Title of entry: Object Permanence

Synonyms: Continuity, Identity, Persistence, Recognition, Selfhood, Time

Definition: The apparent maintenance of object identity over time, especially during periods of non-observation.

Introduction

Typically-developing human beings and at least some other animals tend to regard the objects around them, including other organisms, landscape features and artifacts, as maintaining their identities – remaining the "same thing" – over time whether they are observed continuously or not. Objects are, in other words, regarded as "permanent" or "persistent" by default. Both experimental and theoretical practice in psychology largely adopt the "naïve realist" assumption that objects having the properties they are typically perceived to have are ontologically real, i.e. they in fact exist in an observation-independent way and in fact maintain their identities over time. Given this assumption, object permanence is the recognition or understanding of the continuous, identity-preserving existence of objects (see Hoffman, Singh and Prakash, 2015 for a critique of naïve realism). As object permanence must in any case be inferred from sensory input and memory, the ontological question of whether objects are in fact permanent can be set aside, in practice, in favor of the more properly psychological questions of how object permanence is inferred, how the ability to infer object permanence develops, and how and why an ability to infer object permanence evolved within animal lineages exhibiting

complex cognition. It bears emphasis that "inferences" of object permanence are typically, but not always (e.g. Eichenbaum, Yonelinas and Ranganath, 2007), automatic: subjects typically "perceive sameness" instead of having to consciously infer it.

Short versus long-term object permanence

The conditions under which human infants, children and adults infer object permanence during short (seconds) visual displays have been intensively studied, primarily using visual occluded-motion paradigms (reviewed by Flombaum, Scholl and Santos, 2008; Fields, 2011). Infants infer trajectory continuity and hence object permanence for a specific range of trajectory shapes and occlusion times beginning at about three months old; by two years old, infants employ essentially the same trajectory-shape and occlusion-time criteria used by adults. Smooth trajectories and relatively short occlusion times robustly indicate object sameness and hence object permanence; apparent "absorption" of an object by an occluder followed by "emission" of a visually-indistinguishable object from the occluder after a long delay or from a position unreachable by a smooth trajectory suggest non-sameness and hence a violation of object permanence. Trajectory-based object permanence is impervious to a wide range of feature changes, e.g. of size, shape or color of the moving object, in both infants and adults.

While philosophical conundrums such as the "Ship of Theseus" have been discussed since the pre-Socractic period, the inference of object permanence over longer periods – tens of seconds to decades – of non-observation has received relatively little direct experimental investigation. On the shorter end of this temporal range (10s of seconds to minutes), numerous studies have demonstrated that infants are surprised, as adults are, by object permanence violations as early as 2.5 months old (reviewed by

Baillargeon, 2008). For example, surprise is elicited when an object is placed behind an opaque screen, which after a short delay is lifted to reveal that the object is no longer there. As the period of non-observation increases, however, experimental manipulations become progressively more difficult and studies tend to be framed in terms of "object recognition" instead of "object permanence." Object recognition in the sense used here requires object permanence; i.e. it requires an inference of continuing object identity. If for any reason object permanence cannot be inferred, the perceived object is "seen" not as the same thing observed before, but rather as novel. Such failures of recognition occur, for example, in severe anterograde amnesia, e.g. Korsakoff syndrome (reviewed by Fama, Pitel and Sullivan, 2012), demonstrating that short-term object permanence may be preserved but long-term object permanence lost. The relative contributions of semantic memory, episodic memory, and causal reasoning to object recognition following moderate to long periods of non-observation (hours to decades) remain to be determined and may vary widely with object type and context (reviewed by Eichenbaum, Yonelinas and Ranganath, 2007; Scholl, 2007; Fields, 2012).

Insight into the difficulty of characterizing object-permanence inferences across longer gaps in observation comes from fundamental computer science. Recognizing complex objects requires mereological (part-whole) reasoning. In most situations, mereological relations cannot be defined precisely; they are only "rough" or heuristic (Düntsch and Gediga, 2000). A low levels of granularity, "parts" become generic and indiscernible, rendering highly-similar assemblages effectively indiscernible. At higher levels of granularity, parts may change their properties over time and hence require part-level judgments of "sameness." In this setting, additional information, e.g. causal or historical information, must be added to track individual object identity. Such information is strictly unavailable during periods of non-observation, so object identity becomes both hypothetical and dependent on the choice of heuristics, e.g. the choice of features or causal constraints to regard as

"essential" for maintaining object identity.

The tools and techniques of developmental robotics (reviewed by Baldassarre and Mirolli, 2013; Cangelosi and Schlesinger, 2015) provide new empirical approaches to object permanence. These range from replicating classic experimental paradigms such as occluded motion using fully-specified visual-processing and inference architectures to investigations of self-motivated environmental exploration, multiple object tracking, sensory-motor coordination and language learning. Such studies make explicit not only the memory resources and inferences needed to establish object permanence but also the role of assumed or inferred object permanence as an enabler of complex cognition and behavior.

Is object permanence innate?

The essential role of object permanence in human cognition has long led to it being considered innate (Baillargeon, 2008). In functional terms, object permanence being innate means that the human neurocognitive system already has the organization needed to express behavioral responses indicating an inference of object permanence at or soon after birth. Recently-developed protocols for functional imaging of neonates, including preterm neonates, allow the functional connectivity of the long-range networks implementing inferences of visual object permanence (e.g. the visuo-motor, categorization and salience networks) to be tracked in parallel with emerging infant abilities (e.g. Ball et al., 2014; Gao et al., 2015).

While systematic pathological disruption of object permanence in infants has not been demonstrated,

considerable evidence indicates that the perceptual processing pathways that implement object permanence are affected in autism spectrum disorders (reviewed by Gomot and Wicker, 2012; Fields and Glazebrook, 2017). Hundreds of genes, many of them known to act prenatally to influence neural growth and connectivity, have been associated with autism (reviewed by Geschwind and Flint, 2015); these potentially provide a molecular avenue for investigating the emergence of object permanence both developmentally and evolutionarily.

A special case: The self

A particular instance of object permanence is crucial for development of a coherent psychology: the experienced self and its associated body. The experienced self is fixed as a reference point for other objects and object-directed actions early in infancy and may be innate (reviewed by Rochat, 2012). How the experienced self is to be defined conceptually, how it is implemented, and how it is updated to track physical and psychological changes remain significant open questions (e.g. Metzinger, 2011; Klein, 2014). Evidence that the default-mode network, which is implicated in representation of the self (reviewed by Buckner, Andrews-Hanna and Schacter, 2008), is already largely functional in early infancy (Gao et al., 2015) may shed light on the development and assignment of permanence to the experienced self.

Object permanence and time

The idea that an object can change its state cannot be formulated without an assumption of object

permanence. Conversely, the idea of object permanence cannot be formulated without a sense of time and hence at least one object – a clock – that changes state. An internal, not necessarily conscious sense of duration sufficient at least to distinguish "now" from "then" is, therefore, required for object permanence. The human implementation of such an internal "clock" is beginning to be mapped out (reviewed by Merchant, Harrington and Meck, 2013; Mathews and Meck, 2014); however, a mechanistic connection between time perception and object permanence has yet to be made.

Phylogenetic distribution and evolutionary history

Food caching, wayfinding, tool construction and use, long-term pair bonding, and negotiated social relations all require recognizing an object or a location as "the same" after a period of non-perception and hence suggest object permanence. Comparative studies of object permanence have, accordingly, focused on birds (many species, reviewed by Güntürkün and Bugnyar, 2016), social carnivores (primarily domestic dogs, reviewed by Zentall and Pattison, 2016), cetaceans (primarily dolphins, e.g. Johnson, Sullivan, Buck, Trexel and Scarpuzzi, 2015), and great apes (all species, e.g. Karg, Schmelz, Call and Tomasello, 2014). The experimental tasks employed typically replicate in a species-appropriate way those used with human infants or children. While both experimental designs (e.g. Jaakkola, 2014) and inferences from small sample sizes (e.g. Thornton and Lukas, 2012) in this literature have been criticized, there is broad consensus that animals exhibiting complex cognition rely on object permanence.

The deep divergence between birds and mammals (approx. 300 million years; Güntürkün and Bugnyar, 2016) indicates either a deep evolutionary origin of object permanence or significant convergent

evolution. The question of whether object recognition and wayfinding abilities in rodents, reptiles, or even social insects can be regarded as evolutionary precursors or rudimentary forms of object permanence therefore bears consideration. Conclusive demonstration of a lack of object permanence, e.g. conclusive demonstration of a systematic inability to recognize "the same individual" after some period of non-observation, in a mammalian system would also be valuable in clarifying the evolutionary history of this capability.

Object permanence and the Social Brain

The Social Brain hypothesis is a pillar of human evolutionary psychology (reviewed by Dunbar and Shultz, 2003; Adolphs, 2009). The complex social relations envisioned as the primary drivers of human cognitive, emotional and behavioral evolution within the Social Brain framework inevitably involve abilities to reliably identify particular individual humans over long periods of time and hence moderate to long periods of non-observation. Such abilities require an inference of continuing existence with individual identity maintenance; hence they require object permanence.

Evolutionary-developmental perspective

Object permanence allows infants and children to exchange fitness-enhancing attachment signals with their mothers, other family members, and non-family caregivers. It can, therefore, be regarded as an ontogenetic adaptation (Bjorklund and Pellegrini, 2002). It continues, however, to enable qualitatively new capabilities across the lifespan, e.g. the ability to regard abstracta such as religions or social

organizations as maintaining their identities over time. As the selective pressures acting on these later-developing abilities may be different from those acting during infancy or childhood, the robust childhood expansion of object permanence capabilities away from family members to “objects” in general may be regarded as a deferred adaptation.

From a mechanistic perspective, the relevant questions are how the mechanisms enabling object permanence in infancy develop pre- and perinatally, how they later expand as the infant and then the child interacts with her environment, and how this extended developmental system evolved within the animal and particularly primate lineage. The direct mechanistic coupling of evolution and development characteristic of “evo-devo” biology (reviewed by Müller, 2007; Carroll, 2008) has yet to be achieved within psychology. The centrality of object permanence to complex cognition, together with its broad phylogenetic distribution, suggest that it is an ideal test case for such an endeavor. A deep understanding of how the pre- and postnatal developmental mechanisms that support object permanence have evolved in both avian and mammalian lineages may provide new insights into the generation of novel cognitive and emotional variants and the selective pressures that act on them over evolutionary time scales.

Conclusion

With every new demonstration of quantum superposition or entanglement at macroscopic scales (e.g. Wiseman, 2015), the likelihood that observation-independent, time-persistent objects can even be defined at the level of fundamental physics decreases. If the objects of humans perception cannot be defined within physics, an understanding of what they are and what it means for them to maintain their

individual identities over time must be developed within psychology. Hoffman, Singh and Prakash (2015) have suggested that "objects" are in fact bundles of organism-specific fitness consequences. If this is the case, object permanence is the inference that fitness consequences that are correlated at one time will remain correlated at subsequent times. Sophisticated neurocognitive mechanisms are required to make such inferences. Developmental robotics, functional neuroimaging of infants and evolutionary developmental psychology provide new conceptual and empirical tools that can be combined with the traditional methods of experimental psychology to identify these mechanisms and to characterize their development and evolution.

Cross-References: Attention And Memory, Autism, Evolutionary Developmental Psychology, Evolutionary Foundations of the Attachment System and Its Functions, Face And Object Recognition, Human Visual Neurobiology, Kin Recognition, Ontogenetic Adaptations

References

Adolphs, R. (2009). The social brain: neural basis for social knowledge. *Annual Review of Psychology*, 60, 693–716.

Baillargeon R (2008). Innate ideas revisited: For a principle of persistence in infants' physical reasoning. *Perspectives in Psychological Science*, 3, 2–13.

Baldassarre, G. and Mirolli, M. (Eds.) (2013). *Intrinsically Motivated Learning in Natural and*

Artificial Systems. Springer, Berlin.

Ball, G., Alijabar, P., Zebari, S., Tusor, N., Arichi, T., Merchant, N., Robinson, E. C., Ogundipe, E., Ruekert, D., Edwards, A. D. and Counsell, S. J. (2014). Rich-club organization of the newborn human brain. *Proceedings of the National Academy of Sciences USA*, 111, 7456–7461.

Bjorklund, D. F. and Pellegrini, A. D. (2002). *The Origins of Human Nature: Evolutionary Developmental Psychology*. American Psychological Association, Washington DC.

Buckner, R. L., Andrews-Hanna, J. R. and Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, 1124, 1–38.

Cangelosi, A. and Schlesinger, M. (2015). *Developmental robotics: From babies to robots*. MIT Press, Cambridge.

Carroll, S. B. (2008). Evo-devo and an expanding evolutionary synthesis: A genetic theory of morphological evolution. *Cell*, 134, 25–36.

Eichenbaum, H., Yonelinas, A. R. and Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience*, 30, 123–152.

Dunbar, R. I. M., and Shultz, S. (2007). Evolution in the social brain. *Science*, 317, 1344–1347.

Düntsch, I. and Gediga, G. (2000). Rough set data analysis. *Encyclopedia of Computer Science and*

Technology, 43, 281–301.

Fama, R., Pitel, A.-L. and Sullivan, E. V. (2012). Anterograde episodic memory in Korsakoff syndrome. *Neuropsychological Review* 22, 93–104.

Fields, C. (2011). Trajectory recognition as the basis for object individuation: A functional model of object file instantiation and object-token encoding. *Frontiers in Psychology: Perception Science*, 2, 49.

Fields, C. (2012). The very same thing: Extending the object token concept to incorporate causal constraints on individual identity. *Advances in Cognitive Psychology*, 8, 234–247.

Fields, C. and Glazebrook, J. F. (2017). Disrupted development and imbalanced function in the global neuronal workspace: A positive-feedback mechanism for the emergence of autism in early infancy. *Cognitive Neurodynamics*, 11, 1–21.

Flombaum, J. I., Scholl, B. J. and Santos, L. R. (2008). Spatiotemporal priority as a fundamental principle of object persistence. In: Hood, B. and Santos, L. (Eds), *The origins of object knowledge*. Oxford University Press, New York, pp 135–164.

Gao, W., Alcauter, S., Smith, J. K., Gilmore, J. H. and Lin, W. (2015). Development of human brain cortical network architecture during infancy. *Brain Structure & Function*, 220, 1173–1186.

Geschwind DH, Flint J (2015) Genetics and genomics of psychiatric disease. *Science* 349:1489–1494.

Gomot, M. and Wicker, B. (2012). A challenging, unpredictable world for people with autism spectrum disorder. *International Journal of Psychophysiology*, 83, 240–247.

Güntürkün, O. and Bugnyar, T. (2016). Cognition without cortex. *Trends in Cognitive Sciences*, 20, 291–303.

Hoffman, D. D., Singh, M. and Prakash, C. (2015). The interface theory of perception. *Psychonomic Bulletin & Review*, 22, 1480–1506.

Jaakkola, K. (2014). Do animals understand invisible displacement? A critical review. *Journal of Comparative Psychology*, 128, 225–239.

Johnson, C. M., Sullivan, J., Buck, C. L., Trexel, J. and Scarpuzzi, M. (2015). Visible and invisible displacement with dynamic visual occlusion in bottlenose dolphins (*Tursiops* spp). *Animal Cognition*, 18, 179–193.

Karg, K., Schmelz, M., Call, J. and Tomasello, M. (2014). All great ape species (*Gorilla gorilla, Pan paniscus, Pan troglodytes, Pongo abelii*) and two-and-a-half-year-old children discriminate appearance from reality. *Journal of Comparative Psychology*, 128, 431–439.

Klein, S. B. (2014). Sameness and the self: Philosophical and psychological considerations. *Frontiers in Psychology: Perception Science*, 5, 29.

Mathews, W. J. and Meck, W. H. (2014). Time perception: The bad news and the good. *Wiley*

Interdisciplinary Reviews, Cognitive Science, 5, 429–446.

Merchant, H., Harrington, D. L. and Meck, W. H. (2013). Neural basis of the perception and estimation of time. *Annual Review of Neuroscience*, 36, 313–336.

Metzinger, T. (2011). The no-self alternative. In Gallagher, S. (Ed.) *The Oxford Handbook of the Self*. Oxford University Press, Oxford, UK, pp. 287–305.

Müller, G. B. (2007). Evo-devo: Extending the evolutionary synthesis. *Nature Reviews Genetics*, 8, 943–949.

Rochat P (2012) Primordial sense of embodied self-unity. In: Slaughter, V. and Brownell, C. A. (Eds.) *Early development of body representations*. Cambridge University Press, Cambridge, UK, pp 3–18.

Scholl, B. J. (2007). Object persistence in philosophy and psychology. *Mind & Language*, 22, 563–591.

Thornton, A. and Lukas, D. (2012). Individual variation in cognitive performance: Developmental and evolutionary perspectives. *Philosophical Transactions of the Royal Society of London*, 367, 2773–2783.

Wiseman, H. (2015). Quantum physics: Death by experiment for local realism. *Nature*, 526, 649–650.

Zentall, J. R. and Pattison, K. F. (2016). Now you see it, now you don't: Object permanence in dogs. *Current Directions in Psychological Science*, 25, 357–362.