The Georgia Institute of Technology

CS 6795 Introduction to Cognitive Science

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1 Problem

The system of the frog's mind can be described in terms of the connectionist network. A connectionist system is comprised of nodes that are interconnected with other nodes. These nodes communicate through excitatory or inhibitory signals (Horgan, 1997). Over time, through experience and learning, these connections can be modified and strengthened or weakened (Thagard, 2010). The situation with the frog demonstrates an excellent simplistic example of this idea. Thagard (2005) describes concepts as distributed representations in these nodal networks where different features, such as a tail and whiskers, are combined to identify a more complex structure such as a cat. One may propose that the frog's mind contains a collection of units representing the concept food, a mosquito, and perhaps even pleasure. The frog's mind receives the percepts of the mosquito. The concept of a mosquito is connected to the concept of food. The nodal network associated with food is connected to an internal reward structure such as pleasure. These links need not transmit large amounts of symbolic information (Feldman & Ballard, 1982) and thus the frog may act with the speed necessary to catch the mosquito. Throughout the frog's life, these links become stronger and the so-called weights between the nodes increase.

When dealing with these distributed networks, one must also assess how a decision can be made when only simple signals are being transmitted. Feldman (1982) proposes a winner-take-all network. In this framework, only the unit with the highest potential will have an output above zero after a settling time. Each unit computes the maximum of the competitor's inputs and then inhibits the other input. In this way, the frog is able to make the decision to stick out its tongue and catch the mosquito.

2 Problem

2.1 Part a

One may describe the monumental task of memorizing a large quantity of the digits of the rational number, pi, as one of data organization in the case of a non-visual strategy. Organizing data into discrete units exemplifies a cognitive technique called chunking. Chunking is a procedure whereby many data points are reduced into a smaller number to facilitate cognitive processing (Thagard, 2005). It is usually used to help remember strings of information, such as telephone numbers, but in this case, one must create comparatively large chunks for storage in long-term memory.

A connectionist network offers an appropriate model for this process. One might begin by repetitiously reciting a chunk of 7 digits. The numbers in the series correspond to multiple individual nodes. The links between these nodes have weights associated with them representing the strength of the connection between the nodes (Horgan, 1997). These weights are systematically updated as the connections become stronger. After the weights have been strengthened above some threshold, the sequence is stored in long-term memory and is said to have been memorized. This process is repeated for each successive chunk of digits. After a collection of digit chunks has been stored to memory, one could then memorize sets of chunks to create even larger chunks.

2.1.1 Advantages/Disadvantages

The most obvious advantage is the ability to remember large quantities of numbers or other data. Another advantage of this method is the effectiveness of this technique. Many of the other competitors besides Tammet in the memorization of pi use long strings of digits in their chunks. Some come up with mnemonics to represent large chunks (Caveman, 2009).

One issue with this memorization technique is that errors would be compounded if a chunk was forgotten as opposed to a single digit. Although this is true, in the competition of memorizing pi, forgetting even a single digit would result in a large enough error to take one out of the competition. One more disadvantage for this type of memorization is the amount of time required to perform it. It would require one to perform repetitions and recitations many times over which could end up taking quite a long time.

2.2 Part b

One might describe the task of memorization in terms of a problem space as defined by the SOAR architecture. The goal state is represented by accurate memorization of a large portion of pi. In this architecture, different states within the problem space are linked via associations. Therefore, for one to adequately link from the initial state to the goal state one must form new associations (Lehman, Laird, & Rosenbloom, 1996). In the memorization of pi, as each number is concatenated on the list, Tammet states that the pattern in his mind becomes increasingly complex. For Daniel Tammet, these associations are a complex web of visual, textural, and emotional data. The initial state is linked to the goal sate of memorization via these complex patterns that comprise the associations. Tammet creates the appropriate associations to link from the initial state to the goal state.

2.2.1 Advantages/Disadvantages

An obvious advantage is the ability to remember large bits of information as Daniel Tammet does. Another advantage is that these imagistic memories of Daniel Tammet are stored with multiple sensory associations. A Thagard puts it (2005), pictorial, or imagistic, representations have the advantage of conveying more information over sentential. Tammet is able to associate words, numbers, and colors together in his memory. A single word can be stored in his memory with an emotional, textural, and visual representation. Recent studies demonstrate that emotional valence leads to higher performance on word recall (Majerus & D'Argembeau, 2011) which would further complement Tammet's strategy.

A disadvantage to this type of memorization that Tammet employs is that the additional information associated with what he is memorizing is very subjective. That is, only he has these specific associations with the numbers. This results in a significant disadvantage since if he were to attempt to communicate these memories in their encoded form much more information would have to be given than the alternative. Although presenting the memorized information in its encoded form would be inefficient, it is unclear whether or not Tammet must spend more time in decoding these memories in his mind than someone who does no visual encoding at all. Another disadvantage of this strategy is that this type of memorization my only be specific to this sort of task, i.e. memorization of long strings of numbers.

2.3 Part c

One may assess the strategy employed to memorize information through a double dissociation set of tasks. We must be careful not to simply test whether or not one is thinking visually or non-visually as opposed to whether or not they are memorizing visually or non-visually. The first task,

Task A, would employ a technique that exploits the "Stroop effect," which is a phenomenon associated with reaction time in naming the font or ink color of a word (or, in this case, a number) (Nikolić, D., Lichti, & Singer, 2007). The task would be to display a range of numbers and ask the person to assign a color to each of them (presumably the color that the digit is associated with if testing a synesthete employing a visual strategy for memorization). Next, multiple digits colored in opponent colors (ex. Green versus red) to the colors designated as well as digits colored as the participant assigned them would be presented. The participant would then be instructed to name the ink color of the text.

This task would be used to isolate users of a non-visual strategy who would be expected to perform better. One would expect a non-visual oriented person to respond in the same amount of time regardless of whether the color is the designated color or its opponent. A visual oriented person would be expected to take longer to identify the color of the text f opponent color as opposed to the colors designated.

This second task, or Task B, would be to display the image below (Figure 2.3a) and have the participant quickly state whether or not they discern any shapes, and if so, what shape. This test is derived from V.S. Ramachandran's *A Brief Tour of Human Consciousness* (2004) as a test for synesthetes who visualize numbers as colors.

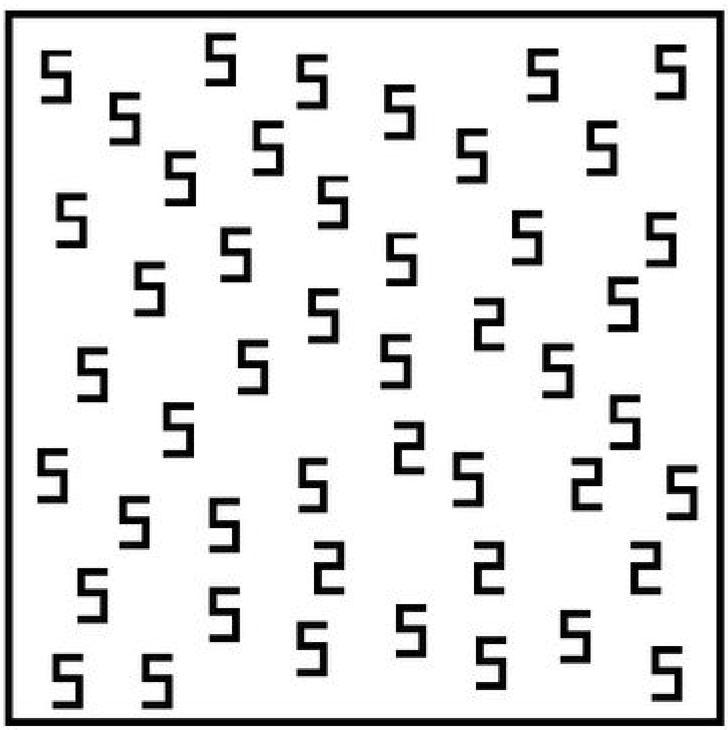

Figure 2.3a: Synesthete test image.[19]

For this visual strategy oriented task, Task B, one would assume a person employing the visual strategy for memorization to perform the task well and readily find the shape present. A person employing a non-visual strategy would be expected to perform poorly on this task and not recognize the shape present as shown in Figure 2.3b. This task could be augmented with a similar range of tests to isolate false data or ambiguity.

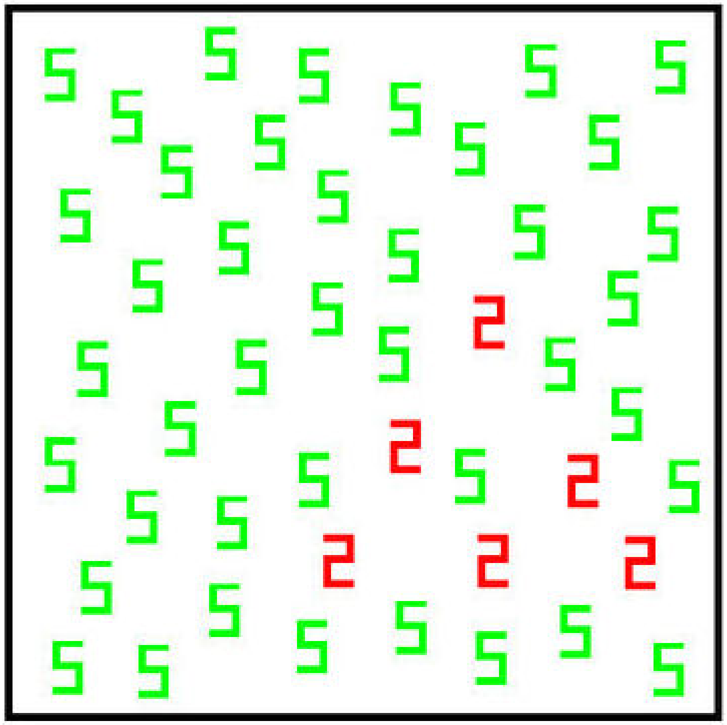

Figure 2.3b: Synesthete test image solution.[19]

For both of these tasks, A and B, one should be able to isolate people who employ the visual, or synesthetic technique versus the non-visual.

3 Problem

3.1 Part a

3.1.1 Concepts

Margolis and Laurence regard concepts as “the most fundamental constructs in theories of the mind,” (Laurence & Margolis, 1999). A schema is defined by Thagard (2005) as being not a strict definition or definitive list of features of an entity or situation, rather it is a subset of features that define it. To describe the successful performance on the mirror test, one must have a concept of self, which here is defined as the memories and rules that are associated with one’s self. Internally, these features make up the schema of self. For one to realize that a mirror image is one’s self, they must take in the percept of the image of the mirror and assign the schema, or concept of self to the image they perceive.

Concepts are acquired by sensory experience and through encountering a thing for which the concept is formed (Thagard, 2005). One can encounter many people in the world. Likewise, animals may encounter other animals of the same species. For a person, these encounters build up the concept of people. Although this is true, one may not necessarily have to encounter others of their species to form a concept of themselves. Encountering other beings or species might be a sufficient condition for forming this concept. In that case, the concept may be more appropriately labeled *cognitive agent*, rather than person or chimpanzee. In either case, once one forms this concept of an individualistic cognitive agent they could successfully apply this concept to the percept of the reflection in the mirror.

3.1.2 Analogies

From the idea of concepts, one might have issue with the presumption that one could simply apply their sense of self to some reflection in a mirror. A more likely explanation can be made through the idea of analogies. Thagard et al. (1990) regard this as a problem of analogical problem solving, where one has a source analog from which one may propose a solution to a target. The source being the internal concept of self and the target being the image perceived from the mirror. According to Thagard (2005), “representation of analogies needs to include representation of causal relations.” In this case, one could say that a person looking at the mirror must realize that the relationship between the mirror and the world is that it reflects the surroundings and the image displayed in the mirror is that reflection. To form the analogy, this relationship must be apparent and then one must form the connection between the reflected image and their internal representation of self. Once the percept has been acquired, a plausible and useful source analog must be selected. Next a mapping between the source and target analogs must occur. Once this connection has been made, there is a transfer of relevant information from source to target (Thagard et al., 1990) and one is able to relate the image in the mirror to their own physical presence. Finally learning occurs and one has successfully formed the analogy and thus passed the mirror test.

3.1.3 Images

Percepts of the world can be thought of in terms of an imagistic mental representational form. If one is familiar with the physical features of oneself, then they perhaps have formed a mental image. This mental image is a depiction of the physical features of the agent within their own mind. Mental images are not necessarily restricted to visual representations (Thagard, 2005). Perhaps the image also represents the thoughts or feelings of an agent. People have the ability of empathy, which is an assessment of the emotional state of others. One may regard the perception of emotions and even thoughts of others as a part of a mental image of them. When looking into the mirror, if the mental representation of a person or animal is consistent with the internal image, then they may be able to recognize that the internal representation and the external object being perceived are the same. However, this connection is not arbitrarily made. An imagistic explanation is hardly complete, but it can be augmented with the idea of visual analogical mapping. As noted by Yaner and Goel (2006), the evaluation of mappings between target and source is an ongoing problem in computational models since several sources may be retrieved for any one target. Regardless of this issue in models, once a cognitive agent makes this mapping they are able pass the mirror test.

3.2 Part b

Define self-awareness based on course materials. Write in such a way that the reader understands all of the terms used.

One might describe self-awareness in terms of a mental model. A mental model is a cognitive construct that organizes information and enables reasoning. Mental models are similar to real life models in that they can be descriptive, predictive, and contain diagrammatic components that have a structural correspondence to the situation they reference (Nersessian, 2002). The mental model of self could be described through the concept of self referred to previously, which here is still defined as the memories and rules that are associated with one's self.

A mental model plays a direct representational or analogical role of the thing represented (Johnson-Laid, 1980) unlike a mental image which is merely an internal construct. As stated above with regards to analogical mapping, in the mirror test scenario a target analog would be the reflected image in the mirror. The source analog is obtained through internal reasoning based on the mental model of self. For one to be self-aware, one must apply the percept of oneself in a mirror (target) to the mental model of self (source) through a mapping. There is a transfer of information from source to target and subsequent learning occurs. From this process, we derive the meaning of self-awareness, in which one has a mental model of oneself that can be applied to the perception of one's physical body in a mirror.

More generally, since it need not be a physical percept, the target could even be an internal concept. For instance, a person may try to plan some future event, like going to the grocery store. Although this situation is more abstract, the same analogical mapping occurs, but in this situation one maps the concept of self to the concept of a future self. Other scenarios could be derived in a temporal since as in the previous example, or perhaps in a hypothetical situation.

4 Problem

4.1 Part a

Use 3 theories to give a cognitive science account of the results described and conclusions drawn.

4.1.1 Connections

Owen et al. propose and perform a test of the widely held belief that computerized brain trainers can yield general improvements in cognitive ability. What Owen observed was that improvements were made on all training tasks each group was trained in for all groups, including the control group. However, their results show that the specialized training group (group 1), the general cognitive training group (group 2), and the control group (who answered obscure questions) showed no generalized improvements in cognitive functioning. The experimental groups showed benefit from the training programs, however, they were specific to the tasks they were being trained. In other words, there was no significant broad improvement in general cognitive ability as is assumed by the computerized brain training pop culture following.

We may regard the results of Owen et al. (2010) in terms of a connectionist network. No direct benefit was observed in the areas of training each experimental group participated in. If we assume a connectionist model of cognition, we are able to describe the processes involved in the brain training activities of the participants in Owen et al.'s study. First we must identify the network of connections to be modified.

The areas focused on in the benchmarking test are: reasoning, paired-associates learning (PAL), spatial working memory (SWM), and verbal short-term memory (VSTM). Our connectionist model should describe the changes seen through training in each of the four categories. Since "improvements were observed on all training tasks" for each of the groups, our model must only isolate the abilities common to the task one was trained for and then describe the disconnect between the abilities tested in the benchmark tests. Owen et al. describe the first test, "The first test (reasoning) was based on a grammatical reasoning test that has been shown to correlate with measures of general intelligence or g. The participants had to determine, as quickly as possible, whether grammatical statements (for example, the circle is not smaller than the square) about a presented picture (a large square and a smaller circle) were correct or incorrect and to complete as many trials as possible within 90 s," (Owen et al., 2010). Thagard (2010) tells us that learning and experience should modify connections, either by strengthening or weakening them. One node in this network could be for the parameter of interest of "image relations*"*. Using Feldman & Ballard's (1982) unit/value principle, an image relation is performed on a single unit in our network. In the case described above, the image relation is defined as “is smaller than” to describe the relation between the circle and square. Another unit could perhaps be “relative features” which determines characteristics that are different on each image. Over time, image relations and relative features units strengthen and the person improves in the task of comparing images presented.

For another task, “The second test (verbal short-term memory(VSTM)) was a computerized version of the ‘digit span’ task, which has been widely used in the neuropsychological literature and in many commercially available brain-training devices to assess how many digits a participant can remember in sequence. The version used here was based on the ‘ratchet-style’ approach in which each successful trial is followed by a new sequence that is one digit longer than the last and each unsuccessful trial is followed by a new sequence that is one digit shorter than the last. In this way, an accurate estimate of digit span can be made over a relatively short time period.” The unit associated with this task could be described as “remember digit,” which could theoretically be strengthened over time (although the results from Owen et al. are not promising to have any significant change in the number of digits one could remember in a short amount of time). Ultimately, since this node is not the same as the nodes strengthened during the first task, image relations and relative features, no generalized improvement is observed. Not only do these training tasks not relate to each other, but they also do not relate to the abilities tested for in the benchmark tests. Therefore, no improvements in the benchmark abilities should occur, just as Owen et al. conclude.

4.1.2 Mental Models

One may describe the acquisition and training in terms of model-based reasoning. According to Sun et al. (2006), “Model-based reasoning is a process of constructing representations in the form of a model (e.g., physical models, mathematical models) and deriving inferences through manipulation of the model, which requires a set of desired knowledge acquiring skills.” In the tasks put forward by Owen et al, we can describe the process through which the participants train by assuming the representations they form and the subsequent inferences they make. We are also able to define certain skills the participants must utilize to increase their performance on the tasks given.

The third task given to participants is described as, “Versions of the third task (spatial working memory (SWM)) have been widely used in the human and animal working memory literature to assess spatial working memory abilities. The version used here required participants to ‘search through’ a series of boxes presented on the screen to find a hidden ‘star’. Once found, the next star was hidden and participants had to begin a new search, remembering that a star would never be hidden in the same box twice. Participants were allowed to make three errors in total before the test was terminated." (Owen et al., 2010). The model formed for this third task may entail forming assumptions about the general nature of this problem. For instance, one may assume the constructs of a series of boxes and that a star must be contained in one of them.

Through promoting model-based reasoning, one is able to strengthen links between the subcomponents in the problem solving process (Sun, Newstetter, & Nersessian, 2006). The subcomponents in this process might be described as inductive reasoning and creative inferencing. The former can be described as how one deduces the causal relation between the premises and the solution for a generalized procedure, and the latter as how one identifies the relation, itself. The mental model applied must strengthen the subcomponents associated with successfully performing only this task and not the tasks tested on the benchmarking test. For each group trained in a specific area, they gained benefits in that area only without generalized improvements. One might expect that, to achieve generalized improvements, more appropriate subcomponents must be derived if they exist at all.

4.1.3 SOAR Architecture

Another way to interpret the results of Owen's study is looking at it through the frame of the SOAR Architecture. As we note in Sec. 2.2, through this architecture, different states within the problem space are linked via associations. Therefore, for one to adequately link from the initial state to the goal state one must form new associations (Lehman, Laird, & Rosenbloom, 1996). There also exist intermediary states that eventually link to the goal state. For the participants of Owen's study, the goal state is comprised of different things for the different tasks they train for. The fundamental disconnect between the benchmark *abilities* and the trained *behaviors* seems to lie in their definitions. The participants in Owen's study train for certain behaviors, such as determining weight relationships, determining differing characteristics between objects, or moving crates that effect other crates in the area of reasoning (Owen et al., 2010). Here, we argue that these tasks do not correspond to the abilities tested for in the benchmark test.

In their paper, Lehman et al. (1996) list the common factors of cognitive behaviors. Some things listed are, "It is goal-oriented," or "it requires learning from the environment and experience." Both of these features are unique to behaviors and are separate from features that describe abilities. Abilities offer a cognitive skill that allows the cognitive agent to perform a wide variety of problems. Using the SOAR architecture, we can describe the initial state and its link to the goal state of producing desired behaviors through forming associations. However, the abilities seem to be a part of a richer form of problem-solving or perhaps result from a subconscious aspect of thought that SOAR does not cover. One can create rules or associations about problems in the training session, but these rules are not applicable to all cases. One has only formed associations in a very narrow problem set. This could even be a result of the repetitiveness of the tasks performed during training. Since there is little variation in the type of problem for each task type (reasoning, planning, memory, attention, etc.), perhaps very specific rules are created. These specific rules offer no increase in cognitive abilities, since abilities are defined to cover a broad range of problems which confirms the result observed in the study.

4.2 Part b

Describe 3 important skills for an expert in your field.

In the field of electrical engineering, more specifically in wireless and radar applications, one must have many technical competencies. One such competency is a comprehensive understanding of electromagnetics, which is at the core of all wireless technologies including radar. As a cognitive task, this could be described as involving working memory (to analyze problems in the space of electromagnetics), reasoning, knowledge, and long-term memory (to retain competencies and fundamental knowledge of the core concepts in this field). Radio frequency (RF) circuit design is another important skill since many very specific tasks require design of completely novel hardware. From a cognitive standpoint, this can be regarded as a task of long-term memory, knowledge, representation, and reasoning. Another important skill is design experience. One must be able to create designs using current software packages and the most relevant electronic components. As a cognitive task, this skill requires learning, knowledge, memory, and attention.

4.3 Part c

Owen et al. (2010) shows improvement in the areas being trained, however, not in generalized intelligence. The training tasks designed must take this into consideration. The tasks, to illicit any true and useful improvements, must then be directly applicable to the skills that we wish to be improve. For all of these tasks, our design will incorporate multiple aspects of learning. Penuel (1999) states that “novices learn to become experts through practice in solving a variety of problems in a domain.” We can create this variety, although Penuel also notes that collaboration and reflection should occur to enhance learning. Thus, training should be performed in collaboration with others who are also training. The learning should occur in “communities of practice,” thus we should also surround the novices by experts who are performing the duties being trained for.

Since, as Owen et al. make clear, no generalized enhancement occurs in brain trainers we avoid this assumption and train only for the specific tasks and skills necessary for the novices to become more expert-like. The computer-based training regime consists of solving relevant problems in electromagnetics and in RF circuit design. We also must train the novices in current software packages for design. We accomplish this through giving assignments that require extensive use of the most current software. Our computer training program guides the novice through example programs prior to completion of more extensive designs to increase their familiarity with the tools required.

5 References

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