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Editorial da 1ª edição
Inteligência Coletiva e Ambientes Interativos

Responsável pela edição:
Prof. Dr. Sérgio Roclaw Basbaum

O conjunto de artigos que o leitor ora acessa constitui o primeiro número da publicação eletrônica da TECCOGS, que tem como objetivo dar visibilidade e recorte às áreas de conhecimento tratadas no “Programa de Pós-Graduação em Tecnologias da Inteligência e Design Digital” (TIDD) da PUC-SP. Proposta audaciosa e inovadora, como o é a do TIDD, vem promover e fomentar a pesquisa sobre a interface homem-máquina, numa sociedade mediada e operacionalizada por aparatos tecnológicos. O TIDD posiciona-se, assim, com o olhar voltado para os desafios do futuro, para a compreensão dos processos tecnológicos e sociais em curso, com base em três linhas de pesquisa: Aprendizagem e Semiótica Cognitiva, Inteligência Coletiva e Ambientes Interativos, Design Digital e Redes. Desse modo, coloca-se numa interseção marcadamente interdisciplinar, em que temas normalmente do âmbito das ciências humanas são convidados a aproximar-se das pesquisas tecnológicas de ponta e dos problemas das inteligências artificiais, na constatação de que não há mais horizonte na cultura em que o ser humano não se veja interagindo, servindo-se e definindo-se mesmo na interação com diversos tipos de aparatos tecnológicos, chamados já tantas vezes, e provavelmente de modo insuficiente, de "próteses" - que assumem presentemente a forma de computadores pessoais, notebooks, celulares, consoles de jogos, dispositivos móveis, tablets etc...

A questão da cognição, e das chamadas Ciências da Cognição (em inglês, usualmente Cognitive Science), que se articulam em torno deste problema, envolve hoje um número crescente de disciplinas, que vão desde a filosofia da mente e da consciência - num leque que vai do puramente lógico à filosofia de estilo fenomenológico -, avançando em direção à antropologia, à cultura, à semiótica e à linguística cognitiva, à psicologia, e então até às ciências mais "duras" da computação e da inteligência artificial aplicadas ao software e a modelos maquínicos, à robótica, e finalmente a biologia e as neurociências. O campo é amplo e desafiador, a discussão ainda aberta, o que convida um número crescente de pesquisadores a buscar inserção nesse debate - nas Américas, na Europa, na Ásia. Em tal debate pode-se acompanhar desde as já em si imensamente amplas e controversas discussões sobre a (própria definição de) consciência, cognição e inteligência, até as diferentes formas de compreensão da educação - das mais transformadoras, e formadoras, às mais instrucionais e, portanto, informadoras -, passando pelas várias linhas de abordagem da linguagem, em seu âmbito lógico, semiótico, linguístico e hipermidiático, bem como as questões da psicologia, da cultura e do corpo biológico e pós-biológico. Diante do escopo da questão, o que trazemos ao leitor é um recorte significativo de artigos originais, propositivos, que testemunham o vigor e a atualidade destas questões, oferecendo uma porta de entrada às discussões contemporâneas.

O artigo do Prof. João Fernandes Teixeira, "Some Remarks On The Logic And Epistemology Of Computation", dirige-se a uma questão que já aponta, de saída, as dificuldades crescentes e a importância da área: para que seja possível conceber a idéia de uma máquina que simule ou realize a inteligência humana, seria necessário superar limites já de há muito apontados no modelo de máquina proposto por Turing na primeira metade do século XX (1936). Os casos mais conhecidos de crítica a essa computação "clássica" são os artigos de Lucas na década de 1960, e os trabalhos mais recentes de Penrose, na década de 1990: a mente artificial não seria capaz de lidar com paradoxos, nem tampouco conceber as premissas (intuitivas) não dedutíveis do sistema, como demonstrou, falando de modo muito simplificado, o lógico austríaco Kurt Gödel, ainda na década de 1930. Como caminho para a solução de tais impasses, Teixeira recorre a recursos da lógica paraconsistente que vem sendo desenvolvida no Brasil a partir dos trabalhos de Newton da Costa, para mostrar que paradoxos e posições aparentemente incomputáveis podem ser formalizadas numa lógica não clássica que reflita, por exemplo o modo de operação da inteligência senso-comum, aquela que opera no cotidiano do mundo real, enfrentando problemas reais.

Se Teixeira se dirige a questões de um fundo lógico que deve formalizar as possibilidades e limites do pensamento, em "A Cournotian Approach to the Emergence of Relational Collectives", Carlos Lungarzo *e* Alfredo Pereira Júnior buscam, por sua vez, tratar a questão da funcionalidade das áreas cerebrais buscando ultrapassar as noções localizacionistas clássicas (como mostra a entrevista de João Teixeira, o localizacionismo é ainda um paradigma extremamente presente, quiçá dominante mesmo, a despeito das muitas refutações e de contradições já amplamente apontadas) por meio da descrição dos processos biológicos que poderiam dar sustentação à emergência das propriedades cognitivas da mente. Segundo Lungarzo e Pereira Jr., as funções cognitivas seriam mais adequadamente descritas como propriedades relacionais ao invés de funções matemáticas. Interessantemente, se Teixeira sugere o caminho de uma computação analógica para refutar as críticas mais fortes às possibilidades de desenvolvimento da inteligência artificial, Lungarzo e Pereira Jr. sugerem que "*inferências partindo de estruturas cerebrais para as atividades mentais são raciocínio semântico baseado em similaridades*"; de tal forma, que, de algum, modo, poder-se-ia sugerir, são as propriedades análogas às da metáfora que se colocam em jogo para resolver os impasses dos modelos computacionais clássicos da inteligência. Vale notar que Lungarzo e Pereira Jr. procuram remontar a operações biológicas do cérebro para sustentar suas proposições, o que representa um estilo distinto daquele da lógica formal em que se dá a discussão conduzida por Teixeira. Não é possível determinar qual destas abordagens - uma de uma lógica formal aplicada aos sistemas vivos outra no âmbito das possibilidades meramente formais - teria precedência: ambas se co-implicam, se determinam e desafiam todo o tempo, num território intensamente interdisciplinar. Como localizar estruturas físicas (ou não físicas) que permitam a emergência de algo como a mente humana sem ter disponíveis modelos formais do que possa ser tal mente, e daquilo que deva ser buscado? Como tem defendido David Chalmers, precisamos de todas as abordagens e definições que formos capazes de produzir, tal a amplitude do fenômeno da consciência e do desafio aí colocado.

Também interessantemente, a questão da percepção se coloca: naturalmente, quaisquer modelos ou representações que possamos construir do real, sejam eles baseados em estruturas e categorias cognitivas a priori ou não, dependem de que se perceba um mundo. O debate sobre a percepção abre uma dobra igualmente ampla no debate, e alguns aspectos dessa discussão estão aqui representados na questão da sinestesia, discutida no artigo do Prof. Cretien Van Campen. Ao longo dos últimos 20 anos, especialmente, o fenômeno da sinestesia - fusão sensória, tradução do estímulo endereçado a um sentido numa experiência associada a outro sentido (por exemplo ouvir sons e ver cores) - vem sendo retomado como possível modo de compreender questões da percepção, da mente, da cognição e da consciência. Fascinante, até mesmo revestido de uma certa aura de mistério, o tema da sinestesia também tem sido intensamente associado às poéticas digitais e a aspectos da intensa carga de sensações agenciada pelas redes digitais e pelos ambientes hipermidiáticos. Van Campen, na linha proposta em seu livro *The Hidden Sense* (MIT Press, 2006), sugere que a sinestesia deva ser entendida não como um fenômeno que articula modularidades estanques relacionadas aos estímulos perceptivos, mas como espaços entre, como um outro sentido que pode ser percebido por qualquer um que volte sua atenção ao modo como percebe o mundo, verificando em sua relação com o ambiente o modo como as sensações se complementam e se associam de modo conjunto e integrado, de modo singular em cada indivíduo - e é daí que este autor também sugere a importância de uma educação para os sentidos. O tema é amplo, como todos que atravessam a revista e o programa: mas o trabalho de Van Campen tem como contribuição em especial, no âmbito desta edição, não apenas fazer um valioso inventário de diferentes momentos da história da filosofia em seu tratamento da questão da percepção, como o mérito de trazer também a questão da cultura de algum modo ao escopo dos artigos.

A edição se completa com uma entrevista e três resenhas de livros recentemente publicados. A entrevista com o Prof. João Fernandes Teixeira, realizada pela Profa. Ana Guimarães permite compreender um pouco da trajetória deste pesquisador que é hoje um dos mais importantes em atividade no país, a maturação de suas posições mais recentes e os desafios que se colocam ao campo hoje, no Brasil e no mundo. As resenhas cobrem livros de Cláudio Costa (Filosofia da Mente: Jorge Zahar Editor, 2005), Jorge Albuquerque Vieira (Ciência: Formas de conhecimento – arte e ciência. Uma visão partir da complexidade (Vol. 2): Expressão Gráfica e Editora, 2007) e Alex Primo (Interação mediada por computador: comunicação, cibercultura, cognição: Sulina, 2008), que ampliam o leque de debates proposto pelo TIDD e pela revista, permitindo ao leitor com interesse nas áreas de pesquisa do programa, aventurar-se nas questões das relações entre filosofia, neurociência e cognição, no entendimento da natureza do pensamento científico e nas possibilidades cognitivas abertas ou agenciadas pelos aparatos digitais. Vale destacar nesta edição, o empenho da Profa. Lúcia Santaella, coordenadora do PPG-TIDD, sem cuja determinação, esta revista não seria possível; bem como o empenho das professoras Lucila Pesce, Ana Guimarães Jorge e Cândida Almeida - esta última responsável pelo projeto gráfico da revista. Desejamos a todos uma boa leitura!

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São Paulo, dezembro de 2008

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Como ler a filosofia da mente

ENTREVISTA com Prof. Dr. JOÃO DE FERNANDES TEIXEIRA[1]

Por Prof. Dr. Ana Maria Guimarães Jorge*

João de Fernandes Teixeira bacharelou-se em filosofia pela USP e obteve o grau de mestre em lógica e filosofia da ciência na UNICAMP. É PhD. pela University of Essex, Inglaterra. Fez pós-doutorado no Centro de Estudos Cognitivos da Tufts University, em Boston, tendo como orientador o Prof. Daniel Dennett. É pesquisador do CNPq. Integra o programa de pós-graduação em filosofia da Universidade Federal de São Carlos onde é professor titular.É também professor convidado no TIDD da PUC-SP. Publicou vários livros na área de filosofia da mente e ciência cognitiva, dentre os quais se destacam Filosofia da Mente e Inteligência Artificial (Edições CLE-UNICAMP, segunda edição 2006), Mente, Cérebro e Cognição (Vozes, terceira edição 2008) Filosofia e Ciência Cognitiva (Vozes, 2004) e Filosofia da Mente: neurociência, cognição e comportamento (Claraluz, 2005).

1. **Poderia fazer um relato sobre sua trajetória nos estudos da cognição? O que esse livro atual "Como ler a filosofia da mente" representa a essa altura de sua ação de pesquisador?**

Comecei a me interessar por ciência cognitiva e filosofia da mente no início da década de 1980, quando era aluno do mestrado em lógica e filosofia da ciência na UNICAMP. Em seguida houve dois grandes episódios que marcaram minha formação nessa área: meu doutorado na Inglaterra, onde vivi por quatro anos e meu pós-doutorado nos Estados Unidos, dez anos depois, com Daniel Dennett. Ao longo de toda essa trajetória, que já dura mais de 20 anos, posso dizer que mantive uma motivação filosófica fundamental: o estudo do problema mente-cérebro-consciência. Quanto ao "Como ler a Filosofia da Mente" este é meu nono livro. Meu primeiro publiquei em 1990, na coleção Primeiros Passos, da Editora Brasiliense, chamava-se "O que é Inteligência Artificial" e hoje está esgotado. De lá para cá muita água rolou sob a ponte. Escrevi vários tipos de livros, alguns paradidáticos, outros de divulgação e outros onde expus algumas de minhas idéias acerca de mente e cognição. Alguns foram bem recebidos, outros não.

O objetivo do livro que publico agora é dito logo na primeira página: apresentar a filosofia da mente em 60 minutos, sem perder a precisão e a seriedade que o assunto requer. O convite que recebi da Editora Paulus, para iniciar a coleção "Como ler Filosofia" nesse formato foi um verdadeiro desafio. Sigo, assim, a idéia

[1] Entrevista baseada no recente livro de João Teixeira Fernandes, **Como ler a filosofia da mente.** São Paulo: Paulus, 2008.

mestra dessa coleção: fazer um livro simples, curto, de linguagem acessível, para ser usado por alunos de graduação em filosofia, psicologia, ciência da computação e áreas afins. Por causa desse formato, ele é um livro muito barato: custa apenas dez reais.

Mas é preciso estar atento para o fato de que, embora o propósito central do livro seja expositivo, o livro possui o mérito de sustentar algumas teses que podem ser polêmicas, que se não forem entendidas pelos neófitos o será pelos iniciados. Um exemplo disso é a sugestão de que algumas posições wittgensteinianas não poderiam ser mantidas depois do aparecimento da neuroimagem - que sugiro na forma de uma provocação ao leitor que ler o capítulo sobre o materialismo. Arrisco também algumas especulações acerca da relação entre neuroimagem e filosofia da mente. Não resisti também à tentação de adicionar algumas pitadas de humor em algumas passagens, como, por exemplo, no capítulo sobre Descartes e também quando digo que os materialistas têm medo de assombração.

2. Como vê a dissociação e a unificação dos termos mente-corpo e mente-cérebro?

Essa é uma ótima questão. No que diz respeito às relações entre mente e cérebro não vejo com simpatia as posições reducionistas. Isso quer dizer: não tenho simpatia por projetos teóricos que visam à redução do mental ao cerebral. Defendo um materialismo não-reducionista. A mente não se reduz ao cérebro, da mesma maneira que no jogo de xadrez as regras e estratégias não se reduzem à composição físico-química do tabuleiro e das peças. Mas isso não é dualismo. O jogo de xadrez tem uma realidade independente do material que utilizamos para fazer as peças e o tabuleiro, mas não haveria jogo de xadrez se não dispuséssemos de algum material para representar o tabuleiro, as peças, e as regras. Não podemos suprimir inteiramente o material com o qual construímos um tabuleiro e suas peças. Essa é a idéia do materialismo não-reducionista.

Ora, essa posição foi muito defendida pelos filósofos da mente da década de 1970, que a batizaram com o nome de funcionalismo. Eles diziam que a mente era o software do cérebro (hardware). Mas o que eles mais enfatizavam era que o substrato material da mente poderia ser variado indefinidamente. Com isso eles queriam justificar a possibilidade de que dispositivos que não têm a mesma composição físico-química de nosso cérebro, como, por exemplo, os computadores, também podem ter uma vida mental, dependendo de seu software.

Esse tipo de funcionalismo da década de 1970 é uma posição muito exagerada e quase ninguém o defende hoje em dia. Pois ela implica que qualquer dispositivo, desde que possa efetuar computações, poderia, em princípio, instanciar uma mente.

Talvez meu notebook pudesse adquirir uma mente se tivesse o software adequado.

Ora, atribuir todo esse peso somente ao software é algo questionável.Não podemos mais ignorar o papel do cérebro na produção da mente. Por outro lado, parece que a neurociência hoje em dia quer passar a idéia de que somente seres dotados de um cérebro semelhante ao nosso poderiam pensar e ter experiências conscientes, como se somente os pássaros pudessem voar e não os aviões, por serem estes últimos feitos de metal e não terem asas.

Mas um novo tipo de funcionalismo está aparecendo e, com ele, uma nova maneira de conceber o materialismo não-reducionista. Esse novo funcionalismo está surgindo da necessidade urgente de se pensar a interseção entre a robótica e a neurociência, o que é, hoje em dia, um grande desafio para a ciência cognitiva. A robótica tem mostrado que precisamos de dispositivos específicos para simular comportamento inteligente e, também, que isso não é privilégio de cérebros humanos.

3. Ao longo dos anos, a comunidade científica mundial vem atribuindo diferentes sentidos a diversos princípios conceituais. Como os limites entre "consciência" e "mente" são definidos em processos de investigação experimentais?

O problema é que eles não são bem definidos. Se você pegar um livro como o de Crick e Koch "The Astonishing Hypothesis" vai verificar que eles usam o termo "consciência" como se fosse sinônimo de mente. Contudo, se você ler algumas páginas do "The Conscious Mind" de David Chalmers, vai verificar que os termos não são definidos de modo sinonímico.

Há também uma grande confusão entre os sentidos da palavra "consciência", que às vezes é usada como se designasse "mente" e outras como se designasse "autoconsciência". Não bastasse isso, há a confusão suscitada pela língua inglesa, que fala de "awareness" e "consciousness".

Creio que dificilmente chegaremos a um consenso quando se fala de consciência e tampouco se mente e consciencia são a mesma coisa como quer uma grande maioria de neurocientistas. É por isso que será difícil um dia aceitarmos como *definitiva qualquer teoria da consciência que nos seja apresentada, seja por filósofos, seja por cientistas. Na verdade não sabemos exatamente do que estamos falando e a confusão lingüística/semântica é reflexo disso.*

4. Há possibilidade de se conceber que haja conhecimento imediato dos conteúdos mentais? E a mediação nesse processo de autoconsciência sobre o que se pensa no momento em que se pensa?

Descartes achava que temos acesso direto ao conteúdo de nossos pensamentos. E, de fato, não precisamos de nenhum tipo de instrumento para acessarmos nossa mente; esse acesso parece ser imediato, o que já não ocorre, por exemplo, com o nosso fígado. Precisamos fazer no mínimo uma radiografia do nosso fígado para saber o que está acontecendo nele. Nesse sentido, Descartes parecia ter razão.

Hoje já não temos certeza se sabemos tudo o que pensamos, pois há quem acredite na existência de crenças inconscientes, ou seja, de estados mentais cujo conteúdo seria inconsciente. Não acreditamos mais que mente seja co-extensiva à consciência. Mas acho que nem Descartes parecia acreditar nisso. Ele teria sido mal interpretado. Outro dia estive lendo uma carta que ele endereçou ao padre Gibieuf onde ele praticamente admite a existência de um inconsciente.....Veja só!

5. Quais os pontos fracos e fortes do "localismo" como tendência de investigação cognitiva e que tipo de relevância tem para seus estudos atuais?

Temos aí duas premissas que divergem, ou seja, que não acredito que possam ser aproximadas.

Localizacionismo e holismo / equipotencialismo cerebral são posições opostas. Hoje em dia a neurociência optou pelo localizacionismo, pois acha que sua principal tarefa é elaborar um mapa do cérebro. Haveria regiões especializadas no cérebro, cada uma responsável por uma determinada função. Cada uma corresponderia a um determinado "mecanismo cerebral". O holismo acredita no oposto; que o cérebro funciona "por mutirão" onde todas as regiões colaboram num determinado momento para executar uma tarefa.

A neuroimagem contribuiu muito para o localizacionismo, mas mesmo assim ainda não há um consenso quanto ao modelo de cérebro que deva ser adotado. Sabemos hoje que a funções cognitivas básicas correspondem áreas especializadas do cérebro, o que nos impulsionaria em direção ao localizacionismo, mas ainda não se chegou à mesma conclusão quanto às chamadas funções cognitivas superiores ou complexas.

Como todos os filósofos da mente, tenho acompanhado de perto a evolução desse tipo de investigação. Seus resultados influenciarão de forma decisiva o modo de conceber a mente. Há quem pense que o localizacionismo nos levará inevitavelmente ao reducionismo, o que seria mais difícil no caso do holismo/equipotencialismo onde a idéia de uma "função distribuída" não nos permitiria uma equação tão rápida entre função cognitiva e área cerebral/grupo de neurônios.

6. **Quanto à afirmação, em termos locais, que estados mentais podem ser reduzidos a estados cerebrais (neuroimagem), o que é entendido como *qualia* estaria ignorado nesse processo?**

Penso que os qualia continuarão indetectáveis pela neuroimagem. Se pensar em algo "amarelo" faz com que a mesma região do meu cérebro e do seu cérebro cintile, ainda assim não há como detectar, pela neuroimagem, se o amarelo que estou percebendo é mais intenso do que o seu. Creio que o problema dos qualia é ainda um grande desafio a ser enfrentado pela ciência.

7. **O que vem a ser o contato causal entre o físico e o mental? A ligação entre físico e mental sempre foi explicada com base num tipo de causalidade (causa-efeito / ação-reação)?**

Não sabemos ainda como esse contato ocorre, tampouco se ele de fato ocorre. Há algumas hipóteses neurológicas, mas ainda especulativas. E, em geral, o que se quer explicar é como o mental pode causar algo no mundo físico, seja um comportamento ou uma alteração no corpo. Esse é o problema da causação mental, que atualmente desafia os filósofos da mente. Queremos saber como é possível um estado mental modificar o nosso corpo, como é possível "morrer de amor", como *nos diz Antonio Damásio. Se antes se tentava saber como a matéria poderia afetar a mente, agora parece que o problema se inverteu: é preciso explicar o contrário, que embora seja algo intuitivo e que possamos observar no dia-a-dia ainda permanece um mistério. Como um aborrecimento pode alterar meu corpo? "Aborrecimento" não é algo subjetivo, um estado mental que pode afetar uns e não outros? Como o aspecto subjetivo de um estado mental pode ter força causal?*

8. Como concebe o futuro dos estudos de filosofia da mente e de ciência cognitiva no Brasil?

Nos últimos anos tem havido uma verdadeira explosão de interesse pelos estudos de ciência cognitiva e filosofia da mente. Para se ter uma idéia, há dois anos inaugurei um site, "Filosofia da Mente no Brasil" www.filosofiadamente.org só com material da área em português. Esse site já teve mais de 6.000 visitantes. Há um interesse crescente por filosofia da mente por parte de estudantes de filosofia, psicologia e ciência da computação. Estudos que relacionem mente e cérebro são uma grande inquietação na segunda metade do século XX e no século XXI. No Brasil isso não é exceção, embora estejamos longe de atribuir-lhes a mesma importância e os mesmos investimentos que lhes são destinados nos Estados Unidos, no Canadá, na China e na Europa.

Mas a academia brasileira tem sido míope. O despreparo e a desatualização de nossos docentes traduziu-se em preconceito contra essas novas disciplinas. O caso da filosofia é o pior. Ao contrário do que se poderia esperar, alguns professores de filosofia no Brasil ainda são extremamente dogmáticos e avessos a qualquer novidade.

A academia sempre foi historicamente míope em toda parte do mundo. Mas no Brasil há um fator agravante: sua incapacidade de se organizar impede o desenvolvimento de iniciativas interdisciplinares. Isso está levando há muitos equívocos. Um deles é essa moda atual de achar que ciência cognitiva é neurociência, ou melhor, apenas neurociência. Estamos desenvolvendo uma geração de neurocientistas que, como diz uma colega minha, "querem pegar pensamento com pinça".

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SOME REMARKS ON THE LOGIC AND EPISTEMOLOGY OF COMPUTATION

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ABSTRACT

The paper focuses on some logical and epistemological aspects of the notion of computation. The first part questions the Church-Turing thesis as a fundamental principle concerning the limits of computation and some of its consequences for Philosophy of Mind and Cognitive Science. The second part discusses one of the main presumptions of the traditional conception of computability, namely, its reliance on the absolute character of classical logic which is taken as an underlying framework.

The aim of this paper is twofold. First, I shall present some shortcomings of the standard conception of computation based on what was termed Church´s Thesis, i.e., the claim that the class of functions which can be computed by machines is identical to the class of functions that can be computed by Turing machines. Second, I shall emphatically point to a further theoretical limitation of our current, orthodox conception of computation, namely, its assumption of classical logic as the definitive background from which one could decide what machines can compute. Finally, I shall briefly examine some of the consequences of these two lines of criticism to Philosophy of Mind and to Cognitive Science. The inheritance of Church´s Thesis as well as of the assumption of classical logic as an absolute constraint to machine computation seem to have originated a myth - the myth that Turing´s article of 1936 sets forth once and for all the limits of what *any* machine can compute. Such a mythical interpretation of Turing´s conception of computation also gives rise to endless discussions concerning the existence of non-computable cognitive activities and possible asymmetries between minds and machines or human brains and machines. Examples of the inheritance of this mythical red herring are the work of John Lucas (1961) and, more recently, of Roger Penrose (1989, 1994). Furthermore, I suggest that philosophers of mind and cognitive scientists were too hasty in dispensing with the physical-symbol classical cognitivist approach to Artificial Intelligence. As we shall see, the rejection of the view that the brain´s cognitive activity can be simulated by a computing machine takes for granted the theoretical limitations we refer to, and, without offering a supporting argument, shun the possibility that the human brain might be a non-classical computing machine.

I

What reasons can we avail ourselves to question the absolute character of Church´s Thesis? Is there computation beyond Turing-machine computation? Or is Turing computation the upper bound of our theoretical resources to conceive of computation? I shall press the claim that there is more to computation than what our classical framework deploys. Moreover, I shall outline what I consider to be some serious cracks in the orthodox conception of computation.

To begin with, Turing´s view of computation presented in his paper of 1936 takes for granted that the range of computable functions coincides with what can be done by a human being acting in accordance to an algorithm. The algorithm is a mimicry of what human beings perform when they realize an effective procedure. But no one seems to have ever questioned why the limits of human computation and the limits of machine computation are to overlap. (Wittgenstein in his Philosophical Investigations sec. 1096 ascertained that : "Turing Machines: These machines are *humans* who calculate") Such a mimic conception of computation seems to be implicitly encompassed by Church´s Thesis. The latter ascertains that the range of what is computable is identical to the range of what is computable by a Turing machine, and, in so doing, it implicitly endorses the view that no physical or notional device which could, in principle, compute beyond what human beings can compute. But we shall return to this point later on.

Turing was aware that his conception of computation quickly led to what seemed to be an insurmountable limitation, i.e., the problem of uncomputable functions. For example, his conception of computation was restricted to the set of the integers; real numbers were to be excluded as uncomputable. Moreover, there were uncomputable functions even amongst the integers, namely, his famous "halting function" which gave rise to his Halting Theorem. The recognition of such constraints seems to be the *leitmotiv* of Turing´s Ph.D. thesis, published in 1939 and yet systematically overlooked by contemporary cognitive scientists. In this thesis Turing introduced what he called "oracle-machines" or O-Machines, i.e., ordinary Turing Machines augmented with a primitive operation set to return the value of uncomputable functions on the integers. Nonetheless, Turing has never provided an explanation of how an O-machine was supposed to perform its operation: oracles were black boxes. In neither case (1936, 1939) does Turing offer a discussion of what mechanisms should occupy these black boxes.

Contemporary cognitive scientists would rather not be reminded of the quick boundaries of the orthodox conception of computation. They leave this task to the apocaliptical knights who wish to proclaim the failure of the mechanical model of mentality. Still, many of the theoretical conundrums raised by the issue of the non-algorithmicality of some human cognitive functions could be avoided if we eschew the orthodox interpretation of Church´s Thesis. I believe such a task begins to be accomplished, and that, to such a goal, emerging work on alternative conceptions of computation is of paramount importance. No less important is the idea that the traditional notion of computation starts to be shaken, both by conceptual and technological changes.

Let us consider, for instance, some alternatives to discrete, Turing-machine computation. In an influential paper, Copeland (1997) calls attention upon the recent revival of analog computing machines as well as the role of analogical representation. There are analog machines which cannot be modeled as Turing Machines. However, such analog machines can perform computations which cannot be accomplished by Turing Machines.

How do such analog machines work? To begin with, they differ of Turing Machines so long as they process analog representations. Analogical is any representation whose structure corresponds to that of which it represents. For instance, the longer a line on a map, the longer the road line it represents. Following the same strand, numerical quantities can be represented by potential difference in an electric analog computer. But the importance of analogical representation and of analog computers strikes us once they allow us to build machines which can perform computations which *cannot* be carried out by Turing machines. Copeland (1997) provides an example of such an analog computer, an idealized, *notional* machine (as are Turing machines) he labels M1.

M1 is devised to represent continuously valued physical magnitudes; so, let us suppose that M1 represents electrical charges and that any real number can be represented by some quantity of charge. M1 is a simple device, with a very simple programmable control structure. When the representation of a real number x is presented as input, M1 delivers a representation of $3x$ as output. Since x may be either a computable number or an uncomputable number, M1 computes an uncomputable function.

The action of M1 can only be *approximately* simulated by a Turing machine if for any real number *x* and for any integer *k*, some Turing machine provides the first *k* places of a decimal representation of *x* and the first *k* places of 3*x*. But even the possibility of an *approximation* between M1 and a Turing machine is highly questionable, for it presupposes a demonstration that the action of an analogue computer can always be described and simulated on a digital machine. Such a demonstration, as far as I know, has not been attained so far. So viewed, M1 is a typical example that there may exist computations which are not carried out by Turing machines. Or, in other words, the notional existence of a machine such as M1 is a counterexample to Church´s Thesis.

In addition to analogue computers, connectionism can also provide examples of computation over real numbers which break away from Church´s Thesis. For reasons of space, I shall not revise the available literature on this topic, though it is fair at least to mention some who have taken the subject-matter seriously: McClelland and Rumelhart (1986), Smolensky (1988), Garzon & Franklin (1989), Wolpert & McLennan (1993), Siegelmann & Sontag (1994), and Korb (1996).

It would be enough to refer to analogue computation and to connectionism as providing vivid examples that *machine computation* cannot be taken as synonym of *Turing-machine computation*. However, there is another line of attack to Church´s Thesis which is worth mentioning. At the outset of this section, I have emphasized that one of the main assumptions of Turing´s notion of computation is the implicit equation between the limits of human and machine computation. We may suppose that such an implicit equation is blurred once we consider quantum computation. The speed of quantum computation cannot be attained by any human being. In this sense, quantum computation breaks away from orthodox computation, *but only in this sense*: the uncomputability of the halting function does remain in quantum computation despite the increase in velocity. The same applies to all classical limitations pointed by Turing.

II

We shall now turn to a brief examination of one of the main assumptions of the orthodox conception of computation, namely, the absolute character of the standard recursion theory and of the framework provided by classical logic. Surely classical logic was the paradigm of the thirties and the forties, but from that it does not follow that classical logic should be taken as an absolute presumption when one conceives of computation nowadays. Why can´t we rethink the orthodox notion of computation in the light of non-classical logic?

The absolutist character of orthodox computation and of classical logic go hand in hand. But once we abandon such an assumption we may also discard some classical, orthodox limitations to computation which fill out our traditional, cherished textbooks. The most striking result which emerges from the rejection of classical logic as an absolutist paradigm is the possibility of devising alternatives to the Halting Theorem.

In a former paper of mine (Teixeira & Sarmento, 1997) I have shown that by using DaCosta´s paraconsistent logic C_1+ it is possible to ascertain the existence of an algorithm for the problem of non-terminating computations. Our claim for the existence of a Halting Algorithm can either be envisaged as an extra pattern of reasoning of classical logic allowed by C_1+ or as a particular application of C_1+ - an application which shows that Turing´s Halting Theorem is valid only on the assumption that human reasoning can be fully represented by classical logic.

Let us recall the statement of the Halting Theorem and its proof : Given an arbitrary Turing Machine program P and an arbitrary set of input data set I , there does not exist a single Turing Machine program that halts after a finite number of steps, and that will tell us if P will ever finish processing the input I .

Proof: Once computable sequences are enumerable, consider a_n as being the nth. computable sequence and $\phi_n(m)$ the mth. representation in a_n . Be β the sequence taking
$1-\phi_n(n)$ as its nth. representation. Once β is computable there does not exist a number k such that $1-\phi_n(n)= \phi_k(n)$ for every n. If we take n=k it follows that $1=2\phi_k(k)$. *Absurd.* Therefore, computable sequences are *not* enumerable.

A more intuitive understanding of the Halting Theorem and of its proof can be given by the following example. Let us consider a computation on a natural number *n*. If we call such a computation $C_{(n)}$ we can conceive it as providing a family of computations where there is a separate computation for each natural number, 0,1,2,3...i.e., the computations C(0),C(1), C(2),C(3)...C(*n*) are the action of some Turing Machine (TM) on the number *n*, taken as the machine input.

Suppose we have some computational procedure *A* which, when it terminates provides a demonstration that a computation such as C(*n*) does not ever stop. If in any particular case *A* itself ever comes to an end, this would provide us with a demonstration that the particular computation that it refers to does not ever stop. Furthermore, we say that *A* is sound if it does not give us wrong answers. For, if *A* were unsound, then it would erroneously assert that the computation C(*n*) does not ever terminate when in fact it does. But if this is the case, the performing of the actual computation C(*n*) would eventually lead to a refutation of *A.*

In order for *A* to apply to computations generally, we shall need a way of coding all the different computations C(*n*) so that *A* can use this coding for its action. All the possible different computations C can in fact be listed as:

C_0, C_1, C_2, C_3, C_4 ...,

and we can refer to C_q as the *q*th.computation. When such a computation is applied to a particular number *n* we shall write:

$C_0(n), C_1(n), C_2(n), C_3(n), C_4(n)$,....

This ordering can be viewed as a numerical ordering of computer programs. Moreover, this listing is *computable* i.e., there is a single computation $C_\bullet$ which gives us C_q when it is presented with *q*, or, in other words, the computation $C_\bullet$ acts on the *pair* of numbers, *q,n* (*q* followed by *n*) to give $C_q(n)$.

The procedure *A* can now be thought of as a particular computation that, when presented with the pair of numbers *q,n,* tries to ascertain that the computation $C_q(n)$ will never halt. Thus, when the computation *A terminates* we have a demonstration that $C_q(n)$ *does not halt*. Being dependent on the two numbers *q* and *n*, the computation that *A* performs can be written *A*(*q,n*), and we have:

(1) If *A*(*q,n*) stops, then $C_q(n)$ does not stop.

Now let us consider the particular statements (1) for which *q* is put equal to *n*. With *q* equal to *n*, we now have:

(2) If *A*(*n,n*) stops, then $C_n(n)$ does not stop.

We notice that $A(n,n)$ depends upon just *one* number, n, not two, so it must be one of the computations C_0,C_1,C_2,C_3.. (as applied to n), since this was supposed to be a listing of *all* the computations which can be performed on a single natural number n. Let us suppose that it is in fact C_k, so we have:

(3) $A(n,n) = C_k(n)$.

Now examine the particular value $n=k$. From (3) we have:

(4) $A(k,k) = C_k(k)$.

and from (2), with $n=k$

(5) If $A(k,k)$ stops, then $C_k(k)$ does not stop.

Substituting (4) in (5) we find:

(6) If $C_k(k)$ stops, then $C_k(k)$ does not stop.

From this we deduce that the computation $C_k(k)$ does *not* in fact stop, for, if it did, then it does not, according to (6). But $A(k,k)$ cannot stop either, since by (4) it is the *same* as $C_k(k)$. Therefore, our procedure A cannot ascertain that this particular computation $C_k(k)$ does not stop even though it does not.

According to such a presentation the unsolvability of Turing´s Halting Problem is derived from the second part of Cantor's diagonal slash:

(5) - If $A(k,k)$ stops, then $C_k(k)$ does not stop.

Substituting (4) in (5) we find:

(6) - If $C_k(k)$ stops, then $C_k(k)$ does not stop.

Furthermore, we saw that from this we must deduce that the computation $C_k(k)$ does *not* in fact stop. For if it did then it does not, according to (6). But $A(k,k)$ cannot stop either, since by

(4) $A(k,k) = C_k(k)$

it is the *same* as $C_k(k)$. Thus our procedure A is incapable of ascertaining that this particular computation $C_k(k)$ does not stop even though it does not. The existence of A is denied for it implies a contradiction. Since $A(k,k) = C_k(k)$ we can write:

(7) If $A(k,k)$ stops, $C_k(k)$ does not stop.

(8) If $A(k,k)$ does not stop, $C_k(k)$ does not stop.

(7) and (8) can be rewritten in the form:

(9) *A* is sound,

and

(10) *A* is not sound.

A cannot exist for it encompasses a contradiction.

Nevertheless, it is agreed on this formulation of Turing´s Halting Problem that

(11) If *A* is sound *A(k,k)* stops and $C_k(k)$ does not stop; *A(k,k)* does not stop and $C_k(k)$ stops.

Now if we consider such a formulation of Turing´s Halting Problem in the light of paraconsistent reasoning (and by contrast to classical logic) one cannot infer that

(12) If *A(k,k)* does not stop, $C_k(k)$ does not stop.

Since in the light of paraconsistent reasoning one cannot infer the truth of (12) from (9) and (10) we can ascertain that the existence of *A* is possible. Such an ontological assertion is supported by paraconsistent reasoning derived from C_1+ which, by contrast to classical logic, does not lead to trivialization in the presence of contradictions.

As it is also remarked by Copeland (1997b), the proof of the Halting Theorem proceeds by *reductio* but, in a paraconsistent setting the derivation of a contradiction is insufficient for rejecting the assumption that leads to it, namely, the assumption that *there may exist* a Turing machine capable of computing the halting function. Such a result displays a further horizon for computing theory, i.e., the possibility of developing the new emerging field of *paraconsistent computability theory*.

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III

Since C_1+ is mechanisable (for it is axiomatisable) we can plausibly sustain that mental processes involved in solving the problem of terminating/non-terminating computations may result from algorithmic procedures. Once we can represent our own reasoning pointing to the existence of a Halting Algorithm as the result of a mechanical process we can shun the alleged impossibility of modeling cognition without having to appeal to some piece of “intuitive” understanding which would remain inexplicable - a cornerstone assumption which underlies the thesis that there are non-computable or non-algorithmic processes in human cognition. This mythical red herring marshaled by John Lucas (1961) and by Roger Penrose (1989, 1994) as the main plank to criticize the physical-symbol classical cognitivist approach to Artificial Intelligence cannot be sustained unless one gullibly ascertain its two major assumptions: that human minds (or brains) are *classical* logical machines and that machine computation can be equated to *Turing-machine* computation. Perhaps human minds are very powerful formal systems - systems whose strength is likely to be derivable from their intrinsic inconsistency which allows them to compute *more* than the classical systems they construct. Such a powerful and inconsistent formal system manifests in what is currently labeled *common-sense*.

REFERENCES

Copeland, B.J. (1997) - "The broad conception of Computation" - **American Behavioral Scientist**, **40**: 6 pp.690-716.

Copeland, B.J. (1997b) - "**On the relativity of computability**" (forthcoming).

Garzon, M. & Franklin, S. (1989) - "**Neural computability: II. Abstract**" - *Proceedings of the IJCNN - International Joint Conference on Neural Networks*, I, pp.631-637.

Korb,K.B. (1996)- "**Symbolicism and connectionism: AI back at a joint point**" In D.L. Dowe, K.B. Korb & J.J. Oliver (eds) - *Information, statistic and induction in science*, Singapore: World Scientific pp.247-257

Lucas, J.R. (1961) - "**Minds, machines and Gödel**" *Philosophy* **36**, pp.120-124.

Penrose, R.(1989) - **The Emperor´s New Mind** , Oxford U.K., Oxford U.P.

Penrose, R. (1994) - **Shadows of the mind: A search for the missing science of consciousness**, Oxford U.K., Oxford U.P.

Rumelhart, D.E., McClelland, J.L. & the PDP Research Group (1986) - **Parallel distributed processing: Explorations in the microstructure of cognition, Vol. I, Foundations**. Cambridge: The MIT Press.

Siegelmann, H.T. & Sontag, E.D. (1994) - "**Analog computation via neural networks" - Theoretical Computer Science**, **131** pp. 331-360.

Smolensky, P. (1988) - "**On the proper treatment of connectionism" - Behavioral and Brain Sciences**, **11** pp. 1-23.

Teixeira, J.de F. & Sarmento, G. - "**Solving Turing´s Halting Problem?**" (forthcoming)

Turing, A. M. (1936) - "**On computable numbers, with an application to the Entscheidungsproblem**" - *Proceedings of the London Mathematical Society,* **42**, pp.230-65.

Turing, A.M. (1939) - Systems of Logic Based on Ordinals. **Proceedings of the London Mathematical Society**, **45**, pp.161-228.

Wolpert, D.H. & McLennan, B.J. (1993) - **A computationally universal field computer that is purely linear** - (Technical Report 93-09-056) Santa Fe, NM: Santa Fe Institute.

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REVISTA DIGITAL DE TECNOLOGIAS COGNITIVAS

The Hidden Sense: On Becoming Aware of Synesthesia[1]

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Synesthetic perception in science and art

Synesthesia has received much attention in science, art and in particular in the overlapping fields of digital art and multimedia in the last decade (cf. Collopy 2000, Brougher et al. 2005, Ward 2008). Artists and scientists in these fields share a common interest in human perception. In the arts, synesthesia refers to a range of phenomena of simultaneous perception of two or more stimuli as one gestalt experience (van Campen 2007). In neuroscience, synesthesia is more strictly defined as "the elicitation of perceptual experiences in the absence of the normal sensory stimulation" (Ward & Mattingley 2006: 130).

About one in twenty-three persons has a type of 'neurological' synesthesia (Simner et al. 2006). Over 50 types have been reported (Day 2008), and people differ in intensity of the experience (cf. Dixon et al. 2004). The most common type of synesthesia is colored weekdays, while the type of perceiving colored letters and numbers is most studied by scientists, and the type of colored sound and music is most explored by artists (van Campen 2007).

The neuroscientific definition of synesthesia limits the number of so-called 'synesthetes' to 4% in the population. This number contrasts with the large amount of people who are interested in art forms that present synesthetic experiences to the public.

This raises questions like: is synesthesia genetically fixed at birth? Or is there a range of types of synesthetic perceptions in which a genetical disposition for synesthesia can be developed? How wide is that range? How do biological, social and cultural factors interact in this process? How do people develop different synesthetic sensibilities?

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[1] This article is an adapted and elaborated version of parts of the final chapter of my book The Hidden Sense: Synesthesia in Art and Science (Cambridge MA: MIT Press 2007).

Slightly different from the current neuroscientific view on 'neurological synesthesia', I will propose in this article a new view on synesthesia that also includes social and cultural interactions, which I assume will account better for individual differences in the awareness of synesthesia.[2]

Synesthesia in philosophical perspective

The ancient Greek philosophers observed that humans have separate sense organs –eyes, ears, nose– but at the same time also have one undivided experience. This raised the question of how sensory experiences are unified. The ancient philosophers did not define synesthesia in our current neurological and psychological terms, but they expressed a notion of synesthesia in posing the philosophical question: How can human beings perceive a unity in the multitude of sensory impressions (i.e. the unity of experience)?

The answer offered by the Greek philosopher Aristotle (384 BC–322 BC) was not only original then, but has stayed valid to our day. Behind the exterior senses, he assumed the existence of what came to be called a *sensus communis*, which perceives the common qualities (or qualia) in the different exterior senses (Ferwerda & Struycken 2001). For instance, we perceive brightness, rhythm, and intensity in images, sounds, smells, odors, and tactile sensations (By the way, our notion of *common sense*, though the modern definition is slightly different, nonetheless is derived from this concept.)

Aristotle's ideas had a great influence on medieval thought at the time when a theory of the working of human perception was established known as the 'three-chamber theory'. The medieval Italian theologian Thomas Aquinas (1225–1274) posited the existence of three chambers in the human brain. In the first chamber, the sensory impressions, sent by the exterior senses, were perceived by the common sense (*sensus communis*), which stimulated imagination (*imaginativa* and *fantasia*). In the second chamber, cognition (*cogitativa*), reason (*ratio*), and judgment (*aestimativa*) determined value with the help of former perceptions from memories (*memorativa*), which were housed in the third chamber (Adler & Zeuch 2002). This theory, which retained its power for centuries, entered Renaissance

[2] Due to media attention, the people awareness of 'neurological synesthesia' has increased tremendously in the last decades. The estimated prevalence of colored-letter synesthesia in the mid 1990s was 1 in 2,000 (Baron-Cohen et al. 1996), and has recently increased to 1 in 100 (Simner et al. 2006).

thought with only slight changes. The Italian renaissance artist Leonardo da Vinci shared the Thomist principles, but he located the *sensus communis* in a more central position, within the second chamber.

The idea of a common sense explains a large part of human multisensory perceptions, but it does not explain synesthetic perceptions nor their variety among individuals. One, it is not common to perceive sounds in color; and two, the disagreement of synesthetes on, say, the 'right' color of a musical tone, cannot exactly derive from common sense.

During the Enlightenment and, later, the Romantic period, a number of philosophers acknowledged individual differences in the common sensory perception of the physical environment. The eighteenth-century German philosopher Alexander Gottlieb Baumgarten (1714–1762), who was the founder of aesthetics as a philosophical discipline, stated that not only the human intellect but also the human senses have the ability to know (van Campen 1994). The cognition of the senses, however, differs from rational cognition by the human intellect because whereas the intellect uses rational principles such as logic, the senses immediately perceive aesthetic qualities in sensory impressions.

One example is the ability to perceive a melody in a series of sounds. A melody is a form that is perceived by common sense as a meaningful unity, or *Gestalt*, as it would later be named by German philosophers. In France, the philosopher Jean-Jacques Rousseau made a similar distinction between the *raison sensitive* and the *raison intellectuelle* (Adler & Zeuch 2002).

For the first time in history, philosophers regarded the senses as active, creative organs of human perception. And it was recognized that humans differed in their abilities to use common sense. Some people are more gifted, more creative, and more susceptible to qualities of nature than others.

In the late eighteenth century, the German philosopher Immanuel Kant (1724–1804) made an important distinction between the *sensus communis*, which he said was equal for all humans, and the *sensus communis aestheticus*, which he said showed individual differences (Kant 1790). All people have the common sense to perceive the rhythm in a dance, or in the percussion in a musical piece, and even that these rhythms may match. Fewer people, however, have the aesthetic sense to perceive color nuances in the sound of a cello. Though these examples are taken from the present, the conceptual distinction by Kant gave room to categorize what I have called 'synchronesthetic' and synesthetic perceptions (van Campen 2007, chapter 9). The *sensus communis* is a common gift to perceive matching qualities in different sensory domains. The *sensus communis aestheticus* is a personal gift of perceiving special aesthetic qualities in multisensory domains. The German poet and naturalist Johann Wolfgang von Goethe (1749–1832) drew on Kant's idea of the *sensus communis aestheticus* and considered it an autonomous creative force of the human imagination (van Campen 1994).

These theories were developed in the field of aesthetics. Synesthetic perceptions are not always beautiful or aesthetic, according to numerous reports by synesthetes. In the beginning of the twentieth century, the aesthetic theory of gestalt perception (after the German "Gestalt") was reformulated as a more general theory of human perception (van Campen 1994). In this view, not the idea of universal beauty was considered central to gestalt perception, but rather the inner necessity of the perception. For instance, the perception of a melody is a fundamental component of anyone's perception, whether one likes the melody or not (Arnheim 1954).

Gestalt psychologists such as Max Wertheimer, Wolfgang Köhler, Erich von Hornbostel and others, proposed a radical new view of human perception in the first decades of the twentieth century (Arnheim 1954, van Campen 1994). According to this new view, when one looks out of an open window, one does not compose a view as from a mosaic of optical, auditory, olfactory, and tactile little precious stones, but rather one immediately perceives the view as an integral image or a gestalt, of, say, horses, trees, and flowers. Only when one focusses on a detail −distinct colors, figures, sounds, and smells− one notices the component elements.

Still, this gestalt theory does not yet satisfy all the questions raised by synesthetic perceptions. Some people are more sentient than others in perceiving gestalts in the environment, but how does one explain that one synesthete perceives it as the sound of a piano as a purple haze, while another perceives it as the taste of a strawberry-flavored ice cream?

Around the 1950s, the French philosopher Maurice Merleau-Ponty elaborated on the individual differences in gestalt perceptions. According to his view, all human experiences are based in the human body, which explains the unity of the senses. The body is not only a physical thing, but is rather a subjective sense organ for each person. All kinds of stimulation of one's body create responses that mingle in a flux of impressions before one becomes aware of them. In fact, the body shapes sensory experiences on an unconscious level ('under sea level', so to speak) and one is aware only of the tip of the iceberg. Unconscious body experience is essentially synesthetic, according to Merleau-Ponty (1945). All sensory impressions correspond and talk to each other on a preconscious level. Out of this preconscious flux of impressions, some gestalts emerge. And since everybody's body experience is personal, the emerging gestalts are similarly personal, and thus different from each other.

These gestalts are 'givens' in human experience −experiential facts. Only when you start to consider them do you become aware that they are different from others', according to Merleau-Ponty. A synesthete may perceive a deep blue *K*, but only when he abstracts from this experience does he observe separately the color blue and the letter *K*, and can think of the fact of their correspondence. In his initial experience, the color-and-letter combination is a gestalt, a necessary unity.

Several contemporary thinkers have articulated this philosophy of the unity of the senses in light of self-reports by synesthetes and results of scientific experiments. The American psychologist Lawrence Marks (1978) has adopted the Aristotelian idea of common sensualities, such as brightness, in his matching studies. He adheres to the theory that all sensory systems have evolved from the skin and are in fact still interconnected with this large sense organ that forms the basis for the unity of the senses. The American neurologist Richard Cytowic (2002) has searched for a brain equivalent of this bodily unity of the senses and suggested to look at the limbic system, a part of the brain which has evolved as a function of general bodily functions such as nurturing, caring and fighting.

Finally, as heirs of Goethe's theory of the organic creative power of human perception, the German neuropsychologist Hinderk Emrich (2002) and the American neuropsychologist Vilayanur Ramachandran (2004) have pointed to the plasticity of the brain as responsible for making possible the autonomous organization and reorganization of sensory information.

A New View

Continuing this line of philosophical thought, I have reached for a new view on synesthesia, or, more accurately, a new perspective on a field of synesthesias, as I think that the plural form suits the variety in descriptions by synesthetes better. Not only in my interviews, but also in the discussion lists on the Internet, one can observe the great variety in synesthetic descriptions (Day 2008, van Campen 2007). Lists of types of synesthesia contain over fifty categories (Day 2008). And even if one asks synesthetes within one category to describe their experience of, say, colored letters, the responses may differ greatly in intensity, form, and location (Hubbard et al. 2005). For instance, some synesthetes will say that colored letters appear before their inner eye, whereas others report projections of color that lie as shadows on printed letters (Dixon et al. 2004). The perceived colors differ in form, spatial arrangement, transparency, solidity, intensity, and nuance. Instead of being a well-defined area of perception, synesthesia appears in these reports as a set of related perceptual phenomena that show a great variety in form and intensity.

Nonetheless, the wide variety in types of reported synesthesia shows a cultural bias. As far as I know, no synesthete has reported odored-taste synesthesia, since that is common experience in Western culture. Westerners normally do not distinguish sharply between smells and tastes. But Western synesthetes would report colored-smell synesthesia, which is generally uncommon in Western culture. Conversely, the Desana in the Amazon area commonly experience smell in color ('color energies'), and so they would not report that as an uncommon synesthesia (Classen 1993). This example shows that reports of synesthesia may be partly biased by the culture one lives in (Howes 2005).

Not all synesthetes are equally aware of their synesthetic perceptions. We rely on the reports by self-conscious synesthetes. Obviously, one needs to be aware of one's synesthetic perceptions to report them. Many synesthetes only become aware of their synesthesia when, in the course of social intercourse with family and peers at an early age −when they are about five or six years old−, they realize that it is a perceptual oddity. After this first sudden discovery, synesthetes become aware of more aspects of their synesthesias, often in social exchange with other synesthetes. Some grown-up synesthetes report that they still discover new layers in their synesthetic perception of the physical environment (van Campen 2007).

Inspired by the theory of Merleau-Ponty, I picture the wide variety of synesthesias as conscious or semiconscious sustainable, solid, perceivable gestalts that emerge like shapes in the stream of a river. They are layered, come clear to the surface, or lie just beneath it. When they make sense, they are solidified, fixated as gestalts in daily perception, like a familiar melody. Once one has perceived a melody in separate notes, each time one hears this sequence of notes, one perceives the melody forever as a unity instead of its constituent parts.

In general, people are not aware of all their perceptions. And synesthetes are not aware of all their synesthetic perceptions, either. When you get older you become more aware of the layeredness of the tangible world. As a child you perceive, say, red and blue. As you get older you learn to distinguish many kinds of blues and reds. Your awareness of the perceptible world is deepened and refined. In this way, not all synesthesias will be perceptible from childhood. Not that one were not able to see them as a child, but as one grows up one is more aware of their existence. Many synesthetes remember their synesthesias in childhood, but only became aware of them as such when they, say, read a newspaper article on synesthesia.

Our awareness of the number of sensory organs might serve as an analogy. Most people are aware of five senses: vision, hearing, taste, smell, and touch. When additional senses –such as movement and balance – are mentioned, people easily become aware of more sense organs. They have always used these sense organs, but they were not really aware of them.

The same holds for synesthesia and other multisensory perceptions. To a certain extent, people can become aware of the 'darkness' of sounds or of the musical rhythm in visual animations. To a limited extent, people are simply not aware of many synesthesias because they have never paid serious attention to them. Most people are only familiar with a small number of provinces of the empire of the senses. It is as though one's conscious perception was limited to a little garden in the middle of a jungle. One tasted the five types of vegetables that grow in the garden and overlooked the exotic fruits in the surrounding jungle.

I do not think that every person can become aware of all types of synesthesia. There are obviously brain constraints on that. But I do think that many persons are not aware of their synesthetic potential, simply because they use only a portion of their senses.

In general people link their sensory perceptions to exterior senses; color perceptions to their eyes, or sound perception to their ears. Synesthesia is not connected to an exterior sense organ. Synesthetic experiences do not enter the body at one point, whence they flow to consciousness. Synesthesia is not grounded in an external sense organ. It is not an ordinary sensory function. Synesthesia operates in the area between the senses. Its etymology –*syn*: together; *esthesia*: perceiving– refers to this function. The sense of synesthesia is not observable at the exterior human body, but lies hidden beneath the senses. It remains hidden in most people who do not have synesthetic perceptions. But in some it stands up, and they perceive synesthesia consciously.

Finally, these and other observations served me as steps to a new view on the wide panorama of personal reports of synesthesias. I have come to see them as personally developed abilities to perceive uncommon multisensory gestalts in the physical environment. I would compare this ability to a hidden sense. It may take a person a lifetime to unveil the hidden sense that allows her to perceive synesthesias in the physical environment.

Awareness of synesthesia

Can you become aware of synesthesia? Yes indeed, though it may take a long time and a lot of concentration. You have to learn without examples, because synesthesia is personal, and there is no educational program available to help you. You will have to find it all by yourself. You cannot imitate another synesthete or follow his or her suggestions, either.

One way to begin is to become aware of common sensual correspondences like those in the rhythms in music and film, or the correspondences in the 'brightness' of the sound of vowels and colors. Once you have trained yourself to be aware of these common sensualities, you can start to explore your personal sensualities and perhaps discover your synesthesias, though no guarantees can be given, of course.

It may sound strange to hear that you can become aware of a neurological phenomenon that seems fixed and hard-wired. On the contrary, the brain is flexible and will develop multisensory connections that are meaningful (Pascual-Leone & Hamilton 2001, Sur et al. 1990). Synesthesia is hidden in the senses. To experience it consciously, you will have to explore and go looking for it.

Though the awareness of synesthesia most commonly emerges in childhood, I believe one can become aware of it and start to use it at any age. Synesthetes report that they have become aware of their synesthesias in all stages of life. Some discover their synesthetic gifts as preschool children, some in the years when they learn language and math in school, and some as grown-ups. Nonetheless, when adults become aware of it, they report that it was already existent in their childhood (van Campen 2007).

Presumably everyone is born with a kind of synesthesia. During the first year of life, this general synesthesia apparently is cut back or pruned to fewer intersensory connections (Maurer & Mondloch 2004). In the second year and later, the synesthetic connections will only survive when they probably are useful to the child; otherwise they are pruned away. So at a young school age everybody will have a number of neural synesthetic connections, some more than others, and some people are more aware of it than others. Several children know already at the age of seven that their numbers are colored, whereas other children only realize it decades later, when they are tested with a consistency test for colored numbers, for instance.

For a number of children in the ages of about three to six, it is quite normal for music to have colors, tastes, or smells (Werner 1934). You can ask young children and perhaps they will tell you about it. When children go to primary school and start to learn cognitive skills such as writing and calculating, their synesthetic gifts seem to subside into the background. The cognitive training asks much of their concentration and energy. Little energy is left to explore their sensory skills. Take, for example, the decrease in drawing skills and imagination at that age, which is reported by teachers and child psychologists alike (Werner 1934, Eisner 1979).

Learning the letters of the alphabet and counting numbers is an important moment in the development of children and in particular of synesthetes, because at this phase the symbols get their solidified colors. It is the earliest age synesthetes can remember consciously when numbers and letters have their particular colors and shapes.

During the school years and adolescence, socialization becomes a factor in the awareness of synesthesia. Children do not like to be different from their peers. They do not want to be ridiculed. Announcing that you perceive letters and numbers in color may seem rather deviant in the eyes of the other children of your age. Little is known of the social processes that influence the awareness of synesthesia. So far, scientists have been more interested in the neurological and perceptual aspects and less in the social development of young synesthetes.

Even among adults, the reactions of others play an important role in the way synesthetes deal with their perceptual gifts. Only a few decades ago, synesthetes would regularly consult neurologists for medical advice concerning their 'deviant perceptions'. In this medical setting, synesthesia was often considered a neurological deviance or a rare disease by nonsynesthetes. The neurological label that has been attached to synesthesia might still inhibit a number of synesthetes from speaking freely about their synesthetic perceptions. In this light, it is revealing that relatively more synesthetes in liberal and artistic communities report in public on their synesthetic abilities.

In general, people's reactions to the confessions by synesthetes are still stigmatizing. Do not underestimate the number of people who think that synesthesia is a mental handicap. Moreover, because synesthesia is not visible, people often doubt the veracity of what synesthetes report: "Behave normally" is a common reaction.

The fact is that synesthetes do behave normally. It is people in their social surroundings who react strangely to their confessions. Hopefully, once synesthetes get recognition, they may eventually be compared to late medieval artists who started to see and use linear perspective in their paintings, and who were stigmatized and ridiculed at that time. Now, we honor them as innovators who taught us to see the sensory world in new ways.

Awakening to the multisensory perceptions is one key to synesthesia, but other keys are exposing oneself to new sensations, not being ashamed, expressing one's synesthesia, communicating it to others, being able to experiment with it – all are important in the learning process that starts somewhere in childhood with the neurological development of multisensory connections and continues as a lifelong journey in becoming aware of all synesthesia's sensory aspects.

The role of synesthetic art in education

Young children look at the world differently than adults do. For preschool children, the boundaries between themselves and their surroundings are less sharp than for grown-ups. As we know, preschool children and even some children of the primary school age perceive their environment as a magical world where puppets and castles come alive (Werner 1934). The same holds for their bodies and the incorporated senses. Compared to grown-ups, children are less aware of their body as an entity separate from the environment. In their perception, an 'angry castle' may move forward and make growling sounds when it smells the dragon in the mountains. This is an example of a perception that can be very vivid for a young child. I do not say that children cannot distinguish between images and sounds, but only that the boundaries between the senses, their bodies, and the outside world can be more or less sharp from day to day, and from one mood to another. The child can even act out being the 'angry castle'.

Grown-ups are more analytical. If they sense their synesthesias, they will analyze their perceptions into the well-known sensory categories. Saying that you perceive colored sounds implicitly contains the analysis of the original perception into two abstract categories: colors and sounds (Merleau-Ponty 1945). Young children do not yet perceive in an analytical way, and an adult might have great difficulty explaining to a young child that his or her perceptions consist of separate elements like colors and sounds. For the child, the color and sound form an indivisible whole, a gestalt that cannot be separated into elements without losing its meaning and sense. And I must say, the child is right. The adult sticks to a theory of synesthesia, while the child sticks to the original perception. Young children do not often distinguish between sensory domains in their perceptions: a smelling sound may be as real for a child as a green rectangle −who knows?

Once children go to school, their sensory development is squeezed between the main lessons in cognitive development and the less-valued lessons in physical development. In the end, children are judged in school on their cognitive skills, not on physical and sensory skills. Most schools pay little attention to the sensory development of their children. The ability of children to know the world not only by means of words and numbers but also by their own senses, let alone the awareness of their synesthetic abilities, is hardly developed at school. Consequently, multisensory development is in effect halted by neglect. I believe that children would profit from a rebalancing of cognitive and physical-sensory skills in the school program. They would have more opportunities to preserve their synesthetic talents and develop them.

For a long time we have taught our children at school that sensory experiences are separated into five senses according to the Western division, which is based on the exterior characteristics of eyes, ears, mouth, nose, and skin. We do not teach children to follow their own senses and we do not encourage them to explore their multisensory experiences of the environment. How different is the case for the children of the Desana, who grow up in a culture where they are familiarized from the cradle with the multisensory color energies of objects? It is this difference that makes the Desana children more aware of the 'synesthetic' color energies of sounds, tastes, and odors than their North American and European peers.

When Western children enter adolescence they start looking for new stimuli, to explore and test their environments. New and experimental art forms are challenges for their brains. Experimental art forms challenge the regular ways of perceiving via the five sensory domains that they have learned in school, and open ways to multisensory perceptions in audiovisual art forms, for example. It is easier for them to discover colored patterns in a new piece of electronic music than in the well-known *Four Seasons* by Vivaldi because they have learned from their parents and teachers how to listen to the Italian composer, but not how they should listen to new electronic music or an audiovisual digital work of art. Experimental art forms have a viable function in helping people find new ways of experiencing and perceiving, including synesthesia.

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References

Adler, H., and U. Zeuch. **Synästhesie: Interferenz, Transfer, Synthese der Sinne**. Wurzburg: Königshausen & Neumann, 2002.

Arnheim, R. **Art and Visual Perception: A Psychology of the Creative Eye**. Berkeley: University of California Press, 1954.

Baron-Cohen, S., et al. "Synaesthesia: Prevalence and Familiality." **Perception 25**(1996): 1073–79.

Brougher, B., J. Strick, A. Wiseman, and J. Zilczer, eds. **Visual Music: Synaesthesia in Art and Music Since 1900**. London: Thames & Hudson, 2005.

Campen, C. van. **The Hidden Sense: Synesthesia in Art and Science**. Cambridge MA: MIT Press 2007.

Campen, C. van. **Gestalt van Goethe tot Gibson. Theorieën over het zien van schoonheid en orde**. (Gestalt from Goethe to Gibson. Theories on the vision of beauty and order). Utrecht: Utrecht University, Ph.D thesis, 1994.

Classen, C. **Worlds of Sense**. London: Routledge, 1993.

Cytowic, R. E. **Synaesthesia: A Union of the Senses**. Cambridge, Mass.: MIT Press, 2002.

Collopy, F. "Color, Form, and Motion. Dimensions of a Musical Art of Light." **Leonardo** 33, no. 5(2000): 355–60.

Day, S. **Types of synesthesia**. http://home.comcast.net/~sean.day/html/types.htm. Accessed on August 7, 2008.

Dixon, M., D. Smilek, and P. M. Merikle. "Not All Synaesthetes Are Created Equal: Projector Versus Associator Synaesthetes." **Cognitive Affective and Behavioral Neuroscience** 4, no. 3(2004): 335–43.

Eisner, E.W. (1979) **The educational imagination: on the design and evaluation of school programs.** New York: Macmillan.

Emrich, H. M., U. Schneider, and M. Zedler. **Welche Farbe hat der Montag?** Stuttgart: Hirzel, 2002.

Ferwerda, R., and P. Struycken. **"Aristoteles" Over kleuren**. Budel, Netherlands: Damon, 2001.

Gage, J. **Colour and Culture: Practice and Meaning from Antiquity to Abstraction**. London: Thames & Hudson, 1993.

Howes, D. (ed.) **Empire of the Senses. The Sensual Culture Reader**. Oxford: Berg, 2005.

Hubbard, E. M., et al. "Individual Differences Among Grapheme-Color Synesthetes: Brain-Behavior Correlations." **Neuron 4**5(2005): 975–85.

Kant, I. **Analytik des Schönen**. 1790; reprint, Amsterdam: Boom, 2002.

Marks, L.E. **The Unity of the Senses: Interrelationships Among the Modalities**. New York: Academic Press, 1978.

Maurer, D., and C. J. Mondloch. "Neonatal Synesthesia: A Re-evaluation." In **Synesthesia: Perspectives from Neuroscience**, edited by L. C. Robertson and N. Sagiv. New York: Oxford University Press, 2004.

Merleau-Ponty, M. **Phenomenology of Perception**. 1945; London: Routledge, 2002.

Pascual-Leone, A., and R. Hamilton. "The Metamodal Organization of the Brain." **Progress in Brain Research** 134(2001): 427–45, 2001.

Ramachandran, V. S. **A Brief Tour of Human Consciousness: From Impostor Poodles to Purple Numbers**. New York: Pi Press, 2004.

Simner, J. et al. "Synaesthesia: The Prevalence of Atypical Cross-Modal Experiences." **Perceptio***n* 35 (2006): 1024–1033.

Sur, M., S. L. Pallas, and L. Roe. "Cross-Modal Plasticity in Cortical Development: Differentiation and Specifiation of Sensory Neocortex." **Trends in Neuroscience** 13(1990): 227–33.

Ward, J. **The Frog Who Croaked Blue. Synesthesia and the Mixing of the Senses**. London: Routledge, 2008.

Ward, J., and J. B. Mattingley. "Synaesthesia: An Overview of Contemporary Findings and Controversies, " **Cortex** 42, no. 2(2006): 129–36.

Werner, Heinz. "Unity of the Senses." In **Developmental Processes: Heinz Werner's Selected Writings**, edited by S. S. Barten and M. B. Franklin. Volume 1. 1934; reprint, New York: International Universities Press, 1978.

A cournotian approach to the emergence of relational collectives

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Abstract

Computational processes in cellular networks are supported by complex molecular and ionic mechanisms, composing a distributed semi-parallel architecture where each processing unit has partial information about the others. How do cognitive functions of organisms emerge from this kind of computational process? The concept of *Cournotian Process* characterizes the kind of interaction that occurs between multiple independent factors eliciting the emergence of a common product. As in the classical concept of *chance* advanced by Cournot (1838), the meeting of independent causal lines (i.e. semi-deterministic processes) generates a result that cannot be described as a *function* of the factors, but as a *relational* collective. In this work we suggest that the resulting *cognitive functions* should be described by *mathematical relations* instead of mathematical functions, and that the inference from brain structures to mental activity is a semantic reasoning based on *similarities*.

Key Words: *emergence, Cournotian processes, cognitive functions, relational collectives, similarity.*

1 - Introduction

According to Information and Systems Theories, an empirical measurement involves an interaction between an observer, in some extent also a receiver of information, and a physical system, taken as the source of information. The physical system has a temporal dynamics that can be partially captured by means of a series of measurements.

In order to explain and predict phenomena, the observer elaborates mathematical theories, aimed to cover the temporal dynamics. In the classical deterministic framework, the dynamics is assumed to be completely described by mathematical *functions* (one-to-one or many-to-one mapping of first-order relations), which could in principle be computed by a single Turing machine.

In this paper, we argue that biological and cognitive processes occurring in systems composed of partially independent units should be conceived as mathematical *relations* (including one-to-many mappings) called *Cournotian Processes*. Initially, we distinguish mathametical relations from functions, in the context of their usage in empirical science.

The classical Newtonian schema of causation inspired the functional concept of causality (Mackie, 1972):

Effect = f (Cause 1, Cause 2, Cause 3,....)

where **f** specifies how the set of causes relate to the effect. Causes and Effect are conceived as physical changes that occur in the system, relative to its initial and boundary conditions.

Mathematical functions describe a univocal relation between the causes and the effect. How do the causes relate to each other? There are two possibilities:

a) they are previously correlated, such that there is a function **F** that deduces **f**;
b) they are not previously related, and therefore a function **F** that deduces **f** *does not exist previously;* i.e., **f** comes to existence only at the moment when the causes interact. This possibility is illustrated by the concept of

"chance" as *an absence of previous correlation of causal chains*, according to the proposal advanced by A. Cournot (1838).

Biological processes in a cell (e.g. metabolic networks) or in the whole organism (e.g., different tissues and systems working autonomously) are parallel in a stronger sense than in classical computation, since they contain *simultaneous phenomena that cannot be composed or decomposed in sequential processes*. This aspect has been recognized in several approaches, as probability theory, fuzzy logic, and non-linear thermodynamics of dissipative structures.

Another typical factor present in biological computation is that the mechanisms amenable to be described by algorithms have a property of self-organization, conferring a spontaneity to their dynamic evolution. A central aspect of such processes, is *the availability, for each parallel processing unit, of information about the states of the other units*. However, because of architectural and (possibly) general physical constraints (as e.g. the finite velocity of signal transmission), information about the system available for each unit is partial. The global, self-organizing processes that characterize such systems is based on the partial information that each processing unit has about the others. In this sense, self-organization is also an internal learning process by which the parts of the system may increase their degree of communication and become more integrated.

The motivation to develop our approach comes from difficulties in understanding cellular information processing in terms of classical Connectionism, and, with more reason, in terms of a sequential model. Weng, Bhalla and Ivenger (1999) note that, even in an extremely simplified approach, the arrangements of signaling molecules are similar to redundant functions, although their kinetic properties can be very different. The authors suggest that in the absence of complete knowledge of the quantitative parameters of these systems, it is possible to reach a rough perspective of their evolution by analyzing the *linear* pathways.

A serious difficulty found in this strategy is the interaction of each linear pathway with other pathways, sometimes from distant regions of the cell. This branching of the pathways into molecular networks is not completely solved in the classical Connectionist model, where a network is analyzed into parallel connections between a large number of interconnected conventional processors, thus dividing the process in several *threads* (Hillis, 1985). The network then executes a parallel algorithm (Cormen, 2002, p. 688ff) that is more complex than the sequential ones, but still in the context of a classical Turing machine.

As biological systems are able to process information independently of an external controlling agent, but depending on the capacity of communication between the cells, Cournot's reasoning about the interaction of independent deterministic processes to generate a new, partially unpredictable phenomenon, seems to be a plausible approach to this biological spontaneity. His intuition was that a non-deterministic result could emerge from the interaction of deterministic processes that evolve independently of each other until the moment when they interact.

This intuition is formalized here. First, we characterize a spatio-temporal process evolving in time, under the constraints of classical physics.

2- Formalization of Dynamical Processes

Consider a biophysical process **P**, consisting of sub-processes internal to the brain, their mutual interactions, and their interactions with the body and the environment. The system where **P** occurs is named **S** (it is, of course, larger than the brain). Also consider a cognitive process **M** that emerges from **P**.

M *strongly emerges* from **P** in **S** IFF**:**

1. There is a constructive method to apply the laws (**L_1, ..., L_n**) that rule the evolution of **S** (i.e., the laws of physics, chemistry and biology), when the initial (**S(0) = f)** and boundary conditions **(S(a) = k, S(b) = k'**, etc.) are known**;**
2. If **E** is a state of **P**, then the probability of obtaining a complete description of **E** from **L_i** applied to **S(t) = f***, keeping the boundary conditions constant (or computing all their variations and their consequences), is lower or equal to the probability of obtaining **E** from a simple random sampling.

In other words, **M** is *strongly emergent* in **S** if the laws of the system cannot *predict* a state with more accuracy than by chance. This situation is colloquially expressed in the statement: “it was not possible to *deduce* the states of **P** based on the laws of **S**”. For instance, the process of memory retrieval possibly is strongly emergent relatively to brain activity, because the (complete) knowledge of the laws of neuroscience, together with (complete) knowledge of initial and boundary conditions, would not be sufficient to predict the memory trace that a subject is going to remember.

Knowing the *structural restrictions* that rule the evolution of a system may help to predict what is going to happen, with a higher probability than by chance.

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This possibility has been frequently used in scientific research in cognitive neurobiology; e.g., when genetically modified mice do not express a protein with a specific role in brain processes, it is possible to predict the corresponding deficit in mental functioning (see e.g. Mayford et al., 1996). In order to clarify how a structuralist view can contribute to the understanding of mental emergence, we begin by defining the concept of *structure*.

A structure can be conceived as a model-theoretic *set* subject to some *restrictions*. More precisely, the definition of a structure requires the reference to *a family of basic sets*, possessing the elements under restriction. Such families of sets are called *universes*. The simplest structures, called *mono-sorted*, are those that possess only one universe. As the universes correspond to classes of objects, it is usual to call a structure with **n** universes a *many-sorted structure*. For practical purposes, in empirical sciences, we use only enumerable structures (including, in some cases, infinite structures).

Consider an enumerable structure **A**. It is possible to define an infinite number of structures having **A** as their universe. In order to define a specific structure **E(A)**, some definitions are needed. For each **n**, let $\mathbf{A^n}$ denote the **n**-th Cartesian power product of **A**. **P(B)** is a set composed by all parts of any power set **B** (for **B = A,** $\mathbf{A^2}$ **, ...** etc.). Consider, for each **h=1, ... n**, the union of the sets:

$$\mathbf{P(A^1)\ U \ldots U\ P(A^h)\ U \ldots U\ P(A^n)}$$

The union is indicated by **A***. **R** belongs to **A***, and then to *one* of the $\mathbf{P(A^h)}$s, such that **R** is in $\mathbf{A^h}$ and, therefore, it can be identified with a *relation* with weight **h**. Observe that the union of the $\mathbf{P(A^h)}$s is necessarily a disjunct one. If **G** pertains to $\mathbf{A^h}$ and $\mathbf{A^k}$ then **G** is a **h**-uple and, at the same time, a **k-**uple, what is impossible except if **h=k**.

By fixing the condition that **R** is uniform, we obtain a function **f** with weight **h-1**.

Re(E) e **Fu(E)** are the *designed subsets* of **A*,** respectively called *the set of relations* and *the set of functions* of the structure **E(A).** The *constants* of **E(A)** correspond to the case when the weight of the elements in **Fu(E)** is **0**. The *properties* in **E(A)** correspond to the case when the weight of the elements in **Re(E)** is **1**. Also, the **Re(E)s** with weight **0** are the *sentences* of **E(A)** (which are identified with *probability values,* or with truth value in the binary case).

E(A) is characterized by the sequence **(A, Re, Fu).** The *syntax* of **E(A)** is composed by symbols and rules (drawn from set theory) that allow its construction. The *semantics of* **E(A)** is the set of rules that attribute *meaning* to elements of **A**, to relations in **Re(E)** and to functions in **Fu(E),** and also attribute a probability value to its sentences, when they occur.

We note that there is a large controversy about the "meaning of *meaning*" in the philosophy of language. In this paper we adopt the Tarskian theory, for which the meanings of terms and relations in one structure - the "object language"- are the corresponding elements and relations in an *isomorphic* structure - the "meta-language".

3 - Dynamical Processes, Determinism and Randomness

Consider a process generated by a mechanism **d** that heats a mercury column **m** in the interval (**t0, t1)**. Among the properties that an observer can identify in this process is the temperature of **m** in **t0** and **t1**, and other state variables of **m**. The elements **d** and **m** can be considered as belonging to a set **B**, where **R(d,m)** is the relation of **d** heating **m**, and **P(m,t)** is the temperature of **m** in the instant **t**. The structure **E = B, R, P** represents in a simplified way the state of the process of heating in a given instant (Lungarzo, 1970a, 1970b).

Along time, it is possible for **B** to change, e.g., by adding a sample **m'** of another material to the system heated by **d**. In this case, the set **B** is modified**: {d,m} {d,m,m'}**. Analogously, also **R** is modified, since now **d** heats both **m** and **m'**. Therefore, also the structure of the system - besides its states - undergo a temporal evolution. In this case, it is necessary to formalize this situation using several sets, representing different *universes*.

Given a sequence of sets **B1, ..., Bn** composed of objects, we define a many-sorted structure **E**, with **Bi** universes, as:

$$\left\langle \mathbf{B}_1, \ldots, \mathbf{B}_n ; \left(\mathbf{R}^i_j\right)^{i=1,\ldots,n}_{j=1,\ldots,m(i)} ; \left(\mathbf{F}^i_j\right)^{i=1,\ldots,n}_{j=1,\ldots,p(i)} \right\rangle$$

where:

1. The sets $\mathbf{B}_i$ are finite;
2. For each **i{1, ..., n},** $\mathbf{R}^i_1, \ldots, \mathbf{R}^i_{m(i)}$ are relations (or properties) in $\mathbf{B}_i$.
3. For each **i{1, ..., n},** $\mathbf{F}^i_1, \ldots, \mathbf{F}^i_{p(i)}$ are functions in a proper Cartesian product of sets $\mathbf{B}_{i_1}, \ldots, \mathbf{B}_{iq}$ in $\mathbf{B}_i$.

An object is a **dynamical structure** IFF:

1. is a family of many-sorted structures {**Et | tT**}, being **T** a connected set of real numbers;
2. All the **Et** are of the same kind, .
3. For each **t**, the components (relations, functions) of **Et** are functions (eventually, constant functions) of **t**.

A *process* is a ordered pair formed by a dynamical structure and a closed finite interval of **T**. If **P** is a process, then **a<b, P = , [a, b].** By **P(t)** we indicate the dynamical structure **Et**, for the instant **t [a,b]**. As all the structures composing a process are of the same type , it can be called the *process type*. Such an uniformity does not block the possibility that a relation ceases to exist (in this case, it may be identified as a null relation , without changing .)

P(t) denotes the *state* of the process in the instant **t**. The structure **Et** represents the *configuration* of the system in the instant **t**. Consider the process **P=(, [a,b])**; then, **P(a)** is the *initial state* of **P**, and **P(b)** is the *final state* or *result* of **P**.

A *knowledge landscape* **C** is the structure **P, Ag, S** where **P** is a process, **Ag** is a set of cognitive agents with potentially unlimited logical capabilities, and **S** is a set of sentences that contain sufficient information for the description of **P**. If **P = , [a, b],** then the process is *deterministic* IFF **(Ag)** (If knows the initial state of **P(a)** with certainty, then the probability that knows the result **P(b)** is **1**).

This is a purely epistemological definition of determinism. If the agents know the initial state with certainty, they are able to interpret all the sentences that describe this state and to deduce all the consequences from them; therefore they can calculate the results with maximum probability. As an example of deterministic process, let **P** be the process of feeding a computer with the information necessary to factorize the number 2142 into primes, using Euclid algorithm and showing the result on the screen. In ideal conditions (without mechanical or electronic failures) **P** is deterministic. Of course, the prediction of the final state depends on the information contained in **S**. This information can change in another landscape.

A process is *not-deterministic* or *random* when there is at least one agent for whom the probability of knowing **P(b)**, given **P(a)** in **C,** is lower than **1**. Intuitively, it is possible to quantify randomicity of a process, based on the quantity of agents failing to predict **P(b)** with probability equal to **1**, but this aspect is not relevant for our present argumentation.

Consider two *simultaneous* processes **P** e **Q**, such that **P = , [a, b]** and **Q = ’[a, b]**, and the landscapes **C = P, Ag, S** e **C’ = Q, Ag, S.** Now assume that:

1. (**Ag)** such that knows **P(a)** with certainty, but the probability that knows **Q(b)** é **<1**, or
2. (’**Ag)** such that knows **Q(a)** with certainty, but the probability that knows **P(b)** é **<1**.

In this case, the agents cannot predict with maximum probability the result of a possible interaction of **P** and **Q.** When this kind of situation occurs, we can say that **P** and **Q** are *independent* (while the *dependent* processes are those called “solidaires” by Cournot, 1838, §30)

Given two processes **P** and **Q**, such that **P = , [a, b]** and **Q = ’, [c, d]**, **P** is a *sub-process* of **Q**, **(P? Q)** IFF:

1. c a < b d, and

2. is a substructure of ’ for each **t [a, b].**

When = **’**, the sub-process is *normal*, and denoted by **P ?*Q.** If **P ?*Q** and

c = a, then **P** is an *initial sub-process* of **Q**.

Now consider a finite sequence of deterministic processes, each pair of them being mutually independent, all of the same type , but each one defined in a different landscape **Ci:** $\langle P_1, ..., P_h \rangle$, such that **i{1, ..., h}, Pi = i, Ii,** being **Ii** non-disjunct time intervals.

If **P** is the *supreme* (upper bound) of the relation **?** of all **Pi**, then a process **Q** is *generated* by **Pi** processes IFF given **t0** for some of the **Ii,** for all **t t0** the structure of **Q** is an *effect* of the interaction of the structures **i** of **Pi**.

4 - Cournotian Processes

A *Cournotian* process **Q**, generated by the **Pi**s, is a non-deterministic process at the union of the landscapes, such that **Q ? P**. Intuitively speaking, a Cournotian process is a non-deterministic process generated by deterministic and independent processes, when the result of the interaction of the generating processes is not “larger” than the supreme of the sub-processes.

For instance, first consider a process **P** in landscape **C.** At **0** h of a chosen day, from the point **x0, y0** of the earth surface, a projectile **p** with mass **m** is shot with initial velocity **v0**, forming an angle with the earth’s tangent. Also assume that it moves in a virtual vacuum. If **S** is the set of sentences that describe the properties of the process, then any agent who knows with certainty the state **P(0)** can predict the state **P(t)** in **t>0**, with probability **1**. For **t = 40** seconds, the state **P(40)** is totally defined by the mass of **p** (the same) and the coordinates of **p = (v0 cos40), (v0 sen40 - 800g),** being **g** the gravity force. Formally, **P** is the pair **, [0, 40]** where is the structure containing **p**, the initial values and the empty space. The relation **R(p, t, ...)**, defining the coordinates of **p** are time-dependent, and therefore the structure is a dynamical one.

Also a process **P'** occurs, in the landscape **C'.** At **0** h in the same day, a satellite **s** crosses the point **x1, y1** of the earth surface at the height **h**, with dynamical variables known for all **Ag'**. At the instant **t**, the agents **Ag'** can calculate the state **s** with probability **1**.

Now consider that at the instant **t'** the projectile **p** collides with the satellite **s**. Agents from each landscape can calculate the instant **t'** when the collision occurs**.** However, each group does not know the variables of the other process. Therefore, the conjoint process **Q**, beginning at **t'** and leading to the separate drift **p** e **s** after the collision, cannot be predicted with probability 1, for both groups of agents. Therefore, in the conjoint landscape **D** the process **Q** is not deterministic.

Cournotian processes can be analyzed in the framework of Dynamical Systems Theory, including the informational properties of the systems, as proposed by Zadeh and Desoer (1963).

The model of a physical system **M** is a *dynamical system* IFF **M = I, O, , , ,** such that:

1) **I, O,** are sets and e are functions;

2) If **s** , then **s** is a *state* of **M;**

3) If **fI** and **hO**, then **f** and **h** are functions with domain in **T** (a non-null temporal interval);

4) The *range* of **f** is **Ra(f)**, i.e. **f:T Ra(f)** and **h:T Ra(h);**

5) The **I** functions are the *inputs* and **O** functions are the *outputs* of **M**;

6) The function is the *read-out*, which satisfies the properties:

6.a $\rho : (T \times \Sigma \times I) \longrightarrow O$

6.b **t, s, f** $(T \times \Sigma \times I)$, :**t, s, f** $\longrightarrow$ **hO**, such that

h(t) =df **(t, s(t), f(t))** is the *response* of **M** in the instant **t**, when its state is

s and the feeding input is **f**;

We call the *state transition function*, such that:

1) $\sigma : (\Delta \times \Sigma_0 \times I) \longrightarrow O$ **,** for **= {t, t'T2 | t t'}** and **0** being the set of all initial states;

2) t, t' , s0 0, j I, it follows that **: t, t', s0, j** ⟶ **s,** such

that **s(t) =df (t, t', s0, j)** denotes the state produced by the input **j** at the instant **t**,

from the state **s0** that occurred at **t'.**

The state transition function must satisfy the following axioms:

1) *Transitivity*: for **t, t'T,** such that **t' t**, **s0** , and **j, j' I,** if **j(t) j'(t)** in **[t, t'],** then **(t', t, 0, j) = (t', t, 0, j')**

2) *Associativity*: **t t' t" T**, **0** , **j I, (t", t', (t', t, 0, j), j) = (t", t, 0, j)**

The quantitative changes in a continuous dynamical system are usually presented by a system of linear or non-linear differential equations, referring to a function defined in **R D D**, with **R** being the set of real numbers and **D** the set representative of the system to be modeled. The standard problem is to solve the equations, considering the initial and boundary conditions:

xD (0, x) = x

t, t'S (t, (t', x)) = (t+t', x)

In the perspective of the axiomatic definition above, the transition function guarantees the existence of a solution for this problem. In the above example, the evolution of the projectile and the satellite can be represented by this kind of differential equations. They can be solved using the transition function ; its results can be read by the function and the set **D** is **R3**. However, *the Cournotian process produced by the collision of the projectile with the satellite cannot be represented by a differential equation, because the solution is not a function.* If the process is studied as deterministic chaos, the deterministic phase leads to a bifurcation with an infinite branching of possible states. Therefore a Cournotian process, even in the case that the initial conditions are exhaustively known in the instant **t = a**, may become unpredictable in **t = b**.

In the study of Cournotian processes, the tools of Dynamical Systems Theory are able to exactly describe only the initial deterministic phase, before the independent causal lines meet. At this point, *a new phenomenon emerges*, one that cannot be deduced from the previous dynamics of the system.

After formalizing the Cournotian processes, it is possible to understand how to predict the result of this kind of process with a probability greater than chance. The agents, having only partial knowledge about what is going to happen after the causal lines meet, cannot deduce the outcome, but can make probabilistic inferences.

It is easy to show that this kind of computing is broader than the classical functional (or single deterministic Turing machine) approach. If the properties **P** are deduced from the theory **T(N)**, then, trivially, they can be inferred from the Cournotian process, since the deduction is the limit case when the probability value equals **1** (i.e., a sentence **e** is deducible from **e*** if the probability of **e** is **1** always that the probability of e* is **1**). Therefore, our approach can account for both the deductive and the non-deductive derivations.

5 – Structural Reasoning and Emergent Relations

The term *structuralism* is used in several areas of scientific methodology and epistemology, referring to formal procedures used with problems that require the consideration of *non-trivial* structures. In this sense, *structuralism* has been used to refer to theories in Economy, Anthropology, Linguistics and Psychology. In this paper, we conceive structures in a pragmatic framework, as *theoretical abstractions or models* used in the context of empirical science, to organize the available data and make predictions.

There are at least three different concepts of *structuralism*:

1) in Chomsky´s classical studies of grammar, efforts were directed to find *combinatorial structures* that operate on linguistic elements, following formal rules, in order to explain the categories of natural language. These efforts concentrated on the syntactic aspects of language, leaving semantics on a secondary plane;
2) in the context of philosophy of mind, structuralism is related to “bottom-up” approaches, aiming to explain psychological functions from neuroscientific theories and data, in opposition to the “top-down” methodology of cognitive science that is focused on psychological functions (see Fodor, 1983);
3) in the context of the sciences of life, structuralism refers to biological structures (macromolecules, cells, tissues, organs, body systems), a case when it is *not* opposed to the consideration of functions (i.e., *biological* functions), since biological structures and functions are complementary concepts (structures refer to the components of living systems, and functions refer to the activities that such structures display in time).

The Chomskyan concept of structuralism (item 1, above) is based on a previous distinction between syntactic and semantic aspects of natural language, made in the context of Model Theory. The structures used as models also have their own syntax; however, their *application* to theories is not necessarily syntactic. There are other aspects of semantic evaluation; for instance, when a statement **e** is satisfied in a model **M**, this means that **e** is *true* in **M** (in the Tarskian approach, "truth" is an *isomorphism* between structures).

Eventually, the inferences used in Model Theory may have been considered as syntactic by some authors, since for *first order* logic the syntactic and semantic approaches lead to the same results, according to Henkin´s Completeness Theorem. However, from a conceptual perspective both are different.

The complementarity of structural and functional aspects can be achieved by considering higher-order systems, as assumed in non-reductive explanatory strategies. In first-order systems, functions are *internal* to one structure (in our previous formulation, one **Fu(E)** for each **E**). However, for higher-order systems it is possible to construct relations that link different and/or hierarchically ascending structures. For instance, if **E** and **E'** are first-order structures, it is possible to construct a second-order relation **r: E Ë E'**.

Consider **M** to be a set of cognitive properties, and **N** a neuroscientific theory that is true. **S** is a model of the brain and its interactions with the body and environment. Also assume that the standard model of **N** is isomorphic to **S,** and that there is a set of statements **M** expressing the properties of mental phenomena that cannot be predicted/deduced from **N**. These are *strongly emergent* properties, according to our previous definition.

The reason why mental phenomena are not deducible from **S** can be made explicit straightforwardly. Cognitive phenomena are expressed by a class of predicates that is semantically separated from the predicates used to express biophysical processes; there is no middle term, and therefore these classes of predicates – as usually stated – belong to separate semantical categories. Therefore, there is not a valid syntactic pathway to deduce statements about mental properties from statements about biophysical properties, unless:

a) *bridge principles* are formulated, providing a connection between (at least) one biophysical predicate and one mental predicate, as proposed by Reductionism (Bickle, 2003), or

b) mental predicates are reformulated using biophysical predicates, as proposed by Eliminative Materialism.

It is of central importance for our proposal to consider a semantic-structural, non-syntactic form of reasoning that is the basis for ascription of probability values: the *judgment of similarity* (see Gärdenfors, 2000). The notion of *similarity* expresses the existence of *partial correspondences* between structures (see Pereira Jr., 1999) and therefore operates in the domain of a second-order relation **r.** Prediction about **E'** based on knowledge of **E** is called *reasoning with similarities*.

In the study of the brain/mind system, we consider **E** as the brain structure (with respective internal functions, described by neuroscientific theories) and **E'** as the mental structure (with respective internal functions, described by psychological theories). As we adopt a non-reductive explanatory strategy, we do not identify both structures (as in Identity Theories) and we do not try to syntactically deduce **E'** from **E** (even with the usual inclusion of bridge principles).

We propose the second-order relation **r** to be conceived as a semantic relation based on similarity. At this moment we are not able to formalize this model and will limit our exposition to five sketchy examples where the formalization could be applied.

6 - Some Examples from Neuroscience

Emergent cognitive functions, not deducible from a (hypothetically complete) neuroscientific theory, can be predicted by structural similarities between brain activities and mental experiences. We give five examples to illustrate how reasoning by similarity works in the context of cognitive neurobiology. The exemples display similarities between alterations in brain activity and the corresponding alterations in mental activity. Such similarities advance one step beyond the merely temporal correlations found by current techniques in cognitive neuroscience, helping to explain the relative success of biological psychiatry in the treatment of several kinds of psychopathology.

First, animals with a deficit in protein CaMKII (Calmodulin-dependent Protein Kinase II) activity display a deficit in memory formation (Wang et al., 2003). Based on this experimental finding, it is possible to infer that the lack of a function **f** in **S** implies the lack of a function **f'** in **M.** This reasoning is *induction by vicariance.*

A second example is: a decrease in serotonin levels predicts the onset of depression. Once serotonin is a neuromodulator that increases the efficacy of synapses, a decrease in serotonin levels would also decrease the efficacy of synaptic communication. Although we do not know exactly what synaptic communication has to do with *mood*, a mental phenomenon, we can find a similarity between serotonin decrease and a decrease in mental disposition. This reasoning is *induction by similarity.*

The third example is an experiment that produced an *increase* in molecular function. It is well known that the membrane receptor NMDA is involved in the capacity of associative learning. Genetically modified mice with over-expression of the NMDA receptor are predicted to display improved learning capabilities, since this receptor works as a coincidence detector, providing neuronal excitation upon receiving two excitatory pulses in a narrow time window. Associative learning is a mental function that consists basically of connecting different stimuli. It is not the case that the pulses received by the NMDA receptor at each neuron correspond to the stimuli to be associated; however, its physiological function has some degree of similarity with the mental function. This is also a case of *induction by similarity*.

The fourth example is a case when *increasing* the quantity of one kind of molecular component leads to a *decrease* of mental activity. Also in this case there is *induction by similarity*, but this time with inverse proportionality. It is well known that the transmitter GABA and its receptors have a physiological function of inhibiting neuronal activity. Substances that perform the same function of GABA (binding to the benzodiazepinic receptors) are used in Psychiatry as tranquillizers, in the treatment of anxiety and psychoses. Anxiety is a mental phenomenon, having properties that cannot be deduced from biophysical processes in the brain. However, we can find a similarity between the physiological function of promoting neuronal inhibition and the mental function of tranquillizing.

The last example is the approximation of the dynamics of a signaling ion (Ca^{++}) with mental processes as learning, memory formation and consciousness (see Koch, 2003, and also Robertson, 2002, for a similar proposal regarding Ca^{++} waves in astrocytes). Koch's reasoning is based on a *timing analogy*. The timing of Ca^{++} entry in synaptic ion channels and binding with receptors in the post-synaptic density is analog to the timing of such mental processes, so it was inferred to be related with them.

In the five examples, the structural correlations do not follow logical or biophysical laws, and could be taken as pieces of scientific fiction, except for the fact that all of them have been experimentally demonstrated. The second and fourth examples correspond to widely used pharmacological drugs. The first example was extensively reviewed in Bickle (2003). The third example was confirmed by the breeding "Smart Mice" (see Tang et al., 1999).

7 - Concluding Remarks

As in the classical concept of *chance* advanced by Cournot (1838), here we considered emergence processes as resulting from the meeting of independent causal lines (i.e. semi-deterministic processes) generating a product that cannot be described as a *function* (but as a mere *relation*) of the multiplicity of factors involved in the process. Therefore, biological and cognitive functions would correspond to mathematical *relations*.

The occurrence of emergence in Cournotian processes is predictable - although not deductible - by semantic reasoning based on similarities. If biological and mental processes derive from Cournotian processes, we need knowledge about structural properties of living bodies and brains to perform such reasoning and predict emergent mental properties. When researchers attempt to construct life or mentality artificially, the possibility of making these inferences can be lost.

References

Alkon DL, Nelson TJ, Zhao W, and Cavallaro S. (1998) Time Domains of Neuronal Ca2+ Signaling and Associative Memory: Steps Through a Calexcitin, Ryanodine Receptor, K+ Channel Cascade. *Trends in Neuroscience* 21 (12) 529-537.

Bickle, J. (2003) **Philosophy and Neuroscience: a Ruthlessly Reductive Account.** Dordrecht: Kluwer.

Cormen, T.H. (2002) **Introduction to Algorithms**. Cambridge: MIT Press.

Cournot, A. (1838) **Recherches sur les Principes Mathematiques de la Theorie des Richesses**. Paris: Hachette. Italian translation by Biblioteca Dell'Econ, 1875; English translation by N. T. Bacon published in Economic Classics (Macmillan, 1897) and reprinted in 1960 by Augustus M. Kelly.

Fodor, J. (1983) **The Modularity of Mind**. Cambridge: MIT Press.

Gärdenfors, P. (2000) **Conceptual Spaces: the Geometry of Thought**. Cambridge: MIT Press.

Hillis, WD. (1985) **The Connection Machine**. Cambridge: MIT Press

Hull, DL. (1974) **The Philosophy of Biological Science**. NJ: Prentice Hall.

Leon, M and Johnson, B.A. (2003) **Olfactory Coding in the Mammalian Olfactory Bulb**. *Brain Research Reviews* 42: 23-32.

Loewenstein, W.R. (1999) **The Touchstone of Life: Molecular Information, Cell Communication and the Foundations of Life**. New York: Oxford Univ. Press.

Lungarzo, C. (1970a) Espacio y Tiempo. Buenos Aires: **Cuadernos de Filosofía**, 2ª Série, Num. 4.

Lungarzo, C. (1970b) El Concepto Lógico de Estructura. Buenos Aires: **Cuadernos de Lógica**, Num. 22.

Mackie, J. (1972) **The Cement of the Universe: A Study of Causation**. Oxford: Oxford Univ. Press.

Mayford M, Bach ME, Huang YY, Wang L, Hawkins RD, Kandel ER. (1996) Control of memory formation through regulated expression of a CaMKII transgene. **Science** 274(5293): 1678-83.

Panksepp, J. (1998) **Affective Neuroscience: the Foundations of Human and Animal Emotion**s. New York: Oxford University Press.

Pereira Jr, A. (1999) Representation in Cognitive Neuroscience. **In: Understanding Representation in the Cognitive Sciences: Does**

Representation Need Reality? New York, Boston, Dordrecht: Kluwer Academic/Plenum Publishers, p. 49-56.

Reilly SC, Cossins AR, Quinn JP, Sneddon LU. (2004) Discovering genes: the use of microarrays and laser capture microdissection in pain research. **Brain Research Reviews** 46 (2): 225-233.

Robertson, JM. (2002) The Astrocentric Hypothesis: proposed role of astrocytes in consciousness and memory formation. **Journal of Physiology-Paris** 96: 251-255

Stephan, A. (1999) Varieties of Emergentism. **Evolution and Cognition 5** (1): 49-59.

Tang YP, Shimizu E, Dube GR, Rampon C, Kerchner GA, Zhuo M, Liu G, Tsien JZ. (1999) Genetic enhancement of learning and memory in mice. **Nature** 401(6748): 63-9.

Thagard, P. (2002). How Molecules Matter to Mental Computation. **Philosophy of Science**, 69: 429-446.

Waddington, C.H. (1977) **Tools for Thought**. London: Jonathan Cape.

Wang H, Shimizu E, Tang YP, Cho M, Kyin M, Zuo W, Robinson DA, Alaimo PJ, Zhang C, Morimoto H, Zhuo M, Feng R, Shokat KM, Tsien JZ. (2003) Inducible protein knockout reveals temporal requirement of CaMKII reactivation for memory consolidation in the brain. **Proc Natl Acad Sci U S A**. 100(7): 4287-92.

Weng G, Bhalla US, Iyengar R. (1999) Complexity in biological signaling systems. **Science** 284(5411): 92-96.

Zadeh, LA and Desoer, CA. (1963) **Linear System Theory**. New York: McGraw-Hill.

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Resenha da obra "Filosofia da mente", de Cláudio Costa.

Por Prof. Dr. Ana Maria Guimarães Jorge

A obra "Filosofia da mente", de Cláudio Costa apresenta, na introdução, um breve panorama do surgimento de estudos mais sistematizados sobre filosofia da mente, de 1949, com a obra "O conceito da mente", publicada por Gilbert Ryle. Costa aponta para o diferencial dessa idéia, no sentido de que trouxe novas metodologias de análise filosófica rumo aos domínios científicos recentes da neurofisiologia, psicologia cognitiva e inteligência artificial. Assim, os avanços tecnológicos na área da computação forneceram bases para realização de reflexões filosóficas sobre questões como a da natureza da mente, dos estados de consciência e dos processos cognitivos. Os objetos de estudos da filosofia da mente entendem os estados mentais (sensações, percepções e quasi-percepções, emoções, cognições, estados conativos, ou mesmo volitivos) enquanto eventos, processos e disposições que conjuntamente compõem o processo mental.

Um aparte, nessa obra de Cláudio Costa, ao se refletir sobre a cognição, seu sentido é aproximado da ação processual da crença, do saber, do pensar e do raciocinar enquanto ação autodeliberada e preditiva. O que parece compreender o conceito na acepção de processo cognitivo. Nesse sentido, alguns questionamentos levantados pelo autor são objetos de maior atenção na obra, como é o caso da seguinte questão: o que são os estados de consciência?

Costa afirma que mente e consciência são co-extensivos nas investigações cognitivas, ou neurocognitivas, pois todos os seres têm a capacidade de consciência, ou de algum nível de consciência. Para a delicada questão do conceito de consciência, o autor a define como "*experiência integrada que a mente tem da realidade externa e interna*" (COSTA, 2005: 10), afinal, complementa que "*não há consciência sem experiência*". O caráter dessa experiência, citando as idéias de D. M. Armstrong, da linha funcionalista, faz-se sob duas modalidades sensórias: a perceptual e a introspectiva. A primeira capta experiências pelos órgãos sensoriais e implica consciência perceptual, ou experiência que a mente tem da realidade externa. A segunda se refere ao caráter reflexivo, ou de autoconsciência, na captação da realidade interna dos estados mentais, assim as mentes agem de modo mais sofisticado na monitoração de seus processos mentais ao coordená-los e planejá-los rumo a algum fim.

A idéia da mente parece, a partir disso, ser analisada no âmbito da ação e da reação individual, ou mesmo que a mente está restrita ao indivíduo, o que também impõe restrições ao conceito de experiência. O autor argumenta que muitos animais apresentam consciência perceptual, mas essa atividade perceptual não é sofisticada e "flexível para ser literalmente chamada de "experiência"" (COSTA, 2005: 14). Outra vertente dessas investigações é que há ausência de consciência introspectiva, por exemplo, no ato de dirigir automaticamente rumo a alguma direção, em que ocorre predomínio da consciência perceptual mecânica (COSTA, 2005: 12). Mais do que isso, de um modo geral, a tese causal do funcionalismo é a de que "*a mente não se define pelo que é, mas pelo que faz*". Assim, o estado interno é causado por um *input* perceptual que por sua vez causa *outputs* comportamentais (COSTA, 2005: 28). Entretanto, a controversa questão implícita da apercepção dos estados internos não foi desenvolvida nesse livro.

O autor ainda argumenta que problemas centrais acerca do conceito de consciência serão aclarados à medida que a consciência for entendida como "*uma propriedade física emergente da matéria biológica e completamente redutível a ela*" (COSTA, 2005: 15). Isso certamente será devido às explicações neurocientíficas sobre o funcionamento do cérebro e dos processos de percepção e de representação.

Outra conceituação controversa se dá acerca da relação mente-corpo-cérebro. Para versar sobre tal relação, o autor recorre à exposição e à crítica de princípios específicos da leitura do dualismo cartesiano, behaviorismo analítico, eliminacionismo, funcionalismos, e teoria da identidade, essa última pela qual admite ter simpatia. Na relação mente-corpo, dualismo e fisicalismo, ou materialismo, compartilham de algumas premissas, o primeiro entende a mente como distinta e independente do corpo material enquanto o viés fisicalista a define como material ou mesmo sem existência. A isso responde o dualismo interacionista de Descartes que aproxima a mente da idéia de substância: "*ser algo que existe sem precisar de outra coisa para existir*" (COSTA, 2005: 16-17). Costa habilmente aponta para os pontos frágeis dessa noção dos interacionistas indagando: como é possível que a substância mental, isenta de extensão física, possa interagir causalmente com o corpo?

O behaviorismo analítico define o mental como "*um conjunto de entidades subjetivas e privadas*". Disposições comportamentais e circunstanciais como a dor, o desejo, a raiva, o amor, ou as crenças substituem a idéia de "mental" e da *res cogitans* cartesiana. O autor se contrapõe a esse argumento ao exemplificar que a dor não deva ser uma mera disposição para verter lágrimas, gemer, mas sim implique uma sensação profundamente desagradável cujas conseqüências são particulares de indivíduo para indivíduo (COSTA, 2005: 19). Ainda, as propriedades intrínsecas dos corpos, o vidro é quebrável e a pólvora é explosiva, não podem ser dissociadas dos próprios corpos como disposições de comportamentos.

O eliminacionismo, primeiro com P. K. Feyerabend, e depois com Paul e Patrícia Churchland, criticam o uso das terminologias populares e sensos comuns a elas atribuídas como algo a ser evitado pela ciência. A neurociência, em específico a neurofisiologia, deverá obliterar e substituir as crenças oriundas da psicologia popular. Costa aponta para o estrabismo desse ponto de vista ao afirmar que conceitos complexos como peso, massa, calor, por exemplo, são assimilados pela ciência e que as crendices generalizadas pelo senso comum são investigadas e adaptadas pela ciência. O senso comum em sua prática descritiva dos fenômenos possibilita ao cientista refinar as idéias, tornando-as razoáveis em vez de refutá-las ou eliminá-las. O papel da neurociência talvez seja o de fornecer fundamentos à psicologia (COSTA, 2005: 23).

A teoria da identidade, ou *type-type identity theory*, com os filósofos Herbert Feigl, U. T. Place e J. J. C. Smart concebem que "*(tipos de) estados (eventos, processos) mentais são a mesma coisa que (tipos de) estados (eventos, processos) cerebrais*" (COSTA, 2005: 23). Segundo as ciências empíricas, identidades implicam macroestruturas abrigando microestruturas, assim, parece coerente identificar estados mentais, sensações, emoções, desejos, a estados neurofisiológicos específicos como uma solução naturalista para o problema mente-corpo, reduzindo tudo a acontecimentos físicos. Contudo, a questão dos *qualia* é a primeira pedra no sapato dos adeptos da identidade, pois parece que o mental é irredutível ao material. *Qualia* traz em sua definição a problemática em questão: "*qualidades fenomenais privadas e diretamente experienciadas de eventos mentais como sensações, emoções e imagens mentais*". Como identificar os *qualia* como eventos cerebrais? A plasticidade cerebral apresenta outra pedra. Como os estados mentais podem univocamente ser identificados com os estados cerebrais? O belo exemplo dado pelo autor é o de que "*mesmo quando eu tiver um mesmo pensamento no futuro, parece improvável que os percursos neuronais venham a ser exatamente os mesmos que agora*" (COSTA, 2005: 25-26).

O funcionalismo atribui papéis funcionais aos estados mentais, a dor é então algum estado interno indeterminado definido por relações funcionais de *inputs*, *outputs*, o que impossibilita a concepção daquilo que possui caráter qualitativo-fenomenal na consciência, como é o caso dos *qualia*. Costa argumenta que a dor é um estado qualitativo-fenomenal subjetivo e desagradável independente de qualquer coisa.

Simular a dor não é sentir a dor, o que implica conceber que os "*qualia* são propriedades que se limitam a cérebros biológicos" (COSTA, 2005: 31).

Costa se posiciona a crer na coerência de alguns princípios da teoria da identidade de tipo, especificamente com o seguinte argumento comparativo: se a detecção de ondas eletromagnéticas sem que se experiencie a luminosidade visível é possível com auxílio de células fotoelétricas, então, no caso dos *qualia*, não seriam eles modos subjetivos de entidades com capacidade de apresentação intersubjetiva sob o aspecto neurofisiológico? Outro ponto importante, mas praticamente sugerido, o fato de que o caráter informativo dos *qualia* se daria por sua própria característica de irredutibilidade. Aqui se inicia sugestão de diálogo com as teorias da informação, entretanto, soa desconectado dos pontos-chave dessa obra por não apresentar extensão argumentativa. O autor continua, o "*saber como as cores são vistas*" por alguém que passa pela experiência é o mesmo que dizer "*Só agora sei o modo como o processo neurofisiológico de experiência das cores se apresenta à perspectiva subjetiva*" (COSTA, 2005: 35). Entretanto, há se pensar que na descrição neurofisiológica dos *qualia* os tipos de unidades neurofuncionais são predominantes no nível cognitivo. Ou melhor, invertendo a questão, "*o nível cognitivo parece estar intrinsecamente relacionado ao nível mais basal dos qualia*". Crenças são fundadas em elementos sensoriais e afetivos vinculados às experiências sensíveis (COSTA, 2005: 38).

Nos estudos de filosofia da mente, a identidade numérica de uma coisa no tempo é aproximada da identidade pessoal de um indivíduo permanecendo no tempo durante estágios sucessivos de existência. O autor dirá que se trata da ""*mesmidade" de uma pessoa no tempo, na independência das transformações contingentes que ela possa sofrer*" (COSTA, 2005: 39). Teorias advindas da física e da psicologia definem os critérios dessa identidade pessoal, sendo que a primeira estabelece bases físicas para um critério de continuidade de um mesmo corpo humano e de seu cérebro, e a segunda, define o critério em termos mentais como a permanência de traços de personalidade, de caráter, de habilidades e de crenças do individuo. O autor entende a continuidade de um corpo como um mero sintoma que não garante a identidade pessoal enquanto que a permanência de um mesmo cérebro no indivíduo parece ser algo mais constitutivo. A continuidade física é vista, então, como não necessária à identidade pessoal, mas um critério de conexão física causal como a estrutura molecular na manutenção da identidade da pessoa em momentos subseqüentes é necessária. Há ainda critérios mistos que tendem a adotar uma versão adaptada e frágil da lógica do "*silogismo em barbara*": se puder se preservar um critério físico e um mental, por exemplo, e *grosso modo*, estrutura molecular aliada a alguma habilidade do indivíduo, então, há preservação da identidade pessoal.

O que se pode inferir dos pontos expostos no último parágrafo é que o argumento dos critérios de identidade parece falseado e redundante, ou melhor, por um lado, os exemplos fisicalistas dados separam a condição corporal da cerebral, como se o corpo gozasse de condição passiva e amorfa na formação da identidade dos organismos. Outro ponto brevemente desenvolvido, também pela característica da proposta estrutural do livro, mas bastante controverso, trata da permanência da memória pessoal como um critério não necessário para a identidade pessoal. Segundo o autor, ao se imaginar uma pessoa que sofra um acidente e perca as lembranças passadas, entretanto que mantenha seus outros traços psicológicos como personalidade, caráter, habilidades, memória proposicional, há de se pensar que se trata da mesma pessoa, ou que a identidade pessoal foi em geral preservada. Paira uma lógica funcionalista de extração de elementos constantes da permanência de algo que parece imutável como a condição de se continuar a ser aquele indivíduo independentemente das qualidades relacionais complexas cerceadas de seu organismo. Nesse momento, a opinião ou simpatia do autor pela explicação da teoria de identidade de tipo mostra insipiência de contra-argumentos feitos de forma hábil pelo autor sobre as fragilidades conceituais de outras teorias. Ocorre sugestão ainda de uma tendência de psicologismo da física e de fisicalismo da psicologia, nesse último caso ao serem isoladas funções estruturais fisiológicas daquelas qualitativas psicológicas. Há de se olhar de novo para a interessante idéia apontada anteriormente por Costa (2005: 38) de que "*o nível cognitivo parece estar intrinsecamente relacionado ao nível mais basal dos qualia*". Crenças são fundadas em elementos sensoriais e afetivos vinculados às experiências sensíveis.

COSTA, Claudio (2005). **Filosofia da mente**. São Paulo: Paulus.

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Resenha da obra "Ciência: Formas de conhecimento – arte e ciência. Uma visão partir da complexidade (Vol. 2)", de Jorge Albuquerque Vieira.

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Jorge Vieira persegue, há tempos, uma Teoria da Complexidade. Cientista cauteloso, não define, nem limita o que seria tal teoria. Apenas indica caminhos, de bases sólidas, para uma compreensão do mundo que nos cerca. Este livro trata de forma ousada e natural alguns conceitos básicos, como realidade, representação e sociedade. Já no primeiro capítulo "O Significado da Astronomia como Ciência Observacional", Vieira nos apresenta uma classificação das ciências, destacando a Astronomia. Entretanto, para um leitor mais cuidadoso, pode-se facilmente perceber similaridades metodológicas entre essa ciência e outras. O livro sempre transmitirá esse caráter generalista, de um princípio básico que norteia as ciências.

No segundo capítulo, "Função de Autocorrelação e Gramática", há uma exposição dos conceitos básicos sobre as séries temporais, matéria-prima para cientistas de várias ordens. Neste, fica claro que, analisar e modelar uma série de dados é o exercício de um texto complexo, com uma gramática própria. "Caos e Semiótica" é o título do terceiro capítulo que mapeia os sistemas não lineares e apresenta uma representação adequada destes sistemas. O diagnóstico de caos determinista é um roteiro dentro deste capítulo, que orienta e alerta para uma correta análise de séries de dados, evitando uma confusão entre caos e processos estocásticos simples. A Semiótica é uma ferramenta que aparece neste e em outros capítulos, sempre com a solicitação de cuidado ao se adotar um caminho pouco explorado, mas nem por isso a ser evitado.

A definição detalhada do que é um sistema e as ferramentas para medidas de sua organização são dadas no quarto capítulo, "Quantificação de Organização em Sistemas Naturais". Como um relâmpago que, tanto ilumina, quanto assusta, o texto revela um segredinho da realidade: pedras, pessoas, nuvens, galáxias, todos são sistemas de objetos, que se comunicam através de sistemas de signos.

Quais seriam as estruturas de sociedades humanas? No último capítulo, "Sistemas Psicossociais", há uma pausa no rigor matemático que permeia os anteriores, mas que solicitam ao leitor uma profunda análise do seu próprio contexto. Não é demais correlacionar as percepções de Vieira sobre as sociedades agônicas, descritas como sistemas bastante vulneráveis às crises externas, como podemos perceber com as atuais crises ambientais e econômicas. Sistemas procuram permanecer no ambiente, enfatiza o autor.

Este livro é de especial interesse aos cientistas que se ajustam mais à definição de "naturalistas", observadores sem preconceitos, abertos à diversidade e que se opõem à "megera cartesiana" roseana. É também de Guimarães Rosa um possível resumo da mensagem de Jorge Vieira: “*Vivendo, se aprende; mas o que se aprende, mais, é só a fazer outras maiores perguntas*”.

VIEIRA, Jorge de Albuquerque. (2007) **Ciência: Formas de conhecimento – arte e ciência. Uma visão partir da complexidade (Vol. 2)**. Fortaleza: Expressão Gráfica e Editora.

Resenha da obra "Interação mediada por computador: comunicação, cibercultura, cognição", de Alex Primo.

Por Profª. Ms. Cândida Almeida (candidaalmeida@yahoo.com.br)

Já não é raro encontrarmos pesquisas, trabalhos experimentais, obras e projetos que contemplem às discussões sobre tecnologia e cibercultura. Um tema extremamente atraente, recheado de dúvidas e ancorado em um território verdadeiramente nebuloso e movediço. Travar embates teóricos nessa área é como andar com luz escassa em grutas. Não pelo medo que pode provocar, mas pela dificuldade que temos em saber exatamente o que acontece nesses ambientes. Muitos de nós, pesquisadores da área de tecnologia, tentamos com eficiência mapear esse território, questionando seus aspectos técnicos, suas diversificadas formas de troca de informação, suas possibilidades de composição poética e artística, sua capacidade dinâmica na educação, entre tantos outros pontos de vista para abordar a gigantesca mudança que vivemos desde o uso em massa dos computadores.

Olhamos criticamente para esse cenário, donde dúvidas, problemas, hipóteses e idéias vão estourando feito Rebento, na concepção mais Gilberto Gil-liana possível. "Tudo que nasce é Rebento, tudo que brota, que vinga, que medra". A impressão que dá é a de que estamos diante de um contexto que nunca se resolverá em tempo, pois estaremos sempre reedificando as dúvidas em função do próximo detalhe tecnológico. Em um bate-bola infindável, pesquisadores, artistas, programadores e toda a indústria da tecnologia (dos fabricantes de *hardware* aos desenvolvedores de software e redes) se lançam contra o tempo para tentar explicar, questionar e projetar os avanços tecnológicos, suas circunstâncias e seus efeitos diretos e indiretos.

É reconhecendo esse cenário, que Alex Primo vem grifar com veemência a importância de termos claro o que é a interatividade, um dos conceitos mais importantes para o estudo na área de tecnologias digitais. Como o próprio autor alerta – citando Arlindo Machado - , é difícil acessarmos com clareza o que de fato é a interatividade, pois atrelado a ele, existe uma utilização larga com sentidos variados, o que inclui a sua exploração como efeito de marketing positivo. Quando uma empresa, por exemplo, quer dar a impressão de produto novo e que estabelece intimidade com o consumidor, o uso publicitário da palavra "interativo" atrai o interesse do consumidor, pois é um termo que pressupõe avanço, relacionamento e aproximação pessoal, no consenso comum.

Em outra esfera, vemos o alargamento da utilização da idéia de interatividade como conceito, mas como se esse conceito já estivesse esgotado e que seu significado fosse dado como geral e simbólico por toda a comunidade acadêmica. Isso implica dizer que muitos pesquisadores, se esquecem de travar o embate com o motor da tecnologia, a interatividade. E, muitas vezes, resolvem esse “problema” direcionando o entendimento conceitual para um esclarecimento meramente tecnicista do conceito. Ou seja, tratando a interatividade como uma possibilidade do meio ou suporte.

O livro “*Interação mediada por computador: comunicação, cibercultura, cognição*” foi escolhido para o primeiro número da revista TECCOGS por trazer à tona, a importância de tratarmos de forma crítica e profunda um conceito essencial a todo e qualquer embate teórico que envolva a discussão (em qualquer grau) sobre tecnologia. Primo realiza um verdadeiro inventário crítico do conceito, mapeando uma larga gama de teóricos que encararam e encaram o uso da “interação” como guia para as pesquisas que abordam as relações sociais mediadas por computador e outros suportes que mediam as trocas de informações interpessoais.

Ao longo do livro, Primo cita e discute criticamente categorias propostas por alguns teóricos que se aprofundaram mais no tema e assim vai construindo de forma lúcida, o terreno para a sua própria proposta dos tipos de interação que existe. Nesse contexto são apresentadas e questionadas as três situações interativas pensadas por John Thompson, os tipos de sistemas (ainda pensando sobre a TV) de Raymond Williams, as características determinantes para os sistemas interativos de Andrew Lippman, o “cubo da interatividade” de Jens Jensen, entre outras várias propostas realizadas para explicar e diferenciar os tipos e níveis de interação.

Apesar do rigor científico nesse mapeamento, o diferencial de Primo não está na sua própria criação de diferenciação dos tipos de interatividade, mas na forma como ele fundamenta a sua proposição. Descartando o uso exclusivo das Teorias da Comunicação como ferramenta para se pensar a interatividade mediada por computador, ele aponta claramente que esse é um problema que deve ser tratado do ponto de vista de sua complexidade.

Em um exercício diferencial, chama para formar seu alicerce a abordagem sistêmico-relacional que oferece, por sua vez, suporte teórico para identificar qualitativamente os tipos de interação e entender os processos de organização que ocorrem no fluxo e disponibilização de informação pelos meios de comunicação interpessoal. Assim, Primo trata a interatividade como uma propulsora qualitativa imbuída em um organismo que pode diferenciar-se, dependendo do tipo de abertura entrópica ao qual está sujeito. Enquanto sistema mais aberto, mais entrópico, o organismo tem um nível de interatividade mais profundo, cujas estruturas tendem a ser mais imprevisíveis. De outro lado, aponta também sistemas mais fechados, de entropia mais baixa, não permitindo grande variação em sua estrutura.

Outro ponto diferencial e forte na discussão de Primo é pontuar a importância da, já citada aqui, interpessoalidade que ocorre nos processos interativos mediados por computador. Um processo de comunicação extremamente complexo do ponto de visto relacional e cognitivo, que envolve a interação, ou seja, a ação entre pessoas no ciberespaço. Questionar a interatividade, segundo Primo, significa se aproximar do todo complexo que envolve a produção, disponibilização, troca e ação no ambiente em rede, através dos processos dialógicos, respeitando uma dinâmica que é antes de tudo um acontecimento relacional e não um fim em si mesmo.

Nossa proposta não é revelar o conteúdo e defender sua proposta, mas indicar o estudo de um livro que traz sérios e contundentes questionamentos conceituais, que se ampliam mais quando o autor crítica o uso equivocado de termos como "usuário", "receptor" e "utilizador', ao se fazer referência aos agentes dos processos interativos. Longe da passividade inerente aos meios de comunicação de massa, o papel das pessoas que participam da comunicação interpessoal é o de serem acionadores de trocas, propulsores de relações cognitivas que se revelam exatamente no ENTRE, no inter.

PRIMO, Alex (2007). Interação **mediada por computador: comunicação, cibercultura, cognição**. Porto Alegre: Sulina.