

RUNNING HEAD: Giving Cognition a Hand

Giving Cognition a Hand: A Review of Ellis' (2018) *Bodies and Other Objects: The
Sensorimotor Foundations of Cognition*

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In the early days of the cognitive revolution, one of the catchphrases was "mind is to brain as software is to hardware". Given that software and hardware were usually conceived to be relatively independent (e.g., a single program could run on different computers, a single computer could run different programs), such a catchphrase, and such an approach, suggested a relative independence of cognitive processes from the material substrate in which those processes were embedded or instantiated. Consistent with this, methodologies in the first few decades of the cognitive revolution generally focused on accuracy rates, response times, and other behavioral measures. With the subsequent development of brain imaging technologies, and the declaration of the "Decade of the Brain" in 1990s, cognitive scientists began to give more consideration to the neural underpinnings of cognitive processing. Also, with the recent development of notions regarding "embodied cognition", cognitive scientists began to focus on how being in the body (and on how properties of the body) influenced cognitive processing. Ellis' *Bodies and Other Objects* (BOO) makes a strong case for considering the importance of the body for cognition; indeed, BOO's subtitle *The Sensorimotor Foundations of Cognition* makes the presence and role of the body in cognitive processing quite explicit.

Ellis suggests cognition is not properly described by accounts that treat the body as a receiver of elementary sensations that are processed in the sensory pathways and brain; rather, cognition is better described as a synthesis and coupling between an active agent and the world in which that agent is embedded. Contrary to previous views that conceived of the brain as a general-purpose computer, Ellis suggests the brain and nervous system are more correctly

conceived of as mechanisms for controlling the body in space and time. Such a view highlights the importance of embodied cognition; importantly, this view also suggests that being in the world is not like being contained within a receptacle, but rather involves a connectivity of the agent and the world. Many different areas of literature are discussed in BOO, including the phenomenology of perception, the human visual system as an active system for detecting behavioral possibilities rather than as a relatively passive system that derives descriptions of the world, tool use and how the making and using of tools influenced the human perceptual-motor systems and extension of the agent's effective body, the idea that mirror neurons evolved to facilitate joint action (i.e., actions involving two or more individuals, e.g., passing a cup from one individual to another individual), the role of material culture in shaping human societies and human brains, and language as a cultural artifact that arose to facilitate joint action.

Perception and Action

A primary domain of discussion in BOO is perception and action (referred to "Vision and Action" in BOO, but which can be broadened to include nonvisual senses). Ellis reviews studies that reveal how judgments of objects (e.g., cups) are facilitated when those objects are oriented to be more easily graspable, and judgments involving such micro-affordances reveal important properties in visual object representation. These effects seem similar to spatial biases such as the Simon effect and other effects based on S-R compatibilities (for review, see Umiltà, Bonato, & Rusconi, 2018). Ellis further develops the notion of affordance, and he suggests that invariant information is located not in the optic array but in the learned relationships between the agent and the tool. However, given that (the majority of) skilled tool use presumably involves haptic information, it is not clear why BOO does not consider the broader notion of a global array (cf. Witt & Riley, 2014) that could contain such information. The approach in BOO suggests that to

look for meaning (information) solely in the head or solely in the optic (or perhaps global) array is to look in the wrong place, as meaning is in the relationships between agents and objects (p. 34). Ellis also suggests there could be different classes of affordance, and this is consistent with McBeath's (2018) discussion of three types of regularities involving invariant universals, natural regularities of biological objects and scenes, and culturally or behaviorally learned regularities.

The approach in BOO suggests that being in the world involves having a cognitive system tuned to the affordances and properties of the world and that the function of the brain and nervous system is to predict states of the world. However, many spatial biases that are actually optimized for everyday experience (as they are tuned to the affordances and properties of the world and thus predict the state of the world) look like errors in the laboratory. For example, the approach in BOO is consistent with representational momentum (a spatial bias in which the judged location of a moving target is displaced in the direction of anticipated motion, for review, see Hubbard, 2005, 2018b) and with boundary extension (a spatial bias in which the remembered locations of the boundaries of a scene are displaced outward, for review, see Intraub & Gagnier, 2018). Although both of these spatial biases could be viewed as errors, representational momentum could alternatively be viewed as a successful adaptation that compensates for neural processing times and helps perceivers interact with moving targets in real time, and boundary extension could alternatively be viewed as a successful adaptation that primes perceivers regarding what is likely to be perceived in the next fixation. Interestingly, a similar argument has been made for the adaptiveness of some visual illusions regarding direction and velocity (e.g., Weiss, Simoncelli, & Adelson, 2002), which can also be considered as spatial biases.

The view of spatial biases such as representational momentum and boundary extension as adaptations is consistent with Ellis' suggestion that relationships between agents and objects

"become embedded so that they form a body of implicit knowledge that provides the basis of expectations of the consequences of various types of visual exploration" (p. 54). Consistent with a notion that some spatial biases might be adaptations rather than errors, Ellis suggests "there is much to discover by releasing humans from their chin rests and fixation crosses" (p 38), and BOO makes a strong case that perception and action need to be investigated in fully engaged agents, moving and acting in ecologically valid environments, rather than in artificial tasks in artificial laboratories¹. One related area of research involves predictive processing, in which top-down effects influence representation to minimize the error between perception and action (e.g., Lee & Mumford, 2003; Rao & Bullard, 1999). Indeed, Bendixen, SanMiguel, and Schröger (2012, p.129) suggest predictive processing "helps in anticipating the movement's continuation (which, in turn, allows for the adaptation of own [sic] motor acts)", and this suggestion is consistent with Ellis' notions and with representational momentum and boundary extension. A second related area of research involves studies on action-specific perception, in which perception of attributes of a stimulus such as size, velocity, or steepness are tied to the ability or physiological state of the perceiver and data collection often involves perceivers interacting with stimuli in real-world settings (e.g., see Witt, 2018).

The existence of spatial biases might appear at odds with claims that visual perception is direct, but there need not be an incompatibility if Gibsonian and ecological approaches describe different parts of sensorimotor pathways. For example, one account of representational momentum (Hubbard, 2006, 2019) involves two stages, the first of which is a default displacement based on sensitivity to subjective effects of environmentally invariant physical principles (i.e., higher-order isomorphisms [regarding properties of objects or the environment and properties of representation] that have been incorporated into the functional architecture of

representation), and the second of which allows for modulation of that initial displacement by other task- or stimulus-specific knowledge or information (e.g., anticipated changes in direction, target identity). Such an approach is consistent with predictive processing (see discussion in Hubbard, 2019) and with Ellis' suggestion of a predictive hierarchical network, in that a lower-level might provide a default displacement, but top-down or higher-level influences can then modulate that displacement. Similarly, just as representational momentum or predictive processing might result from selective priming within a network representation of space, so too might effects of hand shape or orientation on subsequent perception result from selective priming within a network representation of space. More generally, invariant information specifies the initial content of the representation which can then be modulated by other information.

Tool Use

Another domain of discussion in BOO is tool use. Ellis follows Gibson (2015) in suggesting that objects in the world are perceived in terms of what we can do with them. Our sense of body includes the tools we use, and in this Ellis follows Merleau-Ponty (2002) and is consistent with Bateson (1972). If used skillfully, tools extend the manipulative capacities of our skeletomuscular system and are perceived as part of the body rather than as part of the environment. An additional example of this is seen in the "tool effect" demonstrated by Michotte (1991; for review, see Hubbard, 2013a), in which an object that is used to launch a target into motion is perceived to be a part of the agent doing the launching rather than as an object separate from the agent. Such a finding is consistent with findings discussed in BOO regarding how visual receptive fields are extended to include the tool that is being used. Indeed, such examples suggest that the boundaries between tools and bodies are less absolute than commonly supposed and can extend to incorporate objects operated on by our intentionality. Incorporation of tools

into our body's manipulative capabilities is consistent with the "extended mind" idea, in which much of human cognition is "offloaded" into the world and the mind is constituted by a coupling of events in the brain and events and objects in the world (p. 166). A recent example of such an offloading that is discussed in BOO involves using a smartphone to store phone numbers, addresses, and other information.

The approach in BOO suggests that the making of tools reveals glimpses of the mental processes of the individuals who make those tools. Actually, this notion need not be limited to tools, but might apply to many types of objects made or used by humans. For example, a sensitivity to dynamic information contained within a painting or sculpture might convey information regarding how the object was made (i.e., what forces acted upon the object). Such a sensitivity might involve awareness of the brush strokes or other (tool-related) actions, which could provide information on the sequence of actions used to create the object (Freyd, 1993), or it might involve awareness of a dynamic inherent within the structure of a depicted object, such as the depiction of a protagonist straining against a heavy weight or other force (Arnheim, 1974). Indeed, Leyton (1992) speculated that the history of forces that acted on an object might be recoverable from (i.e., encoded in) the shape of an object (e.g., a dent or scratch on an object provides information about the stimulus that caused that dent or scratch). Thus, information regarding the use of tools, as well as other influences on an object, could encode other potentially useful information. Indeed, sensitivity to such dynamics is not limited to the dynamics related to tool use, but could include other types of dynamics as well (e.g., effects of gravity in depictions of lifting or supporting a heavy object, Hubbard, in press).

Ellis defines "toolspace" as that (peripersonal) space within which objects can be operated on by tools used by an agent. The representation of toolspace responds dynamically to

events that occur within that space, remapping space and sensory events (e.g. an object appears closer when an agent holds a tool with which he or she intends to reach to that object, Witt, Proffitt, & Epstein, 2005). Adaptation in the nervous system brought about by tool use changes the agent's spatial or other relationship to the object in the world, as the agent's reach is literally extended. The toolspace of an agent is also expanded by synchrony of that agent's motor system with the motor systems of other agents within sight of each other. Joint action in toolspace is particularly important, and BOO contains an extended argument suggesting that the mirror neuron system is involved in joint action. Consistent with this, BOO suggests that mirror neurons do not just mirror (i.e., do not just respond in an imitative manner) but can also respond in a complementary manner and are part of a system for coordination of joint action with other agents on material culture (p. 93). The same brain networks do the work of producing action and predicting action, thus resulting in the mirrorlike properties of some neurons. Importantly, BOO notes that mirror neurons typically mirror actions (with a tool) and do not mirror mere grasping (of that tool), thus further supporting a role of the mirror neurons in joint action.

The approach in BOO suggests that learning a tool-based skill involves more than just acquiring a fixed set of rules and is more like a conversation between an agent's sensorimotor systems and the stimulus. In this view (as well as that of Merleau-Ponty, Bateson, and others), a tool is considered an extension of the agent's own body. An example of this discussed in BOO involves knapping of flint (an early use of tools), in which specific knapping actions need to be adjusted to reflect specific properties of a given rock (constant adjustment of the knapping to the consistency of materials, etc.), but the idea can be generalized to any type of task in which there is adjustment and feedback in acquiring a skill. More specifically, the agent's perceptual system must become attuned to the requirements of the task and learn the appropriate visual and haptic

information. Thus, skills are shaped by the material culture and social culture in which they develop and in which the agent is immersed. It would appear that representations are shaped by the environment, and such a shaping is consistent with that previously suggested by Hubbard (2005) to underlie sensitivity to the effects of environmental invariants. Additionally, BOO suggests that differences in material cultures produces differences in cognitive architectures. Given the interplay between tool use and language, such a notion seems reminiscent of the Whorf-Sapir hypothesis regarding the relationship of language and thought.

Joint Action

A third domain of discussion in BOO is joint action between agents. BOO suggests that many instances of tool use (and other interactions with objects that aren't explicitly tools) involve joint action with another agent on a common object. The intentions of an agent are visible in the kinematics of his or her movements and can be "picked up" by an observer; as a consequence, in everyday interactions we have direct access to another agent's intentions because intentions are expressed in embodied actions (p. 96). Such access is not limited to other agents' bodies, but can be picked up from artifacts, as well; as noted earlier, sensitivity to dynamics involving movement or support of weight might underlie aesthetic responses to paintings and sculptures (see also Hubbard, 2018a). Similarly, sensitivity to the intention of another agent is relevant in phenomenal causality (for review, see Hubbard, 2013b); as shown by Heider and Simmel (1944) and subsequently many others, humans seem predisposed to attribute intentions to the actions of non-human stimuli. Such attributions are often based on patterns of movement, and this is consistent with the notion that intentionality can be encoded in a pattern of embodied actions (i.e., movements of the body or other object). Information regarding non-intentional dynamics

can also be picked up from movement kinematics (e.g., the effect of gravity on the weight of a lifted object, Valenti & Costall, 1997).

The approach in BOO suggests that the ability to pick up the intentions of another agent based on that agent's embodied actions is a result of mere exposure to sensory signals, and that sufficient exposure to (i.e., immersion within) the world will yield models of objects and events that have causal effects on sensory receptors. This idea is consistent with White's (2012) theory that visual perception of force is based on learning the associations between proximal haptic experiences of force and visual kinematic patterns and then applying those associations when subsequently viewing similar distal visual kinematic patterns in the absence of concurrent haptic experience. Just as physical force is not a visual property, intentionality is not a visual property; however, with experience we learn that different types of visual kinematic patterns are associated with different levels or types of physical force, and we similarly learn that different visual kinematic patterns are associated with different levels or types of intentionality. Similar effects of mere exposure to sensory signals resulting in a sensitivity to information can be seen in many other domains (e.g., implicit learning of artificial grammars, Reber, 1996; expectancies regarding musical tension, structure, and affect, Bigand & Poulin-Charronnat, 2006).

Predicting the actions of others is important because many social interactions involve physical exchange (e.g., passing a cup). Ellis states we "may extrapolate from memory inputs so as to project a short distance into the future, allowing our hand, for instance, to anticipate where a proffered object will be" (p. 100). This would appear to involve representational momentum, but rather than involving the singular observer and computer-animated geometrical objects typically used in studies of representational momentum, Ellis' example involves joint action on a physical object being passed to us by another intentional agent. Studies of representational

momentum have not often considered effects of joint action (for exceptions, see Jordan & Knoblich, 2004; Jordan & Hunsinger, 2008), but BOO suggests joint action is an important contributor to the representation of information regarding localization of a target. Indeed, predicting the actions of others is important even if "the other" is not another human; Ellis suggests we ascribe agency to our artifacts (which might be especially true if artifacts do not function as expected or if we do not have physical or design knowledge, cf. Dennett, 1987). Ellis also suggests the intentionality of the maker is often embedded in an object; thus, social relationships can include objects and artifacts, which might therefore be said to have a social life. Such an ascribing is not limited to human artifacts, though, but can include elements of the natural world (e.g., Hubbard, 2012).

The approach in BOO suggests that possession of brains and dexterous hands led to "shared intentionality", which provides the foundation of efficient cultural transmission (regarding tool use) and joint action, reciprocal actions, and helping others. Shared intentionality is a cultural product, and two agents working together generate matching (or perhaps complementary) representations of the task. Such sharing would seem to be necessary for successful engagement in joint action. This is consistent with BOO's suggestion that the mirror neuron system should be conceived of as part of a system for joint action with other agents in real time within material culture (p. 93). In such joint action, anticipating the actions of other agents is like anticipating the locations of targets in representational momentum, and this highlights how biases that might initially appear to be errors can actually be useful adaptations. Relatedly, Ellis suggests evolutionary changes can be accelerated by niche construction (i.e., shaping or modification of the organism's environment as a consequence of that organism's activities) at physical, social, and cultural levels. Furthermore, natural selection and niche

construction enter into a reciprocal relationship, and this suggests the possibility of a cognitive epigenetics in which shared intentionality contributes to evolutionary processes as well as niche construction.

Language

The final domain of discussion in BOO involves language, and Ellis discusses how development of language influenced and was influenced by development of material culture and social culture. Dexterous hands allow social communication using a protolanguage, and BOO suggests this could have supported subsequent development of the mirror neuron system. There are close links between gesture and speech, and a protolanguage combining pantomime with culturally-defined gestures could have facilitated development of tool use and language. Such a notion is consistent with findings that speech perception and pantomime involving hand gesture share common brain regions (e.g., Goldenberg, Hermsdörfer, Glindemann, Rorden, & Karnath, 2007). Given that language could be considered a form of joint action (e.g., a conversation involving multiple people), some of the capacities that contribute to joint action would have contributed to making a language-ready brain. BOO suggests that dexterity (i.e., development of toolspace), combined with the transparency of human intentionality that is required for joint action, provided the basis for the communication system that became language (p. 163). Rather than language reflecting some innate mental architecture (cf. Chomsky, 2006), BOO suggests that mental architecture comes to reflect the formal systems employed by a culture, including its language. In general, language is a cultural artifact that is constrained by earlier adaptations of sensorimotor systems to the need for coordinated actions in social groups but is also shaped by material and social cultures of its users.

Final Thoughts

Although BOO is a relatively slim volume, it contains a wealth of theoretical ideas, discussion of empirical findings, and suggestions for future research. Ellis provides an admirable linking of what might initially appear as several separate domains (vision and action, tool use, joint action, language) into a framework supporting a unified theory of human cognition. In this framework, human cognition is conceived as the means by which exchanges within a constantly evolving network of skillful bodies and objects are regulated so as to further human interests (p. 171). This framework challenges many assumptions and beliefs in cognitive science regarding the separation of different behavioral domains and the relative independence of cognitive processes from body processes. BOO maintains that most of our actions are highly skilled and depend upon synergistic coupling of an agent with objects (including other bodies) and events in the world. Even so, internal models can generate the expected actions and allow a measure of prediction error by comparison of forward flow of sensory-driven activation with subsequent perception (p. 107). This can help an agent predict his or her own actions (and the consequences of those actions) as well as the actions (and the consequences of those actions) of other agents. Such prediction is facilitated by mirror neurons, which can respond in a complementary as well as an imitative fashion, and so can optimize performance in joint action in real world setting.

BOO stresses the importance of material culture and social culture and proposes that the agent responds to a thing-in-the-world rather than to a representation-in-the-head. In this view, events and objects in the world are like scaffolding for events and objects in the mind (p. 166). Indeed, much of our material culture is scaffolding in this sense. Speech and language are a similar scaffolding for joint action or for individual action. Language (and writing) is an in-the-world, rather than an in-the-head, representational system. Use of symbols allows higher-level cognition to be implemented in human neural networks that evolved for sensorimotor purposes.

Curiously, Ellis suggests we need a new taxonomy of actions (p. 172) to replace our taxonomy of (folk psychological) mental terms (e.g., beliefs, desires, etc.), and this is consistent with views such as eliminative materialism which suggest we need to replace our folk psychological terms regarding mental states (e.g., perhaps with neurologically defined terms). Although many of the points in BOO regarding the importance of vision and action, tool use, joint action, and language are well taken, it isn't clear that a new taxonomy is needed, although there is a clear need for grounding whatever taxonomy is used in embodied cognition. Ultimately, the grounding of cognitive science on a sensorimotor foundation that is proposed in BOO is a promising approach that could give rise to multiple questions and avenues of investigation.

References

- Arnheim, R. (1974). *Art and visual perception: a psychology of the creative eye* (the new version). Berkeley, CA: University of California Press.
- Bateson, G. (1972). *Steps to an ecology of mind*. New York: Ballantine Books.
- Bendixen, A., SanMiguel, I., & Schröger, E. (2012). Early electrophysiological indicators for predictive processing in audition. *International Journal of Psychophysiology*, *83*, 120-131.
- Bigand, E., & Poulin-Charronnat, B. (2006). Are we "experienced listeners"? A review of the musical capacities that do not depend on formal musical training. *Cognition*, *100*, 100-130.
- Chomsky, N. (2006). *Language and mind*, 3rd ed. New York: Cambridge University Press.
- Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press.
- Freyd, J. J. (1993). Five hunches about perceptual processes and dynamic representations. In D. Meyer & S. Kornblum (Eds.), *Attention and Performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (pp. 99-199). Cambridge: MIT Press.
- Gibson, J. J. (2015). *The ecological approach to visual perception* (classic edition). New York: Psychology Press.
- Goldenberg, G., Hermsdörfer, J., Glindemann, R., Rorden, C., & Karnath, H. O. (2007). Pantomime of tool use depends on integrity of left inferior frontal cortex. *Cerebral Cortex*, *17*, 2769-2776.
- Heider, F., Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, *57*, 243-259.
- Hubbard, T. L. (2005). Representational momentum and related displacements in spatial memory: A review of the findings. *Psychonomic Bulletin & Review*, *12*, 822-851.
- Hubbard, T. L. (2006). Bridging the gap: Possible roles and contributions of representational momentum. *Psicologica*, *27*, 1-34.
- Hubbard, T. L. (2012). Causal representation and shamanic experience. *Journal of Consciousness Studies*, *19*, 202-228.
- Hubbard, T. L. (2013a). Phenomenal causality I: Varieties and variables. *Axiomathes*, *23*, 1-42.
- Hubbard, T. L. (2013b). Phenomenal causality II: Integration and implication. *Axiomathes*, *23*, 485-524.
- Hubbard, T. L. (2018a). Aesthetics and preferences in spatial and scene composition. In T. L. Hubbard (Ed.), *Spatial biases in perception and cognition* (pp. 222-240). New York: Cambridge University Press.
- Hubbard, T. L. (2018b). Influences on representational momentum. In T. L. Hubbard (Ed.), *Spatial biases in perception and cognition* (pp. 121-138). New York: Cambridge University Press.
- Hubbard, T. L. (2019). Momentum-like effects and the dynamics of perception, cognition, and action. *Attention, Perception, & Psychophysics*, *81*, 2155-2170.
- Hubbard, T. L. (in press). Representational gravity: Empirical findings and theoretical implications. *Psychonomic Bulletin & Review*.
- Intraub, H., & Gagnier, K. M. (2018). Expanding space: Does imagination affect boundary extension for visual scenes? In T. L. Hubbard (Ed.), *Spatial biases in perception and cognition* (pp. 193-208). New York: Cambridge University Press.

- Jordan, J. S., & Hunsinger, M. (2008). Learned patterns of action-effect anticipation contribute to the spatial displacement of continuously moving stimuli. *Journal of Experimental Psychology: Human Perception and Performance*, 34, 113-124.
- Jordan, J. S., & Knoblich, G. (2004). Spatial perception and control. *Psychonomic Bulletin & Review*, 11, 54-59.
- Lee, T. S., & Mumford, D. (2003). Hierarchical Bayesian inference in the visual cortex. *Journal of the Optical Society of America, A, Optics, Image Science & Vision*, 20(7), 1434-1448.
- Leyton, M. (1992). *Symmetry, causality, mind*. Cambridge, MA: MIT Press.
- McBeath, M. K. (2018). Natural regularities and coupled predictive perceptual and cognitive biases: Why we evolved to systematically experience spatial illusions. In T. L. Hubbard (Ed.). *Spatial biases in perception and cognition* (pp. 276-294). New York: Cambridge University Press.
- Merleau-Ponty, M. (2002). *Phenomenology of perception*. New York: Routledge.
- Michotte, A. (1991). The perception of the “tool effect”. In: G. Thinès, A. Costall, & G. Butterworth (Eds.). *Michotte’s experimental phenomenology of perception* (pp. 87-103). Hillsdale, NJ: Erlbaum (original work published 1951).
- Rao, R. P. N., & Ballard, D. H. (1999). Predictive coding in the visual cortex: A functional interpretation of some extra-classical receptive field effects. *Nature Neuroscience*, 2(1), 79-87.
- Reber, A. S. (1996). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious*. New York: Oxford University Press.
- Umiltà, C., Bonato, M., & Rusconi, E. (2018). S-R compatibility with physical and representational locations: The Simon, SMARC, and STEARC effects. In T. L. Hubbard (Ed.). *Spatial biases in perception and cognition* (pp. 60-76). New York: Cambridge University Press.
- Valenti, S. S., & Costall, A. (1997). Visual perception of lifted weight from kinematic and static (photographic) displays. *Journal of Experimental Psychology: Human Perception and Performance*, 23, 181-198.
- Weiss, Y., & Simoncelli, E., & Adelson, E. H. (2002). Motion illusions as optimal percepts. *Nature Neuroscience*, 5, 598-604.
- White, P. A. (2012). The experience of force: the role of haptic experience of forces in visual perception of object motion and interactions, mental simulation, and motion-related judgments. *Psychological Bulletin*, 138, 589-615.
- Witt, J. K. (2018). Spatial biases from action. In T. L. Hubbard (Ed.). *Spatial biases in perception and cognition* (pp. 307-323). New York: Cambridge University Press.
- Witt, J. K., Proffitt, D. R., & Epstein, W. (2005). Tool use affects perceived distance, but only when you intend to use it. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 880-888.
- Witt, J. K., & Riley, M. A. (2014). Discovering your inner Gibson: Reconciling action-specific and ecological approaches to perception-action. *Psychonomic Bulletin & Review*, 21, 1353-1370.

Footnote

¹ In a related example, some authors have suggested pursuit eye movements cause representational momentum, as some studies reported representational momentum for smoothly moving targets is decreased when participants are not allowed to visually track those targets (for summary, see Hubbard, 2018b). However, in everyday life, people generally fixate task-relevant stimuli, and the approach in BOO would suggest that having experimental participants fixate away from a target whose location they know they will have to report is highly artificial and thus not necessarily informative regarding normal functioning. The approach in BOO is consistent with the suggestion that the decrease in representational momentum when participants are not allowed to track a smoothly moving target more likely reflects a disruption of normal inputs to whatever mechanisms generate representational momentum rather than a causal role for pursuit eye movements per se (especially given that representational momentum occurs for visual implied motion or frozen-action stimuli and for nonvisual stimuli, none of which evoke pursuit eye movements).