# Indiana Undergraduate Journal of Cognitive Science

A Journal of Research and Writing in Cognitive Science

## Volume 5  Contents  2010

### Articles

<table>
<thead>
<tr>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous Noun and Category Learning via Cross-Situational Statistics</td>
</tr>
<tr>
<td>The Connection between Compositional Language and the Theory of other Minds</td>
</tr>
<tr>
<td>Dynamic Design: Cognitive Processes in Design Sketching</td>
</tr>
<tr>
<td>Embodied Cognition and Naturalized Perspectivism: Cognitive Science Returns to Phenomenology</td>
</tr>
<tr>
<td>THE MNS (mirror neuron system) in embodied semantics: Activation Patterns of the Mirror Neuron System in Visual Linguistic Processing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarun Gangwani, George Kachergis, Indiana University</td>
</tr>
<tr>
<td>Evan Galup, Indiana University</td>
</tr>
<tr>
<td>Moira R. Dillon, Yale College</td>
</tr>
<tr>
<td>Brian Wermcrantz, Grinnell College</td>
</tr>
<tr>
<td>Joann Song, Advisor Jaime Pineda, University of California, San Diego</td>
</tr>
</tbody>
</table>

### General Information

<table>
<thead>
<tr>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-2010 Editorial Board, Indiana Undergraduate Journal of Cognitive Science</td>
</tr>
<tr>
<td>Author / Submission Instructions</td>
</tr>
</tbody>
</table>

**On the Cover:** Cover Art by Michelle Capriles-Escobedo, Brush Design from http://scully7491.deviantart.com/
Simultaneous Noun and Category Learning via Cross-Situational Statistics

Tarun Gangwani, George Kachergis

Department of Psychological & Brain Sciences / Cognitive Science Program

Indiana University

Abstract

Previous research shows that people can acquire an impressive number of word-referent pairs after viewing a series of ambiguous trials by accumulating co-occurrence statistics (e.g., Yu & Smith, 2006). The present study extends the cross-situational word learning paradigm, which has previously dealt only with noun acquisition, and shows that humans can concurrently acquire nouns and adjectives (i.e., a natural category with a distinctive, unifying feature). Furthermore, participants are able to learn ad hoc categories of referents consistently co-occurring with a label, while simultaneously learning instance labels. Thus, humans demonstrate an impressive ability to simultaneously apprehend regularities at multiple levels in their environment.

Keywords

Categorization, concept learning, statistical learning, language acquisition, cross-situational learning

Introduction

Many objects have hierarchically organized labels. For example, one may refer to one’s pet with the basic-level name “dog,” or with a subordinate-level name, e.g. “golden retriever.” Labels can also describe a particular category instance: e.g., one’s golden retriever may be named “Rex.” Hence, objects can be referred to using specific names (e.g., Rex) or using a category label at any level of specificity (e.g., golden retriever, dog, mammal, etc.).

To succeed in learning a natural language, people must learn labels at many levels of abstraction: instance, subordinate, basic, superordinate. These labels are often consistent with physical or abstract referent properties that make that label salient (e.g., all mammals have hair or fur). Although some categories have members that share a number of perceptual properties (e.g., dogs typically bark, have four legs, and are furry), other categories may have members that share no perceptual characteristic (e.g., things in the kitchen), but belong to a common context or share abstract properties. Categories that share unifying perceptual
features are dubbed natural categories, and those that share abstract properties (or context) are dubbed ad hoc categories.

For a learner to acquire knowledge of an object’s names at different levels, it likely requires many co-occurrences of each label and the object in many different situations. The theory that a word’s meaning may be learned by experiencing multiple, individually ambiguous naming events is dubbed cross-situational statistical word learning (Pinker, 1984), and has proven to be an effective word learning mechanism in adults and children (Smith & Yu, 2008; Yu & Smith, 2007). Previous studies have investigated the effects of word-object pair frequency and the contextual diversity of the learning situations (Kachergis, Yu, & Shiffrin, 2009a), the effects of prior knowledge on learning additional pairs (Klein, Yu, & Shiffrin, 2008), and the mutual exclusivity bias (Yurovsky & Yu, 2008). In the present study, we investigate whether learners can make use of cross-situational statistics to acquire both 1-to-1 (i.e., subordinate-level) and 1-to-many (i.e., basic-level) labels when they are presented concurrently.

In the cross-situational word learning paradigm (Yu & Smith, 2007), subjects are exposed to multiple words and multiple objects on each of a series of training trials and then asked to identify which object each word refers to. A typical training trial consisted of four objects (A, B, C and D). Four pseudowords are played on each slide (a, b, c, and d), where each refers to one object out of four on each slide (A-a, B-b, etc.). The correct pairings on any given training trial remain ambiguous, as the word-presentation order is randomized, and thus does not systematically correspond to any object’s location. No word to referent pairing ever appeared in two consecutive trials, as this would trivialize the learning of that pairing (see Kachergis, Yu, & Shiffrin, 2009b). In a typical training block, participants would attempt to learn 18 word-referent pairings from 27 12-second trials, during which each stimulus pair appeared six times. At test, learning was assessed by asking participants to identify which object from a subset of four of the 18 objects corresponded to a pseudoword trained on. On average, participants learned 9 to 10 out of 18 pairings, but a couple subjects learned every pairing (Yu & Smith 2007). The regular co-occurrence of a word and an object is sufficient for people to learn to pair that word and referent.

In this study, there will be only two objects on each training trial, but three words will be played. Two of these words (the instance labels) name the displayed referents, and the other word (the category label) refers to both objects on the screen as well as two other objects for each block. A total of 12 word-to-referent (1-to-1) associations and 12 category-to-referent (1-to-many) associations will be shown in each block. In two of the three experimental blocks, the objects used are uncommon items (e.g. strange tools) and the category label refers to four randomly determined objects (the ad-hoc category condition). In the other block, the natural category condition, the objects are uncommon shapes with one of three distinct features on a set of four objects. Each category label will always refer to the same feature for each object. So, if objects A, B, C, D have a hook shape, category label X will denote objects with a hook and a, b, c, and d will name each object, respectively.

Therefore, an example training trial would be objects A and C on the screen and words c, a, and X played. At the end of training, there will be two separate tests to measure learning of 1-to-1 and 1-to-many relations. For the 1-to-1 relation, participants will need to choose which
object from all the objects trained on matches a word played using 12-alternative forced choice testing (12AFC). For the 1-to-many relation, participants must choose from three objects, where each object is a representative of each category that the word played belongs to (3AFC). Additionally, subjects will also be asked to do a similar test, but with novel objects, to gauge participants’ ability to generalize.

Participants are not informed of the hierarchical nature of the mappings: they are simply instructed to learn which words belong with which objects. From their perspective, there will be some words (the category labels) that appear more often, and with more referents. It likely will take some time for subjects to realize that these labels are not simply noise, but are consistently appearing with four referents. In the Yu & Smith (2007) study, there were 18 1-to-1 relations (18 objects and 18 referents) to be learned. In addition to 12 1-to-1 relations (12 objects and 12 referents), the present study also tests the participant to learn 12 1-to-many relations (which includes 4 stimuli in each category), even though there are fewer total stimuli in memory.

Even though we have seen that people are good at learning 1-to-1 relationships, the main question to be answered is whether people can learn both 1-to-1 and 1-to-many relationships simultaneously. In order to test this, the experiment was organized in three blocks. Block 1 is an ad-hoc condition focusing on simultaneous category and name learning ability. The ad-hoc condition is first to gauge whether subjects can notice and learn the category relationship even if there is no perceptual feature to clue them into the relation. Block 2 is a natural category condition which, in distinction to the previous block, focuses on categorization using an external feature and generalization to novel objects. With the second block, subjects should have a better chance of grasping the 1-to-many relationships. Block 3 is another ad-hoc condition to investigate the effects of having a natural category condition in the previous block. While the function of the category label becomes clearer in the 2nd and 3rd blocks, there still may be difficulty in keeping track of both types of associations. In the present study, we mainly investigate whether people can learn both relationships simultaneously, but one condition also tests the effect of having a shared, external feature amongst the objects.

**Experiment Overview**

The experiment utilized the cross-situational paradigm by presenting the subjects with a set of words and pictures across several training slides. Each training slide displayed two objects from a set of 12 stimuli, which were presented simultaneously with three nonsense words from a set of 15 words played through a speaker. The stimuli were presented in a random order, and for each block different stimuli were used. Subjects were trained on several pairings of 1-to-1 or word-to-referent associations as well as several pairings of 1-to-many or category associations. The 1-to-1 relationship is a word that co-occurs most often with a single referent. In contrast, the 1-to-many relationship is a word that co-occurs equally often with four referents. For example, the word *dog* is associated with many referents (e.g. puppies, golden retrievers, etc.), so its relationship with its associated stimuli is 1-to-many.
On each training trial, three words and two pictures were presented, where one of these words represented a 1-to-many label (the category label).

The subjects were trained on two different conditions (in three blocks):

**Block 1** was an *ad-hoc category* condition, in which the objects had no obvious shared perceptual features.

**Block 2** was a *natural category* condition, in which the objects in each category’s objects share a salient feature (e.g., a hook or arrow shape).

**Block 3** was another *ad-hoc category* condition (with different stimuli) to gauge attention shift after learning natural categories.

The subject, after repeated pairings of the words and the stimuli, was then tested on their knowledge of the category label relationship as well as the name of the object. To test the 1-to-1 relationships, subjects heard each word they were trained on and chose one object from all the 12 objects presented in that block. To test the 1-to-many relationship, subjects heard a word they were trained on and chose one stimulus from three stimuli on screen, chosen at random as a representative member of each category. Since the relationship between the category label and the stimuli that are associated with it were not explicit in the ad-hoc condition, one can posit that performance will not be as strong as in the natural category condition.

**Subjects**

Participants were 24 undergraduates at Indiana University who received course credit for participating. None had participated in other cross-situational experiments.

**Stimuli**

Each training trial consisted of two novel objects shown on a computer screen. For the ad-hoc conditions, these objects were mostly strange tools. For the natural category condition, these objects were odd shapes with different textures filling the surface and one of three features protruding from the shape. These objects on screen were shown concurrently with 3 pseudowords, spoken sequentially. The 45 pseudowords generated by computer are phonotactically-probable in English (e.g. “stigson”), and were spoken by a monotone, synthetic voice. The 36 pairs of training stimuli were randomly assigned to three sets of 12 word-object pairings, one set for each block. Additionally, four word-object pairings were randomly assigned to 3 sets of 4 word-object pairings in each block to distinguish each category set. In the natural category condition, an additional 12 pairs of testing stimuli were used for a generalization task.
Figure 1: Examples of objects used in experiment. Each object was assigned at random a label to name it and a label to unify it into one of three categories. **Left**: In the natural category condition, objects with multiple types of textures and three different protruding shapes were used in training. **Right**: In the ad hoc condition, objects had no apparent unifying feature.

![Examples of objects used in experiment.](image)

<table>
<thead>
<tr>
<th>Words</th>
<th>X (12)</th>
<th>Y (12)</th>
<th>Z (12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A  B  C  D</td>
<td>E  F  G  H</td>
<td>I  J  K  L</td>
</tr>
<tr>
<td>a</td>
<td>6  2  2  2</td>
<td>0  0  0  0</td>
<td>0  0  0  0</td>
</tr>
<tr>
<td>b</td>
<td>2  6  2  2</td>
<td>0  0  0  0</td>
<td>0  0  0  0</td>
</tr>
<tr>
<td>c</td>
<td>2  2  6  2</td>
<td>0  0  0  0</td>
<td>0  0  0  0</td>
</tr>
<tr>
<td>d</td>
<td>2  2  2  6</td>
<td>0  0  0  0</td>
<td>0  0  0  0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Referents</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
<th>l</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>b</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>c</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>d</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 2: The completed association matrix after each block. Words indicate the words played and referents indicate the objects associated with each word by letter. Each word and referent association was seen 6 times, as indicated on the diagonal. Additionally, each referent appeared with every other referent 2 times, but never appeared with referents outside its category (as indicated by the shaded regions corresponding to each grouping). Each category label was played to correspond with its respected shaded grouping 12 times.
Training for each condition consisted of 36 trials. Each training trial began with the appearance of two objects, which remained visible for the entire trial. After two seconds of initial silence, each word was heard (randomly ordered, duration of one second) followed by two additional seconds of silence, for a total of 9 seconds per trial.

After each training phase was completed, participants were tested for knowledge of noun labels (i.e., word-object mappings) and category labels (i.e., word-shared feature mappings). A single word—an instance or a category label—was played on each test trial. On noun test trials, all 12 referents were displayed. On category test trials, three referents were displayed; one exemplar from each of the three categories defined by the unifying perceptual feature.

**Procedure**

Participants were informed that they would experience a series of trials in which they would hear some words and see some pictures. They were also told that their knowledge of which words belong with which objects would be tested at the end. After training, their knowledge was assessed using 12-alternative forced choice (12AFC) and 3-alternative forced choice (3AFC) testing: on each test trial a single word was played, and the participant was instructed to choose the appropriate object from a display of all 12 or 3 objects representative of 3 categories of objects. Condition order was counter balanced.

**Results: Block 1 – Ad Hoc Category**

Figure 3 displays the learning performance for the two types of associations (1-to-1 and 1-to-many) the subjects were tested on. Subjects performed well on identifying the explicit 1-to-1 relations, performing significantly better above chance during testing ($M = .52$, $t(22) = 10.219$). Subjects’ performance on recognizing the category relation was also above chance but the results were not as notable.

Figure 4 displays the correlation between 1-to-1 and 1-to-many performance across all the subjects tested. There is no trend present when subjects are first presented with an ad hoc condition ($r^2 = .197$).
Figure 3: Learning performance for 1-to-1 and 1-to-many mappings in Block 1. Participants performed far more above chance (9%, 12AFC) for 1-to-1 pairings than in for 1-to-many pairings (33%, 3AFC).

Figure 4: Correlation of 1-to-1 performance to 1-to-many performance across all subjects. No significant trend is present upon first presentation of an ad hoc condition.

**Results: Block 2 – Natural Category**

Figure 5 displays the learning performance for the two types of associations tested as well as performance on generalizing the explicit category feature trained on to new stimuli at test. The test slides for generalization were the same as the test for the 1-to-many test slides except that the only previously-seen parts of the stimuli were the distinct, unifying features (e.g., a hook) that were seen in training to distinguish the different category types.
In contrast to Block 1, the 1-to-1 performance was decreased ($M = .33$), and 1-to-many learning reached a higher level of performance: the blatant category similarity shifted their attention ($M = .59$). In addition, their ability to generalize the explicit feature is reflected in their significant performance above chance ($M = .53$).

Figure 6 displays the correlation between the 1-to-1 performance and the 1-to-many performance. Again, no significant trend is present ($r^2 = -.095$).

Figure 5: Performance on 1-to-1 and 1-to-many associations for Block 2. Subjects performance contrasted sharply from Block 1 as their performance on 1-to-1 testing decreased but their 1-to-many performance increased. Subjects also performed well at the generalization task, solidifying their ability to learn category relations.
Figure 6: Correlation of 1-to-1 performance to 1-to-many performance across all subjects. No significant trend is present upon first presentation of an ad hoc condition.

**Results: Block 3 – Ad Hoc Category (itera)**

Figure 7 shows the learning performance for the two associations to serve as a comparison to the results in Block 1 (Figure 1) as this Block is the same condition as Block 1. Here, the performance on 1-to-1 testing is much lower than that of Block 1 ($M = .34$, $t(22) = 4.875$), and performance on 1-to-many testing is much higher than Block 1 ($M = .53$, $t(22) = 4.289$). It is important to note that these results occurred after the natural category condition in Block 2.

Figure 8 shows a positive correlation between 1-to-1 and 1-to-many performance after Blocks 1 and 2 ($r^2 = 0.59$).

![Performance on 1-to-1 and 1-to-many associations for Block 3. In comparison to Block 1 (the first ad-hoc condition test), subject performance on 1-to-1 relations decreased and subject performance on 1-to-many relations increased.](image)
Discussion

Objects are frequently associated with multiple labels. The participants were tested to see if they could learn both the 1-to-1 and 1-to-many label for each referent. In one block, participants were also tested to see if they could generalize their knowledge of a concept to novel objects. Subjects at first did not grasp the need to learn the category label and thus likely disregarded it as noise (1-to-many, $M = .49$) but did very well on the 1-to-1 relationship ($M = .52$). After the second block with the natural categories, subjects’ performance on category learning markedly improved ($M = .59$), but the performance on the explicit 1-to-1 relationship dropped ($M = .33$). Therefore, in this experiment there was an apparent trade-off: if a participant focuses on learning which word names which picture, their performance is markedly well in this type of learning. If the participant focuses on the category relation, then their performance is improved in the 1-to-many association instead of the 1-to-1 association.

Specifically, Block 1 demonstrates that subjects at first have a strong bias to naming objects and a need to ignore certain information unless they are clearly indicated of its importance beforehand. Block 2 suggests that after the explicit feature is presented, subjects may shift their attention to this explicit feature, which overall had decreased their learning of 1-to-1 relations. Intriguingly, Block 3 shows that subjects can still recognize a categorical relationship, even with no extrinsic feature present. But, their learning performance for 1-to-1 associations did not improve even after being experimented on both of the conditions in this
One of the conclusions of Rosch & Mervis’ (1975) study was that category members need not share the same feature, but only need to resemble each other. In our study, Block 3 suggests that category members may not even resemble each other, as performance was still well above chance for the category relationship. However, their performance did slightly decrease as compared to the results in Block 2 (Block 2: \(M = .59\); Block 3: \(M = .53\)), suggesting that having a natural feature present does facilitate learning.

Why was it that, on average, a participant could not perform equally well in both associations? Even after Block 2, the performance on the 1-to-1 association did not increase by a significant amount. However, mean performance alone may not be a correct measure of simultaneous 1-to-1 and 1-to-many learning. In Figure 8, the correlation between 1-to-1 vs. 1-to-many performance is shown, and there is a positive trend \((r^2 = .59)\): a subject’s performance on one type of relationship does affect their performance on the other type. As further evidence for simultaneous learning, for incorrect 1-to-1 answers given on the 12AFC test at the end of each Block, subjects were at chance for naming an object in the same category \((M = .39)\). Therefore, a majority of participants did learn both types of associations.

For future studies, we would like to see whether subjects can retain the category relation over a longer period of time, i.e. one or two weeks. Another possibility is to use more complex structures for category learning. For example, two words and two referents are played on each trial, with only one word naming a referent and another word naming a category only, but not the other referent. For example, words \(a, X\) are played and referents \(A, C\) are displayed. In later trials, subjects could be trained on either 1-to-1 or 1-to-many, but not both types of relations. This could further complicate the 1-to-1 bias participants may have and block the ability to learn certain referent names.

Acknowledgements

Thanks to Brenden Sewell, editor of the Undergraduate Journal for Cognitive Science at Indiana University, for allowing me to publish, as well as the IU Undergraduate Cognitive Science Conference for inviting me to do so. Special thanks to George Kachergis for mentoring me through the entire process, as well as lab directors Chen Yu and Richard Shiffrin.

References


The Connection between Compositional Language and the Theory of other Minds

Evan Galup

Indiana University

Abstract

In this paper I wish to disambiguate the components of TOM, analyze them, and focus on the single pre-requisite that is commonly said to “systematically aid” TOM, namely, compositional language (Fitch, 2004). I will argue that compositional language is neither necessary nor sufficient for having a theory of other minds, and support this thesis with examples from animals that do not have compositional language, but do exhibit characteristics of TOM, and examples from organisms with compositional language, but do not provide evidence for having a TOM. The paper culminates with a call for further conceptual analysis of TOM, and suggests a promising direction of building layers of attribution of the concept as “sorites” type, admitting of degrees of ascription.

A. Introduction

When a predator is approaching, a doe that is separated from her fawn will act depending on the movement and direction of the predator. Specifically, if a predator is equidistant from both the doe and her fawn, and it begins to move towards the fawn, the mother will make herself the object of a chase seemingly to avert the impending attack. She runs up towards the predator and moves so as to explicitly prompt the predator to chase her. If, however, the predator is close to the fawn but moving away from it, and towards the mother, she will stand and wait in observance of the situation. This indicates that the doe seemingly possesses a capacity to infer from the behavior of the predator whether it is planning to attack the fawn (Byers, 2002)

This example, of a non-human animal, from here on animal, inferring the mental state of another invokes an important question about mental state attribution in the fields of Philosophy, Psychology, and Animal Cognition. Can we freely attribute a ‘theory of minds,’ hereby TOM, to the doe in this example?

B. Prevalent conception of TOM

1 ‘Theory of mind’ and ‘theory of other minds’ are often used interchangeably and ambiguously in the literature to denote attribution of mental states to self and to others. In this paper, I will use TOM to mean ‘theory of other minds,’ indicating attribution of mental states to others.
Throughout the literature, the definition of TOM is often vague and thus it is difficult to clarify what exactly constitutes having TOM. The clearest reading of the culmination of these definitions can be taken from a paper written by Penn and Povinelli, hereby PP-TOM. What can be gathered is that the prevalent conception is that TOM is the theory describing how an agent infers and predicts behavior (states) of other agents based on a theory about the relation between observable elements and unobservable states of mind (Penn and Povinelli, 2007).

By this definition we should be able to predict someone’s behavior based on something observed about them, something unobserved, and what we can infer about both. For example, I walk into a room and I see a man throwing a chair at another younger man. In this scenario, I have observed a man behaving in a certain way, e.g. throwing a chair, and can infer based on this behavior that he must be angry, or have an unobservable state of anger. Another example may be that I ask my friend how she is, and she says that she is fine but she nervously looks around when she answers. In this case, I am observing my friend say that she is fine, and I also observe that she nervously looks around. From this, I infer that she must be feeling something else besides fine or she would not have nervously looked around (an unobservable state of mind).

However, this conception leaves room for many questions to be answered. One question that needs attention is what kind of relation between observable behaviors and unobservable states of mind is needed in attributing TOM. Often times, correlation between events is confused with causation. So, observing a behavior may correlate with an unobservable state of mind, or the observed behavior causes, or brings about, the unobservable state of mind. This definition does not clearly state what kind of relation, whether correlational or causal, exists between the behavior and the state of mind.

PP-TOM also leaves room for debate about what the necessary conditions for having TOM are. We know that there is an unobservable state of mind and an external cue, but is there a domain of relevant states of mind when attributing a TOM? In other words, are there particular states of mind that should be emphasized according to how relevant they are to the situation?

Finally, PP-TOM does not address the preconditions for having TOM. We do not know, from this definition, what, if any, are the predispositions necessary for having TOM. The ambiguity of PP-TOM facilitates ease of depriving or attributing TOM to agents. Although the definition seems intuitive and acceptable *prima facie*, it can be used to support a superior position about the cognitive status of humans. Human language is the only language that can satisfy the three assumptions underlying this definition.

This common conception of what it means to have TOM assumes three capacities about the organism that has TOM and how it attributes mental states. First of all, it assumes understanding of the concept of “mental states.” Secondly, it assumes having a “theory.” And finally, it assumes having prerequisite skills of inference and prediction. Moreover, this definition is assuming that an agent can recognize a relation that seems to occur between states of mind and behavior from specific instances. So, agents are generalizing from instances to form a broader theory that enables them to have a system of recognizing this pattern of behavior. The only type of agent that could form a broader concept of specific
instances would be one in which the language enables them to generalize and create an abstraction from particular instance. The intuitive conception of TOM, thus, presupposes conceptualization, inferences, and abstraction that are commonly associated with agents who have compositional language.

C. Compositional language and TOM

A compositional language is one in which the compound units (e.g. sentences) are built systematically and in accordance with specific rules from atomic components (e.g. words). This property of a language has three major consequences. First, the syntactic value of the compound is a function of the values of the parts. The semantic value of the compound, e.g. the meaning of a sentence, is a function of the values (meanings, references) of the components. Most importantly, a compositional language has the property of productivity. It allows speakers to create and understand an infinite number of compounds from a finite number of building blocks.

A debate exists as to whether a theory of other minds can exist without compositional language. PP-TOM implies that pre-lingual babies and non-human animals may never have TOM. Babies would have the potential of acquiring TOM as they acquired language, but in the case of animals, they would never have the possibility of having TOM. On the other hand, agents with language, such as Autistic people, would be likely candidates for having TOM.

D. Proponents of TOM attribution to animals

In 1978, David Premack and Guy Woodruff published an article that strived to answer the question of whether chimpanzees have a theory of mind. They provided chimps with various videos of people encountering problems that they needed to solve. The experimenters then showed videos of solutions that corresponded to the problems portrayed in the videos. If the chimpanzee matched the solution video with the problem video correctly, which they did, then the experimenters concluded that the animals had a theory of mind. This paper sparked a heated debate then and is still popular in modern day animal cognition research.

Michael Tomasello and his group reexamine the question of whether the chimpanzee has a theory of mind in response to the article by Premack and Woodruff in 1978. Tomasello et al. wanted to sift through evidence supporting that animals have TOM by performing a series of experiments that they feel are the most revealing of the true nature of the chimpanzee’s abilities. As a result, they derived several experiments that examined the chimps’ ability, or lack thereof, to understand goals and intentions, to understand others’ perception and knowledge, ability to follow gaze, and communication by gesturing and had positive results (2003). Taking into account the evidence produced by the experiments, Tomasello et al. conclude that chimpanzees have a theory of mind in a broad sense; but in a narrow sense, they may not because they don’t have the ability to discern false beliefs (Tomasello et al., 2003).
Dale Jamieson is a very strong proponent for claiming that animals have minds. In his paper “Science, Knowledge and Animal Minds,” he addresses this issue and offers theories as to why we attribute or fail to attribute mental states to animals. Ultimately, he argues that knowing animal minds is not so different from knowing human minds. In his opinion, the capability to make an inference from behavior becomes a matter of interpretation, familiarity, and shared conventions (Jamieson, 1998).

E. Opponents of attributing TOM to animals

Even though several proponents claim that animals have TOM, many researchers are still reluctant to label animals as having TOM. Daniel J. Povinelli and Jennifer Vonk hold firmly onto the position that the type of evidence researchers have used to support the idea that animals have a theory of mind is not adequate to support the narrower claim that chimps possess a theory of mind. They believe that the type of data accumulated by studies helped an interpretation that misconstrues the animal behavior as attribution of mental states. Because of the way humans view their own minds, they project this onto how they view the minds of other animals, especially a species like the chimpanzee, which is so evolutionarily close to humans (Povinelli and Vonk, 2003).

Another opponent to endowing animals with TOM is Clive Wynne. In his book, Do Animals Think? (2004), Wynne defines ‘theory of mind’ as the “ability to act on the basis of the contents of the mind of another being,” (162). As he breaks down former experiments and evidence for theories, he ends up concluding that the amount of complex information needed to explain the happenings of the animals’ minds, in fact, takes away from the validity of the arguments proposed by supporters of attributing TOM to animals. In Wynne’s words, “But so long as simpler explanations of an animal’s behavior are available, the jury must stay out…” (182).

Similar to the arguments brought forth by Povinelli and Vonk, and Wynne, in 1998 C.M. Heyes in her work “Theory of mind in non-human primates,” finds similar problems with the research undergone with primates to assess their cognitive capabilities. Like Wynne, she feels that some of the explanations presented for animals’ behavior are interpreting the behavior into something that it is not. In other words, she finds it important to only use mentalistic explanations in the face of evidence that clearly indicates that the response of the animal is beyond a simpler explanation (Heyes, 1998).

Although the requirements for experimental evidence made by Povinelli and Vonk, Wynne, and Heyes are seemingly appropriate, their reluctance to attribute TOM is unwarranted. They want assurance that animals are not acting on a mere behavioral code; however, a similar argument could be made regarding the attribution of TOM to humans. A theory of other minds is implemented in order to help explain behavior, and the reluctance to attribute TOM on the basis that animals act from a behavioral code would actually be further reason to look into what is prompting the animal to act in such a way.

F. Compositional language is not sufficient for having TOM
Autism is a disorder that has symptoms that fall on a spectrum from mild to severe. However, most cases usually “…are characterized by varying degrees of impairment in communication skills, social interactions, and restricted, repetitive and stereotyped patterns of behavior,” (NIMH, 2009). Autistic people, here on AS adult or AS child, are commonly said to not have a theory of other minds based on a series of experiments that should provide evidence of the absence of certain cognitive abilities. AS children are given a list of tasks to perform and each task tests a specific cognition. If they fail these tasks, they are said to not have TOM. Examples from the autistic spectrum show that having compositional language is not sufficient for having TOM. If compositional language is sufficient for having TOM then it follows that if there is compositional language then there is also TOM. If AS children have a compositional language but are said to not have TOM, then we can conclude that compositional language is not sufficient for having TOM.

Research compiled by Simon Baron-Cohen tested the ability of people with autism on various cognitive abilities and they are the following:

1. mental-physical distinction
2. understanding mental functions of the brain
3. appearance-reality distinction
4. first order false belief tests and second order false belief tests
5. “seeing leads to knowing”
6. deception
7. recognizing words that indicate a mental state and distinguishing them from other words
8. usage of mental states words in spontaneous speech
9. spontaneous pretend play
10. imagination
11. monitoring one’s own intentions
12. understanding causes of emotion
13. inferring from gaze direction when a person is thinking or what a person might want
14. understanding metaphor, sarcasm and irony/understanding in a context
15. correlation with real life situations

One test measured AS children ability to distinguish mental properties from physical properties. The test began by someone reading a story to both AS children and normal children. In the story, two characters talked about their experience with a dog; one of which had a mental experience with the dog, e.g. wishing for a dog, and the other character had a physical experience, e.g. holding the dog. Then the children were asked questions about the experiences of the characters (Baron-Cohen, 2000). For example, the children might be asked, “who can want to buy a dog tomorrow?” or “who can play fetch with the dog?” Clearly, the answer to the first question would be the character having the mental experience, e.g. wishing for a dog, and the answer to the second question would be the character that is having the physical experience, e.g. holding a dog. By the age of four, children without autism can successfully make the distinction between mental and physical whereas AS children cannot.
In addition to having difficulties distinguishing between mental and physical properties of experiences, AS children also cannot differentiate between mental and physical functions of the brain. The majority of normal functioning children age three to four know that the brain serves both mental and physical purposes. They know that things such as dreaming, wanting, thinking, etc. are considered mental functions. They can distinguish the mental functions from the physical ones such as moving or running. AS children, when asked to tell the two types apart cannot decipher the difference (Baron-Cohen, 2000) By virtue of their difficulty with this type of problem, they are also having a problem rooted in the failure to simulate. In this scenario, AS children are not able to put their mental states and physical states into words. They experience both, but when asked to distinguish they cannot represent the experience in their minds in order to attach a mental state or physical state word to it.

Another distinction that is crucial to independent survival is the ability to tell the difference between what is apparent versus what is real, or as Baron-Cohen calls it in his research, the “appearance-reality distinction”. The experiment performed was one in which children, with and without AS, were given an object that looks like something else and they were told to say what it actually is. In this particular instance, they were given a candle shaped as if it were an apple. When presented with the question of what the object was, children without autism would successfully say that the candle looked like an apple, but actually was not actually an apple. However, when AS children were asked the very same question, they would say that the candle shaped like an apple actually was an apple (Baron-Cohen, 2000). In this example, the children fail to have a sense of physical perspective. They cannot distinguish the apparent from what is real. For example, to look at a road continuing ahead gives the illusion that the outside lines of the road will converge, when they will actually remain parallel. Similar to this metaphor, AS children cannot decipher when something is apparent versus when it is real.

Another way that researchers have tested the cognitive faculties autistic spectrum disorders is by measuring how AS children detect first order false beliefs (Baron-Cohen, 2000). A first order false belief is when one agent, B, knows that another agent, M, holds a belief that is not true. These tests assessed the abilities of normal functioning children, and AS children to make a distinction between their own belief and someone else’s belief. One ways to examine their ability to recognize two persons’ differing beliefs is by looking at “Snow White”, a fairy tale, in which the characters hold differing beliefs from each other, and from the readers of the story. So, in “Snow White”, Snow White believes that the old woman she encounters is innocent, even though the reader knows that the old woman is actually the evil witch. Based on this experiment, children can be measured on their ability to discern a false belief. If a child can discern what the character thinks is true, versus what is actually true, then they have recognized a false belief. When AS children are reading or listening to this fairy tale, they say that Snow White thinks she is getting an apple from an old woman, but that they (the children) know that the old woman is actually the witch in disguise. On the other hand, when provided with the same story, AS children cannot recognize that Snow White is holding onto a false belief. When faced with the same question of the identity of the old woman, AS children will repeat what they know from the plot of the story. In other words, the would say that the old woman is just an old woman with an apple,
instead of recognizing what the plot tries to hint which is that the old woman is actually the evil witch in disguise (Baron-Cohen, 2000). The ability to detect when someone holds a false belief is crucial for knowing what action to take in light of the circumstances of a situation. Whether it is detecting a first order false belief or a second order false belief, both require the ability to have mental perspective. To have mental perspective is to be able to recognize the difference between what I know and what another person B knows.

The communicative device of knowing who knows/does not know something in order to determine the appropriateness of informing someone of something ($p$) is what Baron-Cohen calls “seeing leads to knowing.” AS children and normal functioning children are different in the way they understand where knowledge comes from and their ability to extract from this knowledge who knows $p$ and who does not know $p$. The experiments designed to measure this ability revealed that some AS children did not understand this concept (Baron-Cohen, 2000). As humans, we try to inform people of what they do not know rather than telling them what they already know. Also, we may say things we know as a realization when we find out something for the first time. This ability is a prerequisite for deception. In other words, I know $p$ and I know that B does not know $p$ (Baron-Cohen, 2000).

The ability to deceive people is practiced by children of four. Again, deception requires understanding of other minds because I know $p$ and I know that B does not know $p$. So, I know that I can tell B $p$ even if it is false. AS children usually cannot deceive someone else, nor can they detect when they have been deceived. One game Baron-Cohen used to test how AS children deceive was to engage in a game where an AS child had to hide a penny in one hand and not tell the other person which hand it was in. Instead of allowing the other person to guess randomly, the AS child would keep the hand closed that held the penny, but they would open the empty hand, so as to give away which hand the penny was in by the disjunctive property. Some other things they would do would be hiding it but then hint to the person where the penny was hidden (Baron-Cohen, 2000).

AS children cannot recognize words indicating a mental state such as “think,” “dream,” and “desire,” and they cannot recognize them as different than words indicating a physical state (Baron-Cohen, 2000). Baron-Cohen holds this to be indicative of a narrow mental vocabulary, although it also shows that AS children lack a sense of familiarity or recognition of recurrent mental state words.

When measuring how often AS children “make-believe” or pretend play, Baron-Cohen found that they engage in doing so far less than other children (Baron-Cohen, 2000). He attributes it to potential problems with imagination or attention, but it could also be attributed to an inability to imitate. For example, if I want to pretend that I am drinking tea, I cannot do so without having seen someone else drink tea. I cannot imitate $x$, so I cannot pretend that I am doing $x$.

If it is a problem with imaginative faculties, it could be due, again, to a problem of simulation. Moreover, to imagine an idea, I need to represent something that I have not seen previously in my mind. In the Baron-Cohen experiments, imagination was measured by asking AS children to draw things that do not exist and found that they hesitated to do so or had less success when they did try (Baron-Cohen, 2000).
The ability to *monitor one’s own intentions* was demonstrated to be deficient in AS children by asking them to do an activity in which the outcome was manipulated. For instance, they were asked to aim for a specific target, but an experimenter manipulated the outcome. As a result, their intention, even if they correctly aimed, did not necessarily align with the actual outcome. Most children, without autism, would answer that they meant to hit a specific target, even if they actually did not, whereas an AS child would state that his/her intended target was the target that was actually hit, even if the experimenter manipulated it (Baron-Cohen, 2000). Monitoring one’s own perspective is also part of having correct mental and physical perspective; I need to know the difference between what I think/meant to do and what actually happened.

Understanding what *causes emotions* emerges in children around the ages of four to six years old. AS children typically have difficulty understanding the mental causes of emotion (Baron-Cohen, 2000). For example, I can be sad because I thought of something that I do not want to happen, and it would be a mental cause for sadness. The inability to understand a mental cause of emotion can be attributed to a difficulty to recognize familiar feelings or emotional states.

Humans gather large amounts of information from others’ body language. Within the autistic spectrum, Baron-Cohen finds that AS children and adults cannot gather information from *eye gaze* specifically. Eye gaze can indicate how much information a person has from where they were looking and provides the ability for another person to make an inference about information obtained based on the direction of someone’s gaze. A deficiency of such an ability would make an AS person unable to have perspective of information (Baron-Cohen, 2000).

Other experiments involving language and figurative speech showed that AS children had much less success than other children in understanding *pragmatic* elements of conversation, i.e. understanding in a context including understanding metaphor, sarcasm, and irony (Baron-Cohen, 2000).

Since the absence of these cognitive abilities renders AS children and adults as agents without TOM, each ability must be constitutive of having TOM. From this research, I have composed a list of components, both declarative and procedural, in which each is a component of TOM. They are as follows:

1. imitation
2. simulation
3. familiarity
4. the ability to read body language
5. having perspective—physical, mental, and informational
6. deception

It is possible to use this list in order to see if agents without compositional language, animals, show evidence of the constituents of TOM. If the animals, non-compositional language users, show evidence of the cognitive abilities lacking in people with Autism, then we can conclude that compositional language is not necessary for having TOM. In order to make the examples more vivid, I have restricted my research to examples of those animals in
the wild or under experimental conditions in which they were not taught any prerequisite abilities.

**G. Compositional language is not necessary for having TOM**

A study performed with the racket-tailed drongo species of bird revealed evidence of imitation of another in order to strengthen one’s own success. In this observation, it was noted that racket-tailed drongos, when flying in a mixed species flock, would actually imitate the call of a different species within the flock. By attracting members of a different species, in addition to their own, they manage to increase the success of their foraging skills. So, the drongos used imitation for their individual purposes. In fact, when the researchers tested how appealing the calls were in a playback experiment, the calls with imitation were more attractive to the other species (Goodale, Kotagama 2006).

New Caledonian crows were the subjects of a study to discover if crows could do something “useful” by Joshua Klein. As it turned out, one of the crows named Betty, was able to solve a problem by simulating the solution. Betty needed to get a piece of food out of a long tube but she was only given a straight wire. After several attempts, Betty took the straight wire and fashioned it into a hook so that she was able to hook the food in the bottom of the tube. Betty successfully represented what she could do with her only tool, in other words she simulated a solution, in order to obtain the food (TED.com).

Pigs and sows also display components of TOM. In this case specifically, they show evidence of familiarity in social situations. In an experiment discussed in an article by Moore et al. three experimental groups were placed in a pen together for about two weeks. Then, the experimenters introduced ten new sows to each group of thirty pigs. They observed behaviors of the sows and pigs and noticed at a certain point in time that approximately 80 percent of newly introduced members were resting together in the same place while only about ten percent were resting in that same area. At 21 days of being together, with both old members and new, the animals were finally integrated randomly amongst each other (Moore et al. 1993). This shows that the sows and pigs had an awareness of what was familiar and what was not, and also, tended to prefer the familiar to the unfamiliar until better accustomed to the new environment.

A study done with chimpanzees shows that they are able to recognize familiarity and to read body language. Seven chimpanzees were placed in a situation with both unfamiliar and familiar people. The experiment was based on the observation of the unfamiliar people by the chimpanzees to assess if there is a change in behavior towards the unfamiliar people. The unfamiliar people either gave a treat consistently to other chimps or people with whom the seven chimpanzees were familiar, or consistently did not give to other chimps or familiar people. The author notes that the chimpanzees were not typically in favor of begging for food from strangers. Taking this into account, the results are even more remarkable. Despite their aversion to begging for food, the chimps eventually began to gesture to the unfamiliar people who they had observed to consistently give to their peers, and avoided those who consistently withheld the treats. In the next phase of the experiment, new unfamiliar people were brought in who continued to either give or withhold. From the chimps experience with other
unfamiliar people, the chimps took much less time in deciding whether to gesture and to whom. Upon first observation of a giving unfamiliar, chimps gestured to the person as soon as available (Subiaul, 2008).

David A. Leavens worked with orangutans and demonstrated orangutan’s ability to modify communicative techniques based on how well they make a point and obtain the proper response. The orangutans in this experiment adjusted their communication based on “who knows what” and who does not. This is similar to the “seeing leads to knowing” principle of autistic deficiencies and, thus, a prerequisite for deception. A caretaker with food and the orangutan need to interact successfully in order for the orangutan to receive the food. The experiment reveals the various ways that orangutans are able to adjust their communication in accordance with what the caretaker gives, or fails to give, to the orangutan. In this experiment, if the caretaker was not looking at the orangutan, the orangutan would use auditory or tactile forms of communication. On the contrary, if the caregiver was looking at him/her, the orangutan would use visual means. Additionally, orangutans were able to repair “communicative episodes.” For example, they would stop communicating totally if the experimenter delivered food they requested. However, if they were not given the correct food, they communicated persistently until they received it. Part of the experiment examined the relation between orangutans and their human caretakers, but it also studied communicative relations within the species. In this case, the orangutans altered their methods depending on how well they were understood by the other. Specifically, when they were partially understood, they persisted by repeating similar signals. Alternatively, when they were misunderstood entirely, they changed their methods by introducing new signals with hopes of making the exchange successful (Leavens, 2007).

Cuttlefish have a curious way of deceiving the very ones with whom they desire intimacy. Australia is home to the Giant Cuttlefish, but although the name may be misleading, not all of the cuttlefish in Australia live up to their title. Often times, the smaller males fall by the wayside when it comes to finding a female cuttlefish during the mating season. By size, the smaller cuttlefish do not have much of a chance of winning a female’s attention. Consequently, they have adopted a strategy that helps to fool the females into selecting them as a mate. Due to the shifting nature of the cuttlefish’s skin, they are very capable of blending in with an array of environments. Additionally, then can use this same skin shifting ability to change their skin to mimic that of a female cuttlefish. When they do this, they can swim alongside a female, getting her to think that he is actually a female and then successfully mate with her. In fact, the females have begun to actually select the male cuttlefish in disguise at a higher rate than that of selecting a larger, undisguised male (Sciencentral, 2009).

An example of deception can be seen when observing one species of jumping spider, Portia. This example is based on the behavior of Portia when stalking prey in the wild. In order to capture her prey, she performs a series of tricks to deceive before the attack. First, she plucks at her own web to simulate a wounded insect that is struggling to get out of the web. When this attempt fails to create notice, Portia creates “a kaleidoscope” of other methods to try to get the attention of the prey (Jackson and Wilcox, 2002). One of the signals achieves success and the prey moves closer to her. Noting the advance, Portia repeats the
signal and the prey continues to advance. When the wind blows, she uses it to her advantage to get closer to her prey. She moves towards the prey and actually takes a longer route in order to strike from an unexpected direction (Jackson and Wilcox, 2002).

H. Conclusion

From this research, we can generate the conclusion that TOM attributions do not necessitate language. If provided with the opportunity for further studies within this field, I would like to consider some suggestions for more effectively studying TOM. TOM does not have to be an “all or nothing” argument. Whereas multiple cognitions can comprise TOM, it is possible to have partial attribution of TOM. It is possible for a non-compositional language user to have TOM without having a complete set of components. They may have a disjunctive subset of necessary components that together, function as one sufficient condition for having TOM. And finally, attribution may not be psychological, but rather, functional. We can distinguish TOM from f(TOM), where TOM refers to the ability to read and attribute mental states to oneself and others, f(TOM) refers to the process by which agents function as though they do have a ‘theory of other minds’ and act as though they are goal-oriented. In this case, TOM is adaptive for the agent making attribution. In my future endeavors within this field of study, I will intently consider these suggestions in hopes of refining how we attribute TOM to cognitive agents.

References


1. Introduction

In the 1956 film *Le Mystère Picasso (The Mystery of Picasso)*, Pablo Picasso completes twelve paintings. Due to specific camera angles and special transparent paper, the viewer only sees the appearance of marks; she only hears the hush of brush strokes, the mutters of the artist, and the brief interludes of instrumental music. After the film’s taping, the twelve paintings are destroyed.

Picasso’s process, or the processes of any great master, is so rarely exposed that the viewer becomes acutely aware of the thoughts that must occur during the creation of his piece. The final product therefore acquires much more meaning. Not only does the work exist as a completed piece, but also it exists as a series of additions and subtractions, decisions and changes-of-mind, continuations and reversals. The artist’s choices are mysterious. The viewer cannot help but wonder why the master knew to put that stroke in that particular place, with that specific color, at that chosen time.

The cognitive processes in design thinking are complex. It is exciting and important to learn about these cognitive actions; great works of creativity have not only caused great awe and amazement in human civilization, but more simply hold the secret to how we see, move through, create, and relate to our visual, spatial, and temporal world.

Because of the complexity of processes in design cognition, it is necessary first to delineate the categories of cognitive action, and second to create a general taxonomy by which they can be classified. These tasks become even more challenging considering that a large part of design cognition is visual, not verbal. Though a designer can explicitly learn basic skills through either verbal instruction or physical practice, novel design creations may come from an implicit reorganization or “riffing” off of prior verbal or spatial learning. It can be difficult for even the most advanced designers to explain their thought process behind each decision (Suwa, Purcell, and Gero 1998). It is the quiet mystery of the creative process that presents both the challenge and also the interest in decoding design thinking.

Sketching, either with traditional materials or with computer aided design programs, offers a window into the cognitive process of design. Sketches serve not only as a record of an idea, but also as a hotbed of visual cues from which new ideas can be generated (Schon 1983). Designers are thus thought to have a dynamic relationship with their sketches, where
each physical/perceived aspect suggests a move or alteration for the next sketch. Further, a mark’s function and meaning can both initiate a design move, and also adapt in response to an already established design move (Goldschmidt 1994).

Two overlying principles define the dynamic process of design. Emergence, or unexpected discovery refers to the creation of unanticipated, new ideas in response to visual cues from an existing sketch. Reinterpretation refers to the transformation and adaptation of previous ideas, already expressed in the original sketch (Menezes and Lawson 2006). These two principals are based on cognitive actions of different categories, that is, they are responses to different kinds\(^1\) of visual cues in the sketch. The relationship among these different types of cognitive actions, and their persistence through the duration of the sketch, can be mapped to form a holistic description of the design process.

In the first section of the paper, I will outline the schema of design cognition presented by Suwa, Purcell, and Gero 1998. In response, I will present possible limitations to their model, which I find makes it ultimately insufficient for explaining both top-down and also bottom-up influences on design decisions. In conducting my analysis, I will appeal to research comparing traditional versus digital design methods. Finally, I will evaluate the effectiveness of some current digital design programs to complement the cognitive design processes outlined in my research.

2. A Schema for Cognitive Action in Design

I have already made one important distinction between emergence and reinterpretation in dynamic manipulation of ideas in sketching. Though important, this distinction is rather superficial considering the numerous and varied cognitive actions that contribute to the generation or refinement of an idea.

Several attempts have been made to devise a more informative, general taxonomy for design analysis. One approach divides design into process and content. Process includes problem solving, planning, determining goals, and strategizing. Content refers to what designers see, think about, and depict (Dorst and Dijkhuis 1995).

Another approach attempts to address the difference between visual and non-visual information in designs. The visual elements are the “what” and “where” qualities of each mark, and the relationships of these qualities to one another. Non-visual elements are the knowledge about and the functionality of the design (Suwa and Tversky 1996). The advantage of a visual/non-visual distinction is that it not only explores different types of elements in a sketch, but also examines possible dependencies among them. For example, an architect recognizes that the shape and size of one of the depicted features (a visual element) in a sketch would create a functional response in the movement of crowds through the space (a non-visual element). Though this form/function connection may seem simple, the addition of even more types or kinds of classifications, and a webbing of these classifications, permits an intricate map of cognitive actions in design (Suwa, Purcell, and Gero 1998).

\(^1\) Kinds of visual cues will be detailed and explained later in the paper.
Suwa, Purcell, and Gero 1998 provide multifarious and specific categories for the cognitive processes of design thinking. With these classifications, they are able to both elucidate the relationships among them, and also delineate the origin of emergent and reinterpretive ideas in sketching. The coding scheme is based on four central practices: first, the distinction between visual and non-visual elements (an extension of what was presented above), second, the level of information processing required for each cognitive action, third, a theory of cognitive actions employed in environmental assessment\(^2\), and fourth, their intense video and audio observation of working designers, specifically, architects (Suwa, Purcell, and Gero 1998).

**Segmentation** is the process by which each design move is identified as an individual action. Demarcating individual actions permits a further dimension of analysis, time, which can expand on the dependencies and relationships among different kinds of cognitive actions.

Suwa, Purcell, and Gero 1998 have defined four categories, or *kinds* of cognitive actions: *physical*, *perceptual*, *functional*, and *conceptual*. These categories reflect not only what is visual versus what is non-visual, but also what they hypothesize to be a hierarchy in information processing. They assume that information entering the human cognitive apparatus is first appreciated by the material senses (*physically*), then perceptually (*visually*), then semantically (*functionally* and *conceptually*, i.e. non-visually). The hope is not only that these different categories of design processes occur in a hierarchical order, but also that the higher-level actions are dependent on the lower level actions.\(^3\) That way, the schema is designed to code both the actions themselves, and also the relationships among them (Suwa, Purcell, and Gero 1998).

The lowest-level cognitive actions are *physical*. These actions include marking, writing, or depicting, motioning with a hand or pencil, and looking at existing depictions. The **perceptual** category refers to the visuo-spatial cues outlined in the sketches: shape, size, and texture, spacial elements among parts: proximity, intersection, and arrangement, and composition of elements: grouping and uniformity. **Functional** considerations refer to a non-visual conception of information stemming from the depicted visuo-spatial information. Functional elements include first the behavioral effect of the depicted elements on people and the natural surrounding, and second the psychological and psychophysical effect of the depicted elements on the people who move through the outlined space (Suwa, Purcell, and Gero 1998). The idea of functional kinds originated from previous research in environmental assessment, and its affect on human psychology (Gero and Sudweeks 1994; Altman and Wohlwill 1983; Garling and Evans 1999; Suwa and Tversky 1997). In designing a successful space, functional elements cannot be ignored or underappreciated.

Finally, **conceptual** elements refer not to visual or spatial elements, but rather to the designers’ aesthetic preference, or subjective evaluation of success or failure of a certain design move. Often conceptual elements occur in response to a collection of different elements of the previous categories. However, conceptual action also refers to the initial goals of the design. Finally, conceptual elements reflect the designer’s ability to discover

---

\(^2\) A more detailed description of “environmental assessment” will follow.

\(^3\) Though these assumptions are necessary for the Suwa et. al. schema, I will later describe how they limit the scope and applicability of this model.
new information from existing information, and to break down existing information or goals into sub goals (Suwa, Purcell, and Gero 1998). **Table 1** outlines the four different categories of cognitive actions, and describes their defining qualities.

<table>
<thead>
<tr>
<th>Category</th>
<th>Names</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>D-action</td>
<td>Make depictions</td>
<td>Lines, circles, arrows, words</td>
</tr>
<tr>
<td></td>
<td>L-action</td>
<td>Look at previous depictions</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>M-action</td>
<td>Other physical actions</td>
<td>Move a pen, move elements, gesture</td>
</tr>
<tr>
<td>Perceptual</td>
<td>P-action</td>
<td>Attend to visual features of elements</td>
<td>Shapes, sizes, textures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attend to spatial relations among elements</td>
<td>Proximity, alignment, intersection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organise or compare elements</td>
<td>Grouping, similarity, contrast</td>
</tr>
<tr>
<td>Functional</td>
<td>F-action</td>
<td>Explore the issues of interactions between artefacts and people/nature</td>
<td>Functions, circulation of people, views, lighting conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consider psychological reactions of people</td>
<td>Fascination, motivation, cheerfulness</td>
</tr>
<tr>
<td>Conceptual</td>
<td>E-action</td>
<td>Make preferential and aesthetic evaluations</td>
<td>Like-dislike, good-bad, beautiful-ugly</td>
</tr>
<tr>
<td></td>
<td>G-action</td>
<td>Set up goals</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>K-action</td>
<td>Retrieve knowledge</td>
<td>–</td>
</tr>
</tbody>
</table>

(Suwa, Purcell, and Gero 1998)

The second aspect of this schema that requires a detailed description is the relationship between these four descriptive categories and their persistence through the duration of the sketch. **Longevity** refers to the creation and sustainment of an idea within the framework of emergence and reinterpretation principles. The step in the design process during which the idea is first discovered, or during which it is revisited, determines its temporal status. The longevity category, or **index**, is classified as **new**, **continual**, or **revisited**. If a designer performs an action in one of the four cognitive categories for the first time, then this action is classified as **new**. If a cognitive action is continued from the segment immediately preceding the current segment, this action is classified as **continual**. Finally, if the designer returns to an idea generated in a previous, but not contiguous segment, then this action is considered **revisited** (Suwa, Purcell, and Gero 1998). **Table 2**, **Table 3**, and **Table 4** outline the previously described categories with the added index variable.
<table>
<thead>
<tr>
<th>Action ID</th>
<th>Definition</th>
<th>Name/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_{rr}</td>
<td>D-action n</td>
<td>c or r L-action</td>
</tr>
<tr>
<td>D_{rc}</td>
<td>D-action n</td>
<td>Nil</td>
</tr>
<tr>
<td>D_{rc}</td>
<td>D-action r or c</td>
<td>Nil</td>
</tr>
<tr>
<td>D_{rd}</td>
<td>D-action r or c</td>
<td>c or r L-action</td>
</tr>
<tr>
<td>D_{sy}</td>
<td>D-action n</td>
<td>n, c or r P-action</td>
</tr>
<tr>
<td>D_{so}</td>
<td>D-action n</td>
<td>n, c or r (F- or P-) action</td>
</tr>
<tr>
<td>L_{.}</td>
<td>L-action r or c</td>
<td>Nil</td>
</tr>
<tr>
<td>M_{sl}</td>
<td>M-action n</td>
<td>n, c or r P-action</td>
</tr>
<tr>
<td>M_{sd}</td>
<td>M-action n</td>
<td>c or r L-action</td>
</tr>
<tr>
<td>M_{s}</td>
<td>M-action n, c or r</td>
<td>c or r L-action</td>
</tr>
<tr>
<td>M_{st}</td>
<td>Impossible to define by our coding scheme</td>
<td>Use tools</td>
</tr>
<tr>
<td>M_{gc}</td>
<td>Impossible to define by our coding scheme</td>
<td>Hand gestures</td>
</tr>
</tbody>
</table>

(Suwa, Purcell, and Gero 1998)
<table>
<thead>
<tr>
<th>Action ID</th>
<th>Category</th>
<th>Definition</th>
<th>Name/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{sg} )</td>
<td>P-action</td>
<td>n</td>
<td>Nil</td>
</tr>
<tr>
<td>( P_{ln} )</td>
<td>P-action</td>
<td>n</td>
<td>n D-action</td>
</tr>
<tr>
<td>( P_{imp} )</td>
<td>P-action</td>
<td>n</td>
<td>n P-action</td>
</tr>
<tr>
<td>( P_{lp} )</td>
<td>P-action</td>
<td>n</td>
<td>c or r (L- or D- or P-) action</td>
</tr>
<tr>
<td>( P_{rp} )</td>
<td>P-action</td>
<td>n</td>
<td>Two c or r (L- or D- or P-) action</td>
</tr>
<tr>
<td>( P_{exp} )</td>
<td>P-action</td>
<td>n</td>
<td>n (D- or P-) action and c or r (L- or D- or P-) actions</td>
</tr>
<tr>
<td>( P_{rn} )</td>
<td>P-action</td>
<td>n</td>
<td>Two n (D- or P-) actions</td>
</tr>
<tr>
<td>( P_{cf} )</td>
<td>P-action</td>
<td>c</td>
<td>c (L- or D- or P-) action</td>
</tr>
<tr>
<td>( P_{cr} )</td>
<td>P-action</td>
<td>c</td>
<td>Two c (L- or D- or P-) actions</td>
</tr>
<tr>
<td>( P_{esg} )</td>
<td>P-action</td>
<td>c</td>
<td>Nil</td>
</tr>
<tr>
<td>( P_{sf} )</td>
<td>P-action</td>
<td>r</td>
<td>c or r (L- or D- or P-) action</td>
</tr>
<tr>
<td>( P_{sr} )</td>
<td>P-action</td>
<td>r</td>
<td>Two c or r (L- or D- or P-) actions</td>
</tr>
<tr>
<td>( P_{esg} )</td>
<td>P-action</td>
<td>r</td>
<td>Nil</td>
</tr>
<tr>
<td>( P_{pgr} )</td>
<td>P-action</td>
<td>r</td>
<td>n (D- or P-) action and c or r (L- or D- or P-) action</td>
</tr>
</tbody>
</table>

n, c and r denote ‘new’, ‘continual’ and ‘revisited’ respectively.

(Suwa, Purcell, and Gero 1998)
3. Pros and Cons of the Suwa, Purcell, and Gero 1998 Schema

The first advantage of the Suwa et. al. system is that it successfully creates a generalized vocabulary by which to define primary, singular design actions. The generalized vocabulary allows for a structured, hierarchical diagram of design thinking, which informs three important questions: which primitive design actions play an integral role in design thinking, how do they play this role, and what is the origin of generated ideas (Suwa, Purcell, and Gero 1998)? Examining the relationships among the elements in the diagrams, their dependencies, their hierarchies, and their feedback is not only important for understanding the complex cognitive functions of design, but also is important for the possibility of extending their influence to other cognitive processes.

Though the coding system proposed by Suwa, Purcell, and Gero 1998 has definite analytical applicability, it also has some problems. Their method bases the four-category breakdown on supposed information processing demands (Suwa, Purcell, and Gero 1998). Not only can these information processing demands be uncertain, but also their connection to higher and lower cognitive “levels” is unreliable and undefined. A one-to-one

<table>
<thead>
<tr>
<th>Action ID</th>
<th>Definition</th>
<th>Name/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_{np}</td>
<td>F-action</td>
<td>Think of a function independently of depictions</td>
</tr>
<tr>
<td>F_{n}</td>
<td>F-action</td>
<td>Associate a new depiction, feature or relation with a new function</td>
</tr>
<tr>
<td>F_{n-1}</td>
<td>F-action</td>
<td>Re-interpretation</td>
</tr>
<tr>
<td>F_{sp}</td>
<td>F-action</td>
<td>Continually think of a function independently of depictions</td>
</tr>
<tr>
<td>F_{c}</td>
<td>F-action</td>
<td>Continually think of a function</td>
</tr>
<tr>
<td>F_{r}</td>
<td>F-action</td>
<td>Remember a function</td>
</tr>
<tr>
<td>F_{pr}</td>
<td>F-action</td>
<td>Remember a function independently of depictions</td>
</tr>
<tr>
<td>F_{i}</td>
<td>F-action</td>
<td>Implement a previously explored function by creating a new depiction, feature or relation</td>
</tr>
</tbody>
</table>

n, c and r denote ‘new’, ‘continual’ and ‘revisited’ respectively

(Suwa, Purcell, and Gero 1998)
correspondence between information processing levels may be too simple, especially considering the possibility that feedback between categories can happen implicitly, before the cognitive action is expressed (Hawkins 2004). Though this method strives to create an informative webbing of the connections among four levels of cognitive action, it fails to address the possibility that implicit feedback, especially from higher-order, goal-directed areas of the brain, might alter the explicitly expressed chain downwards.

Despite their under-emphasis on feedback from higher-level design cognition, the Suwa, Purcell, and Gero 1998 method does purport to show some validity directly within their classification system. That is, though their theory cannot be globally applicable to design thinking because of their failure to outline both directions of influence, the Suwa, Purcell, and Gero model offers some important information about the cognitive actions that are outlined in the schema. Their schema is robust enough to ask: do particular kinds of cognitive acts dominate in the design process, and do actions in a certain cognitive level tend to correlate with actions belonging to another level (Suwa, Purcell, and Gero 1998)? This second question especially, could expose where some of these implicit feedback connections would occur if they somehow became measurable.

Though Suwa, Purcell, and Gero do admit that their schema requires a mostly bottom-up interpretation of the cognitive actions in design, they offer no implications of this limitation to the applicability of their model. Consider for example that an architect draws an arc in her sketch. The cognitive arrow could go one of two ways: (i) the arc was drawn for no specific reason and with no explicit goal in mind. After drawing it, the architect decided that this shape would allow for a proper view and flow for its visitors through the depicted space. Or, (ii) the architect had in mind the goal of both creating a pleasant view and also allowing reasonable room for crowds. Some previous knowledge about arcs in space informed her drawing an arc into the design (Suwa, Purcell, and Gero 1998). Because a simple verbal or observational evaluation from a designer or sketch may not resolve the direction of thought processes in creating this arc, Suwa, Purcell, and Gero 1998 have decided to focus on the bottom-up method, or the (i) analysis, where physical and then perceptual phenomena inform higher cognitive function. Though this restriction makes sense within the structure of their code, and the code’s focus on information processing as a measure of cognitive demand, it similarly ignores a top-down, or feedback hypothesis, which is undeniably present in educated design scenarios.

Again, if one adopts this bottom-up schema however, Suwa, Purcell, and Gero 1998 are able to determine some important connections and dependencies among their categories. First, if one recalls, the different categories become associated with a timeline over which the design is created and refined (segmentation). The first temporal phase of the design process involves problem analysis, the second consists of spatial arrangement, and the third requires functional exploration. Each of these phases is established by the frequency of certain categories of cognitive design action. Functional actions cluster in the functional exploration stage, and physical actions dominate the problem analysis phase (Suwa, Purcell, and Gero 1998).

Suwa, Purcell, and Gero 1998 also examine how the usage frequency of these four cognitive categories varies with reference to one another. One finding is that when drawing
is frequent \((physical)\), then looking at existing drawings \((perceptual)\) becomes less frequent and vice versa. They also found that the visuo-spatial material perceptible in sketches act as cues for functional associations (Suwa, Purcell, and Gero 1998). See Figure 1a and Figure 1b for an example of these complete coding webs, which do include some top-down processes.

**Figure 1**

![Diagram](image)

This last point, that visuo-spatial cues in sketching can elicit functional ideas and interpretations, is evidence for the idea of dynamic design. To recapitulate from above, the hypothesis behind a dynamic design processes states that information in sketches act both as a recording for ideas, and also as a treasure trove of visual cues that effect new goals, conceptions, and directions for future iterations of sketch. Therefore, both initial goals and knowledge drive a designer in a top-down fashion, and also perceptual features of the drawing itself, and the physical drawing process, contribute in a bottom-up fashion to the development of a design. Suwa, Purcell, and Gero 1998 summarize their conclusions about the role of sketches in design cognition: “sketches serve as a physical setting in which design thoughts are constructed on the fly in a situated way (Suwa, Purcell, and Gero 1998).”
4. Differences in Design Cognition for Traditional versus Computer Aided Design

Examination of the cognitive actions of design sketching has shown that sketches are an important setting for the creative process. Designers like architects for example, have many materials available with which to make or aid in sketching. The abundance of computer aided design (CAD) programs has lured some designers away from traditional materials; it is becoming increasingly necessary that all designers have some familiarity with digital design tools. Though both traditional materials and CAD are valid methods for creating visual sketches, many designers find themselves feeling more comfortable, preferring, and advancing their skill-set in only one. The questions surface: which tool encourages the kinds of cognitive actions during sketching that allow for the most creativity and development in the sketch/design process, and how might these tools be improved or combined to maximize the design process?

A paper by Bilda and Demirkan 2002 examines these two questions using a coding scheme very similar to the one outlined above. Their results show that traditional media have advantages over digital media regarding attention to, and reaction to visuo-spatial cues, specifically the relationship between elements in the design, and the quantity and variety in problem solving methods to address the design goals. CAD tools do offer the unique capability of modifying parts within a sketch without having to make an entirely new iteration. CAD also more seamlessly supports the development of the conceptual phase of the design process (Bilda and Demirkan 2002), as technical drawing skills are less of an obstacle when drawing aids are provided by the software.

The Bilda and Demirkan 2002 paper evaluates the number and kinds of cognitive action in each of three testing stages. One group undertakes a design challenge through traditional, then digital, then traditional methods (HAND-CAD-HAND), and the other group approaches the design problem CAD-HAND-CAD. Evaluating the segmentation and types of cognitive action in each of these phases yields the results summarized above. In addition, the research shows some evidence about sketching media in general that may in itself effect the differences in cognitive action. For example, whereas traditional media promotes the physical description of form in the sketch, digital media promotes its conception in the mind (Marx 2000). The detailed, intense, and rapid visualization of forms in digital media encourages more imagination of form rather than physical depiction of form; therefore, the next iteration/alteration more likely occurs in the designer’s head rather than on paper (Won 2001). This internal cognitive manipulation offers an explanation for the greater number of cognitive actions observed in the traditional media verses the digital media. 

There are several other notable aspects of digital design programs that may prove significant in their contribution to the overall design process. Because CAD encourages rich visual imagery, digital design tools are more time consuming; designers become bogged

---

4 Once again, this schema tests explicit cognitive action. If the digital media encourages more implicit actions, then fewer recorded actions may not be due to fewer cognitive actions in digital sketching en masse, but rather fewer that are sensitive to this particular evaluative tool.
down by the details of the visual stimuli in the sketch. However, when designers actively sketch in CAD, they rarely use these details as visual cues from which to exercise their conversation with the sketch (Bilda and Demirkan 2002). CAD software is also non-responsive to many physical acts of design, including arm movements, gestures, doodling, and physically copying. Copying proves a particularly important act in sketching because it usually precedes a reinterpreative process (Bilda and Demirkan 2002).

One important design action that is highly prevalent in the use of digital media is the modification of existing forms (Bilda and Demirkan 2002). Instead of physical actions of copying and gesticulating, the digital environment offers the ease of slight modification and movement of forms.

One must consider the advantages and disadvantages of each method when attempting to combine them to maximize design processes. Suwa, Purcell, and Gero 1998 and also Bilda and Demirkan 2002 highlight the abundance and importance of physical action in the beginning stages of the design process. Here, the weight of the pencil, the physical act of copying, and the outline of a rough relationship among forms is most important. Appealing to the bottom-up design process outlined by Suwa, Purcell, and Gero 1998, perceptual features are only afterwards appreciated and evaluated for their functional value.

It seems that CAD software would maximally contribute to the latter parts of the design stages: adding to the concept and goal of the design, and permitting the small modification of highly detailed graphics. After the initial stages of design, the explicit, physical design process has already been completed, and the more implicit, knowledge-based, and visualization advantages of CAD can start to contribute to the development of the design concept. In terms of the explicit/physical versus implicit/visualization capabilities in traditional and digital media, designers may derive their comfort and preference for either tool from their comfort with either of these problem-solving methods.

5. Evaluating Current Digital Design Tools and Software

Bilda and Demirkan 2002 suggest one method to encourage the physical cognitive actions in digital design by structuring software so that it mimics some of the more important aspects of design in traditional materials. For example, the act of copying could be simulated by introducing a transparent layer (Bilda and Demirkan 2002) to a current sketch that would either mechanically copy an area of the sketch, or allow the designer to trace certain parts of the sketch.

Though some attention can be given to making functions within digital design packages more like traditional design materials, it may be more beneficial to improve the transition from beginning stages in traditional design, to finishing and refining stages in digital design. Digital design has definite advantages in later stages, but the time and effort to translate or recreate the analogue sketch in digital media is not only difficult, but also time consuming. Without a proper translational tool, the creative and design progress in the traditional media may be lost. Because of these translation issues, designing both outside and inside CAD may seem redundant, or disconnected.
Many digital design programs are working to improve this translation process so that the work outside of the computer does not go to waste, and is seamlessly transitioned into CAD software. This way, there is no overlap, loss of design creativity, cognition, or information, and there is no gain of computer artifact in the design. Rather, the digital software performs maximally: allowing for small manipulations, holistic visualizations, simulation, representation of finer detail, and more universal communication of design concept through a rendered, realistic model.

Research has been devoted to creating effective translation tools that use mathematical algorithms to turn two-dimensional sketches into three-dimensional models in CAD software. As mentioned above, drawn sketches offer an ambiguity that aids in the physical and perceptual actions of dynamic design. However, current design software demands a high level of precision, and a lack of ambiguity. Put differently, “The acronym CAD evokes a common imagery of grid snaps, tight tolerances, and exactitude, and these inflexible constraints can severely inhibit the freedom and abstraction necessary for exploratory design (Schweikardt and Gross 2000).” The benefits of a more pictorially ambiguous beginning, combined with the need for a better translation between analogue and digital sketching, has fostered a new kind of CAD software.

One program, called Digital Clay is intended to interpret hand-drawn sketches as three-dimensional digital models (Schweikardt and Gross 2000). Programs like Digital Clay involve digital design elements, and computer-based sketch recognition software. The translation is outlined simply: (i) designers sketch with traditional media, (ii) the drawing is latched and rectified, (iii) the boundaries and vertices are labeled, (iv) three-dimensional coordinates are assigned, (v) the model is displayed in Virtual Modeling Reality Language (VMLR), (vi) the translated model is ready for further digital manipulation (Schweikardt and Gross 2000). With these six steps, Digital Clay attempts to mimic free sketching in traditional media, and translate the sketch into a highly revisable digital environment.

Another type of digital design program does not translate analogue sketches into a digital environment, but aims to use certain techniques of analogue sketching in a digital setting. With this method, no translation is needed. Again, the more important aspects of early sketches are the ambiguity of forms, and the physical act of depicting them. FiberMesh incorporates several key components of analogue sketching in a digital setting including a highly sensitive control function, the ability to iteratively refine the design, and the reuse of existing parts in a design. FiberMesh also attempts to mimic analogue sketching through its reliance on drawn curves to define and characterize surfaces and objects. The advantage of the highly sensitive control function is that it, like a pencil, is interactive and smoothly responsive (Nealen, Igarashi, Sorkine, and Alexa 2007). The next iteration of such a program should consider the weight, and repetition of the line, and the direction in which the curves are drawn.

6. Design Cognition Contributes to the Larger Framework of Understanding Cognition

---

5 “Latched” refers to the closing and connecting of lines in a drawing. “Rectified” refers to the straightening of lines in a drawing.
In design, sensory or physical information enters the human perceptual system and filters through levels of analysis defining individual characteristics, perceptual qualities, functional qualities, and conceptual qualities. Yet, there must also be a downward stream of associations flowing from a more holistic understanding of the principles of design. That is, there must be some benefit, or at least some effect, of learning about design to make “better,” undoubtedly more top-down decisions in the creative process. For example, recognition of certain sequences and tendencies in a design with reference to learned theories about what makes a good design, draws attention to certain depictions in that design, and may influence design choices as a result. This knowledge is the learned knowledge, semantic knowledge, and the conceptual knowledge, at the top of the cognitive ladder.

Unlike a sensory-based system such as the visual system, a cognitive hierarchical system of design may not be specified to one particular region or cell type. Still, information enters this network and is passed on, cut apart, added to, reorganized, edited, and redirected because of recognition of learned or observed sequences and patterns. This top-down evaluative process in design is most active in highly trained designers, such as artists and architects, and should therefore be inseparable from many models of dynamic design. Because Suwa, Purcell, and Gero 1998 apply a mostly unidirectional schema to the design cognition of skilled architects, there is major fault in their applying that schema to that population.

Multidirectional design cognition is important; it seems nearly impossible that only one information processing direction could produce the type of rapid, complex cognitive action that is required in dynamic design. Though perhaps silent, implicit, and to this date immeasurable, the implicit cognitive action, and the feedback from higher-level cognitive control centers are integral to the understanding of dynamic design. The next question for studies in design cognition, then, is how these hidden connections can be exposed either through behavioral patterns, or through patterns in brain activation.

7. The Power of Hierarchies and Pattern Recognition in Human Conception of the World

Pattern recognition, and the interaction among different kinds and levels of cognition are helpful in modeling and understanding both complex and simple functions of the mind. In The World Well Lost, contemporary philosopher Richard Rorty presents what one can interpret as a keen, unexpectedly neuroscientific analysis of human perception of the world. He states,

Now to put my cards on the table, I think that the realistic true believer’s notion of the world is an obsession rather than an intuition. I also think that Dewey was right in thinking that the only intuition we have of the world as determining truth is just the intuition that we must make new beliefs conform with a vast body of platitudes, unquestioned perceptual reports, and the like (Rorty 1972).

We can infer from this statement that human coordination of knowledge, and conception of the world, comes from an obsessive observation and absorption of frequently reoccurring
patterns among us. These high frequency events turn into the stereotypes, platitudes, and habits that form our common semantic knowledge. From this semantic knowledge, we form our rationally driven mutual expectations about the outside world and about each other. Not only is Rorty proposing a human obsession for patterns, but he is also saying that this obsession, and organization process, comes naturally and implicitly to us by intuition.

Here too we can recognize a repeated theme. I have attempted to show that this understanding of a feedback-dependent organization of the mind can be applied to higher cognitive functions such as design cognition. Rorty, now, has applied such a structure to the general method by which humans move through, and share the world.

One final example of this worldview is also taken from philosophy. In *Walking the Tightrope of Reason*, Robert Fogelin summarizes one of Kant’s more important ideas in how humans conceive the world. He writes: “The first is that the world as we apprehend it is shaped or organized by mind-imposed concepts or categories. The world as it appears to us is not a pure deliverance of the sense but is instead the joint product of what the senses give us and what the mind imposes (Fogelin 71)” In this excerpt, the conceptual understanding of the world shapes how we perceive it, just as the IT cells shape how we see a curve, and just as the goal of our design informs our depiction of forms in dynamic design.

8. Conclusion

I first ask my reader to consider the power behind the design process. Then, I focus on a specific explanation of dynamic design. Through my explanation, I set the groundwork for comparing design’s high-level cognitive functioning with other functions of the mind. In unifying ideas from neuroscience, design, and philosophy, I present an explanation of the universality in the organization, appreciation, and practice of complex phenomena, especially those we experience as awesome expressions of the human mind.

References


Embodied Cognition and Naturalized Perspectivism: Cognitive Science Returns to Phenomenology

Brian Wermcrantz

Philosophy, Neuroscience

Grinnell College

Abstract

This paper draws together interdisciplinary support for a recently popular trend in cognitive science known as embodiment theory. In addition, it forwards an argument for a phenomenological approach to cognitive science that understands the perceiving subject as essentially embodied and thus calls for the development of a more holistic methodology for the scientific study of cognition. I critically investigate embodiment theory as it pertains to Cartesian dualism, behavioral psychology, artificial intelligence, Merleau-Pontian phenomenology, and, finally, a Wittgensteinian critique of phenomenological language. My analysis argues that embodied cognitive science should adopt the stance of what I call, “naturalized perspectivism.” As opposed to a representationalist approach to cognition, this stance rejects the conception of the perceiving subject as an organism that acts by following internalized rules and perceives using mental representations of an objective, external world. Instead, by taking the naturalized perspectivism stance towards embodiment theory, I posit that human organisms have evolved to see the “natural world” in similar, objective ways only insofar as we share similar bodies and particular evolutionary-friendly embodied goals. That is, during the process of perception and learning, an organism’s cognitive system cuts across brain-body-world divisions by constantly reconstituting the “sensory world” as it offloads its dispositions into sensory objects themselves for its own embodied, evolutionary purposes.
representations of an objective, external world. Instead, by taking the naturalized perspectivist stance towards embodiment theory, I posit that human organisms have evolved to see the “natural world” in similar, objective ways only insofar as we share similar bodies and particular evolutionary-friendly embodied goals. That is, during the process of perception and learning, an organism’s cognitive system cuts across brain-body-world divisions by constantly reconstituting the “sensory world” as it offloads its dispositions into sensory objects themselves for its own embodied purposes. To ward off charges of relativism, I argue that naturalized perspectivism and embodiment theory together are fully grounded in evolution insofar as they understand the body, and the similarities between bodies by virtue of our shared evolution, to be the fundamental source of the behavior and development of the organism’s cognitive system. By understanding embodiment in this way, phenomenological accounts of perception, such as Merleau-Ponty’s, are open to evolutionary and biological forms of explanation. Furthermore, the viability of naturalized perspectivism is further supported by Wittgenstein’s critique of rule following and his private language argument.

As a scientific account, embodiment theory provides a powerful explanatory model of mental functioning on both theoretical and practical levels. On the theoretical level, it avoids conceptual problems common to other approaches: the problem of mind-body interaction for Cartesianism, the problem of learning without mental states for behavioral psychology, and the frame problem of computation-based artificial intelligence. Furthermore, an embodied approach to cognition starts by viewing the brain as a device for helping to determine actions that allow the organism to survive in challenging and rapidly changing environments over the course of its life. In this way, it is a theory that foregrounds the practical dimensions of mind in such a way as to make them more open to evolutionary forms of explanation. Such an account supports how the evolutionary process has constrained the development and function of the nervous system. In this regard, embodiment theory argues that the mechanisms of perception have developed according to one of nature’s overriding rules: that natural selection promotes brain-body-world interactions that constitute the most efficient and adaptable ways of responding to threats and rewards in the organism’s environment.

To showcase these virtues, it is useful to explain how embodiment theory would respond to three problematic theories of the past, the first being Cartesian dualism. Descartes divides the world into two distinct kinds of metaphysical substances, minds and bodies, which have categorically different essences, thought and extension respectively. Descartes recognizes, however, that mind and body appear to be causally connected; when I think in my mind, “raise my arm,” my body begins to move. One way Descartes attempts to explain mind-body interaction is with his representational theory of perception that holds that the mind makes internal mental representations of the external world. To support this representational model of perception, Descartes needs to address the question concerning precisely how the mind and body, as metaphysically separated, interact to form these mental representations. In an attempt to solve this problem, Descartes argues for the existence of God, who would ensure that external objects are represented in the mind in a non-deceptive, non-transformative manner. Operating under the dualist conception of a “thinking self” faced with the task of establishing the existence and authenticity of “external, bodily
objects,” Descartes is forced to invoke a non-deceiving God who guarantees that our minds (when functioning properly) accurately represent bodies. Such a God thereby warrants the legitimate causal connection between mental representations and extended substance. Thus, unless invoking an omniscient God can be considered an explanation, Cartesian dualism cannot explain in concrete terms how the mind as thinking substance and the body as an extended “space occupier” actually interact to form mental representations. Descartes’ dilemma faces any representationalist view of cognition, such as emergence theories and other contemporary dualisms.

Embodiment theory avoids the Cartesian problem of mind-body interaction by understanding the mind as extended or essentially “embodied” in its immediate environment. From the start, embodiment theorists examine the mind not as composed of metaphysically distinct thoughts, but instead as the mental operations of bodies affording particular actions in particular situations. As opposed to Cartesianism, embodiment theory holds that knowledge of the “external world” cannot be warranted exclusively by God because, if that were the case, then subject-sensitive influences, such as action goals and embodied skills, could not affect perception, when in fact they do in a very important way. As a demonstration of this fact, Andy Clark provides an insightful example of how a baby learns about slopes. He cites a longitudinal study that investigates an infant’s knowledge regarding maneuvering about inclines during its transition from crawling to walking. Understandably, as the crawlers increase in experience, they gradually begin to avoid or learn how to maneuver about the steeper slopes. Remarkably, even after receiving extensive training crawling up an incline, once infants learn how to walk they must entirely re-learn information about steep slopes (Clark, 1997, p37). Essentially, the first time infants walk up the very same slope they once so cleverly navigated on all fours, they demonstrate a lack of information as if they were exploring the area for the first time. Thus, it appears that knowledge and perception are action-specific on a foundational level. If stored mental representations were the medium for knowledge and perception, then the infants would be able to use at least a portion of what they learned from crawling when they started to walk. That is, an infant would be internally representing features of the slope itself, independent of its current embodied projects in the “external world.” Instead, the subject learns about slopes only by virtue of how he or she can respond in a given situation, or, as Clark puts it, “how slopes figure in specific contexts involving action” (37). Whereas Cartesianism holds that we acquire knowledge of, and perform actions in, the world of bodily substance via constant recourse to mental representations, embodiment theory recognizes that our bodily engagement with our current environment shapes our knowledge and perception to begin with. Accordingly, our sensory perceptions consist exclusively of action-laden content because, from the start, they depend on how our bodies are currently behaving towards particular sensory objects in a way that affords skillful, coordinated action towards them. Thus, without any mention of mental representations, embodiment theory recognizes that mental knowledge and “external” bodily features of the world interact coextensively.

A viable model for the specific mechanism underlying this embodied approach to cognition and knowledge acquisition can be found in “reflex circuit” proposed by John Dewey. As an early proponent of embodiment theory, Dewey explains how an embodied
approach addresses shortcomings associated with behavioral psychology, a second problematic theory of perception. Dewey describes the stimulus-response model of behaviorism as “sensation-followed-by-idea-followed-by-movement” (358). This is to say that, according to the behaviorist, stimuli are first given as self-contained objects in the environment, which are then passively collected by sensory organs, and then responded to according to learned stimulus-response patterns. As the basis of this model, behaviorism holds that only observable bodily action (i.e., not mental states) should be the focus of objective, scientific inquiry. But, if sensory objects are self-contained, external objects, and if we do not have mental states, how then does the perceiving subject determine relevant similarities between their current sensory experience and their past stimulus-response pairings? Furthermore, how are the stimulus-response histories stored without memories (i.e., mental states)? Dewey avoids this problem by replacing the linear, mechanistic stimulus-response model with a multi-directional circuit.

According to Dewey, at the “first” stage of perception, sensation, behaviorism falsely posits that stimulus and response operate as independent, self-constituted entities. Alternatively, Dewey recognizes that stimulus and response are members of one fluid, coordinated exercise, what he calls the “reflex circuit.” To explain this model, Dewey discusses the famous example of the child and the flame. While a child reaches for a flame, the act of seeing constantly interacts with the act of reaching. According to Dewey, in an account of action, stimulus and response have determinate content only insofar as they coordinate with each other to carry out a unified function. Dewey describes this when he writes, “[i]f the light did not inhibit as well as excite the reaching, the latter would be purely indeterminate, it would be for anything or nothing, not for the particular object seen” (1896, p358). Here, Dewey makes clear that for the flame to be a stimulus—for it to enter the reflex circuit as the beginning of an action— it must already be engaged with the motor system. In this sense, stimulus and response feed into each other during the process of both perception and learning. Clearly, then, sensory stimulus and motor response cannot be distinct, self-contained entities because, if that were the case, stimuli would be inconsequential for the respective motor action. For the act of reaching, the multi-directional feedback dynamics between eye, hand, body and world guide the motor response and, at the same time, the processing of sensory stimuli. By recognizing that the feedback loop of the sensory-motor system itself guides action, without the need for constant recourse to mental representations, embodiment theory endorses what Clark calls “soft assembly,” where an equal-patterns approach of a multitude of local, constantly-adapting interactions between motor and sensory systems leads to emergent features such as coordinated movement. In this way embodiment theory provides a much more efficient and adaptable stimulus-response model: as Clark articulates, “multi-factor, decentralized approaches […] yield robust, contextual adaptation as a cost-free side effect” (1997, p43). Thus, stimulus-response dynamics constantly guide and adjust the organism’s processing of sensory stimuli—a readily adaptable and highly efficient model that does not require mental states and can better account for immediate learning, unlike the behaviorist model.

Dewey also challenges the behaviorist model in terms of the “second” stage of action, the response. When the child is burned, he genuinely experiences the response sensation
only by virtue of the previous eye-arm-hand coordination, not as an entirely new experience. Learning occurs “only because the heat-pain quale enters into the same circuit of experience with the optical-ocular and muscular quales” (Dewey, 358). As the response occurs, the stimulus is reconstituted to be “seeing-of-a-light-that-means-pain-when-contact occurs” (Dewey, 359). Behaviorists would claim that the response was an essentially new experience, arguing that the continual pairing of two, essentially distinct experiences (e.g., touching and burning) would mediate learning and response via classical conditioning. However, Dewey recognizes that, because stimulus and response are part of one fluid exercise, real learning (i.e., learning that has consequences for future action) occurs precisely at the point when the sensory stimuli are reconstituted and reorganized within the overall sensory-motor system. Hence, for a response to have real consequences for learning, it must be integrated with the stimulus: “the so-called response is not merely to the stimulus; it is, so to speak, into it. The burn is the original seeing” (Dewey, 1896, p359). Essentially, we learn to view the sensory object in a way that immediately elicits and affords an intelligent response (e.g., avoidance behavior by seeing the flame as “pain-when-touched”). In learning, the subject constantly offloads his or her “memory” into the sensory stimuli themselves, and thus uses the world as its own best representation. In other words, the embodied subject feeds back what he or she has learned into the way the world shows up in the next circumstance. As the mind extends into the world in this way, there is no need for mental representation or internal world maps.

Understanding learning as stimulus reconstitution affords embodiment theory an evolution-friendly account for how our sensory-motor system has evolved to use instincts as a cost-effective tool for efficiently avoiding harmful stimuli. For example, when we view a pile of spoiled food, we instinctually and immediately begin to feel nauseated; the stimulus (i.e., the food) itself is reconstituted to be “stomach-nausea-when-viewed.” Without the need for recourse to repeated stimulus-response conditioning, embodiment theory ensures that as few as one response can reconstitute the sensory object to entail immediate and long-term leaning. Furthermore, because sensory stimuli are constantly changing in this way, embodiment theory accounts for how each stimulus-response experience is radically unique as it is phenomenologically experienced. Whereas behaviorism struggles to account for how the subject notices similarities between his current context-situated stimulus perception and abstracted stimulus-response pairs from his past (without recourse to internally stored memory), embodiment theory realizes that the organism’s phenomenological engagement with the world immediately provides these connections and similarities. That is, by offloading “memory” into the phenomenal objects themselves, these objects elicit an intelligent response as soon as they enter the reflex circuit. Generally speaking, the perceiving subject constantly uses the world as a backdrop, storing (i.e., embodying) his or her dispositions and past experiences into the world itself. In this way, the organism uses the world itself as its map (i.e., its own best representation) without the mediation of internal representation.

Thus, the reflex circuit of embodiment theory takes stimuli and responses as not self-contained items, but instead as mutually-constituted components of their overall circuit from the onset of their involvement in action and perception. For a stimulus to register –the very
fact *that* it is a stimulus for a subsequent response—requires it to be interpreted as something that has importance for coordinated action. The “Gestalt effect” has particular relevance here. When a group of individuals view a Gestalt image, such a necker cube, an “identical” picture will be perceived differently between subjects as one of two forms (e.g., a cube facing inwards or outwards, a young lady or an old lady). This demonstrates that we do not view objects atomistically, but instead, from the start, as action-relevant, holistic forms; to borrow a phrase from Wittgenstein, all seeing is seeing *as*. It is not that we interpret or infer form and meaning from the “identical set of lines that comprise the picture,” but rather the reverse: we are presented with a meaning-laden, already-formed Gestalt image and only then do we decompose the image into smaller, formless segments from which we infer its atomistic make-up. For example, when viewing the old-young lady image, the horizontal line towards the center gains its meaning as it functions in the overall image: as either the mouth of the drooping face of the old woman, or the necklace of a young lady. In this way, the Gestalt effect also reveals how embodiment theory understands stimulus and response as components that obtain their respective meanings top-down via the overall function of the reflex circuit to which they belong. In one reflex circuit, the stimulus of a flame’s light can excite neurons in the brain that elicit the arm as a response action, whereas simultaneously, in another reflex circuit, pain in the very same sensory-motor areas of the arm can be the stimulus for the response of withdrawing the arm. Such an account provides the organism with an adaptable and efficient mechanism for learning in a dynamic environment without the need for mental representation.

In addition to its theoretical and practical virtues compared to behaviorism, embodiment theory also provides a viable alternative to another recent model of perception, computation-based artificial intelligence (AI). This view of cognition, known as “computationalism,” attempts to model the human mind using computations within a computer’s internal representations, symbol circuits and world maps. Researchers in this field designed the CYC computer, one of the largest AI projects to date, which consists of a vast bank of internally stored “information units” that serve as a detailed encyclopedia of explicit facts, maps and rules about the world. To operate in the world, the computer uses these explicit facts and internal world models as a knowledge base from which to calculate an intelligent response.

As a result of this set-up, embodiment theory finds computationalism to be “dualistic” in two regards. First, although the CYC computer’s symbol manipulation circuits are physical, they are not embodied. That is, even though they do not belong to a distinct, non-physical substance (i.e., Cartesian dualism), central preprocessing still operates via abstract, encoded symbols, which are *dismembered* in that they are not comprised of features of actual bodies in actual situation in the world, but instead abstract variables and symbols used for a multitude of sensory inputs. The second way computationalism is “dualistic” is that it *abstracts* away from the local environment. That is to say, the CYC computer gathers sensory input and then computes abstract, representational models of the world for centralized symbolic processing. For example, when directing a robot arm, the program
directs movement by adjusting the position via constant reference to an internally represented world model and intended position for the arm. On the spot, local dynamics between the device’s motor system and the sensory environment do not “soft-assemble” coordination, nor can they re-organize or change the CYC perceptual inputs, as with stimulus reconstitution in the reflex circuit. Instead, sensory stimuli are cognized via permanent physical circuits.

These two “dualisms” give rise to the frame problem. According to Daniel Dennett, an early commentator on the problem’s relevance to AI, computation-based AI must face the insurmountable problem of how to successfully infer the effects of an action without explicitly calculating every one of its action’s non-effects. Dennett explains this predicament with an example of a robot designed to remove from a room an object resting on a wagon. As with any centralized, disembodied device, the robot determines how to act based on explicitly calculating what it should do via symbol manipulation and internal world models. In Dennett’s example, the robot fails in its task because it cannot predict the consequences of its actions: pulling the wagon out also brought with it a time bomb sitting next to the object. Although it knew the bomb was on the wagon, this brave artificial creature did not explicitly predict that the action of pulling out the wagon would also bring with it the bomb. Hence, a second version, the “robot-deducer,” is designed to calculate all the outcomes of its actions before doing anything. This unfortunate robot gets blown up as it sits deducing one-by-one every single consequence of pulling the wagon out of the room no matter how irrelevant (e.g., will removing the wagon change the color of the walls?). Thus, the designers program a third robot capable of differentiating between relevant and irrelevant implications of its actions. Still, however, the time bomb eventually explodes as the robot sits explicitly ignoring the thousands of implications it has determined to be irrelevant (Dennett, 1984, p2).

In total, Dennett’s example demonstrates that in order to have the most basic form of adaptive intelligence, computation-based AI must explicitly rule out every obvious irrelevant consequence of its actions before acting in the world. In the robot’s language of “mathematical logic” it is necessary to make explicit not just the changes brought about by its actions but also all those features of the environment that do not change. Before conducting any response, the CYC computer must make explicit all the minor features about the world that we as humans assume but wouldn’t bother to overtly say or predict. Any and all commonsense facts about the world must be either stored or calculated one by one. Adding more and more data to the CYC’s knowledge bank will not solve the frame problem. Thus, computationalism is both a terribly inefficient model of cognition. Without any potential for adaptation when faced by a dynamic environment computationalist artificial creatures are fatally flawed.

Embodied AI uses a decentralized, layer-based architecture to provide a better chance of avoiding the frame problem. Clark cites research done by Rodney Brooks at MIT’s AI lab, where a robot is built with several activity-based “layers” (1997, p12). These robots are composed of a collection of embodied, non-centralized subsystems, each of which consists of a complete behavior-determining, input-to-action description. For example, one layer could be “stop if an object is directly ahead.” As learning takes places (and as the robot “evolves”), more and more layers are added incrementally, each stage creating a functional whole. One of Brook’s layer-based robots, Herbert, can successfully navigate a dynamic environment and
collect soda cans. By virtue of his layered architecture, the robot can readily adapt and respond to obstacles in its path. There is no central processing or internal mapping, but simply a collection of competing layers that are selected according to sensory inputs. In this way, the environment via the robot’s sensory-motor mechanisms guides the creature along by activating layers that automatically focus on the particular relevant features (to the layer) and naturally assume that certain other unexamined features remain present in the background. As with the reflex circuit, these embodied layers process stimuli, from the start, as components of coordinated action. For example, if we are to apply this model to the child maneuvering about a slope, one could imagine the infant adding, deactivating, and switching between cognitive “layers” as they are elicited by its moment-to-moment bodily engagement with the slope. Particular features of the slope are not processed as mental representations of self-contained, external bits of data, but rather components that afford particular actions according to the overall dynamics of the current reflex circuit (or layer) that is activated. In this way, Hubert’s intelligent behavior is soft-assembled via constant local, dynamic interaction between the environment and a multitude of competing and subsuming layers. If one layer is damaged, for example, the system compensates automatically and carries on acting –what Clark refers to as a “robust” solution (1997, p43). Because of this adaptive strategy, an embodied approach to AI enables the subject to act and survive in a dynamic world by replacing computation-based “mathematical logic” with de-centralized engagement with the real world.

Thus, when compared to Cartesian dualism, behaviorism and computationalism, embodiment theory presents itself as a model better prepared to avoid theoretical problems and to provide practical solutions. In total, an embodied approach asserts that perception and learning are a matter of reconstituting elements of the natural world according to subject-sensitive embodied projects (e.g., crawling, walking, reaching for a flame, etc.). As Clark writes, “Intelligence and understanding are rooted […] in something more earthly: the tuning of basic responses to a real world that enables an embodied organism to sense, act and survive” (1997, p4). On this view, it seems that embodiment theory posits that an organism’s sensory-motor reflex circuits afford a world that “enables [it] to sense, act and survive” (Ibid.). To this effect, embodiment theory insists that stimulus reconstitution does not occur via mental representations (or “interpretations”), but in the world itself as it is lived and phenomenologically experienced by the organism. Embodiment theory urges cognitive science to revise traditional dualistic conceptions that understand the natural world as an external and pre-given substrate from which we contemplate, conceptualize or infer conscious representations. Alternatively, according to an embodied approach, the world is to be understood (under a monist framework) as enacted and afforded continuously by the subject’s embodied relation towards it. In order for cognitive science to provide the most accurate, objective understanding of the organism’s cognitive system, it must take into account the fact that the world exists as phenomenologically distinct and perspective-laden for each embodied subject. That is, as the organism learns and perceives, he or she does not reconstitute a pre-established world (i.e., start from scratch, so to speak), but instead reorganizes his or her most recent enacted perception of it. In this way, the world always
exists as an action-laden perspective from an embodied subject. Learning (i.e., stimulus-response patterning) is continuously phenomenologically offloaded into the world itself.

Because this readjustment does not function in a separate realm of mental representation, embodiment theory is committed to the notion that a subject’s perspective can have important influences on the natural world (qua phenomenology) insofar as embodiment theory maintains its monistic conception. As Merleau-Ponty puts it, “the subject does not live in a world of states of consciousness or representations from which he would believe himself able to act on and know external things by a sort of miracle” (2002, p189). Thus, for cognitive science to remain progressive and accurate, it must include first-person phenomenological reports within the data of science. One of the first advocates of embodiment theory, Maurice Merleau-Ponty, provides an analysis of such data.

At the beginning of his book, *Phenomenology of Perception*, Merleau-Ponty asks us to reexamine our understanding of the term “sensation.” For Merleau-Ponty, the Cartesian notion that we experience the world as internal representations of the external, bodily world in fact “corresponds to nothing in our experience” (1964, p3). Whereas Descartes investigates how a “thinking subject” relates to his “external world,” Merleau-Ponty starts his investigation by taking the relation to be direct, immediate and embodied. He rejects mind-body and subject-object dualisms in favor of understanding the mind and perception as essentially embodied from the start. Merleau-Ponty argues that ordinary phenomenal experience presents us *immediately* with a world of “external objects”—not separate, self-contained internal representations or sensations from which we infer the object. Moreover, and central to Merleau-Ponty’s theory of perception, we experience the object *through our bodies*; our physicality influences what we see and is the necessary and permanent condition of experience. In this way, sensory perceptions are not mental states or intentional representations, but instead ways that our conscious intentional body comports itself to objects in our situated experience. Merleau-Ponty references various Gestalt images and perceptual illusions, which demonstrate how we always view objects as meaningful holistic forms with distinctive foregrounds and backgrounds. If our phenomenal scene was atomistically built, then “[w]e ought, then, to perceive a segment of the world precisely delimited, surrounded by a zone of blackness” (2002, p54).

According to Merleau-Ponty, in the process of perception the human organism is always faced with the task of orienting its body so as to achieve its best relation with perceptual objects—what he describes as its “maximal grip.” In this way, an accurate sensory perception is nothing more than a skilful bodily engagement with an object, or as he writes “an optimal body-environment relationship that relieves the ‘tension’” (as cited in Dreyfus, 138). In other words, the coherence of images emerges when the body properly adjusts itself so that it can act on the object. Likewise, for an individual walking about in museum, for example, Merleau-Ponty asserts that it is just a natural fact that our body, even without our conscious, explicit violation, will want to move to the ideal viewing angle to see the paintings with maximal clarity of detail and overall form. Oscillation towards equilibrium occurs as of we were riding a bike. Thus, the dynamic relationship between objects and our bodies is normative in that it adjusts to arrive at better or more correct bodily engagement with the object.
As an extension of maximal grip, Merleau-Ponty’s account of learning has many similarities with the reflex circuit of embodiment theory. According to Merleau-Ponty, at the first stage of learning, we act like centralized computers: we deal with the world (poorly) by decomposing it into context-free, often quantitative discriminations (e.g., driver noting his speed be consistently looking at the speedometer), and then act according to a list of rules that address these features (e.g., shift once every 15mph). However, as the beginner learns, he or she starts to notice additional aspects of the situation and becomes more closely engaged with it. For example, whereas a novice driver approaching a dangerous curve at a high speed will proceed to explicitly consider the angle, speed and outside conditions, the expert drive will feel that he is going too fast and then decide to ease the break. The expert driver has a vast repertoire of situational discriminations that allow him to make subtle, refined discrimination in his environment. Merleau-Ponty argues that it is precisely not a matter of collecting more and more “stored” rules via mental representations for one to follow. Instead, skill acquisition occurs when new dispositions emerge in response to the situation. Thus, intelligent behavior is when subject’s dispositions ensure that in the phenomenal experience the relevant similarities show up that elicit a natural coordinated response. As a way of addressing the frame problem head-on, Merleau-Ponty recognizes that the ability to restrict perceptual intake to the relevant features for action and response is an essential part of learning. In his words, a “person’s projects polarize the world, bring magically to view a host of signs which guide action” (as cited in Dreyfus, 2005, p132). These “signs which guide action,” that show up in the objects themselves are very similar to the offloaded “memories” inserted during stimulus reconstitution in Dewey’s model. Situation-focused dispositions, as with layers and reflex circuits, warrant that the embodied subject naturally focus on relevant features and inexplicitly assume that certain other non-effects remain in the background. Thus, learning for Merleau-Ponty and Dewey is the gradual replacement of reasoned, rule-following responses with intuitive reactions where the subject uses the world itself as a means to elicit a response without having to mentally represent the world. It is important to take note that “learning” understand as such remains distinct from very basic forms of learning (such as simple rule following), which indeed occurs frequently in life. A model example is muscle memory where an individual skillfully performs tasks without the intermediary conscious reference to rules. As with the reflex circuit, Merleau-Ponty’s phenomenological account posits that the organism uses the world itself (as it is experienced) as its own map and best “representation.”

The later philosophy of Ludwig Wittgenstein supports the viability of naturalized perspectivism. In particular, Merleau-Ponty’s account of perception and skill acquisition lends itself very closely Wittgenstein’s insights on rule following. Generally speaking, Wittgenstein argues that “no course of action could be determined by a rule, because every course of action can be made out to accord with the rule” (1958, p201). To explain this, he provides the example of an individual (presumably) following the rule “plus 2” while actually adding increments of +4 after he or she passes 1000 (1958, p185). Wittgenstein’s point is that we successfully operate not by explicitly following a rule. To understand correctness of use, there is no recourse to some internal authority beyond the actual application in use of “the rule.” This is because there is no fact of the matter that determines
the correct application of some internal rule. Rather, skillful and intelligent behavior is revealed in use via community assent. Wittgenstein describes our participation in a community with pre-established criteria for correctness as the “form of life” that we adopt in language and action. Thus, this general characterization of Wittgenstein supports embodiment theory insofar as it understands human action not to be a process of following and applying internal rules, but rather as a means of engaging in the world.

Wittgenstein extends his discussion on forms of life in his critique of a private language, which suggests the presence and viability of embodiment theory in language. Here, Wittgenstein’s conception of how a child learns language offers particular support for the approach of naturalized perspectivism. In Wittgenstein’s account, we learn phenomenological (i.e., sensation) language by participating in a pre-established form of life, or “system of reference by means of which we interpret an unknown language” (1958, p206). That is, when a child is hurt, he is trained to use words to express his pain instead of crying. In this way, the child learns psychological vocabulary through public training in which non-verbal pain behavior is gradually replaced by verbal pain behavior. In Wittgenstein’s words, “the verbal expression of pain replaces crying and does not describe it” (PI 244). Hence, when a child articulates pain behavior, he or she does not introspect or “describe it” (i.e., concentrate on what is occurring in some ‘inner realm’ and then ostensibly name it), but instead chooses to express pain behavior in another form (i.e., verbal pain behavior). The stage is already set in that, as we learn language, we enter into a pre-established relationship between verbal pain-expressions and pain-behavior expressed in the bodily actions of other speakers. As children, we learn sensation words, and are understood communally, insofar as we have the “right,” not the “justification,” to use certain expressions (1958, p289).

Wittgenstein stresses this distinction to illustrate how a child learns the proper use of words: by participating in the sensation language game and being positively reinforced if other participants understand, not according to conditioning based on whether our “mental representations” matches our verbal expressions. In total, Wittgenstein’s critique demonstrates that phenomenological language has no purchase on the subject’s radically singular phenomenological experience. Because language is naturalized by the body and the community, we can meaningfully operate within the sensation language game.

Remarkably, Wittgenstein’s private language argument also explicitly advocates for an embodied approach to proper linguistic conception of the mind and body. He argues that if we conceptually divide the psychological and physical realms, then certain absurd examples of language in everyday use seem possible. The fact that “I can have your pain” is semantic nonsense, and not some empirical inaccuracy, shows that such a claim is grammatically illegitimate in our sensation talk. Commenting on the referential conception of language, Wittgenstein writes, “this picture with its ramifications stands in the way of our seeing the use of the word as it is” (PI 305). Thus, meaning exists insofar as we decide to adopt the established grammar —and with it the proper conceptual distinctions— of a particular language-game. The proper conceptual distinction acquired by children is not between inner and outer, but instead between two types of outer. That is, the only way to communally understand the use of sensation language rests on how the child learns the distinction between two types of body: those resembling living things and those that do not. This
connection arises from how a child is conditioned to use the sensation language-game where sensation terms are tied to their expression through their parent’s living body. Under this framework, statements like “that rock has pain” properly do not hold meaning. A child verbalizes behavior by replacing bodily actions (i.e. crying) with the articulation, “I am in pain.” Generally put, we are trained not to identify mental events with sensation terms, but to participate in an established way that living things act. Thus, Wittgenstein provides an account of language use and acquisitions that is against representaionalist rule-following and in favor of an embodied approach. Moreover, he provides a theory of phenomenological language that allows each individual to have a radically unique, phenomenological sensation, while at the same time to be able to successfully communicate his or her perspective in a meaningful way.

In total, as a scientific, phenomenological and linguistic account, embodiment theory takes a perspectivist stance on the mind. Because the perceiving subject enacts the natural world relative to his or her embodied projects and histories, the perceptual experience is significantly different for each subject. By taking a perspectivist stance on the study of cognition, embodiment theory opens itself to charges of “anything-goes” relativism. Such accusations, however, ignore the fact that although subject-sensitive influences effect perception, they do so in a very naturalistic, evolutionarily-determined way. That is, human organisms have evolved as a species that share a basic bodily structure and evolution-friendly drives. We perceive a similar world insofar as we share certain bodily features that afford particular bodily comportments to sensory objects as they are phenomenologically experienced. As Merleau-Ponty demonstrates, bodily experience is a prerequisite for any form of perception. Thus, naturalized perspectivism, properly conceived, defends itself from charges of relativism by anchoring the plurality of our phenomenological experiences (i.e., different stimulus reconstitution between individuals) to a general, biologically-shared world.

Summarizing, it thus becomes clear that, embodiment theory, with the support of Merleau-Ponty and Wittgenstein, presents a viable model of perception. An embodied approach to cognition argues that the motor system engages with the world via a multitude of competing and subsuming reflex arcs. Learning occurs as we offload “memory” into the world and in turn create new layers and new situation-specific discriminations. Such a model lends itself nicely to evolution’s tendency to build intelligent creatures circuit-by-circuit (or layer-by-layer) in functional wholes that can most efficiently and adaptively respond to the dangers and rewards in one’s dynamic environment. By realizing that our cognitive architecture naturally restricts perceptual intake to relevant features, phenomenology appears to be an influential aspect of perception and thus an important subject for cognitive science. To this effect, the stance of naturalized perspectivism accounts for how a subject’s embodied dispositions create for it a world where it can most efficiently operate and socially interact as a biological organism. If it is to incorporate these insights, cognitive science must take the world not as an objective, universal substrate, but as importantly different according to features of each organism’s body. Overall, the interdisciplinary support gathered in this paper encourages researchers to begin to recognize the deeply interconnected nature of the mind and body.
Acknowledgments

I would like to thank my academic advisor, Professor John Fennell, for his constant diligence, patience, and excellent teaching skills over the course of this senior year Mentored Advanced Project and as an academic mentor for the past two and half years.

References


THE MNS (mirror neuron system) in embodied semantics: Activation Patterns of the Mirror Neuron System in Visual Linguistic Processing

Joann Song, Advisor Jaime Pineda

Department of Cognitive Neuroscience

University of California, San Diego

Introduction

Investigations concerning the phenomena of implementing linguistic expressions via observation resulted in arbitrary conclusions prior to the use of neuroimaging and electrophysiological techniques. Recently, neuroscientists have discovered a potential neurological basis for how we understand the intent of others and translate perception to action. Numerous studies have established that neurons located in the ventral premotor cortex (area F5) of Macaque monkeys were activated both when executing and observing actions. Evaluating this special class of cells, known as ‘mirror neurons,’ can give us insight into a broad range of questions concerning its correspondence to social cognition as well as the development of language.

Comparative anatomical mappings of brain regions between Macaque monkeys and humans demonstrate that the ventrolateral prefrontal cortex (area F5) in monkeys is cytoarchitectonically homologous to BA44 (Rizzolati, Arbib, 1998; Petrides, 2002), a region generally assumed to control language in humans, which is also known as Broca’s area. These premises form the basis for the hypothesis that area F5 serves as an anatomical precursor for a language area (Rizzolatti, Arbib 1998). Neurophysiological evidence supporting the role of area F5 in controlling hand movements (Fogassi, 2001), in conjunction with theories proposing gestural origins for language (Arbib, 2008), inductively leads to the conclusion that area F5 also serves as the functional precursor of a language area in humans (Rizzolatti, Arbib, 1998).

Contrary to these proposals, a few researchers have expressed skepticism regarding these evolutionary claims attributing functional and anatomical homology between the Macaque rostral area of the ventral premotor cortices (F5c) and the human BA44 (Zubicaray, Postle, McMahon, Meredith, Ashton, 2008) due to the lack of evidence that “mirror neurons in a premotor region in any common ancestor of humans and macaques” exist (Toni, Lange, Noordzij, Haggort, 2008).

Based on empirical evidence, a sensorimotor schema in the F5/BA44 exhibits the transitive property of creating neural representations when processing action depicting
phrases, such as “bite” and “grab”, which indicates that it might be involved in understanding actions semantically. Furthermore, observation of movement (i.e. specific hand gestures) led to the activation of motor evoked potentials within humans, suggesting that this neural network also functions in bridging perception to action between a sender and receiver via the process of “motor embodiment” (Rizzolatti, Arbib, 1998). To reiterate, when perceiving the action of a “sender” this causes the “receiver” to have a surrogate perceptual experience by preparing the same muscles needed to execute that observed action. In particular, measurements suggest that actions using effectors such as the hand, foot, and mouth were transferred as precise motor representations in the observer (Glenberg, 2008).

According to the embodied cognition framework, conceptual knowledge is implemented by “modality-specific input/output systems” (Kemmerer, Castillo, 2008). A linguistic analogy of this conceptualization, known as embodied semantics, suggests that comprehending verbal depictions of actions results in an internal simulation of that action (Fischer, Zwaan, 2008). The process of conceptualizing action verbs appears to integrate motor areas in the frontal lobe, particularly in the premotor cortex (Kemmerer, Castillo, 2008). Neuroimaging studies of the human cerebral cortex reveal that linguistic stimuli elicits mirror neuron activity in Brodmann’s area 44 (BA44), supporting the hypothesis that the MNS has a functional role in semantic representation (Kemmerer, Castillo, 2008; Glenberg, Sato, Cattaneo, Riggio, Palumbo, Buccino, 2008).

Opponents of embodied cognition argue for an alternate explanation; a disembodied theory comprised of amodal motor representations of verb meanings, devoid of activation in the frontal lobe (Toni, Lange, Noordzij, Hagoort, 2008). Contesting evidence such as the absence of preferential activation within the BA44 during presentation of words and non-words seems to infer that this region is unrelated to the processing of semantic or abstract information (Zubricaray, Postle, McMahon, Meredith, Ashton, 2008).

The legitimacy of this argument has been substantially outweighed by the mounting data endorsing the embodied cognition framework. Various experiments consistently confirm that semantic processing results in activation patterns of the frontal lobe, among other regions (Glenberg, 2008; Hauk, 2004; Kemmerer, Castillo, 2008; Aziz – Zadeh, 2006). According to the authors Kemmerer and Castillo (2008), simply viewing action-related words elicited the response of the motor homunculus.

It has been suggested that the level of mirror neuron activity can be measured quantitatively by utilizing electrophysiological methods. Mu rhythms, defined as EEG oscillations in the 8-13 Hz frequency band, are attributed as reflecting modulation of sensorimotor regions by mirror neuron activity in the premotor cortex (Pineda, 2005). Changes in the amplitude of the mu rhythm during goal-oriented actions suggest that these waves represent cognitive processing such as retrieval of motor representations. An inverse relationship is exhibited by mu rhythms in which synchronization during idle states results in higher amplitude, and desynchronization during increased cortical activity correlates with mu suppression (Pineda, 2005). Thus, greater mu suppression is attributed to a higher level of mirroring activity.
Given the various analyses and supporting evidence, conclusive inferences can be generated to predict that processing linguistic information, particularly lexicon forms, should cause mirror neurons to discharge. This raises a number of additional questions: would comprehension of initially nonsensical or abstract characters engage mirror neurons? If so, would reading action verbs subsequent to learning the meaning of the new characters elicit more activity, resulting in greater mu suppression than reading nouns? Based on embodied semantics, it will be hypothesized that the process of learning the meaning of foreign action-depicting lexicons will indeed engage the mirror neuron system. Moreover, attaching semantic significance to initially meaningless symbols or characters should elicit more mirror neuron activity for the verbal - action – related words than the nouns.

2. Methods

2.1 Participants

The group of subjects who participated in this experiment included 15 undergraduate students from the University of California. Ten out of the fifteen subjects were native English speakers with no prior exposure to the Korean or Japanese language. There were variances within this group for languages learned but all of them were highly competent in English.

<table>
<thead>
<tr>
<th>Experimental Group data</th>
<th>Non – Koreans (N = 10)</th>
<th>Koreans (N = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age</td>
<td>Mean = 21.3 years</td>
<td>Mean = 20.8</td>
</tr>
<tr>
<td></td>
<td>(σ = ± 5.62)</td>
<td>(σ = ± 2.67)</td>
</tr>
<tr>
<td>Male to female ratio</td>
<td>1:1</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Age range</td>
<td>18 to 24</td>
<td>20 to 23</td>
</tr>
</tbody>
</table>
Languages learned

English, Spanish, Vietnamese, Chinese, Czech, Malayalam, Hindi, Cantonese, ASL, Gujarati, Urdu, Korean, English

All subjects were right-handed and had no history of psychological disorders or traumatic brain injuries. Visual stimuli displaying Korean lexicons were presented to these English speakers. Subsequent to training they had to validate their comprehension of these foreign symbols. The control group consisted of five native Korean speakers whom regarded themselves as highly fluent in Korean. Initially these speakers were able to understand and distinguish the Korean words either as an action verb or noun so training was not necessary.

2.2 Experimental Procedure for English Speakers.

In general, the experimental procedure differed for the English natives, as Korean speakers did not receive any training or post-EEG assessment. The procedure for the English native speakers was arranged in three segments: a pre-training EEG recording session, a training session, and post-training EEG recording session.

Visual stimuli consisted of four Korean words: two action verbs (e.g., “grab” and “bite”), two effector related nouns (e.g., “grape” and “scissor”), and a baseline condition of meaningless character strings (####) to account for any noisy input unrelated to the event.

2.22 Experimental Procedure for Korean Speakers

This version of the experiment for native Korean speakers (control group) resembled the post-training EEG recording condition. Since participants in the control group are already able to comprehend the significance of the four words, reinforcement was not necessary. The EEG only recorded the activation during presentation of visual stimuli. Prior to the EEG recording, Korean subjects were also asked to complete the quiz to validate comprehension of the Korean words.

2.3 General Experimental procedure

An electroencephalogram (EEG) was used to examine the subject’s response. All together, we recorded from nineteen sites in the anterior, posterior, and medial
region (F7, F8, F3, FZ, F4, FP1, FP2, T5, T6, O1, O2, T3, T4, C3, CZ, C4, P3, PZ, and P4). The mastoids were used as reference points.

Pre-Training EEG Recording

For the initial pre-training EEG recording session, English speakers were presented with a block of four Korean lexical items: two action-related words (“grab” and “bite”), two effector-related nouns (“grape” and “scissor”), along with a baseline condition of meaningless strings (####). Four images representing the two action verbs and two nouns were displayed in the training session. The Presentation program by Neurobehavioral Systems was used to present the visual stimuli on a computer screen approximately two feet away from the subjects. Each word was presented thirteen times each for three seconds. The baseline condition was presented six times during the entire presentation. The Korean words appeared briefly on the screen in succession, with variations in the order of words presented. There was a two-second interval between each visual stimulus. In order to ensure that participants were actively observing the foreign words, they were instructed to count the number of baseline conditions in the entire presentation. All together a total of 57 visual stimuli were displayed on the screen during the pre-training.

Training of English Speakers

Following the initial recording of EEG, English speakers were trained to interpret the semantic meaning behind each Korean word. The Psyscope program was used for the training segment. A single Korean lexicon was presented simultaneously on the screen with four images depicting each word displayed on different corners. The baseline character was omitted. Subjects were instructed to click on the picture corresponding to the Korean lexicon in the center based on their inferences. Feedback was given after each input to aid subjects in deductively forming semantic representations for each word. Participants repeated several trials until they achieved a nearly perfect success rate and validated their comprehension of the four Korean lexicons. Altogether they completed three blocks of training. Each block of training had thirty trials. After training participants displayed their comprehension of the Korean words or symbols by writing the English definition for the Korean words that were presented to them.

Subjects finally took a comprehensive quiz post-training which consisted of eight questions. Each Korean word was displayed twice and the order of words presented varied for each subject. All subjects wrote the correct English definition of the Korean word all eight times for the quiz to proceed to the post-training.

Post – Training EEG Recording

Similar to the pre-training EEG recording session, subjects were presented with 13 blocks of 4 Korean words consisting of two action verbs and two nouns, along with 6 baseline conditions. Each word was presented for 3 seconds similar to the pre-training. Participants were asked to count the number of baseline conditions to ensure that they were paying attention to the presentation. There was a 2 second interval between each visual stimulus presentation. In contrast to pre-training, participants
were now able to categorize and comprehend the foreign words as validated by the quiz. The quiz consisted of eight questions in which the subjects had to write the English definition of the Korean word presented to them. Each word was repeated twice and for every quiz the words were presented in random order. Each subject wrote the correct response for every word.

2.4 Data Analysis

The EEG device was used to measure the mu wave (alpha band, 8-13Hz) and selectively depict the activation of mirror neurons. In order to complete the data analysis the SPSS program was used to do comparisons of conditions and electrodes. First, I analyzed three separate general linear models of the anterior, medial, and posterior region by doing repeated measures of two factors including five levels of conditions and six levels of electrodes. This was done for the pre and post-training data from the non-Koreans as well as for the control group of Koreans. The options were set to display descriptive statistics, more exactly the mean, for the two factors (conditions and electrodes) as well as conditions by electrodes. Also, for comparing main effects the confidence interval was adjusted to the Bonferroni setting in which the significance level was 0.05 or lower. In order to determine whether or not a factor showed significance, the Greenhouse – Geisser had to be less than the significance level for the tests of within – subjects effects.

2.5 Results

![Graph](image)

**Figure 1.** This bar graph represents the mean mu power for each condition from the non-Korean group prior to training. It encompasses the data from the electrode sites in the medial region (C3, CZ, C4, P3, PZ, & P4).
The mean mu power for each Korean word is roughly the same amount of enhancement relative to the baseline before training. There is no distinction between the verbs and the nouns at this point so it is expected that there is no relationship within categories.

**Figure 2.** This bar graph represents the mean mu power for each electrode site from the medial region prior to training. In the analysis of the pre-training comparing conditions by electrodes from the medial region, there was a main effect found for conditions, $F(4, 36) = 4.288$, $p < 0.05$ as well as a marginal significance for the electrodes, $F(5, 45) = 3.690$, $p = 0.064$. 

**Figure 2.** This bar graph represents the mean mu power for each electrode site from the anterior region prior to training.
Figure 3. This bar graph represents the mean mu power for each electrode site from the anterior region (F7, F8, F3, FZ, F4, FP1, and FP2) before training.

There was a main effect for the electrodes from the anterior region, $F(6, 54) = 6.898, p < 0.05$ whereas there was no relationship or significance for the conditions.

Figure 4. This bar graph represents the mean mu power for each condition from the electrode sites in the posterior region (T5, T6, O1, O2, T3, T4).

Figure 5. This bar graph represents the mean mu power for each electrode site in the posterior region. The ANOVA of the data from the posterior region revealed that there was a main effect for both the conditions, $F(4, 36) = 4.861, p < 0.05$, as well as electrodes, $F(5, 45) = 7.575, p < 0.05$. Once again there was no significance found for the conditions by electrodes.
Figure 6. This bar graph represents the mean mu power of the conditions for the electrode sites from the medial region after training.

The analysis of post training data from the medial region revealed that there was a main effect for the conditions, $F(4, 36) = 4.678$, $p < 0.05$, but not for the electrodes. Subsequent to training, the mean mu powers for the conditions are still relatively the same, which is contrary to our predictions of there being a distinction between the verbs and nouns. Also, there is an enhancement in mu power from the pre-training graph for the conditions relative to the baseline, when it was expected that the graph would reflect a decrease after training.
Figure 7. This bar graph represents the mean mu power for the conditions from the electrode sites from the posterior region subsequent to training.

Figure 8. This bar graph represents the mean mu power for the electrodes from the posterior region after training.

The ANOVA for the post-training data from the posterior region revealed that there were main effects for both the conditions, $F(4, 36) = 5.757$, $p < 0.05$, and electrodes, $F(5, 45) = 8.515$, $p < 0.05$. A comparison of the graphs in figure 4 and figure 7 shows that there is a slight reduction in mean mu power for the conditions grape, grab, and scissor relative to the baseline whereas there is an increase for bite. In the graphs of the electrodes for the posterior region (Figure 5, Figure 8), the mean mu power remains generally consistent for both pre and post – training.
Figure 9. This bar graph represents the mean mu power for the conditions from the electrode sites in the anterior region (F7, F8, F3, FZ, F4, FP1, FP2) after training.

Figure 10. This bar graph represent the mean mu power for the electrode sites from the anterior region after training.
The ANOVA for the post-training data from the anterior region revealed that there were main effects from both the conditions, $F(4, 36) = 3.198, p < 0.05$, and electrodes, $F(6, 54) = 9.122, p < 0.05$. Compared to pre-training, there is a main effect for conditions after training and an increase in mu power for the electrodes.

There were no main effects found from the analysis of general linear models comparing mu suppression to electrodes. This was also the case when comparing the factors of verbs and nouns to electrodes. Similarly, the data analysis from Korean speakers did not show any significant findings.

3. DISCUSSION

Results from the present study showed that there was a main effect for conditions and for electrodes in the three regions but not for conditions by electrodes. Also, when analyzing the mu power data, no main effect was to be found.

Overall, the data results were inconsistent with our predictions that English speakers who learned the meaning of Korean symbols would engage mirror neuron activity, especially for action verbs, and this would produce a decrease in mu power relative to the baseline, signifying an increase in mu suppression. Analyses of mu power also failed to reveal a main effect for conditions and electrodes or for the categories of verbs versus nouns which is contrary to the emphasis placed on increased mu suppression as stated in the hypotheses. A possible reason for the failure to find main effects in mu suppression might be due to the small subject pool, a lack of thorough training, or the attention given to counting the symbol used in the baseline condition.

In order to obtain more accurate results we plan on replicating this study by reinforcing the training so subjects are not simply learning via visual recognition. Also, we will have subjects construct the words themselves by choosing from a pile of cards with Korean lexicons. In order to account for the importance given to the baseline, for the presentation of stimuli we will have subjects count the original symbol (####) while including (but not counting) an additional insignificant symbol to use as the baseline.

For future research it would be beneficial to replicate this study using the same paradigm with a larger subject pool. Also, it might be useful to implement training with a different language; one that uses the same alphabet, rather than an unfamiliar alphabet.

After replicating this study with a more difficult training session, if the data results were to reflect our hypotheses it would imply that mirroring activity mainly had a role in the semantic acquisition of this set of Korean words. Supporting evidence for this inference could lead to further research investigating motor resonance in language acquisition, specifically in action depicting words.

References


Indiana Undergraduate Journal of Cognitive Science

2009 – 2010 Editorial Board

Executive Editor
Brenden Sewell, Indiana University

Associate Editor
Michelle Capriles-Escobedo, Indiana University

Student Reviewers
Brian Slattery, Indiana University
Anna Handy, Indiana University
Ronak Shah, Indiana University

Faculty Sponsors
Dr. Ruth Eberle, Director of Computer Technology and Adjunct Professor of Cognitive Science & Informatics, Indiana University
Dr. Robert Goldstone, Chancellor’s Professor and Director of Cognitive Science Program, Indiana University

Web Design / Programming Support
Michelle Capriles-Escobedo, Web Designer, Indiana University
Muhammad Nubli Mohd Kasa, Systems Analyst/Programmer, Cognitive Science Program, Indiana University
Indiana Undergraduate Journal of Cognitive Science
http://www.cogs.indiana.edu/icogsci/journal.html

Author Instructions

I. General Information
The Indiana Undergraduate Journal of Cognitive Science invites submissions of original writing by undergraduate students. Submissions may come from any area within Cognitive Science including, but not limited to: artificial intelligence, anthropology, biology, computer science, linguistics, philosophy, psychology and neuroscience.

II. Submission / Paper Format
Submissions should be sent directly to the editorial board as an attachment in Microsoft Word or Adobe PDF format. Articles should be no more than 25 pages double-spaced and should be edited for grammar and style before submission. Submissions should include a Title Page that includes the following information: Article Title, Author Name, Major, and E-Mail Address. This information will not be published and is for contact purposes only.
Authors should submit their work via E-mail to the Indiana Undergraduate Journal of Cognitive Science Editorial Board at iacs@indiana.edu. Once your submission is received, a confirmation E-mail will be sent by the Editorial Board. All submissions will be considered equally and no preference will be given to any particular discipline within cognitive science.

III. Review / Acceptance Process
After submission, the Editorial Board and a panel of reviewers will review all articles and will decide which papers will be published in the current edition of the journal. Authors will be notified by E-mail if their paper is accepted for publication. Authors will also be notified by E-mail if their paper is not selected for publication. After acceptance, authors are required to submit their paper in Microsoft Word format to allow the Editorial Board to make formatting and grammatical edits. Once these changes have been made, the Editorial Board will contact the authors to obtain final approval of the above changes and to obtain written publication permission.

IV. Disclaimer and More Information
Articles published in the Indiana Undergraduate Journal of Cognitive Science are considered copyrighted. However, this journal is not a binding publication. Authors are free to submit their work to any other publications they wish.
For more information about the journal, please contact Brenden Sewell, Executive Editor of the Indiana Undergraduate Journal of Cognitive Science at brrsewel@indiana.edu or by the means below.

Indiana Undergraduate Journal of Cognitive Science
819 Eigenmann Hall - 1910 E. 10th St.
Indiana University - Bloomington, Indiana 47406
E-Mail: iacs@indiana.edu
http://www.cogs.indiana.edu/icogsci