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Abstract
Both metaphysics and cognitive science raise the question of what natural concepts or properties are. A link between the two is notoriously hard to establish. I propose to take natural concepts or properties to be those that are revealed in interaction. The concept of affordances is refined and naturalized to spell out how interacting with objects grounds concepts. I will call this account "Ecological Empiricism". I argue that the notion of naturalness within this framework turns out to be a gradable – there are more or less natural properties – and dependent on the perspective taken – metaphysically natural properties are different from cognitive natural properties. From a metaphysical point of view, perfect correlations between actions and sensory input are relevant, which are best approximated by scientific measurement. For cognition, simple or basic actions are relevant. Although metaphysical and cognitive naturalness does not coincide according to Ecological Empiricism, it presents a common framework with a uniform conception of naturalness.

Keywords Affordances · Naturalness · Concepts · Grounded Cognition · Measurement

1 Ontological Naturalness and Epistemic Access

Intuitively, some predicates refer to properties that nature provides by itself, while other predicates seem to refer to properties that are at least partly made up by us. Goodman (1955) provides the classical example "grue", claiming that such predicates/properties[1] are not natural. Whether a property is natural or not is said to have important consequences: Only natural properties are those that are "projectible", according to Goodman, i.e. they can be used in inductive arguments. Lewis (1983,

[1] I take it that properties are natural, and that predicates can be called "natural" iff they refer to natural properties.

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1986) argues that he needs perfectly natural properties for several interrelated problems, among them identifying duplicates (things sharing the same natural properties), identifying laws of nature and identifying causal relations.

However, as the "new riddle of induction" (Goodman, 1955) shows, there are epistemic problems lurking: Whenever we come up with natural predicates, it is notoriously hard to justify that they pick out natural properties. The trouble seems to stem from the fact that all proposed criteria for natural predicates do not relate to the structure of the world in the right way, unless we presuppose a somewhat direct epistemic access to the world. For example, the criterion of logical simplicity is problematic since it only works if the right simple predicates are taken as a basis; however, language is relatively flexible concerning simple predicates, such that the epistemic problem is at best shifted to specifying simple predicates (for example, Lewis, 1986 proposes to define those predicates as simple that refer to perfectly natural properties, which obviously does not solve the epistemic problem; see also Loewer, 1996, p. 109).

Lewis (1983) argues for perfectly natural properties because he needs them to solve several puzzles arising from his metaphysical theory. He seems to be happy to accept perfectly natural properties as unanalyzable metaphysical primitiva: Perfectly natural properties are those that two perfect duplicates share. Since duplicates should stay duplicates independently of changes in their surroundings, Lewis argues that all perfectly natural properties are intrinsic properties.

Gärdenfors (2014) approaches the problem by providing criteria for cognitive naturalness that specify which concepts are natural for a cognitive system. These criteria involve geometric features (convexity) and principles of cognitive economy and efficiency. However, these criteria do not directly link to the structure of the world. According to Gärdenfors (2000, p. 82), this missing link might be provided by evolution: The evolutionary adaptation of our cognition has shaped our conceptual systems such that they match the structure of the world. While this might be plausible at first sight, already quite simple cases give rise to doubts. Take for example the case of color vision: Our color concepts do not pick out certain wavelengths, but rather much more complicated patterns that not only reflect worldly structures but also structural features of our sense organs and cognitive processing. This is obvious in the case of context effects: a patch of one and the same color (i.e. emitting light with one and the same wavelength) is perceived as differing in color when presented in different color contexts (Long & Purves, 2003). This means that perceived color is not projectible in Goodman's sense: If the strawberry appears red now, it does not follow that it will also appear red in other contexts / under different conditions.[2] Thus, our color concepts formed by evolution do not seem to successfully capture properties that would qualify as natural in the metaphysical sense.[3]

[2] For this reason, either the green/grue example of Goodman is not a very good example to start with or Goodman does not refer to the color concepts of our perceptual experiences, but to some "scientificized" version.

[3] This is not to say that there are no evolutionary explanations of why we perceive colors as we do (although this is also debated). The point is that color perception is quite far from tracking the basic structure of the world. For example, Land & McCann's (1971) retinex theory proposes that relations

The underlying problem is long known and discussed: On the one hand, if nature determines natural properties, there is no guarantee that we are able to epistemically access them.[4] On the other hand, if natural properties are determined by our mind (or our perceptual make-up), there is no guarantee that naturalness relates to the structures of the world at all. I take Kant's dictum "Gedanken ohne Inhalt sind leer, Anschauungen ohne Begriffe sind blind" (Kant, 1787, B75) to reflect this basic problem as well as the riddle of induction by Hume (1977): Since we do not have direct access to the structures of the world, there is always a gap between ontologically natural and cognitively natural properties.

This way of posing the problem presupposes that there is a clear distinction between "the world" and "the mind". While this distinction is very plausible on first sight, monist conceptions ultimately speak against such a strict distinction. Whether we believe that mental properties can be reduced to physical properties or that they supervene on the latter, "the mind" in such pictures is conceived of as part of "the world". My proposal to approach the problem is thus to take this picture seriously by focusing on the structure that contains both "the world" and "the mind".[5] More precisely, the proposal is to talk about those properties that are revealed to us by interacting with the world. Such properties can be said to be natural, since they reflect both the nature of the objects around us and the nature of our sense apparatus and our mind.

According to this view, there are two types of non-natural properties: Firstly those that are not revealed to us at all, and secondly those that are made up by us without relating to the structure of objects at all. The second class of properties is also ruled out by Goodman and Lewis; the first class contains properties that might be part of the structure of the world, but which are necessarily hidden to us in the sense that we cannot have any empirical access to them. They can only be inferred by means of inferences to the best explanation, which is the case for intrinsic properties, for example. As argued for by structural realists (Ladyman, 2023), it is doubtful how much they contribute to our explanations and thus how good our justification is for conceiving of them as ontologically real.

Because the account is based on the idea that natural properties are somewhat directly revealed to us, it has some resemblance to the logical empiricist ideas of the Wiener Kreis (Creath, 2022). However, it is not based on the idea that we passively pick up sense data which function as truth makers for protocol sentences (Carnap,

Footnote 3 (continued)
between colors are tracked; however, these relations are not part of the basic (i.e. "natural") structure of the world, they are derived. Moreover, the theory cannot explain all effects of color vision (cf. Palmer 1999, especially p. 978; for a general overview on the complexity of color perception, see Gegenfurtner & Kiper 2003).

[4] Attempts to overcome this problem might be found in scientific realism, which is itself notoriously hard to defend against skeptic arguments.

[5] I do not wish to argue for anti-realism in the sense Putnam (1981), for example, did. I am ready to accept that there are mind-independent things in the world. However, minds are as much part of reality as mind-independent things are. Our epistemic access to such mind-independent things is possible exactly because our minds are part of the same reality. However, as I will argue for later, our access to the mind-independent things is of course not mind-independent and thus our conception of these things is neither.

1928; Schlick, 1934).[6] It is rather based on the idea that interaction with objects is the basis of our access to properties, which is an idea put forward in ecological psychology. For this reason, I will call my account "Ecological Empiricism".

I will develop Ecological Empiricism in four steps: First, I will critically discuss the notion of affordances as introduced by J.J. Gibson (Gibson, 1979; Gibson & Pick, 2000). Affordances are claimed to be properties of objects that they have in relation to our actions. However, this notion has some severe problems and does not fit into a monistic world view that excludes non-reducible intentions. For this reason, I will, second, present a naturalized account of affordances that is able to maintain its explanatory virtues without the ballast of direct perception and non-reducible intentions. Third, I will discuss different sources of correlations that form the basis of learning affordances. This will allow for a systematic distinction between different kinds of affordances and thus different kinds of natural properties. Forth, I will sharpen the resulting notion of naturalness and point out its relation to other accounts, in particular its ability to account for the kind of naturalness that metaphysicians look for.

2 Affordances: Properties Based on Interaction

J.J. Gibson was impressed by the ability of babies and toddlers to interact with their surroundings: Only by visual information, they are able to know, for example, whether an object affords crawling over it or not (as demonstrated, for example, in the 'visual cliff' experiments by Walk & Gibson, 1961). The classical cognitive explanation would require the children to go through a syllogism similar to "object x has the property of supporting weights smaller than y; I have a weight smaller than y; therefore, object x supports me crawling". This explanation is, according to Gibson, cognitively and conceptually way too demanding to be plausible in the case of little children. His alternative idea was that children could directly perceive the property of being crawl-on-able, so that perception alone would suffice to elicit the action without the necessity to work through demanding syllogisms (Gibson, 1979).

He called such properties "affordances" and claimed them to be relational properties, ascribed to objects by subjects, that emerge from the interaction between organisms and objects. Moreover, he insisted that they are objective properties directly perceivable. There are several deep problems with this notion (Tillas et al., 2017): It remains unclear, what it could mean for a property that is partly constituted by the interaction between a subject and an object to be (purely) objective. One strand of interpretation tries to reduce affordances to physical properties of both the object and the subject (e.g. Scarantino, 2003; Turvey, 1992); such reductionist accounts lead to very complex physical properties, and it is not at all clear that they can fulfill the explanatory role of affordances any better than rather simple physical properties like being solid (Tillas et al., 2017). Another strand of interpretation puts a lot

[6] Schlick also refers to the procedures we have to undertake to make a certain observation. However, his examples of the "Konstatierungen" involve expressions of direct passive perception only.

of weight on the intentions for the according actions, which is then interpreted in a non-personal, non-subjective way (e.g. Heft, 1989; Stoffregen, 2003); such accounts introduce strange entities that do not find any place in a naturalized metaphysics (Tillas et al., 2017).

Another troublesome feature of Gibsonian affordances is that they are directly perceivable. While it is unclear what "direct perception" is meant to refer to, it seems to imply that we cannot be wrong about them. One simple criterion for direct perception of a property is that the following counter-factual holds: If the property was not present, *ceteris paribus*, it would not have been perceived (van Riel, 2008). Clearly, this condition is not fulfilled by Gibsonian affordances: A paper chair looking like a wooden chair would, even under favorable conditions, still be seen as sit-on-able although it could not support the perceiver's weight. Affordances are thus not directly perceivable, at least not in the way Gibson claimed.

This very short discussion yields three desiderata for a naturalized account of affordances:

1) They should not be interpreted as complex physical properties, in order to save their explanatory role. This means that actions have to play a constitutive role for affordances.
2) They should not rely on metaphysically demanding concepts like impersonal and/or objective intentions.
3) Our ability to perceive them should be plausibly explained without unrealistic epistemological consequences.

3 A Naturalized Account of Affordances

To meet the second desideratum for a naturalized account of affordances,[7] intentions should not be taken for granted unless an independent naturalized account of intentions is available. Instead of developing such an independent account, I will start with unintentional movements as the basis for – what I call – basic affordances, which then function as the basis for intentions. Babies show a wealth of unintentional movements long before birth and after birth. These movements can be registered by the baby, either by registering the (unintentional) motor commands issued or the kinesthetic feedback from tendons and muscles. Moreover, such movements will systematically elicit certain sensations, for example the sensation of touching something via the pressure sensors in the skin. Following the idea of sensorimotor contingencies (Noë, 2005; O'Regan & Noë, 2001a, 2001b), the baby is thus able to register systematic covariations between the own (unintentional) movements and sensory feedback and thus to learn to "master" these sensorimotor contingencies.[8]

[7] This account was developed in Tillas et al. (2017) in some detail. Here, I will introduce the account with special focus on the metaphysical considerations pertinent to naturalness.

[8] In fact, systematic covariation plays an important role in different accounts of perceptual learning, and I take my account of affordances to be in line with most of them, among them Billman and Heit (1988), Hommel et al. (2001), Hohwy (2013).

They thereby learn basic affordances like being touchable, being bump-into-able, being soft, being supportive etc.

Basic affordances are basic in the sense that they are the basis for learning further complex affordances. They are also basic in the sense that they are non-conceptual and do not presuppose intentions. I take concepts to be mental entities that represent properties and that can thus be combined with object representations to form mental representations with predicating content (thoughts).[9] Basic affordances, however, cannot be used to represent a specific property of an object; rather, they represent states of the mover. In this sense, they might be called "subjective", although they also include information about external objects. Yet, this information is only implicitly contained and not reflected in the structure of the basic affordance. For this reason, basic affordances are neither conceptual nor concepts.

Basic affordances do not presuppose intentions, because they are learned on the basis of unintentional movements alone. At the same time, they build the basis for intentions/intentional movements: The mastery of the systematic contingencies allows the baby to purposefully elicit a certain sensation again. In other words: she can intentionally bring a sensation about by performing a certain movement. The only additional mental faculty that is presupposed for such (simple and basic) intentional movements is some sort of desire with a content like "I want to have that sensation" (for example, the experience of touching the teddy bear). A similar grounding of intentional movements is also possible on higher levels of affordances; for example, the intention to walk is based on the ability to walk, which in turn involves the mastery of the complex sensorimotor contingencies of walking.[10] So my claim is that intentional movements in general are grounded in affordances, ultimately in basic affordances.

After having acquired the most basic affordances, the child can discover new systematic contingencies between these basic affordances and directly visible features of the objects (see also Fig. 1). In this way, the child will learn what it means for an object to look touchable or soft. Moreover, the child can start to skillfully explore the world around her by performing intentional actions (also based on basic affordances) to gather more systematic contingencies between directly visible features and basic affordances. The result of this learning process[11] is the formation of complex affordances relating visual information to (possible) actions. The child learns to detect indirectly visible features, for example features like looking soft or looking supportive.

[9] This is based on the idea that the generality constraint (Evans, 1982) is a minimum requirement to be met by conceptual representations. For more details see (Vosgerau, 2009, 2011; Vosgerau & Synofzik, 2010).

[10] An illustrative example for what this mastery involves is the case of Ian Waterman, who – after the loss of his proprioceptive senses from the neck downwards – had to learn to walk anew (Cole, 2016).

[11] Several very different learning models have been proposed that could explain how such unsupervised learning of covariances might take place, among them the rule-based "focused sampling" by Billman and Heit (1988) and the neural-network-based Bayesian learning mechanism proposed in Predictive Coding (Hohwy, 2013).

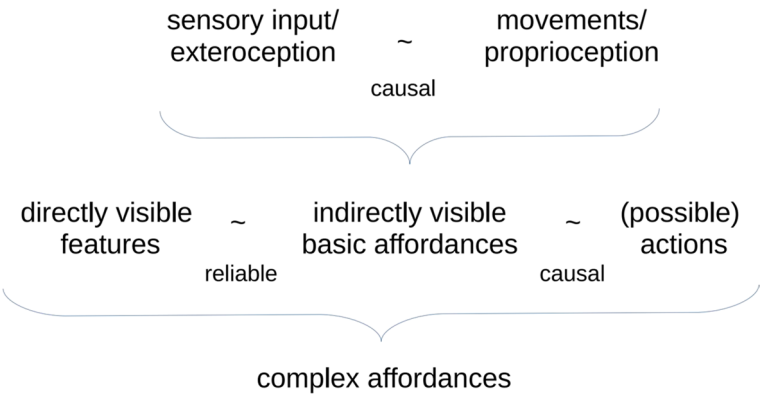

Fig. 1 Basic and Complex Affordances

The step from basic to complex affordances involves two major shifts: 1) a shift towards visual input and 2) a shift towards intentional movements (= actions). This implies a third shift, namely the shift from direct perceivability to indirect perceivability. Complex affordances are thus close to Gibson's conception in that they relate visual input to actions. The main problems of Gibson's conception, however, are avoided by basing complex affordances on basic ones; in this way, intentional movements are not presupposed – they can be explained on the basis of basic affordances. Moreover, problems with direct perceivability can be scrutinized and resolved; the basis of the learning process does indeed involve directly perceivable features, not only in the visual but also in all other modalities. Nevertheless, complex affordances, although partly based on directly visible features, turn out not to be directly perceivable, which meets the third of the desiderata above – after all, not all things that look soft (complex affordance) are soft when touched (basic affordance).

The first desideratum requires that affordances be not reduced to complex physical properties. This is the case since the own movements of the child are constitutive for affordances. Therefore, it is not the case that the child first learns a physical, quasi-objective description or conception of her own movements, which could then be combined with equally physical descriptions of the stimuli. Rather, the immediate uptake of the own movements forms the basis for exploring the surroundings. Likewise, the understanding of the physical features of objects arises on the basis of this immediate uptake of the own movements and on direct perception, i.e. on (basic) experiences. Those experiences are akin to basic experiences or sense data of Logical Empiricism (Carnap, 1928; Schlick, 1934; Creath, 2022). The decisive difference to Logical Empiricism is that the sense data in my account are not taken to be "meaningful" by themselves, i.e. perception is not taken to be a passive information collector. The sense data only become "meaningful" to the child by exploring the systematic contingencies between these sense data and the own movements, i.e. the interaction with the world. Because of this "ecological" feature of my account, I will call it "Ecological Empiricism".

Because affordances are based on own movements and experiences, they are in some sense subjective or at least not fully objective. With further cognitive development, the child can abstract away from the subjective parts, whereas abstraction means to ignore these parts (Vosgerau & Synofzik, 2010; Vosgerau et al., 2015). They will not completely vanish; rather, the cognitive system will treat such representations as if they were representing properties of objects and nothing more. With this abstraction step, a conceptual level is reached (Vosgerau, 2009, 2011); the cognitive system has now mental representations that stand for properties of objects and can be attributed to objects, i.e. concepts. For example, the basic affordance of being-bump-into-able turns into the concept of being solid, when the child abstracts the movement components of the affordance and applies it to objects.[12] Likewise, the complex affordance of being-walk-on-able turns into the concept of a path,[13] and the affordance of being sit-on-able into the concept of a seating.

I cannot develop a full account of the proposed abstraction mechanism here but only hint at some ideas. To abstract away from parts of the information means not to use this part in further processing. A promising approach to spell this out is the Predicitve Coding Theory (Friston, 2005; Hohwy, 2013): By using hierarchical Bayesian networks, the incoming information is predicted. The prediction is compared to the input and only the differences (i.e. the information that was not predicted) is further processed. In my picture this would mean that the child learns to predict the input on the basis of its own movements ("master the sensorimotor contingencies"). Both the experience of the movement and the predicted changes in input are then attenuated and not further processed, such that the remaining information is taken to be about objects (in predictive coding terms: a hidden cause of the sensory stimulation is hypothesized).

As far as I can see, this account differs from invariance accounts. Gärdenfors (2019, 2020) presents an empiricist version of how "core knowledge domains" – as introduced by Spelke (2000) – are learned. Scrutinizing the notion of "invariances" (Gibson, 1979), his claim is that certain features in the environment are invariant, for example places (they stay the same independently of changing the objects at that location). Such invariances can be detected by the child, such that core knowledge about objects, for example, can be acquired. My account, however, sets in one step before this: Regarding the visual input, invariances are rare (if there are any). For example, the visual input on the retina changes when moving the eyes, both in terms of the color information and in terms of the geometrical shapes (cf. O'Regan & Noë, 2001a). Thus, seeing one uniform color ("color constancy") has to be learned;

[12] As a reviewer pointed out, this is an example of a property applying to so called "Spelke objects", that is a notion of objects that children form very early in life. As will become apparent in the next paragraphs, I think my account can be understood as an extension of Spelke's account for even earlier stages in live, providing an empiricist basis to her nativist picture. This empiricist base goes even beyond the base proposed by Gärdenfors (2019, 2020).

[13] Of course, there is more to the full blown concept of a path than being walk-on-able. However, by abstraction the nucleus of the concepts is available that can be enriched by further information later. If you find it more appropriate, you could also call this nucleus a concept of being solid ground or something like this.

equally, seeing something as a rectangle has to be learned, since the projection on the retina will never be a rectangle (because the retina is curved) and will change with every eye movement. Instead of invariances, we find systematic covariances between movements and sensory input. These covariances can be learned, and by way of abstraction, invariances can be "computed" or – in the terminology of predictive coding – be hypothesized as the hidden causes of the sensory input. In this sense, invariant features of objects are already abstracted representations based on basic affordances, essentially (but implicitly) containing information about the own movements.[14]

Although the concepts that are directly based on affordances abstract away from the movement components, they still contain them. It is hence fair to say that these concepts are still relational concepts that link properties of the objects to actions of the cognizer. This is to say that even if we conceptualize something as a seating, the sit-on-ability in the sense of the affordance will still be present. Thus, those concepts have a direct connection to the own (possible) actions, such that the explanatory value of affordances can be secured, even in the case of conceptual representations. The conceptualization of something as a seating contains the information that I can sit on this thing, and thus I don't need to run through practical syllogisms to perform the according action and sit down on this thing.

Probably, language plays a big role in the abstraction process that leads to objective concepts, i.e. concepts that are expressed in language and that we do not recognize as being relational anymore ("objective" here is used in a double sense: concepts are objective firstly in the sense that they apply to objects and secondly in the sense that the can be shared between subjects). Presumably, the actions and experiences underlying these concepts are so similar across human individuals that we can easily abstract away from them and make linguistic communication (and maybe thinking) much more efficient (Berio, 2021; Tillas, 2014). However, this point has to remain pure speculation in this paper. If right, it could explain why we often oversee the "subjective" parts and the relational nature of our concepts, both in everyday conversation and probably even more so in philosophical theorizing.

So far, we have discussed complex affordances involving relatively simple actions like sitting or walking. Of course, actions (and intentions) become more complex themselves when the child grows up. Accordingly, more and more complex affordances are learned. For example, the affordance of being-write-on-able presupposes a lot of skills, other affordances and probably also concepts. The basic idea, though, stays the same: there are systematic contingencies between a certain action (writing on things) and our perception (reading what we wrote) that are the basis for learning such affordances. In this way, whenever there is some kind of systematic contingency or correlation between actions and perceivable outcomes, an affordance can

[14] The same point applies, as far as I can see, to Kornblith's (1995) stable property clusters that are taken to be invariant and so to provide a basis for our understanding of the world. In fact, the epistemic problem cited in the introduction of this paper remains for all mind-independent properties, independently of whether they are metaphysically primitive, stable property clusters or invariances. The only chance to avoid the epistemological problem is – in my view – to add the active component of interaction to the picture.

be learned. This is even true for correlations that only exist because of conventions, as for example the affordance of posting letters of letter boxes (having a certain form and color, depending on the country you are in), the affordance of clicking on links (e.g. words that are displayed in blue and underlined), or the affordance of using a fish knife for the fish and not for the butter. In fact, the sources of such correlations are so manifold that I will devote the next section to their discussion.

4 Sources of Correlations

Affordances are based on correlations (or systematic contingencies) between (intentional or unintentional) movements and sensory input. From a metaphysical point of view, these correlations stem from different sources, so different kinds of affordances can be distinguished on the basis of the respective source of correlation they are based on.

Basic affordances exploit systematic contingencies between unintentional movements / proprioception and sensory input / exteroception. I assume these correlations to stem from causal processes, for example the movement of the arm against the wall causing the pressure sensation in the hand.

Complex affordances arise on the basis of systematic contingencies between directly visible features and actions, mediated by basic affordances. The correlation between basic affordances (e.g. being hard or bump-into-able, respectively) and the possible action is still causal, since it is basically the same as for basic affordances: My moving the arm and hitting the wall causes the pressure sensation in my fist. However, the correlation between directly visible features (or features directly perceivable through other sense modalities) and the basic affordances can vary greatly. For most cases, they are not "strict" correlations but merely reliable ones. For example, a chair might look solid while it is not; still, most chairs looking solid are indeed solid and sit-on-able. For this reason, complex affordances are not directly visible (as discussed above).

I will not attempt to provide a full list of sources of correlation but only point out some important ones. One source might be – at least from a metaphysical perspective – purely contingent. For example, insects with a yellow-black pattern are often poisonous. Obviously, this correlation is actually quite weak because of cases of mimicry. Still, we can learn the according affordance of looking poisonous (or harmful) on the basis of this contingent correlation (and the fact that we and other animals do is the reason for the success of mimicry). Another source has been hinted at above: social conventions. Our society creates a lot of correlations between visible features and sometimes quite complex actions, as it is the case for post boxes and hyperlinks, pictograms and maybe most sorts of non-linguistic signs.[15]

[15] One might wonder if even linguistic signs could be explained on the basis of affordances. However, I am convinced that due to the symbolic character of linguistic signs, there is much more to be learned than a correlation between a sound and a possible action.

Even on the level of complex affordances, causal relations might underlie the correlations between directly perceivable features and actions. The glowing of a piece of metal, for example, is caused by its high temperature, which in turn causes a burning sensation when being touched. Thus, the affordance of looking hot is ultimately based on causal relations. However, such causal relations are not exclusive in the sense that there are more ways to make a material glowing than heating it up. For this reason, such causal relations do not provide strict correlations but only reliable ones.

In some cases, we might even find exclusive causal relations. One example might be the height of the mercury placed in the oven: there seems to be no other possibility to get the mercury to this height than heating up the oven (at least not without destroying the thermometer). If this is true, there might be a strict correlation between the height of the mercury and certain possible actions involving the oven, for example baking bread. I will come back to this example later.

A short side note seems to be in order: The possible actions on which affordances are based can become more abstract and more unspecific as well. This is already true for movements: we started with simple movements like moving the arm, but we soon reached a level of more complex movements like walking. Moreover, the possible actions can become more abstract in the sense that they are less and less tied to specific movement patterns. For example, baking bread involves a lot of different movements and can be realized by very different sets of movements. One might even wish to extend the notion of action to activities that do not involve any corporeal movement, like cognitive actions (thinking, learning, investigating or gaining knowledge). Since I am not concerned here with theories of action, I will not pursue this issue further; however, my account of affordances is open to such non-corporeal actions in principle. If the idea of enactivism is on the right track, such activities should be explainable by corporeal action in the end, anyway. However, I will treat such intellectual activities as actions in the following, if only for illustrative purposes.

The last source of correlation I want to mention is a mathematical or numerical source. The idea is that certain numerical relations can be detected, for example that a rod is twice as long as another rod, which might afford using it in a certain construction. A simpler example is the detection that some object is less wide than the door, which affords carrying the object through the door. There have been many debates about the metaphysical status of such numerical relations (Michell, 2021), which I do not plan to comment on. However, it seems to be clear that such relations are or are based on metaphysically quite primitive features, such that the correlations arising from them are probably among the most perfect ones we can find in nature.

5 Naturalness and Metaphysically Interesting Naturalness

I started with the hypothesis that natural properties are those properties that are revealed to us by interacting with the world. My naturalized account of affordances was intended to elaborate on the interaction with the world part. I will now discuss the notion of naturalness that arises from this conception of action-based concepts.

In a first approach, all properties that are captured by an (objectified) affordance can be said to be natural, since they are revealed in interaction. However, this would mean to broaden the notion of naturalness in an undesirable way. In the end, the (metaphysical) idea of naturalness as referring to some kind of mind-independence should not be abandoned altogether. At the same time, a sharp distinction between mind-independent properties and mind-dependent ones is impossible, because according to my account, all (relevant) concepts involve some "mind" part.

A distinction between different kinds of affordances can be made according to the source of correlation they are based on. I will exploit the intuition that the stricter a correlation is, the less mind-dependent it is, or, to put it in other words: the more it reflects the basic structure of the world (while the mind is still part of it). If we apply this idea to the notion of naturalness, the notion becomes gradable[16]: There are more or less natural concepts, depending on how reliable the correlation is they are based on. Insofar as there might be perfectly reliable correlations, there might also be perfectly natural properties. However, most properties will be more or less natural.

Apply this to the examples discussed above: being hard (an objectified basic affordance) is more natural than looking solid (an objectified complex affordance), since the first one is based on causal and very reliable correlations, while the latter is based on much less reliable correlations. Likewise, the property of being an instrument for piercing is more natural than the property of being a fork, because the correlation between the makeup of the instrument and its piercing ability is grounded in physical, and thus reliable facts, while the property of being used as a fork is at least partly based on social conventions, which are much less reliable.

The classical example for a non-natural property is being grue: being green at a time t_1 and blue at another time in the future t_2 (Goodman, 1955). According to my proposal, this property is not natural simply because it is not revealed to us in interaction with the world; more precisely: there is no correlation between this property and possible actions. The reason is that the property is construed in such a way that it is completely independent from our way of interacting with grue things. However, if we construe a different, structurally similar property that does involve our way of interacting, it turns out a natural property. Take, for example, the property of being green when looked at from angle α and blue when looked at from angle β. This property is natural because it is revealed to us in interaction: we can explore the correlation by walking around the object or by turning it in our hands. This property (or a very similar one involving even more colors and maybe the angle between the light source and the perceiver) is called "nacreous" or "shimmering" in English.

Are there perfectly natural properties? The answer to this question depends on whether there are perfect correlations. Our intuition seems to be that what I called exclusive causal relations and numerical relations are the best candidates for providing perfect correlations. We develop methods (i.e. ways of acting) to reveal such correlations, and we call that measurement. According to the classical Representational Theory of Measurement (Tal, 2020, 2021), measurement is the mapping of

[16] Naturalness turns out to be a gradable notion also in the account of Douven & Gärdenfors (2020), for example, where different principles determine naturalness at the same time.

directly perceivable features onto numbers, while the directly perceivable features are taken to reflect the measured property. Take, for example, the mercury thermometer: An object's property of having a certain temperature is transformed into a directly perceivable feature of the mercury column, namely its height. The height in turn is mapped onto numbers by the scale. The measurement outcome is the ascription of a certain temperature to the object. Measurement can thus be understood as a complex action – namely setting up the measurement instrument in the right way – that is aimed to produce systematic correlations between an object's properties and directly perceivable features, which are then mapped onto numbers. It can thus be understood to produce affordances that could be expressed as "being able to yield a certain outcome when measured". Of course, this affordance is often fully objectified, giving us the impression that there is a direct uptake of information about the world, or to put it in Galileo Galilei's words: "this grand book, the universe, […]is written in the language of mathematics" (Galilei, 1957, p. 237f). However, this point has been discussed and criticized (Mari et al., 2017; Teller, 2018).

The objectification of measured properties also gives us the possibility to connect different affordances. Measuring a certain temperature can be described as an epistemic action of gaining knowledge. Once we have the knowledge, we can establish further affordances. Take the above example: If the oven's temperature reached a certain point, it is ready for baking bread. In this sense, we can construct the affordance that is based on the correlation between the height of the mercury and the action of baking bread. However, I think it is plausible to assume a more complicated structure, involving abstractions of both the sensory input side and the action side: Based on affordances, we learn the concept of heat, for example by touching things and getting burned. With the increasing complexity of our actions, we discover that heat affords quite different actions. In this way, our concept of heat gets more and more abstract in the sense that we abstract away from the specific actions and sensory inputs we started with. The most abstract "action" is the epistemic action of gaining knowledge. In this sense, a measurable property is a property that affords being known (or that is knowable). Because of our conceptual apparatus, we can then use the knowledge to explore further actions we can perform. So, the idea here is not that all of our actions are based on non-inferential perceptual processes involving affordances; the idea is that affordances are the basis for the conceptual, inferential processes.[17]

Let us come back to the question whether there are perfectly natural properties. Measurement processes involve two correlations: the mapping from the measured property to a directly perceivable property, and the mapping from the directly visible property to numbers. At first sight, it seems that the first correlation is based on causal processes, like in the case of the mercury column. However, these processes are not exclusive causal, since there are a lot of other factors that come into play. For example, the material of the thermometer holding the mercury is one such factor,

[17] When an action is often performed, it will be "automatized" (Bargh & Chartrand, 1999). Within Ecological Empiricism, this could be described as learning a new affordance on the basis of correlations that we bring about by applying our conceptual, inferential apparatus to perform the relevant action.

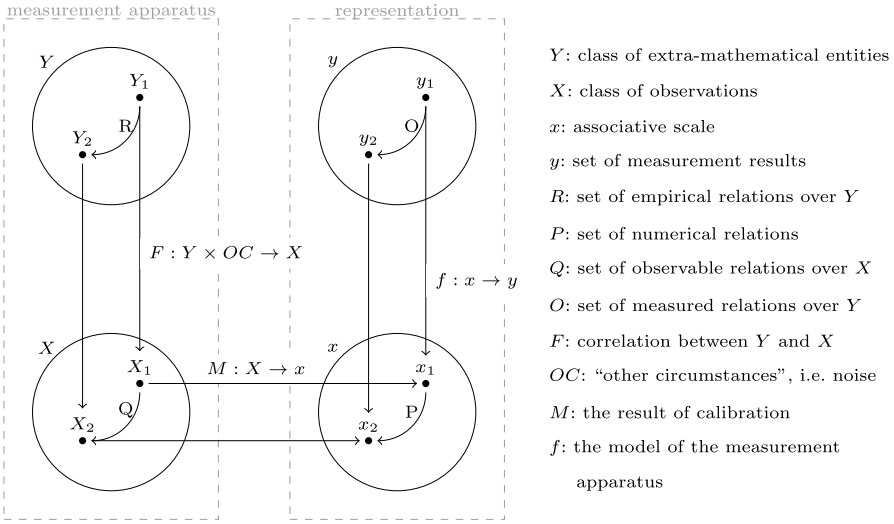

Fig. 2 Measurement according to Boumans (2005)

since it will expand with temperature itself. There has been a long debate about the best design of thermometers around such questions (Chang, 2004, pp. 76–84). For this reason, causal models of the measurement apparatus are created that help to estimate possible distortions in the mapping of the measured property onto the directly perceivable property. The Representational Theory of Measurement has been criticized to overlook this fact (Frigerio et al., 2010), and an extension has been proposed under the label "Model-based Accounts of Measurement" (Boumans, 2015). In Fig. 2, the left side represents the measurement apparatus that maps the measured properties *Y* to directly perceivable properties *X*, which is expressed by the function *F*. The "observations", i.e. the directly perceivable properties, are then mapped onto numbers by the function *M*, which is the result of calibration. Since *F* involves "other circumstances", for example distortions from other factors playing a causal role, we formulate a model of the measurement apparatus *f*. Instead of taking the outcome of *M*, namely the numbers *x* assigned to the observations, at face value, we try to estimate the distorting factors that might have had an impact and compute the magnitudes of the measured properties by applying *f* to the numbers. The result takes the form "the measured property has the magnitude $x \pm \varepsilon$ with probability p" and is called "the measurement outcome" (JCGM, 2012: 2.9; Tal, 2013, p. 1165).

The second correlation, namely the mapping from observations to numbers, is a strong candidate for a perfect correlation. However, the mapping requires quite fundamental assumptions, as explicated in detail by the Representational Theory of Measurement (Krantz et al., 1971; Luce et al., 1990; Suppes et al., 1989). In short, the relations *R* between the measured properties have to be homomorphic to their numerical representation *P*. Unfortunately, it is impossible to test this requirement independently of the measurement procedure; thus, the claim that there is a such a prefect mapping has the status of a theoretical assumption rather than an observation

(Tal, 2017, 2021); it is a presupposition for measurement, not its outcome. This means that the question of how reliable the mapping is, cannot be answered empirically. Of course, the development of measurement apparatuses is like a hermeneutic circle; incoherent results inspire improvements of the apparatus, such that the results get more and more coherent. In the end, however, the justification for taking measurement results as reflecting (only) properties of objects is an inference to the best explanation (a very strong one indeed), but not itself given or observed.

I am discussing measurement in this detail to stress two points: First, measurement, like perception, is not the passive intake of information, but rather a complex activity that reveals properties otherwise hidden. The revealed properties are essentially relational properties with the measurement activity as one relatum and the object as the other. Like in perception, we often abstract away from this relational structure by ignoring the action part. However, this is only possible on the basis of a lot of assumptions and theorizing (creating the model). I am not suggesting that this fact makes measurement dubious or uninformative. I am just emphasizing that the world doesn't provide information by itself so that we can read it off. Rather, only by interacting with the world, properties are revealed and those properties are essentially relational, i.e. dependent on our way of interacting with the world.

Second, there is no empirical "proof" that the correlations exploited by measurement are perfect correlations. However, the whole activity of measuring including calibration procedures and the refinement of models aims at establishing perfect correlations. At least for the numeric correlations, a perfect correlation is assumed. In the end of the complex development of measurement apparatuses and procedures, a kind of inference to the best explanation based on the coherence of measurement results and models gives us very good reasons to believe that scientific measurement comes as close to perfect correlations as we can get. In other words: scientific measurement is our best means to explore the structure of the world around us. However, it is still based on interaction with the world and establishes relational properties that can be analyzed as (very complex) objectified affordances.

Since metaphysics is mostly interested in the mind-independent structure of the world, affordances based on perfect correlations are the most interesting ones from a metaphysical point of view. Thus, measurable properties are the most natural properties for metaphysics, and within the measurable properties those are most natural, for which the coherence of measurement and models is the greatest. Presumably, this is probably the case for at least the basic properties of physics, which fits the intuition of (different sorts of) physicalism.

According to my account, however, there might also be non-measurable and thus non-natural properties, namely intrinsic properties. Since intrinsic properties are not relational and thus independent from interaction, they cannot be conveyed by specific forms of interaction. This consequence matches the intuitions of "Ramseyan Humility" (Lewis, 2009) and the basic idea of structural realism (Ladyman, 1998).[18]

[18] Of course, there is much debate about these pictures, especially about the status of intrinsic properties. One might argue, for example, that intrinsic properties can also be established on the ground of inferences to the best explanation. I am personally very skeptical about this line of thought, but I am not going to take part in the discussion in this paper. As far as I can see, my account would have to claim that

In this point, my proposal seems to depart from Lewis's (1983, 1986) conception of perfectly natural properties which he argues to be intrinsic. He does so because he needs perfectly natural properties to define duplicates, i.e. objects that are perfectly similar. In my picture, perfectly natural properties are not intrinsic – they are based on our interaction with these objects. Thus, the notion of duplicates that would arise from my account is no longer the notion of an objective, mind-independent duplicate, i.e. two objects that are indiscernible *per se*; it is rather the notion of two objects that are indiscernible *for us*. I believe that this is a desired consequence of a view that tries to take our minds as part of the world we seek to describe (metaphysically). Accordingly, if we take my notion of a perfectly natural property and import it into Lewis's theory, we will end up with objects indiscernible for us, with causal relations and laws of nature detectable by us. I'm not sure if this is a good metaphor: We put ourselves into the Humean mosaic as producers of regularities through our interaction with the mosaic.

From a cognitive point of view, however, the mind-independent structure of the world is not the main concern. Rather, the question is which properties our cognitive apparatus is set up to detect and to take as a basis for further cognition. From this point of view, the most interesting properties are probably those that are based on very reliable correlations and simple/basic movements. For example, being hard seems to be a very natural property from a cognitive point of view, while this property might be further analyzed from a (meta)physical point of view.[19] Further constraints of the sensory and cognitive apparatus might be specified, especially when it comes to ojectifying or conceptualizing affordances (i.e. abstracting away from the movement-parts to treat them as concepts). I take Gärdenfors' (2014) approach to be mainly concerned with such constraints, spelling out processes that lead to full blown conceptual structures in detail.

According to Ecological Epmiricism, naturalness is thus not only gradable, but also dependent on the perspective taken. What counts as a natural property is also dependent on whether you are interested in metaphysics or in cognition. I take this to be a virtue of my account, since it presents a common framework for metaphysical and cognitive naturalness, which are very hard to relate otherwise. The commonality between the two is that both are grounded in our interaction with the world. They differ in the kinds of interactions that are rated most relevant: while for the cognitive account, simple or basic interactions are taken to be relevant, highly complex interactions that are designed to provide perfect correlations (scientific measurement) are most relevant from a metaphysical perspective.

Footnote 18 (continued)
intrinsic properties are never natural properties (they are not revealed in interaction), even if there would be very good reasons to assume them as part of the basic structure of the world.

[19] Color concepts might also be a very good candidate for cognitively natural concepts, although they are not good candidates for metaphysically natural properties.

6 Conclusion

Ecological Empiricism is based on the idea that properties of objects are only revealed to us in interaction. Interacting with objects gives us the possibility to learn systematic correlations between actions and sensory input, which are the basis of learning affordances. Abstraction turns affordances into concepts that are still inherently (though not explicitly) relational, since they contain not only information about the objects but also about the perceiver. Still, these concepts are natural in that they reflect our best epistemic access to the world. Naturalness, so conceived, is gradable: concepts can be more or less natural, depending on how strong the correlations are they are grounded in. From a cognitive perspective, simple or basic interactions with the world are most relevant for exploring which concepts are the most natural ones. From a metaphysical perspective, however, perfect correlations are the most relevant ones; insofar scientific measurement is a form of interacting with objects that is designed to produce perfect correlations, measurable properties are the most natural properties from a metaphysical point of view.

Many questions have been left out or have only been touched upon in this paper. For example, much more is to be said about abstraction mechanisms leading from affordances to concepts and how they produce the conceptual structure allowing inferences. Likewise, I only assumed that inferences and conceptual reasoning can also lead to (new kinds of) actions which in turn can lead to learning new affordances. In this sense, my claim is not that perceiving affordances is the only way to perform an action or that every action is elicited by affordances. However, my claim is that affordances form the basis on which our conceptual abilities are grounded. How exactly this grounding works in detail, how such grounded concepts can develop an inferential "life of their own", and how this conceptual thinking influences the learning of new affordances had to be left open in this paper.

My take on metaphysical and cognitive naturalness had to remain quite sketchy, too. Obviously, a lot of details have to be added to turn Ecological Empiricism into a full blown account of naturalness. However, I hope to have sketched a framework apt to develop such an account that takes seriously both the "world" and the "mind" part in our conception of nature and natural properties. I argued that the framework can bridge the gap between metaphysical and cognitive naturalness by conceptualizing them in the same way, while it can also capture its differences by sorting out what correlations are the most relevant from the respective perspective.

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