Human Developmental Research
2005. Vol.19, 165-176

2004年度日本発達心理学会国際ワークショップおよび公開講演会の報告

日本発達心理学会企画委員会委員長：大藪 泰（早稲田大学）

2004年8月23日（月）から26日（木）までの4日間，オーストラリアのグリフィス大学助教授の Paul Treffner 先生をお迎えし，（財）発達科学研究教育センターとの共催で，国際ワークショップを開催しました。Treffner 先生は，身体運動の協調を，生態心理学ならびにダイナミカル・システムズ・アプローチの立場から活発に研究されている新進気鋭の研究者です。ホストを務めてくださったのは国立情報学研究所の古山宣洋先生です。今回のワークショップには29名の方がご参加になりました。Treffner 先生には6つのセッションで講義をお願いしました。さらに，各2回の質疑応答セッションと参加者による研究発表のセッションを開き，いずれも活発な議論が行われました。この議論には，Treffner 先生の共同研究者で奥様でもいらっしゃる Mira Peter 先生（グリフィス大学）にもお加わりいただき，大変有意義な4日間となりました。

ワークショップの3日目には，「コミュニケーションの基礎としてのジェスチャーの協調と直接知覚」をテーマとした公開講演会も開催いたしました。国際ワークショップ，公開講演会ともに盛況のうちに終わらせていただくことができました。共催していただいた（財）発達科学研究教育センターの皆様に改めて感謝申し上げます。

ホストの古山先生からのご原稿と，Treffner 先生からいただいた，ワークショップの概要に関するご原稿を以下に掲載させていただきます。

日本発達心理学会2004年度国際ワークショップ担当特別委員：古山宣洋（国立情報学研究所）

今回の国際ワークショップで Paul Treffner 先生ならびに Mira Peter 先生の招聘を実現させて頂き，素晴らしい国際交流の機会を与えて下さったことにつきまして，この会を主催して頂いた日本発達心理学会ならびに共催して頂いた（財）発達科学研究教育センターに対して，この場をお借りして深い感謝の意を表させて頂きたいと思います。特に，ワークショップの準備から実施に至るまで格別のお取り計らいとご尽力を頂きました，日本発達心理学会企画委員会の大藪泰委員長ならびに委員諸氏，そして発達科学研究教育センターの深尾雅彦事務局長には特別御礼申し上げたいと思います。また，公開講演会におきまして Treffner 先生の講演を通訳して頂いた福井星一先生に，そして，最後になりましたが，ワークショップならびに公開講演会に参加して会を盛り立てて下さった参加者の皆様に，心より御礼申し上げます。

Paul Treffner 先生は，1985年に計算機科学・人工知能の修士号（英エセックス大学）を，1993年に実験心理学の博士号（米コネチカット大学）を取得されました。そして，コネチカット時代の指導教官でもあり，生態心理学の指導的な立場にある Michael Turvey 教授や，ポストク時代を過ごした米アトランティック大学の Scott Kelso 教授との共著論文の他，運動協調に関する論文が多数ある，この分野の次世代を担う有望な研究者です。現在では，生態心理学ならびにダイナミカル・

システムズ・アプローチの観点から，コミュニケーションにおける身体的な協調，自動車運転等における移動の問題などに取り組まれています。

以下，ワークショップおよび公開講演会で Treffner 先生がお話しされたテーマ，ならびに，ワークショップでの参加者による研究発表について，ごく簡単にご報告させて頂きます。なお，Treffner 先生がなされた講演内容につきましては，各講演について Treffner 先生ご自身による詳しい報告を本文に引き続き掲載致します。末尾に挙げられた参考文献と合わせてお読み頂ければ，この分野に関する相当深い知見を得ることができると思われますので，そちらもあわせてご覧頂ければ幸いです。

Treffner 先生による講演の概要は以下の通りです。発声と肢体運動の協調をはじめとした運動協調について，生態心理学ならびにダイナミカル・システムズ・アプローチ（DSA）の立場から，その理論的・方法論的基礎から応用に至るまで詳細に解説して頂き，特に発達研究に対する示唆を論じて頂きました。基礎編である第一日目は，自己組織化現象を示す代表的な例として B-Z 反応の実演も交えながら，DSA の基礎となる物理現象とその理論について解説して頂き，物理学を専門としない多くの参加者にとって得がたい機会となりました。２日目以降は，運動協調モデルとして提案されている HKB モデルが如何に発展してきたかについて，ご自身の貢献にも触れながら，具体的に解説して頂きました。3 日目には，共同研究者であり，奥様でもいらっしゃる Mira Peter 先生との共同公開講演会が開催され，「コミュニケーションの基礎としてのジェスチャーの協調と直接知覚」という演題で，DSA をコミュニケーションに応用した研究について講演して頂きました。最終日の４日目には，DSA の発達に対する示唆について詳しく論じて頂きました。

参加者による研究発表は，6 名の有志によってなされました。発表テーマは以下の通りです。工藤和俊さん（東京大学）は，人間の運動における分散が有機体-環境間の協調を表していることを示す，様々な水準の運動に関する実験およびシミュレーション結果を紹介下さいました。松裏寛恵さん（東京大学）は，ある乳児がリーチングを獲得する際に見せた姿勢調節の発達的変化を縦断的に追った観察データをもとに，リーチングと姿勢調節が手を携えて進行していくことを報告下さいました。久保田直行さん（都立大学）の発表では，ロボットと人間のコミュニケーションに関して，シンボルが知覚行為循環のダイナミックスに基づいて解釈されることが論じられ，これを設計原理に取り入れたロボットの実演が行われました。柴田寛さん（東北大学）の発表では，二者間の連係動作として物体の受け渡し場面が取り上げられ，手渡された円筒を受け取る際にはたらく物理的・社会的な制約に関して検討した実験結果が報告されました。佐藤由紀さん（東京大学）の発表では，一人芝居で著名なイッセー尾形氏の芝居において，反復的に生起する身振り動作によって異なる意味を荷った台詞が有機的に結合され，これにより，台詞の意味が重層的に構造化されていく過程が詳細に報告されました。後安美紀さん（ATR NIS）の発表では，同時多発会話を演出の特徴とする平田オリザ氏が演出を手がけた演劇のリハーサルから本番にかけて，複数の話者による発話の開始点のタイミングがどのように構造化され，変化していくかに関する分析結果が報告されました。講師からは，どの研究発表も示唆に富んでおり，これからのさらなる発展が期待されるとの講評を頂き，発表者にとっても，討議に参加した他の参加者にとっても，大変有意義な会となりました。企画に

携わったものとして，ここで活発になされた学術的な国際交流を機に，本国際ワークショップで取り上げられたトピックに関する研究が，今後，本邦においても発展していくことを願ってやみません。

The Japan Society of Developmental Psychology International Workshop 2004 Dynamical and Ecological Approaches to Development and Behaviour

Paul Treffner, PhD

It is with great pleasure to provide this series of lectures to members of the Japan Society of Developmental Psychology (JSDP). Dr. Mira Peter and I would like to extend our sincere thanks to Prof. Yasushi Oyabu, Chair of the JSDP Planning Committee for inviting us and deciding that a series of lectures on ecological psychology would be of benefit to the future of developmental psychology in Japan. We also thank Prof. Koichi Negayama for hosting our Public Lecture. Special thanks go to Dr. Nobuhiro Furuyama for his initiation of our visit and for all his hard work in organising the workshop. To the many other members of JSDP who made our time both during the lectures and afterwards very enjoyable and valuable, “Domo arigato gozaimashita!”, it was a wonderful experience.

1. Physical self-organization as the basis of biological coordination and control

In the first lecture I introduced the *physical* basis of biological coordination and control. This is known as self-organization and is an idea opposed to the notion that control of the “self” comes from a higher, non-physical source (e.g., from a so-called “motor program”, “executive”, or “little man in the head” – the *homunculus*). The modern theory of biological control and coordination reformulates the mind-body problem by realizing that there is really no such thing as “the mind” – at least not in the original sense of this word as introduced by Descartes as meaning, literally, the *soul*. Such dualisms as between mind and body are scientifically untenable.

Descartes’ notion of the soul was given some degree of respectability when the technical term of “mind” was introduced to replace the religious concept of “soul”. But careful analysis shows that to somehow separate the physical (body) from the non-physical (mind) is nonsense. What if, as modern physical science shows, all behaviour can be understood not by reduction to matter, but reduction to *principles*? Such “principled reductionism” is how the theory of pattern formation and self-organization can be used to successfully address issues of body morphology and behavioural patterns in time.

In this lecture I introduced the paradigmatic example of physical self-organization—Bénard convection, and I also demonstrated the development of spiral waves and temporal rhythmic beating patterns (like a heart beat) using nothing but a few chemical compounds in a glass bowl—the so-called Belousov-Zhabotinsky (B-Z) reaction. These patterns—generated by principles of physical self-organization (not "programs") can be described by the new geometry and mathematics of fractals, chaos, and dynamical systems. The key concept used here is *pattern stability*. To create the chemical reaction, I used the simple "recipe" from the back of Ian Stewart's excellent book on self-organization, complexity, and the new biology, "*Life's Other Secret*".

I then described such patterns using very simple and easy-to-understand mathematical concepts such as the potential well model of pattern stability (e.g., visualize hills and valleys and little balls—the tops of hills are unstable points ("*repellors"*), and the bottoms of valleys are stable points ("*attractors")*) (Davies, 1988; Glass, Mackey, 1988; Goldberger, Rigney, & West, 1990; Liebovitch, 1988; Mandelbrot, 1990). This forms a basis for understanding Scott Kelso's and Michael Turvey's development of the potential well model to understand complex biological movement patterns (Turvey, 1990; Turvey & Carello, 1996).

2. Dynamical systems approach to coordination and control

In this lecture I continued the development of Kelso's dynamical systems model of human movement. The model was developed to describe the fundamental phenomenon of self-organization—the *phase transition*. In the early 1980s, Scott Kelso discovered that as he wiggled the two index fingers of his left and right hand faster and faster, they spontaneously changed their pattern of coordination from same direction (different muscles activated; *anti-phase*) to opposite directions (same muscles activated; *in-phase*). After working with and seeking theoretical advice from Prof. Hermann Haken, the theoretical physicist in Stuttgart who developed the theory of the laser (recall the incoherent-to-coherent atomic phase transition in the laser), Kelso was able to show that the transition from anti-phase to in-phase wiggling of the two index fingers was strictly analogous to a physical phase transition between two patterns—one that lost stability (anti-phase) and spontaneously gave rise to another more stable coordination mode (in-phase). The subsequent paper by Haken, Kelso, and Bunz in 1995, a classic in the field, gave rise to the so-called HKB equation. The transition is similar to the switch from a trot to a gallop in a horse, or sitting to standing in a child's development, and perhaps even, from confusion to understanding with respect to our cognitive experience.

The key notion is that these are dynamic patterns and a mathematical description is a powerful and perhaps the best way to define the phenomena. Importantly, these are *informational dynamics*—the phenomena are described at the level of wholistic patterns. Almost

100 years ago, Gestalt psychology began exploring similar phenomena – “the whole is different from the sum of the parts” (Koffka). Indeed, a molecular or atomic level of analysis is simply irrelevant to capturing these kinds of wholistic phenomena. *New* laws are needs—the laws of pattern stability and pattern change. Haken introduced the relevant terms to describe these patterns—terms such as “order parameter: (to describe the pattern; e.g., in-phase or anti-phase) and “control parameter” (to refer to the state that when changed brings about a *spontaneous* change in pattern; e.g., frequency of movement, or speed).

Such notions of pattern-based self-organization are now well-known in the new physics. Within quantum mechanics, a level of analysis many consider difficult to apply to everyday experience, there are similar concepts that not only explain the microscopic level of analysis but, importantly, how the microscopoic (small) is related to the macroscopic (large). Concepts such as David Bohm's theory of the “implicate order” which is ultimately a theory of how information interacts with and guides matter (by the so-called “quantum potential”) may be related here. In this theory macroscopic states are irreducible; coherent wholes involve principles of connection that are currently difficult to understand but provide considerable insight into the nature of “pattern”.

The mathematical description of such physical phenomena are paradigm-shattering and should be considered carefully by all scientists purporting to have an interest in psychological matters where, by “psychological” phenomena, we necessarily mean *information-based*. From this view, psychology is the science of *how information shapes behaviour*.

3. Asymmetry, laterality, and handedness

In this lecture I explored asymmetry, laterality, and dynamics. The functional asymmetry of the upper limbs and of the cerebral mechanisms that subserve them is well known. For most people there is a bias toward using the right hand for manual tasks, and although the two hands undoubtedly work together as a synergy, in both unimanual and bimanual tasks performance distinctions between the upper limbs can be readily observed. Although few distinctions can be stated formally in strictly quantitative terms, it is apparent that any asymmetry found in right-handed (RH) people tends to be in the opposite direction in left-handed (LH) people, although they are not simple mirror-images of each other. The degree of laterality expressed is, however, always a function of the particular task constraints (or as Gibson called them, the *affordances*). For example, musicians who play keyboard instruments (which necessarily permit greater independence of the hands), express a greater degree of handedness than do musicians who play strings and woodwinds (which necessarily require integrated movements). Although moving the two limbs together in a 1:1 manner is easy and almost all children can do it, it is known that the hands can, with some training, learning, and/or development, produce more complex, nonisochronous rhythms such as 1:2 or 2:3. These are known as resonances or polyrhythms and their pattern stability is related to music theory, chords, harmony, and the perception of patterns as pleasing (i.e., concordance and aesthetics; Treffner & Turvey, 1993). Performance of polyrythms is optimal provided the preferred hand (or foot) taps the faster rhythm. This requirement has been interpreted in terms of the degree of attention which can be directed at the preferred or nonpreferred limb (Amazeen, Amazeen, Treffner, & Turvey, 1997; Riley, Amazeen, Amazeen, Treffner, & Turvey, 1997).

In this lecture I developed the HKB theory to address *asymmetrical* patterns of performance (such as due to handedness) and showed how the phenomenon of attention could be addressed and incorporated in a principled way into the theoretical HKB model (via the mathematical model's "c" and "d" terms)

4. Dynamical systems approaches to learning and development

The HKB model has been extended to address issues of learning. Building upon material covered in the preceding lectures, I described and explained the work of Kelso, Zanone, and colleagues. In this research, it was shown that learning a new behavioural pattern involves creating new stable states in the dynamical system—states known as *attractors*. Imagine creating a new "valley" in the potential well model that describes the overall, macroscopic, mathematical organization of one's neuromuscular system. When a new attractor is installed, then because of the existence of mathematical symmetry, additional new stable states and attractors will automatically be introduced. For example, it was shown that learning a 90 degrees coordination pattern between the fingers (right finger leading in a "trot" pattern) automatically allowed the person to produce –90 degrees (left finger leading). (This is like a "trotting horse" sound if tapped on the table). So the new pattern is inherited (automatically for free!) as a consequence of the mathematical patterns underlying the organization of the behaviour. The relation of learning to development was also introduced and how learning can be conceived as the optimization of dynamical patterns (Newell, 1996; Thelen, 1995; Thelen & Smith, 1995), and as the stabilization of previously unstable patterns (Treffner & Kelso, 1999)

5. Gestural coordination and direct perception as a foundation of communication

In the Public Lecture, I addressed perhaps the most complex of human behavioural phenomena—communication and language. The last decade has witnessed a dramatic rise in research investigating the common neural and functional basis for speech perception and speech production, and most recently, manual gestures. Indeed, interest is rapidly growing in the hypothesis that natural language emerged from a more primitive set of linguistic acts based primarily on *manual gestures* (Corballis, 2003).

Gestures emerge in children even before they start to speak and are produced by speakers from all cultural backgrounds. They are observed in speakers even when they are alone as well as in blind speakers when speaking to other blind persons. Thus, gestures seem to be tightly coupled to the speaking process. Given that gestures and speech are the foundation of human communication and that human communication is rhythmic in nature, one issue that we explored was how speech gestures are synchronized and coordinated with accompanying hand gestures.

We approach the issue of speech-hand coordination from both a dynamical systems perspective and a direct perception (i.e., ecological) perspective (Gibson, 1979/1986). Of special interest is how attention and laterality entail stability and functionality. Given that both speech perception and production have origins in the dynamical generative movements of the vocal tract, known as articulatory gestures, the notion of a “gesture” can be extended to both hand movements and speech articulation. The generative actions of the hands and vocal tract may therefore provide a basis for the (direct) perception of linguistic acts. Such gestures are best described using the methods of dynamical systems analysis since both perception and production can be described using the same language.

In one set of our experiments we used a phase transition paradigm to examine the coordination of speech-hand gestures in both left- and right-handed individuals. We explore coordination (in-phase vs. anti-phase), hand (left vs. right), lateralization (left vs. right hemisphere), focus of attention (speech vs. tapping), and how dynamical constraints provide a foundation for human communicative acts (Treffner & Peter, 2002, 2003).

Results revealed that right-handers and left-handers showed striking similarities in coordination of in-phase and anti-phase speech-hand movements when using their right hand (i.e., left cerebral hemisphere). Any observed differences were mostly restricted to the left hand under anti-phase coordination. Additionally, it was observed that participants actively stabilised their speech-hand coordination patterns prior to the transition to in-phase primarily by utilising factors such as intention, attention, perceived synchrony, and laterality. The model we propose provides motivation for an asymmetric potential equation that can encompass cognitive factors such as attention and intention in a straightforward manner and adds to efforts to include aspects of psychological phenomena often assumed unapproachable from a dynamical systems perspective.

We followed up on the preceding results with another set of experiments. Given that our data indicated that the dynamics of coordinated speech-hand movements may play a significant role in conveying the essence of an utterance as well as clarifying the intentions of a speaker, we investigated the effect of speech-hand gesture synchronization on the *perceived* meaning of a sentence. In addition, we explored the role of context on the perceived meaning given that from an ecological perspective issues of meaning must be "bound to" and "grounded" within the organism-environment context (Shaw, 2003). We created an animated male human character who uttered the sentence: "Put the book there now." The sentence was without any prosody [multimedia animations were shown during the seminar]. The temporal alignment of an accompanying "beat" gesture (i.e., hand motion in front of the chest that extends and flexes at the wrist) was modified such that it could occur at one of 23 different locations in the utterance. A table in the background was also included in half the trials. There were two control conditions where no gesture was present (with and without table).

Results revealed that coordinating a hand gesture with different points in an utterance influences the perceived meaning of a sentence. Thus, hand gesture (^) may provide prospective, future-oriented (as well as retrospective, past-oriented) information about a speaker's intentions and thus the meaning of an utterance (e.g., "put the *bo^ok* there now" = definite perceived focus on "book"). Importantly, environmental context affects the clarity (i.e., understanding) of the perceived intentions of a speaker, such that when a perceived environmental affordance is compatible with the speaker's utterance, clarity and understanding increases (e.g., table in background + "put the book ^*there* now" = definite perceived focus on "there"). These results suggest that embodiment (gestures) and environment (affordances) are *both* essential for grounding language in a dynamic meaningful environment.

6. Dynamical systems approaches to learning and development

In this lecture I provided my perspective on the relation between dynamical systems approaches to learning and the theory of development as outlined by Esther Thelen and colleagues. Clearly much is to be learned form the self-organization paradigm when asking questions about the "causes" of development—or more generally—of pattern emergence and pattern change. The self-organization approach clearly questions assumptions that material causes lead to pattern emergence. *It is not all in the genes!* That can not be the case. Worse, it may be even more perplexing as self-organization theory shows that pattern change is a macroscopic phenomenon. It can not be *reduced* to material, separate components. If anything, genes must act as just another constraint, and are probably best characterised as shaping the overall *informational constraint* on the material substructure of molecules and atoms.

As James Gibson pointed out, psychological phenomena (both explicit behavioural patterns and implicit experience) must fundamentally require an *information-based* (not sensation-based) explanation. Just as my perception of a chair can not simply be *in* my head (for then how explain the phenomenological experience of the chair as *out* there, not in here?), so too the explanation of overt patterns of behaviour can not simply be due to the stuff *in* there (the genes). It is, surely, an ecology (Gibson), a synergy (Haken), a Gestalt (Koffka), a coalition (Shaw &

Turvey), a communion (Buddhism)—a deep and inextricable interaction between organism and environment. We may not yet fully understand development and learning as it is perhaps the "holy grail" for behavioural science, but we must at least try and get the framework and paradigm correct within which to start a search for an answer to the mysteries of growth, development, and goal-directed change.

7. Direct perception and locomotion

In this lecture I described recent research we had conducted into the role of ecological information in the control of driving and locomotion. James Gibson was the first psychologist to say anything sensible about locomotion and indeed Gibson and Crooks (1938) still reveals ideas that are not clearly understood even today but seem to make much good sense (Warren, 1998). Such concepts include the "field of safe travel" around a car and driver that effectively protects them—in a *functional* sense—from colliding with other vehicles. The field, perhaps although originally based on intuitions related to Einstein's concepts of fields in physics, is clearly well conceived today as a Gibsonian perceptual field that specifies affordances—a medium consisting of a structured energy distribution that has different intensities in different directions. This is another *macroscopic* concept that is an attempt to show that macroscopic patterns of behaviour have a commensurate description in macroscopic patterns of light in the case of visual perception (or sound in the case of audition). The ecological approach to perception and action shows that perception-action is a function of an organism-environment interaction based on macroscopic patterns of energy distributions (e.g., light) (Turvey, Carello, & Kim, 1990). Most importantly, the psychological and philosophical concept of *meaning* is addressed in a Gibsonian framework by realising that information specifies or "points to" affordances. Affordances are the meaningful properties of the environment that potentially afford actions to the organism. Gibson had to invent a concept such as affordance to capture the fact that perception is inherently meaningful in the same way that an organism is inherently a part of an environment. This is a Darwinian notion – Gibson based his ideas strongly on Darwin's theory of natural selection; so too have neo-Gibsonians (e.g., Reed, 1996). As Gibson said, perception is *not based on sensations* although sensations are a mere side effect of the process. Rather, perception (and action) is *based on information*. It was Gibson's genius, ahead of his time, to see this and to conduct experiments that showed that the resultant behaviour could not be reduced and explained by "parts"—it was the *whole pattern* of light that mattered (he worked with the Gestalt psychologist Koffka in the US for a few years but extended Gestalt notions of the causes inside the brain to encompass causes and reasons in the environment).

I also described our research into locomotion using virtual reality. At the Complex Active Visualization (CAV) lab, we set up a treadmill in front of large 2.5 m x 5 m screens. We could create virtual walking (or running) experiments. I showed that safe driving and locomotion is based on *stability*—just as a dynamical systems account of behaviour is based on an understanding of the creation of functionally stable states (Treffner & Kelso, 1999). By increasing postural stability in the car (e.g., by bracing a knee against a door during cornering or foot against footrest during braking) one's perceptual sensitivity increases and so control is improved (Treffner, Barrett, & Petersen, 2002). I also discussed classic issues such as time-to-contact (the "tau" variable) and how one can perceive the timing of events *directly*—as Gibson long ago intuited—and so control one's actions in a direct manner. For example, one can *see the future* when driving a car and can *see* when to begin to apply the brake for a gentle deceleration so as to avoid a crash—it is a function of current optical expansion patterns (not thoughts or concepts!). Driving is a perceptual process not a conceptual process. That's why it is not good to think too much while driving. Indeed, our experiments on hands-free mobile phones show that engaging in a conversation is very bad for the control of driving as it compromises one's attention to the perceptual information for control Treffner & Barrett, 2004). Perception and action are intimately coupled—it is the concept of "perception-action" that we, as ecological psychologists, are trying to understand.

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