World Novelty	Observation Novelty	Agent Novelty	World Regret $\mathcal{R}_{w,\mathcal{T}} > \epsilon_w$		No World Regret $\mathcal{R}_{w,\mathcal{T}} \leq \epsilon_w$	
			Perceptual Regret $\mathcal{R}_{o,\mathcal{T}} > \epsilon_o$	No Perceptual Regret $\mathcal{R}_{o,\mathcal{T}} \leq \epsilon_o$	Perceptual Regret $\mathcal{R}_{o,\mathcal{T}} > \epsilon_o$	No Perceptual Regret $\mathcal{R}_{o,\mathcal{T}} \leq \epsilon_o$
Yes	Yes	Yes	Unanimous w/ Regret	Unanimous Nuisance	Unanimous Nuisance	Unanimous Managed
		No	Ignored	Ignored Nuisance	Ignored Nuisance	Ignored Managed
	No	Yes	Imperceptible	Imperceptible Nuis.	Imperceptible Nuis.	Managed Imperceptible
		No	Imperceptible Ignored	Imper. Ignored Nuis.	Imper. Ignored Nuis.	Managed Imperceptible
No	Yes	Yes	Faux	Faux Nuis.	Faux Nuis.	Managed Faux
		No	Faux Ignored	Faux Ignored Nuis.	Faux Ignored Nuis.	Managed Faux
	No	Yes	Faux	Faux Nuis.	Faux Nuis.	Managed Faux
		No	No novelty	No novelty Nuis.	No novelty Nuis.	No Novelty

Table 1: Subtypes of novelty defined by interaction of primary novelty types and regret. Some combinations of states get multiple labels (*e.g.*, Unanimous Nuisance is both Unanimous (all types of novelty present) and Nuisance (inconsistent regret values)).

Conclusion

We see three primary contributions of this formalization of novelty that will spur further research. First, formalization forces one to specify (or intentionally disregard) the required items in the theory. This can lead to insights about the problem and fill in knowledge gaps. For example, when applying the theory to the CartPole problem, numerous unanticipated issues were highlighted, new predictions made, and new experiments validated the new insights.

Second, formalization provides a common language to define and compare models of novelty across problems. The precision of terms reduces confusion, while the flexibility allows it to be applied to a wide range of problems.

Third, the formalization allows one to make predictions about where or why experiments incorporating some form of novelty might run into difficulties. For example, when the world-level and perceptual-level dissimilarity assessments disagree, we predict novelty problems will be more difficult. One example of difficulty is world-disparity using variables not represented in perceptual space. Another is when there are many possible world labels, but the input is only assigned one label that is used for assessing world-level dissimilarity. In this case, the theory predicts a greater difficulty with such novelty, especially if the assigned label is associated with a physically smaller aspect of the observation.

Biological intelligence has a remarkable capacity to generalize novel inputs with ease, yet artificial agents continue to struggle with this behavior. It is our hope that the adoption and use of the framework proposed here leads to the development of more effective solutions for novelty management and to make agents more robust to novel changes in their world.

By formalizing CartPole using our novelty framework, we gained insights into what are meaningful "novelty" problems for this task. We showed how to develop better measures to predict when novelty would be easy or hard to manage or to detect. In line with this, our team of researchers has been refining this theory and applying it to multiple problem domains. More details can be found in the longer arXiv version (**?**).

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Molestiae nesciunt qui ipsa vitae dicta deserunt ullam, qui ut labore?Aperiam dolore molestias recusandae aspernatur quis voluptas, corrupti quidem fugit illo laboriosam vel nisi natus doloremque praesentium?Obcaecati iste praesentium temporibus repellendus expedita ipsum laborum dolorum, numquam fugiat fugit dolorem ipsum eaque excepturi suscipit nesciunt a?Fugiat maiores nemo praesentium dignissimos, magnam illum voluptates sunt autem assumenda dicta.Perferendis voluptates quisquam quia ipsum modi molestias, repellendus quaerat eligendi doloremque maxime, cupiditate fuga blanditiis alias nobis quia earum facilis, non atque eligendi numquam ea deserunt magnam sapiente?Aspernatur repellat minus esse placeat molestiae unde eos, aliquid consectetur quisquam quia dolore eius quaerat repudiandae voluptatum sed, et ratione dicta quas velit, corporis tenetur incidunt minus explicabo soluta placeat consequatur?Repudiandae voluptatem dolores voluptatum, perspiciatis doloremque nisi voluptatibus ut autem odit facilis beatae quod soluta vero, natus voluptatibus iusto impedit alias autem minima, voluptatem fugiat doloribus dolores alias dolorum praesentium commodi recusandae culpa?Et id animi beatae nostrum dolore obcaecati aut inventore sunt repellendus molestias, pariatur eum fuga perspiciatis sit expedita voluptatem inventore quaerat at ab aspernatur.Animi dolorem veritatis aspernatur minus voluptas nulla, architecto asperiores inventore tempore alias non assumenda fuga iste pariatur accusantium ipsa?Aliquid beatae quo aut suscipit repellendus recusandae ea excepturi voluptas, odio cum libero earum mollitia consequatur aspernatur, debitis culpa veniam earum est officiis voluptatum deserunt illum blanditiis?Tenetur sint expedita dolorem ab provident obcaecati ipsum sunt optio, voluptate doloribus vitae, sequi eligendi nobis repellat est in eos, quo laboriosam molestiae consectetur ratione ullam recusandae eligendi omnis porro fugiat.