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Technological functions: their conception, manifestation and production.

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In *Technical Functions – On the Use and Design of Artifacts*, Wybo Houkes and Pieter Vermaas have developed a theory of technical functions that focuses on the attribution of technical functions to artifacts. They aim at a non-essentialist account of technical functions by reference to use-plans. 'Use plan' means, a more or less standardized way of manipulating objects in order to realize a practical goal , which is not only the business of designers but also of users. Houkes and Vermaas develop their theory by starting from the idea that artifact-using can be reconstructed as the execution of a use plan of those artifacts. In their account, they incorporate elements of existing intentional, causal-role and evolutionist function theories, which is why they call it the ICE-theory of technical functions. The theory can be applied for evaluating the use of artifacts because it enables us to *reconstruct* technical functions by reconstructing the use plan of those artifacts. In other words, the ICE-theory allows for evaluative purposes regarding the justifiable ascription of functions to artifacts relative to their use plans. In general, I am sympathetic about the ICE-theory. Also, I value their methodological approach, in particular because they explicitly articulate the desiderata their theory must meet, and because the authors are very explicit about the scope of their theory.

Houkes and Vermaas are explicit about the fact that their theory has a limited scope: it is a theory about justifiably function ascription to artifacts. Nevertheless, the authors suggest that their theory is relevant for the design of artifacts, which is a claim I doubt. My own ideas about technical functions – or, technological functions as I call them – have been formed through the perspective of the engineering sciences. The engineering sciences are scientific research practices in the context of technological applications. They aim at *newly creating and improving technological functions* that are physically embodied and exerted through technological artifacts such as (assemblies of) materials, processes, apparatus and instruments (Boon, 2011).

Against this background, my difficulty with Houkes and Vermaas' ICE-theory of technical functions is that it only accounts for function ascription to artifacts with hindsight. It does not clarify much about the interrelated activities of scientific research, design and development by means of which technological artifacts with certain intended technical functions come about. Put differently, I don't see how their account might accommodate philosophical accounts of creating and improving technological artifacts.

In part, this short-coming of the ICE-theory may be attributed to the choice of the authors to take philosophical accounts of functions in biology as their starting-point, which in my view, has confined their approach and the possible outcomes unfavorably. Hence, whereas Reydon (this issue) rejects the suggestion of Houkes and Vermaas that their ICE-theory could also be applied for function ascriptions in other domains, in particular, biology, I argue that their ICE-theory for function attribution to artifacts has been modeled too much after ideas about biological functions, thus ignoring the contribution of the design and development process. This appears from the fact that – in spite of talk about design – Houkes and Vermaas seem to take technological artifacts as somehow pre-given rather than objects that are being designed and developed in view of certain intended technical functions. This take on the matter is similar to how in accounts of biological functions species are taken as pre-given rather than designed. As a consequence – and also, because Houkes and Vermaas do not aim at an account of what it means for things to *have* functions, that is, a theory of the *nature* of functions – the seemingly most significant question that arises due to this approach is how the attribution of a technical function to the artifact can be justified.

Reydon (this issue) is especially critical about the role of the designer in applying the ICE-theory to biology. In his critique, he assumes that the biologist would have the role of the designer. Conversely, in my view, the ICE-theory fits to a Deist-teleological view on biology, in which the designs of different species spring from the mind of the designer-God. Applying the ICE-schema to biological functions would then yield:

> The designer-God, *D*, and Adam, *a*, justifiably ascribe the physicochemical capacity to Φ (e.g., the capacity to fly) as a function (e.g., flying) to a part of the body of a species, *x*, relative to a use plan *up* for *x* and relative to an account A, *iff*:
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> I. The designer-God, *D*, and Adam, *a*, believe that a part of the body of a species, *x* (e.g., wings) has the capacity to Φ (e.g., to fly); *D* and *a* believe that *up* (e.g. birds using wings in such and such a way) leads to its goals (e.g., transporting itself from position A to B, or catching a prey, or protecting itself against predators) due to, in part, *x*'s capacity to Φ (e.g., due to, in part, wings' capacity to fly).
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> C. *D* and *a* can on the basis of A (e.g., that the designer-God has created wings such that they can lift a bird by means of thermals) justify these beliefs.
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> E. Adam communicated *up* (e.g., birds using wings in such and such a way) and testified these beliefs to other humans; or Adam received *up* and testimony that the designer-God has these beliefs.

On this account, concepts of a specific function, as well as how this function is physically embodied and exerted spring from the mind of the designer, *D*. Subsequently, the designer, D, and other rational beings, *a*, decide whether the materialized artifact indeed has the envisioned function, which involves that all sentences of the ICE-theory apply. Therefore, the three theories of functions gathered in the ICE-theory apply in the following way: (I.) The intentions of the designer-God have fixed the function of, say, wings, which is in accordance with *intentionalist theories of function*. (C.) Also, the function of (parts of the body of) a species *x* (e.g., wings) is related to the causal role that *x* has in the whole system (e.g., birds can fly), because an explanation of why birds can fly has been given in terms of why wings enable birds to fly (A) – which agrees to *causal-role theories of functions*. (E.) Finally, the physicochemical capacity to Φ (e.g., the capacity Φ to fly) counts as an evolutionist function of a species (e.g. birds) because that capacity contributed positively to their reproduction. Applying Houkes and Vermaas' reading of *evolutionist function theories* to my Deist-teleological interpretation of the ICE-theory points out that the designer-God believed that the capacity to fly contributes positively to the reproduction of birds, and that Adam has received this understanding of the function of wings from the designer-God. In sum, the ICE-theory enables a systematic account of how Adam justly attributed functions to the species that God showed him and asked to give names.

Clearly, my interpretation unjustly ignores several features the ICE-theory has and which account for the fact that human designers are neither omniscient nor omnipotent and possibly not omnibenevolent either. These limitations are responsible for occurrences in which designed artifacts are not useful (e.g., because the bird has wings but there are no thermals in nature) or not completely successful (e.g., because the aerodynamics of the wings are sub-optimal) or their functioning may be physically restricted (e.g., because there are only thermals in the early morning). Nonetheless, the other side of being a human designer is their ability to find creative solutions and new applications. Houkes and Vermaas call these four phenomena *use versatility*, *possible lack of success*, *physical restrictions* and *innovation*. These phenomena are reflected in the four desiderata they propose for the theory of technical functions (p. 5). These desiderata must account for the fact that: (1) artifacts have a limited number of enduring proper functions as well as more transient accidental functions (*the proper-accidental desideratum*); (2) our ideas about the proper functioning of an artifact may disagree with its actual functioning, which enables us also to decide on its malfunctioning (t*he malfunctioning desideratum*); (3) there exists a measure of support for ascribing a function to an artifact, even if the artifact is dysfunctional or if it has a function only transiently (t*he support desideratum*); and , (4) designers and users have the ability to ascribe intuitively correct functions to innovative artifacts (t*he innovation desideratum*).

However, in spite of these features of the ICE-theory the issue remains that functions usually are not *attributed* to technological artifacts afterwards. In real practice, conceptions of technical functions, and the artifacts embodying these functions, result from an often troublesome process of scientific research, design and development carried out by scientific researchers, engineers and users. Hence, the concept of a technical function and the design of the technological artifact that supposedly will manifest it usually do not spring spontaneously from their minds. Therefore, the ICE-theory seems to be very restricted in the sense that it only offers a conceptual tool for evaluating whether an artifact has a designated function – that is, to assess whether someone (e.g., the designer or the seller) justly claims that this artifact has such and such a function.

In the remainder of my contribution, I aim to explore how to go about in developing an account of technological functions that also accommodates the design and development of technological artifacts for performing desired functions. I will propose that at least three notions are needed for developing this account, namely, *conceptions* of technological functions, *manifestations* of technological functions, and *physical phenomena* (e.g., substances, properties or processes) that *produce* (or are held responsible for) the functioning or malfunctioning of a technological artifact.

The roles these notions play in accounting for a technological function can be made somewhat more concrete by means of a very simple example, for instance, how researchers and engineers think about paint. The desired technological function(s) of paint include properties such as protecting a surface, workability in its application, durability and aesthetic qualities. Hence, our *conception* of the technological function of paint involves these kinds of qualities. The *manifestations* of the technological function(s) involve perceivable, measurable and/or quantifiable properties of paint such as its color, its viscosity, and its fastness of drying, its adherence to a surface, its smoothness, its shininess, its hardness, and the stability of these properties. Examples of *manifestations of technological dysfunctions* of paint are properties such as, the tendency to maintain ripples; the increase of its viscosity when applied at higher temperatures; the tendency to capture air-bubbles; the toxicity of the solvent; its poor scratch-resistance; formation of cracks in hardened paint; loss of color; and, the tendency to turn yellowish under the influence of sun-light. A common sense kind of approach to the improvement of the technological functioning would be trial-and-error interventions with the *technological artifact* at hand, for instance, by systematically testing the effects of different kinds of solvents or pigments or filling materials in the case of paint. Sometimes this is considered as a typical engineering approach. Though, different from, and often additional to the trial and error approach, the *engineering sciences* focus on creating and intervening with the physical *phenomena* that produce the proper and/or improper functioning of technological artifacts. Examples of such phenomena are evaporation of solvent; molecules responsible for the color of paint; degradation of color-molecules under the influence of heat or light; chemical or physical properties of pigments; and properties such as viscosity, diffusivity, hydrophobicity and surface-tension of the solvent and polymers. The role of such physical phenomena is particularly important for understanding the contribution of the engineering sciences to the design and development of technological artifacts.

Scientific research that concerns the technological functioning of technological artifacts aims at finding ways for *improving* their functioning. Improving the technological functioning of paint may involve reducing the degeneration by sun-light of the pigments or the varnish polymers. Other examples of improving technological functions are, enhancing the energy efficiency of engines; preventing the production of side-products of chemical processes; and, improving the mechanical properties of biodegradable fibers used in medicine. Additionally, scientific research aims at *creating* technological functions that do not exist as yet. Examples are, an instrument that measures toxic levels of compound X in air; a membrane that separates pollutant P from waste-water Z; a molecule that converts sunlight to electrical energy; a material that is super-conductive at relatively high temperatures; and a chemical process that exclusively produces one of the isomeric forms of a drug that has chemical composition M.

This brief example illustrates that technological artifacts – i.e., (assemblies of) materials, processes, apparatus and instruments –contain and/or generate physical phenomena that produce the (mal) functioning of these devices that we perceive or measure – i.e., the manifestations of technological (mal) functioning. For a technological artifact to perform its desired technological function(s), researchers and engineers aim at producing the properties that are manifestations of its proper functioning, and prevent or change the occurrence of those that are manifestations of its malfunctioning. The engineering sciences usually translate technological problems (e.g., the problem of how to *create* or *improve* a technological function) into scientific questions by conceiving of the (mal) functioning of a technological artifact in terms of the physical phenomena held responsible for its (mal) functioning (or, more precisely, the manifestations thereof). These phenomena then become subject of scientific research, which, besides other things, aims at knowledge that enables thinking about possibilities to create, reproduce, prevent, control, improve, or otherwise intervene with these phenomena by means of technological interventions and artifacts.

I propose that in research and design contexts *conceptualizing* improvable or newly makeable technological functions involves sensibly discerning and putting together distinct kinds of knowledge, which I will briefly outline (also see Boon, forthcoming). Conceptualizing technological functions may commence with articulating a *problem* that puts forward the practical purpose of a technological function, such as 'world-wide depletion of fossil fuels', or 'water pollution', or, 'UV-light effected degradation of polymers'. Additionally, more or less abstract technological ideas on the type of *solution* involve conceptions of types of technological artifacts that perform relevant technological functions. Examples are: 'solar cells for producing electrical energy', 'ultra-thin conductive layers in solar-cells for reducing energy-loss of striking sun-light', 'membranes for physicochemical removal of toxic metals', 'additives that prevent the formation of free radicals', 'UV-light reflecting nano-particles in paint', and 'biologically functioning membranes for producing metal-ion-pumps'. Pointing out these kinds of possible solutions requires technological, empirical and/or theoretical knowledge of how diverse technological artifacts function. Usually this involves empirical, technological and theoretical knowledge about the physical phenomena that may produce a specific (mal) function. Examples are: knowing that membranes are capable of separating molecules from water, and understanding how their specificity for certain types of molecules is attained, but also, knowing that membranes easily get clogged in concrete technological applications; knowing that nano-particles have the capacity of reflecting UV-light, and understanding how they do that, but also, knowing that nano-particles may be toxic. Furthermore, conceptualizing *new* technological functions may draw on knowledge of phenomena that, considered from a theoretical perspective, may be utilized for performing a desirable function. An example is 'artificial photosynthesis' for the production of electricity or fuels (e.g., Pandit et.al, 2006). Conceptualizing these kinds of technological functions involves the idea of 'technologically mimicking' parts of the natural photosynthesis. The conception of this technological function can be developed by thinking about ways of technologically *copying* parts of bio-chemical pathways through a technological device; in other cases, it involves the mere *conceptual use* of certain principles in terms of which scientists understand the functioning of technological or natural systems. An example of a principle devised for such conceptual use, is 'that light is harvested by means of light-harvesting molecules in biochemical pathways of plants or algae,' (e.g. Savoilainen et.al, 2008).

Why are the three notions proposed here – i.e., conceptions *of*, manifestations *of* and physical phenomena *for* technological functions – better suited as a starting-point for developing an account of technical functions than existing I, C and E theories of functions that where originally developed in the context biology? Firstly, as has been sketched above, the three notions point at important features of the development of technological artifacts in research and design practices. Secondly, the given examples make plausible that the notion of *conceptualizing* technological function is crucial for explaining how technological artifacts are designed and developed. The conception of a technological function entails the different kinds of knowledge. Elsewhere, I suggest that this so-called 'epistemic content' of the concept of technological functions enables thinking about improving or creating them, which implies that concepts function as 'epistemic tools' (see Boon, forthcoming). In short, the formation of concepts of technological functions usually starts from thinking about possibilities of improving existing functions or creating new ones. It involves the use of relevant *empirical, technological and theoretical knowledge* about technological *problems*, existing *artifacts* and *functions*, and about physical *phenomena* that, on the one hand, are *generated by natural objects and/or technological artifacts*, and on the other hand, *produce the manifestations of their (mal) functioning*. Hence, resulting conceptions of technological functions consist of assemblies of heterogeneous bits of knowledge relevant for thinking about the actual technological production of these functions (i.e., producing them by means of artifacts and technological interventions). Thirdly, analogous to my account of conceptions of technological functions, the ICE-theory may also be understood as an account of aspects entailed in the conception of a technical function of an artifact relative to its use plan. In that way, the ICE-schema enables a sensible reconstruction of the conception the designer and/or users have in mind of the function of an artifact. For, the ICE-schema points out which aspects are relevant with regard to 'justifiable function ascription to artifacts, relative to their use plans.' Similarly, my second notion, 'the manifestation of a technological function' may account for 'the physicochemical capacity to Φ,' in the ICE-account. Also, the third notion, i.e., 'the physical phenomenon which produces the technological function,' may account for the relevance of 'the causal explanation, or account, A, of the belief that the artifact has this capacity,' in the ICE-theory. In other words, this third notion may cover the causal explanation needed in an account of justifiable function ascription. Clearly, this latter comparison can only be very sketchy. Nevertheless, I suggest that the three notions proposed in this contribution may be suitable for developing an account of technological functions that accommodates both evaluative purposes *and* explanations of technological design and development.

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