Modern Ideomotor Theory of Goal-Directed Action is not What You Think: A Commentary on Custers (2023)

Bernhard Hommel 1 & Andreas B. Eder 2

1 Department of Psychology, Shandong Normal University

2 Institute for Psychology, University of Würzburg (JMU)

Motivation Science, *2024*

Author Note

Bernhard Hommel https://orcid.org/0000-0003-4731-5125

Andreas B. Eder https://orcid.org/0000-0002-4722-5114

Correspondence concerning this article should be addressed to Andreas B. Eder, University of Würzburg (JMU), Institute for Psychology, Röntgenring 10, 97070 Würzburg, Germany. Email: andreas.eder@uni-wuerzburg.de

Abstract

The ideomotor principle assumes that actions are cognitively represented by their perceivable outcomes, and that goal-directed action is prepared and initiated through the selection of a desired action effect. Custers (2023) claims that the ideomotor principle is plausible for the goal-directed production of body-related action effects, but not for sensory effects in the distal environment. For the production of latter, he argues, causal beliefs about actions and effects provide a better explanation. In this commentary, we challenge this conclusion by pointing out that it rests on selective reading of the available evidence, on various misunderstandings and misinterpretations of the ideomotor principle, and on an outdated view of ideomotor theory. We discuss recent advancements in ideomotor theorizing, show how they account for flexible action control, and advocate a unified, ideomotor perspective on human intentional action.

Keywords: ideomotor principle; theory of event coding; propositional framework;

In his presidential address, Custers (2023) evaluates the state-of-the-art regarding accounts of human action control in terms of ideomotor theory. He argues that “the evidence for ideomotor action obtained by the dominant paradigms in the field is open to alternative interpretations” (p. 261), such as accounts in terms of “propositions” or “causal models.” We contend that the key arguments of Custers are based on an outdated view of ideomotor mechanisms, a rather selective reading of the literature, and a number of misunderstandings/misinterpretations. In this commentary, we address four such issues.

1. Ideomotor theory relies on priming

Custers’ considerations are based on studies using the paradigm introduced by Elsner and Hommel (2001). These studies involve action-effect learning (acquisition phase) followed by priming the actions by presenting their previous effects (test phase). Significant priming effects demonstrate that actions and effects became associated to a degree that presenting the effect can reactivate the action. This phenomenon has been established beyond doubt, as shown by neurophysiological studies, where hearing previously self-produced sounds activated brain regions implicated in movement planning (Dignath et al., 2020; Elsner et al., 2002; Melcher et al., 2008). However, this does not mean that all biases obtained with the Elsner/Hommel paradigm are due to effect-induced action priming. As Elsner and Hommel (2001) have discussed and studied in depth, participants might use various strategies to simplify the task. The studies discussed by Custers add to this evidence and suggest task characteristics under which certain strategies may become more likely. Outside the laboratory, action selection is influenced by many factors such as motives, social rules, and expectations. Ultimately, selected actions must be turned into an executable action plan, which is the focus of ideomotor theory. Unlike Custers, ideomotor theory is explicit and transparent about how this works mechanistically.

However, neither does ideomotor theory predict that irrelevant action effects are the only or the main contributor to action selection (see the ‘intentional weighting principle;’ Memelink & Hommel, 2013), nor does it deny that response strategies overshadow or outcompete their impact on selection. Therefore, the evidence cited by Custers highlights the limitations of some versions of the Elsner/Hommel paradigm but does not challenge ideomotor theory itself.

2. Ideomotor theory relies on Hebbian learning

In his "Reflections on the ideomotor account,” Custers (2023) employs a classical straw man argument. He asserts that “the formation of bidirectional associations by means of Hebbian learning through trial and error is the most plausible explanation for how representations that support such goal-directed action are acquired” (p. 266) and then criticizes the ideomotor approach for lacking the flexibility to explain intentional action. However, neither the Theory of Event Coding (TEC; Hommel et al., 2001), the most comprehensive ideomotor-inspired theoretical framework, nor Elsner and Hommel (2001), the primary focus of Custers’ critique, endorse Hebbian or associative learning rules as outlined by classical learning theories. On the contrary, Elsner and Hommel explicitly state that some of their foundational assumptions oppose classical learning theory, especially regarding backward conditioning—the assumption that associations acquired in one direction [X→Y] can spread activation in the opposite direction [Y→X]. This concept is integral to Elsner and Hommel’s theoretical framework but is explicitly rejected by classical learning theory (Hall, 1984). Custers incorrectly posits that Hebbian learning is the primary mechanism underlying ideomotor action control. This assumption, along with his argument that ideomotor theory is incapable of addressing single-shot acquisition of action-effect contingencies, is a misinterpretation.

First, ideomotor theorizing emerged in the middle of the nineteenth century (Stock & Stock, 2004), well before Hebb introduced his neural learning rule in 1949, making it unlikely that the former relies on the latter. Ideomotor theory posits that knowledge of action effects can be acquired through direct observation of action-effect contingencies. This explains how young infants, who are not yet capable of intentional learning, could learn about action effects (Verschoor et al., 2010). However, this process is just one of multiple avenues for acquiring action-effect knowledge. Other important learning processes include social imitation (Elsner, 2007; Paulus, 2014) and verbal instructions (Eder & Dignath, 2017; Theeuwes et al., 2015). Thus, the ability to acquire action-effect knowledge through means other than direct observation does not contradict modern ideomotor theory.

Second, the fact that action-effect learning can be extremely rapid (Wolfensteller & Ruge, 2011), and even result from a single pairing of action and effects (Dutzi & Hommel, 2009; Hommel, 2005), confirms that repetition is not necessary for the acquisition of action-effect knowledge. TEC posits that features of stimuli, actions, and effects are stored in episodic event files (Hommel, 2004; Hommel et al., 2001), similar to the memory format proposed by instance theory (Logan, 1988), which also rejects associationist thinking. Hence, while we agree with Custers (2023) that "Hebbian learning is not the only process through which goal-directed actions … can be learned," this does not discredit ideomotor theorizing.

It is important to note that most experiments on ideomotor control were conducted in controlled environments, allowing for the acquisition of action-effect contingencies based on a simple contiguity principle (Elsner & Hommel, 2004). However, real-life perceptual conditions are much more complex. For example, a swimmer trying to discern which motions make him swim faster may need many repetitions to identify the relevant factors. As environmental complexity and movement coordination increase, learning increasingly depends on the continuous monitoring of action-effect contingencies across times and situations (Altavilla et al., 2018). This mode of learning amounts to correlational or Hebbian learning. Therefore, dismissing specific learning types is premature, as their efficiency likely depends on the context. In any case, there is no justification for claiming that ideomotor theorizing is exclusively tied to Hebbian learning. Thus, potential limitations of Hebbian learning do not invalidate the ideomotor framework.

3. Associative learning is inconsistent with flexible action control

Although the relationship between Hebbian/associative learning and ideomotor theorizing is less intimate than Custers (2023) suggests, the contribution of action-effect associations to goal-directed action control warrants further elaboration. Does acquiring action-effect knowledge through 'associative' (repetition-based) learning lead to the inflexibility in action control that Custers suggests?

Custers examination of this issue unfolds through three arguments. First, he posits that "action-outcome representations cannot be fixed" (p. 266) because a single movement can result in multiple outcomes depending on the context: a keystroke might produce a letter on a computer monitor, a note on a piano, or the sound of a ringing doorbell. Secondly, he differentiates between "proximal" (body-related) and "distal" (environment-related) outcomes, arguing that the former are more rigidly linked to bodily actions than the latter. He claims that because a "motor program always produces the same outcome as there is a one-to-one relation between activation of the motor program and its bodily consequences, this hard-wired or overlearned relation can be the result of Hebbian learning" (p. 267). However, his use of the terms does not follow TEC terminology, which is grounded in the approaches of Heider (1930) and Brunswik (1944).

According to them, any perceived or produced event has *both* proximal *and* distal representations. From the cognitive system's viewpoint, the body is part of the environment, thus negating a distinct representational status for "body-related" versus "environment-related" outcomes as Custers suggests. Third, and inferred from the previous assumptions, Custers argues that associations formed by Hebbian learning are involved in producing body-related outcomes but cannot account for flexible goal-directed actions. By implication, this assumption invalidates ideomotor theory—and all other theories that rely on associative learning mechanisms—as account of goal-directed action.

Logically speaking, conclusions are only valid if their foundational premises are sound, which, in this case, they are not. Consider the first premise in the light of GOALIATH—a recent theory of how humans represent and use goals to select intentional actions (Hommel, 2022). GOALIATH posits that action-effect contingencies are stored, together with co-occurring stimuli and other context elements, in event files. Goals consist of sets of selection criteria, such as wanting to drink a cup of coffee *efficiently* and *safely*. These criteria are matched against available event files that compete for selection. Typically, the selection favors movements that have been experienced as more efficient and safe, like using one's dominant hand at a slow pace for a safe outcome. This system of selection is highly flexible. If the dominant hand is occupied, the system may favor the free hand, or even a foot if necessary. Goals are not organized hierarchically or pre-existing; various selection criteria can be activated for different reasons. For example, individuals under time pressure might always have their “fast” criterion activated, while others might prioritize the “safely” criterion. This results in a more flexible action-control system than the one envisioned by Custers.

And yet, the relations between actions and their effects can be as fixed or flexible as needed. GOALIATH does not prioritize a specific method of acquisition nor specify the permanence of event files. They can be formed in one shot and updated readily with environmental changes or solidified through associative/Hebbian learning to become resistant to change. The malleability or rigidity of event files is an empirical question and does not affect the mechanics of action control. Additionally, having each action linked to multiple outcomes does not pose a problem. For example, even if the selected grasping action for drinking coffee has been used to grasp other objects previously, these experiences are unlikely to interfere with the current goal. This is because ideomotor theory posits that the selection mechanism is guided by representations of desired outcomes, not by the actions themselves. Thus, the action-effect logic of ideomotor theory creates more flexibility in action control. This flexibility in goal-directed action is fundamentally independent of the specific learning process or the stickiness of its results.

Custers' second premise rests on an outdated view of motor control. Since the seminal works of Lashley (1933) and Bernstein (1967), motor science has recognized that nearly every single movement can be carried out in numerous ways—the notorious ‘degree-of-freedom problem.’ Muscles can be co-activated in different ways to accomplish the same movement, and slight variations in body posture can significantly alter the feasibility, efficiency, and naturalness of movements (Turvey & Fonseca, 2009). This equifinality issue was discussed by Heider (1926) and Brunswik (1944), emphasizing that the relationship between distal (‘environment-related’) and proximal (‘body-related’) representations is not fixed. Prinz (1992) also highlighted this issue with respect to action control, leading to his formulation of a shared representational domain for perception and action, foundational to TEC.

Recent developments in ideomotor theorizing have also embraced concepts from cybernetic control theory to address the issue of equifinality. Goal-directed actions must be adjusted to the affordances of varying situations to reach a desired state (the action goal). Therefore, the outcome of the action is coded not just in terms of the intended final state but also as the transition from the current to the desired end state (Kunde et al., 2017). For instance, when a person intends to turn on the ceiling light, pressing the light switch is guided by the desired transition from darkness to illumination. Consequently, the action plan to press the light switch is only formed when the room is dark, not when it is already lit. According to cybernetic control theory, this transition represents a discrepancy that the individual aims to minimize (Powers, 1973). Conceptualizing action outcomes as desired perceptual transitions hence takes the start condition for the action explicitly into account. Additionally, several perceptual transitions are typically possible in a given situation, meaning, agents have a choice between the transitions they want to achieve (Eder, 2023). By activating and selecting the transition that best fits the individual's needs and preferences, action is automatically tailored to the situation, serving as the starting point for the desired transition.

We thus conclude that (highly overlearned) associations between codes of motor activities and codes of sensory effects do not render action control inflexible, nor are associations with body-related effects qualitatively different from what Custers refers to as 'environment-related effects.'

4. Explicit strategies can (or are needed to) explain ideomotor phenomena

Custers (2023) presents various alternative interpretations of findings traditionally viewed as supportive of modern ideomotor theory. These alternative interpretations suggest (1) that participants have acquired explicit (i.e., intentionally collected, consciously accessible) knowledge about actions and sensory effects; (2) that from this knowledge, they created propositions (e.g., “If I press this/that key, then this/that sound will occur.”) that become integrated into a causal model; (3) that subsequently (in a test phase), this causal model somehow interacts with ongoing action control and produces what appears to be an ‘ideomotor effect.’ Let us examine these assumptions sequentially.

The first question is whether people acquire explicit knowledge during tasks like those of Elsner and Hommel (2001). While we have no reason to believe they do not, the crucial aspect is whether this can account for ideomotor effects, such as the difficulty of carrying out a response when presented with stimuli that previously served as action effects for another response. Several findings challenge this idea. For instance, Custers’ explanation implies that conditions impairing the acquisition and use of a "causal model" should reduce ideomotor effects. However, priming can be induced by subliminally presented effect stimuli (Kunde, 2004; Le Bars et al., 2016) and is unimpaired by a cognitively-demanding secondary task (Elsner & Hommel, 2001, Exp. 4), and it occurs in young infants and non-human animals—all with very limited capacity for propositional reasoning (Shin et al., 2010; Verschoor et al., 2010). Moreover, ideomotor action control can be disrupted while propositional reasoning is preserved. Birbaumer and colleagues (2012) observed this in completely locked-in state patients. Despite being paralyzed and lacking muscular control, these patients could answer knowledge questions (e.g., “Berlin is the capital of France” (yes/no)) using a brain-computer interface, demonstrating retained propositional reasoning but an inability for voluntary action production—a state referred to as 'ideomotor silence.'

The second question is whether explicitly acquired propositional knowledge of action-effect relations can explain ideomotor effects. Logically, it cannot. While the proposition “when I press the left key, a particular sound X occurs” might be valid, it does not imply that encountering sound X should prompt pressing the left key. Propositional accounts excel when empirical phenomena depend on matching the order of related elements at acquisition and test. However, Elsner and Hommel (2001) showed that this match is not essential for retrieving and using acquired knowledge, which argues against directional cause-effect beliefs. Custers attempts to circumvent this conclusion by rephrasing associative predictions in propositional terms. For example, he suggests that forming the proposition that a left response produces a high tone, and a right response a low tone, “may make it harder to switch to using the opposite mapping.” However, this assumes entirely different relations: the acquired mapping relates tones to the responses they produce, while the test phase mapping turns tones into stimuli indicating which response to carry out. If propositions are as directional as claimed, there is no logical relationship between the acquisition and test phase mappings. Even if participants make illogical use of propositions, the directional format should not activate responses upon presentation of a tone. In conclusion, proposition theorists face a dilemma: either propositions are as directional as claimed, and cannot account for ideomotor effects, or they are bidirectional like associations, which raises the question how propositions and associations differ. Indeed, proposition theorists consider it possible that propositions are built from associations (De Houwer et al., 2016).

A further issue with Custers’ account is the lack of any motivational rationale. The premise that participants intentionally acquire seemingly unnecessary knowledge of action effects, only to later apply it in ways that often impair their performance, prompts questions about the underlying motivations. With respect to the classical Elsner and Hommel (2001) paradigm, one may argue that the re-use of the same stimuli and responses in the acquisition and test phases may somehow encourage the re-use of previously acquired knowledge. However, research has demonstrated that stimuli resembling action effects can prime actions leading to clearly unpleasant outcomes (e.g., the experience of a painful electric shock), offering no incentives for their deliberate use (Beckers et al., 2002; Eder et al., 2015; Strohmaier & Veling, 2019). Furthermore, a readiness to action is generated even when participants are not tasked to react (Elsner et al., 2002; Melcher et al., 2008).

Coda

In summary, Custers' (2023) challenge to ideomotor theory falls short on several fronts. He constructs a straw man by unnecessarily linking ideomotor theory to Hebbian learning, incorrectly claims that flexible action control cannot arise from representations formed through associative learning, and proposes a propositional framework that raises more questions than it answers. While tempting, adding a propositional action control system to the ideomotor framework would violate the principle of parsimony and likely result in an incoherent account that is a postdictive giant but a predictive dwarf.

References

Altavilla, C., Cejuela, R., & Caballero-Pérez, P. (2018). Effect of Different Feedback Modalities on Swimming Pace: Which Feedback Modality is Most Effective? *Journal of Human Kinetics*, *65*, 187–195. https://doi.org/10.2478/hukin-2018-0026

Beckers, T., De Houwer, J., & Eelen, P. (2002). Automatic integration of non-perceptual action effect features: The case of the associative affective Simon effect. *Psychological Research*, *66*(3), 166–173. https://doi.org/10.1007/s00426-002-0090-9

Bernstein, N. A. (1967). *The coordination and regulation of movements*. Pergamon Press.

Birbaumer, N., Piccione, F., Silvoni, S., & Wildgruber, M. (2012). Ideomotor silence: The case of complete paralysis and brain–computer interfaces (BCI). *Psychological Research*, *76*(2), 183–191. https://doi.org/10.1007/s00426-012-0412-5

Brunswik, E. (1944). Distal focussing of perception: Size-constancy in a representative sample of situations. *Psychological Monographs*, *56*(1), i–49. https://doi.org/10.1037/h0093505

Custers, R. (2023). Thoughts about actions and outcomes (and what they lead to). *Motivation Science*, *9*(4), 261–271. https://doi.org/10.1037/mot0000306

De Houwer, J., Hughes, S., & Barnes-Holmes, D. (2016). Associative learning as higher order cognition: Learning in human and nonhuman animals from the perspective of propositional theories and relational frame theory. *Journal of Comparative Psychology*, *130*(3), 215–225. https://doi.org/10.1037/a0039999

Dignath, D., Kiesel, A., Frings, C., & Pastötter, B. (2020). Electrophysiological evidence for action-effect prediction. *Journal of Experimental Psychology: General*, *149*(6), 1148–1155. https://doi.org/10.1037/xge0000707

Dutzi, I. B., & Hommel, B. (2009). The microgenesis of action-effect binding. *Psychological Research*, *73*(3), 425–435. https://doi.org/10.1007/s00426-008-0161-7

Eder, A. B. (2023). A perceptual control theory of emotional action. *Cognition and Emotion*, *37*(7), 1167–1184. https://doi.org/10.1080/02699931.2023.2265234

Eder, A. B., & Dignath, D. (2017). Influence of verbal instructions on effect-based action control. *Psychological Research*, *81*(2), 355–365. https://doi.org/10.1007/s00426-016-0745-6

Eder, A. B., Rothermund, K., De Houwer, J., & Hommel, B. (2015). Directive and incentive functions of affective action consequences: An ideomotor approach. *Psychological Research*, *79*, 630–649. https://doi.org/10.1007/s00426-014-0590-4

Elsner, B. (2007). Infants' imitation of goal-directed actions: The role of movements and action effects. *Acta psychologica*, *124*(1), 44–59. https://doi.org/10.1016/j.actpsy.2006.09.006

Elsner, B., & Hommel, B. (2001). Effect anticipation and action control. *Journal of Experimental Psychology: Human Perception and Performance*, *27*(1), 229–240. https://doi.org/10.1037/0096-1523.27.1.229

Elsner, B., & Hommel, B. (2004). Contiguity and contingency in action-effect learning. *Psychological Research*, *68*(2), 138–154. https://doi.org/10.1007/s00426-003-0151-8

Elsner, B., Hommel, B., Mentschel, C., Drzezga, A., Prinz, W., Conrad, B., & Siebner, H. (2002). Linking Actions and Their Perceivable Consequences in the Human Brain. *NeuroImage*, *17*(1), 364–372. https://doi.org/10.1006/nimg.2002.1162

Hall, J. F. (1984). Backward conditioning in Pavlovian type studies. *The Pavlovian Journal of Biological Science : Official Journal of the Pavlovian*, *19*(4), 163–168. https://doi.org/10.1007/BF03004514

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological theory*. John Wiley & Sons. https://pure.mpg.de/rest/items/item_2346268_3/component/file_2346267/content

Heider, F. (1926). Ding und Medium. [Thing and medium.]. *Symposion: Philosophische Zeitschrift für Forschung und Aussprache*, *1*(2), 109–158.

Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences*, *8*(11), 494–500. https://doi.org/10.1016/j.tics.2004.08.007

Hommel, B. (2005). How much attention does an event file need? *Journal of Experimental Psychology: Human Perception and Performance*, *31*(5), 1067–1082. https://doi.org/10.1037/0096-1523.31.5.1067

Hommel, B. (2022). GOALIATH: A theory of goal-directed behavior. *Psychological Research*, *86*(4), 1054–1077. https://doi.org/10.1007/s00426-021-01563-w

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The Theory of Event Coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences*, *24*(5), 849–937. https://doi.org/10.1017/S0140525X01000103

Kunde, W. (2004). Response priming by supraliminal and subliminal action effects. *Psychological Research*, *68*(2/3), 91–96. https://doi.org/10.1007/s00426-003-0147-4

Kunde, W., Schmidts, C., Wirth, R., & Herbort, O. (2017). Action effects are coded as transitions from current to future stimulation: Evidence from compatibility effects in tracking. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(3), 477–486. https://doi.org/10.1037/xhp0000311

Lashley, K. S. (1933). Integrative functions of the cerebral cortex. *Physiological Reviews*, *13*(1), 1–42. https://doi.org/10.1152/physrev.1933.13.1.1

Le Bars, S., Hsu, Y.-F., & Waszak, F. (2016). The impact of subliminal effect images in voluntary vs. Stimulus-driven actions. *Cognition*, *156*, 6–15. https://doi.org/10.1016/j.cognition.2016.07.005

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*(4), 492–527. https://doi.org/10.1037/0033-295X.95.4.492

Melcher, T., Weidema, M., Eenshuistra, R. M., Hommel, B., & Gruber, O. (2008). The neural substrate of the ideomotor principle: An event-related fMRI analysis. *NeuroImage*, *39*(3), 1274–1288. https://doi.org/10.1016/j.neuroimage.2007.09.049

Memelink, J., & Hommel, B. (2013). Intentional weighting: A basic principle in cognitive control. *Psychological Research*, *77*(3), 249–259. https://doi.org/10.1007/s00426-012-0435-y

Paulus, M. (2014). How and why do infants imitate? An ideomotor approach to social and imitative learning in infancy (and beyond). *Psychonomic Bulletin & Review*, *21*(5), 1139–1156. https://doi.org/10.3758/s13423-014-0598-1

Powers, W. T. (1973). *Behavior: The control of perception*. Aldine Publishing Company.

Prinz, W. (1992). Why don't we perceive our brain states? *European Journal of Cognitive Psychology*, *4*(1), 1–20. https://doi.org/10.1080/09541449208406240

Shin, Y. K., Proctor, R. W., & Capaldi, E. J. (2010). A review of contemporary ideomotor theory. *Psychological Bulletin*, *136*(6), 943–974. https://doi.org/10.1037/a0020541

Stock, A., & Stock, C. (2004). A short history of ideo-motor action. *Psychological Research*, *68*(2), 176–188. https://doi.org/10.1007/s00426-003-0154-5

Strohmaier, N., & Veling, H. (2019). Bypassing the gatekeeper: Incidental negative cues stimulate choices with negative outcomes. *Cognition and Emotion*, *33*(5), 1059–1066. https://doi.org/10.1080/02699931.2018.1523136

Theeuwes, M., De Houwer, J., Eder, A., & Liefooghe, B. (2015). Congruency effects on the basis of instructed response-effect contingencies. *Acta Psychologica*, *158*, 43–50. https://doi.org/10.1016/j.actpsy.2015.04.002

Turvey, M. T., & Fonseca, S. (2009). Nature of Motor Control: Perspectives and Issues. In D. Sternad (Hrsg.), *Progress in Motor Control: A Multidisciplinary Perspective* (S. 93–123). Springer US. https://doi.org/10.1007/978-0-387-77064-2_6

Verschoor, S. A., Weidema, M., Biro, S., & Hommel, B. (2010). Where Do Action Goals Come from? Evidence for Spontaneous Action–Effect Binding in Infants. *Frontiers in Psychology*, *1*. https://doi.org/10.3389/fpsyg.2010.00201

Wolfensteller, U., & Ruge, H. (2011). On the timescale of stimulus-based action–effect learning. *Quarterly Journal of Experimental Psychology*, *64*(7), 1273–1289. https://doi.org/10.1080/17470218.2010.546417