国際研究集会
「創造性とは何か？－複雑適応系における創発現象－」
（YITP-W-08-11）

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京都大学基礎物理学研究所

１）What is Creativity?
Emergent Phenomena in Complex Adaptive Systems
http://www.kier.kyoto-u.ac.jp/ICAM/complexity/conference08.html

２）国際研究集会

３）京都大学経済研究所との共催
International Institute for Complex Adaptive Matter 協賛
Asia Pacific Center for Theoretical Physics 協賛
早稲田大学複雑系高等学術研究所 協賛
林原生物化学研究所 協賛

４）開催期間
2008 年１０月２０日～２３日

５）開催場所
コープイン京都　会議場

６）世話人
西村和雄（京都大）相沢洋二（早稲田）野間俊一（京都大）
蛯名邦禎（神戸大）郡司幸雄（神戸大）Alberto Oliberio (Univ. Rome)
Mark Blumberg (Univ. Iowa)　H. Atmanspacher（Inst. Psychology）
村瀬雅俊（京都大）

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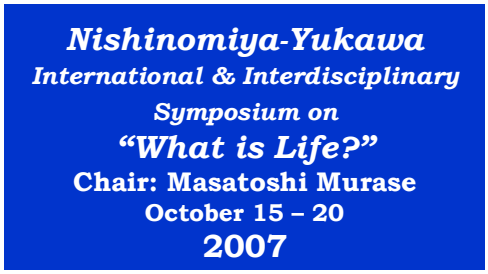
■M. Murase *“The Dynamics of Cellular Motility”* John Wiley & Sons（1992）
http://hdl.handle.net/2433/49123

７）背景

2007 年 10 月 15 日～20 日（6 日間）に、西宮湯川国際シンポジウム「生命とは何か？湯川のこれから１００年の夢」を開催した。



Proceedings:
Progress of Theoretical Physics
Supplement No.173, 1—370 (2008)

http://www.yukawa.kyoto-u.ac.jp/contents/seminar/archive/2007/ny2007/

物理学、分子生物学、ナノ化学、計算科学、認知科学、複雑系生命科学などさまざまな分野の研究者が集い、分子モーター、分子設計、遺伝情報分子解析、細胞情報処理、モデル細胞系の計算科学論、生態系、こころの進化など、生命現象のさまざまなトピックスについて学際的な討論を活発に行なった。京都大学総長裁量経費の支援を受けて、国際的には ICAM（Institute for Complex Adaptive Matter）および APCTP（Asia Pacific Center for Theoretical Physics）からの助成を得ると共に、京都大学７部局（経済研、霊長類研、化学研バイオインフォマテックスセンター、こころ未来研究センター、生態学研究センター、三才学林、オープンコースウエアー）の協賛を得て、参加者９０名（うち外国人は６カ国より 19 名）が集い活発な議論を行った。　討論されたトピックスの多様性にもかかわらず、生命系において普遍的に存在すると思われる構成原理を探求するという機運がいっそう高まった。

国際シンポジウム「生命とは何か？湯川のこれから１００年の夢」の論文集は、Progress of Theoretical Physics: Supplement No.173, 1-370 (2008) に掲載。
http://www2.yukawa.kyoto-u.ac.jp/~ptpwww/

2007年12月6日～9日（4日間）には、Santa Fe 研究所でModels of Emergent Behavior in Complex Adaptive Systems （Organizer: David Pines 他）が開催され、本国からは西村和雄と村瀬が参加した。ここでは、物理系・経済系・社会系、生命系などに関する現象やモデルの提示につづいて、異分野の研究者からさまざまな観点に基づく討論が展開された。特に、それぞれのシステムの特性によらない普遍原理の探求が重要なテーマであった。2008 年 1 月 14 日～17 日（4 日間）には、2008 ICAM 運営委員会（於：Santa Fe）が開催され、本学から村瀬が出席し、先の国際会議の成果報告と今後の計画の紹介がなされた。さらに、2008 年 9 月 9 日～12 日（4 日間）には、Dynamic Days Asia Pacific（組織委員長：原山卓久、ATR）が開催され（於：奈良）、複雑系・生命系における同期現象・カオス動力学・創発現象などが集中的に討論された。

こうした我が国の内外における創発現象に対する物理系・生命系・経済系への関心の実質的な高まりを踏まえ、本国際会議では前回参加していない新たな外国人を世話人に加え、表記の日程で研究会計画を提出することとなった。

８）テーマ

創発現象を理解しようとする際に、まず重要なことは「創発性とは何か？」あるいはより一般的に「創造性とは何か？」といういわゆる創発性・創造性の明確な定義づけに関する問題意識を持つことである。その方策として、モデル系の構築と解析は欠かせない。具体的には、まず明確に記述可能な構成要素が、全体として１つのシステムを構成する際に、どのような拘束条件で、要素レベルの機能には見られなかった全く異質な機能が自己発生するかを理解する必要がある。

具体的な方法論として、以下の２つを検討する。

(a) 実在する‘複雑’系の縮約モデルの探求

(b) 仮想的な‘単純’素子から構成可能な‘Toy’モデルの構築

第 1 の方法論を探求する際には、もちろん現実の創発現象に関する最新のトピックスを熟知する必要がある。ポストゲノム時代の今日、分子生物学の新たな知見の１つは、遺伝子の働きには遺伝プログラムが進行するにあたって、履歴が刻印されるメカニズムの存在が明らかにされたことである。つまり、「生物個体は、遺伝的に決定されないように、遺伝的に決定されている」ということがわかってきたのである。M. Blumberg は生物個体の環境－さらには、その親やそのまた親の環境との遭遇をとおして得た‘経験’が、世代を超えて子孫に‘継承’されるという驚くべき実験事実を提示している。対象としているシ

ステムの挙動を探求する際に、その時点では生存していない祖先の経験が刻印されているという視点は、たんにシステムの要素還元をすすめることだけでは、解決されない重要な問題をはらんであり、創発現象を考察する際にきわめて重要と思われる。つまり、複雑な生命系の維持・発展には、遺伝子に基づく絶対的な制御可能性が、はじめから想定されていないわけで、この絶対的制御系の不在という事実は、社会経済の推移をどのように制御可能かなどに関連して、西村和雄の研究テーマ複雑系経済学における経済の予測可能性を論じる際にも重要な問題提起と思われる。

別の具体例として、脳機能マッピングが挙げられる。最近の著しい画像診断技術の進歩によって、記憶や学習、新奇性に対するストレス反応などのタスクのもとで、脳機能の部域差や動的特性が精密に測定されるようになってきた。A. Oligerio は、神経生物学研究所所長として、脳機能・脳領域の相関ダイナミックスの第一人者である。しかも、動物実験のデータから、こうした脳活動変化が遺伝子レベルの発現変化とも密接に相関することが明らかになってきた。遺伝子レベルから、神経細胞、神経細胞集団、脳領域にまでおよぶ階層的複雑系の自己制御可能性と、その逸脱として生じるさまざまな疾患は、縮約モデルを構築する際に重要な視点を提供する。こうした観点から、野間俊一による臨床研究は、意義深い視点を提供する。

第 2 の方法論を探求する際には、創発性が出現可能な仕掛けが必要不可欠である。そのためには、階層的な拘束条件をあらかじめ用意しておくことが必要であるということが、制御工学の観点から予想される。工学者の鈴木良次が主張しているのは、ローカルな拘束とグローバルな拘束の共存である。システムが全体として適応的に機能しながらも、要素レベルではシステムを駆動しうる不安定性が要求される。ここで重要なことは、拘束条件として階層性をあらかじめ用意しておく必要があるが、その階層性を‘種’あるいは‘核’として、より高次の階層性が持続的に構成できるような原理とその具体的な表現型の探求である。例えば、トポロジー的に全く異質な閉じた構造（自己）と開いた構造（非自己）をあらかじめ用意しておいて、両者の循環から複雑な階層構造が出現するという‘自己・非自己循環原理’（村瀬雅俊、京大学術出版会、2000）

■村瀬雅俊『歴史としての生命 ： 自己・非自己循環理論の構築』京大学術出版会 2000 年
http://hdl.handle.net/2433/49765

は、１つの指導原理の可能性として考えられる。これとは独立に、理論生物学者の郡司幸雄は２つの全く異なる系として、有限系と無限系を想定し、両者の対応関係を計算論的に再構成することによって、創発現象を探求のための‘Toy’モデルを研究している。

International & Interdisciplinary
Workshop on
What is Creativity?
Emergent Phenomena
in Complex Adaptive Systems

Co-Chair: Masatoshi Murase
Kazuo Nishimura
October 20 – 22
2008

Proceedings
Ed. Masatoshi Murase
"Emergent and Hidden Dynamics"
(Tentative Title)
John Wiley (2010)

Invited Speakers

Mark S. Blumberg

Professor
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National University of Singapore

Shigeru Miyagawa

Professor
Department of Linguistics & Philosophy
Massachusetts Institute of Technology

Ludwik Leibler

Director
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Speaker's comments

What is Creativity?

Masatoshi Murase

Yukawa Institute for Theoretical Physics
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Masatoshi Murase
2007. Oct. 15. photo by Prof. Serhiy A. Tsokolov

Logic starts from the division of subject and object, and belief distinguishes between what is seen and what is not seen. The Western mode of thinking can never do away with this eternal dilemma, this or that, reason or faith, man or God, etc. With Zen all these are swept aside as something veiling our insight into the nature of life and reality.

Daisetz T. Suzuki 1938

. . . our science — Greek science — is based on objectification . . . But I do believe that this is precisely the point where our present way of thinking does need to be amended, perhaps by a bit of blood-transfusion from Eastern thought.

Erwin Schrödinger 1958

What is creativity? Despite the advanced studies of Western science and the progress of modern technology, we have not yet answered this problem satisfactorily. What is worse, it is a double problem that we cannot realize how we are deeply influenced by the traditional way of Western thinking in attacking the above problem. Owing to the dichotomy of subject (or endo) and object (or exo), together with its corresponding reductionism, we have specified more and more the detailed components of a complex system and have also required the reproducibility principle that the complex system shows the same responses to the same stimuli under the same conditions. A dichotomy perspective of this kind, which has been

central to modern science, stands on the assumption that opposites are mutually exclusive and even contradictory.

Contrary to this dichotomy perspective, there is an alternative complementarity perspective typical of Eastern philosophy, which is surprisingly similar to Niels Bohr's complementarity principle in modern physics. It actually suggests that opposites are not mutually exclusive, but merely complementary to one another, because opposites are thought to be only different aspects of the same wholeness. This means that there is no clear distinction between subject (endo) and object (exo). As there is no definitely isolated object, the reproducibility principle is mostly violated. We must therefore pay much attention to the transients —or processes — during the past history of the complex systems such as living systems.

On the basis of this complementarity idea, we are encouraged to have a holistic view by integrating fragments of knowledge at various component levels and time scales when investigating the history of life. In this sense, we need a new synthesis of Western science and Eastern philosophy, instead of considering either of them separately. Only then, it is possible to attack the long-standing question: What is creativity?

Along these lines, in the present paper, a process of endo-exo circulation is introduced as an essential paradigm of creation or life itself. As a living organism is engaged in challenges from both its internal and external environments, it contains unlimited conflicts and oppositions, which in turn must be the driving force for its evolution and development. It is such reconstructive dynamics that can give rise to an identity of the living organism. The resultant identity of creature or life is represented by the Eastern image of the Mandala as an emergent symbol generated by the process of endo-exo circulation.

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1) M. Murase Environmental pollution and health: an interdisciplinary study of the bioeffects of electromagnetic fields, SANSAI: An Environmental Journal for the Global Community. Kyoto University No.3, 1-35 (2008) http://hdl.handle.net/2433/49793

2) M. Murase "Endo-exo circulation as a paradigm of life: towards a new synthesis of Eastern philosophy and Western science" In: *What is Life? The Next 100 Years of Yukawa's Dream* (eds. Masatoshi Murase and Ichiro Tsuda), Progress of Theoretical Physics Supplement No.173, 1-10 (2008).

Biographical Sources and Systematic Studies of Aspects of Creative Work in Science

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Any biography of historically influential individuals faces the problem of how to balance the achievements of their work and their private life. It is obvious that some scientific discovery, artistic breakthrough, or philosophical insight can be better appreciated if private affairs, particularly including their psychological manifestations, accompanying the development of such an achievement are considered and understood. Hankins (1979) supports this view:

> We can say at least one thing with certainty about biography: the ideas and opinions expressed by our subject came from a single mind and are integrated to the extent that that person was able to integrate them in his own thoughts. ... Science is created by individuals, and however much it may be driven by forces from outside, these forces work through the scientist himself. ... Letters written under great emotional stress are the best grist for the biographer's mill, because they lead straight to the heart of the subject's personality and reveal the groundsprings from which his actions come."

Nevertheless there is a tendency to underrepresent psychological elements in biographical work. According to von Meyenn (1997),

> a still neglected chapter in the history of science literature is the integration of psychological factors, which Stefan Zweig has demonstrated in his historical portraits. For a complete description of the forces shaping individuals and, hence, their scientific work, their *psychological conditionality* would have to be included together with *internal scientific constraints* and *social boundary conditions*. Since in most cases access to the necessary source material is restricted by a screened private sphere, such an enterprise can only be carried out under exceptional circumstances.

There are a number of cases in which, at least to some extent, such exceptional circumstances are given. For instance, quite a body of material is available for Helmholtz, Einstein, Poincaré, Pauli, to mention just a few. For more sources the reader may consult classic volumes by Paulhan (1901), Wallas (1927), Hadamard (1954), or – more recently – Kantorovich (1993) or Miller (2000). Another selected collection of highly interesting quotes can be found in Simonton (1988), whose research for three decades has been devoted to a detailed understanding of the psychological processes associated with creative work and insight.

On the basis of a wealth of biographical material on creative thinking, Hadamard (1954) suggests four stages, each of which is inevitable for genuinely creative work.

He calls these stages *preparation*, *incubation*, *illumination*, and *verification*. The first and the last of them mainly function at the level of conscious, analytical thinking. The second and the third stages, however, strongly involve unconscious processes as the core of actual insight. Let me cite two quotations, by Poincaré and Einstein, as examples. In his essay on "Mathematical Creation", Poincaré (1913) says:

> One evening, contrary to my custom, I drank black coffee and could not sleep. Ideas rose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. ... It seems, in such cases, that one is present at one's unconscious work, made partially perceptible to the over-excited consciousness, yet without having changed its nature. Then we vaguely comprehend what distinguishes the two mechanisms or, if you wish, the working methods of the two egos.
> Most striking at first is this appearance of sudden illumination, a manifest sign of long, unconscious prior work. The role of this unconscious work in mathematical invention appears to me incontestable. ... Sudden inspirations ... never happen except after some days of voluntary effort which has appeared absolutely fruitless and whence nothing good seems to have come, where the way taken seems totally astray. These efforts then have not been as sterile as one thinks. They have set going the unconscious machine and without them it would not have moved and would have produced nothing.

Einstein (ca. 1905) responded to a questionnaire by the French psychologists Claparède, Flournoy, and Fehr, published in *L'Enseignement Mathématique*, with the following words:

> The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements of thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined.
> There is, of course, a certain connection between those elements and relevant logical concepts. It is also clear that the desire to arrive finally at logically connected concepts is the emotional basis of this rather vague play with the above mentioned elements. But taken from a psychological viewpoint, this combinatory play seems to be the essential feature in productive thought – before there is any connection with logical construction in words or other kinds of signs which can be communicated to others.
> The above mentioned elements are, in my case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the mentioned associative play is sufficiently established and can be reproduced at will.

These two selected quotations could be supplemented by many others. Here is a compact characterization of Hadamard's stages with some additional comments.

1. *Preparation*: As Poincaré emphasizes, no creative insight can "happen except after some days of voluntary effort which has appeared absolutely fruitless".

Intense conscious work on a problem, sometimes even for years (as Gauss (1805) reports in a letter to Olbers), precedes the final solution. Frustrating efforts without success characterize this stage.

2. *Incubation*: At some point the problem is removed from conscious focus, intentionally or by distraction, but the preceding conscious work "has set going the unconscious machine". Unconscious elements "rose in crowds; I felt them collide" (Poincaré), and "this combinatory play seems to be the essential feature in creative thought" (Einstein). According to Simonton's (1988) model, permutations of unconscious elements form and dissolve involuntarily by chance.

3. *Illumination*: When "the mentioned associative play is sufficiently established" (Einstein), "pairs [of unconscious elements] interlocked, so to speak, making a stable combination" (Poincaré). A particular configuration of unconscious elements stabilizes and, thereby, becomes conscious. This is the crucial moment in which an insight reveals itself. Often this happens holistically, not successively unfolded in time.

4. *Verification*: Finally, this insight has to be reconstructed in a logical way, i.e. by a succession of rational arguments which can be communicated. "Conventional words or signs have to be sought for laboriously only in a secondary stage" (Einstein).

In Simonton's fairly detailed "chance–configuration model" (Simonton 1988) for the second and third stage, there is one central issue: stability. The permutating unconscious elements during incubation are not (asymptotically) stable, but float freely, coming and going by chance. Only a particular one among these configurations has stability properties implying its transition into a conscious idea. In a Darwinian formulation of creative processes, stability provides a selection criterion among many chance possibilities. For other features and consequences of this model, see Simonton (1988).

The question of why and how particular configurations are distinguished by their stability remains unresolved though. In this respect, some speculative ideas addressed by Pauli and inspired by Jungian depth psychology are of interest. Pauli (1952) proposed the idea of psychophysical correspondences ("synchronicities") between psychological and physical subdomains of an underlying hypothetical background reality.

> The process of understanding nature, as well as the blissful experience in this process, when a new insight becomes conscious, seems to be based on a correspondence, a kind of congruence, of inner images pre-existing in the human psyche with external objects and their behavior.
> At this point it seems most satisfactory to me to introduce the postulate of a cosmic order, eluding our direxT access, which is distinct from the world of appearances. ... The relation between sensual perceptions and ideas would

then follow from the fact that both the soul of the observer and the observed object are governed by the same objective order.

The origin of the stability properties addressed above could then be conceived at the level of this objective, psychophysically neutral order, and stable configurations would manifest themselves in the selection of particular correspondences out of many possible ones. Examples of serendipity as described by Simonton (1988), resembling features of Jungian synchronicity, are interesting candidates fitting into this picture.

Summarizing, this contribution outlined how biographical material can be useful beyond simply presenting the life and work of an individual in some mutual relationship. It is clear that sometimes particular aspects of work can influence the development of an individual's life, and it is also clear that life events and their psychological repercussions can sometimes influence the direction of scientific work. Studying creative moments using biographical material on the relationship between life and work goes beyond such direct ideas of influence.

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Developing Creations and Creating Development

Mark Blumberg

The source of creation and creativity is closely tied to the issue of design. With regard to evolution, the argument from design -- the notion that evidence of design implies the existence of a designer -- played a seminal role in early Creationist thinking and has experienced a resurgence in the form of Intelligent Design. Curiously, biologists and psychologists routinely invoke a more subtle form of the argument from design: for biologists, the notion of genes as "blueprints" and "programs" that "hardwire" the brain to produce particular instincts has many of the same attributes of "Designer Thinking," as does many current theories concerning the role of consciousness in human behavior. The current trend among some developmental psychologists to imagine highly complex cognitive skills built into the brains of human newborns -- thus siding with nature in the nature-nurture debate -- is a natural extension of Designer Thinking into the realm of human development. In this talk, I will examine these and related issues from a variety of perspectives with the aim of showing that the antidote to Designer Thinking is rigorous, detailed analysis of the origins of biological forms, behaviors, and cognitions. A key theme of this talk will be that "freaks" -- that is, developmental anomalies -- powerfully illustrate the centrality of development to evolution as well as the creative flexibility inherent in the developmental process.

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Creativity in Pathology -- On Dissociation and Questions of the Self-Existence

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The number of the patients with dissociative disorder has been increasing in recent years. The basic character of dissociative disorder is the two-phasic pattern of usual states and unstable states. And various dissociative symptoms, such as personality alteration, are formed with creativity of the patients in order to avoid falling into unstable states. Because most patients with dissociative disorder are worried about the reason why they exist, the occurance of dissociative disorder essentially contains questions of the existence of the patients themselves. Creative activities of human beings might result from anguish of the self-existence.

Self-healing rubbers via supramolecular assembly.

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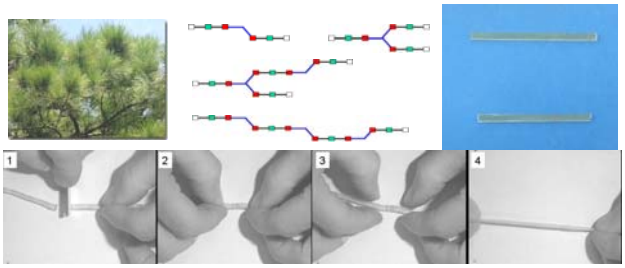
Hydrogen bonds between molecules play an important role in determining the structure and function of biological systems. The most familiar hydrogen bond motifs are water molecules, the nucleobases found in DNA and RNA, and amino acids found in proteins. Supramolecular chemistry, an exciting research field defined as the "chemistry beyond the covalent bond", often looks for inspiration in biological world and largely employs hydrogen bonds and uses with gusto their versatility and directionality. Complex structures and materials have been synthesized by such an approach, from protein and peptide assemblies, supramolecular catalysts and molecular sensors, to stimuli responsive materials. In my talk I will focus on supramolecular polymers, small molecules which due to their non-covalent interactions and self-assembly behave in many aspects like polymer materials. The tremendous development of polymers in 20th century opened or was crucial for emergence of new cutting edge technologies and applications, from electric to entertainment (movie) industries, from airplanes to packaging, from micro- or nano- lithography to adhesives, from soft contact lenses to super-tough plastic car bumpers. We believe that a creative and efficient use of non-covalent bonds to obtain polymer-like systems should open new avenues. For example, using supramolecular assemblies of small molecules should help to better solve "easy-processing good-properties" dilemma: to be easily processable macromolecules have to be small and flow easily, but small macromolecules do not entangle and form lousy polymer materials. Incorporating, thermo-reversible non-covalent bonding moeities which are open at processing temperatures and close at working temperature should provide a way out of the dilemma. The sensitivity of such bonds to physical and chemical environment and external fields is an asset to design unique stimuli responsive materials and systems. Last but not least, covalent bonds irreversibly break when polymer material is damaged. Could a solid, e.g. a rubber, self- mend after damage? Is self-healing possible without flow?

Rubbers exhibit enormous extensibility up to several hundred percent compared with few percent for ordinary solids and ability to recover their original shape and dimensions on release of stresses. Rubber elasticity is a property of systems consisting of macromolecules either covalently cross-linked or connected in a network by physical associations such as small glassy or crystalline domains or ionic aggregates. Covalent cross-links or strong physical associations prevent flow and creep. We have designed and synthesize molecules that associate together to form both chains and cross-links via hydrogen bonds.

In principle multifunctional molecules with an average functionality higher than 2 are able of forming directional supramolecular networks and thus, behave like covalent polymer networks provided the associations of functional groups are directional and robust. Unfortunately, strong interactions between molecules favour crystallization and supramolecular networks made of “model” monodisperse identical associating molecules behave like semi-crystalline plastics, i.e., resins or fibres and not elastomer-like materials. Our solution to prevent crystallization consisted of using mixtures of multifunctional branched oligomers with a controlled distribution of shapes and lengths and equipping them with a variety of strongly associating groups. The challenge was to avoid phase separation of different species. For this purpose, we use as a starting material fatty dimer acids made from natural renewable resources, vegetable oils and available in bulk quantities and various compositions.23 They are liquid at room temperature and in contrast to other classical diacids they do not crystallize but form glasses. The glass transition can be varied by dosing the oil from which fatty diacids are made. Even more interestingly for our purpose, these starting materials can contain variable amounts of trimer acids. We thus solved the problem of synthetic availability of multitopic molecules.

However, the amount of molecular disorder brought by the presence of fatty acid trimers is not sufficient to prevent crystallization, we therefore used a two steps synthesis. In the first step, we prepared oligomeric backbones from vegetable oil fatty acid. In the second step, we provided these prepared backbones with groups capable of self-complementary and/or complementary associations. The control of molecular architecture: variety, size and distribution was of course a crucial issue.



When properly controlled, the system shows recoverable extensibility up to several hundred percent and little creep under load. In striking contrast to conventional cross-linked or thermoreversible rubbers made of macromolecules, these systems when broken or cut can be simply mended by bringing together fractured surfaces to self-heal at room temperature. Repaired samples recuperate their enormous extensibility. The process of breaking and healing can be repeated many times. These materials can be easily processed, reused and recycled. Their unique self repairing properties, the simplicity of the synthesis, the availability from renewable resources and low cost of raw ingredients, fatty acids and urea bodes well for future applications.

1. Cordier, P., Tournilhac, F., Soulié-Ziakovic, C., Leibler, L. Nature 2008, 451, 977-980
2. P.Y.W. Dankers, E.W. Meijer, Bull. Chem. Soc. Jpn. Vol. 80, No. 11, 2047–2073 (2007)

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The Human Linguistic System Engenders Creativity Through Recursive Operations

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Every human language has, at its core, a common engine for generating the structures that shape the linguistic expressions. This engine is referred to as "Universal Grammar," and various models of it have been proposed since the 1950s when this way of looking at human language came into being through the works of Noam Chomsky. In the most recent instantiation, it is believed that there are two primary components to the engine:

- Binarity
- Recursiveness

These two components interact with each other to imbue the human linguistic system with the potential to generate unique and potentially infinite structures, endowing it with the power of creativity.

Binarity is found in the most fundamental operation of language, called Merge, which takes two linguistic elements (words or phrases or even parts of words), and merges them into a two-member set with a particular internal structure. The Merge operation makes strong predictions about what is possible and what is not possible in human language. It explicitly prohibits a three-member set. So, for example, the phrase *the big apple*, which is composed of three elements, (1) *the*, (2) *big*, (3) *apple*, would not have the three-member structure of *the-big-apple*, but rather, the structure is (*the (big apple*)), where *big* and *apple* first combine for form a two-member structure (*big apple*), and this single structure then combines with *the* to form another two-member structure. Using a variety of empirical tests, we can show that this structural analysis is the correct one. It has even been shown that a conjunction such as *John and Mary*, which appears obviously to be a three member set, in fact isn't. The conjunction *and* first combines with *Mary* to form the two-member set (*and Mary*), and this combines with *John* to form the structure (*John* (*and Mary*)). Again, there are tests to show this. We also predict that there should not be a one-member set. If there appears to be a one-member set, it must be that there is a "silent" element that combines with the pronounced member to form a two-member set. It is there, but it just isn't pronounced. A great deal of work in the past twenty years has been devoted to the study of these silent elements in human language, called *empty categories*. From this Merge component of the Universal Grammar, the creative aspect emerges with the potential of combining elements in novel two-member combinations, a potential we see realized often in the infant's ability to come up with imaginative utterances.

Recursiveness refers to the fact that the operation of Merge may take place without limit, making it possible to produce a potentially infinite structure that adheres to the two-member set structural description. The only reason why we don't hear infinitely long sentences in use is due to factors external to Universal Grammar, such as memory

limitation, social etiquette, and so forth. Recursion contributes to the creative nature of human language by allowing a variety of structures big and small to be built.

One interesting consequence of viewing human language as described above is that, contrary to appearance, human language does not appear to exist primarily for communication. Although it is used for this purpose, binarity and recursiveness do not necessarily lead to an optimal design for communication. For example, we saw that recursiveness leads to infinite structures, which obviously would not be felicitous for communication. If not for communication, what could be the primary purpose of the human linguistic system? One possibility is that it is to represent human thought in some nontrivial sense. In that regard, and as pointed out by Noam Chomsky recently, when we reflect on everyday language use, it is a fact that the vast majority of the time, we use language in our own head instead of communicating with others. If this is anyway on the right track, we have a picture of human creativity that finds one underpinning — there are others — in the specific design of the human language composed of binarity and recursiveness.

Creativity in Science: Theoretical Predictions in Chemical and Biological Physics

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Electron-molecule collisions have been found to play a crucial role in the radiation damage of biological molecules. Electrons also drive many of the atomic and molecular processes in planetary upper atmospheres and initiate most of the relevant physics and chemistry associated with the plasma processing of materials for microelectronics and modern electric lighting technology. In spite of the importance of these fundamental processes, relatively little is known about them. Only components of the fundamental physics are well understood, and only a few of the required cross sections and rates for the multitude of important molecules are known with confidence. At a larger scale, we are seeking a thorough understanding of the mechanisms that take place at the molecular level and that are associated with the function and disease of biological molecules.

This talk will give a short introduction to some of the important fundamental processes in electron-driven processes and the theory needed to describe them in a predictive manner. It will also give an overview of how calculations can help us understand the dynamics of biological molecules. I will present results of a complete ab initio study of vibrational excitation and dissociative electron attachment to nitric oxide that illustrate the predictive power of our computational treatment of these processes. I will discuss a prime example that exhibits much of the complexity of electron-driven chemical and physical processes on polyatomic molecules by reporting our findings on dissociative electron attachment to the simplest organic acid: formic acid. I will also show how simulations are helping us elucidate the mechanisms by which proteins bind metal ions and how this process may lead to the disruption of structures that are associated with neurodegenerative diseases.

Potential universal mechanisms for stress focusing in experimental non-equilibrium fluid flows

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ABSTRACT:

Complex fluids are often characterized by the instabilities they exhibit during flow. These instabilities are attributed to localized regions of extreme stress leading to failure. Modeling these mechanisms often involve details of the local geometry of the system. Experimental studies of two such systems indicate that there might be broader principles involved. The two systems considered are compression induced folding in a molecular monolayer related to lung surfactants, and a classic problem of thermal convection in a gas driven by temperature gradients and buoyant forces. Both these systems undergo transitions from a base state where the base state is ordered, to one where this order is broken through locally induced instabilities. In both cases, the ordered and disordered states are bistable and have been observed to co-exist. The presentation will discuss the nature of symmetry breaking in these systems and explore potential unifying themes in the dynamics of these other wise disparate systems.

Feeling Communication: Social and Physical Interactive Communication and Entertainment

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Communication is one of the most fundamental needs and desires of most organisms, especially humans. Media has made advances in many ways, for example allowing communication over long distances including sound, voice, and text. The advent of the Internet, broadband, virtual worlds, and mobile devices allows remote communication through screens (providing audio/visual communication), even while on the move, however we can have a lack of understanding of real feelings between the sender and receiver. As described in previous research[1], the metaphor of communicating through a screen or window limits the sense of immersion and limits the ability for humans to communicate effectively. In traditional human communications, body gestures and touch[2] can sometimes more deeply explain the intended mind and provide intrinsic information, which makes for a more rich communication exchange. Furthermore, we often communicate emotionally using all the senses simultaneously, including sight, touch, sound, but also through taste and smell, such as sharing a meal together or cooking for a partner. We thus need to create fundamentally new forms of media to connect humans in the physical world and through the virtual world co-space, not just in the transmission of information and verbal communication, but through meaning and nonverbal communication to increase the sense of telepresence using all the senses. We believe this will allow more opportunities for people to make meaningful exchanges using media in the co-space. As a fundamental aim of this research, we also want to use these new communication media to enhance positive and happy communication through a novel cute filter for co-space communication which helps bring interesting content and increases happiness through humor, unexpected delights and meaningful exchanges. This research will strive towards those aims through a combination of fundamental technology and human computer interaction research.

Feeling communication focuses on emotional communication that can deeply send our feelings and emotions to others. In other words, feeling communication does not only convey raw data or information, but also our deep feelings, intentions, expressions and culture. This will revolutionize the present digital communications and enhance social, business, and entertainment communication.

At the fundamental level, we need to develop new theoretical models of communication that unleash the potential for innovation in co-space communication from physical media through the virtual world. Human communication habits and preferences are continuously changing and evolving. A contemporary model includes the role of media and user context and provides for a model that recognizes the more complex context of the communication process and the possibilities of new media being truly extensions of man. Our model goes beyond this approach and focuses on human emotions, feelings, and nonverbal language as key components in the communication process. Recent studies have helped to illustrate that human senses are more acute and versatile than expected. For example, the studies show subjects using the sense of smell to determine the emotions of another person in much the same way as ants use pheromones[3]. This type of research is just beginning to unfold new mysteries of human perception and mind, which shows the potential for a new and more meaningful sense of presence with these new media technologies. Aside from the need for a new model of communication, we also look to improve the nature of human-to-human communication, particularly through the co-space of physical and virtual world. The highly connected nature of people using the Internet also leads to our disconnectedness in physical social spaces, providing weaker links to general society and in some cases reducing the community and social aspects of life. This research will examine a new trend of applying positive or cute real-time communication filters in co-space communication.

[1] Raskar, R., Welch, G., Cutts, M., Lake, A., Stesin, L., and Fuchs, H. (1998). The office of the future: a unified approach to image-based modeling and spatially immersive displays. In Proceedings of the 25th Annual Conference on Computer Graphics and interactive Techniques SIGGRAPH '98. ACM, New York, NY, 179-188.
[2] J. Cassell and K. R. Thorisson. (1999). The power of a nod and a glance: Envelope vs. emotional feedback in animated conversational agents. Applied Artificial Intelligence, 13(4-5):519–539.
[3] Chen, D. & Haviland-Jones, J. (2000). Human olfactory communication of emotion. Perceptual and Motor Skills, 91, 771-781.

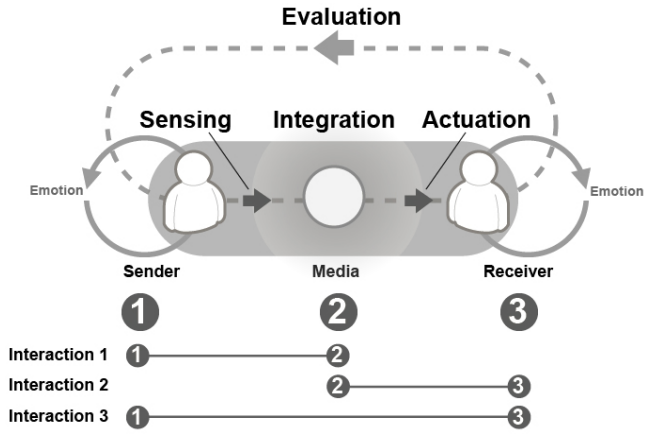

Figure 1: Architecture of our research

In our approach we design four main components in our defined feeling communication as described below and summarized above in Figure 1.

Interaction 1: Sensing – This interaction is between the sender, the sender's environment and the media. The sensors can detect five sensory cues from the sender and her environment. An example is that the various sensors in the smart media can measure the sender's behaviors, intentions, and emotional changes.
Interaction 2: Actuation – This interaction is between the media and the receiver. The actuator can actuate certain sensory cues, which can represent the emotion or feeling of the sender, according the transmitted parameters. Following the example above, the smart media can make various visual, auditory, tangible, smell and taste expressions on it such that the receiver could also understand the meaning of those expressions.
Interaction 3: Integration – This interaction is between the sender and the receiver. This interaction needs the integration of human emotions and various expressions to understand the sender's and receiver's messages and emotional state.
Evaluation: The blurring of the virtual and the real world is a phenomenon of the present day. There are new communication technologies that are now enabled by advances in the sciences and computing which were not possible a decade ago. It is possible to now create situations in which the real world and virtual world can be connected such that new forms of expression and understanding are uncovered. Some communication theory can help to understand this interaction, but this type of large-scale immersion using all five senses simultaneously for remote communication in the shared virtual and physical space has not been explored. We are in the search to evaluate and uncover these connections and provide thought leadership in the understanding of human communication.

To develop such a feeling communication system, there are fundamental, theoretical issues that must be addressed, and a there is a need to refine the theory and provide insightful experimental results, user experience, and usability studies. Hence, the research issues which we will address through a combination of engineering, social science, and human computer interface studies include the following:

Emotional communication using multi-sensory media: In the world of co-space, physical presence takes a major role and it should dive into a new dimension of cutting edge technologies offering improvements to ordinary day-to-day feelings and experiences. We can use new technologies related to multimodal sensing and actuation to give the user more definition in their experience in the co-space environment. Visual, Auditory, Haptic, (Olfactory) Smell, and (Gustatory) Taste are the five sensors that humans use for environmental sensing, and emotional feeling communication. In addition to traditional communication through telephone and videoconferencing, the use of haptics, smell, and taste communication will enable a new paradigm of communication and have great research potential. Research into taste and smell communication has just begun to be explored in the field of human computer interaction.[4] It is a field, which still presents great technical challenges leading to early technical breakthrough results. We will make use of these two senses for feeling communication media in combination with touch, sight, and sound, and enable users to utilize new media for conveying a sense of emotion. Here we identify two main components in taste and smell communication: sensing and actuation.

Positive communication in co-spaces through cuteness: One of the main negative effects that have been seen in virtual and on-line communication is an increase of negative and sometimes even violent or dangerous communication. This could be even more fearsome if in co-spaces the negative effects are transferred from the virtual world to the physical world. To address this issue this research also focuses on providing a communication filtering method that we will improve positive and happy communications among humans in both the real and virtual worlds. This takes advantage of the cuteness factor in designing innovative interactive devices and systems, which we can use to transform user inputs and system inputs into cute outputs in real time. Under this multi-disciplinary methodology, next generation user interfaces can be built to increase happiness and provide more positive experiences in feeling communication. To achieve this our research will proceed to an invention that we term a cute filter, as described below:

[4] Brewster, S., McGookin, D., and Miller, C. (2006). Olfoto: designing a smell-based interaction. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006). R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, and G. Olson, Eds. CHI '06. ACM, New York, NY, 653-662.

Cute filter of communication: The shift to user experience design focus emphasizes the importance of aesthetics and form over function. Consider as an example the iMac, which was virtually the same computer as previous versions but with an added stylish cover, which persuaded traditionally non-computer users to buy into the world of computing and hence, sold more units. We propose a series of cute filters that take advantage of the 'cuteness' factor and transform inputs from the user or environment and provide a digitally calculated output, which appeals to the user. Using a cute filter, users can freely choose the cuteness parameters such as color, size, motion, smell, and taste to adjust their desired cute output. The cute filter converts the sensor input and sends it for actuation. We propose five filters, which are based on the five human senses. We aim to decompose each sensory cue (visual, audio, tactile, smell and taste) into individual streams of digital values. Similar to the way in which a sound equalizer adjusts the components of audio, the cute filter can boost the color, texture, shape, taste, smell, or motion in the output via the automatic processing and deliver happiness with individualized precision. Our research seeks to uncover the meaningful aspects of sensory perception, which can be manipulated to increase the cuteness factor. Our vision extends to building novel modules such as tactile sensors and actuators for texture processing. Present research addresses the texture sensing for only a selected amount of textures. But our research will mainly focus on feeling the different kinds of textures. It also widen our research areas in to developing a tactile glow such that when you wear it and use the glow to touch textures, you can feel different touch feelings (ranging from hard and cool, to soft and furry). Such research of texture sensing and actuation presents immense technical challenges, which may include even some degree of bioengineering or a fusion of miniature cameras and pressure sensors for a clearer sensing and actuating. This also broadens our research in to the areas tapping the physiological aspects of the human brain that controls the touch senses of human anatomy, smell and taste. In addition to the challenges presented above, the devices are required to be of high speed in regards to performance especially when combined with cute filtering. Our research on smell and taste filter will develop a real-time cute smell/taste changing device which can be used to create a cute fragrance automatically to replace uncomfortable bad smells. The research will aim to conclude what are “opposite” smells to produce for smell the technique similar to noise cancellation headphones for sound. In the research we will address the taste-reconstructing device which used to reconstruct the perception of a taste by stimulating the taste buds using actuating mechanism. Also we propose empathetic media, using elements of cuteness to appeal and motivate users, present surprising elements, build relationships with them, and leave them with positive feelings.