Why isn’t flow flowing? Metatheoretical issues in explanations of flow.

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Published version

FARROKH, David, STONE, Joseph, DAVIDS, Keith, STRAFFORD, Ben and RUMBOLD, James (2024). Why isn’t flow flowing? Metatheoretical issues in explanations of flow. Theory and Psychology, 34 (2), 257-276.

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FARROKH, David, STONE, Joseph A., DAVIDS, Keith, STRAFFORD, Ben W. and RUMBOLD, James L. (2024). Why isn’t flow flowing? Metatheoretical issues in explanations of flow. Theory & Psychology, 34 (2), 257-276.

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Article

Theory & Psychology
2024, Vol. 34(2) 257–276

DOI: 10.1177/09593543241237492
journals.sagepub.com/home/tap

Why isn't flow flowing? Metatheoretical issues in explanations of flow

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Abstract
A flow state describes intrinsically rewarding experiences of complete absorption in a task. While descriptive accounts of flow have gained prominence in "popular" psychology, scientific research has reached a crisis point due to perceived limitations of current theoretical explanations for the experience. Here, we evaluate key metatheoretical frameworks underpinning previous explanations of flow and situate the need for reconsidering the ontological status of flow experiences and the causal entailments that might be needed to explain them. We consider the possibility that the subject–object dualism implied, and the organismic asymmetry apparent in prevalent metatheoretical frameworks, may create intractable problems for explanations of flow. Finally, the suitability of the ecological metatheory and eco-physical variables for explaining flow experiences is discussed.

Keywords
affordances, ecological dynamics, flow, impredicativity, scale

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The concept of flow was first proposed by Csikszentmihalyi (1975) after initial research into activities that were experienced as intrinsically rewarding (autotelic). Flow is defined as an "enjoyable experience of full absorption in an activity in which the demands are perceived as optimally compatible with one's skills" (Peifer & Engeser, 2021, p. 424). Flow has been an important concept in the positive psychology movement (Csikszentmihalyi, 2000), and is widely recognized as a desirable state due to its association with positive emotional and psychological outcomes (e.g., well-being, personal growth, clear focus, heightened control) across the lifespan (Freire et al., 2021). Traditionally, flow has been considered a multidimensional construct comprising three antecedents and six characteristics (Csikszentmihalyi, 1990). A balance between skills and challenges, clear goals, and unambiguous feedback are considered important preconditions of flow whilst distortion of time, merging of action and awareness, concentration on the task at hand, loss of self-consciousness, autotelic experience, and sense of control are characteristics of the experience itself (Csikszentmihalyi, 1990).

In the decades following Csikszentmihalyi's (1975) initial work, flow grew into a globally recognized concept (Csikszentmihalyi, 2021). More recently, however, progress in understanding flow has stalled due to perceived limitations of current prevailing theorizing (for a review, see Alameda et al., 2022; Jackman et al., 2019). These issues are well-documented and generally acknowledged in flow research spanning different fields of psychology (see Peifer et al., 2022; Swann et al., 2018). In this position paper, we do not seek to provide a comprehensive review of the history of, or current issues in, the field at the theoretical level. Rather, the arguments are focused on the contention that traditional metatheoretical commitments and assumptions may exert a limiting effect on flow researchers' attempts to explain flow in many different domains. This position paper illustrates how ontological and epistemological positions that may restrict understanding of flow remain pervasively assumed, even as researchers studying flow have sought to address potential shortcomings in the field. We first examine the motives and context surrounding Csikszentmihalyi's original work and then critically examine metatheoretical issues in the explanation of flow. In order to facilitate development of the field, here, we suggest an alternative metatheoretical framework for flow research, highlighting ways in which new concepts of measurement and explanation underpinned by this framework may enrich an understanding of flow.

Desiderata for an explanation of flow: Ontological and epistemological considerations

Swann et al. (2018) argued that, due to its descriptive nature, Csikszentmihalyi's original work on flow is best characterized as a model rather than a theory. Swann et al. (2018) emphasized that explanation is the core of a good theory and reiterated the need to understand the causal mechanisms of flow and generate testable predictions. Similarly, outstanding questions about the antecedents of flow (Peifer et al., 2022) highlight the role of causality in explaining flow. While we agree that understanding the causes of flow is an important objective, there are several key issues that require attention before causality can be meaningfully discussed.

The protracted difficulty explaining how and why flow experiences emerge suggests that not only theoretical, but also metatheoretical reconsideration may be essential to progress in understanding. Scientific research programs operate within nested conceptual frameworks in which metatheory defines the ontological and epistemological contexts within which theories are constructed (Juarrero, 2023; Molenaar et al., 2014). When considered as an integrated whole, these nested structures comprise a paradigm (Kuhn, 2012). Importantly, different metatheories may utilize different conceptualizations of causality and, consequently, endorse different forms of explanation (Stepp et al., 2011). The metatheory that a theory of flow has been developed within determines the responses to ontological and epistemological questions about what experiences such as flow are, and how we can understand them. For example, the assertion that flow is a subjective state reflects metatheoretical commitments (of the prevailing conceptualization in cognitive psychology) which influence empirical methods (e.g., emphasizing verbal reports of subjective experience, identifying putative neural correlates of subjective experience) used to study flow.

There may be two key issues that implicate metatheoretical challenges in current explanations of flow. First, a major concern is that traditional psychological theorizing, emphasizing the role of mediating internal states in understanding behavior and experiences, has developed an *organismic asymmetry* in its explanatory rationale, a bias which has neglected the importance of understanding the person–environment coupling (Dunwoody, 2006). A relevant causal explanation of human behavior or experience requires an understanding of the relationship between insights at many different scales of analysis including sociological, developmental, behavioral, and neural (Turvey, 2018). Any conceptualization of the relationship between these scales reflects ontological and epistemological stances and determines the *causal entailment* (strict logical implication) structures utilized in explanations of a phenomenon. Theories developed at one scale may provide an explanatory conceptualization that may be difficult to interpret at another scale of analysis without reconsideration of the metatheoretical framework for understanding the relationships between events observed at different scales (Kelso, 1995).

Second, the relationship between flow experiences and physical events, such as the actions of the performer, needs to be better understood. The relationship between psychological and (neuro)physiological theories of flow is of particular importance since integration has so far been viewed as problematic (Alameda et al., 2022). Any proposed relationship between these psychological and neurophysiological forms of analysis unavoidably implicates metatheoretical positions about the nature of mind and body, and relations between. Summarily, for causes of flow to be explained, the ontological status of the experience, the temporal and spatial scales of events relevant to it, and the relationship between these scales must be better understood. An examination of metatheoretical frameworks that have explicitly or implicitly guided theories of flow, and an analysis of their suitability is, therefore, critical for the progression of research. In the following section, the historical context of flow is overviewed, and some constraints that may have been imposed on its metatheoretical framing are examined.

The origins of flow

While flow has become a relatively well-known concept, the events surrounding and leading to its development are less commonly discussed. Examining this additional context may help to situate Csikszentmihalyi's original ideas and inform discussion of the present and future of flow. Csikszentmihalyi's early life was profoundly influenced by war, the loss of his brother, and the relocation of his family (Csikszentmihalyi & Lebuda, 2017). These hardships provided the motivation for Csikszentmihalyi's life work in psychology:

> I don't think anyone was happy with this way, with all the killing. People had to start again with nothing. It was such a wasteful and horrible way of living; on the other hand, humans could do all the other wonderful things. So that was the basis for my attitude towards knowledge, towards learning, it was to learn somehow to make life better. (Csikszentmihalyi & Lebuda, 2017, p. 813)

As such, Csikszentmihalyi's (1975) early work engaged with sociology and philosophy to analyze the meaningful activities that underpinned functioning societies. Csikszentmihalyi was attracted to the intersection of three areas of psychology: intrinsic motivation, play, and peak experience, but these areas had always been considered independently. The concept of flow emerged from interviews that explored participants' (e.g., surgeons, artists, athletes) experiences in activities that required significant investment of energy and skills but provided few traditional or extrinsic rewards as outcomes.

A central theme of this early work was dissatisfaction with prevalent metanarratives that claimed that motivations for human behavior could be exhaustively explained by extrinsic factors such as power, money, pleasure, or approval. Rather, the title of Csikszentmihalyi's (1975) first book, *Beyond Boredom and Anxiety*, is suggested by some to be a subtle reaction to prominent behaviorist B. F. Skinner's (1971) book, *Beyond Freedom and Dignity* (Engeser et al., 2021). Csikszentmihalyi (1975) observed that people were not only willing to forego extrinsic rewards to participate in certain activities, but experienced these activities as deeply, intrinsically rewarding. The metatheoretical landscape of psychology at the time of flow's inception, therefore, exerted a significant influence on the way flow was framed. The need to respond to external and deterministic paradigms in psychology may have contributed to the internal and subjective ontological framing of flow experiences.

Explanations of flow

Commencing academic training in the heyday of behaviorism in psychology, Csikszentmihalyi (1975) was dissatisfied that "inner experience ha[d] been exiled to a scientific no-man's-land" (p. x). Instead, Csikszentmihalyi chose a method that would prioritize the first-person experience of participants. As such, he turned to a phenomenology underpinned by principles of information (processing) theory to inform his explanation of flow (Csikszentmihalyi, 1990). Consciousness was construed as residing in an internal representation of the world, which is constrained by humans' limited capacity to process information. Csikszentmihalyi (1990) asserted that "a mental event can be best understood if we look at it directly as it was experienced", while conceding that "it is understood that whatever happens in the mind is the result of electrochemical changes in the central nervous system" (p. 26).

Csikszentmihalyi (1990) expressed concern about overly mechanistic explanations of flow and preferred first-person reports. Although different research traditions have different understandings of retrospective and descriptive forms of data collection, a causal explanation of flow would likely benefit from additional methods that collect data during flow activities (Peifer & Tan, 2021). Given Csikszentmihalyi's (1990) original assertion that flow occurs in the optimal internal processing of information, the prevailing assumption has been that the mental processes or "cognitive mechanisms" underlying flow experiences must be identified and correlated with neural or physiological processes occurring inside the performer (e.g., Dietrich, 2004).

While many different psychological and neural theories of flow have been proposed, the assumed conceptualization of mental and neuropsychological processes defines the metatheory adopted. For example, early attempts focused on the subjective experience of "effortless attention" in flow, proposed implicit processing and automaticity of skills as underpinning cognitive mechanisms, and linked to neural processes such as transient hypofrontality (Dietrich, 2004). Although both the effortlessness of attention and transient hypofrontality have been called into question (Harris et al., 2017), these criticisms have tended to emerge within the same cognitive metatheoretical framework and the assumed relationships between mind, body, and experience, and the form of explanation pursued have rarely been challenged. Just as concerningly, despite the proposition of numerous neural theories of flow (e.g., Gold & Ciorciari, 2021; Huskey et al., 2018), a recent review summarized that "evidence is sparse and inconclusive, with major methodological shortcomings that prevent us from drawing solid conclusions" (Alameda et al., 2022, p. 358). Alameda et al. (2022) questioned "whether we are indeed ready to identify and quantify reliable neural correlates of the flow state" (p. 360).

Considering these criticisms, it is worth examining the nature of the cognitive processes that neural theories of flow have purported to ground in physiological processes (Sullivan, 2016). While different theories have been proposed (e.g., Peifer & Tan, 2021; Swann et al., 2015), a number of component processes are typically arranged in a chain-like sequence. For example, the integrated model proposes that flow in sport occurs "through a positive event, which leads to positive feedback and increased confidence, which in turn results in a challenge appraisal and the setting of open goals—the pursuit of which leads to the experience of flow" (Swann et al., 2021, p. 54). Neural theorists of flow (e.g., Dietrich, 2004; Harris et al., 2017) then attempt to identify the neural processes responsible for cognitive processes such as the cognitive appraisal of a task or the setting of goals. In the following section, we show the influence of the cognitive metatheory on this explanatory strategy.

Origins of cognitive psychology

While it is often assumed that scientific psychology emerged relatively recently, some have traced the foundations of modern cognitive psychology much farther back in history. For example, Edward Reed (1982) located the roots of mainstream cognitive psychology in the Cartesian hypothesis of corporeal ideas—that all awareness is awareness of brain states (dating back to the first half of the 17th century). This hypothesis is corollary to the idea that sense data is impoverished and must be enriched via some mediating process within the nervous system before perceptual experience is arrived at. The key outcome of this hypothesis is that perception of the world becomes a three-term relationship in which organisms only experience some internal process that mediates between perception and actions in the world (Turvey, 2018).

In the 20th century, after World War II, the development of information theory (Shannon, 1948) allowed the relationship between signals in input and output channels to be precisely understood, providing a key breakthrough in the development of computers. The Cartesian hypothesis that mind and matter intersected in the brain (Reed, 1982) was combined with information theory to underpin computational models of mental processes mediating between putative input (sensory systems) and output (action systems) channels as the cognitive metatheoretical framework approached its current form. The ontological commitment to defining cognition as symbolic operations performed on mental representations defines the metatheoretical framework of the cognitive paradigm in psychology.

The cognitive metatheory is exemplified by Newell's (1980) physical symbol system hypothesis in which symbol manipulation performed by algorithms of computers is used as a theory-constitutive metaphor for cognition. The physical symbol system hypothesis is built on the assumption that cognitive systems are *nearly decomposable*, or that the timescale at which a putative mental process operates can be considered independently (Simon, 1977). The importance of separation between timescales must be emphasized since it is central to common forms of explanation that assume cognitive abilities arise from stable components that make distinct, independent contributions to a behavioral outcome (Kelty-Stephen & Wallot, 2017; Van Orden & Holden, 2002). For example, the assumption of near decomposability is reflected in the common models of processing stages in response times (e.g., Sternberg, 1969) because the interval between stimulus and response is considered to function independently of the longer timescales it is embedded within (Van Orden et al., 2003).

The preference for linear causal chains (efficient cause) as an explanatory form within the cognitive metatheoretical framework has important implications. Only *predicative entailments*, which refer to causes flowing upward from parts to wholes, are considered. *Impredicative entailments* that involve closed loops between parts and wholes are discouraged because they confound chain-like explanations (Chemero & Turvey, 2007). Hence, observations at the scale of the performer must be explained with reference to smaller scales of analysis, such as neurophysiology. Practically, these commitments have motivated "box and arrow" models of cognitive processes purportedly corresponding to system components, modeled as networks in the brain.

With these assumptions in place, causal mechanisms are typically sought in subcomponents of the individual performer's body and within an isolated temporal window. The activity of the nervous system during a flow activity is, therefore, assumed to underpin cognitive processes that result in the experience of flow. Notably, this form of explanation reflects the epistemological and ontological stances of the cognitive metatheory and accepts only certain types of (i.e., linear, efficient) causality. As will be discussed in a later section, there may be good reason to believe additional forms of causality are operative in flow. It is worth stressing, therefore, that calls for causal mechanisms (e.g., Swann et al., 2018) of flow are underspecified, and implicate metatheoretical commitments that must be examined.

Csikszentmihalyi (1990) made his commitment to the cognitive metatheory explicit in his endorsement of information-theoretic analyses of mental processes. More broadly, the claim that flow experiences are necessarily subjective, internal, and representational in nature would need to be overturned for any explanation of flow to depart from the cognitive metatheory. Given the challenges in explaining flow within cognitive psychology, concepts such as the nine-dimension model and the four-quadrant model have come into question (Swann et al., 2017). The conservation of the cognitive metatheory is evident, however, in the continued assumption that one must look inside the individual to observe the causes of flow. In conclusion, the deep roots of the cognitive metatheory have shaped both the conceptualization and study of flow across many different subdomains of psychology (for notable exceptions see Montull et al., 2020; Vervaeke et al., 2018). In the following section, we delve more deeply into points at which the relationship between flow and the cognitive metatheory becomes strained, implying the need for more research within alternative conceptual frameworks.

Limitations and anomalous findings

While Csikszentmihalyi's (1990) formal explanation located the source of flow experiences inside the individual, there are several key points of tension with the cognitive metatheory. For example, it has been claimed (e.g., Nakamura & Csikszentmihalyi, 2014) that dynamic interactions should be emphasized rather than decontextualized traits of the individual. It is also understood that flow does not exist independently in either individuals or activities but arises when concrete feedback provides intrinsic motivation and supports a continuous stream of action (Csikszentmihalyi, 1975). This ideation of feedback is expanded upon in claims that an essential feature of flow activities is the sustained merging of action and awareness that occurs when action "resonates" with the performance environment (Csikszentmihalyi & Bennett, 1971).

Additionally, although Csikszentmihalyi's version of phenomenology referred to an internal mirror of the world, other flow researchers have pursued phenomenological interpretations of flow which center the performer–context relationship. For example, Jackman et al. (2022) highlighted the importance of performers' interactions with performance environments for understanding spatial, temporal, and social aspects of flow experiences. Jackman et al. (2023) also drew attention to phenomenological accounts of the mind–body–world relationship in flow.

These recognitions of performer–environment interactions in flow raise important questions about the process by which action and perception are related to the environment via concrete feedback (i.e., information for action). Because flow describes experience in skilled performance, precise spatiotemporal relations with the performance environment are necessitated. For example, a pianist must relate to the performance environment (i.e., piano) with both spatial and temporal precision to play the right notes in the right order. It is possible that the prevalent cognitive framing of flow through internal states has limited further exploration of these questions, which might benefit from forms of explanation provided by the ecological metatheory (see the Future directions section). Rather than exploring what form of coupling between the performer and the environment would support adaptive movements in flow, Csikszentmihalyi's metatheoretical commitments lead back to a series of internal processes thought to regulate consciousness (Nakamura & Csikszentmihalyi, 2014), with the relationship between the performer and performance environment remaining unexplored in many prominent theories of flow.

The recognition that behaviors must relate unambiguously to a performance environment presents a major obstacle to all explanations of flow situated within the cognitive metatheory. Theories that conceptualize flow experience as an internal representation of the world, such as Csikszentmihalyi's (1990) claim that consciousness is a mirror that imposes "a reality of its own" (p. 26), preclude understanding of unambiguous relations with an external performance environment (Turvey, 2018). Notably, even if the physical correlates of a subjective experience were identified, no information about an individual's relation to a performance environment would be provided since a subjective experience is not reliably related to actual states of affairs (Michaels & Carello, 1981). This is highly problematic because in many flow activities (e.g., rock climbing, gymnastics, surfing) not only the performance, but also the safety of the performer, requires an unambiguous relationship with the environment.

A striking example is provided in Kotler et al.'s (2022) account of the neurobiology of the onset of flow, which utilizes a fictional scenario involving a motorcycle rider who must swerve to avoid a collision on the highway. While a sequence of events at the neural scale is described in great detail, when it comes to the relationship between these neural processes and the environmental context (i.e., rapidly approaching obstacles), the authors state that "the relationship between these two categories of context is not completely understood" (p. 10), although it is recognized that this context must play a role in some manner. This ambiguity is quite surprising since a rider traveling at such high speeds must maintain a very precise spatiotemporal relationship with the environment if grave danger is to be avoided. Since the consequences for the performer exist at this level of performer–environment relations, it is reasonable to propose that the meaning of the activity for the performer may exist at this scale. In the next section, we discuss the ontological status of experience in flow states.

The content of flow experiences

If flow refers to some subset of experiences, we must also ask what these experiences refer to. In other words, what are experiences we call "flow" experiences of? More broadly, the question concerns the ontological status of experience. In the cognitive metatheory, the influence of Descartes' hypothesis of corporeal ideas leads to the conclusion that experience refers to internal (e.g., neural) states of the performer (see Csikszentmihalyi's endorsement of this relationship in the earlier section, Explanations of flow). However, consider again the motorcycle rider who has been cut off by another vehicle while traveling at a high speed. It would seem highly implausible that the content of the rider's experience cannot refer to the scale at which the consequences for the rider exist. These consequences cannot be found exclusively in the internal or neural states of the rider, or the objective (context-free) properties of the impeding vehicle. Determining the consequences, and therefore the meaning, of the event requires reference to both the physical performance environment, and also the unique action capabilities of the rider. This relationship cannot be defined internally, as it has causal entailments that extend beyond the mind of the performer into the specific relations between their body and the physical environment.

An alternative metatheory

For a performer's actions to be adaptive, as they are in flow states, they must reliably identify higher order properties of the performer–environment system. The content of such experiences is, therefore, neither objective nor subjective, but "double-barrelled" since it cuts across this divide (James, 1912/1976). Utilizing and expanding on this relational ontology, Gibson (2014) termed these offerings of the environment, with respect to the action capabilities of the performer, *affordances*. Affordances can be thought of as the semantics of ecology (Turvey & Carello, 2012) and present a logical candidate for the content of experience in flow.

For actions to "resonate" with the environment (Csikszentmihalyi & Bennett, 1971), performers must perceive how features of the environment present opportunities for action, given their own capabilities (Warren, 1984). For example, a skilled rock climber may perceive a feature of the rock face that affords grasping. This feature is simultaneously both an "objective" property of the rock and a "subjective" property because it is defined in relation to the capabilities of the performer and may not afford grasping for another, less-skilled, climber (Gibson, 2014). Given the abilities of the climber, however, the "graspability" of the rock is not a subjective evaluation. The relationship between the climber's abilities and the feature of the rock exists outside the mind of the performer as a property of a distinct performer–environment system, and the success of the climber's performance depends on their ability to perceive and utilize available affordances like these (Davids et al., 1994). Critically, the ecological metatheory holds that organisms and environments have been codetermined and begins from an ontological position of organism–environment mutuality (Gibson, 2014).

As exemplified, the concept of affordances may be uniquely suited to explaining the deeply intertwined relationship between actions, perceptions, meaning, and challenges in flow experiences. Much of the confusion in current explanations of this relationship can be shown to result from limitations of the subject–object ontology. For example, Engeser et al. (2021) claimed that it is not the objective balance between challenges and skills that determines aspects of flow such as sense of control, but rather the subjective evaluation of this match. While it is likely that measurement of the challenge or in objective (context-free) units is insufficient, the subjectification of the relationship may be equally problematic. If the experience refers to a process of subjective evaluation, an epistemological gap between these internal processes and the environment that is acted on is created. This loss of contact with the performance environment could present a major obstacle to scientific progress since actions in flow are observed to relate to the performance environment with a tremendous degree of precision, and it is this relationship that determines the meaningful outcome of the event.

In conclusion, if perception is (i.e., a three-term relationship) as proposed in the cognitive metatheory, internal states of the performer become the content of experience in flow, and the adaptive relationship to the performance environment must be presupposed rather than explained. While the ecological concept of affordances would be considered as a candidate to overcome this issue, it is incompatible with the cognitive metatheory and subject–object dualism. Critically, the ecological metatheory denies that experience must be equated with subjectivity (Seifert et al., 2023) and holds that affordances may be perceived directly in an impredicative, two-term relationship between the specific performer and the performance environment (Turvey, 2018). These conclusions are supported by a strong tradition of empirical research in ecological psychology (e.g., Lee & Reddish, 1981; Warren, 1984). The practical advantage of these commitments is that the nature of the relationship with the performance environment can be explained without the limitations of solely subjective or objective accounts. Exploring alternatives to the cognitive metatheory may also have implications for the conceptualization of causality in flow.

Causality outside of the cognitive metatheory

The difficulty of explaining flow within the cognitive metatheory might also be understood as a limitation of forms of explanation that have resulted from prevailing conceptualizations of causality (Chemero & Turvey, 2007; Juarrero, 2023). Traditionally, causal entailments have been thought to proceed exclusively from component to function (Turvey, 2007), meaning abilities of the whole should be understood through the contribution of the parts. An outcome or function observed at one level (e.g., an individual performer) must be explained with reference to a smaller scale such as a subcomponent or part of the performer's body. These restrictions on causality imply context-free forms of explanation but do not allow for reference to larger scales such as the performer–environment system, strictly speaking.

This entailment structure in cognitive psychology is exemplified by claims that components such as attentional networks in the brain cause functions such as selective attention observed in flow (Harris et al., 2017). The assumption that flow results from the contributions of some number of hard-assembled components within the performer has motivated explanation in the form of linear chains of efficient cause. However, a growing body of research suggests that the goal-directed behavior of adaptive organisms may not be approachable in terms of efficient or chain-like cause and may require the introduction of *impredicative entailments* (Chemero & Turvey, 2007; Rosen, 1991; Van Orden & Holden, 2002). Impredicative entailments originate in the analysis of set theory and paradoxes arising from sets that contain themselves as members, thereby creating a circular relationship between parts and wholes (Aczel, 1988). For example, an individual's status as the tallest member of a group is defined with reference to the whole group (i.e., context) that the individual is a part of. Impredicative entailments are, therefore, useful for considering causal relationships that involve interactions between multiple scales or levels such as brain, body, and environment.

Impredicativity

Impredicative definitions are central to the issue of subjective and objective explanations of flow. Nakamura and Csikszentmihalyi (2002) claim that "there is no objectively defined body of information and set of challenges within the stream of the person's experience" (p. 91). Traditionally, objectivity has been associated with predicative definitions that require reference to some independent, context-free unit of measurement. For example, a bike ramp measured in meters is defined predicatively because the unit of measurement is independent of the system being measured. This predicative definition is context-free and does not reflect differences in the unique abilities of different performers. A bike ramp measuring 2 meters may provide too great a challenge for some performers to experience flow and too little for others. In recognizing the insufficiency of predicative definitions, flow theories have unnecessarily equated nonpredicative definitions with subjectivity.

By contrast, the "jump-ability" affordance of the ramp is impredicative because it is defined with respect to the greater performer–environment system the ramp is a part of. The ramp may afford jumping (and flow experiences) when it participates in some performer–environment systems but not others. The action capabilities of the performer are the important unit of measurement (Warren, 1984). More generally, impredicative entailments are needed to formalize affordances (Chemero & Turvey, 2007), but they should not be confused with subjective evaluations. Impredicatively defined properties refer to real relations and track both mind-independent properties of the performance environment as well as the abilities and dispositions of the specific performer. The relationship between the specific performer and the flow activity can, therefore, be accounted for without framing flow as a subjective experience of internal processes.

While predicative definitions may be sufficient to model operations within formal symbol systems or computer programs, events occurring within complex performer–environment systems (e.g., flow activities) likely require richer impredicative definitions that refer to circular interactions between scales (Rosen, 1991; Turvey, 2018). Impredicative definitions are context-dependent and reverse the direction of explanation towards larger scales an observation occurs within. Notably, performers in flow must perceive impredicative properties (i.e., affordances) to act adaptively. For example, a skier who perceives a large obstacle looming in their visual field may experience a sense of anxiety which grows as the affordances to navigate around the obstacle dissolve. Affordances and impredicative entailments may be useful in understanding challenges posed by flow activities. A new form of measurement with direct relevance to key issues in flow research may, therefore, be made available by the ecological metatheory.

In this expanded understanding, the function of a system component may be understood to depend on impredicative loops involving higher levels of organization (larger spatial and temporal scales of embedding context; Turvey, 2007). Rather than having predefined functions, components may spontaneously take on a function by virtue of their relationship to the embedding context. For example, a smooth piece of cardboard may spontaneously take on the function of a sled when surrounded by children and snow-covered hills.

Systems that are soft-assembled and context-dependent have been called interaction-dominant (Ihlen & Vereijken, 2010; Van Orden et al., 2003). Because the function of a given component changes fluidly with context, the behavior of interaction-dominant systems cannot be reduced to the independent contribution of modular components (e.g., attentional networks in the brain) and explanation via linear causal chains is contraindicated. If flow experiences are dominated by interactions, the difficulty encountered by common forms of explanation might be explained. The conceptualization of nested systems afforded by the ecological metatheory may also clarify the role of neuroscientific research on flow (Dotov, 2014; Van Orden et al., 2012).

Notably, impredicative, interaction-dominant systems exhibit nonlinear interactions between scales, directly contradicting the cognitive hypothesis of near-decomposability and independence of timescales (Kelty-Stephen & Wallot, 2017). Events at one scale may be interdependent with events at other scales, such that no single characteristic scale for system description may exist (Marom, 2010). Scale-free phenomena pose problems to some, but not all, definitions of mechanistic explanation (see Bechtel, 2015), so there is a need for precision when discussing suitable forms of causal explanations of flow. While the cognitive metatheory has largely ignored the prospect that psychological phenomena might be scale-free and interaction-dominant, the difficulty explaining flow warrants further consideration of this possibility.

Scale and flow

In the second section of this article, two key questions were identified pertaining to scale that must be addressed by explanations of flow, including: (a) which scales of events are implicated in flow experiences and (b) what causal relations hold between these scales. In the section entitled Origins of cognitive psychology, we outlined the influence of the cognitive metatheory on the way these questions have been responded to by extant theories of flow, outlining the implications of cross-scale interactions for causality and explanation. We now turn our attention towards explanatory scale(s) of analysis for flow more explicitly.

All empirical research on flow must select some scale of analysis. This scope has narrowed from career-scale reflections to event-based methods (Jackman et al., 2022). Concerningly, however, "nothing is yet known about the dynamics of flow intensity that occur during flow" (Peifer & Engeser, 2021, p. 427). Practically, this means that once some window of time is selected, flow measures must determine whether this activity as a whole should be classified as a flow experience. As such, questions have been raised over the number of components needed in the flow experience to warrant classification, whether flow is best understood as a discrete or continuous phenomenon (Peifer &

Engeser, 2021), and whether the use of cut-off points to demarcate flow experiences is appropriate (Jackman et al., 2017). However, the fundamental issue of how many scales a single flow experience may spill across must still be addressed.

The intermittent and erratic nature of many natural phenomena such as turbulence remained a mystery for centuries due to the "difficulty of determining the actual duration of time over which the total observable turbulent energy is spread" (Mandelbrot, 1999, p. 119). The assumption that a turbulent flow could be neatly separated and classified gave way to the recognition that "zooming in" on turbulent flows revealed large areas of laminar flow that contained pockets of turbulence within them (Mandelbrot, 1999). This insight motivated the development of fractal and multifractal methods that deal with the scaling laws which characterize numerous phenomena ranging from seismic events to response times to weather patterns (Bak, 1996; Kelty-Stephen et al., 2013; Mandelbrot, 1999; Van Orden et al., 2005). Flow research could consider the possibility that "zooming in" on an activity that has been designated as a flow experience might reveal stretches of nonflow experiences with brief periods of flow nested within them. Stated differently, it is unclear that chain-like sequences within a single scale should be prioritized over nonlinear cascading relationships between scales (Wallot & Kelty-Stephen, 2018).

Let us consider a several-hour period of surfing that has been categorized as a flow experience. It is intuitively apparent that this flow experience contains periods of relative inactivity (e.g., waiting for a wave), and periods of higher intensity (riding a wave) nested within it. Further, within the experience of riding the wave, finer scale fluctuations of the intensity of flow likely exist at critical points of the surfer's interaction with the wave. Moreover, this several-hour window may be nested within a larger scale event such as a week-long surfing trip. However, these cascading relationships between scales are excluded in explanation via linear chains of cause and effect (Wallot & Kelty-Stephen, 2018). In the event flow entails nonlinear interactions between scales of events, explanations that take the form of a sequence of internal components related by efficient causality may fail. In interaction-dominant systems, the function of components may be contingently determined by these interactions and, therefore, lack the requisite stability to support common chain-like models (Sullivan, 2016). In such cases, cascade modeling may become an important part of causal explanation (Dixon et al., 2012; Kelty-Stephen et al., 2013).

The hallmark of phenomena that arise due to cascading relationships across scales is *intermittency* (Mandelbrot, 1999). Flow has been characterized as unpredictable, mysterious, and mercurial (Swann et al., 2012), so it might also be described as intermittent. Although further research and additional methods would be needed to confirm the presence of cross-scale interactivity, Ceja and Navarro's (2009) finding that instances of flow are distributed neither randomly, nor regularly, but chaotically provides some initial support for this possibility. Additionally, scale-free patterns may support adaptivity in biological systems and have been associated with health and well-being (Van Orden et al., 2011). In fact, the strength of cross-scale interactivity has already been linked with skilled performance (Nonaka & Bril, 2014) and task engagement (Bennett et al., 2022). While a universally positive interpretation of scale-free patterns in behavior is simplistic and their meaning likely depends on context and task constraints (see Kelty-Stephen et al., 2023), their established presence in many adaptive processes warrants further consideration of their relationship to flow experiences.

While questions of scale are of immediate concern for a causal explanation of flow, they also relate to broader questions about flow as a concept. Csikszentmihalyi (1975) expressed frustration that the concept of flow was often trivialized. As illustrated in our earlier section, Desiderata for an explanation of flow, Csikszentmihalyi's vision for the concept was motivated by questions of a much grander scale; meaning and flourishing in human life. Notably, it is in the impredicative and multiscaled loops of semantic closure that "law-determined physical aspects of matter become functional (i.e., have survival value, goals, significance, meaning, self-awareness, etc.)" (Pattee, 2012, p. 212). A metatheoretical framework that emphasizes formal symbolic operations on internal representations may struggle to retain this sense of meaning. Indeed, Wertsch (1991) cautioned that this strategy implies that "cultural and social issues can be incorporated as additional variables once the basic forms of mental functioning in the individual have been isolated and understood" (p. 85).

To understand how flow activities obtain their meaningful nature, scales that reach beyond the internal states of the performer must be consulted. Minimally, the scale of analysis must reliably link the performer to the performance environment, but the nested nature of environments and events suggests an analysis that extends across many, if not all, scales. It is possible that reconceptualizing flow experiences within the framework of adaptation across nested scales of context—as suggested by the ecological metatheory—may enable the concept to remain meaningfully linked to questions about individual and societal flourishing and as Csikszentmihalyi intended.

Future directions

The difficulty of explaining flow has often led to doubts over the concept itself (e.g., Hassmén et al., 2016) but these failures can also be interpreted in a different way. Since nearly all theoretical explanations of flow can be shown to assume the cognitive metatheoretical framework, it is possible that flow represents an anomalous finding for the cognitive metatheory. As illustrated in the preceding sections, the subjective framing of experience and the assumption of a single, characteristic timescale at which cognitive mechanisms create a causal chain may be poorly suited to explaining flow. The difficulties encountered by this specific set of explanatory tools should not be taken to mean that flow cannot be satisfactorily explained, however. New theories that can generate testable predictions about flow experiences should be developed within alternative metatheoretical frameworks.

The ecological metatheory developed by James Gibson (2014) and the tools provided by dynamical systems theory (Kelso, 1995) and multifractal geometry (Mandelbrot, 1999) may be particularly well-positioned to support novel explanations of flow. This confluence has been termed ecological dynamics (Araújo et al., 2006; Davids et al., 1994), and brings an established record of theoretical innovation and fruitful empirical research in domains such as skill acquisition and human performance. While a full theory of flow from an ecological perspective is beyond the scope of this article, the ecological metatheory possesses the tools required for both the necessary theoretical explanation and empirical research.

For example, eco-physical variables have been proposed as useful for addressing the proposed organismic asymmetry in traditional cognitive explanations of phenomena (e.g., Seifert et al., 2023), such as flow experiences, considering the role of ecological cognition in a performer's adaptation to a performance. Eco-physical variables define the relations between each individual and the environment (Seifert et al., 2023) and have been used to continuously track fluctuations of collective system variables related to meaningful possibilities for action (Correia et al., 2013) as well as self-regulation in performance (Carvalho & Araújo, 2022). Given that flow entails skillful, adaptive behaviors, the ability of eco-physical variables to deal with fluid, multiscaled system (re) organizations that contain impredicative entailments is highly advantageous. Put simply, flow is a phenomenon that involves exquisite sensitivity to a performance environment, but current forms of explanation point inward toward subcomponents rather than outward toward contextual relations. Tools such as eco-physical variables may enable the personally meaningful nature of flow experiences to be analyzed with increased precision.

Conclusion

The challenges in explaining flow experiences suggest that the suitability of metatheoretical frameworks within which explanatory theories have been developed should be examined. Since the assumption that cognition consists of the internal processing of information was endorsed by Csikszentmihalyi and also holds a hegemonic position within psychology, it is not surprising that it has been assumed by theories of flow, despite the organismic asymmetry. We have drawn attention to the ontological and epistemological assumptions of the cognitive metatheory, particularly as they relate to the nature of experience, perception, and causality. We have considered the possibility that these assumptions may preclude a satisfactory explanation of flow but, minimally, we believe they are sufficient to motivate the development of theories of flow within alternative metatheoretical frameworks. Finally, we propose that the alternative stances the ecological metatheory adopts on these issues provide a strong foundation for theoretical and empirical research on flow.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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References

Aczel, P. (1988). *Non-well-founded sets*. Center for the Study of Languages and Information Publications.

Alameda, C., Sanabria, D., & Ciria, L. F. (2022). The brain in flow: A systematic review on the neural basis of the flow state. *Cortex*, *154*, 348–364. https://doi.org/gqt5nw

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, *7*(6), 653–676. https://doi.org/10.1016/j.psychsport.2006.07.002

Bak, P. (1996). *How nature works: The science of self-organized criticality*. Springer.

Bechtel, W. (2015). Can mechanistic explanation be reconciled with scale-free constitution and dynamics? *Studies in History and Philosophy of Science: Part C. Studies in History and Philosophy of Biological and Biomedical Sciences*, *53*, 84–93. https://doi.org/kv25

Bennett, D., Roudaut, A., & Metatla, O. (2022). *Multifractal mice: Operationalising dimensions of readiness-to-hand via a feature of hand movement*. In S. Barbosa, C. Lampe, C. Appert, D. A. Shamma, S. Drucker, J. Williamson, & K. Yatani (Eds.), *CHI '22: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1–18). Association for Computing Machinery. https://doi.org/gqkhrw

Carvalho, A., & Araújo, D. (2022). Self-regulation of learning in sport practices: An ecological dynamics approach. *Asian Journal of Sport and Exercise Psychology*, *2*(1), 3–7. https://doi.org/10.1016/j.ajsep.2022.03.003

Ceja, L., & Navarro, J. (2009). Dynamics of flow: A nonlinear perspective. *Journal of Happiness Studies*, *10*(6), 665–684. https://doi.org/cf7sjr

Chemero, A., & Turvey, M. T. (2007). Complexity, hypersets, and the ecological perspective on perception-action. *Biological Theory*, *2*, 23–36. https://doi.org/bz78kz

Correia, V., Araújo, D., Vilar, L., & Davids, K. (2013). From recording discrete actions to studying continuous goal-directed behaviours in team sports. *Journal of Sports Sciences*, *31*(5), 546–553. https://doi.org/10.1080/02640414.2012.738926

Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety: Experience of play in work and games*. Jossey-Bass.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.

Csikszentmihalyi, M. (2000). The contribution of flow to positive psychology. In J. E. Gillham (Ed.), *The science of optimism and hope: Research essays in honor of Martin E. P. Seligman* (pp. 387–395). Templeton Foundation Press. https://works.swarthmore.edu/fac-psychology/542

Csikszentmihalyi, M. (2021). Foreword. In C. Peifer, & S. Engeser (Eds.), *Advances in flow research* (pp. v–vii). Springer. https://doi.org/kv26

Csikszentmihalyi, M., & Bennett, S. (1971). An exploratory model of play. *American Anthropologist*, *73*(1), 45–58. https://doi.org/ctbvjz

Csikszentmihalyi, M., & Lebuda, I. (2017). A window into the bright side of psychology: Interview with Mihaly Csikszentmihalyi. *Europe's Journal of Psychology*, *13*(4), 810–821. https://doi.org/kv28

Davids, K., Handford, C., & Williams, M. (1994). The natural physical alternative to cognitive theories of motor behaviour: An invitation for interdisciplinary research in sports science? *Journal of Sports Sciences*, *12*(6), 495–528. https://doi.org/bprfjj

Dietrich, A. (2004). Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition*, *13*(4), 746–761. https://doi.org/b4pwzr

Dixon, J. A., Holden, J. G., Mirman, D., & Stephen, D. G. (2012). Multifractal dynamics in the emergence of cognitive structure. *Topics in Cognitive Science*, *4*(1), 51–62. https://doi.org/d4f9vv

Dotov, D. G. (2014). Putting reins on the brain. How the body and environment use it. *Frontiers in Human Neuroscience*, *8*, Article 795. https://doi.org/10.3389/fnhum.2014.00795

Dunwoody, P. T. (2006). The neglect of the environment by cognitive psychology. *Journal of Theoretical and Philosophical Psychology*, *26*(1–2), 139–153. https://doi.org/10.1037/h0091271.

Engeser, S., Schiepe-Tiska, A., & Peifer, C. (2021). Historical lines and an overview of current research on flow. In C. Peifer, & S. Engeser (Eds.), *Advances in flow research* (pp. 1–29). Springer. https://doi.org/kv29

Freire, T., Gissubel, K., Tavares, D., & Teixeira, A. (2021). Flow experience in human development: Understanding optimal functioning along the lifespan. In C. Peifer & S. Engeser (Eds.), *Advances in flow research* (pp. 323–349). Springer. https://doi.org/kv3b

Gibson, J. J. (2014). *The ecological approach to visual perception: Classic edition*. Psychology Press. https://doi.org/gkzqbm

Gold, J., & Ciorciari, J. (2021). A neurocognitive model of flow states and the role of cerebellar internal models. *Behavioural Brain Research*, *407*, Article 113244. https://doi.org/gng6d7

Harris, D. J., Vine, S. J., & Wilson, M. R. (2017). Neurocognitive mechanisms of the flow state. *Progress in Brain Research*, *234*, 221–243. https://doi.org/kv3d

Hassmén, P., Keegan, R., & Piggott, D. (2016). *Rethinking sport and exercise psychology research: Past, present and future*. Springer.

Huskey, R., Wilcox, S., & Weber, R. (2018). Network neuroscience reveals distinct neuromarkers of flow during media use. *Journal of Communication*, *68*(5), 872–895. https://doi.org/gnd44q

Ihlen, E. A., & Vereijken, B. (2010). Interaction-dominant dynamics in human cognition: Beyond $1/f\alpha$ fluctuation. *Journal of Experimental Psychology: General*, *139*(3), 436–463. https://doi.org/cfjtdp

Jackman, P. C., Allen-Collinson, J., Ronkainen, N., & Brick, N. E. (2023). Feeling good, sensory engagements, and time out: Embodied pleasures of running. *Qualitative Research in Sport, Exercise and Health*, *15*(4), 467–480. https://doi.org/10.1080/2159676X.2022.2150674

Jackman, P. C., Crust, L., & Swann, C. (2017). Systematically comparing methods used to study flow in sport: A longitudinal multiple-case study. *Psychology of Sport and Exercise*, *32*, 113–123. https://doi.org/10.1016/j.psychsport.2017.06.009

Jackman, P. C., Hawkins, R. M., Crust, L., & Swann, C. (2019). Flow states in exercise: A systematic review. *Psychology of Sport and Exercise*, *45*, 1–36. https://doi.org/ggsfnt

Jackman, P. C., Schweickle, M. J., Goddard, S. G., Vella, S. A., & Swann, C. (2022). The event-focused interview: What is it, why is it useful, and how is it used? *Qualitative Research in Sport, Exercise and Health*, *14*(2), 167–180. https://doi.org/kv3j

James, W. (1976). *Essays in radical empiricism*. Harvard University Press. (Original work published 1912)

Juarrero, A. (2023). *Context changes everything: The path to coherence*. MIT Press.

Kelso, J. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. MIT Press.

Kelty-Stephen, D., Similton, O. D., Rabinowitz, E., & Allen, M. (2023). Multifractal auditory stimulation promotes the effect of multifractal torso sway on spatial perception: Evidence from distance perception by blindwalking. *Ecological Psychology*, *35*(4), 136–182. https://doi.org/10.1080/10407413.2023.2287752

Kelty-Stephen, D. G., Palatinus, K., Saltzman, E., & Dixon, J. A. (2013). A tutorial on multifractality, cascades, and interactivity for empirical time series in ecological science. *Ecological Psychology*, *25*(1), 1–62. https://doi.org/gjfxx7

Kelty-Stephen, D. G., & Wallot, S. (2017). Multifractality versus (mono-) fractality as evidence of nonlinear interactions across timescales: Disentangling the belief in nonlinearity from the diagnosis of nonlinearity in empirical data. *Ecological Psychology*, *29*(4), 259–299. https://doi.org/10.1080/10407413.2017.1368355x

Kotler, S., Mannino, M., Kelso, S., & Huskey, R. (2022). First few seconds for flow: A comprehensive proposal of the neurobiology and neurodynamics of state onset. *Neuroscience & Biobehavioral Reviews*, *143*, Article 104956. https://doi.org/kv3k

Kuhn, T. S. (2012). *The structure of scientific revolutions*. University of Chicago press.

Lee, D. N., & Reddish, P. E. (1981). Plummeting gannets: A paradigm of ecological optics. *Nature*, *293*(5830), 293–294. https://doi.org/bpws8x

Mandelbrot, B. B. (1999). *Multifractals and 1/f noise: Wild self-affinity in physics (1963–1976)*. Springer. https://doi.org/kv3m

Marom, S. (2010). Neural timescales or lack thereof. *Progress in Neurobiology*, *90*(1), 16–28. https://doi.org/db8vqh

Michaels, C. F., & Carello, C. (1981). *Direct perception*. Prentice-Hall.

Molenaar, P. C., Lerner, R. M., & Newell, K. M. (Eds.). (2014). *Handbook of developmental systems theory and methodology*. Guilford Publications.

Montull, L., Vázquez, P., Rocas, L., Hristovski, R., & Balagué, N. (2020). Flow as an embodied state. Informed awareness of slackline walking. *Frontiers in Psychology*, *10*, Article 2993. https://doi.org/ggj9vv

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. In C. R. Snyder, & S. J. Lopez (Eds.), *Handbook of positive psychology* (pp. 89–105). Oxford University Press.

Nakamura, J., & Csikszentmihalyi, M. (2014). The concept of flow. In M. Csikszentmihalyi (Ed.), *Flow and the foundations of positive psychology* (pp. 239–263). Springer. https://doi.org/gdj4vq

Newell, A. (1980). Physical symbol systems. *Cognitive Science*, *4*(2), 135–183. https://doi.org/bn9vtz

Nonaka, T., & Bril, B. (2014). Fractal dynamics in dexterous tool use: The case of hammering behavior of bead craftsmen. *Journal of Experimental Psychology: Human Perception and Performance*, *40*(1), 218–231. https://doi.org/f5rrwn

Pattee, H. H. (2012). Evolving self-reference: Matter, symbols, and semantic closure. In H. H. Pattee, & J. Rączaszek-Leonardi (Eds.), *Laws, language and life: Howard Pattee's classic papers on the physics of symbols with contemporary commentary* (pp. 211–226). Springer. https://doi.org/gnhsjz

Peifer, C., & Engeser, S. (2021). Theoretical integration and future lines of flow research. In C. Peifer, & S. Engeser (Eds.), *Advances in flow research* (pp. 417–439). Springer. https://doi.org/kv4r

Peifer, C., & Tan, J. (2021). The psychophysiology of flow experience. In C. Peifer, & S. Engeser (Eds.), *Advances in flow research* (pp. 191–230). Springer. https://doi.org/kjt2

Peifer, C., Wolters, G., Harmat, L., Heutte, J., Tan, J., Freire, T., Tavares, D., Fonte, C., Andersen, F. O., van den Hout, J., Šimleša, M., Pola, L., Ceja, L., & Triberti, S. (2022). A scoping review of flow research. *Frontiers in Psychology*, *13*, Article 815665. https://doi.org/gpwfzw

Reed, E. S. (1982). Descartes' corporeal ideas hypothesis and the origin of scientific psychology. *The Review of Metaphysics*, *35*(4), 731–752. http://www.jstor.org/stable/20127739

Rosen, R. (1991). *Life itself: A comprehensive inquiry into the nature, origin, and fabrication of life*. Columbia University Press.

Seifert, L., Araújo, D., & Davids, K. (2023). Avoiding organismic asymmetries in ecological cognition: Analysis of agent-environment couplings with eco-physical variables. *Adaptive Behavior*, *31*(2), 163–168. https://doi.org/kv4z

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, *27*(3), 379–423. https://doi.org/b39t

Simon, H. A. (1977). The organization of complex systems. In H. A. Simon (Ed.), *Models of discovery: And other topics in the methods of science* (pp. 245–261). Springer. https://doi.org/kv45

Skinner, B. F. (1971). *Beyond freedom and dignity*. Hackett Publishing.

Stepp, N., Chemero, A., & Turvey, M. T. (2011). Philosophy for the rest of cognitive science. *Topics in Cognitive Science*, *3*(2), 425–437. https://doi.org/bxf5tc

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica*, *30*, 276–315. https://doi.org/ftg756

Sullivan, J. (2016). Construct stabilization and the unity of the mind-brain sciences. *Philosophy of Science*, *83*(5), 662–673. https://doi:10.1086/687853

Swann, C., Crust, L., Jackman, P., Vella, S. A., Allen, M. S., & Keegan, R. (2017). Psychological states underlying excellent performance in sport: Toward an integrated model of flow and clutch states. *Journal of Applied Sport Psychology*, *29*(4), 375–401. https://doi.org/gdj4wq

Swann, C., Goddard, S. G., Jackman, P. C., Schweickle, M. J., & Vella, S. A. (2021). Flow and clutch states. In E. Filho & I. Basevitch (Eds.), *Sport, exercise and performance psychology: Research directions to advance the field* (pp. 46–60). Oxford University Press.

Swann, C., Keegan, R. J., Piggott, D., & Crust, L. (2012). A systematic review of the experience, occurrence, and controllability of flow states in elite sport. *Psychology of Sport and Exercise*, *13*(6), 807–819. https://doi.org/f3964m

Swann, C., Piggott, D., Crust, L., Keegan, R., & Hemmings, B. (2015). Exploring the interactions underlying flow states: A connecting analysis of flow occurrence in European tour golfers. *Psychology of Sport and Exercise*, *16*(3), 60–69. https://doi.org/ggnwp2

Swann, C., Piggott, D., Schweickle, M., & Vella, S. A. (2018). A review of scientific progress in flow in sport and exercise: Normal science, crisis, and a progressive shift. *Journal of Applied Sport Psychology*, *30*(3), 249–271. https://doi.org/ggf57x

Turvey, M. T. (2007). Action and perception at the level of synergies. *Human Movement Science*, *26*(4), 657–697. https://doi.org/fgj39s

Turvey, M. T. (2018). *Lectures on perception: An ecological perspective*. Routledge.

Turvey, M. T., & Carello, C. (2012). On intelligence from first principles: Guidelines for inquiry into the hypothesis of physical intelligence (PI). *Ecological Psychology*, *24*(1), 3–32. https://doi.org/ghnd69

Van Orden, G. C., & Holden, J. G. (2002). Intentional contents and self-control. *Ecological Psychology*, *14*(1–2), 87–109. https://doi.org/bcp4j5

Van Orden, G. C., Holden, J. G., & Turvey, M. T. (2003). Self-organization of cognitive performance. *Journal of Experimental Psychology: General*, *132*(3), 331–350. https://doi.org/chhfzw

Van Orden, G. C., Holden, J. G., & Turvey, M. T. (2005). Human cognition and 1/f scaling. *Journal of Experimental Psychology: General*, *134*(1), 117–123. https://doi.org/b548p4

Van Orden, G., Hollis, G., & Wallot, S. (2012). The blue-collar brain. *Frontiers in Physiology*, *3*, Article 207. https://doi.org/10.3389/fphys.2012.00207

Van Orden, G. C., Kloos, H., & Wallot, S. (2011). Living in the pink: Intentionality, wellbeing, and complexity. In C. Hooker (Ed.), *Philosophy of complex systems* (pp. 629–672). North-Holland. https://doi.org/djqc8f

Vervaeke, J., Ferraro, L., & Herrera-Bennett, A. (2018). Flow as spontaneous thought: Insight and implicit learning. In K. C. Fox & K. Cristoff (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming* (pp. 309–326). Oxford University Press.

Wallot, S., & Kelty-Stephen, D. G. (2018). Interaction-dominant causation in mind and brain, and its implication for questions of generalization and replication. *Minds and Machines*, *28*(2), 353–374. https://doi.org/gdh85k

Warren, W. H. (1984). Perceiving affordances: Visual guidance of stair climbing. *Journal of Experimental Psychology: Human Perception and Performance*, *10*(5), 683–703. https://doi.org/bk83vs

Wertsch, J. V. (1991). A sociocultural approach to socially shared cognition. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 85–100). American Psychological Association. https://doi.org/bhp5jv

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