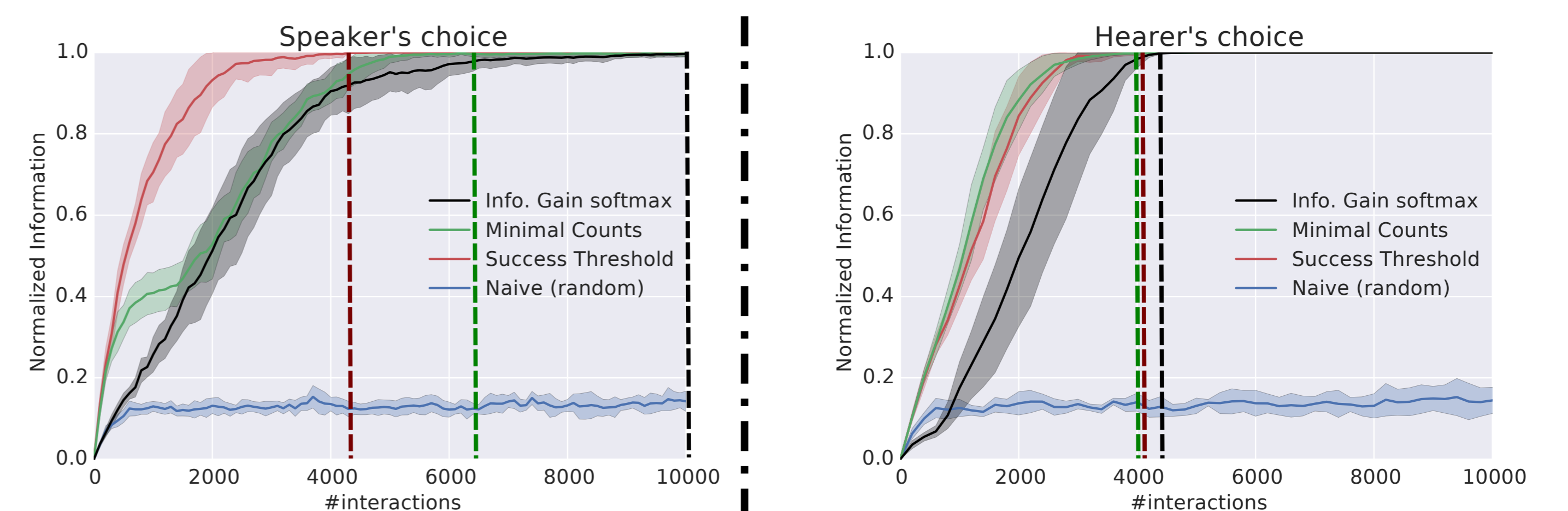
Measure used in this work: Average correlated info over all possible couples in population  
\*: In these examples, M=3 and W=4

## Choosing parameters $\alpha, n, \beta$



Convergence speed dependance on strategy parameters, for active 3 strategies and 2 active interaction scenarios. In all cases **hearer's choice scenario parameters are more robust** to change in value. Snapshots are taken for concurrent strategies spanning a relevant parameter interval, at different time steps (500, 1000, 2000, 5000, 10.000 interactions). Vertical lines show parameter values chosen for the comparisons in results section. (M=W=N=20, averaged over 8 trials)

## Results



• Naive strategy converges slowly (after 1.000.000 interactions – not depicted here).  
• **Hearer's choice policy is more efficient** for all active learning strategies.  
• Last 5% of information are acquired slower when the speaker is choosing.  
Vertical lines show full convergence time for each strategy. (M=W=N=20, averaged over 8 trials)

## References

- [1] P. Wellens, "Adaptive Strategies in the Emergence of Lexical Systems," 2012.
- [2] L. Steels, "Language games for autonomous robots," *Intelligent Systems, IEEE*, vol. 16, no. 5, pp. 16–22, 2001.
- [3] P.-Y. Oudeyer and F. Delaunay, "Developmental exploration in the cultural evolution of lexical conventions," in *proceedings of the 8th international conference on epigenetic robotics: modeling cognitive development in robotic systems*, 2008.
- [4] W. Schueller and P.-Y. Oudeyer, "Active Learning Strategies and Active Control of Complexity Growth in Naming Games," in *proceedings of the 5th International Conference on Development and Learning and on Epigenetic Robotics*, 2015, pp. 220–227.

## Source code and notebooks

<https://github.com/flowersteam/naminggamesal>