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# Representing Varieties of Novelty

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**Abstract**
We develop a simple framework to represent whether a creative invocation of an agent is considered creative at all by a recipient or simply nonsensical, mad, or ridiculous. The framework is meant to be a mode of representation, and its central ideas include an insight from philosophy of mind, psychological findings, analysis of analogical reasoning, and from simple logic common to artificial intelligence researches. The minor motive is how to represent and reason (in simple way) novelties that is supposed to be useful for other research agenda, from cognitive psychology to consumer behavior researches. The major motive is to explore the possibility to gain more understanding about the mind by mirroring mental content to a representing external device that is easier to manipulate but not very far apart from necessary empirical inquiry.
**Keywords:** creativity, cognitive architecture, novelty, structure mapping

## 0. Intro

Discoveries, inventions, innovations, all are the subject matter of discussing creativity. On the other hand, how can a creativity put to work be appreciated by people, recognized as something new that might be useful, valuable, interesting, or at least, worth mentioning when needed at all?

First thing first, considering the building blocks of all creative instantiation, I will quote Mary Shelley's:

> *"Invention, it must be humbly admitted, does not consist in creating out of void, but out of chaos; the materials must, in the first place, be afforded..."*

Mary Shelley (1831).
*Frankenstein, Introduction.*

In order to be able to understand a creative work, one must have the same knowledge of underlying principles such that it works at all with the creator. Be it nativistic or acquired, non-existence of such knowledge will make the work does not work no matter how creative it is for the creator.

### *0.1. Lesson from Scientific Discoveries*

Cruising literatures, we can see researches on scientific discoveries that are found abundant. A conclusion I would like to mention is that in scientific reasoning, there must be heuristics that comes before problem statement. There are axioms and rules of inference in logic and mathematics, added with empirical cross-check in physics, as there are 'baseline' and 'known standard' control in experimental biology (Baker & Dunbar, 2000) that I think generalize to other more empirically-inclined sciences, from social psychology to consumer research. The heuristic is not uniquely found in a given, probably well-developed, civilization as Peter Carruthers (2002) suggests, that scientific reasoning requires no different cognitive architecture between a hunter-gatherer and a researcher; both use the same mechanism applied to different use: tracking animals and pursuing a scientific conclusion.

To simplify the heuristic that often goes brute and trial-and-error guided, scientists use shortcuts. The most widely acknowledged is analogy such that a suspected law that applies to an organism just might work to different but similar organisms (Gentner, 1983; Dunbar, 2001). Then there is priming (Schunn & Dunbar, 1996) or an implicit process of retrieving old knowledge for current problem solving.

Hence, for the case of scientific discoveries, we are forced to have a kind of means-ends analysis, that is, a procedure that search the network of models, generate the changed models by adding or deleting propositions, and test whether the newly generated models have reached the desired goals (Sowa, 2000). Given a problem and a set of rules to conclude from, added with sufficient empirical test, a scientific discovery is verifiable through and through, no matter how far we have to infer each possibility, even if it is not at all a work of single scientist, but collective toiling enclosed in a distributed reasoning (Thagard, 1997) when some scientists working together can reach a final state together despite their different heuristics during the process.

That is one of the natures of scientific discovery. Given different states and heuristic, we can recall Hilary Putnam's scientific realism (Putnam, 1982)[1], such that, for those who have different lingo, namely, different axiomatic system, ontological commitments and surrogate of objects, they definitely will come up with or pay attention to problem solving derived from their own lingo and not the other. Only that, they all must obey, for example, empirical verification.

In non-scientific domain, however, the difference of a lingo from others is unobvious and not one explicit rule can gave them place to compare such that one creative work can be said more acceptable than others. We can expect that, for example, literary criticisms are by and large not aimed to come to an agreement, not today, neither tomorrow.

[1] Putnam's (1982:199) own version:

> "Some philosophers of science would say that 'There are electrons flowing through the wire' can be true only in sense that this statement (in conjunction with theory and auxiliary hypotheses) yields true predictions, or, in more sophisticated version, in the sense that it has a model satisfying various "constraints" (including yielding true predictions)."

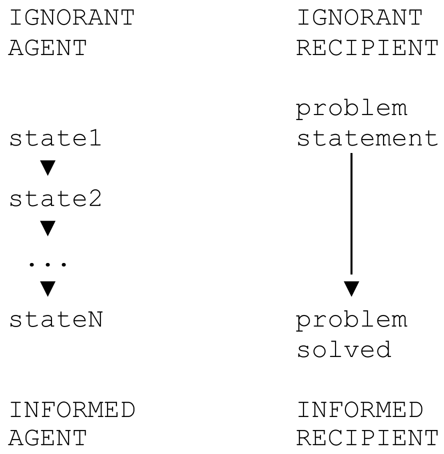


Figure 1 **Scientific Discovery**

With wrong or inconclusive inferences omitted, a recipient is able to (sometimes obliged to) keep track all inferences such the problem be solved[2].

*0.2. Problems with Non-scientific Domains*

In case of non-scientific domain, the rule of inference is less obvious or less anticipated. To paint is to create something perceivable with eyes and valued in certain way instead of combining colors and manipulating frequency of certain electromagnetic waves reflected to the retina and interpreted as a range of spectrum. A song is a valuation of sequential chords, melody and timbre instead of mechanical wave manipulation following classical physics. A catchphrase or slogan is a chain of words associated to another word, each represents an object instead of a subset of a combinatorial explosion governed by recursive rules.

I am not to talk about art in general but only to show how it departs from science with respect to how it, during its creation, differs from scientific discovery. Still, there are non-scientific creation found valuable by the recipients, there are that not. In non-scientific domain, it is not problem solving that is pursued but indeed there is a goal.

For a recipient, there is not necessarily any problem statement at all, as much as there is not necessarily any obligation to keep track the procedure from which a goal is reached. Besides, the goal may be superfluous, abundant in time span, may come and go before come again, apart from whether the goal is a result of creativity or merely repetitious toiling or even regular instantiation indistinguishable from others.

Still for a recipient, the goal reached in such a creative way is definitely something new. Only that this new thing is either valuable or superfluous at all since there is no obligation for recipient to keep track, no initial problem statement from which the new thing is produced that must be known to her. Instead, there must be a specific valuation process to determine whether a new thing is acceptable or making any sense or not at all for her in a given setting.

[2] When transition from one state to another is a form of generalization over certain data streams, the analysis is that of Hume's inductive inference problem (*Cf.* Schulte, 1999).

If a goal passes this valuation process, provided that the goal is unknown to recipient's current belief space, the creator is often called creative. If otherwise, the creator is mad or worse, ridiculous. In a popular phrase, there is only a thin line between creativity and madness.

Heretofore, the goal is called *novelty* to differ it; from *creativity* as a process to generate new things in one's mind; from *discovery*, *invention* or *innovation* as an object produced by a creative work, abstractly or actually brought to reality (how these three differs from each other is not the focus of this paper). Heretofore, the valuation process is called *constraint*.

It is our work to find out what is the nature of the constraint, what kind of novelty that may pass through it, at least only to a certain degree of representational framework. One way to find out: try to *find what sequence of states a recipient has in mind* when a creative work is presented to her so she can judge that the work is novel after all.

```
IGNORANT        IGNORANT
AGENT           RECIPIENT

state1
  |
state2
  |
 ...
  ▼              ▼
stateN          goal

INFORMED        INFORMED
AGENT           RECIPIENT
```

**Figure 2 Non-scientific Creativity**

All undesirable inferences omitted, a recipient is not necessarily able to keep track of all inferences since the problem statement may be unknown even to the creator and the valuation of goal is not necessarily determined by inferences (be it conceptual framework, process, extrinsic factors of any kinds) that leads to the goal.

## 1. Computationalism Revisited

Applying similar analysis of scientific discovery to non-scientific works or in general, to non-sufficiently axiomatized domains requires a coding so both agent and recipient will have the same ontological commitment concerning objects within the domain; or otherwise, there will be no novelty or constraint at all to accept or rule out unambiguously. Putting it bluntly, we need a well-defined mode of representation for any given information *generated* by *agent* and *received* by a *recipient*, all within a domain. Learning from early development of generative linguistics, we need a descriptive adequacy (all possible propositions) and an explanatory adequacy, *viz.* our previously defined constraints.

However, as we can see, the domains mentioned above are not always well-defined in propositions known to certain logic. For example, a song as a sequence of tone of certain frequency and simultaneously invoked words known as lyrics is well-defined through first-order logic, but whenever timbre of the musical instrument and the voice plays a significant role, first-order logic (i.e.: the 'only game in town' in artificial intelligence) will come up with irritating representational explosion.

This technical difficulty does not only haunts AI researchers and logically-inclined philosophers (e.g.: Johnson-Laird, 1980; *cf*. Shapiro, 1995 for comments) but also brings to life other various hypothetical approaches to cognitive architecture. For now, playing quick and dirty, we may call sensori-perception modular, that is, whatever the process and the input are, there must be an information well-defined as output that enters a central-processing device that is responsible for a belief revision or fixation.

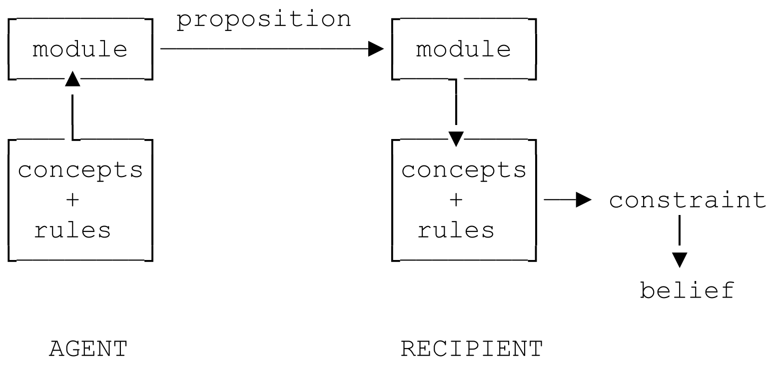


Figure 3 **Agent-Recipient Diagram**

An agent, using concepts and rules to combine concepts produces a proposition that is received by a recipient with a module such that the content can reach recipient's own central process. If the proposition passes the constraint, the recipient is now considered to believe (that is, have a particular propositional attitude) that the (content of) proposition is true before it comes to fixation. The truth condition can come from external or environmental settings ("*I believe that the world is round*") that passes into central process through different modules, or from relation with other propositions already kept in belief space ("*I believe that John loves Mary, so it is unlikely that John hurts Mary*"). In this paper, we will only deal with the latter, the belief space.

This modularity affects central process containing belief set such that the input becomes perceptually sensitive. Such sensitivity might produce ambiguous propositions (a Müller-Lyer illusion, for example), or propositions that falls outside the scope of well-defined objects (for example, the so-called non-conceptual content, impossibility to name each distinct color generated by 16-bit digital coding, *cf*. Bermúdez, 1995). Meeting this condition, our constraints will become weaker, so we will only deal with non-ambiguous and conceptually-distinguishable propositions.

### *1.1. Persistence of Mental Content*

Going back to business, let us first explore propositions that in the first place only has little possibility to become ambiguous. And to do this, first let us visit our central process. Note that the following is a theory of commonsense reasoning and not scientific one. Even if we want to describe that non-scientific novelty is detected in a way close to but not exactly in forms of deduction, the axiomatization does not necessarily follow the same procedure science must follow. Postulation that 'force is proportional to mass and acceleration' is different from axiomatization that 'John loves Mary'. We are interested in the truth of the former, but not in the latter: it's just a token of mental event and not in any way a law of nature depicting a never ending objective reality every physicist must believe.

Technically-developed physical symbol system hypothesis (Newell & Simon, 1976) says that there is some computer program whose intelligence matches that of humans. Technical difficulties aside, we have a possibility to make all possible space of search. Its philosophical insight is straightforwardly found in the persistence of mental content (Fodor, 1987), one thing that hypothetically guarantees that there is a chain of thought in the central process *ceteris paribus*.

The kind of psychology derived from it is called commonsense or folk psychology, and propositional attitudes (e.g., belief, desire) the chain of thought contains (derived from external entities in environment or from other beliefs) are deemed to be responsible for potential or actual behavior.

Later development of this hypothesis becomes what is known as holism or globalism (*Cf*. Fodor, 2000 for brief description) in the whole body of classical modularity thesis, insisting that central process is not modular at all in terms that what it takes as input and invokes as output is domain-independent.

### *1.2. More on Ceteris Paribus Conditions*

The ceteribus paribus conditions (heretofore, CPC) implicitly gives constraint to, Jerry Fodor gave an example, a proposition $P$ a recipient believes that says, $(\forall x \forall y)\ rival(x,y) \Rightarrow prefers\_discomfiture\_of(x,y)$, such that $P$ holds for the recipient with all else being equal.

In English, there is a recipient who believes that if someone $x$ is a rival of someone else $y$, then $x$ likes $y$ to being frustrated, ceteris paribus, e.g.: the recipient does know the meaning of rivalry, the recipient is not asleep and still alive, the recipient is human after all, or whatever. Ceteris paribus implies that something is true when it is true or when it is likely to be true[3]. In practice, CPC is what we have in our knowledge base, that is, a proposition is true according to a recipient because a recipient asserts its truth.

With respect to the same English expression, CPC prevents the recipient to conclude that $x$ will kill $y$ as an overt behavior of $x$ due to what recipient has in mind unless more propositions are added by the recipient.

Setting appropriate CPC to any propositions is a tricky business for computationalism and it has different desired effect to the content of the proposition. However, we will use CPC as a key to our representational framework in later sections, set them *explicitly* in a knowledge base, then let a recipient choose propositions such that a chain of thought is constructed out of that knowledge base, and let this chain be her CPC for a given context.

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[3] Philosophical illustration is from Fodor (1987:254):
"... commonsense psychology relies upon its ceteris paribus clauses, so too does geology.";
much similar to illustration of physical symbol system hypothesis by Newell and Simon (1976:123):
"They have more the flavor of geology or evolutionary biology than the flavor of theoretical physics."

*1.3. Modularity Invades*

Insights from evolutionary biology and evolutionary psychology influence the whole modularity thesis in various aspects. One of the most prominent is massive modularity, saying that human cognitive architecture is what evolution gives shape to us . In turn, any intelligent capability is a result of adaptive requirement. The module hence enters the central process and the domain becomes more specific. Later development, along with various findings in folk-theoretical experiments shows that there are some parts that are modular in central process, but some are not, that is, domain general as holism might suggest.

I have given brief reviews on this (Suroso, 2004a; Suroso, 2004b) and I think it is not necessary to give another note. Three points worth mentioning from my previous review concerning central process (Suroso, 2004b): 1) there is a conceptual sensitivity for that given a derivation, substituting variables might only work, that is, makes sense according to human commonsensical reasoning, for one, but not the other, even if there is another proposition that guarantees that both variables should work with the derivation; 2) there is a derivational problem for that some regular inferences do not work as expected, for example, a modus ponens is easily recognized but not for modus tollens (Recall Wason Selection Task.), and; 3) there is a frame problem where an implicit proposition required by a derivation is not included so the derivation does not come to a point as expected.

Giving emphasis to 1) means that we should pay more attention to cognitive conceptual universal of *H. sapiens* if any at all such that what it suggests in one recipient is likely to be applicable to other recipient. Point 2) sets the limits of the mind-computer metaphor our persistence check framework should point out in later sections, while point 3) is much related to what a knowledge engineer should do, that is, setting all possible propositions, ceteris paribus.

*1.4. Setting the Constraints*

Given each conditions briefly explained above, we are now ready to set up the constraints. For present work, we will not include memory since for a recipient in case of detecting a novelty, a memory is only a tool for, among others, priming (see Schunn and Dunbar's explanation cited above). We can say that what is forgotten but presented again to the recipient without her remembering it is said to be novel, but it is not if she can remember it again at any given time.

We are not also to talk about perceptual sensitivity and let CPC takes its roles. Imagine that for whatever follows, there is an index saying that each entity is ceteris paribus what it is as presented in central process, meeting non-ambiguous and conceptually-distinguishable criteria.

Rather, we are to talk about a cognitive architecture that obeys physical symbol system hypothesis. In setting the constraint, here is a sequence of steps: 1) all possibilities and each possible derivation, represented in a knowledge base; 2) what is more or less possible to derive or conclude, or simply anything that makes sense expressed by instantiations of propositions, and; 3) what is creatively novel and what is ridiculous from anything that makes sense according to the recipient.

Section 2 on Perch describes steps 1) to 2), and section 3 deals with the rest.

## 2. Perch: An Experimental Framework

Perch (PERsistence CHeck) is our experimental framework developed based upon the idea that propositional attitudes that shape mental content are persistent at all, of course, ceteris paribus. What is pursued is how human really, having instantiated propositions, comes up with a chain of thought and such chain can be, inter alia, contracted to shorter chain with the rule of hypothetical syllogism.

If mental content and mental causal power are persistent at all, then, whichever track a recipient is forced to choose, her conclusion or theorem about a given context is the same. If not, however, we can arrive at different possibilities.

When derivation fails, for example, CPC shows their power such that it will never be sufficient to represent belief space one really has in an external device to an acceptable degree of accuracy because the CPC in recipient's mental content differ from what has been mirrored in an external knowledge base. But this possibility only leads us to a mental barbarism such that given a well-define input, we will never be able to predict the output to a certain degree at all. If this is so, holistic computationalism fails to be a theory of mental content at all because it simply explains nothing. Saying that CPC can never be mirrored is saying that for whatever a recipient says, there is an uttered proposition in her head, "But I never really mean it." Hilarious!

Another possibility, when derivation fails at all, it is unlikely that human reasons at all, but instead, they have a huge memory slot in belief space. For any proposition ready-to-send to a recipient, there is a ready-to-use interpretation already memorized. No such thing as compositional semantics. Even more hilarious, at least for George Miller.

On the other hand, when holism remains in sense that it is immune to mirroring mental content and externally-made knowledge base, it is unlikely that holism is testable at all or worse, it is unlikely that mental content is persistent at all. In the framework soon be presented, the motive is not to decide truth or falsity of mental content with respect to some external possible worlds. Rather, the motive is only projected towards setting the limits of persistence of propositional attitudes towards anything it can contain.

### *2.1. What Perch is*

Perch is knowledge representation that consists of 4 components *U*, *KB*0, *KBN*, *W* where *U* is unit structure or unit knowledge base, *KB*0 is knowledge base before instantiation, *KB*1 is knowledge base after instantiation, *KBN* is *KB*1 with hypothetical syllogism applied, and *W* is number of possible consequents of an antecedent. We will define each of the elements step by step as follows.

**Definition 1 Unit Structure *U*.** Unit structure *U* is proposition of the form $p_\beta \Rightarrow p_{\beta 0} \otimes p_{\beta 1} \ldots \otimes p_{\beta w}$ where $p$ is any regular proposition that represents natural language expression such as 'John loves Mary'. $\otimes$ is logical connective similar to regular 'exclusive or' operator such that '$p_0 \otimes p_1 \otimes \ldots \otimes p_W$' means exactly one proposition from $P = \{p_0, p_1, \ldots, p_w\}$ is true. '$\Rightarrow$' means regular implication, such that the left hand side of $\Rightarrow$ is antecedent and its right hand side consequents. $W$ is a set of integers, $W = \{0,1,\ldots,w\}$.

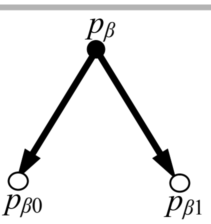


Figure 4 **Unit Structure**

A unit structure with $w = 2$. Arrow denotes an implication and only one of implications $p_\beta \Rightarrow p_{\beta 0}$ and $p_\beta \Rightarrow p_{\beta 1}$ is true. Black dot represents antecedent, white dots represent consequents.

**Proposition 1.** Given a unit structure $U$ with an antecedent $p_\beta$ and instantiation of one consequent $p_\delta$, we will have $U, p_\delta \mid\!- p_\beta \Rightarrow p_\delta$. For $w = 2$, let us write both consequents of the form $p_\delta \vee \neg p_\delta$ with respect to the definition of $\otimes$. From $U, p_\beta, p_\delta \mid\!- p_\beta, p_\beta \Rightarrow p_\delta \vee \neg p_\delta, p_\delta$; then $U, p_\beta, p_\delta \mid\!- p_\delta \vee \neg p_\delta, p_\delta$; we derive $U, p_\beta, p_\delta \mid\!- p_\delta$; before finally reach $U, p_\delta \mid\!- p_\beta \Rightarrow p_\delta$. This also applies for $w > 2$ by treating the consequents as $p_\delta \vee p_{\delta^*}$, $P' = P - \{p_\delta\}$, $\neg p_\delta \Leftrightarrow p_{\delta^*}$, and $p_{\delta^*} \in P'$.

**Definition 2 Indices**. The indices of both antecedent and consequents in all unit structures follow the rewrite rules as follows:

$$p_{\{\}} \Rightarrow p_0 \otimes p_1 \otimes \ldots \otimes p_w$$
$$p_\alpha \Rightarrow p_{\alpha 0} \otimes p_{\alpha 1} \otimes \ldots \otimes p_{\alpha w}$$
$$p_\gamma \Rightarrow \{\}$$

To understand the notation fully, first we define height $l_\alpha$, that is, from $p_\alpha$, $l_\alpha = |\alpha|$, and $|\alpha|$ is the number of characters used in the index of $p_\alpha$. $p_{\{\}}$ gives $l_{\{\}} = 0$ and $p_\gamma$ gives maximum height such that $l_\alpha \le l_\gamma$. For example, consequents of an antecedent $p_{01}$ and $w = 2$ (so we can use binary digit) are enclosed under the form $p_{010} \otimes p_{011}$. This definition also suggests that each consequent of a given height is antecedent of the next height except for $p_\gamma$.

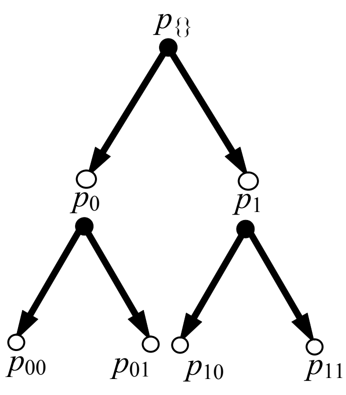


Figure 5 **Knowledge Base Level 0**

A *KB*0 with $l_\gamma = 2$ and $w = 2$. $p_{00}$ and $p_{01}$ is allowed to denote the same proposition $p_{10}$ or $p_{11}$ denotes such that $p_{00} \equiv p_{10}$ and $p_{01} \equiv p_{11}$, or $p_{00} \equiv p_{11}$ and $p_{01} \equiv p_{10}$.

**Definition 3 Knowledge Base Level 0, *KB*0.** Given all unit structures *U*, *KB*0 is defined as follows:

i) *KB*0 is the set of *U*'s whose $p_\alpha$ is of any heights $l_\alpha = \{0,1,\ldots,|\gamma|\}$

ii) In *KB*0, it is allowed to apply the same consequent more than once such that $p_{\alpha i} \equiv p_{\beta j}$; $l_{\alpha i} = l_{\beta j}$ and $\neg(p_\alpha \equiv p_\beta)$. These conditions ensure the occurrence of same consequents only at the same height and they do not come from the same antecedent. Practical purpose of this is that we can prevent explosion of the number of *p*'s since for $w = 2$, the number of *p*'s is $2^{|\gamma|+1}$-1.

**Definition 4 Knowledge Base Level 1, *KB*1.** Given an instantiation of one of all possible consequents at all heights we will come to all resulted implications as shown in Proposition 1. With an instantiation of all consequents in any given height written altogether as $Q = \{p_{l=0}, p_{l=1},\ldots, p_{l=|\gamma|}\}$, we obtain $KB1 = \{p_{l=0} \Rightarrow p_{l=1}, p_{l=1} \Rightarrow p_{l=2},\ldots,p_{l=|\gamma|-1} \Rightarrow p_{l=|\gamma|}\}$ such that *KB*0, *Q* |- *KB*1. *Q* is considered to be CPC. Note also that in case of *KBN*, $N > 0$, we often use the index of the form $p_{l=0,1,\ldots|\gamma|}$ since *w* no longer counts.

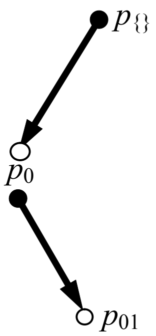


Figure 6 **Knowledge Base Level 1**

A resulted $KB1 = \{p_{\{\}} \Rightarrow p_0, p_0 \Rightarrow p_{01}\}$ from *KB*0 with $l_\gamma = 2$, $w = 2$ and $Q = \{p_{\{\}}, p_0, p_{01}\}$.

**Definition 5 Knowledge Base Level *N*, *KBN*.** We can generalize from *KB*1 with hypothetical syllogism, from $p \Rightarrow q$ and $q \Rightarrow r$, infer $p \Rightarrow r$, so we have $KBN = \{p_{l=0} \Rightarrow p_{l=N}, p_{l=1} \Rightarrow p_{l=N+1},\ldots\}$ such that *KB*1 |- *KBN*, $N = \{1,2,\ldots,|\gamma|\}$.

All definitions above are the features of Perch framework and it is sufficient for demonstrating persistence through, among others, the ability of a recipient to infer *KBN*. The Perch framework follows the inspiration suggested by holism for saying that if mind is computational at all, then it is likely that mind also has hypothetical syllogism as one of its rule of inference.

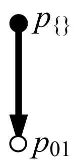


Figure 7 **Knowledge Base Level 2**

A resulted $KB2 = \{p_{\{\}} \Rightarrow p_{01}\}$ from $KB1 = \{p_{\{\}} \Rightarrow p_0, p_0 \Rightarrow p_{01}\}$.

More intuitively, we can describe Perch framework as a form of multiple choices test with finite number of choices for each question and each choice becomes the next question such that it has its own multiple choices. The pair of question and chosen answer is connected with conjunction 'if …

then …'. Exceptions only happen in the first question because it has never been an answer and in the last answer because it will never be a question.

### 2.2. Domains

Developmental psychology, ethnobiology, and in general folk theory only suggest very loose categorization of domains. The most common is 'animate and inanimate' in naïve physics (Heyman, *et*. a*l*., 2003), or 'the class of objects that can be sick and the class that cannot' in folk biology (Atran, 1998). This categorization, if put to work with Perch framework, does not give an ease to constructing appropriate propositions.

In order to accommodate different domains, first we are to define what domain is. In Perch framework, domains at the first level is defined as classification of concepts that compose each proposition. At the next level, domain is set of propositions and relations of them to each other. Domain specificity then suggests that we can rule out logically-valid propositions a recipient *do not* use when thinking in a domain.

Our general framework to interconnecting domains so we can arrive at a desired effect is simply by creating 2 *KB*0's, each represents unit structures of each domain, and the interconnection can be put to work along two ways: *first*, by mapping across domain we borrow from the study of analogy (Gentner, 1983) that only considers structure of propositions and not its conceptual content, and *second*, by conceptual classification we borrow from experimental results in folk theory (e.g.: Medin, *et. al*., 2000; Ahn, *et. al*., 2001).

But before that, we must decompose propositional logic representation in Perch into its constituents, i.e.: atoms and predicates, such that we will have in return, representation in predicate logic[4].

#### 2.2.1. Transforming Propositions

Given a proposition "John loves Mary", we can simply represent it as $p$ in propositional logic, or as *love*(*John*, *Mary*) in predicate logic. For all formulae in propositional logic, atomic or complex, there must be exactly one of its counterpart in predicate logic.

Suppose $q \equiv$ 'John hurts Mary'. Then for:

*i)* $p \Rightarrow \neg q$

*ii)* $love(John, Mary) \Rightarrow \neg hurt(John, Mary)$;

both propositions i) and ii) means the same natural language expression, "If John loves Mary, then John does not hurt Mary."

For Perch framework, it is not necessary to use predicate logic, since it pursues mainly the persistence of mental causal powers, say, the ability to infer *KBN*, maximal number of choices $w$ a recipient can reason persistently; the effect when positions of $p$'s are interchangeable in *KB*0, or; the propositions that implicitly (i.e., represented simply as $p$ but conceptually sensitive with respect to

[4] Some textbooks treat both kinds of logic as one and the same, i.e.: first-order logic treating $p$ as 'formula' and $f(x)$ as 'terms' for $p = f(x)$.

its natural language expression) contains certain concepts or conceptually-sensitive propositions that are likely to be chosen or not by a recipient.

For mapping across domain where conceptual sensitivity plays a significant role, explicit use of predicate logic is required so all unit structures in *KB*0 must be represented in predicate logic from the first place. What Perch framework gives to mapping across domain is instantiated propositions $Q$ as we shall see in section 2.2.2.

### 2.2.2. Structure Mapping

First we start from a revised version of Dedre Gentner's (1983:156-7) representational framework of all propositions in predicate logic as follows:

1) Domains and situation are psychologically viewed as systems of objects, object-attributes $a$ and relations between objects $r$. In what to follow, we will treat $a$ simply as $r$ with arity 1.
2) First essentially syntactic distinctions among predicate types: i) unary predicate is called 'attribute', ii) $n$-ary predicates, $n > 1$ is called 'relations'; an attribute *red*: *red*(*ball*), a relation *hit*: *hit*(*ball*,*wall*).
3) Second essentially syntactic distinctions among predicate types: i) 'first-order predicate' takes atom as argument, ii) 'higher-order predicate' takes formula(e) as argument; first-order predicate *hit*: *hit*(*ball*,*wall*), second-order predicate *see*: *see*(*John*, *hit*(*ball*,*wall*)).

Besides analogical reasoning that this form of representation is mainly aimed at, it also supports representation of reasoning about domains with similarity (Tversky, 1977), or (with different way of problem description) metaphorical reasoning that is in line with embodied cognition (e.g.: Narayanan, 1999; Suroso, 2003) or conceptual blending (Turner & Fauconnier, 2002).

Revised Gentner's original version: in a structure-mapping, we have $KB_B$ and $KB_T$, each is respectively base and target domain such that there is $M$ that maps an anchor argument (an argument that appears in all propositions of *KB*0; the argument can be variable or constant) $x_b$ in propositions of $KB_B$ to other anchor argument $x_t$ in propositions of $KB_T$. Hence we obtain:

$$x_b \longrightarrow x_t$$

Expression above reads "$M$ maps $x_b$ to $x_t$." Its negation is written as:

$$x_b \text{ -/-> } x_t$$

that reads, "$M$ does not map $x_b$ to $x_t$."

For now, we can consider $KB_B$ as $Q_B = \{a_1(x_b), a_2(x_b),\ldots, r_1(x_b, x_i), r_2(x_b, x_j),\ldots\}$ and $KB_T$ as $Q_T = \{a_1(x_t), a_2(x_t),\ldots, r_1(x_t, x_i), r_2(x_t, x_j),\ldots\}$ (see Definition 4). In English, we can say that through $M$, "$x_b$ is like $x_t$." For example, the famous Rutherford's analogy: "An atom is like our solar system."

Extending to the level of propositions, below are the rules to come to acceptable structure mapping:

i) Decide which relations are preserved.

$$r_1(x_b, x_i), r_2(x_b, x_j), \ldots \longrightarrow r_1(x_t, x_i), r_2(x_t, x_j), \ldots$$

ii) Decide which relations are not preserved.

$r_1(x_b, x_i)$, $r_2(x_b, x_j)$, … -/-> $r_3(x_t, x_i)$, $r_4(x_t, x_j)$, …

iii) Each proposition is only used once in a mapping from base to target.

iv) When the heights of both $KB1_B$ and $KB1_T$ are not the same, i.e., $l_{\gamma;B} \neq l_{\gamma;T}$, the remaining unused proposition that is mapped to nothing:

$r_5(x_b, x_i)$ —> …

or

… —> $r_6(x_t, x_i)$

is treated as ii).

Following Rutherford's analogy, we can say for example, "An atom containing an electron that revolves around the nucleus is like our solar system where a planet revolves around the sun," but not "A sun is yellow just like a nucleus is."

We are then allowed to decide which predicates apply to both domains with an anchor argument of both base and target, and which ones that do not. Let us define another parameter $\delta$, that is the number of the mapped propositions obtained by i), and $\delta^*$, the number of the unmapped ones obtained by ii). The comparison between the number of mapped and the unmapped ones comes up with four types of comparison:

*i)* *literal similarity* is a comparison in which a large number of predicates is mapped from base to target relative to the unmapped ones; "The K5 solar system is like our solar system."; $\delta >> 0$, $\delta^* \approx 0$ (Read the expression $a >> b$ as '$a$ is bigger relative to $b$' since the usual use '$a$ is much larger than $b$' does not always apply when $\delta$ and $\delta^*$ are small.)

*ii)* *analogy* is a comparison in which relational predicates, but few attributes are mapped; "An atom is like our solar system."; $\delta >> \delta^*$, $\delta^* \neq 0$

*iii)* *anomaly* is a comparison based on neither attributes nor elements of both domain; "Coffee is like the solar system."; without setting more CPC of base and target domain, such that $CPC_B$ is $Q_B \cup Q_{B^*}$ and $CPC_T$ is $Q_T \cup Q_{T^*}$ where $Q_{B^*}$ and $Q_{T^*}$ are two arbitrary sets other than $Q_B$ and $Q_T$ respectively, it is hard to think where this makes sense at all; $\delta \approx 0$

*iv)* *appearance match* is a comparison in which a large number of attributes is mapped, but not the relations; "A sun flower looks like the sun."

From these types of comparisons, then we can define varieties of novelty:

1) NOVELTY1 comes from applying i) and it gives the most making-sense structure mappings. The mapping gives something more like a scientific truism, only that the axiomatization does not necessarily follow that in scientific discovery.

2) NOVELTY2 comes from applying ii) and it gives making-sense structure mappings but not as precise as NOVELTY1.

3) NOVELTY3 comes from applying iii) but it gives the least making-sense structure mappings that depends on CPC from outside the $Q_B$ and $Q_T$; the closest one to ridiculousness.

We do not include iv) since it is much related to perceptual sensitivity that is outside the scope of the paper. We will see how this is put to work in section 3.

To add more power to structure mapping, let us define a reversed work, a reversed structure mapping. Given $Q_B$ and $Q_T$, $l_{\gamma;B} = l_{\gamma;T}$, $\delta >> \delta^*$, we can add to $Q_T$ more propositions such that we in turn have $l_{\gamma;B} < l_{\gamma^*;T}$, $l_{\gamma^*;T}$ is the new maximal height of $Q_T$. Reversed structure mapping is written as:

$$r_{1^*}(x_t, x_i) ==> r_{1^*}(x_b, x_i)$$

where $r_{1^*}(x_t, x_i)$ is newly added propositions, but the mapping now applies from target to base. To preserve the analogy, we must put another constraint, $l_{\gamma^*;T} - l_{\gamma;T} << \delta$. The reverse structure mapping can be handy to do structure mapping from two *KB*0's with different heights.

There is a lack in Gentner's initial idea. Saying that our solar system is where we humans live, what revolves around the center of Milky Way, what brings Copernicus to accused infidelity, etc., will definitely be saying that an atom is where something lives, what revolves around something, what brings someone to something and we can never find substitutes for those somethings and someone. We can generate propositions of the same kind as many as we want, i.e., making $\delta^*$ larger and larger, and it will definitely brings structure mapping farther and farther from desired analogy.

This is the famous frame problem. One way to handle that is to assume the strength of CPC and use a closed world of propositions. Experiments (e.g. from Dunbar) does not mirror knowledge base to a machine, and judgment whether something is analogical is from the experimenter, not suggested by a machine. Taking *KB*0 as the one and only source of CPC can prevent an explosion of propositions and structure mapping can function well, though at the same time, it will set the CPC too strong relative to what a human being might actually have.

### 2.2.3. Conceptual Classification

This is much more risky approach compared to structure mapping since its background assumption is much relied upon various efforts of experimental approach not anyone can generalize very smoothly, and even if so, coarse-grainedness is assumed from the first place.

For example, in the study of folk biology, a kind of essentialism applies such that people act as if biological kinds have a (hidden) essence that provides conceptual stability over changes in more superficial properties (Medin, *et. al.* 2000).

Let us move further with essentialism. Ahn, *et. al.* (2001) gives a brief description of all causal relations between a surface property and its hidden essence shown in Fig. 8.

Experiments then suggest that certain concepts implicitly contain essence that causes their surface properties, rather than different essences cause the same surface property (Fig. 8b). The height of chain also counts in this essential causation since people only tend to use one essence instead of multiple essences tied together in an implicational chain to come to a surface property such that for a given concept, that is, a biological natural kind, $l_\gamma \approx 1$ (Fig. 8c). People also tend not to

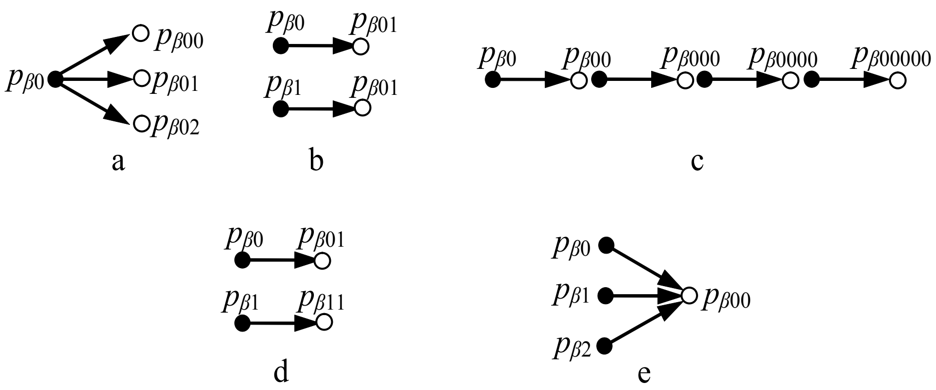


Figure 8 **Possible Causal Structure in a Category**

(adapted from Ahn, *et. al.*, 2001).

Essentialism only approves a) over other causal structures. From experiments it is shown that people tend to categorize biological objects (animals, plants) from its essence, that is, the antecedent, rather than its surface properties, that is, the antecedent. For example, a) shows that tigers have stripes ($p_{\beta 00}$), eat meats ($p_{\beta 00}$), and are fierce ($p_{\beta 00}$) because the essence of being tigers ($p_{\beta 0}$) says so.

use different essences such that each causes one unique surface property (Fig. 8d). Lastly, to come to a surface property, people are unlikely to use different essences (Fig. 8e).

We can see that in case of folk biology, it is likely that the chain of thought by hypothetical syllogism people use is so short in categorizing a flora or fauna based on its essence and surface property (see also Atran, 1998; Coley, *et. al.*, 1999; Ahn, *et. al.*, 2000). This particularly answers one of research agenda determined by Perch framework in case of folk biological domain. Other use of such findings is to construct appropriate propositions in structure mapping such that an essence of a folk biological natural kind becomes an atom and its surface properties being the attribute.

The next question is, are there further generalization of folk biology to other domains? If essentialism assumes nativism (Most experiments involve pre-school participants.), then do more-culturally-defined objects (e.g.: alcohol, carburetor, quasar, television) also have essence or are they some kind of second-order concepts that are not necessarily innate but derivable from first-order innate concepts with essence or they are fully acquired at all?

For present purpose, so far we have not found useful conceptual classification of culturally-defined domain, and for this, experimenters should expand their object of experiments to larger domains or otherwise, start to consider more general learning mechanisms that involve larger domains. One thing we can conclude, given a conceptually-sensitive domain, learning put aside, folk theory applies.

### 3. Two Cases of Novelty

We are now ready to demonstrate how novelty can arise as detected by a recipient, given a data in forms of $Q_B$ and $Q_T$.

*3.1. Anomaly: Fable*

> "Be ashamed of yourself," said the frog.
> "When I was a tadpole, I had no tail."
> "Just what I thought!" said the tadpole.
> "You never were a tadpole."
>
> Robert Louis Stevenson
> *The Tadpole and the Frog*, from *Fables*

In deciding whether the short fable is a form of novelty or not, let us recall Scott Atran's folk biological notion of tadpole and frog:

> "... a tadpole and frog are in a crucial sense the same animal although they look and behave very differently, and live in different places. Western philosophers, such as Aristotle and Locke, attempted to translate this commonsense notion of essence into some sort of metaphysical reality. ..." (Atran, 1998).

Now, given tadpole and frog as folk biological categories with the same essence, that is, frog, we can assume $Q_B$ from $KB1_B$ described by Atran's 'the frog world'. We can also directly construct $Q_T$ from $KB1_T$ given by Stevenson's fable.

Let the capitalized arguments used in propositions as a surrogate[5] or an identity such that it denotes an individual among a collection of objects with the same attributes and relations. Call the frog Froggy. The resulted 'frog world' is as follows:

$p_{\{\};B}$ A frog had a tail.
frog(x,time(Now)) $\Rightarrow$ has_tail(x,time(Before_Now))
$p_{0;B}$ A frog was a tadpole.
frog(x,time(Now)) $\Rightarrow$ tadpole(x,time(Before_Now))

We might expect that what will happen is literal similarity or NOVELTY1 since during the conversation between Froggy and tadpole, what happens is only syllogism, that is, Froggy is a frog so it is necessary for Froggy to have all attributes and relations any other frog might have. Then, let there be a $KB1_T$ given by the fable with its $Q_T$ as follows:

$p_{\{\};T}$ Froggy had no tail.
frog(Froggy, time(Now)) $\Rightarrow$ $\neg$has_tail(Froggy, time(Before_Now))
$p_{0;T}$ Froggy was never a tadpole.
frog(Froggy,time(Now)) $\Rightarrow$ $\neg$tadpole(Froggy,time(Before_Now))

Let us then try to apply the structure mapping with anchor variable *x* in base domain and constant

[5] Some informal definition of surrogate: a replacement of a variable *x* in a proposition *f*(*x*) with a unique constant *c*. From $(\forall x)\ f(x)$, we derive *f*(*c*), and *c* is a surrogate such that any other replacement must not use constant *c* since *c* denotes to a unique object.

Froggy in target domain:

1) frog(x,time(Now)) ⇒ has_tail(x,time(Before_Now))
 -/-> frog(Froggy,time(Now)) ⇒
 ¬has_tail(Froggy,time(Before_Now))
2) tadpole(x,time(Before_Now)) frog(x,time(Now))
 -/-> frog(Froggy,time(Now)))
 ¬tadpole(Froggy,time(Before_Now))

Obviously, no attributes nor relations overlap in all propositions containing anchor variable x and anchor constant Frog, $\delta \approx 0$, $\delta^* \approx 0$. This novelty given by the fable is NOVELTY3, an anomaly. If CPC outside $KB0_T$ (e.g.: Froggy is *fictitious because it talks*, or *told by the famous Robert Louis Balfour Stevenson*, or *something beyond essence and essentialism*, etc.) are removed, the novelty becomes mere madness.

This is indeed mysteriously puzzling. However, we hypothesize that we can put this kind of novelty in a discourse, i.e., in a long chain of thought not necessarily composed only of hypothetical or disjunctive syllogism but also disjunction, conjunction, etc. Only that it will not be well-functioning as anomaly at all if in the discourse, the number of anomalies exceeds the number of what is not anomaly.

Can we imagine a frog that never had a tail, and flies, has feathers, eats snakes instead of being eaten by them, and it has various attributes that violate essentialism, and the frog is truly found in a weirdest fiction ever written and people buy it? I can't. Rather I would take it as totally different species. If I were presented a Perch worksheet, I would surely choose abstain in most questions. Too bad the fable is only four lines long.

### *3.2. Analogy: Slogan*

This example, unlike previous one in section 3.1. does not have a data to refer to. So we will use an example of possible $Q_B$ and $Q_T$.

Here is the $Q_B$:

$p_{\{\};B}$ Good shoes are what runners need.
$p_{l=1;B}$ The shoes must be shoes comfortable to wear.
$p_{l=2;B}$ They must be designed in sophisticated way.
$p_{|\gamma|=3;B}$ The shoes must be created by intelligent people.

In Perch, $KB3_B$ must be of the form "If good shoes are just what every runner needs, then the shoes must be created by intelligent people."

Subsequently, here is the $Q_T$:

$p_{\{\};T}$ Good things are exactly what people need.
$p_{l=1;T}$ Good things are durable.
$p_{l=2;T}$ Good things must be designed in sophisticated way.

$p_{|\gamma|=3;T}$ Good things must be created by intelligent people.

In Perch, $KB3_T$ must be of the form "If good things are just what people need, then those things must be created by intelligent people."

By doing a structure mapping, we will have:

1) need(runner,good(shoes))
—> need(people,good(things))
2) ware(*x*,good(shoes) $\wedge$ comfortable(good(shoes))
-/-> durable(good(things))
3) sophisticated(design(*x*,good(shoes)))
—> sophisticated(design(*x*,good(things)))
4) create(intelligent(people),good(shoes))
—> create(intelligent(people),good(things))

Since more relations are mapped relative to the unmapped, $\delta >> 0$, $\delta >> \delta^*$, this analogy holds: "Good shoes for a runner are like all the good things in the world for people." But how come, being unmapped at 2), both $KB1_B$ and $KB1_T$ still continue to coincide in 3) and 4)? This can happen since higher types can share the same lower types (see Definition 3).

Let us continue by reversing the work. Suppose we add to $Q_T$ such that $l_{\gamma;T} = 4$. Hence we might have:

$p_{l=3;T}$ Good things must be created by intelligent people.
$p_{|\gamma^*|=4;T}$ Good things are intelligent.

And doing the reversed structure mapping we apply additional reversed mapping:

5) intelligent(good(things)) ==> intelligent(good(shoes))

or in English, "Good shoes are intelligent just like all the good things in the world are," that is definitely NOVELTY2, and constraint on reversed structure mapping is not violated, that is, given $Q_T$ and $Q_B$, $l_{\gamma;B} = l_{\gamma;T}$, and $l_{\gamma;B} < l_{\gamma^*;T}$, $\delta >> \delta^*$, the reversing still obeys $l_{\gamma^*;T} - l_{\gamma;T} << \delta$. But we are no longer allowed to apply $KB5_B$ that reads in English, "Good shoes for a runner are good shoes that are intelligent," since in $Q_B$, the path from $p_{\{\}}$ to $p_{|\gamma^*|}$ is not 'smooth', i.e., in structure mapping 2) there is an unmapped relation. After reversed structure mapping, only *KBN* with smooth path that is allowed.

The result of reversed mapping is very close to a slogan of adidas_1 appeared in *Rolling Stone Magazine*, *May 2005*:2 (Indonesian edition), 'the world's first intelligent shoe'. However, this is not from data, not selected from a big *KB*0 whatsoever, and this section is only a demonstration of how structure mapping and its reversal are put to work.

## 4. Summary

This paper from the first place reckons much with different topics despite its very narrowlydesigned aim. The motive is only to confer findings and theorizing in one place with findings and theorizing in another so a potential incoherence is less to become unavoidable.

Summarizing the whole framework, first we emphasize the difference between scientific and non-scientific discoveries such that the former has an explicit heuristic while the latter does not. The main interest of the paper is to shed light on the latter, but in doing so, a general framework is not yet accessible.

So we first evaluate physical symbol hypothesis and computationalism until we can come up with typical cognitive architecture. Such architecture has a central process whose input are propositions parsed unambiguously by perceptual modules, and whose output is either a belief revision or fixation or even overt behavior. All the processes within follow computational rules such that propositional attitudes are what to process and their contents are persistent ceteris paribus, since if otherwise, we cannot think, reason and generate behavior at all.

To represent the persistence, we develop a framework called Perch such that the framework can give instantiations of propositions that altogether can be assembled in a chain of thought through logical rule of thumb, e.g., modus ponens. If the chain of thought exists at all, then to a certain degree, mental contents are indeed persistent.

Given all propositions resulted from Perch, we then develop a way to map two different domains, and if the mapping succeeds, it can give rise to three kinds of novelty, i.e.: literal similarity, analogy, and anomaly. Finally, how a novelty can be detected by a recipient is illustrated in two brief example, one derived from real data, one from assumed data.

## 5. Remarks and Further Works

### *5.1. Perch and Philosophy of Mind*

The weakness of Perch is that it only consists of unit structures, that is to say, it only uses implications, hypothetical syllogism and disjunctive syllogism. We can make more complex formulae used in Perch framework however, but the power of its implicational structure remains, that is, it can connect different formulae and come up with a chain of thought immediately that ends in an object, yet, it is still familiar for laypeople.

Perch also does not have an abstain choice since if a recipient does not choose anything at any height, she will not be able to continue to the next height. Dealing with this depends on the insight of the knowledge engineer, probably from the first place, by assuming that the choice is preferential or ordinal.

Now what do we have in our backyard? Philosophers up till now is still being intrigued by the radical mind-machine metaphor with respect to the relationship between mental content and behavior, and not mental content with one another. Hopefully, Perch is a framework to explore the latter.

### *5.2. Perch and AI*

Perch framework is again a tool for setting all necessary constraints commonsense reasoning would use in daily practice. Perch is designed to detect persistence, and persistence to a certain degree implies limitation (of mind-machine metaphor).

Present direction in AI researches is indeed following a logically-inclined but not empirically-driven mode of development. If there is a good theorizing such that all empirical findings from developmental psychology, ethnobiology, cognitive psychology, cognitive anthropology and psycholinguistics can be more generalizable (this is another motive of building Perch framework), then AI researches can turn the direction towards more empirically-supported framework of creating an artificial agent.

This, someday, probably can bring new strategy (one may add another meaning to the jargon 'computational psychology') in later development of cognitive science in general.

### *5.3. Representational is not Preferential*

The aim of this paper is representational only so we cannot compare directly, what is more preferred by a recipient between two successful structure mapping and hence, two novelties. In short, the motive is only targeted at 'things that has never been thought of before' that even includes what has been forgotten, and not 'things that has never been thought of before, some is more creative than others.' Preference can also be interpreted as a base to compare, for example, trivial and outstanding novelty.

We will leave preferential and memory issues to further agenda.

### *5.4. Desideratum*

The Perch framework proposed is an empirical framework. Without a working experiment or empirical acquisition of past experiments, it is not a working experimental framework at all. Structure mapping that becomes a useful tool in determining varieties of novelty relies much upon what is obtained by Perch framework. Hence, structure mapping has the same lack.

However, present purpose is intended to give a representational framework rather than an experimental report.

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