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Research Report

CONCEPT FORMATION: 'OBJECT' ATTRIBUTES DYNAMICALLY INHIBITED FROM CONSCIOUS AWARENESS

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We advance a dominant neural strategy for facilitating conceptual thought. Concepts are groupings of "object" attributes. Once the brain learns such critical groupings, the "object" attributes are inhibited from conscious awareness. We see the whole, not the parts. The details are inhibited when the concept network is activated, ie. the inhibition is dynamic and can be switched on and off. Autism is suggested to be the state of retarded concept formation.

Our model predicts the possibility of accessing nonconscious information by artificially disinhibiting (turning off) the inhibiting networks associated with concept formation, using transcranial magnetic brain stimulation (TMS). For example, this opens the door for the restoration of perfect pitch, for recalling detail, for acquiring accent-free second languages beyond puberty, and even for enhancing creativity.

The model further shows how unusual autistic savant skills as well as certain psychopathologies can be due respectively to privileged or inadvertent access to information that is normally inhibited from conscious awareness.

Keywords: concept formation; nonconscious skills; autistic savant; language acquisition; absolute pitch; creativity; cortical inhibition; transcranial magnetic stimulation; unconscious skills; autism.

1. Introduction

The fact that cognitive processes are largely nonconscious has been periodically reported through the ages, although often ignored. Helmholtz [21] observed that we are not aware of the elements used to form a judgement - we make "unconscious interferences" based on prior experience. We are not conscious of the details that make up the percept. Such details are inhibited from our conscious awareness. Instead, what we see depends largely on what we already know [17, 55, 53]. Basically we force fit every image into a known percept. We are concept driven! On the other hand certain brain-damaged people, like autistic savants [59], would appear to have the opposite strategy. They have privileged access [52] to nonconcious information and processes but are not concept driven as discussed at length by Snyder and Mitchell [52, 53]. Savants are rare individuals who, although severely brain impaired, display islands of astonishing excellence in specific areas including drawing, memory, music, calendar calculations, and arithmetic [2, 22, 24, 28, 40, 47, 54, 59]. They typically have no idea how they do it.

If privileged access to nonconscious processes results from brain damage, that is by turning off (inhibiting) part of the brain, then this suggests that inhibiting mechanisms deny normal individuals such access [52, 53]. This is a key insight to our work. And, the fact that such access can even occur spontaneously following an accident [31, 59] or at the onset of fronto-temporal lobe dementia [36] suggests that the inhibition can be switched off artificially in an otherwise healthy individual. In fact, as we discuss below, evidence is accumulating that the inhibition is dynamic and can be switched off and on.

Indeed, Snyder and Mitchell [52, 53] suggest that savant-like skills reside in everyone, but that only individuals with a rare form of brain damage, like autistic savants, gain privileged access to these skills. Snyder further proposed (see Carter [6]) that such nonconscious skills might be accessed artificially by temporarily shutting off those parts of the brain implicated in the savant syndrome by using "slow" magnetic brain stimulation over the left fronto-temporal lobe. Consistent with this hypothesis, it was found [56] that transcranial magnetic stimulation (TMS), known to suppress cortical activity [42], improved 'literal' savant-like abilities, like drawing skills and proof reading in healthy individuals.

So, it is becoming clear from magnetic brain stimulation (TMS) studies, as well as from the phenomenon of acquired savants [31, 36, 59], that by turning off part of the brain, it is possible to access processes, information and even 'skills' which are not normally consciously accessible and that this process can be switched off and on. These observations set the stage for our paper.

Indeed, a dominant strategy of the brain is emerging from these observations. It gives rich insight into how neural architectures evolve to impart conceptual thought. It builds on research that newborns, unlike adults, are probably fully aware of the raw sensory information available at lower levels of neural processing and that they quite possibly have excellent recall of this information. But, with maturation, such awareness and recall is largely suppressed from executive awareness. Instead, the maturing mind becomes increasingly aware only of concepts (groupings of raw details which encapsulate the familiar) to the exclusion of the details which comprise the concepts. We believe that this strategy of suppression is continued with the formation of metaconcepts (groupings of concepts), resulting in the awareness of metaconcepts, to the exclusion of the concepts that compose the metaconcepts.

A neural model is presented which captures this strategy of dynamic inhibition. Its most provocative prediction is that nonconscious skills and lower level unprocessed information can be exposed in normal people by artificially switching off the neural circuits responsible for the suppression associated with concept formation. In addition, we believe that it should be possible through this procedure to acquire an accent-free second language beyond puberty, to restore perfect pitch, to amplify creativity and to enhance recall of details. Our model further suggests that certain psychopathologies, such as bipolar disorder and aspects of schizophrenia, could be due to inadvertent access to nonconscious processing. And, autism appears like a failure of concept formation. Finally, synaesthesia [9] could itself be related to some form of privileged access to unconscious information that exists within everyone as previously suggested [52].

2. Infants Access Raw Sensory Data

As mentioned above, the mature brain is largely concept driven with details suppressed from conscious awareness. Young infants probably are not! This possibility is dramatised by what neonates can do that we cannot. There is growing evidence that infants see the world much more literally than we do. They experience the raw sensory data available at the lower levels of information processing. A number of studies provide evidence for this interpretation.

For example, evidence is accumulating that infants have eidetic imagery and that this becomes less pronounced over the course of the child's development [14, 18, 19]. In other words, infants seem to have superior visual recall. Consistent with this, infants at 6 months can discriminate between monkey faces as well as between human faces, but **not** after 9 months [41].

This perceptual contraction of the visual domain with development is mirrored in the acoustic domain. For example, consider our ability to discriminate between different phonemes, the building block sounds of speech. At 4 to 6 months, infants can discriminate between phonetic differences in foreign languages, but by 10 to 12 months this ability is restricted to their native language only [8, 29]. Further, it is likely that infants have "absolute pitch" , something which is rare in adults (fewer than 1 in 10,000) [49, 50, 55, 61].

Finally, it has even been suggested [34] that neonates are not only aware of all of their senses, but they also have synaesthesia [9], whereby they perceive the world with their senses mixed. The incidence of synaesthesia in the adult population is rare.

In summary, evidence suggests that, unlike adults, neonates are aware of their sensory information but that this fades with maturity. This view differs from that commonly thought, whereby maturity is believed to bring greater **awareness** of the details within our environment. More accurately, as we discuss below, it is that maturity confers greater **expectation** of what is in our environment, not greater awareness.

3. The Mature (Concept Driven) Brain

We do not 'see' the world through a literal interpretation of our senses. Rather, we 'see' it through our knowledge as accumulated through past experiences [17, 55, 53]. Our brains impose meaning on sensory information. They present us with a coherent picture the best hypothesis, when in reality there is always some ambiguity. Compelling evidence for this comes from a variety of sources, for example by various illusions, especially in the visual and auditory domains [17, 23, 46, 52, 53]. Such illusions are often the result of the brain making false assumptions based on prior knowledge from past experience. For example, assuming that we live in a world with light coming from above leads to errors in deriving shape in unusual or contrived situations [55]. Also, recent work on illusions shows that the primary sensory cortex does not have signals fixed by the sensory input. On the contrary, the sensory input is altered to be consistent with the hypothesis [7, 11, 60].

We argue that all of this is a consequence of the brain constructing concepts, that is, constructing mental paradigms or templates about the world [52, 53]. Concepts are here taken to be collections of sensory details which characterise familiar "objects", where the "objects" here are used in the broadest sense even embodying complex situations and interactions.

3.1. *Suppression of details*

Once a concept is formed, there is an associated loss of awareness of the sensory details (object attributes) which comprise the concept. Such details are inhibited from executive awareness. Hence, for example, we would anticipate that absolute pitch is suppressed as language develops since it is merely an **attribute** of sound phases [52]. Where there is less developed language, as in monkeys, we would anticipate that absolute pitch remains intact [20]. Other examples are discussed elsewhere [52, 55].

We further suggest that concept building continues throughout life with the formation of metaconcepts, groupings of concepts, which comprise complex cognitive operations. These in turn confer expertise. Once a metaconcept is in place, the concepts that comprise the metaconcept are suppressed from conscious awareness. Everyone has experienced how the details of complex operations can become automatic and nonconscious, such as driving a car.

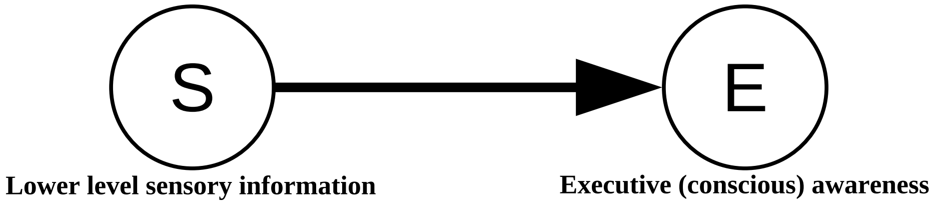

Fig. 1. Model for pre-concept state. Lower level sensory information is reported to the executive (consicous) awareness.

4. Infantile Autism: a Literal Brain - Deficient in Concepts

It is tempting to speculate on what the brain would be like without concepts [53]. Such a brain would have no preconceived notions of the world and its complex interactions. Instead, each scene is perceived as a continuous succession of surprises: a mass of raw details without meaning, a heightened sensitivity to the parts without recognising the whole. This description closely matches that of the developmental disorder infantile autism [2, 12, 28]. In our view, infantile autism is largely described by suspended infancy. Indeed, autism is difficult to diagnose until well into the second year.

The only way for a person with infantile autism to cope is to carve out a limited repertoire, a strict routine. In other words, the autistic person must simplify their behaviour in the world whereas the normal individual simplifies the world by forming mental concepts about what is expected [53]. These two strategies contrast sharply. One imposes order on the external world by carving out a restricted repertoire. The other simplifies the world by force fitting a finite number of mental possibilities on every situation.

Interestingly, because autistic individuals have fewer mental models (concepts) of the world, they can be more aware of novelty [22, 44]. This gives clues to how it might be possible to enhance creativity in healthy individuals as we discuss below.

5. Model for Dynamic Inhibition Associated with Concept Formation

Based on the above observations, we present a simple conceptual model which encapsulates concept formation. Fig. 1 illustrates the pre-concept brain. Here all sensory details are reported directly to conscious ("executive") awareness.

At the other extreme, Fig. 2 depicts the model for the post-concept brain. Here all sensory details are inhibited from conscious awareness. Only the concept or ultimate label of something is reported. However, we emphasise that the inhibition is dynamic. It can be switched off or on depending on whether or not the stimulus activates the concept network. In other words, although "object" attributes are normally suppressed from conscious awareness, they are retrievable through disinhibition.

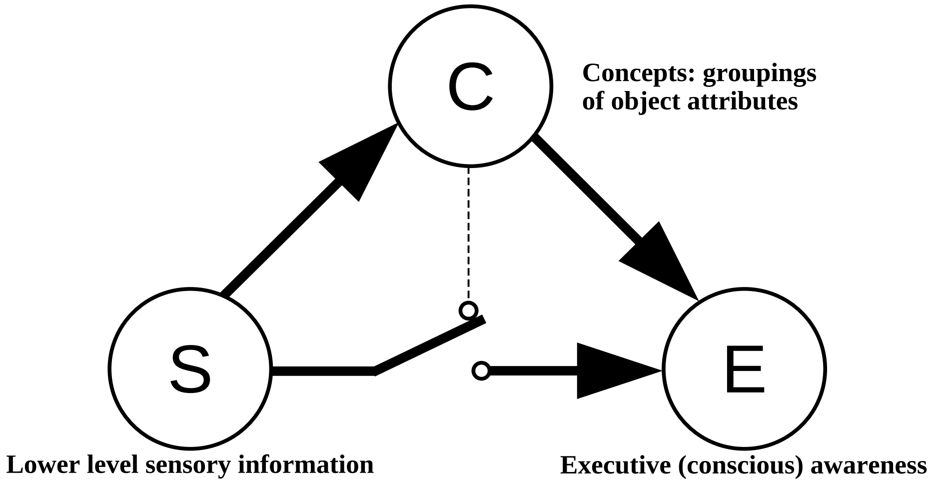

Fig. 2. Model for post-concept state. Only the concept is reported to the executive (conscious) awareness. The attributes of an object are inhibited, but the inhibition is dynamic and can be switched off and on. A concept is a grouping of object attributes.

This strategy of dynamic inhibition is continued with the formation of metaconcepts (groupings of concepts). When the metaconcept network is activated, the concepts that comprise the metaconcept are inhibited from conscious awareness. Metaconcepts encapsulate multiple "lower-level concepts" needed for expertise.

6. Restoring Lower Level Sensory Information Artificially

Our model presented in Fig. 2 suggests that primary and lower level sensory information which is normally inaccessible in adults can be restored by turning off the inhibiting circuits associated with concept formation. In our opinion, this includes absolute pitch, recall of seemingly superficial details, the acquisition of an accent-free second language beyond the age of puberty and possibly a route to amplifying creativity. It may even allow access to synaesthesia as previously suggested [52].

Within our model there would appear two plausible ways to allow a person access to lower level sensory information and nonconscious processing. One way is to remove or destroy the concept networks all together. The person would then be consciously aware of all the attributes of the concept without being able to link these attributes into a coherent meaning in analogy to young infants in the preconcept stage. The second way to allow such access is to remove the inhibition only. Then, the attributes as well as the concept are reported to executive awareness.

There are several techniques which might be used to access nonconscious information and processes.

Perceptual tricks: In some instances, it is possible to trick the brain by psychological subterfuge in order to access lower level object attributes. The technique essentially is to remove the concept or meaning of the object. For example, proof reading of familiar phrases is often not possible even after repeated attempts. But, blocking the meaning by covering all but one word at a time makes it readily accessible. Analogously, learning to draw natural scenes is accelerated by viewing only a small piece of the object at a time, or alternatively, viewing an object, like a face, upside down so that it is unfamiliar [10, 55, 57].

Magnetic Stimulation: Low frequency repetitive transcranial magnetic brain stimulation (TMS) can be used to temporarily turn off those regions of the brain associated with concept formation. This has been used in order to access lower-level "object" attributes, to improve proof reading and to change a person's drawing abilities from the usual schematic nature of an untrained artist to a more naturalistic style [56].

Psychotropic Drugs: Over the years there have been accounts describing the effects of psychotropic drugs in a way that is analogous to the magnetic brain stimulation studies discussed above [26]. Most recently, Oliver Sacks [48] described how he produced "camera-like" precise drawings when under the influence of amphetamines but not at any other time. And, it has even been suggested that early European (savant-like) cave art is due to mescaline induced perceptual states [25].

EEG-assisted Neuro-feedback: There is some evidence for the possibility of accessing nonconscious processes and lower level neural information by EEG-assisted neuro-feedback, essentially by locking into the brain waves associated with nonconscious processing. We refer the reader to Birbaumer's discussion of this technique [3].

7. The Restoration of Nonconscious Abilities

We give several examples to illustrate what special abilities might be possible if the concept centres or their associated inhibitory networks could be temporarily turned off artificially.

7.1. *Enhancing creativity by temporarily turning off part of the brain*

While it may seem counter-intuitive, we suggest that creativity can be enhanced by temporarily turning **off** part of the brain, not by stimulating it.

Now, an appealing view of creativity is the ability to link seemingly disparate ideas into a new synthesis. This, we argue, is very much a normal property of our healthy, concept driven mind. But, and here is the crucial point, so also is our propensity of being blind to the parts or details that make up the whole, as has been outlined above and elsewhere [53]. Such details are inhibited from conscious awareness! Consequently, we are prone to interpret neural data in terms of familiar patterns. And, because we force fit our interpretations into known models, it is difficult to "join the dots up" differently. Creativity demands, in addition to being conceptual, that we at least momentarily see the pattern of dots as they really are.

That we see raw data without interpretation, allowing for a new synthesis.

This is extraordinarily difficult for any normal brain for the fundamental reason discussed above; otherwise, we would be unable to manoeuvre rapidly in the world. Indeed, Kuhn [30] described the leap necessary for a paradigm shift as being equivalent to that required to shift one's reading of the familiar rabbit duck illusion where a person is locked into their initial reading. We revisit this important observation in our discussion section below.

Seeing data without interpretation is unnatural. No wonder so many discoveries are serendipitous or accidental where something unforeseen breaks a person's mind-set. Inventing psychological tricks for this explicit purpose is difficult. Alternatively, we propose using magnetic brain stimulation to temporarily turn off the part of the brain associated with concept networks. The location for the application of TMS is a matter for future investigation, but the evidence suggests it is in the left hemisphere and possibly the fronto-temporal lobe [13, 15, 38].

Finally, it is interesting to consider the often-discussed relation of creativity to madness. Could it be that certain psychopathologies such as bipolar disorder and schizophrenia allow for intermittent and obviously inadvertent access to nonconscious processes and information, ie, to details that are normally suppressed? Rather than believing that such psychiatric disorders induce a distorted or unnatural world, they might actually give a momentary glimpse of the world the way it really is - a world that is not filtered through mental models. Somehow, the psychopathology, possibly through disinhibiting neurotransmitters, shuts off the inhibition normally associated with concept formation in a way that is analogous to magnetic brain stimulation.

7.2. *Acquiring an accent-free second language beyond puberty*

One interesting possibility is that TMS could allow the acquisition of an accent-free second language beyond the age of puberty. This is significant because it is extremely difficult if not impossible for a person to sound like a native speaker if they are introduced to a second language after their teens. A person can be fluent but they retain an accent from their first language. Henry Kissinger, the US Secretary of State, never lost his native accent, but his brother, only a few years younger, sounded as though he were born in the United States [43]. In other words, the ability to mimic sounds is inhibited after puberty. Like shading, which is needed for the brain to extract the concept of object shape but is often not conscious, phonemes are needed to extract the concept of words. Thus, in analogy to shading [55], adults are more aware than young infants of verbal expressions as a gestalt rather than phonetic component parts. But, we now suggest that TMS might be able to temporarily reverse this inhibition, allowing a person to better mimic foreign sounds. Clearly this is a possibility that requires further exploration.

There is some evidence that our suggestion for restoring the ability to sound native is possible. A curious brain disorder to the left hemisphere called "foreign accent syndrome" emerges after a head injury or stroke [5]. Instead of slurring the speech, afflicted people speak fluently but pronounce words differently. The disorder affects pitch, timing, rhythm and vowel sounds *that makes them sound as though they have a foreign accent.* This disorder may also give a clue to the brain regions where TMS should be directed, as does the brain of another person who effortlessly acquired more than 60 languages, reportedly sounding like a native speaker [1, 33]. Also, Hermelin [22] describes a language savant who acquired many foreign languages beyond puberty. It would be interesting to know whether the savant had acquired a native accent. Many autistic savants have exceptional mimicry and musical recall [59].

7.3. *Restoring absolute pitch*

Absolute pitch exists in fewer than 1/10,000 of the adult population [45] and it probably cannot be taught [58]. But young infants [49, 50] and all autistic savants have absolute pitch [37]. Snyder and Mitchell [52] argued that, like all savant skills, perfect pitch resides in everyone but is not normally accessible. We here suggest that transcranial magnetic stimulation of the left temporal lobe could restore absolute pitch in adults.

It is understandable why perfect pitch is usually inhibited in the first year of life with the onset of language. Language is what is of ultimate importance to an individual and not the raw details (the frequency components) that make up the sounds. So, it would appear advantageous to inhibit the awareness of such details in favour of the meaning of sounds [52]. On the other hand, monkeys, who place less emphasis on language, appear to retain absolute pitch [20].

Our mechanism for hearing consists of discrete frequency analyses which afford every individual with the raw apparatus to confer absolute pitch. This observation about hearing has its analogy with vision. For example, our brain performs the calculations necessary to label three-dimensional objects from subtle shading across its surface. Yet, we are unable to consciously access such raw details, otherwise we could draw naturalistically without training [16]. Clearly such information is inhibited from conscious awareness [55, 57, 52]. In other words, it is the object label itself that is of ultimate importance and not the attributes or raw details processed by the brain to formulate the label. As with absolute pitch, it is even possible that newborn infants are aware of subtle shading prior to learning how to see, as are autistic savant artists [57, 52].

But, why do some people have absolute pitch? First we recall that all musical savants [37], and many individuals with autism [4] have absolute pitch. Furthermore, the incidence of absolute pitch is less than that of the incidence of autism. It remains to be investigated whether or not some of those reported to have absolute pitch fall within the upper limit of the high functioning autistic spectrum. On the other hand, absolute pitch seems to be preserved from infancy in those who were exposed to musical instruments at a very young age [61]. This could be an instance where the brain is "tricked" into believing that artificially produced pure tones constitute a language.

7.4. *Improving recall of details*

Our conceptual memory far exceeds our memory for the details leading to the concept. In fact, the opposite seems true. Most of us have experienced how the concept often falsely dictates the supposed details. But the fact that those details are often retained is illustrated by how recognition far exceeds our ability to recall [16, 32].

On the other hand, many savants have extraordinary recall of seemingly meaningless details, often at the expense of recognition [59]. After being hit on the left temporal lobe at 10 years old, one boy became an 'acquired' savant for recalling such details [31]. Our suggestion then is that it might be possible to access such meaningless details by temporarily shutting off parts of the left temporal lobe.

8. Discussion

8.1. *Why block object attributes from conscious awareness?*

We have presented a model for concept formation. In particular, our model illustrates the dynamic inhibition of attributes that define a concept once the concept network is activated. Why has the brain adopted this strategy?

The fact that object attributes are blocked from conscious awareness when a concept is solidified would appear to lend support to the view that the conscious brain has adopted the strategy of economy of reporting. In analogy to the decision making process of a large corporation, the CEO is informed only of the result of deliberations, rather than being party to all the backroom details of deliberations. This strategy accelerates decision making, especially when confronted with only partial information. It might also accelerate the process of learning because, without grouping information into meaningful packets, the brain is overwhelmed [51]. However, as discussed above, concept formation comes at the cost of illusions and prejudice because we tend to 'see' the world through what we know rather that what we actually experience. Indeed, this gives rise to the well-known phenomenon of being blinded by your expertise [53]. But, the fact that the inhibition is dynamic (can be switched off and on), means that in those instances where no decision is reached, the CEO can see the raw details. This presumably occurs in the early stages of learning something that is completely new.

The illustration of Fig. 3 exemplifies the fact that our brain has constructed mental templates (concepts) of the expected, and that we see the world through these templates. Most people in time see a Dalmatian dog immersed in leaves (Fig. 4). This would be impossible unless we had a concept for Dalmatians. So concepts enormously accelerate recognition. But when we showed Fig. 3 to person who was brought up in Africa, and who was unfamiliar with dalmatian dogs, he immediately identified a Hyena - a different animal, facing in the opposite direction (Fig. 5).

Fig. 3. Spots against a white background

Fig. 4. Perceived Dalmatian dog within leaves

He had trouble shifting his interpretation to a Dalmatian even upon prompting. In other words, we see what we know, and are often blind to alternative interpretations. We are blinded by our mindsets [53]. Over the years, many people have identified various objects in Fig. 3, usually those of special significance to their backgrounds, like a Hyena to the African and a vulture to an ornithologist. But, no one offered more than one interpretation in their initial response.

If the dynamic inhibition subserves a computational strategy, then, all other things being equal, we should expect to find a penalty for introducing low- level details, like absolute pitch into the conceptual areas of the left hemisphere. There is evidence that these penalties do exist. For example, Miyazaki and Rakowski [39]

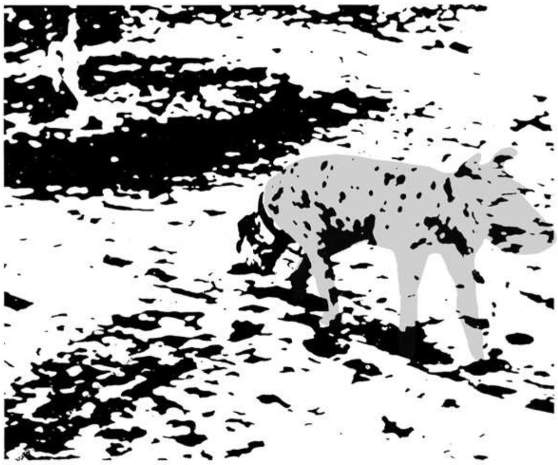

Fig. 5. Hyena

examined the performance of subjects with and without absolute pitch in the recognition of notated melodies [61]. They found the absolute pitch interferes with the recognition of melodies presented aurally transposed relative to the manuscript notation. Also, exceptional recall of seemingly superficial details would also appear to come at a cost in those who otherwise seem to have a healthy mind [32]. And of course, infantile autism, the extreme case of concept deprivation discussed in section 4 above, results in individuals who are overwhelmed with lower level details.

8.2. *Why preserve concept networks beyond their usefulness?*

It would appear that once concepts are formed, they remain tenaciously intact, often well beyond their apparent usefulness. For example, how is irrational fear eradicated? Is the original fear network obliterated or is a new concept network formed that inhibits the initial fear concept network? Recent evidence suggests that the original concept networks are retained, but inhibited [35]. This fits neatly with our view of the formation of metaconcepts (groupings of concepts) in which the concepts that feed the metaconcepts are inhibited from conscious awareness.

The retention of concepts, even when their apparent usefulness is in doubt, is a strategy that facilitates creativity, since it allows for linking seemingly disparate ideas into a new synthesis sometime in the future.

Finally, there may be an evolutionary argument for retaining concept networks. Evolution must proceed through incremental stages. Dismantling old neural structures to build new ones is a more radical approach than using old concepts as building blocks to form new concept networks.

8.3. *Analogies with software engineering*

It is interesting that software engineering has independently exploited some of the strategies we have discussed. The primary goals of software development in the 1990's were robustness and reusability. Both were achieved through object- oriented programming [27], in which data is encapsulated (ie. inhibited from access by other parts of the program) and usually only abstracted versions (concepts) of it are allowed out. Such encapsulation enhanced robustness and also created a Lego-like (concept) plug and play methodology which has had enormous impact in the commercial arena. The ultimate goal is to design software that exhibits creativity like human brains.

9. Conclusions

We have presented a model which captures the strategy used by the brain for concept formation. As the brain develops, 'object' attributes are inhibited from conscious awareness once the 'object' label or concept is solidified, where object is taken in the most general sense. The inhibition is dynamic. It can be switched off and on.

Our theoretical model suggests the possibility of accessing nonconscious 'object' attributes by artificially turning off the part of the brain associated with the appropriate concept network. Accordingly, it is theoretically possible to artificially and temporarily disinhibit the inhibiting circuits associated with the suppression of object attributes and other nonconsicous information. This has major potential implications. For example, we predict that by turning off the appropriate part of the brain it is possible to temporarily restore: absolute pitch, recall for superficial details, to acquire an 'accent free' second language after puberty and even to amplify the creative process itself by allowing a person to have a literal interpretation. Preliminary efforts in this direction have already shown how a person can spot errors in proof reading that were previously missed and how they can dramatically alter their drawing style from a naive childlike style to a more naturalistic style [56].

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