the perception-action interface. However, we disagree with the authors' claim that an answer will be found by postulating a common representational structure for perception and action planning. In fact, we are quite dubious about the authors' contention that "Through integrating information from multiple sources . . . distal feature codes can become more complex than proximal codes . . . as complex as 'sit-on-ableness' to take one of the standard 'affordances' of Gibsonian approaches" (sect. 3.2.1.). Unless the authors subscribe to naive realism, this assumption is too optimistic.

The authors seem to have adopted the stimulus-response connection as their model for the perceiving-acting relation. In our view, this model is fatally flawed. Rarely is action interpretable as responses elicited by stimuli or in the presence of stimuli. Neither is the perceiving-acting relation interpretable as a unidirectional effect of one upon the other. We believe, following Gibson, that the ease and accuracy with which animals get along in the environment can only be understood by recognizing that animal behavior is controlled by information, rather than being a series of triggered or emitted responses to stimuli.

Gibson (1950; 1966; 1979) devoted his entire career to this problem. His effort culminated in several new concepts (e.g., the optic array, affordances, and exploratory – as opposed to performatory – activity). These concepts formed the basis for a new theory in which perception is not simply a response to the physical world or a cognitive interpretation of the effects of the world on us, but an active, ongoing process that enables us to gain a genuine awareness of the meaningful, goal-relevant environment. Ultimately, Gibson viewed behavior as being neither physically caused (i.e., the sensorimotor view of action) nor mentally caused (i.e., the ideomotor view of action), which led to his rejecting not only behaviorism, but also the causal theory of perception.

Hommel et al. pay tribute to Gibson for advancing interactions between perception and action but denounce his rejection of mental representation as "anathema to ecological approaches." The basis for this denunciation may be their narrow interpretation of the concept of ecological information. A key issue motivating the authors to resort to cognitive representations of a common event code seems to be the future-tending, anticipatory nature of goal-directed movements, that is, movements directed at "what must be done" instead of "what is." With an incomplete understanding of ecological information, accounting for future tending, goal-directed behavior can be a daunting task.

Like the authors, the Soviet physiologist Bernstein (1967) assumed that perception provides only awareness of "what is" but not an awareness of "what must be done" and consequently cannot resolve "the problem of action . . . the reflection or model of future requirements" (p. 171). This led Bernstein to resort to probabilistic extrapolation as the basis for modeling the future. However, this is a highly questionable strategy. Patently, experience with a given situation and its contingent events can lead to an expectation of what is likely to occur when the situation reoccurs, and such expectations can shape the selection and conduct of actions. But an *expectation of what might occur* is not the same as *specification of what will occur,* and the latter is necessary for successful prospective control.

How can information specify, not only the present, but also the future, thereby providing sufficient constraint for the prospective control of movements? As a paradigmatic case, consider long-jumpers who must regulate their final few strides to the take-off board while maintaining maximum controllable velocity (Lee et al. 1982). Careful observation suggests that step regulation during the final zeroing-in phase is not a preprogrammed act, as in a single ballistic adjustment, but the result of continuous coupling between perception and action. Although alternative explanations are possible, we believe that the most parsimonious is a recursive function within the information source itself. In recursive functions, each value entails the next, thus making it possible to convert the present into the future (Rosen 1991).

Extending these insights, we used Taylor's Theorem to generate a recursive function of *tau* (the optical information specifying time-to-contact between an observer and an upcoming surface) and demonstrated that future states of *tau* can be specified given current values of *tau* and *taudot* (the rate of change in *tau;* see Kim et al. 1993; 1998; and Lee 1976, for further details). In tasks that demand planning actions several steps ahead of time, *taudot* and *tau* together comprise the minimal recursive function which can be utilized by actors to access future values of *tau*s so that they can modify their behavior ahead of time, thereby achieving precise regulation – an example of prospective control (Kim & Effken 1995; Kim & Turvey 1998). See also Kim et al. (1995) for cases demonstrating prospective (future-tending), perspective (present-tending), and retrospective (past-tending) aspects of information.

In sum, information in Gibson's specificational sense provides the basis for prospective control (e.g., Turvey 1992) that **Hommel et al.** recognize is necessary. Prospective control allows actors to modify an approach on the fly, as goal-related information and situation demands dictate. Moreover, prospective control does not require the complex, integrated internal representation of perception and action the authors propose. Instead, the answer lies in the specificational nature of perceptual information, further constrained by the goals and effectivities of the observer/actor. In such a mutually constrained dynamical system, no "mysterious or arcane explanatory devices" (O'Regan & Noe, in press), such as those proposed by the authors, are needed to link perception and action planning.

Exploring the hyphen in ideo-motor action

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Abstract: This commentary focuses on **Hommel et al.**'s inferences on action planning. It discusses the relevance of anticipated extrinsic movement effects for action control, the problems of a feature-based representation of actions, and the necessity of the acquisition of conditional movement-effect associations.

The Theory of Event Coding (TEC)'s core assumption that actions are represented in terms of – and thus accessed through – their sensorial effects dates back to William James's (1891) ideo-motor theory. In a scathing criticism, Miller et al. (1960) concluded that ideo-motor theory had done little more to bridge the gap between ideas and behavior than inserting a hyphen between them. This may apply to James's introspective approach. Yet, **Hommel et al.**'s excellent target article demonstrates that the ideo-motor gap has turned from a "miracle" into a topic of rigorous empirical investigation. Still, we are exploring the "hyphen," and I want to discuss some shortcomings of recent research, suggesting necessary extensions for the future.

Pertinence of anticipated distal effects to the study of action control. Evidence for the impact of action effects on behavior stems primarily from experimental situations where (1) action effects are presented prior to action execution, or (2) action effects consist of merely movement-intrinsic feedback. Such conditions, however, are less representative for goal-oriented action which by definition is controlled by forthcoming, and thus necessarily anticipated, distal effects. Research relying on action induction and on movement-intrinsic features may therefore limit possible insights into the underlying mechanisms of goal-oriented action.

The fact that the perception of action effects (or effect-resembling stimuli) can induce motor-patterns that typically produce these effects is certainly interesting for a perception-action theory (cf. target article, sect. 2.3.2.2). Yet, this finding does not allow us to infer that effect codes become activated in cases where they are not externally stimulated, nor does it explain how this endogenous activation (i.e., anticipation) of effect codes is accomplished. It is very likely that constraints of action control – as apparent in the psychological refractory period effect or dual-task costs – originate from limitations in the *endogenous* generation and maintenance of effect codes (Greenwald & Shulman 1973). However, action induction provides no appropriate inferential tool to explore these constraints.

Studies dealing with intrinsic (mostly spatial) action features are of limited significance, not only because moving for the sake of the movement is an exception, but because such features are mingled with inherent properties of the motor apparatus that brings the action about. For example, interference between two ipsilateral body movements may result from overlap of spatial action features (Stoet & Hommel 1999). But it may also occur because concurrent ipsilateral movements produce an unstable body posture, or because ipsilateral movements violate basal biological motor-patterns that predominantly comprise activity of contralateral limbs (walking, crawling, etc.), or because they are processed in the same brain hemisphere. Indeed, when actions are coupled orthogonally with extrinsic effects, no effect-overlap costs (rather than overlap benefits) emerge (Kunde et al., in press).

Thus, a thorough understanding of voluntary action will likely require a focus on the impact of action effects that are, (1) internally anticipated (i.e., follow but do not precede the action) and are, (2) extrinsic (i.e., occur outside the body). Although **Hommel et al.** acknowledge this requirement (cf. sects. 4.2.2 & 5.1) there are few studies that fulfill *both* criteria so far, which leaves an uncomfortable discrepancy between TEC's theoretical scope and its current experimental reality (cf. Kunde 2001; Steininger 1999).

How to transform an abstract, feature-based action plan into a concrete motor pattern. TEC suggests that action planning, analogously to (visual) perception, relies on elementary features. In my opinion this analogy is questionable. Whereas the perceptual *analysis* of objects can often be limited to very few attributes (in pop-out search even to a single feature), the *synthesis* of a to-be-performed action cannot be so limited. Features like LEFT and HAND might somehow constrain motor-activity to the left hand, but they fall short of determining one particular out of the plethora of possible left-hand movements. This problem becomes even more apparent when considering more extrinsic effects. Pressing a light switch can be achieved by motor patterns as different as lifting an arm or swinging a hip. How is the inevitable specification of one particular out of the infinite number of equifunctional motor patterns achieved? To me it appears an unappealing theoretical gap that TEC delegates this task to an unspecified "machinery of the 'late' motor processes" (target article, introduction). To become a comprehensive theory of action control, TEC should incorporate, rather than keep out, mechanisms that select one particular out of the usually large number of goal-satisfying behavioural options.

Inconsistent evidence for feature-binding in action planning. **Hommel et al.** assume that features needed to represent a certain event are temporarily less available for the concurrent representation of other events, producing costs of feature overlap. TEC has done an excellent job in inspiring the investigation of situations where such feature-overlap costs occur. Yet, there are situations where they do not occur. For example, Craighero et al. (1999) observed faster discrimination of objects that correspond to a concurrently prepared grasping movement. Hommel and Schneider (in press) found facilitated detection of a visual target by concurrent selection of a feature-overlapping manual response, even at points in time when the response was ready to go, and thus according to TEC, its features were bound. Moreover, would TEC not predict that grasping an identified cup is a complicated task (cf. sect. 3.1.3)? The cup's identification comprises the binding of its features (including location) which are then *less* available for action control, thereby making a cup-oriented action difficult. To me, feature binding would be a more powerful explanatory principle if it was clear *a priori* when it will occur (and when it will not) – otherwise binding smells a bit like a post-hoc helper, recruited whenever feature-overlap costs call for explanation.

These inconsistencies might indicate that feature-overlap costs occur, at least occasionally, for reasons other than binding. They may originate from inhibition of feature codes (Caessens & Vandierendonck 2001), or because an already activated feature requires a larger activation increment to represent another event than at rest-activation level (Müsseler et al. 2001), or because feature-overlapping events are less discriminable as a result of their similarity (Duncan & Humphreys 1989). These considerations need not necessarily be correct but they may provide reasonable, albeit admittedly more traditional, theoretical alternatives.

Movement-effect associations are usually context-sensitive. To be utilizable for goal-oriented action, movement-effect associations must often include the environmental conditions under which they are acquired (Hoffmann 1993). For example, a keypress on a PC-keyboard has dramatically different effects depending on the active program. A natural solution for this problem in TEC would be that movement-effect associations become bound with the stimulus conditions under which they are valid. Hommel et al. (2001) have shown that stimulus-response associations can indeed become "contextualized" in this manner. However, recent studies suggest that contextualization of response-effect associations is much harder to acquire, a fact that TEC should – and probably can – account for (Hoffmann & Sebald 2000; Stock & Hoffmann 2002).

Altogether, TEC has provided an extremely stimulating framework for the experimental study of goal-oriented action, and thus represents – even with some limitations in its present state – a major step towards uncovering the psychological reality of the hyphen in ideo-motor action.

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The CHREST model of active perception and its role in problem solving

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Abstract: We discuss the relation of the Theory of Event Coding (TEC) to a computational model of expert perception, CHREST, based on the chunking theory. TEC's status as a verbal theory leaves several questions unanswerable, such as the precise nature of internal representations used, or the degree of learning required to obtain a particular level of competence: CHREST may help answer such questions.

The target article presents a unifying framework for perception and action, assuming their representation within a common medium. We discuss the relation of the Theory of Event Coding (TEC) to a tradition of computational modelling based on the chunking theory, which also addresses many of TEC's theoretical concerns; in particular, the notion of active perception guided by action sequences. The basic principles of TEC include:

1. Common coding of perceptual content and action goals.
2. Feature-based coding of perceived and produced events.
3. Distal coding of event features.

Principles (1) and (2) argue that action goals should be represented as composite action-events, just as perceptual objects are composite perceptual-features, and that integration is required to make perception an active element in action planning. Principle (3) implies that the level of representation is abstracted from that