

The relationship between double dissociations and cognitive processes



A relationship implies the way things interconnect and includes ways these groups regard and behave towards one another. Double Dissociations (DDs), modularity and connectionist modeling (CM) will be introduced. Discussions about their strengths and weaknesses, how advances in technology have added value to existing data and possible theoretical models will follow. Research community opinions will be explored as these factors impact the extent to which these processes uphold one another.

Prior to 1960 the brain was primarily understood in terms of behaviorism where human behavior was thought of in actions of stimuli and response rather than through structure and organizational process (Cohen, 2000). Computer technology and cognitive psychology seemed to be a natural match as cognitive psychologists frequently used computers for analogies to explain the human brain. Armed with philosophies concerning modularity scientists started to explore ways in which computer technology could model actions of the human brain (Parkin, 1997).

Cognitive neuropsychology leans on the theoretical framework provided by cognitive psychologists and detailed observation of brain behaviors and is noted for comparing differences between how an intact system works and what happens when it becomes damaged. Parkin (1997) shares an example of the difference between determining function for individual modules of an intact television set. He points out that observing modular failures in the set may be more informative than separating out the multiple components and how they contribute to media transmission. Even if one is ignorant of the workings of a television, by observing consistent mechanical failures it can be noted that it is possible for a television to lose sound and retain a picture

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or to retain the picture and lose the sound. By this it could be assumed that the components are independent of one another. The same principles can be applied to mechanical failure in a car or in the human brain where these observations can be found in the form of Double Dissociation (DDs) (Parkin, 1997).

Dissociation is the process of identifying the neural substrate of a specific area of brain function. DD was a term originally used in statistics where 2 independent variables (IV) have different effects on two dependent variables (DV) where one IV affects DV1 but not DV2 and the second IV affects DV2 but not DV1 (Tauber, 1955). In neuropsychology 2 independent brain areas are functionally dissociated by 2 cognitive tests. DDs are seen as the result of traumatic damage, disease or congenital deformities and offer a window into processes that normally operate in symbiotic ways such as the ability to understand and communicate with language (Parkin, 1997).

DDs are sometimes criticised as reductionist however they can be vital signposts for estimating functional perimeters. DDs are useful for showing what happens when functional impairment occurs in one area of the brain leaving another area intact, while in other individuals the opposite functional pattern emerges (Shallice, 1988). It is challenging to find DDs where there are no mitigating factors or co-morbid conditions and some researchers recommend a classification system to rate DD extent and quality (Shallice, 1988; Parkin, 1997).

DF is an individual with a 'single dissociation'. She sustained Visual Form Agnosia when her ventral stream, the area responsible for the conscious

identification of visual objects became impaired. Visual areas in the dorsal stream needed to identify color and texture remained intact so she could identify fruits and vegetables but was unable to identify a card, even though she was able to push it through a slot. She could draw on long term memory to draw objects but later when asked to identify them could not (Milner and Goodale cited in Datta, 2004). D. B. another person was found to have unconscious/covert visual function, allowing her to do better than chance on forced choice experiments which tests knowledge of areas she claimed not to 'see' (Stoerig & Cowey, 1992).

DDs are noted in the contrast between deep dyslexia and surface dyslexia. The term dyslexia describes disorders of language concerning reading and spelling and can be acquired as the result of trauma or can be present at birth). Deep dyslexics have semantic, visual and reading errors (Plaut & Shallice, 1993), they fail to name pseudo words but can name some exception words indicating the non lexical or visual route remains impaired but the phonological/lexical route was intact. Surface dyslexics can accurately name the pseudo words but demonstrate difficulty when pronouncing exception words such as pint which they pronounce as though it rhymed with lint. This indicates the non lexical/ visual route is intact but the lexical/phonological is impaired (Naish, 2000).

Connectionist modeling (CM) is the process of using the computer to model various components of brain function so the patterns of how they work together can be observed. CMs, like the brain are layered for sequential tasks. The influence of the neuron is based on the strength of its connection and learning or recognition is achieved by altering the strengths of

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connections between learning. In models this is accomplished by assigning weights and connections that are determined by predetermined rules (McLeod, Plunkett & Rolls, 1998) Modeling relies on gaining understanding of cognition through rule-guided transformation of mental representations.

Hinton & Shallice (1991) designed a connectionist model and used this to replicate co-occurrences of semantic and visual errors. After training the model to map from orthography to semantics it was lesioned. Three common network properties were identified to reproduce deep dyslexia, distributed orthographic/ semantic representations, gradient descent learning and attractors for word meanings. A fourth factor proved valuable which consisted of increasing the ratio of concrete to abstract semantics. The network replication proved useful for studying deep dyslexic patterns however may not be an accurate representation of how the brain learns (Plaut & Shallice, 1993).

DD and connectionist modelling have worked together to explore prosopagnosia, (face blindness). Face recognition has been traced to the fusiform area of the brain and because it is domain specific and information encapsulated there are characteristic of modularity present (Carlson, 2007). In Prosopagnosia it is common for face perception to show impairment, while object recognition remains intact (Cohen, 2000). Within prosopagnosia some people retain covert recognition without overt recognition. (De Haan, Young, & Newcombe, 1987) explored this, utilizing behavioural techniques with PH, who sustained trauma related prosopagnosia. PH was only able to recognize two out of multiple faces he was tested on, moreover he was unable to discern famous from common faces above the level of chance, yet he

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retained the ability for covert recognition which was identified by the use of galvanic skin response testing and forced word choice testing where he did better than would be possible by chance.

CM to study prosopagnosia was adapted to investigate whether recognition was sequential and temporally driven and how the information was linked to determine comprehension. (Cohen et al, 2000). It was found significance in the first process is unnecessary for successful execution of the adjacent process and this observation was later strengthened by fMRI findings (Cohen et al, 2000).

Adjustments to face recognition CM were the result of what was already known through DDs about overt and covert recognition. The model allowed repetition of the patterns and the ability to alter parameters to resolve questions about timing versus modular involvement. Hidden layers in the network work to average error across the network and the covert learning is seen in the model. It 'learns' by minimizing error to produce responses for information not directly inputted to the model (Cohen, Johnston & Plunkett, 2000) LaVoi & Naish, (2009) urge that the simplicity of available cognitive models can't mirror the complexity of the human brain and that at best the networks are useful for modeling small tasks.

Cognitive neuroscience was originally dominated by case studies, cognitive modelling in the form of neural networks and carefully developed neuropsychological testing tools. DDs were critical tools for discovery (Parkin, 1997). Modularity was observed through behaviour and confirmed at post mortem or through animal studies. Technology lacked capacity to

ethically observe structural brain changes in living participants. The brain was dissected and stained after death so changes could be observed.

Differences in function were more readily seen by brains that were damaged (Parkin, 1997). DDs provided and continue to contribute valuable information in living patients and in lesioned laboratory animals. Brain impairments can also be explored and charted through case studies of cognitive dysfunction in humans and animals. There is considerable research done with animal models due to ethical and financial constraints. One added advantage of animal studies is that multiple generations can be studied in fewer years than it takes a human to reach maturity (Carlson, 2007). Recently Transcranial Magnetic Stimulation (TMS) technology has been used to approximate a lesioned condition however TMS is temporary and fails to show results of long-term impairments.

Hubel and Wiesel used kittens to demonstrate extended light deprivation during critical periods in development can cause permanent visual impairment. When light was restricted to one eye, the seeing eye took over function; however the kittens failed to develop binocular vision. Research delivered insight for ocular dominance and childhood cataracts (Goldstein, 2001). They contributed to visual neurophysiology by demonstrating how signals from the eye are processed by the brain where they generate detection of motion, edges, color and depth perception (Carlson, 2007). The research supports cortical plasticity studies by revealing plasticity can be developmentally triggered as well as domain specific. Similar activity occurs in hearing and motor domains (Ramachandran, Altschuler, 2009). The brain

is dynamic and adapts in impairment which has implications for modularity assumptions and consequent rehabilitation (Purves, 2008).

A 1949 manuscript cited by Scoville and Milner (1957) reveals findings of significant memory loss in two patients with medial temporal lobe surgery (MTLS including the hippocampus. In 1957 Scoville and Milner warned other surgeons not to overlook the role of the hippocampus which brings us to the study of HM. HM was one of Scoville's patients in 1953 and a victim of MTLS. HM's difficulty began with a bike accident at age seven, initially recovery seemed normal but three years later HM sustained intractable seizures. At age 27, HM underwent experimental surgery in hope of limiting seizure activity. The bilateral medial temporal lobe MTLS reduced seizure activity but also impaired HM's ability to learn new information, mental processing speed, and episodic explicit memory, resulted in language impairment and erased long term memory (Scoville and Milner, 1957; Corkin, 1984; Sagar et al., 1985).

He remained a case study from age seven until after his death at age eighty three. Ironically one of the few individuals he continued to recognize was Dr. Scoville who remained involved with his care until his death. There is no evidence of Scoville blaming others or shirking responsibility for his surgical actions. After HM's death at his request and with the guidance of his guardian, HM's brain was donated to science to help others. HM's brain was dissected and the procedure broadcast online (Science Blogs, 2009)

HM's cognitive impairments spanned memory, visual, and language domains providing a long term picture of how network involvement and

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developmental changes may follow the removal of domain specific anatomy. These impairments were more clearly defined by recent advances in imaging technology such as high definition functional magnetic resonance imaging available in HM's later years however some of the impairments may have been present from the onset of his epilepsy.

Deficits on tests of executive functions and hippocampal involvement are common unusual in epilepsy patients, pre and post surgery. They can be prone to perseveration as well as language and motor skill impairments (Hermann et al., 1988; Horner et al., 1996; Martin et al., 2000; Trener and Jack, 1994). H. M.'s neurological examination in 2005 reveals his medications still included prescribed anti seizure medications, Tegretol, Paxil, and Tegretol-X.

Additionally in 2002-4 when HM's brain was re-scanned extensive white matter damage and corpus callosum fiber and cortical thinning beyond that considered normal for his age group was discovered in addition to the original damage from the resection. This may indicate modular damage can impair the networks and other modules that interface with it.

Initially there was resistance in the medical community to naming the hippocampus as the seat of memory because animal models did not demonstrate the same degree of disruption as HM (Barr, Goldberg, 2003). This cultural mindset and lack of information may have been a factor in Scoville's failure to recognize the earlier warning signs about memory retention and hippocampal involvement. The hippocampus was gradually accepted by the medical community as a structure having domain specific

function that was critical to information encapsulation. More recently it has been noted that memory may have significant network features mediated by paths in the frontal lobes rather than an exclusively domain specific module (Barr, Goldberg, 2003). Case studies such as HM (Henry Molaison) are valuable to cognitive neuroscience as they can show the transition of theory over time and how views on what constitute modularity are subject to change.

There are similar findings where severe childhood brain injury led to widespread long term negative effects on white matter architecture and restricted the potential for brain growth. Damage patterns in the hippocampus indicate the white matter injury may come from the lesions restricting long term cerebral blood flow (Tasker, 2006). Neural network architecture could possibly model patterns of learning but would lack the capacity to predict developmental cascades in organic brain matter (Shallice, 1988).

Scientists such as Broca who identified the segment of brain mainly responsible for language understanding and Wernicke who found areas relative to speech production are examples of how DDs increase understanding of localist function. Broca and Wernicke both researched aphasia post-mortem at the same time period in history and compared cases (Purves, 2008).

Wernicke identified the area of the brain responsible for language comprehension and named it Wernicke's area. Carl Wernicke was the scientist who discerned there was a regional difference between patients

with aphasia dividing those with expressive aphasia (produce language) and those who sustained receptive aphasia (understand language) Wernicke located impaired language patients whose left frontal lobe was intact. These patients experienced language impairments in the area of comprehension and even though their speech was well formed it made little sense. Wernicke found that the area of the brain damaged in these patients was a small area in the left parietal cortex. Wernicke's area is considered responsible for accessing words and decoding them for speech, whereas Broca's patients could understand language but could not transform them into understandable speech (Purves, 2008).

Broca found speech accuracy impairment in expressive aphasia was due to the brain's inability to produce language rather than the mouth failing to produce words. (Purves, 2008) Broca's patients included Leborgne who could only repeat the word tan and Lelong whose vocabulary consisted of only five words. Both patients were found to have lesions in the left frontal lobe an area later named as Broca's area. These patients led Broca to assume speech was region specific in the brain. Broca's area is presumed to be the syntax module and Wernicke's area the semantics module (Purves, 2008). Wernicke and Broca's areas until recently appeared to fill some of Fodor's (2000) conditions for modularity including domain specificity, autonomy and information encapsulation.

The extent of this modularity is being examined in the light of more recent findings incorporating high tesla magnetic resonance imaging (MRI).

Additional damaged areas are now identified as contributing to speech

disruption. It was found that although Broca's area specific lesions can cause <https://assignbuster.com/the-relationship-between-double-dissociations-and-cognitive-processes/>

speech disruption, they are unlikely the source of complete and permanent speech impairment (Dronkers, Plaisant, Iba-Zizen, & Cabanis E (2007).

Additional evidence that Broca's area can be largely destroyed and language can remain intact was presented in a case study involving a computer engineer who had a tumor in Broca's region. The tumor and Broca's area were destroyed but he was able to function with minimal language problems and return to his work 3 months post surgery (Grodzinsky & Santi 2002).

Ongoing problems included an inability to create complex sentences, or relay reported speech. The problems were reported as working memory deficits and his recovery was explained by neural plasticity of the surrounding cortical area and a shift of some function to the right hemisphere (Grodzinsky & Santi 2002). It seems unlikely that working memory could be the causation factor as the occupation he returned to is one highly dependent on working memory access. There is no report of auditory working memory in this individual differing from his visual working memory so it may be that Broca's area is not so easily dismissed (Grodzinsky & Santi 2002).

Figure 1 Broca and Wernicke areas NIH publication 97-4257, <http://www.nidcd.nih.gov/health/voice/aphasia.asp> (accessed 17/04/2010)

Evidence from children who learn to read after a TBI indicate those who relearn reading or recover language may not be as fluent as they were previously (Ewing-cobb, Barnes, 2002). The adverse effects of diffuse axonal injury extend to linguistic development in the areas of discourse processing, lexical development and reading. An analogy could be the functional <https://assignbuster.com/the-relationship-between-double-dissociations-and-cognitive-processes/>

capacity deficit experienced when one injures the 'writing' hand and has to adjust to using the alternate one. It appears the older and more expert a child reader is at the time of injury the better chance they have of functional recovery in the area of language (Ewing-cobb, Barnes, 2002). The areas of working memory and speed of processing for mediating recovery were acknowledged by Ewing-cobb and Barnes as an area for further research.

Functional MRI (fMRI) reveals more explicit localization in the way language is used than that proposed by Broca and Wernicke as evidenced by (Lyons, Mattarella-micke, Cieslak, et al, 2009) who maintain language activates domains and networks beyond the areas commonly ascribed to language processing and that the expanded process influences the language experience.

González, Barros-Loscertales, Pulvermüller, Meseguer, Sanjuán, Belloch, et al. (2006) found that neural areas which access word meaning can include related sensory systems. For instance accessing the meaning of the word vanilla may activate the olfaction and gustatory systems. Action language can activate motor regions used to complete these actions (Lyons et al, 2009). One example (figure 5) shows left dorsal premotor cortex activity. This area is considered central to selection of higher level action plans and contributes to increased comprehension of sport specific and signals increase in strength in accordance with levels of expert learning (Beilock et al., 2008).

This is much like the trend cited by Posner, (2004) in regards to the fusiform area being more than face specific with expert learners. Hickok & Poeppel,

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2007; Vigneau, Beaucousin, Herve, Duffau, Crivello, 2006) found left dorsal premotor cortex activity is modulated by personal experience when category specific action related language is used (figure 5)

Figure 2 Shows brain activation differences between expert and novice hockey players when category specific language is introduced indicating language is also accessed via motor pathways (Lyons, Mattarella-micke, Cieslak, et al, 2009)

This may have profound implications for cognitive rehabilitation when Broca's or Wernicke's area are damaged however it is important to note that in spite of the coordination of other networks these areas are still largely domain specific for functional capacity.

Cognitive models can be supportive in logging where, and to what extent cognitive functioning is systematically impaired or spared. They can offer some insight as to whether the function in question is mainly modular or if it is distributed like a network (Cohen et al, 2000, McLeod, Plunkett, and Rolls, 1998; Parkin, 1993). Present cognitive models lack the processing power to model complex modules and the inclusion of multi sensory network architecture (| Naish, 2000)

The modularity assumption is ascribed to philosopher Fodor who conceptualizes the brain as having modular characteristics and goes on to define modularity as domain specific, autonomous, innately specified, hardwired (neuronal path specific), informationally encapsulated, and not assembled (Coltheart, 1999). Multiple areas of the brain are considered to

have modular characteristics but do not meet all the criteria for Fodor's model by (Cohen, Johnson & Plunkett, 2000).

Fodor insists he has never maintained the brain is modular but only that it contains modular characteristics which he goes on to describe. Fodor (1983) does not believe the mind is 'massively modular' explainable by computational or excessively modular models, instead his emphasis is on the function of a mental state rather than its biology and he maintains modularity can be by degrees rather than on an all or nothing basis (Fodor, 2000). Fodor (1983) gave his model (figure 2) three components. The transducers act like perception whose task is to convert precepts or stimuli into signals for neurons. The input systems he envisions interpret the information within mainly modular platforms. The central system operates as an executive system

Fodor suggests basic aspects of vision, and language have modular characteristics and

Fodor describes the central system as responsible for reasoning, problem solving analysis and making choices as network mediated (Fodor, 2000). The diagram below shows a limitation of this model in that it is feed forward only without feedback networks.

Figure 3 Fodor, J. A. (1983) the Modularity of Mind, MIT Press/Bradford Books

Scientists such as Posner, 2003; Gordon, Arns & Paul, 2008 and Williams, Brown,, Palmer, Liddell, Kemp, Olivieri, et al. 2006) have credited neural network models as learning tools from which they have derived theoretical

models of how the brain learns (Posner & Carr, 1992) Two of these models will be briefly described to demonstrate that neural networks contribute to the understanding of the functional patterns of the brain.

Rennie, (2001) a physicist, models the large-scale electrical activity of the brain and mapped the neuronal activity from temporal and localist assumptions. His model has contributed to the development of the integrate theory model where conceptual knowledge of cognition, biology, modelling, physics and even psychiatry are combined to propose how the brain integrates cognitive and emotional feedback (Gordon, Arns, Paul, 2008).

The integrate model could allow for cognitive function based on fight/flight mechanisms and internal/external motivators while still retaining the modular aspects. Although the integrate model was conceptualized by information accessed by observing Rennie's cognitive modelling of the brain, contributions of genomics, neuropsychology, psychiatry, case studies, neuro-imaging and meta analysis are in use to further develop the model (Gordon, Arns, Paul, 2008). This model explores age and temperament stimulus processing changes, and possibilities for personalized psycho-active drug formulation. Fight /flight response is represented in how emotion is processed and its affect on language response. In this model there is feedback and feed forward mechanisms at all levels (Williams, Brown, Palmer, Liddell, Kemp, Olivieri, et al. (2006).

Figure 4 Integrate Model <http://brainNET.net> (accessed 11/04/2010)

Posner employed cognitive modelling networks investigating patterns for attention which informed his theory on executive attention networks and <https://assignbuster.com/the-relationship-between-double-dissociations-and-cognitive-processes/>

assisted the design of attentional network training for children (Posner & Rothbart, 2007). This computer training module used in his research demonstrates functional neural plasticity in that long-term gains in attention, language skills, working memory, visual perception and executive functioning are observed (Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, T. 2009). The advantages extend to near and far transfer tasks such as language acquisition, working memory and cognitive load capacity.

Posner describes the brain as a network but does not deny domain specificity plays a role in identifying localization. His emphasis is on mental states, a position similar to Fodor, (Posner & Rothbart, 2005). Posner refers findings which favour localized mental operations as an opportunity to explore neural plasticity and uses elements of face processing to support his position. Posner references the common activation that occurs in the fusiform area when experts think about a domain of expertise rather than an exclusive face recognition task. He maintains that if we see localizations in the form of mental operations it would be natural for to share operations in common (Posner, 2004). In fact (Corbetta & Shulman, 2002) show localization of separate mental operations within the parietal lobe which merge with a larger network to align attention to specific targets (McCandliss, Cohen, & Dehaene, 2003) Posner and Tang (2009) have recently explored attention state models and how they influence learning and communication. See a diagram of Posner's conceptual model below:

Posner model of localization of aspects of executive attention states www.dana.org/NEWS/cerebrum/detail.aspx?id=23206 accessed (14/04/2010)

The relationship between DDs and the modularity of cognitive processes in conjunction with the role CMs play is informed by ongoing research. Ellis and Young (1988) indicate unearthing a double dissociation, is only a starting point as processes and the aspects they mediate in common need careful identification. Crowder (1972) comments investigating the necessity of a two process theory may be more informative than the properties of individual processes (Plaut, 2003).

DDs and CMs may oversimplify functional processes leading to distorted perceptions of neuroanatomical systems. Dividing executive function and episodic memory may undermine mutual network connections to temporal lobe systems, (Barr, Goldberg, 2003) DDs are useful for showing what happens when functional impairment occurs in one area of the brain leaving another area intact, while in other individuals the opposite functional pattern emerges (Parkin, 1997). The correlations can act as a reference in a similar way to a labelled fuse box which points the way to the specific appliance that caused an overload malfunction in the system. Fuses can be individually tested for function and the electrical impairment can be isolated for further review.

CM simulates to some extent how patterns can develop in response to stimuli and injury. CMs work on an input in/out basis and as a result are unable to account for the complexities of phenotype variations influencing cognition (Naish, 2000). The patterns themselves are more concrete than

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abstract concepts and this may lead to insights about how specific cognitive processes work.

FMRI, TMS, Galvanic skin response, single cell electrical recording, Magnetoencephalography, Quantitative encephalography, Positron emission tomography, Single photon emission computed tomography methods all allow neuro-anatomical functional observations with living individuals/animals. This informs understanding about modularity and the interaction of adjacent structures. It is important to note that each technology has limitations, MRI with temporal resolution, MEG and QEEG with spatial resolutions. With TMS artificial lesions can be created without harm to living participants by means of magnetic stimulation however, this process is time limited and can produce artefacts. These methods add to the foundation laid by early cognitive neuroscience and in some cases lead to confirmation or disputes about the original findings (Carlson, 2007).

Bowers (2009, 2010) for instance notes single cell recordings may be consistent with localist coding rather than a distributed model based on the fact that neurons in the hippocampus and certain areas of the cortex may selectively respond to one stimulus out of many. His assumption is that because the IA word identification model uses single units to code for specific units it is not distributed. Parallel Distributed Processing networks (PDP)s rely on graded constraints and interactivity to determine actions that are consistent with the systems knowledge as determined by connection weights between units. However, (Plaut and McClelland, 2010) claim PDP neural network could learn localist grandmother cells in training specific learning conditions.

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The CMs are built from mathematical formulas using incomplete knowledge, they can be useful for showing patterns however it is illogical to expect them to uphold something they were only created to simulate and this thinking leads to unintentional error in interpretation. Statistically constructed mathematical computer models are built by the National Institute of Highway Safety to assess levels of diffuse axonal brain injury using squid axons (IIHS, 2007). These axons are electrical synaptic models rather than the chemical synaptic structure commonly found in human brains. Chemical synapses are less robust and more vulnerable to secondary cell death than the electrical synaptic structure (Roberts, 2005). Myelination damage cannot be measured by squid axon models. The resulting inaccuracies prejudice compensation claims for diffuse axonal injury survivors who often sustain language and vision impairments as the squid axon model can survive higher impact without brain damage. (Price, 2007)

Cohen reports being disturbed by the ad hoc tinkering of connectionists trying to make the model work. Naish retorts that if connectionists 'tinker' it is only to appear to model what neuro-physiologists claim to have found. He notes the complexity of the brain and notes this leave cases open for contamination by extraneous variables (Naish, 2009). Parkin (1997) states DDs may contain co-morbidities and research will reflect this. Literature tends to report simple conditions because they are easier to understand (Naish, 2009). Rebuttals can include neuro-psychologists calling connectionists 'tinkerers' and connectionists accusing neuro-psychologists of 'cherry picking' cases. This may reflect frustrations of research demands in a rapidly evolving field.

Hinton reports CMs require labelled training data and most data learning relevant data is not constrained by labels. The signals CMs attempt to replicate require different equations than biological neural signals creating comparative discrepancies (Hinton, 2010). The brain processes data for 10^{14} labels @ 10^9 per second, well beyond what computers present