Symposium: The task as the unit of analysis in ecological psychology

SYMPOSIUM: The task as the unit of analysis in ecological psychology
Edward Baggs
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The way that researchers go about asking questions, within a scientific research program, defines the scope of enquiry for the field. That is, the unit of analysis that is chosen has consequences in terms of the kinds of explanations that researchers working within the program can hope to produce. What is the unit of analysis in ecological psychology? This issue was discussed by Warren and Shaw (1985) in a paper that appears in the proceedings of the first meeting of this conference. Warren and Shaw suggest a dual unit of enquiry: ecological psychology is the study of events (changes in the layout of the environment) and encounters (change relative to a specific actor). A more simple scheme collapses the distinction, and has it that the object of enquiry is the task (Bingham 1988). In task-oriented research, it is assumed, sometimes implicitly, that the actor is striving to achieve some goal. The empirical program is then directed at attempting to identify the perceptual invariant implicated in the control of movement in pursuit of that goal.
The aim of this symposium is to ask whether the encounter- or task-oriented approach is still an accurate and useful way of characterizing enquiry within ecological psychology. Does the task concept continue to generate useful research questions? In what ways does it enable and limit enquiry?
First, Edward Baggs notes that the task-oriented approach privileges the study of activities that can be described in terms of optimization relative to a definable goal, and suggests that this leads to an incomplete understanding of exploratory behavior and learning. Next, Paula Silva presents ongoing work that suggests a task-oriented approach can be profitably applied in disability rehabilitation practice in order to promote movement flexibility. Next, Patrick Nalepka presents work demonstrating how a task-dynamic approach can be applied to understanding group behavior, and not just to understanding behavior in individual actors. Finally, Andrew Wilson proposes that, by adopting a mechanistic understanding of tasks, the task-oriented approach can be expanded beyond movement control to the study of actions that would seem to require representational explanations.

Ecological psychology: a science of tasks?
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The empirical program within ecological psychology is concerned with how an actor optimizes performance relative to some task goal. This conception of task-oriented action can be traced back to James J. Gibson's own work on the perceptually-guided control involved in such activities as driving an automobile or landing a plane. An important intuition driving this work, as Gibson later noted, was the view that controlling behavior is a matter of 'maximizing or minimizing something visual, or centering or symmetricalizing something, not merely a matter of reacting to a stimulus' (Gibson 1972, unpublished note quoted in Reed 1988, p. 77). The empirical program that has followed has continued to focus on action that is optimized in this sense.
This methodological approach has proved remarkably successful and productive. A limitation, however, is that the methodology appears only to be suitable for the study of behavior where there is a clearly definable goal that can be described in terms of an optimal solution. Balancing on a beam or swinging for a home run may be describable in such terms. Other activities do not appear to a have a clear optimal solution, e.g. speaking a sentence or constructing a termite mound.
The task-oriented view is not well-suited for characterizing all forms of behavior. For instance, how should we understand exploratory behavior of the type characteristic of human infants? It is tempting to answer that this exploratory behavior is learning behavior directed in search of optimal solutions to tasks. But this overlooks the sense in which learning, at least in humans, is also creative and yields diversity, both between individuals and cross-culturally. Moreover, the task-oriented approach is ill-suited to deal with basic forms of learning that involve changes to the nervous system, such as imprinting or operant conditioning.
Exploratory behavior is not itself goal-directed. It is important here to separate the task-oriented methodology of the research program from its subject matter. I suggest that clarity here is a necessary prerequisite for pursuing an ecological psychology of human learning that goes beyond goal-directed motor control and incorporates social activity.

ICPA 2019 Orals – Thursday July 4

On the practical benefits of a task-oriented approach to perception and action: Implications to the understanding of functional resilience

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A hallmark characteristic of expert motor performance in both mundane and highly skilled tasks is *functional resilience*. This characteristic is marked by the ability to preserve relevant aspects of task performance under variations in contextual conditions. Functional resilience is strikingly lacking in individuals with disabilities. Accounts of disability can be distinguished with respect to the level of analysis that is, tacitly or explicitly, selected to study, explain, and treat reduced functional resilience. Mechanistic accounts assume that resilient performance at the task level is the result of particular characteristics of behavioral patterns at a lower scale (e.g., neuromuscular, biomechanical). Accordingly, interventions inspired by mechanistic accounts aim to reconstitute altered patterns to their paradigmatic form as a means to improve functional resilience.
The realization that rehabilitation interventions frequently fail at helping patients achieve their functional goals promoted a shift to a more systemic view of disability. Systemic accounts define disability as a phenomenon to be understood at the interface of individuals with their environment. This account is supported by solid empirical evidence that similar impairments in body functions can result in very different levels of disability depending on environmental support. Not surprisingly, systemic accounts of disability call for interventions that pursue improvement in task performance more directly. Unfortunately, changes in clinical practice in the face of these developments have been modest at best.
I propose that a task-oriented approach to the study of reduced functional resilience can provide clinicians with the necessary principles to guide the development of transformative interventions. I will support this thesis with recent empirical work inspired by this approach. This work has shown that (a) reduced functional resilience is related to reduced *adaptability* of behavioral patterns to changes in contextual conditions; (b) healthy, adaptive patterns show signatures of metastability; (c) attempts to reconstitute “desired” movement patterns lead to reduced flexibility and performance. I will exemplify how these lessons have inspired an innovative approach to enhance functional resilience of athletes and prevent injuries. This approach focuses on promoting *flexibility* in behavioral patterns through system atic and individualized design of contextual challenges in virtual environments.

Understanding Solution Emergence in Multiagent Interactions using Task-Dynamics

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Tasks or encounters provide a useful carving point to make the study of animal behavior tenable. Taking a *task-dynamic* approach (Saltzman & Kelso, 1987), intentional behavior can be thought of as lawful animal-environment interactions that conform to a sub-space of a task’s solution manifold. Only once the task-dynamics are understood, and the task solution manifold defined, can one come to understand how animals organize their many degrees-of-freedom to form a task-specific device (Bingham 1988) that aligns with a sub-space of the task-solution, as well as understand how animals learn to move across this space during skill development (e.g., Müller & Sternad, 2004; Jacobs & Michaels, 2007; Zhang et al., 2018).
In the case of multiagent activity, the task-specific device must expand to include multiple actors (i.e., the formation of an interpersonal synergy; Riley et al., 2011). What defines the coordinative strategies that human groups use to organize their own behavior to achieve the shared goal of the group? To understand the complexity of multiagent activity, I present an example from my own work, human shepherding, to demonstrate the usefulness of taking a task-dynamic approach in understanding coordinated behavior emergence. In this task, human dyads need to coordinate their behaviors to immobilize a set of fleeing objects. Here, the task-solution is defined by the negation of lateral forces acting upon the object herd, with the optimal solution being to form a circle around the group. Despite task difficulty, a subset of participants learns to perceive this task-dynamic and coordinate their behaviors accordingly. Given differences in constraints acting on individual actors, the same resultant dynamic emerges. This solution exhibited by human dyads is not unlike what is seen in other shepherding and group hunting contexts by entirely different animal-environment systems (e.g., wolves, whales, robots), demonstrating task-dynamic similitude despite vast differences in constraints acting upon animal-environment systems. By making *the task* be the focus of scientific enquiry, one is not only able to make progress towards understanding the organization of individual or group human behavior, but to also provide an understanding of intentional behavior universally.

Task Dynamics and the Information They Create: Mechanisms of Events & Encounters

Andrew Wilson
Leeds Beckett University, LEEDS, United Kingdom

Warren & Shaw (1985) detailed the ecological hypothesis that the appropriate scale for perception-action

psychology was the event, or encounter. Events are defined dynamically, over ecological amounts of space and time. Events dynamics are projected into media such as the optic array as kinematic patterns. These cannot be identical to the dynamics, but they can specify them, and thus organisms can be informationally connected to event dynamics. Ecological psychology's job is therefore to identify action-relevant task dynamics across an organism-environment system, the information variables these dynamics create, and how these real components come together in a *task-specific device* (Bingham, 1988) that produces behaviour that complements the task demands. Critics of the ecological approach note that we have no obvious way to explain how behaviour can be organised with respect to properties that are not currently perceptually specified (so-called 'representation-hungry problems'). In this talk, I will review my recent work (with Sabrina Golonka) in which we have worked to expand the scope of the ecological job description towards these challenges without breaking the above ontological rules.
First, we note that organisms must learn to use kinematic patterns as information, and while they can learn to use them as lawfully specifying designations of dynamical properties, they do not have to do so. This opens up the possibility of convention-based use of information (Golonka, 2015; Wilson, 2018). This in turn allows presently available information caused by one set of properties to connect us to a different set of properties, which can be spatially and/or temporally distant from us. Law-based and convention-based use of information then supports a grounded account of the neural activity which support this 'representation-hungry' behaviour (Golonka & Wilson, 2018a). Finally, because this analysis only relies on the real components of task dynamics and the information they create, ecological psychology can, uniquely, support dynamical mechanistic explanatory models of behaviour (Golonka & Wilson, 2018b).
This analysis is still a sketch and it poses new challenges to ecological psychologists. However, it opens paths towards problems we need to engage with while still living entirely within the ecological ontology of events and encounters.

Symposium: Nested Affordances

SYMPOSIUM: Nested Affordances
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Nested affordances
Symposium organized by Jeffrey B. Wagman and Thomas A. Stoffregen
Affordances are opportunities for action that emerge from task-specific relations between action capabilities and environmental properties. A fundamental, but often overlooked, fact is that for any given animal in any given situation, there exists a multiplicity of affordances. Animals have many properties and environments have many properties, such that there is a many-to-many relationship between action capabilities and environmental properties. For an animal with appropriate action capabilities, a given object has many different affordances, and a given affordance can be actualized by many different means. Consequently, it is generally insufficient for a given animal to merely choose whether to actualize a given affordance. Rather, that animal must choose which affordance to actualize as well as when and how to do so. Such choices should be based on the ability to ability to perform a given behavior in the context of overarching goals, task constraints, and situational norms, and other factors. In short, at any given moment for any given animal, multiple affordances exist and do so in the context of other affordances. That context, we argue, implies that—in some manner—affordances are nested.
Erik Rietveld, will present three perspectives on the nestedeness of everyday life and argue that situated normativity is crucial for understanding so-called higher cognition in a non-cognitivist, non-representational way.
Tetsushi Nonakawill review recent and ongoing empirical research on the development of the use of eating utensils and discusses such development in the context of affordance selection from among many available affordances.
Thomas A. Stoffregenand **Jeffrey B. Wagman**will describe their recent efforts to conceptualize the multiplicity of affordances as a nested means-ends hierarchy in which upper levels of the hierarchy represent goals to be achieved and lower levels represent the means by which to achieve those goals. Stoffregen's talk will focus on the theoretical motivation for these investigations. Wagman's talk will focus on the empirical evidence obtained thus far.

Nestedness in Complex Situations in Human Life
Erik Rietveld
University of Amsterdam, AMSTERDAM, Netherlands

In this philosophical paper, I will present various phenomena of nestedness encountered in real life situations. I will distinguish three different perspectives on such nestedness: the lived experience of the situated individual, the zoomed-in perspective of the empirical observer of human behavior, and the zoomed-out perspective of the practice-oriented investigator (Van Dijk & Rietveld, 2017). I will show how the latter perspective helps to understand

the kind of normativity that characterizes real-life situations of human behavior (Wittgenstein, 1953). Such situated normativity is distinguishing between better and worse in the context of a particular situation (Rietveld, 2008). Situated normativity is crucial for understanding forms of so-called 'higher' cognition (planning, imagination, language use) in a non-cognitivist, non-representational way (Van Dijk & Rietveld, 2018).

Development of skills to use specific affordances: Changes in infant-mother dyads around transitions in infant feeding

Tetsushi Nonaka
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The environment offers many ways of life, and there are all sorts of ways of achieving the same goal (Gibson, 2015). Within such a rich and complex environment, how do our daily skills develop so as to reliably realize a specific set of affordances relevant to a given situation? This talk reviews recent and ongoing empirical research on the development of the use of a utensil for eating—one of the first tool-using skills acquired by infants in some cultures (Nonaka & Goldfield, 2018). Videotapes of mealtimes of 12 infants around transitions from finger/passive feeding to utensil feeding at a nursery school in Japan are subjected to analysis that investigate the relation between 1) infant's feeding actions, 2) infant-caregiver interaction, and 3) gaze behavior of infant who looks to the face of the caregiver. In discussing the development of everyday skills of human life, Gibson (1950) once wrote, "what gets learned tend to be both socially permissible and individually workable, or both proper and expedient." The issue of how our everyday actions come to be "both proper and expedient" is further discussed in terms of the process of affordance selection (c.f., Reed, 1993).

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Nesting of affordances in a means-ends hierarchy

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For any given organism in any given situation, opportunities for action (i.e., affordances) are very numerous. In part due to the sheer number of affordances, researchers often have referred informally to the possibility that affordances might exist in some nested relation to one another. To date, there has been little effort to develop a systematic or formal account of this nesting. We propose such an account. Individual affordances emerge from higher-order relations between properties of the organism and properties of its environment; for example, the maximum height of a stair that can be climbed is an emergent relation between stair height and leg length. Similarly, relations between such nominally distinct individual affordances can give rise to higher-order, qualitatively distinct affordances; for example, the affordance for lifting an object and the affordance for interpersonal coordination can yield an emergent opportunity for dyadic lifting. We propose that opportunities for action that emerge as higher-order entities from relations between lower-order "simple" affordances are real parts of the animal-environment system just as the lower order affordances themselves are part of the animal-environment system. We suggest that lower- and higher-order affordances constitute a nested, means-ends hierarchy, and sensitivity to nested hierarchical relations among affordances can facilitate successful action. In particular, we propose that a central focus of learning and development is the detection and exploitation of higher-order and lower-order affordances in the means-ends hierarchy. We propose not only that individual affordances are specified, but also that hierarchical, means-ends nesting of affordances is itself specified, such that nested relations among higher-order affordances and their lower-order constituent affordances can be perceived directly. That is, we claim that organisms perceive the Affordance Hierarchy, and that it is a fundamental constituent of animate, intentional perception-action systems. Our proposal has implications for learning and development, for concepts of specification, and also for debates about how the Ecological Approach may be applied to behaviors that often have been understood to be outside the domain of direct perception, such as language, or planning.

Empirical evidence for sensitivity to nesting of affordances as a means-ends hierarchy
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Empirical evidence for sensitivity to nesting of affordances as a means-ends hierarchy
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Affordances are opportunities for action emerging from the task-specific fit between action capabilities and environmental properties. Typically, empirical investigations of affordance perception have focused on single affordances in isolation. However, in everyday situations, many affordances exist and do so in the context of other affordances. We have proposed that the multiplicity of affordances comprise a nested means-ends hierarchy in which upper levels of the hierarchy represent goals to be achieved and lower levels represent the means by which to achieve those goals. This talk reviews recent empirical research showing that participants are sensitive to such hierarchically nested means-ends relationships when perceiving affordances for reaching both for themselves and for others (Wagman, Cialdella, & Stoffregen, 2018; Wagman, Stoffregen, Bai & Schloesser, 2017), when assembling tools (Wagman, Caputo, & Stoffregen, 2016a, b), and when perceiving affordances for walking on a ship at sea (Water, Li, Wagman, & Stoffregen, 2019; Walter,Wagman, Stergiou, Erkmen, & Stoffregen, 2017). Overall, the results support the hypotheses that multiple affordances exist, that affordances exist in nested relationships, and that perceivers are sensitive to hierarchical, means-ends relations among affordances for themselves and for others. We believe that our framework advances the ecological agenda by providing a principled account of the multiplicity of affordances that is consistent with the ecological principle of nesting and that respects three fundamental hallmarks of intelligent behavior — goal-directedness, prospectivity, and flexibility. Thus, such a conceptualization may facilitate progress toward what may be the most important goal of ecological psychology—a scientific explanation of agency.

Open topics

Crawling experience predicts infants' behaviour near risky drop-offs - even when they are walking!
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After several weeks of crawling experience infants start to avoid crawling off edges and into bodies of water. However, whether the perceptual-motor learning infants gained through crawling transfers to walking remains uncertain.
To investigate the potential relation between crawling and walking experience on infants' avoidance of real and water drop-offs we tested infants on the "Real Cliff / Water Cliff" apparatus in both a cross-sectional and a longitudinal study design. Infants were classified as non-avoiders if they fell from the platform (rescued by a safety harness) or avoiders if they stayed on the platform or adapted their behaviour to descend safely.
In the cross-sectional approach, we tested 55 crawlers [crawling for 0.4-7.4 months, mean(SD)=3.17(1.89)] and 41 walking infants [walking 0.13-5.19 months, mean(SD)=1.89(1.31)]. Crawling experience was the strongest predictor of crawlers' avoidance behaviour on the real cliff ($\chi2(1)=13.35$, $p<0.001$; $R^2=0.304$; Exp(B)=2.07) and on the water cliff ($\chi2(1)=5.80$, $p=0.016$; $R^2=0.143$; Exp(B)=1.70). Walking experience was linked to walking infants' avoidance behaviour, but crawling experience was the strongest predictor of walkers' avoidance of the real cliff ($\chi2(1)=10.20$, $p=0.001$; $R^2=0.314$; Exp(B)=2.34) and total self-produced locomotor experience the strongest predictor on the water cliff ($\chi2(1)=7.76$, $p=0.005$; $R^2=0.236$; Exp(B)=1.74). However, when comparing experienced crawlers (>41 days of crawling experience, N=31) and new walkers (<41 days of walking experience, N=18), walkers fell more from the real cliff (44.4%) and the water cliff (55.6%) than crawlers on both cliffs (16.1%), raising questions about the extent of transfer from crawling to walking.
To further explore the cross-sectional results, 23 infants were tested twice in a longitudinal design: once after crawling for at least 6 weeks and again when they started walking. The results showed no difference on their avoidance behaviour when they were tested as experienced crawlers or new walkers on the real cliff ($p=1.0$) or the water cliff ($p=0.453$).
There was mixed support for perceptual transfer from crawling to walking, but the weight of evidence suggests that

what infants learn about negotiating risky drop-offs in a crawling posture informs their behaviour when confronted by risky drop-offs even when they adopt a newly-acquired walking posture.

Development of active manipulative behaviour in early infancy

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The hand is involved in perception as well as in action as part of a manipulative action system. Babies are very active experimenting and identifying regularities between actions and its consequences. Hands can be engaged in exploring the world well before babies can show typical eye-hand coordination. This is the main hypothesis of a series of studies we have been conducting on infants and babies in the first 12 months, in contingent and non-contingent situations. In the present study, we investigated the hypothesis that babies would show an increase of behaviours of the hand acting upon an object placed in their hand from birth to three months. Forty five babies were divided into 4 groups: Two days-old (n=26), One month-old (n=6), Two months-old (n=5), Three months-old (n=8). The hand's exploratory action was inferred from clutch behaviour showed during a two-minutes session carried out in a quite room. They were sat in an adapted baby chair when a rod made of rubber, similar in size and shape of an adult finger was placed in the babies' palm and strapped inducing a palmar grip. With a built in transducer in the rod we measured pressure and the number of clutches. One-way ANOVA showed significant differences for the number ($F_{(3,41)}$=3,86, p=0,16) and frequency of clutches ($F_{(3,41)}$=3,13, p=0,036) between groups. *Post hoc* tests indicated differences between 2 Days-old group and 3 Months-old group in number (p=0,016) and frequency of clutches (p=0.009), in average (p=0,049) and variability of pressure (p=0,019), in high peak pressure (p=0,019) and average frequency of peak (p=0,034). There were also differences in the number of clutches (p=0,014) and average of peak duration (p=0,040) between 2 Days-old and 60 Months-old groups. Hence, from birth to three months babies increase the number of times they squeeze the object and also the ways they do it. Grabbing and holding an object is seen by many as a reflex in infants. In our study they showed a variety of ways to hold it that led us to suggest that babies were actually exploring it. Clutching is an active rather a reactive behaviour.

Can a robot have an unintentional behavior when interacting with a human?

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Although social-motor coordination can be performed intentionally (when people voluntarily follow each other's moves), the usual humans' interaction is unintentional (when people are unaware of being synchronized together). Schmidt and O'Brien (1997) were the first to reveal the unintended motor coordination phenomenon when they asked participants to move a handheld pendulum at their own paced either by looking at the other one's pendulum or away from it. The results showed that although the instructions explicitly asked to keep their own frequency, they both synchronize as soon as they saw each other's pendulum. Such a phenomenon is now established in the literature as one of the most important aspect of joint-motor coordination. But does the same principle exist when a human interacts with a non-human agent such as a robot? Several articles showed that human can obviously coordinate intentionally with a robot (e.g., Kilner et al., 2003) but none are focused on unintentional interaction. We will present experiments showing evidences of unintended motor synchronization with robots, indicating that participants have the same frequency and phase locks as the ones observed in human-human motor interactions. However this only demonstrates that the human actor has an unintended behavior, but nothing can be stated for the robot counterpart. In other words, can roboticists build a social robot possessing unintentional characteristics? We will address this concept in the current presentation. We believe that if such a social robot can be designed, the human-artificial agent coordination would be way more realistic. This would open new perspectives in patient-robot interaction or even in human-machine interaction in general.

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Symposium: Non-representational dialogues: ecological psychology and enaction

SYMPOSIUM: Non-representational dialogues: ecological psychology and enaction
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Ecological psychology and enactive approaches share in the commitment of providing a non-representational account of cognitive phenomena. Nonetheless, they have more or less independent histories, and cross-fertilization between the two is still scarce. Seeking to understand the differences and similarities between the two fields, this symposium proceeds from the idea that entering into a sustainable dialogue can result in what Susan Oyama (2011) called “productive probing.” The symposium aims for a mutually beneficial exchange by helping to bring out each other’s blind spots, and finding concrete opportunities for joint investigation of phenomena. It brings together leading experts in ecological psychology and (radical) enactivism that aim to push the boundaries of their fields. Drawing on the phenomena and arguments they encounter in psychology, philosophy, architecture and ethnography each contribution brings a unique perspective to the discussion. The contributions reflect on some of the key concepts used in both ecological psychology and enactivism, as well as on the advantages and limitations of their research methods. Building on their expertise, the speakers of this symposium all show the merits of meeting our non-representational neighbours.

What Shall the Unit of Analysis be for a Non-Representational Approach to Perception-Action?
Harry Heft
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There appears to be considerable common ground shared by Gibsonian Ecological Psychology and Enactivism owing to the dynamic-agentic character of each approach and to their shared rejection of mental representations in accounting for perception-cognition. Still, they differ substantively in several respects, perhaps most fundamentally about *what the proper unit of analysis for psychological inquiry is*. Enactivists take as their unit of analysis and their focus “the organization of living systems” with the cell and its semi-permeable membrane as their model of organismic functioning. They view the organism as an operationally closed system that from a psychological standpoint engages in “sense-making” through which the environment comes into existence for the organism, realized within the body boundary as a “sensorimotor environment” and a “sensorimotor habitat” (DiPaulo, 2017). Although we are cautioned that these latter concepts are not to be taken as “the environment *for* the agent,” overall their framework prompts the same criticism leveled long ago at Tolman’s cognitive behaviorism that it leaves the organism encapsulated in thought within the environmental surround. Ecological psychology, in contrast, takes as its unit of analysis the reciprocal environment-organism transaction. Rather than taking a single cell as its model, perhaps more appropriate would be a single celled *organism* (e.g., an amoeboid) which extends its boundary to encircle and thereby subsume materials in the environment. In the case of more complex organisms, the boundary of the environment-organism transactions shift over time as the organism’s focus of action changes. This stance can be seen when information controls action, when the structure of action shifts in relation to the ‘object’ being engaged, and in instances of intersubjectivity. An environment-organism transaction unit is even more evident phenomenologically when an individual is engaging in tool use. In those familiar cases, as the tool is experienced as an extension of the body and the environment is experienced at the end of the tool the environment-organism boundary has shifted. Historically, this perspective is consonant with Holt’s seminal ideas of adience and the recession of the stimulus, which influenced Gibson in the formulation of ecological psychology.

Ecological Psychology and Radical Enactivism: Time to Contact?
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Ecological Psychology and the Radical Enactive view on cognition, or REC, developed by Hutto & Myin (2013, 2017) have a lot in common. They both endorse a view of perception and thinking as things organisms do, and they both reject internalism, representationalism and computationalism. In this talk, I will briefly motivate what REC stands for, and why it rejects the standard cognitivist construal of all perception and thinking as deriving from processes having representational content. Turning to REC’s positive story, I will elaborate on how it places a history of interactions central in its explanations of how and why organisms act in their current situation. I will stress the role of effects or consequences in establishing what organisms become sensitive to, and raise the question to what extent the history-based REC story is compatible with an affordance based story. I’ll argue that it all depends on what notion of affordance one holds dear, in particular what epistemological work one assigns to it, and whether or

not one sees affordances as explanatory notions. What the contact between EP and REC has in store depends on choices made with respect to these issues.

How architecture affords being-in-the-world? Exploring the enactive, embodied, affective view of spatial experience

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"*Architecture is an envelope and background for life, a sensitive container for the rhythm of footsteps on the floor, for the concentration of work, for the silence of sleep*"[1].These words by the distinguished architect Peter Zumthor capture enduring thought within architectural scholarship that architecture acts as an existential scaffolding to human life, because it accommodates at the same time both the living and lived body.On the one hand, the task of architecture is to provide a shelter and fulfil functional requirements, while at the same time, architectural spaces can be understood as spatial scenarios of emotional and bodily experiences.The aim of this paper is to propose how the long-standing tradition of phenomenology in architecture[2] and the recent interest in cognitive science[3] can be channeled through the enactive-embodied view[4] to provide a rich(er) understanding of how architecture affords being-in-the-world.By drawing on the one hand from the enactive and affective approach to cognition[5,6] and on the other, on the account of affordances as relations between the environment and ability available in the human form of life[7], I discuss how the task of architects can be conceptualized as designing the embodied experience of spatial affordances.Accordingly, it is proposed that architecture can shape and structure our (experience of) being-in-the-world through the design of body-environment interactions, and indivisibility of the affective layer in perceiving and engaging with the affordances of spaces, where the latter are understood as (designed) materializations of the sociocultural patterns, practices, and meanings. Zumthor P.1999 Thinking architecture.
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Avoiding the philosophic fallacy: affordances as real yet precarious

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While ecological concepts, such as affordances, tend to foreground the invariant and stable features of our environment, enactivism highlights the precariousness and ambiguity of life. This difference in emphasis has been played up as a choice between realism and idealism. In this talk I return to the pragmatist roots of ecological psychology to steer clear of this false dichotomy. Starting from John Dewey's work (1929/1958) I will first explore the "philosophic fallacy." The fallacy is to identify determinable or predictable aspects of our life-world, and converting them into a necessary antecedent existence. Aspects that are indeterminate or unpredictable by contrast become a contingent human artefact. A common epistemological consequence of this fallacy is that retrieving reality implies mental disambiguation. Considering affordances to be an ontological category, ecological psychology resists this consequence by insisting perception of affordances is direct. I will argue that this caused ecological theory to re-conceptualize affordances and effectively define ambiguity and indeterminacy out of existence. To avoid this consequence I suggest resisting the philosophic fallacy by taking a processual approach to affordances. On this view affordances are unfinished, perpetually in a process of becoming. Affordances can be viewed as unfolding across timescales as animals and environment together take shape. The talk considers how this pragmatist understanding of affordances can bring the indeterminacy and precariousness of everyday engagement into focus without sacrificing direct perception.

Open topics

Detecting invariants in probabilistic environments: The role of spatial and temporal order of events
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Invariants specify the permanent features of the environment since they are univocally related, one-to-one, to physical properties of the world. From a direct perspective of perception, a probabilistic approach to perception is usually rejected since this approach assumes that organisms generate inferential processes to cope with probabilistic relations of events. An alternative explanation is proposed elsewhere that assumes that organisms adjust their behavior to the probabilistic character of the environment by extracting the permanent properties of the environment over the transformation of temporally ordered events, i.e., extracting invariants of higher order. In three experiments we tested these ideas by exposing participants to relations between the initial and final trajectory of an arrow under three probabilities (p= 1.0, 0.9, and 0.8). In the first phase of the experiment the arrow followed straight trajectories and shifted to broken in the second phase of the experiment, or *vice versa*. In Experiment 1, participants received feedback for their performance by seeing the destination of the arrow (visual feedback) and by receiving a 'correct' or 'incorrect' label (verbal feedback). In Experiments 2 and 3, they received only visual and only verbal feedback, respectively. Results showed that participants were sensitive not only to the probabilistic relations of the arrows in the task but also to the arrow's trajectory and to the features of feedback. Results are discussed in terms of considering the detection of invariants in probabilistic environments not as an inferential process but as one of extracting the permanent properties of the environment over different time scales, which is consistent with the principles of direct perception.

Multisensory Perception and the Neuroscience of Supramodal Information
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Gibson and others have suggested that multisensory 'integration' may be a consequence of detecting a form of information that spans energy media. This 'amodal' or 'supramodal' information is thought to be composed of higher-order energy patterns that can be similarly instantiated in the optic, acoustic, and mechano-haptic arrays. From this *supramodal* account, multisensory 'integration' is considered to be a function of the information, rather than some type of internal cognitive translation occurring across distinct sensory systems. It will be argued that much of the vast behavioral and neurophysiological multisensory data that has emerged over the last 20 years support a supramodal account. These data suggest a perceptual brain which is designed around multisensory input. Areas once thought dedicated to a single sense are now known to work with multiple senses. The multisensory nature of the brain may reflect a cortical architecture for which task, rather than sensory system, is the primary design principle. It will be argued that this construal of the brain is fully consistent with a perceptual mechanism designed to detect supramodal forms of information. Ideas for further investigating this claim will be presented as well as suggestions for how the extant neurophysiological research can be recast in a way that is more consistent with an ecological approach.

Inaudible High-frequency Waves Facilitates Active Perception-Action Cycle
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The human environment is surrounded by wide-ranging frequencies of waves, from that which is sensed as vibration and the audible wave, to the inaudible high-frequency wave that exceeds the auditory limit. Any types of vibrations in nature should contain information, whether audible or not. Many studies focus on the acoustic information in audible waves, and some attend to low-frequency vibration, including the studies by Ito et al. (2011, 2015) which suggested that airflow that corresponds to the low-frequency vibration helps a person locate still objects. Meanwhile, few studies have discussed in regards to inaudible, ultra-high frequency wave from the standpoint of information available for human action and perception. Aiming to find out the effect of the ultra-high frequency vibration on a person's auditory perception, the authors conducted two experiments.
In the first experiment, the participants heard and replied an impression of the sounds in the anechoic room under the conditions where audible and ultra-high frequency sounds were presented, and where the audible sound was presented alone. All participants responded to a difference in auditory impression between the two conditions. In the second experiment, the participants heard the sounds recorded by a microphone attached to their ear canals under the conditions that the face was covered by a rubber mask and exposed to the air. It was found that they distinguished the ultra-high frequency wave in the sound wave only when the face was exposed to the air. Those two experiments were validated by using a dummy head with human-simulating skin and head parts. From these, it

has been suggested that the perception of ultra-high frequency vibration has some different routes from the perception of audible sound through the air.
In this presentation, the authors will propose that the information on vibration sources may exist not only in the audible-band wave but in the ultra-high frequency vibration, and then discuss the routes of the ultra-high frequency vibration.

Visually-guided braking: Controlling deceleration and acceleration with proportional rate control
Didem Kadihasanoglu
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Visually-guided braking can be defined as approaching an object so as to make soft contact without colliding. It is a perceptual-motor behavior, which is well studied in the context of a driving-like braking task. Its execution requires extracting the task-specific information from the optic flow (Gibson, 1979) and using that information in a control strategy to guide movement. The information and control strategies used in visually-guided braking have generally been investigated using experimental set-ups in which only deceleration was allowed. The aim of the present study was to investigate the control strategies for visual guidance of braking when acceleration was also allowed together with deceleration. We tested the use of proportional rate control, which was proposed by Anderson and Bingham (2010, 2011). Proportional rate is mathematically defined as tau/tau-dot. Proportional rate control requires one to move so as to maintain a constant proportion between tau and its rate of change. Ten participants viewed computer displays that simulated an approach along a linear path over a textured ground surface toward a set of road signs. Participants were instructed to stop as close as possible to the signs. They used a joystick attached to the computer to accelerate and decelerate. The neutral position of the joystick corresponded to constant velocity approach. Participants moved joystick from its neutral position to forward to accelerate. They moved it from its neutral position to backward to decelerate. We performed split-half analysis on the proportional rate trajectories. First, the proportional rate trajectories were trimmed to isolate the portions, in which participants actively regulated their deceleration/acceleration. Each trimmed proportional rate trajectory was split into two halves using the median time sample. For each half, a mean proportional rate value was calculated. We found no significant difference between the mean proportional rate values in each half, suggesting that participants moved so as to maintain a constant proportion between tau and rate of change of tau. These results indicate that the proportional rate control can be used to control acceleration as well as deceleration when approaching objects.

The Behavioral Dynamics Approach to Sound Localization
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The behavioral dynamics framework provides a detailed road-map for the modeling of complex, perceptually-guided behavior using differential equations. In general, states of the animal-environment system that are preferred are modeled as attractors of behaviors and avoided states are modeled as repellors. This framework has previously been applied to behaviors such as visually-guided walking (Warren & Fajen, 2004, 2008) and braking (Harrison, Turvey & Frank, 2016). Additionally, these behavioral models have been used to support claims about the use of perceptual information, such as optic flow, to control behavior. Here, we extend this work by developing a behavioral dynamics model of sound localization.
Human sound localization, as traditionally conceived, is the ability of the nervous system to calculate a sound's source position by processing a set of low-level, static cues which encode particular acoustic features, such as binaural intensity and timing differences. As a result of this framing, empirical sound localization research is generally concerned with determining localization accuracy rather than the behavioral dynamics of localization. Additionally, existing research often features simple sound stimuli and head movement restrictions, meant to ensure stable cue presentation. These features further obscure the potential diversity of sound localization behavior. Counter to the traditional approach, we take sound localization to be an extended process of gaze orientation that is continuously guided by richly structured auditory information. Therefore, in our model, the position of a continuous, broadband sound source is modeled as an attractor of head orientation, during an active localization task. Model parameters are tuned using human head rotation data, collected from participants who engaged in a virtual reality sound localization task. The resultant model captures both direct and oscillatory head movement strategies that were observed.

Visual and Haptic Perception of Affordance Properties of Feelies
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Assessing potential affordances of objects is commonplace. Unlike most objects, feelies (Gibson, 1966) were

created to have no inherent or obvious affordance properties, making them a valuable resource to investigate unbiased perception of affordances. Ten of the original feelies were 3D scanned and printed via 3D printer to be used as stimuli (Phillips & Egan, 2016; Norman, et al., 2012). The material used for printing was hard plastic (polylactic acid) with 70% of the interior filled in, and the printing increment was 0.2mm. 18 students were presented ten feelies to explore through vision alone or touch alone (haptically) and were asked to list any possible affordances for each object. Each object was presented a total of three times through a series of three blocks, resulting in a total of 30 trials per participant. Participants were given unlimited time to explore and provide answers. Responses were audio recorded and later transcribed by researchers. The most frequent words used to describe affordances were 'throwing', 'spinning', 'holding', 'toy', 'catching', 'decoration', 'sliding', and 'tossing', among many others. Analyses of the responded affordances showed that visual exploration and haptic exploration yielded different patterns of responses and frequencies. In the visual condition, there was more overlap in affordances listed across objects. In the haptic condition there was less overlap in affordances. This suggests that participants found feelies to look more similar than they feel in terms of afforded actions. Participants listed significantly more affordances for each feelie in the haptic condition compared to the visual condition. Participant response times were also measured, and a significant modality by object interaction was found demonstrating that reaction times were longer in the haptic condition than in the visual condition, but only for certain objects. This suggests that the differences in response time have more to do with the objects themselves than any differences between perceptual modalities. The results were interpreted according to two factors: 1) given mechanical contact, touch offers more immediate sensory experience than vision, and 2) haptic and visual exploration are qualitatively different and result in similarly different patterns of affordance perception.

Symposium: Improvisation and Creativity

SYMPOSIUM: Improvisation and Creativity
Matthew Rodger
Queen's University Belfast, BELFAST, United Kingdom

Creativity and improvisation are often treated as odd eccentricities in traditional Psychology, but observation and reflection would suggest they are much more a central feature of life than an exception. Think about driving in a new city, playing in a sporting match, or even having a conversation. All of these are improvisations, involving assembling and adapting existing skills in new and often creative ways. This poses a challenge for the science of human behavior. How it is that skilled agents (e.g. athletes, musicians, but also humans in general) become able to orchestrate their behaviour adaptively and fluidly with task goals, and to do 'new' things with the patterns of coordination they establish? How do improvisation and creativity emerge in skill acquisition and learning? How do we practice and acquire the skill for acting on novel experiences and situations? How do we rehearse the unrehearsed?
An Ecological approach to these questions arguably offers a fruitful basis for providing scientific explanations of how such improvisatory and creative skills are acquired and enacted. Understanding the perception and learning of affordances which can support adaptive actions may explain how creative solutions emerge in novel situations or with dynamically evolving task goals. Likewise, investigating the role of movement variability and coordination under different constraints may account for the dual stability and flexibility which is required for actions to be both successful and creative.
This symposium will present research into these ideas across a range of different perception & action domains. Seiffert will present research into exploration of affordances in relation to action capabilities by expert and intermediate climbers, and the observation of innovative action sequences in experts. Orth will present research into the role of constraints in the emergence of creative action, in terms of exploration, movement variability, and discovery of new affordances for target-striking actions. Smith will present research studying patterns of exploratory perception-action behaviour when searching for new affordances in a gap-crossing scenario. Finally, Rodger will discuss using digital musical instruments to investigate the mastery of affordances in musical technology and subsequent coordination of acquired skills in musical improvisation scenarios.

Perception of action capabilities in climbing
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The aim of this study was to understand how the perception of action capabilities relates to climbing expertise and the task complexity. Doing so we expect to better understand how experts explore possibilities for action offered by the environment relative to their own action capabilities. In particular, this study investigated (i) whether advanced climbers better perceive their action capabilities (i.e. a reduction in under- or overestimation of their action capabilities) than intermediate climbers, and (ii) whether advanced climbers act nearer to their maximal action capabilities than intermediate climbers. Trials in four conditions (reaching, grasping, grasping and removing, and using a hold to transit to the next hold) have been assigned in different orders to seven intermediate and six advanced male climbers. Each trial consisted in estimating the maximal distance at which the hold can be reached or grasped (by being allowed to move one hand and one leg), grasped (by moving one hand and one leg, then releasing the other hand at the start hold), grasped in order to use this hold to grasp another hold (by moving two hands and one leg) followed by the corresponding action. Data collection concerned (i) maximal distance at which the hold can be reached, grasped or used (absolutely and relative to maximal action capabilities) recorded by a tape take-measure, (ii) success vs. failure recorded by a video camera. Results showed that advanced climbers better estimated their action capabilities by acting nearer to their maximal action capabilities than intermediate climbers, especially in the remove condition. Finally, advanced climbers were able to innovate new sequence of actions in using condition as they chained hands and feet actions differently according to other conditions.

The role of skill and constraints manipulation on the emergence of movement variability and creative motor actions
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Creative motor behavior is both sufficiently original and functional in solving motor problems. Creative actions are assumed to emerge from movement variability in an effort to satisfy interacting constraints (individual, task and

environmental factors). This study examines this proposition in both novices and experts. This is particularly important, because functionality (a requisite criterion of creativity), is likely to have different meanings for individuals of different skill levels. The current study addressed this problem by examining whether skill level influences functional movement variability and subsequent creative action emergence. In doing so, we developed a paradigm to assess the degree of uniqueness (applying unsupervised machine learning to kinematic data) and functionality of actions in a task that required participants to strike a target (instrumentation obtained impact force to measure functionality). The task required participants to adapt to changes in the distance to the target. In adapting to the changes, skilled kickboxers tended to vary their actions to maintain functionality, sometimes leading to new and functional actions, i.e. creative actions. Alternatively, naïve actors tended to vary their actions independent of functionality, sometimes leading to new and ineffective actions. The results of this study showed that the discovery of new and functional actions are promoted by environmental constraints that require movement variability to maintain an overarching task goal. Future research should consider longer timescales of practice (across days or weeks) to determine whether the exploration of actions that are new but less functional (typical for beginners) is correlated with the occurrence of functional actions emerging later through practice.

Different patterns of exploration in perceived and actualized affordances during discovering the affordance of gap-crossing ability

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Creativity, the ability to produce something original or imaginative, requires active exploration and discovery of new affordances. We define exploration at the level of affordances as the structured variation of perception and action (i.e., actualization) over repetitions, to identify novel fits between the actor and the environment. The current presentation asks whether there is structure in exploration and to what extent this structure differs across individuals? Therefore we measured repetitive performance on a gap-crossing task to reveal structured variations in both the perceived and actualized affordance over repetitions. A novel experimental set-up was designed to mimic crossing a stream (which increased in width from 1m to 3m). Adult participants (N=30) were asked to find the maximum point at which they could cross to the other side, their maximal crossing ability reflecting the affordance, over a series of 10 trials/repetitions. For each trial, i) perceived gap crossable, ii) success of crossing and (iii) stability of landing were recorded. These variables were analysed on a trial-by-trial basis to reveal the exploration patterns used by each participant. After the 10 repetitions, the actual maximum crossing ability was determined using a staircase method of adjustment. Results showed a number of different exploratory patterns. For perception, the first pattern (N=13) indicated low variation over the 10 repetitions (± 10 cm of maximal crossing ability), indicating high consistency in affordance perception. The second exploratory pattern in perception (N=17) showed higher variation (-50cm to +30cm of maximal crossing ability), the structure of this variation showed a quadratic increase in perceived gap crossable over repetitions. For actualization, all participants showed variation in success of crossing, however no structure was apparent. For stability of landing, 71.4% of participants showed no variation, the remaining 28.6% of participants showed variation in either the first (10.7%) or second (17.9%) half of repetitions. In conclusion, patterns of structured variation in both the perception and the actualization of the affordance were observed for some, but not all participants. Therefore, new affordances can be discovered through combinations of different exploratory patterns of perception and actualization of affordances.

Using digital musical instruments to study the learning of affordances in support of improvised music performance

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Musical improvisation is a fascinating exemplar of human ability to skilfully adapt existing expertise to new situations and continuously changing goals. As with any area of expertise, it may be practised and enhanced through training. However, the processes by which improvisation skills are acquired are difficult to conceptualise and empirically investigate within the cognitive sciences. Arguably an Ecological Dynamics perspective, according to which skilled performance involves coordinating movement with domain-relevant affordances, may advance a scientific investigation of musical improvisation. This perspective was applied with the use of digital musical instruments (DMIs). DMIs allow control over the acoustic behaviour of a device in relation to a player's gestural inputs, thus the affordances available to support instrumental techniques can (to an extent) be shaped by the designer. Furthermore, altering the task or practice constraints during learning of a DMI allows empirical investigation of the processes which best support acquisition of predefined instrumental techniques, and their subsequent organisation in improvised performance. This approach was taken in an experiment that compared effects of practice structure (blocked vs random) on DMI technique acquisition and subsequent improvised performance. A novel, simplified DMI was developed, consisting of a box embedded with four magnetic sensors hidden beneath a metal plate surface in a diamond configuration. A resonant sound is sustained by moving a magnetic disc across the sensors at regular temporal intervals. Participants learned to control the sound during training and then were asked to improvise a short performance following training. All training trials involved moving through set triangular patterns of sensors, and

these patterns were repeated across consecutive trials for the 'blocked' group, while randomly varied between trials for the 'random' group. Analysis of instrumental technique acquisition (duration for which sound was sustained) and creativity (variation of improvised performance from the trained patterns) showed advantages of randomised training compared to blocked. Thus, regularly altering the constraints through which coordination with a novel DMI's affordance properties is acquired may result in greater stability and flexibility of auditory-motor control, thus better supporting improvisation. This study constitutes an initial step towards an ecological psychology of skill acquisition in music improvisation.

Open topics

Coordinative Gait Adaptations to Visual Task Performance during Object Transport
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Walking through a cluttered environment while carrying an object is a common activity of daily living. Orienting to the layout of the environment is critical for prospective control of locomotion and the object to be transported. The purpose of this study was to understand how individuals altered their intrinsic gait dynamics and coordination variability to support object transport while concurrently attending to visual information. Twenty young healthy individuals walked at different speeds (0.6, 0.9 and 1.2 m/s) on a treadmill and performed the following task conditions: normal walking, walking with an object, and walking while carrying an object and attending to visual information. The object transport task involved carrying a cup with a ball on top that had to be kept within a circular target zone. The visual task involved identifying when a Landolt "C" projected on a screen in front of the participant changed direction. Coordination was assessed based on continuous relative phase analysis (CRP; pelvis-trunk) and frequency relations between arms and legs (Relative Power Index; RPI), along with arm range of motion. The RPI analysis showed that when transporting an object, arm-leg coordination on the constrained side was 2:1 (two arm swings per stride) while the free arm maintained a 1:1 coordination. This finding is significant because it demonstrates that the free arm maintained its intrinsic behavior while the arm performing the object transport task adapted to the step cycle, facilitating manual task performance. Movement amplitude of the free arm decreased from normal walking to the object transport task and decreased further with the addition of a visual task (p-values <.01); this decrease was associated with increased manual task performance. When performing the manual and visual tasks pelvis-trunk coordination was more in-phase (p<.001) and had greater variability (p<.001) compared to normal walking. The larger pelvis-trunk coordination variability observed here may be functional in the context of manual task performance. Taken together, our results demonstrate the reorganization of intrinsic gait dynamics and the functionality of coordinative gait variability in maintaining manual task performance during object transport.

During rhythmic pointing movements, the underlying synergies change with task constraints, and constituent DOF vary in stability
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During rhythmic pointing between two targets, the many degrees of freedom (DOF) in the perception-action system are coordinated such that the end-effector moves as a stable limit-cycle oscillator, of which the characteristics systematically change across task constraints (Mottet & Bootsma, 1999). These end-effector oscillations emerge from interactions between the DOF making up the perception-action system while at the same time the end-effector oscillations constrain these DOF, often referred to as circular causality (cf. Warren, 2006). Consequently, a profound understanding of the emergence of goal-directed rhythmic pointing movements requires knowledge of end-effector oscillations as well as the coordinative patterns of DOF. However, knowledge on underlying synergies linking DOF in a coordinated way to produce end-effector oscillations is sparse. Therefore, the current study examined with uncontrolled manifold analyses whether joint-angles—selected as DOF—were organized in synergies to produce end-effector oscillations and whether the changes in end-effector oscillations under different task constraints—i.e. target sizes and movement amplitudes—were produced with different synergies. Moreover, with recurrence quantification analyses, it was examined whether oscillations of the joint-angles making up the synergies were as stable as end-effector oscillations. Twenty participants performed 40 cycles of rhythmic pointing movements with amplitudes of 5, 10, 20, and 30 cm towards different target sizes leading to IDs of 3.5-6. In line with previous work, end-effector movements showed stable limit-cycle oscillations, with typically varying characteristics across IDs. Joint-angles showed primarily covariation, reflecting a synergistic organization. Interestingly, synergies were located at different places in joint space for different IDs, reflecting that different end-effector oscillations were produced with different synergies. Finally, end-effector oscillations were more stable than oscillations at proximal joint-angles but not at distal joint-angles. Together, the results showed that stable limit-cycle oscillators at the end-effector in rhythmic pointing were produced with different synergies of which the properties changed with task constraints.

Furthermore, variation in the stability of joint-angle oscillations showed that individual joint-angles contributed differently to the emerging synergies. This suggests that links between DOF within synergies are not equal in strength, which is a first step unraveling the processes of circular causality according to which these synergies emerge.

The complexity of coordination in carrying, reaching, and driving: The search for fields of dexterity
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What does it mean to walk carefully? Does it mean to walk *cautiously*, *slowly,* or *fearfully*, as some have suggested? Most researchers have approached the issue in medical and economic terms, and none of these studies, except for Hodges and Lindhiem (2006), has included people carrying items of any substantial weight. 23 parents participated in a study on "carrying household items" in which they walked across a series of uneven steps separated by gaps carrying their child, a sack of groceries, or an open bucket of water. Child and groceries were equal in weight, and water was 6.8 kg. Children generally were cooperative, water was "uncooperative", and groceries were "dead weight." Point light films were shown to 28 participants who rated each kinetic display for carefulness. Observers did not know anything was being carried. Trials on which Water was carried were judged to be more careful than Child and Groceries trials. Observers believed they rated slower, more variable, and gentler patterns as being more careful. A variety of spatial-temporal, force, and kinematic variables differentiated trials on which water was carried from child and groceries trials (e.g., when stepping up, W > C, G for landing time, single support time, and loading peak force). Whether a clear pattern emerges from these measurements remains to be seen. To assess safety, most researchers focus on stability, but what is needed are dexterity (Bernstein, 1996) measures. *Being careful* has to capture openness to changing circumstances and demands as well as stability. Action contexts require attention to the nature of *what* is being carried (i.e., physical, social, and moral parameters). Relations among these dimensions are expected to be heterarchical (e.g., children are not always carried more carefully than other items). The issues facing an ecological account of carrying are similar to those of other actions, such as reaching and driving (e.g., Rosenbaum et al., 2014). The tendency to isolate a single value (i.e., accuracy, efficiency) or to search for fixed orders of constraints may need to yield to a fields of dexterity approach in terms of multiple values (Hodges & Raczaszek Leonardi, n.d.).

Studying Complex Adaptive Systems with Internal States: A Recurrence Based Approach To Idiographic Multivariate Time Series Analysis
Fred Hasselman
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Statistical modelling of observables of complex physical systems with internal state dynamics is notoriously difficult, because, as some scholars point out: "the very notion of probability may not make sense" (cf. Press, 2014). Even if some of the core assumptions about the data generating process are formally met (e.g., stationarity and homogeneity of central moments), one cannot rely on parameter estimates to converge on a characteristic scale.
I will demonstrate that the framework of Recurrence Quantification Analysis and (multiplex) Recurrence Networks can be used for an idiographic analysis strategy in clinical studies which have multivariate time series data available of sufficient length, e.g. multivariate time series of self-reports of human experience (daily ratings of self-esteem, psychological well-being, etc.) recorded over the period of months or years.
Previously published analyses of a number of publicly available datasets will be compared to the recurrence-based analysis approach: First, I will show that spectral density estimates of power-law scaling yield very similar results to scaling exponents derived from the distribution of recurrence times; Second, I compare previous attempts at multivariate time series analysis using Gaussian graphical models ('symptom networks') to analyses of the same data, based on Multiplex Recurrence Networks (MRN). The main conclusion is that the model-free nature, the sensitivity to detect regime changes in noisy data, and the adaptability of the analysis and interpretation of measures to different contexts, qualifies the recurrence-based analysis strategy as the preferred tool for analysing multivariate time series data of observables of complex adaptive systems with internal state dynamics.

Symposium: Gibsonian neuroscience

SYMPOSIUM: Gibsonian neuroscience
Matthieu de Wit
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The ecological approach has been criticized for ignoring the nervous system, treating it as “wonder tissue, resonating with marvelous sensitivity to a host of sophisticated affordances” (Dennett, 1998, p. 204). Indeed, barring a few notable exceptions, over the last few decades ecological psychologists have generally followed Mace’s (1977, p. 43) dictum of “Ask[ing] not what’s inside your head, but what your head’s inside of”. This has provided a healthy counterweight to the neurocentrism that dominates standard cognitive science. There is now much evidence to suggest that active organisms embedded in sufficiently rich environments are indeed sensitive to the information that specifies the affordances that are available to them. This achievement, together with an increased acceptance of enactive, embodied, and situated approaches in mainstream cognitive science has made room for a shift in research focus towards questions about the role of the nervous system in this process; that is, for an ecological or Gibsonian neuroscience. This symposium brings together both theoretical and empirical researchers working on such questions. The aim of the symposium is to showcase the already rich variety in the ecological study of nervous systems. The symposium coincides with the publication of a special issue in the journal *Ecological Psychology* around the theme of Gibsonian neuroscience.

Stinky business: a behavioral study of vicarious functioning in anterior insula
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Gibson (1966, p. 4) claimed that “The same incoming nerve fiber makes a different contribution to the pickup of information from one moment to the next”. This study aims to test this claim of vicarious functioning. Anterior insula is involved in time-to-contact (TTC) judgments of looming, but not receding, stimuli. Notably, it is also active when participants are exposed to aversive olfactory stimuli. In Gibson’s conceptualization, anterior insula might contribute to the pickup of visual looming information one moment and of olfactory information about a repellent substance the next. We ask what happens if participants must deal with both types of information *in the same moment*. Interference of exposure to a repellent substance with looming but not receding TTC judgments would be consistent with Gibson’s claim of vicarious functioning. A lack of (or non-selective) interference would be consistent with either a standard cognitivist conceptualization in which small modular visual and olfactory subregions exist side by side in anterior insula, or with Gibson’s related claim that information can typically be detected in multiple ways involving alternative anatomical structures (i.e., multiple realizability). In this latter interpretation, simultaneous pickup of olfactory information specifying a repellent substance leads to the reliance on (partially) different anatomical structures for the pickup of looming information, or vice versa. The talk ends with a brief discussion of methodological challenges associated with studying Gibson’s concepts of vicarious functioning and multiple realizability in the nervous system.

Gibsonians Need Neuroscience (and Vice Versa)
Vicente Raja
Rotman Institute of Philosophy, LONDON, Canada

In this talk I just want to convince you that, as ecological psychologists or ecological-friendly researchers, we desperately need a robust and detailed account of the role of the brain—and of the nervous system(s), more generally—in perception and action. If you are not convinced of this, this talk will interest you. If you are already convinced, you will probably enjoy it anyways. I will, first, evaluate the reasons why neuroscientists need ecological psychology. I will base my claim in the issues raised by (Krakauer et al., 2017) and by (Pillai & Jirsa, 2017) and, then, show the way ecological psychology may help to solved them. After that, I will change the order of the main characters and will motivate why ecological psychologists need neuroscience. An important part of the ecological theory rests upon the idea that perceivers are able to detect ecological information. Some aspects of how such a detection is carried out are well discussed, but other fundamental aspects of it remain metaphorical. For example, what is to *resonate* to ecological information? What does it mean that “meaningful information can be said to exist inside the nervous system as well as outside” (Gibson, 1966, p. 267)? I think neuroscience may help us to respond to these questions and I will motivate this thought during the talk.

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INFANTS' BRAIN RESPONSES TO LOOMING DANGER: DEGENERACY OF NEURAL CONNECTIVITY PATTERNS

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A fundamental property of most animals is the ability to see whether an object is approaching on a direct collision course and, if so, when it will collide. Using high-density electroencephalography in infants and a looming stimulus approaching under three different accelerations, we previously (van der Weel and van der Meer, 2009) found how the young human nervous system reflects visual information for impending collision. In the present study, using longitudinal data on 25 infants at 4-5 months and 12-13 months we showed that infants' looming-related brain activity is clearly localized in the visual cortex (V1) following retinotopic mapping, but is highly adaptive in its organization otherwise. Analyzing the orientation of electrical source flow, we provided evidence for a high degree of variability, spread across a relatively large area of the visual cortex. The findings revealed a highly dynamic functional organization with connectivity patterns constantly emerging and changing in many different directions between trials. This indicates degeneracy of neural connectivity patterns through reentry principles where neurons temporarily assemble to enable an appropriate looming response with the necessary precision.

Anticipating affordances: ecological psychology meets selectionist neuroscience

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In this talk, we investigate the foundations for a Gibsonian neuroscience. There is an increasingly influential current in neuroscience based on pragmatic and selectionist principles which we think can contribute to ecological psychology. We discuss one previous attempt to integrate affordances with neuroscience: Reed's ecological rendering of Edelman's selectionism. Reed faces the problem of how to account for "value". We then show how the free-energy principle, an increasingly dominant framework in theoretical neuroscience, is rooted in Edelman's selectionism. The free-energy principle accounts for value in terms of selective anticipation. The selection pressures at work on the agent shape its selective sensitivity to the relevant affordances in the environment. By being responsive to the relevant affordances in the environment, an agent comes to have grip on its interactions with the environment and can thrive in its ecological niche.

Symposium: Action-Perception interpersonal dynamics and group behaviour when N>2

SYMPOSIUM: Action-Perception interpersonal dynamics and group behaviour when N>2

Dobromir Dotov[1], Benoît Bardy[2]
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A coalition of two individuals can distribute and coordinate individual action to reach a shared goal. This could be to move a large object or to allow the individuals to move around without colliding with each other. For formal reasons one can expect different sets of phenomena from dynamic coalitions consisting of two, N, and infinitely many units. Increasing the number of agents from dyad to group (N>2) creates new challenges due to compounding of delays and increased task space embedding dimension. It is possible also that the group brings forth affordances for synchronization that are not accessible to the dyad. These questions are investigated through manipulations of complementary individual and collective parameters, eigenfrequency and topology, delay, and type of coupling. The talks report both experimental and modelling efforts, inspired by group situations encountered in real life such as music and crowd behaviour. In particular, the presentation by Bill Warren, resulting from a long line of investigation in individual, dyadic, and group walking, will show the specific inter-individual interactions that allow a group of individuals to move as a coherent crowd. Piotr SÅ‚owiÅ'ski will delve into the formal implications of delayed systems as they pertain to dynamic phenomena such as bi-stability and transitions between coordination modes in dyadic and group synchronization behaviour. Carmela Calabrese will go over results from a multi-agent dynamic mirroring task with manipulations of eigenfrequency and network topology, where the latter could consist of full, sparse, or ring patterns of connectivity. Dobromir Dotov will address whether and why anticipatory synchronization is more easily accessible in group drumming than dyadic drumming.

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Multi-agent crowd dynamics: Visual coupling and network reconstruction
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Coordination in multi-agent systems occurs in both rhythmic and non-rhythmic regimes. A case in point is the collective motion of bird flocks and human crowds, where individual trajectories are spatio-temporally coordinated without synchronizing wing-beats or step cycles. Yet in both regimes the collective dynamics emerge from an informational coupling whose topology affects the global behavior. I'll describe our recent work on the visual coupling between neighbors in a crowd, and preview an analysis of the network topology in real crowds.
When following behind a neighbor, the follower's speed is controlled by canceling the relative rate of expansion (θ-dot/θ) of the neighbor (Bai & Warren, 2018, 2019), and heading is controlled by canceling the angular velocity (ψ-dot) of the neighbor. When walking beside a neighbor, these relations reverse: speed is controlled by nulling angular velocity, and heading is controlled by nulling RRE (Dachner & Warren, 2017). The two variables thus trade off as a sine function of the neighbor's eccentricity. This visual coupling closely simulates our data on participants walking in virtual or real crowds, with a significantly lower RMS Error than our previous model based on the physical distance and velocity of each neighbor (Dachner & Warren, 2018; Rio, Dachner & Warren, 2018). Moreover, the visual model explains the decay of neighbor influence with distance as a natural consequence of Euclid's law of perspective, without an explicit distance term.
The visual model predicts a network of causal influence spreading from de facto 'leaders' near the front of a crowd, as observed in pigeon flocks. With Mario di Bernardo and Maria Lombardi, we are reconstructing these networks from real crowd data. Time-dependent delayed correlations (TDDC) between the time series of heading for each pair of neighbors yield a measure of coupling strength, allowing us to recover a weighted graph and how it evolves in time. We then apply the theory of pining control to predict positions in the network that should be most effective to 'steer' a crowd.
The results show how collective motion emerges from the local visual coupling between neighbors, which determines the network topology in a crowd.

Role of time delays in dyadic and group interactions
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Time delays are a natural element of perception and action. They arise due to the physiology of sensory and cognitive processes and can be affected by the neuropathologies or pharmacological agents. For example psychomotor slowing in schizophrenia or side effects of antipsychotic drugs. I demonstrate that the mathematical models with time delays can be used to quantitatively describe dyadic dynamics and that they provide better insight into the experiments than models without time delays. They capture the transition between discrete and oscillatory movements, exhibit experimentally observed frequency-induced drop of amplitude for the in-phase as well as anti-phase oscillations and have a large, experimentally relevant, region of bi-stability between in-phase and anti-phase oscillations.

I further review the importance of time delays for group/ network dynamics. Time delays in such system act in two ways they can either induce instabilities leading to multi-stability and chaotic motion or they can suppress dynamics and help to control the system. From the perception and action perspective, of particular interest are complex partial synchronization patterns, e.g. chimera states which are characterised by co-existing clusters of synchronous and asynchronous activity. I discuss how such complex dynamics could relate to experiments involving groups of interacting participants.

Emergence of motor coordination in human groups.
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Unveiling the underlying mechanisms of human coordination has attracted the interest of researchers from diverse disciplines of science. In particular, perceptual motor synchronization in human groups is crucial to enhance team performance in musical ensembles or dancers' crews. Most of the existing studies focus on dyadic coordination, and the investigation of ensembles of three or more individuals remains preliminary. In this research, we propose to study motor group synchronization across different experimental conditions, so as to improve our understanding of the main cues leading to human coordination, specifically related to the spatial organisation and the individual characteristics of the participants in the group. To this aim, we built a flexible experimental setup allowing to implement the so-called mirror game, which is considered a paradigmatic coordination task in human groups:

participants performed an oscillatory task and were asked to voluntarily synchronize their motion. We considered two different groups of participant, characterized by homogeneous and heterogeneous natural frequencies, respectively. For each group, we considered 4 different experimental conditions in which the topology of the interaction varied from the most (all-to-all or complete graph) to the least connected topology (path graph). A common feature of all experimental conditions was that when participants synchronized the oscillation frequency decreased compared to the mean individual frequency. Additionally, the way participants were visually coupled influenced more the degree of synchronization in the group than the homogeneity of their individual frequencies. We found that in both groups a more robust motor synchronization emerged in the all-to-all and star graphs. We discuss these results in light of the strength of the visual coupling associated with the manipulated topologies, their natural equivalents in daily life, and we provide suggestions for analytic models capturing the observed group dynamics.

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Collective performance facilitates anticipatory synchronization in group drumming
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Acting in group, such as during musical performance, creates different challenges and possibilities for coordinated behavior relative to single or dyadic performance. In this study we examined 4-person drumming circles of non-professional musicians performing a synchronization-coordination task in Solo and Group conditions. They were instructed to maintain a steady tempo, consistent inter-beat intervals, and synchronize with each other. Furthermore, performance in the latter was analyzed as Individuals-in-Group (individual participants' data) and Group, where the group-level drum hits were defined as the central moments of the individual drum hits, or as the points in time of peak acoustic energy produced by the group. Thus, the following three conditions were compared: Solo, Individuals-in-Group, and Group. Each sequence of inter-beat intervals obtained from the drum hits in a trial was analyzed using lagged auto- and cross-correlations and the parameters of a drift-diffusion model. The attractor strength in Group was highest, followed by Solo, and Individuals-in-Group. Noise was lower in Group than in Solo and Individuals-in-Group. As expected, the lag-1 auto-correlations of inter-beat intervals in the Solo, Group, and Individuals-in-Group modalities were negative, suggestive of self-correction. Importantly, cross-correlations between pairs during group performances were positive at both lag-0 and lag-1, a signature of anticipatory synchronization. This is in contrast to dyadic studies that typically report positive lag-1 and negative lag-0 cross-correlations, indicative of mutually reactive inter-personal dynamics. One explanation for this mutual anticipation is that collective performance by way of its central moment creates a different and more consistent affordance for synchronization. An alternative is that anticipatory synchronization is enabled by the dynamic similarity shared among participants. Unlike finger-tapping studies, here the drumming task was subject to the biomechanical enabling constraints associated with using the whole upper body to produce consistent movement.

Open topics

Ecological optics, a prisoner of geometry: Gibson 1979±40
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Vision science traditionally uses images to illustrate and explain how we see the visual world. Gibson's career is also paved with trade-mark images depicting surface texture, optic flow in landing of an aircraft, etc. Cutting (2000) has criticized Gibson's use of images based on the criteria of fidelity and evocativeness and concluded by stating that "Gibson ended his struggle with an image of a bird flying over a plane surrounded by a spherical representation of a vector field, an image high in evocativeness but less than completely faithful to optical flow. "
But Cutting's criticism is inauthentic. Gibson's approach can better be described by his efforts to move away from images of physical optics towards the natural perspective of ecological optics. He transcended the retinal image and associated concepts such as optical projection and geometric cues in retinal images. Paradoxically, however, throwing away the idea of physical optics of the eye-ball, he invoked another geometry of the natural perspective as used by Leonardo (an imaginary sphere around an observer). Thus, Cutting's "spherical representation of vector field" is actually a depiction of the natural perspective of a moving agent (i.e., bird) with a spherical projection of the surface layout around itself (Gibson, 1979). But moving from physical optics of the eye-ball toward the imaginary sphere of natural perspective kept Gibson's ecological optics within the prison of geometry.
In sum, a critical review of Gibson's ecological optics should be based on not his pictorial representations but the limitation of its geometric nature. Before WWII, Gibson was working on problems inspired by Gestalt Psychology that led to non-geometric ideas such as field of safe-travel (Gibson & Crooks, 1938) but these ideas are left behind and

even today Gibsonians are mostly trapped in the prison of the geometry of natural perspective. After 40 years, it is about time to escape from this prison.

Coordination of resonant tensegrity structures

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University of Connecticut, CESPA, STORRS, United States of America

Coordination of resonant tensegrity structures

In the past fifteen years, increasing attention has been drawn in the field of robotics to the design of tensegrity-based robots and their controllers. Tensegrity systems are structures composed exclusively of several rigid elements connected together by elastic elements. These systems present at least four properties that make them particularly relevant for research in robotics, namely, 1) *prestress*, that is, a preferred self-sustained equilibrium configuration, 2) *equifinality*, or the capacity to move to the preferred configuration independently of initial conditions, 3) multiscale complex *resonance* given by the oscillatory nature of the elastic elements, and 4) widespread *nonlinearities*. In addition to these four properties, it has been argued that tensegrity is the kind of structure that underlies the mammal musculoskeletal system.

Because of the four properties listed above, tensegrity systems are extremely hard, if not impossible to control using classical computational methods. Instead, the right approach seems to be to *exploit* instead of trying to *overpower* the intrinsic dynamics of these mechanical systems. In this paper we will show examples of how resonance constitutes a promising candidate to achieve behavioral goal directed coordination in tensegrity systems. Central signals must be generated so as to steer or shape the oscillatory patterns of tensegrity systems by tuning to their resonant properties or resetting them. The mechanical tensegrity system and the neural central system thus need to couple as two highly complex resonant systems in search of an adaptive equilibrium that brings about functional behavior.
However, we will suggest that the current designs based on simple tensegrity systems still fall short of the kind of complexity that is characteristic of living beings. Indeed, the study of structures such as the cytoskeleton in individual cells or even the extra-cellular matrix at the level of fascia reveal a dramatically quasi-fluid state of permanent synthesis and lysis of tensegrity elements. This implies that our understanding of coordination through resonance is still in its infancy and we need to conjecture the existence of higher order oscillatory relationships that include the dynamic assembly and disassembly of the oscillators themselves.

Accessing the world without agents: Metabolism and cobolism

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Suppose we look at perception and action not as phenomena where the differentiation between the agent and the world can be presupposed. Suppose, we aim to answer the basic question how the world itself came into being for increasingly complex lifeforms over evolutionary time. In such an account, which would start with the world as present for bacteria but also taking in the world as it is accessed by plants and fungi, the animal world of perception-action is tied to a particular organismal configuration. This application to animals connects with existing accounts that aim to articulate our (animal) way of accessing the world, such as von Uexküll's *Umwelt* and the Gibsonian concept of affordances. While such existing notions make intuitive sense and are extremely useful for understanding perception-action relations, their theoretical and empirical status remain difficult to explicate. At this point, progress can be made by turning to new approaches that work from this perspective of aggregating cells and the organizations that these aggregates evolved to handle their interactions with a communal world. I will introduce the concept of 'cobolism' as a tool to systematically address the various features that come into play when such (animal) aggregates evolve increasingly sophisticated body-forms and perception-action capabilities. Cobolism is to be thought of as complementary to metabolism. Metabolism consists of an integrated network of biochemical reactions that together constitute and maintain the biochemical foundation of lifeforms. Cobolism is likewise conceived of as an integrated network, but now of structures and happenings that together organize and control a lifeform's dealings with features that are outside the central metabolic interactions themselves. An organism's cobolism maintains the necessary boundary conditions for these metabolic processes and exhibits many different, often very complex forms, in particular in multicellular lifeforms. 'Cobolism' provides a way to systematically interpret an evolutionary buildup of increasingly complex articulations of the world as accessed by various lifeforms. For perception-action research this will help to provide a more general and systematic foundation for understanding how organisms access their worlds.

Symposium: Integrating the Ecologies of Language, Communication, and Development

SYMPOSIUM: Integrating the Ecologies of Language, Communication, and Development
Catherine Read[1], Joanna Raczaszek-Leonardi[2]
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Language use in relation to perception-action and *development* as changes in organism-environment systems are relatively new topics within Ecological Psychology. However, the "ecological turn" of the embodied and situated approaches to cognition, makes the Ecological Psychology framework and methods especially helpful in tackling some stubborn problems in "mainstream" cognitive science. Language use can be thought of as a control of the flow of interaction through guiding attention and selecting affordances. In development it has a role in improving such control, through educating attention and affecting further perception (J. van den Herik). Whether an array is specifying or nonspecifying depends on use and development. Specification of something in the environment, be it in speech or perception, is an active achievement of agents; there is no information prior to its use in action (J. Kiverstein). Synchrony of speech and gesture facilitates word learning for infants, toddlers, and older children with autism, but not preschool children. Whether a structured ambient array is resonated to depends on age and path of development. Thus, the affordance of the metamodal information created by the synchrony of gesture and speech was not relevant for the task of word learning in the group of typically developing preschool children while it was for younger and for ASD children (N. Rader). Expanding the time-scale on which early interaction is studied reveals a progression from coupling to narratives and intricate structures-in-time, which may both help discern semantic units and help their further structuring (J. Raczaszek-Leonardi). The final paper proposes that communication as the integration of signs during ongoing perceiving-acting (based on uniting the work of James Gibson and Roy Harris) provides a consistent basis for coordinating perception and language use, with the specific example of metaphor in conversation. In the case of adults in conversation with children about pictures the conversational partners integrate metaphoric resemblance into their communication sometimes resulting in the formation of metaphors across utterances and speakers (C. Read). These papers show that the scope of the ecological approach to language, communication, and development can be broadened considerably, and they point to specific generative topics for future research.

Attentional Actions and the Complex Interplay of Time-scales
Jasper van den Herik
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In line with ecological psychology's action-oriented account of cognition, I argue that we are language *makers* rather than *users* of *a* determinate language. In this paper, I explore an aspect of what we do when we make language. We are not born as language makers. We have to learn to talk. But what do children learn, if not the abstract meanings of decontextualised words? Based on the *constraint-view of language* and the ecological conception of learning as the *education of attention*, I conceive of learning a word as learning to perform an *attentional action:* a social action that functions as an enabling constraint on attention, where attention is understood as a selective openness to the field of affordances in relation to a task or goal. An attentional action thus functions by indicating some aspect of a situation to someone else in order to do something together. Attentional actions function akin to ostensive gestures, and therefore cannot be segregated from the situation in which they are performed, nor reduced to the child's behaviour or knowledge.
There is thus a complex interplay of time scales in the education of attention. The differentiation and progressive focussing characteristic of the education of attention unfolds on longer time-scales, as we gradually attune to the affordances in our environments, but also takes place on shorter timescales. Based on recent research on categorical perception, I show how the constrainting effect of attentional actions can be understood as an online modulation of the perceptual system, resulting in a focussing on shorter time-scales. Hearing a particular word, say the word 'chair', thus draws our attention to chair-related affordances. I propose that we can understand this in terms of task-specific devices: when engaging in a particular task, organisms self-organise into task-specific devices. Using language understood along the lines of attentional actions, we not only turn ourselves into walkers and throwers, but also in chair-detectors.

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Meaning is Use: Gibson on Second-Hand Perception
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In the opening chapter to his (1966) book in a section titled “The Cultural Environment” Gibson says “there is no sharp division between” the “natural” and “cultural environment”, and the distinction between “material” and “non-material” culture is “seriously misleading” (p.26). It is misleading insofar as it implies that “language, tradition, art, music, law, and religion are immaterial, insubstantial and intangible” (*Op cit.*) Gibson describes how speaking, sculpting, painting and writing are examples of techniques humans developed over the course of their history for *making* others aware of things outside of their immediate environment. Speech and the other “representative media” Gibson mentions, such as sculpture, painting and writing, made possible what he describes as “second-hand perception” of the environment.
In calling into question the distinction between nature and culture, Gibson’s insight was to recognise that linguistic signs do not belong to a non-material symbolic culture. Gibson’s distinction between primary and secondary perception however had the consequence that he was unable to do full justice to this insight. Gibson makes the distinction between “first” and “second hand” perception in part on the basis of the role of ecological information in each of these types of perception. In the case of first hand perception he claims the “structure of a natural optic array, including its invariants under transformation, specifies its source in the world by the laws of ecological optics.” Second-hand perception in the case of speech depends on a “sort of social agreement as to the signals that will stand for certain percepts” (Gibson 1966: p.281). Gibson seems to have thought of language as getting its meaning from rule-like conventions. But such a view of linguistic meaning reintroduces a separation of the natural and cultural environment Gibson rightly rejects. The way out of this problem is to think of specification of something in the environment be it in speech or perception as an active achievement of agents. There is no information prior to its use in action.

Differences in Perceptual-Environment Systems across Typical and Atypical Development
Nancy Rader
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In considering the organism-environment system, ecological psychologists have tended to think in terms of adult human organisms. However, human organisms change over time with development, and thus, the nature of the organism-environmental system changes as well. Additionally, the developmental paths of children with atypical development will vary from the typical path and this difference will be reflected in the organism-environment system in particular ways. I propose that these organismic-environmental changes with typical and atypical development will lead to differences in resonance to information to be picked up from higher-order aspects across structured arrays, that is, metamodal information. In support of this claim, research will be described that details responses to the synchrony of speech and gesture in infants, toddlers, preschool children, and children with a diagnosis of ASD in support of word learning. For this research, children viewed novel objects presented with a nonce word either with or without a synchronous gesture. While we found that, while the metamodal information created by the synchrony did affect eye gaze across the developmental groups, it was not relevant for word learning in the preschool aged children; these children performed as well and above chance whether the synchrony had been present or not during the presentation of the object and nonce word. However, it was only when speech-gesture synchrony occurred during the presentation of the object and nonce word that word learning was above chance level for infants, toddlers, and ASD children. Thus, the affordance of the metamodal information created by the synchrony of gesture and speech was not relevant for the task of word learning in the group of typically developing preschool children while it was for younger and for ASD children.

Integrating timescales for the emergence of symbolic communication in development
Joanna Raczaszek-Leonardi, Nicole Rossmanith
University of Warsaw, WARSAW, Poland

The paper is a further step in construction of an ecologically valid framework for symbol emergence in development. In the earlier work, we have used semiotic framework to elucidate a rich infrastructure of signification on which symbolic systems depend. We pointed to the processes of tuning the signs functioning as interactive affordances in re-enacted social physics and to the importance of systemicity in symbolic emergence (Rączaszek-Leonardi, Rohlfing, Nomikou & Deacon, 2018). In the present work we present a more detailed investigation into the processes that may facilitate progressive structuring of symbolic communication. We focus on two processes in particular: The first one is the relative segregation of vocal modality from multimodal stream of activities in interaction, which facilitates tuning to the controlling role of the relations among utterances. The second one is the shaping of interactive events by action arcs, i.e., pervasive “structures-in-time” or energetic envelopes, which may facilitate discerning important semantic units (Rossmanith et al., 2014; Trevarthen & Delafield-Butt, 2015; Rączaszek-Leonardi, Rossmanith, Nomikou, Rohlfing, in review).

Direct Perception and Integrationist Communication in the Joint Construction of Metaphors across Speakers and Utterances

Catherine Read
Rutgers University, NEW BRUNSWICK, United States of America

James Gibson soundly rejected the retinal-image-as-code theory of visual perception, but he accepted the assumption that language is a code (1966). Roy Harris spent his career demonstrating that language is not a fixed code that is learned and “drawn upon” in communication, but he seemed to unquestionably accept the retinal-image (representational) theory of vision. If neither perception nor language are based on codes and static moments of sensory stimulation, then some problems of moving from direct perception to communication are obviated. Both perceiving and speaking can then be coherently described and analyzed as ongoing and functionally appropriate to the environment, including other speakers. This paper attempts to provide an account of adults and children conversing about pictures that is consistent with direct perception over time and with integrationist linguistics. Speaking is a perceptually guided action that ongoingly integrates the environment with signs in the process of communicating, whether about the “present” situation, the “past”, or any other timescale. In order to make these ideas and this type of account more concrete I report on the joint integration of metaphoric resemblance into conversation about pictures between adults and children. This integration leads to metaphors across utterances and speakers with children ages 4-10 and young adults. The integration of metaphoric resemblance into conversation happens even with the youngest children, but the forms and complexities of the metaphors constructed across speakers increases across these ages. The overall goal of this work is to strengthen and broaden both Ecological Psychology and Integrationist Linguistics by taking the radical departures from mainstream assumptions that each has built on and coordinating them into a more comprehensive and cohesive approach to perception and language than has heretofore been available.

Symposium: Philosophical Responses to Ecological Psychology

SYMPOSIUM: Philosophical Responses to Ecological Psychology
Gary Hatfield
Philosophy, Cohen Hall 433, PHILADELPHIA, United States of America

Symposium definition: Philosophers have been commenting on Gibson's ecological psychology since its inception in the 1960s and 70s. This has included suspicions of Gibsonian views from within "classical" or "standard" cognitive science of the 1980s, as well as great appreciation of Gibsonian insights by dynamic systems anti-representationalists. This symposium presents philosophical reflections on fundamental aspects of ecological psychology that are friendly but also suggestive of revisions. Hatfield aims to show that Gibson was not as ecologically radical as he might have been in the area of spatial perception. Isaac draws on resources from the Gestalt psychologist Kurt Lewin in order to resolve a tension in the notion of affordance, arising from the dual subjective and objective aspects: affordances are organism relative and yet are considered to exist when the animal is not present and to persist even if the animal's interests and needs change. Orlandi argues that the notion of representation has been misused in psychology, and that, once some sorting is done, there is a organism-level notion of mental representation that could benefit ecological psychology.

Gibson and the Geometric Layout: Not Ecological Enough?
Gary Hatfield
Philosophy, Cohen Hall 433, PHILADELPHIA, United States of America

Railway tracks converge phenomenally into the distance. Is this appearance a misperception? I think not. Construing it as a misperception depends, in my estimation, on a particular task analysis of phenomenal perception: that it aims to present physical scenes in a way that conforms to their mind-independent physical structure. This is a widely held conception, infused even into Gibson's ecological approach.
In his pioneering statement of an ecological approach to visual perception, Gibson emphasized organism-environment mutuality: we should define an animal's environment in relation to the properties and capacities of the animal. He rightly noted that the scientific discipline of physics does not investigate animal environments but rather focuses on the physical world. His ecological psychology took into account ecological facts, such as: the scale of the environment in relation to the organism; the placement of the organism in relation to a scene; standing features of illumination and of surfaces; and the relation of an animal to earth as a supportive substratum and to media such as water or air, and so on.
Despite Gibson's focus on organism-relative properties, his ecological psychology nonetheless privileged physical measurements and descriptions. While offering a variety of classifications of ecologically relevant units, it accepts that, at the relevant scale, the organism responds to and perceives physically objective sizes, shapes, and other properties (geometric spatial layouts, media, substances). Gibson thus retained his 1966 notion that the "objective" is constituted by ordinary physical properties; the standard for normal spatial vision is "the perception of the true layout." By retaining a physically accurate "match" as the standard of successful size perception (160–161), Gibson did not escape, as he might have, the naïve realist preference for an "objective" physical world that perception simply reveals. His loyalty toward what he understood by "direct perception" hindered his ecological revolution. He should have accepted that vision doesn't aim to present a stable metric structure, and that the convergence of the train tracks results from a transformation of a flat metric world into a spatially compressed environment.

Affordances as Vector Fields
Alistair Isaac
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Attempts to precisely define "affordance" have struggled with the apparent tension in Gibson's claim that affordances are "neither objective nor subjective." On the one hand, affordances are organism-relative, depending on their constitution, yet on the other, affordances persist when the organism is absent, remaining stable across changes in its interests and needs. I suggest that a way forward in resolving this tension may be found by drawing on the resources of Gibson's predecessors in gestalt psychology.

Gibson explicitly acknowledged his concept of affordance was inspired in part by Kurt Lewin's 1936 notion of *Aufforderungscharakter* ("invitation character" or "valence"). Lewin (building on Köhler and Koffka) analyzed experience in terms of a phenomenal field. Psychology was to follow the lead of physics, explaining organism behavior in terms of the push and pull within a vector field analogous to electromagnetic or gravitational fields in physics. Valence assigns parts of the environment positive (attractive) or negative (repulsive) character, which combine with distance from the organism to generate the overall field of forces on its behavior. Gibson departs from

Lewin in two ways: (i) he is a direct realist, attributing affordances to an objective, external world, rather than Lewin's phenomenal world; and (ii) he rejects reducing affordance to valence, since valences are not invariant across the organism's interests.

I introduce a generalization of Lewin's basic framework that preserves Gibson's insights, and sheds light on the apparently paradoxical nature of affordances. The essential idea is to treat affordances not as a single vector field, but as emerging from the interaction between multiple fields of force. I distinguish three such fields, characterizing geometrical, actionable, and social possibilities within the environment. These fields are all "objective" insofar as they supervene directly on facts about organisms and their physical surroundings. Furthermore, the geometrical field satisfies Gibson's demand that affordances remain even when the organism is absent, as it is agency-neutral, supervening directly on relative shape within the environment. Nevertheless, the interacting vector field approach to affordances also preserves the most promising aspect of Lewin's theory, namely its quantitative character, suggesting strategies for the measurement, and mathematical modelling, of affordances.

Representing and Tracking
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Current models of visual perception in philosophy and cognitive science tend to use the notion of mental representation too liberally. In explaining how it is that we come to perceive the world as we do, such models make reference to an unconscious construction. A construction, in this context, is understood as a type of inference where representational resources are used to produce visual percepts. I argue that this position is both theoretically and empirically problematic. At the theoretical level, proponents of this kind of position often confuse representations with more generic functional notions. Internal states that merely causally or statistically co-vary with some environmental parameter – for example neurons that reliably fire in the presence of certain environmental elements – are not representations. Thinking that they are trivializes what it means for an internal structure to represent. I offer a proposal for what mental representations are that, following insights from Brentano, James and a number of contemporary cognitive scientists, appeals to the notions of de-coupleability and absence to distinguish representations from mere functional (tracking) states. One of the distinctive features of organisms that represent is their capacity to coordinate with what does not impinge on their senses. Accepting this type of view makes room for a novel, ecological understanding of visual perception.

Symposium: Multi-agent Systems: Task-Dynamics, Asymmetries, Sub-Ensembles and Illustrative Landscapes

SYMPOSIUM: Multi-agent Systems: Task-Dynamics, Asymmetries, Sub-Ensembles and Illustrative Landscapes
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Understanding the complex dynamics of multiagent systems continues to be of great interest to many researchers within the ecological and perception-action community. To highlight the spread and depth of research within this field, the current symposium brings together researchers interested in different multiagent domains and system scales. The first two presentations focus on the dynamics of small-scale multiagent systems (i.e., 2 – 4 actors). More specifically, Mike Richardson will discuss the task-dynamics of the everyday interpersonal and small group cooperative and competitive activities, and how task-dynamic models of multiagent human activity can be employed to develop robust human-machine systems. Tehran Davis then focuses on how the functional asymmetries between co-actors during interpersonal or joint-action tasks can operate to constrain the planning and spatiotemporal stability of multi-agent behaviour at multiple time scales. The second two presentations then broaden the discussion of multiagent systems by examining the dynamics of larger-scale team sport activities. First, Robert Rein examines emergent coordination within team sub-ensembles, demonstrating how the complex dynamics of these sub-ensembles emerges both within and across teams. Finally, Pedro Passos details a new method for identifying the dynamical landscape of penetrative passing action possibilities for ball carriers in football. This method, built upon players relative positions and velocities, allows one to identify where a penetrative pass is likely to occur during game play, as well as the most vulnerable areas of the pitch.

ICPA 2019 Orals – Saturday July 6

Task-Dynamics of Multi-Agent Activity
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Multi-agent coordination is a common part of everyday human activity. Identifying the dynamic processes that shape and constrain the complex, time-evolving patterns of multi-agent behaviour often requires the development of formal models to test hypotheses and motivate research questions. Here we review a task-dynamic framework for modelling multi-agent behaviour and illustrate the application of this framework for a number of everyday cooperative and competitive activities. With an emphasis on synergistic self-organization and dynamic motor primitives, we demonstrate how the patterns of multi-agent activity are entailed by the symmetry of the physical, informational, and biomechanical constraints that exist between two or more environmentally embedded and mutually responsive agents. We also demonstrate how low-dimensional task-dynamic models of human multi-agent coordination can be used to develop robust human-machine systems.

Functional asymmetries in multi-level, multi-scale, multi-agent coordination.
Tehran Davis
Center for Cognition, Action, & Perception, CINCINNATI, United States of America

Successful joint actions require the coordination of behaviors across multiple effectors and timescales. For example, the simple action of passing a ball to another person involves, at minimum, the coordination of eyes, hands, torsos, and limbs both within and across co-actors as they simultaneously address their individual and shared task demands. Individual differences in perceptual-motor abilities and task demands often result in functional asymmetries in how co-actors approach the shared goal. Here, I present work highlighting how these inherent asymmetries constrain the planning and coordination of multi-agent actions at multiple scales. A particular emphasis will be placed on 1) results demonstrating systematic relationships between how actors meet task demands imposed at both individual and combined levels of action; and 2) how these demands trickle across scales influencing the gross actions and patterns of observed multi-agent coordination, including the relative strength and direction of influence (i.e. roles).

Emergent interpersonal coordination in high-performance association football
Robert Rein
Institute of Training and Computer Science in Sports, COLOGNE, Germany

In recent years increasingly it has been recognized that association football may be modelled as a complex dynamical system. The constituting parts of this system are the 22 interacting players who exchange information through various sensory channels like vision and auditory as well as through bodily interactions like passes and tackles. These interactions are further moderated at different time-scales through the basic rules of the game, the a-priori strategy instructed for example by the coaches, and the real-time adaptations governed by the team tactics. One key property of complex dynamical systems is the presence of emergent behavior where for the present purposes, emergent behavior is defined by qualitative difference in the behavior of a collection of components which goes beyond a simple summation of the individual component's behaviors. In soccer, emergent behavior could be for example the collective movement patterns of the players. Few studies however have actually shown emergent behavior in associated soccer. More often some sort of averaging procedures are investigated and specific dynamics of these systems are attributed emergent properties. The present study therefore sought to analyze emergent behavior with respect to movement coordination in team sub ensembles. The results demonstrate how situational coordinated behaviors of player ensembles dynamically appear and disappear during a game. Thereby, these group behaviors not only occur within teams but also across teams and vary with respect to their constituting components'. The present study therefore provides further support for the rationale to model association football as a complex dynamical system governing social group behaviors.

Players' relative position set possibilities of action to illustrate a landscape of passes towards the goal in football
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In team sports performance, a players opportunities for action are strongly constrained by the actions of others in a continuous and reciprocal manner. The aim of current study was to explore a method for illustrating the landscape of

penetrative passing opportunities available to a player based on their current and estimated positions during a football match. We conducted a visual analysis of video footage from competitive elite football performances. From this analysis we identified 20 different attacking situations. Players' relative co-positioning during game play was determined using bi-dimensional coordinates of each player in the (x,y) plane at 25 fps using an automatic video tracking system. This penetration landscape was built upon an iterated geometric figure (updated at 1 Hz), that was defined by the ball carrier, a hypothetical receiver (the attacking player located closest the opponent goal) and the relative positions of the two nearest defenders. It was hypothesized that the width of each geometric figure would illustrate the odds of a penetrative passing opportunity being successful. Moreover, the integration of both defenders and ball estimated positions in the next second would lead to a more accurate indicator of pass penetration success. The defenders estimated position was calculated based on displacement vectors, which provide information regarding the direction and velocity of each defender's running line. It is by overlaying these geometric figures that the action landscape of ball carrier penetrative pass possibilities is "painted". Results revealed that the midfield and the left side corridor were those locations of the field that provided the most opportunities for penetrative passes to occur. Due to the dynamics of players' co-adaptive behaviours it was expected that opportunities for a penetrative pass performed by ball carriers would not have a homogeneous space-time spread across the entire field. The method presented seems to agree with these expectations, demonstrating how a landscape of opportunities of penetrative passes is specified by the competitive environment at each moment in time.

Symposium: Action Coordination in Non-Human Self-Organizing Collectives: Multidisciplinary Lessons from Living and Nonliving Systems

SYMPOSIUM: Action Coordination in Non-Human Self-Organizing Collectives: Multidisciplinary Lessons from Living and Nonliving Systems
Megan Chiovaro, Alexandra Paxton
Center for the Ecological Study of Perception and Action, STORRS, United States of America

Collective intelligence, coordination, and self-organization have been fundamental in the study of human social interaction. These phenomena have more recently been identified as underpinnings in non-human systems. Here, we form an interdisciplinary panel—comprising ecological psychologists, biologists, chemists, and ecologists—with hope of highlighting the potential impact ecological psychology can have in these domains.
Katie Bentley will highlight collective coordination, and evidence of perception-action loops in endothelial cells, which comprise blood vessel walls. **Ben De Bari**, **James A. Dixon**, and **Tianqi Chen** will provide evidence for collective behavior and self-organization in artificial systems, both electrical and chemical. **Andrew Moiseff** and **Jonathan Copeland** will describe work on firefly synchronization and the need for coordination of action among male fireflies from an evolutionary standpoint. **Megan R. Chiovaro** and **Alexandra Paxton** will present pathways for ecological study of *Apis mellifera*, the Western honeybee, focusing on the honeybee's dynamical task-allocation and how it might inform our understanding of human groups.
Given the diverse background of the panel, heterodoxy in approach is nearly inevitable, but we believe contact among these different perspectives is essential for continuing to expand the impact of the ecological perspective to other fields. While the current symposium takes an explicitly non-human view of collective behavior, we hope it will not only improve our basic understanding of inter-entity dynamics but will also spark curiosity and inspire new approaches in the study of human collectives.

Perception- action feedback during Endothelial cell decisions to grow new blood vessels
Katie Bentley
The Francis Crick Institute, LONDON, United Kingdom

Endothelial cells (ECs), which comprise our blood vessel walls, live and work in complex heterogeneous environments. An individual EC is remarkably adept at detecting external signals, physical constraints, and chemical gradients. As a consequence of detecting these external events, the cell changes its internal state, and ultimately undergoes morphological changes, including movement. Thus, the existing evidence suggests that ECs exhibit rudimentary perception and action capabilities, much like those of multi-cellular organisms.

During the generation of new blood vessel networks (angiogenesis), tissues low in oxygen stimulate ECs to grow new network branches. This requires ECs to take on heterogeneous states by collectively competing with one another for lead migratory status via a lateral inhibition patterning process; a leader initiates a new blood vessel comprised of follower cells. The correct patterning of these states is required to generate evenly spaced blood vessel branches. However, we propose here that the traditional biology perspective that cells "select a state, then move" is too slow to account for the rapid, adaptive assignment of the leader/follower cell states during angiogenesis. Here we show that a "move while selecting state" view, which allows sensor-motor (action/perception)

feedback loops during movement to contribute to state determination, provides a more accurate time-based account.

In a simulation study based on biological experiments we here show that migration-induced cell shape changes (action/perception feedback) in an individual EC confers specific, bistable properties to the leader/follower states. When parameters affecting action/perception are modulated, this bistability is lost and the selection of leader/follower states is drastically slowed generating poor vessel branching. We will also report on preliminary in vivo experiments that validate this model prediction in developing intersegmental vessels of the zebrafish embryo.

Collective Behavior in Dissipative Structures

Benjamin De Bari, James Dixon, Tianqi Chen
University of Connecticut, STORRS, United States of America

Examples of collective behavior and self-organization abound in biology: slime-molds, swarms of insects and flocks of birds, and even task-oriented coordination within human dyads. In all these systems, complex coordinated activity emerges through the mutual influence of dynamics and constraints. The activities of constituent elements of the system are subject to environmental constraints and interactive forces, while these constraints are in turn shaped by the activities of the constituents. The properties of self-organizing biological behavior are likely rooted in properties of a broader class of physical systems: dissipative structures.
Dissipative structures are spontaneously ordered systems, driven to self-organize by flows of energy and matter. Organisms are dissipative structures, and thus the study of biological self-organization will be aided by investigation of the physics of dissipative structures. To that end, we study the life-like behaviors of an electrical and a chemical dissipative structure. Our electrical dissipative structure consists of metal beads in shallow oil, which self-organize into branching tree-like structures when subject to sustained high voltage. Multiple trees in the same dish will exhibit coordinative behavior enabled by coupling through a shared electric field, which drives the activity of the trees and is in turn shaped by that activity.
The chemical system consists of benzoquinone (BQ) particles floating on water. These particles are self-propelled by differential surface-tension gradients produced through dissolution into the aqueous phase. When irregularly shaped particles are present together, they will tend to flock together and navigate the dish as a cohesive group. When a physical obstacle with a small opening is present, this flock of particles will 'find' the opening and cross to the other side as a unit. The particles are coupled through surface tension and concentration gradients on the surface of the water, which drive and in turn are structured by the activities of individual particles.
Through the study of these dissipative structures, we aim to elucidate the thermodynamic underpinnings of behavior in biology. The dynamics of collectives of living systems may be the heritage of membership of the class of dissipative structures.

Behavioral consequences of sensory system constraints in the firefly

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Fireflies rely on a visual channel to communicate information about species, gender and availability for mating. In general, this information is carried by stereotyped temporal patterns of monochromatic flashes and stereotyped delays between the male's signal and the female's response. In most firefly species, males search for females by flashing while flying. Such males are said to be 'patrolling.' Stationary females respond to conspecific males, establishing a dialogue that results in the male flying to, and landing near the female. In most species, males patrol independently of other conspecific males (i.e., flashes of different males are not temporally coordinated). In certain species, a collective behavior emerges where flashes of patrolling males are synchronized (i.e., occur simultaneously) with the flashes of other conspecific males.
Behavioral studies of female *Photinus carolinus* fireflies suggest that constraints imposed by the way the female processes visual information may lead to the need for male synchrony. Since patrolling males are flying as they flash, the location of successive flashes appear at different positions. Accordingly, the female must spatially integrate flashes over a wide visual field to receive the male's flashes and recognize the flash pattern. However, in the presence of multiple patrolling males, if each male flashes his species-specific pattern independently and asynchronously within a female's wide visual field, spatial integration by her visual system would sum the asynchronous flash patterns, interfering with her ability to recognize the species-specific pattern and decrease her probability of responding to, and attracting potential mates.
We developed a model based on the temporal pattern of the male flashes and the number of males visible concurrently (i.e., male density). The model predicts the relative ability of the female to detect the species-specific pattern assuming that she is spatially integrating all flashes present in her visual field. The results support our hypothesis that synchrony may be a solution to constraints imposed by the female visual system. Thus, synchronous flashing by fireflies may be an example of how a sensory system constraint can be the driving force for a collective behavior that impacts reproductive success.

Busy Bees: Task Allocation in Apis mellifera as Inspiration for Engineering Effective Human Collectives
Megan Chiovaro, Alexandra Paxton
Center for the Ecological Study of Perception and Action, STORRS, United States of America

Nature is full of complex biological adaptive systems that coordinate their activity for the benefit of the group. The Western honeybee, *Apis mellifera*, is a social invertebrate that exhibits many such collective behaviors. Through self-organized task partitioning, group-level tasks (e.g., foraging, hive maintenance) are completed by individual honeybees tackling smaller, more achievable subtasks, such that the levels of productivity across different components of the pipeline are synchronized. Like any self-organizing system, the colony's behavior emerges in response to both local and global information.
Locally, individual worker bees use specific behaviors to help recruit additional individual bees to complete a task, ensuring that worker supply meets demand (Seeley, 1995). For example, a *forager* bee returning with her pollen load will produce a "shaking signal", encouraging inactive bees to become *receiver* bees if the forager waits too long to pass off her collection. This signal (among others) can be considered local information, only reaching and stimulating action among the individuals in the immediate surroundings.
Global information about hive needs prompts larger-scale action. For example, if a hive gets too hot, the information indicating a need for hive ventilation is available for all members of the colony. Needs indicated by global information are attended to—and fixed—faster than those by local information.
Here, we consider *Apis mellifera*'s self-organizing task-allocation system both in its own right and as a model for understanding task-allocation behaviors in humans. By manipulating the available local and global information and by providing contextual and behavioral constraints similar to the honeybee colony, we will explore the self-organizing dynamics of humans performing a collective-focused interactive online task-pipeline experiment. We hypothesize that, given the right balance of information and individual effectivities, humans will naturally perform task-switching to synchronize productivity of various roles, just as honeybees do.
In studying the collective dynamics of honeybees, we hope to inform the literature of lower-order adjustments used to regulate higher-order outputs. By taking a holistic approach to their coordination of action, we hope to understand how social insects self-organize so efficaciously and what that may mean for the future of human collectives.

Symposium: Becoming one: How hand movements and vocalizations emerge together

SYMPOSIUM: Becoming one: How hand movements and vocalizations emerge together
Lisette De Jonge-Hoekstra
Developmental Psychology, University of Groningen, GRONINGEN, Nederland

When people talk, they move their hands. The vocal and manual systems are thus tightly coupled. This coupling is already evident in infants. In the first talk of this symposium, Abney, Borjon, Yu and Smith discuss how infants between 9-24 months of age change their hand movements when they vocalize, and how this relation between manual and vocal activity changes across development. Their study provides insight into how the early vocal-manual coupling in infants may be a developmental basis for the coordination of gestures and speech in adults. Sometimes the coordination of gestures and speech is less fluent and synchronized. For example, when people perform a difficult cognitive task and discover something new, gesture-speech mismatches occur and the semantic content of gestures and speech may differ. In the second talk, De Jonge-Hoekstra, Cox, Van der Steen and Dixon present a study about how gestures and speech are coupled in easy and difficult tasks. They specifically discuss whether complexity matching between gestures and speech differs during easy and difficult tasks. This study provides a new perspective on the multiscale coupling between the vocal and manual systems within individuals. However, most of our speaking and gesturing happens when we interact with other people. In the third talk, Pouw, Paxton, Harrison and Dixon discuss how listeners can perceive someone else's manual movements in vocalizations. Pouw et al. investigated whether listeners can synchronize their own wrist and arm movements to wrist and arm movements of someone else, while listeners could not see these movements but could only hear their vocalizations. This study suggests that voice acoustics specify movements, providing a new perspective on the social affordances of vocal-motor coupling. The last talk also concerns how we gesture when we interact with others. Trujillo, Drijvers, Holler and Özyürek present how people exaggerate their hand movements, but not their communicative strategy, when they try to communicate with others in noisy conditions. This study demonstrates that how we move our hands is important for modulating communication when needed. Together, the talks in this symposium provide a novel understanding about how hand movements and vocalizations emerge in unity.

The development of vocal-manual coordination in late infancy
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In adult humans, gesture typically accompanies speech but exactly how such coordination emerges in development is unknown. The present study seeks to address whether infants change their hand movements during vocal production and whether this relationship changes across development. A large, longitudinal corpus of naturalistic infant-caregiver toy play is leveraged to examine the developmental trajectory of vocal-manual coordination from 9-24 months of age (44 unique dyads; 128 sessions). During each visit, the dyad played with a set of toys for up to 6 minutes. Infant vocal production was manually coded (3,163 vocalizations) and positional coordinates of manual activity (left and right hand) were collected using motion capture technology. The present study made no distinction between speech-like and non-speech like vocalizations. From 9–24 months of age, vocal production increased in number and frequency. Vocal duration increased from 9-15 months of age, then decreased from 15-24 months. Manual activity was quantified by calculating the positional velocity of the motion capture sensor affixed to the left and right wrist. At a session level, we observed no significant developmental differences in the velocity of the left or right hand. However, there were developmental differences when examining the time series of velocity aligned to the onset of a vocalization. From 9-24 months of age, there was a marked decrease in the variability of manual velocity around a vocalization. All age groups exhibited an increase in the velocity of their manual actions aligned to the onset of the vocalization. For younger infants 9-12 months of age, this increase began approximately 2 seconds before the vocalization's onset. For older infants, this increase was much quicker and emerged less than 1 second before the vocalization. There are two possible interpretations of the results that will require further empirical work. First, it is possible that the co-occurrence between manual action and vocal production reflects motor overflow: that young infants produce varying amounts of incidental movements during the production of increasingly complex vocalizations. The results may alternatively suggest a developmental trajectory in the coordination of manual action velocity and vocal production.

*The first two authors contributed equally to this work.

Complexity matching between gestures and speech in easy and difficult tasks
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Gestures and speech are two salient aspects of multimodal communication in humans. Many researchers have therefore proposed that gestures and speech are tightly coupled. As one of the first, McNeill (1985) describes how gestures and speech align in time and in content. These findings have been replicated in different contexts by many researchers since then. However, gestures' and speech's alignment in content seems to vanish under specific circumstances: When people acquire understanding about difficult, cognitive problems, gesture-speech mismatches occur. This raises questions about how task difficulty affects the coupling between gestures and speech. In this talk, we will approach this coupling as *complexity matching* between gestures and speech. Complexity matching means that two systems synchronize on many different scales of behavior. In a tablet task, loosely based on Fitts (1954), participants *pointed* to two horizontal rows of targets with different colors and *said* the target's location, repeatedly, and as fast and accurate as possible. Participants followed one rule: Point and say the location of a top target that matches the color of the bottom target. In the easy condition, the colors of the bottom targets matched vertically with the colors of the top targets, while in the difficult condition the colors of the bottom targets were randomly distributed. Preliminary analyses indicated that participants in the easy condition were faster in their pointing than participants in the difficult condition, but there was no difference in pointing accuracy. For this talk, we will perform Detrended Fluctuation Analysis (DFA) on the time series of gestures (pointing) and speech to investigate complexity matching between these two. If the degree of complexity matching between gestures and speech differs between the easy and difficult task, this suggests that the decrease in content alignment of gestures and speech is related to a decrease in multiscale synchronization between the two.

Acoustic Specification of Upper Limb Movement in Voicing
Wim Pouw, Alexandra Paxton, Steven Harrison, James Dixon
Center for the Ecological Study of Perception and Action, UCONN, STORRS, United States of America

Co-speech hand gestures communicate complex information to listeners through the visual information created by movement. In the current talk we will introduce the possibility that visual information from gesture is but one of its (communicatively meaningful) products. In our previous research we found that there are direct biomechanical effects of high-impetus upper limb movement on voice acoustics. Namely, when moving the arms (but not wrists) during voicing results in peaks in the amplitude envelope and the Fundamental Frequency of voicing. We suggested

therefore that upper limb movement reaches the phonation system via the myofascial-skeletal network that allows forces to propagate through the body. Here we will present our follow-up research on whether listeners can detect such information about upper limb movement in voice acoustics of another person. In our exploratory study, participants listened to a recording of a vocalizer who was simultaneously producing low-(wrist movement) or high-(arm movement) impetus movements at three different tempos. Listeners were asked to synchronize their own movement (wrist or arm movement) with that of the vocalizer. Listeners coupled with the frequency of the vocalizer arm (but not wrist) movements, and showed phase-coupling with vocalizer arm (but not wrist) movements. However, we found that this synchronization occurred regardless of whether the listener was moving their wrist or arm. This study showed that, in principle, there is acoustic specification of arm movements in voicing, but not wrist movements. For the talk we will have performed a pre-registered confirmatory study wherein we assess the research question in a larger sample with more diverse and naturalistic stimuli.

Adaptation of multimodal communication strategies to noise and failure: evidence from a dyadic interaction task

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In many natural face-to-face interactions we are challenged with communicating in non-ideal settings, such as noisy environments. Typically we are able to successfully communicate despite interference from noise. This partially due to our ability to “filter out” non-relevant noise, but also due to communicative adaptations made by the speaker, which help the signal to be more salient. The classic example of such adaptation is the Lombard Effect, which refers to involuntary changes in speech, such as in intensity and pitch, that make the speech more easily understood by the addressee. While much of this research has focused on adaptations in the auditory signal and in visible speech (ie. lip movements), co-speech hand gestures are an important part of communication which have not been well studied in noise from the production side. Previous research has shown links between speech and gesture production, as well as the intentional shaping of gesture kinematics in response to communicative need. Until now however, there is no research on how speakers respond multimodally to communication in noise. This is particularly relevant because co-speech gestures enhance a listener’s understanding of speech in noise. Here, I present results from a dyadic communication task carried out at the Lowlands music festival. In the task, participants wore headphones with varying (per round) levels of noise. One participant, called the Producer, communicated action verbs (one per round) to the Addressee. For our analyses, we look at the first two attempts at communicating each individual word, using qualitative methods to describe the communicative strategy and quantitative motion capture methods to assess kinematic features. Preliminary results show that increasing levels of noise do not affect the strategy used, nor is multimodality specifically associated with communicating in more or less noise. However, the kinematics of gestures are exaggerated in response to more noise. Similarly, when the first attempt at communication fails, participants typically persisted with the same communicative strategy and modality, but further modulated their kinematics in the second attempt. I discuss these results in relation to social shaping of gestures, speech-gesture trade-off, and the effects of noise and communicative failure on communicative strategy.

Open topics

Ecological investigation of artistic performance and reception

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Artistic achievements, e.g. musical performance and paintings are sources of joy, contemplation and appreciation. These are also records of human movements that brought the artwork into existence. According to the process view of art, the purpose of artistic effort is not only the completion of an artifact but to produce specific impressions in the audience. In the end, art can only make sense in this complex ecological context (Bullot & Reber, 2013). In recent years, statistical analysis of the multiscale structure of human movements repeatedly revealed useful dimensions of synergies between biological intensity measures (changes in hand, eye, posture and neural activity) and cognitive behavior (Ihlen & Vereijken, 2010). These relations now allow us to make surprisingly precise predictions about attention, recognition, comprehension and intent that are arguably at the core of both production and appreciation of artworks. In the present research, paintings and musical performances were submitted to the same set of multiscale investigation as the appreciative activity of the audience. Data analytic tools included box-counting methods on the images, multifractal analyses of sound waves and arm movement of musicians, head and eye movements of recipients. Our pioneer investigation revealed a rich spectrum of interdependencies between the morphology of the artifact and the structure of appreciative movements. The level of expertise and artistic education of the audience

and the fractal structure of the artwork indicate the degree of long-range correlations between recipient and artist movements. Although the present research is only exploratory into aesthetic and psychological concerns, these findings demonstrated the usefulness of a technique that focuses on the interplay between artist, media and appreciation. Bullot, N., & Reber, R. (2013). The artful mind meets art history: Toward a psycho-historical framework for the science of art appreciation.
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Why ecological psychology is needed in landscape studies. A methodological and pedagogical analysis
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Keywords: agency, landscape, teaching landscape, architecture, landscape theory.

One of the most used definitions of landscape in the social sciences is: "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe 2000: Article 1). The perceptional dimension of landscape is widely considered as a fundamental: landscape refers indeed to the multifaced stratification of the relationships between the environment and the human beings. It involves different users, practices and perceptions.
The theoretical approach of ecological psychology has yet to be taken up in landscape studies and I argue that ecological psychology may constitute a valuable tool in teaching and researching in this domain. Ecological psychology can indeed contribute to answer one the main questions about landscape, that is 'how we perceive landscape'? More specifically, it can improve landscape analysis and landscape research from several points of view, by focusing on the role of the perceiver as an agent in relationship with the affordances of the landscape, with the following implications:
1) it allows the naturalization of landscape studies as it introduces a scientific perspective in a context where landscape is often framed mostly in socio-cultural terms not always integrated with ecological science.
2) It allows to analyze landscape perception from an embodied point of view, by complementing analysis belonging to phenomenological geography and philosophical phenomenology.
3) It allows to overcome an image-based approach to landscape, both in the definition and in the evaluation of landscape preferences and practices.
4) It allows including the role of the perceiver-agent as a fundamental starting point in landscape design and management.
In conclusion, ecological psychology introduces in landscape theory and social sciences an embodied-agential based approach than can contribute to a better understanding of what landscape is, how we perceive it and how we can consider it as the cultural-ecological relation between the human beings and their environments.

Escalation and destruction: Evidence for the reorganization of the interpersonal system during conflict
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In many corners of interpersonal coordination research (beyond ecological psychology), there is often an implicit assumption that individuals become more similar over time simply as a result of their interaction. From pendulum-swinging and postural sway to phonemes and syntax, a host of findings suggest that individuals become more similar through mere exposure to another person. However, this work has traditionally focused on synchrony during affectively positive interactions, affectively neutral joint motor tasks, or explicitly cooperative tasks. While studying interpersonal coordination from these contexts has been incredibly fruitful, it necessarily limits our understanding of coordination to only a subset of all possible kinds of interactions that humans can have—or, in dynamical systems terms, to only part of the *state space* of possible interpersonal interactions. In order to understand *why* we coordinate (or synchronize) with one another, we must also understand *how* and *under which circumstances* we coordinate with one another. Here, I will discuss empirical evidence demonstrating how the interpersonal social system reorganizes during conflict—a conversational context that has received (to date) much less focus from the interpersonal synchrony literature—and what this evidence suggests about the context-sensitive emergence of synchrony *and* the context-sensitive effects of synchrony.

Switching hybrid dynamics in tennis

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Switching hybrid dynamics, including continuous and discrete dynamics, has been proposed as a way to describe complex interpersonal coordination as a non-autonomous dynamical system (Yamamoto et al., 2018). In this study, we applied switching hybrid dynamics to soft tennis singles matches. Nine international soft tennis matches, recorded at 30 Hz and 195 points and including more than two rallies, were analyzed, not including serves or returns. The movements of both players were digitized. Deviations from the optimal waiting position were calculated to describe the players' state variables. The optimal waiting position was defined as the center of the possible strike area. The time series of the deviations for both players were segmented over the moment in time that the ball was hit. The time duration between a player's hit and the same player's next hit was defined as one cycle. This period included chasing the ball before the hit, i.e., the 'hitting' phase, and subsequently preparing for the next strike after the hit, i.e., the 'waiting' phase. As external input variables, we defined the deviation from the optimal waiting position as the position of the waiting player when the opponent hit/returned the ball at the end of the waiting phase. Deviations were organized as a bimodal distribution with two discrete states: FAR (F) and NEAR (N). Continuous variables of the waiting player included the angle in polar coordinates. The final state of the waiting player at the moment of the opponent player's hit was defined by a reduction in the dimensions, as a Poincaré map. The resulting external input pattern was classified into four states as a second-order sequential effect: FF, NF, FN, and NN. The resulting final states assumed a special configuration that was based on the time evolution of a Cantor set. Specifically, the movement of players exhibited hysteresis or fractal-like characteristics, using both opponent's movement and own final state as an external input. This implies that switching hybrid dynamics can be used to describe complex alternate interpersonal competition.

Bodily Synchrony as an Index of Social Ability and Affiliation in Interviews

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Past research has shown that bodily synchrony is found in joint actions and that this social synchrony as well as the fractal scaling of variability of bodily movements index the degree of severity of social disorders such as autism and schizophrenia. The current study investigated whether these aspects of social bodily movement also index the degree of social ability in individuals from a healthy population. Since much of the synchrony work on social disorders has been done in the context of diagnostic interviews, the current study employed an interview task in which an interviewer (confederate) asked participants questions about their university. We also investigated the importance of visual information for creating social synchrony by manipulating whether the interviewer and interviewee could see each other during the interview. After completing the interview, the participants were asked to complete questionnaires that evaluated their familiarity with the interviewer as well as assessed their social skills. Results found that not only were bodily movements synchronized and had a fractal nature but also that these dynamical characteristics were related to both the familiarity of the participant with the interviewer and the participant's degree of social competence. Further, removing visual information from the interview had no effect on either social synchronization or the fractal nature of the movements. These results suggest that social synchrony can not only be used as a marker of a social deficit but also as index of social ability in individuals from a healthy population. The results also support previous research that has found that visual information is not necessary for establishing interpersonal synergies necessary for synchronous social couplings in verbal tasks.

Dynamic occlusion reduces the influence of neighbors in human crowds

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Collective motion in human crowds emerges from interactions between an individual pedestrian and neighbors in their field of view (Rio, Dachner, & Warren, *PRSB,* 2018). In previous work, we found that collective motion can be modeled using a behavioral dynamics framework with a visual coupling to each neighbor. Here we show that the addition of partial, dynamic occlusion reduces neighbor influence.

We previously found that a pedestrian controls their speed and heading by nulling the optical expansion and angular velocity of a neighbor, depending on their eccentricity (Dachner & Warren, 2017). Superposition of multiple neighbors led to a successful visual model of crowd behavior (Dachner & Warren, 2018). The model does not require an explicit distance term, because the observed decay in coupling strength with distance is a consequence of Euclid's law of perspective.

However, the influence of neighbors decays gradually to the nearest neighbor, then more rapidly within the crowd (Wirth & Warren 2016). This double decay with distance might be due to the combination of Euclid's law and

neighbor occlusion in the crowd. In the present experiment, each participant (n=15) was instructed to “walk with” a crowd of 8 virtual humans while their trajectory was recorded. A subset of neighbors (0, 2, 4, 6) changed direction (+/-10 °) at a random time. To vary occlusion, the virtual crowd was arranged in two rows of four (near/far row), with the far neighbors either aligned with the near neighbors (occluded) or staggered horizontally (visible). Occlusion was partial and dynamic during a trial. Post-analysis shows the far neighbors were occluded 81% more at the time of perturbation in the occluded condition. Preliminary results indicate that participants changed their heading direction significantly less in the occluded condition than the visible condition (Δ=2.9 deg, $t(9) = 3.35$, $p < .01$).
The findings reveal that partial, dynamic occlusion reduces neighbor influence, implying that visible optic flow, not individuated objects, controls crowd behavior. Further work will model the combined effects of occlusion and Euclid’s law to explain the decay with distance observed in human crowd behavior.