Functions, roles and dispositions revisited. A new classification of realizables

Johannes Röhl, Ludger Jansen

Institute of Philosophy, University of Rostock, Germany

ABSTRACT

The concept of a function is central both to biology and to technology. But there is an intricate debate how functions as well as related entities like dispositions and roles are to be represented in top level ontologies and how they are to be related. We review important philosophical accounts and ontological models for functions and roles and discuss three models for the relation of functions and dispositions. We conclude that mainly because of the need to account for malfunctioning, functions should not be treated as a subtype of dispositions, but as their sibling category.

1 INTRODUCTION

The concept of a function is central to biology as well as to psychology, technology and engineering. However, realizable entities like functions, dispositions and roles are notoriously difficult to understand and there is no consensus how to model them within a top level ontology. Among other things, this is witnessed by the Basic Formal Ontology (BFO; http://www.ifomis.org/bfo). BFO version up to 1.1.1 contained these three categories as immediate children of the category *Realizable*, that were jointly exhaustive and pairwise disjoint. However, in the transition to the new version BFO 2 it is planned to position *Function* as a subtype of *Disposition* (Table 1). In order to bring new light into this problem, this paper discusses the relation of functions to plans (§ 2) and the relation of functions to dispositions (§ 3).

2 FUNCTIONS AND PLANS

2.1 Design functions of artifacts

In ancient Latin, the word "*functio*" was used to describe the duties of certain positions: It was the *functio* of, say, a quaestor to raise taxes. This was, what being a quaestor was about. In general, not only official positions, but all things created by men could be ascribed the use for which they were created as their function or, more precisely, their design function. A screwdriver can be said to have the design function to drive screws because it is produced with the plan to be used for this purpose. A design function, then, is *not* a property that inheres in the functional artifact, but it is the content of an ascription by an agent or a group of agents involving a plan about the future use of this artifact (or of artifacts of this type).

Table 1: Definitions of the children of realizables in BFO 1.1.1 and 2 ('Graz release')

Definition in BFO 1.1.1[1]	Definition in BFO 2[2]
Disposition = A realizable entity that essentially causes a specific process or transformation in the object in which it inheres, under specific circumstances and in conjunction with the laws of nature. A general formula for dispositions is: X (object) has the disposition D to (transform, initiate a process) R under conditions C.	b is a **disposition** means: b is a realizable entity & b's bearer is some material entity & b is such that if it ceases to exist, then its bearer is physically changed, & b's realization occurs when and because this bearer is in some special physical circumstances, & this realization occurs in virtue of the bearer's physical make-up.
Function = A realizable entity the manifestation of which is an essentially end-directed activity of a continuant entity in virtue of that continuant entity being a specific kind of entity in the kind or kinds of contexts that it is made for.	A **function** is a disposition that exists in virtue of the bearer's physical make-up and this physical make-up is something the bearer possesses because it came into being, either through evolution (in the case of natural biological entities) or through intentional design (in the case of artifacts), in order to realize processes of a certain sort.
Role = A realizable entity the manifestation of which brings about some result or end that is not essential to a continuant in virtue of the kind of thing that it is but that can be served or participated in by that kind of continuant in some kinds of natural, social or institutional contexts.	b is a **role** means: b is a realizable entity & b exists because there is some single bearer that is in some special physical, social, or institutional set of circumstances in which this bearer does not have to be & b is not such that, if it ceases to exist, then the physical make-up of the bearer is thereby changed.

[1] http://jowl.ontologyonline.org/bfo.html (last access 12.09.2012).

[2] http://bfo.googlecode.com/svn/releases/2012-07-20-graz/owl-group/bfo.owl (last access 12.09.2012).

They are made *for* a certain purpose, their function. Let us call this the planning account of design function. On this account, the truth-maker of a function ascription is a plan.

From the point of view of the planning account, we can say the following about (design) functions:

- Design functions are grounded in designers' function ascriptions.
- Designers can decide on functions independently of the physical structure of artifacts.
- Thus, independently from its physical structure and its dispositions, an artifact can have any function.
- It will, though, not be able to realize its function unless it possesses a corresponding disposition to do so.

2.2 Use functions of artifacts

The planning account can easily be modified in order to deal with use functions of artifacts. Use functions are directed at those activities that users actually use things for. (Cf. (Mizoguchi et al. 2012, 110) for the distinction of design function and use function and (Preston 2003) for problems of this distinction.) If I use my screw driver to open my paint cans, it has the use function to open paint cans. It has not been produced for this purpose, hence the use function can differ from its design function, though it might be just the same. Moreover, one and the same thing can have many different use functions at different occasions. This account can be extended to biomedical entities. If I use digitalis to kill my wife, I have a certain action plan that involves the participation of both a probe of digitalis and my wife with a certain intended outcome.

2.3 The problem of biological functions

In pre-Darwinian biology, organisms and their parts were described as if they, too, were something created – either, allegorically spoken, by a personified Nature, or by God as a creator. In the latter case, ascribing functions to biological entities could be conceived of as reading the mind of God before the act of creation and as a reconstruction of the reasoning underlying his creation. From this point of view, the planning account can be extended to biological functions: The truth-maker of the ascription of a biological function is, in this framework, God's plan for his creation. In the former case we have something like an as-if parlance, which can be found, e.g., in Aristotle: Although Aristotle rejected the idea that the universe or life had a beginning in time, he often says that Nature has well organized its creatures. We suggest to read this as a *fictionalist* account of biological function, meaning: Were this plant or animal brought about by Mother Nature (a very intelligent designer), she would have done so for good reason. Hence, the planning account can be uphold with a small modification: The truth-maker of the ascription of a biological function no longer is an actual plan, but a plan within the fiction of Mother Nature designing its creatures.

Both accounts show that pre-Darwinian biology had no problem with applying a variant of the planning account to biological functions. While biological entities are still treated as functional wholes, the planning account is no longer viable for the post-Darwinian biology of today. But then the problem arises: What is the ground for a biological function ascription? And this comes down to: What is a biological function?

2.4 Philosophical accounts of biological functions

The concept of a function has been controversially discussed in the philosophy of biology and elsewhere and several accounts have been proposed to illuminate the nature of biological functions (cf. (Ariew et al. 2002) and (Krohs/Kroes 2009) for recent contributions to this debate, cf. also (Johansson et al. 2005) and (Burek et al. 2006) for an elaborate formal ontology of functions). Among the different approaches to functions the most straightforward is the **causal role analysis**: *That X has function F simply means that X has the disposition to causally contribute to some output O of a complex system S* ((Cummins 1975) as characterized by (Boorse 2002); see there for further references).

A well-known problem is that this account is extremely broad and admits many unintuitive functions: It implies e.g. that clouds should be ascribed the function to produce rain, because they undoubtedly have a central causal role in the production of rain (more examples and further criticism in (Boorse 2002)). To avoid this broadness, further conditions have to be added in order to narrow down possible functions of a thing. Intuitively, functions are connected either with some intention as in artifactual functions or a (not necessarily intended or conscious) *goal* in biological functions. A formal characterization of such a **goal-contribution approach** has been suggested by (Röhl 2012). However, many philosophers of science see even such "deflationary" teleological accounts as untenable in post-Darwinian biology.

As an alternative, **etiological acccounts** of biological functions have been suggested (Wright 1973). Instead of looking *forward* to a goal, a function is taken to be dependent on the *history* of a type of biological entity exemplifying the function, i.e. the development by evolutionary selection that accounts for its existence in the first place. However, according to the etiological account, in the first generation of a biological type there cannot be any functions for definitional reasons, although the actual structure of the organs would be "functional", which is very counterintuitive. Moreover, a certain body part may acquire new uses and functions during the evolutionary history of a species, while the early history

and hence the reason for its existence remain the same (Boorse 2002: 66).

In face of these difficulties, Boorse's "general goal-contribution" approach can be considered the "minimal core" of the concept of a function, with system S, system part X and goal G: "X performs function Z in the G-ing of S at t if and only if at t, the Z-ing of X is a causal contribution to G" (Boorse 2002: 70). This is still weak, because functions could be performed only once and accidentally and fulfill this definition. Boorse relies on distinctions like the *normal* function of a *type* as opposed to accidental functions or deviations of single tokens to avoid those counterintuitive accidental functions.

The concept of a **systemic function** as suggested by Mizoguchi et al. (2012: 109) is very similar to this account. With the introduction of a "systemic context" C in addition to a system S and a system part A they define: "C is a systemic context for S and according to C, A is a component of a subsystem of S, the goal of this subsystem is to realize the goal of C, and some behaviors of A play the (functional) role determined by C." This can be applied both to biological and to technical functions. A systemic context C for the human liver (= A) would be the human digestive system (goal: digestion of food and extractions of nutrients) and within the subsystem of fat digestion the function of the liver is the production of bile. The point is that the systemic function is context-dependent in a very specific way, i.e. via a system its bearer is part of. Hence the function of a thing can change depending on the system it is a component of.

2.5 Functions in BFO

In the older versions of BFO, functions, dispositions and roles are sibling subclasses of the class "realizable dependent continuant" (Arp/Smith 2008). This common superclass implies that all three are:

- continuants, i.e. they are wholly present at any time of their existence;
- dependent (like qualities) on the independent continuant (some material thing or system) that is their bearer;
- realizable, which means that they are essentially connected to certain processes, their realizations, and
- the bearers participate in the realization processes. These are the processes they are roles, dispositions or functions *for*.

Note that realizables do not have to be (always or ever) realized (Röhl/Jansen 2011), as, e.g., in the case of a safety mechanism the function of which will only be realized if certain conditions obtain (and they may never obtain).

For the specific differences between functions, roles and dispositions Arp and Smith draw on elements of the debates sketched above (Table 2). The realizations of functions and dispositions take place "in virtue of the bearer's physical makeup" whereas the realizations of roles are not grounded in the physical structure of the bearer, but dependent on circumstances. Functions are distinguished from dispositions by the additional condition that the function bearer possesses the physical structure that grounds the function because of how it came to be there in the first place: In the case of artifactual functions by the intentional design and production, in the case of biological functions by a history of evolutionary selection. So BFO-roles are closer to optional, accidental "use functions" whereas BFO-functions and BFO-dispositions are determined by their causally relevant internal structure and thus close to the goal-contribution account as it is said that the realization of a (biological) function "helps to realize the characteristic physiology and life pattern for an organism of the relevant type" (Arp/Smith 2008: 2). The specific difference of dispositions and functions is again the historical (evolutionary) or the intentional (design) component, respectively. Similarly, these intentional and historical criteria are used in BFO 2 as the specific difference of functions as opposed to non-functional dispositions.

Table 2: Function, role, and disposition in BFO

	Disposi-tion	Artifact function	Biological function	Role
Grounding	internal	internal	internal	external
Modal status	mixed	essential?	essential?	accidental
Relevance of history	no	yes	yes	yes
Dependent on intentions	no	yes	no	yes

3 FUNCTIONS AND DISPOSITIONS

3.1 Dispositions

A common philosophical position takes dispositions as a type of properties (Ellis/Lierse 1994). A disposition is a causal property that is linked to a realization, i.e. to a specific behaviour or process which the individual that bears the disposition will show under certain circumstances or as a response to a certain trigger. Something is water-soluble if it dissolves when put in water. In this fashion dispositions establish a link between (independent) continuants (stable things) and occurrents (processes) and the fundamental connection is the following: *Continuant S has disposition D for realization P and, in case P occurs, S, the bearer of the disposition, is a participant of this process P*. Dispositions are often treated as a special kind

of dependent continuants that are linked to a process of realization by a respective formal relationship to a realization process (Arp/Smith 2008), (Roehl/Jansen 2011), (Jansen 2007). Note that the terminology is often confusing as dispositions and functions are sometimes named according to their realization processes. In the Gene Ontology (http://www.geneontology.org), e.g., many subclasses of the *Molecular Function Ontology*, are described by the term "activity" (as in "bioactive lipid receptor activity") which, paradoxically, does not denote the actual acting (process). In this paper, function, disposition and role will be held strictly distinct from the processes that are their realizations.

3.2 Are functions dispositions?

The central **difference between dispositions on the one hand, and functions and roles on the other** lies in their context-dependence. Continuants may lose or acquire dispositions, but not without fundamental changes within the bearer. In contrast, many functions can be performed by different types of bearers and an object may have different functions in different contexts without any change in itself. Chopsticks, for example, have the function to support eating. Similar sticks found in the wood do not have any such function, though they may have the very same physical structure and hence the same dispositions. Dispositions, that is, are purely internally grounded, while the function of the chopsticks is a historical property due to the way this artifact has been produced. On the other end of the spectrum, social functions and roles are context-dependent or "externally grounded" in the respective context. Biological functions, like those of organs, enzymes etc. are somewhere in between, with an entity usually fulfilling several functions in a certain range of contexts. They are objective systemic functions in the sense mentioned above and not merely ascribed by an agent; their context-dependence is fixed by the functional hierarchy of the respective physiological system. An organ like the liver has many functions like production of bile, glycogene storage, cholesterol synthesis etc. But all these are fixed by the respective physiological systems the liver and its products are functionally involved in. They are not as arbitrary or flexible as the screwdriver that could serve the use functions (i.e. roles) of a can opener or a weapon.

Malfunctioning is (i) having a function but (ii) not living up to it. In a case of malfunctioning the realization of the function either does not happen at all or in an insufficient way. Technically speaking, the output of the thing or system is not in the standard or target range (Del Frate 2012). If the realization can be measured quantitatively, we can distinguish between hypofunction and hyperfunction, that is staying below a lower threshold or exceeding an upper limit for the output parameter of the function. This occurs frequently in biology and medicine, and hypo- or hyperfunctions are often disorders, e.g., hypotension and hypertension disorders of the cardiovascular system with regard to the parameter blood pressure. This definition of malfunction presupposes the very possibility of a function being present without the corresponding disposition. Hence they cannot be identical.

Malfunctioning is therefore a clear indicator of the normative dimension of functions. More generally, we can make value judgements about artifacts or body parts with respect to their function: Something may be a bad saw or a good heart. This **normative aspect** of functions is in general not shared by dispositions. Dispositions can be blocked or incompletely realized, but their bearers are not evaluated in a normative fashion. Therefore it does not seem to be appropriate to classify functions as dispositions. E.g., a lung with a carcinoma may still have the function to serve as an oxygen provider for the body, but the function may no longer be realized because the corresponding disposition (to be able to serve as an oxygen provider for the body) is no longer present. According to Vermaas/Houkes (2003), any theory of function has to give an account for the normative aspect of functions and for the possibility of malfunctions. Now there seem to be at least two distinct ways to interpret this case:

(1) The token lung has lost the disposition and, because functions (a) *are* dispositions or (b) are *dependent on* them, it has also lost the function. Malfunction for a token then means that this token has simply lost the function, rather than that it still has the function without being able to realize it. But we can speak of malfunction rather than nonfunction, because the *type* lung *typically* has both the disposition and the corresponding function to provide oxygene (Boorse 2002: 89; McLaughlin 2009). As McLaughlin points out, being a token of a type involves an evaluative dimension. Other possible sources of the normativity for functions are a means-end relationship or a hierarchical part-whole relation (McLaughlin 2009). These aspects come together in a systemic goal-contribution account, because here the functioning and the malfunction of a part in the functional hierarchy is evaulated with respect to its working as a means to the end/goal of the whole.

(2) The function is ontologically independent of the disposition. The function of a lung as a normative ascription is still there, but because the corresponding disposition is not, there is malfunction. The task of medicine would then be to restore the disposition so the the organ would be (fully) functional again.

While there is no clear-cut argument to decide between these two options, option (2) better allows to account for

healing processes. For according to (2), a healing process consists in restoring a disposition where there is a function without its corresponding disposition. According to (1), however, there cannot be functions without corresponding disposition (e.g., because functions *are* these dispositions). Thus a healing process according to (1) consists in restoring the very function.

3.3 Do functions depend on dispositions?

For all of these reasons, we should assume that functions are not identical to dispositions. Nevertheless, even if they are distinct entities, functions could ontologically depend on dispositions. On the planning account, functions of artifacts are clearly independent from the dispositions of their bearers, as due to the fallibility of human designers the one could occur without the other. From the point of the theistic extension of the planning account to biological functions, however, the existence of a function implies the existence of the corresponding disposition in typical cases, given the usual assumptions of God's omniscience and benevolence. But even if a biological function is typically accompanied by a disposition, this concurrence is not universal, as proved by malfunctioning.

The dispositions as part of the internal structure of a thing determine whether it can fulfill the respective function in a given context. Johansson (2004) calls this the "substratum" of a function. While the function itself is independent from its substratum, its realization depends on its existence. This dependence can be a generic one, because sometimes different dispositions or structures can ground the same function: E.g., the cooling function of a cooler can be implemented in different technical setups (Johansson 2004, 66).

As we know biological functions only through their actual realizations, we would have no reason to ascribe them, unless instances of a certain kind typically displayed that behaviour and, *a fortiori*, possessed a corresponding substratum disposition. How would we know the biological function of, say, a heart, if hearts did not typically have the disposition to pump blood and typically realized this function? So there should be some connection between the function and the disposition of the organ.

On the other hand, many diseases like heart insufficiency are characterized by the very contrast between functions and the lack of corresponding dispositions, and so is malfunctioning in general. Malfunctioning artifacts or diseased organs are characterised by the loss of the disposition to fulfill their function. We conclude that the corresponding disposition is only necessary for the realization of a function, not for the function itself. Because in biological (and many artifactual) cases we can evaluate the performance of token functions with respect to what is a normal realization for the function type, and because the normal realization is dependent on the corresponding disposition, we have a correspondence of function and disposition at the type level or for prototypical tokens. But this is to be distinguished from a token-level dependence of the function on the corresponding disposition. If we want to accommodate malfunctioning, we have to reject the latter.

4 CONCLUSION

We can summarize the discussion by suggesting a **new classification of realizables**. It concurs with BFO 1.1.1 in treating functions as siblings of dispositions rather than special dispositions. It makes use of two independent criteria: essence optionality and structure optionality. A realizable can be optional given a certain physical structure of its bearer. All realizables that are externally grounded, i.e. in some context, are optional in this sense, e.g. all roles. In contrast, dispositions are internally grounded, based on the bearer's physical structure and therefore not optional given the bearer's physical structure. Because a bearer can gain and lose dispositions some dispositions are also optional. But what is at stake here, is optionality given the essence of the bearer. If a disposition is optional in this sense, a bearer can lose it without ceasing to be. However, not all dispositions are optional given the essence of the bearer. Some dispositions, like the disposition of a proton to attract electrons, are essential: Losing this dispostions would imply that the proton ceases to be a proton, i.e. that it ceases to exist. Functions are essential in this sense: Given the essence of being a heart, it is not optional to have the function to pump blood. And given the essence of being a screwdriver, it is not optional to have the function to manipulate screws. We thus end up with a cross classification of realizables, presented in Table 3.

Table 3: A new cross-classification of realizables

	Internally grounded (= non-optional given the physical structure)	**Externally grounded** (= optional given the physical structure)
Essential (= non-optional given the essence)	Essential disposition	Function
Accidental (= optional given the essence)	Accidental disposition	Role

Functions are externally grounded. We argued that there are good arguments not to treat functions as dispositions,

nor to make functions dependent on dispositions. This distinction is our central disagreement with the BFO 2 suggestion discussed above. We also define roles in a rather narrow way, different from Mizoguchi et al. 2012 and other papers (for a very wide notion of role cf. Loebe 2007): On our account, roles are never essential for its bearer. The way of speaking that would assign an essential "breather" or "eater" role to a human being is not to be taken ontologically serious. Breathing and eating are processes, not functions or roles. Humans have to participate in breathing and eating processes on a regular basis, but it is not their role to breathe. Therefore in our classification scheme what are called "use functions" in the literature (cf. 2.2 above) are roles, in agreement with the BFO conception of roles.

All in all, we discussed three different models for the ontological analysis of functions:

- The planning account was able to deal with design and use functions of artifacts, but not with biological functions.
- Equating functions with dispositions leads to problems with malfunctions.
- Only treating functions as a sibling category of disposition own was able to circumvent these problems.

On this latter account, functions are not only disjoint from dispositions, they are also ontologically independent from dispositions. Functions are, however, normally and mostly accompanied by corresponding dispositions. This is the reason why it is so difficult to distinguish between these categories. Malfunctioning, however, requires them to be distinct categories: It happens in case the corresponding disposition is lacking.

ACKNOWLEDGMENTS

This work was supported by DFG grant JA 1904/2-1 within the project GoodOD. Many thanks to Andrew Spear who provided us with a recent draft of the follow-up version of (Spear 2006) and to three anonymous referees for critical and helpful comments.

REFERENCES

Ariew, A., Cummins, R,. and Perlman, M. (2002): *Functions. New essays in the Philosophy of Psychology and Biology*, Oxford.

Arp, R., Smith, B. (2008): Function, Role, and Disposition in Basic Formal Ontology, *Proceedings of Bio-Ontologies Workshop (ISMB2008)*, 45–48.

Boorse, C. (2002): A Rebuttal on Functions, in Ariew et al., 63-112.

Burek, P./Hoehndorf, R./Loebe, F./Visagie, J./Herre, H./Kelso, J.(2006): A top-level ontology of functions and its application in the open biomedical ontologies, *Bioinformatics* 22, No.14, e66-e73.

Cummins, R. (1975): Functional analysis. *Journal of Philosophy*, 72:741–765.

Ellis B, Lierse C (1994): Dispositional Essentialism, *Australasian Journal of Philosophy* 72: 27-45.

Del Frate, L. (2012): Preliminaries to a Formal Ontology of Failure in Engineering Artifacts,in Donnelly , M./ Guizzardi, G. (eds.): *Formal Ontology in Information* Systems (FOIS 2012), ISO Press, 107-130.

Jansen, L. (2007): Tendencies and other Realizables in Medical Information Sciences, *The Monist* 90/4, 534-555.

Johansson, I. (2004): *Ontological Investigations*, Heusenstamm.

Johansson, I./Smith, B./Munn, K./Tsikolia, N./Elsner, K./Ernst, D./Siebert, D. (2005): Functional Anatomy: A Taxonomic Proposal, *Acta Biotheoretica* 53: 153-166.

Krohs, U./Kroes, P. (eds.) (2009): *Functions in biological and artificial worlds. Comparative philosophical perspectives*, Cambridge, Mass.

Loebe, F. (2007): Abstract vs. social roles. Towards a general theoretical account of roles**,** *Applied Ontology* 2/2, 127-158.

McLaughlin, P. (2009): Functions and Norms, in Krohs/Kroes (eds.) 2009, 93-102.

Mizoguchi, R. Kitamura, Y., Borgo, S. (2012): Towards a Unified Definition of Function, in Donnelly , M./ Guizzardi, G. (eds.): *Formal Ontology in Information Systems (FOIS 2012)*, ISO Press, 103-116.

Preston, B. (2003): Of Marigold beer – a reply to Vermaas and Houkes, *British Journal for the Philosophy of Science* 54, 601-612.

Röhl, J. (2012): Mechanisms in biomedical ontology, *Journal of Biomedical Semantics* 2012, **3**(Suppl 2):S9

Röhl, J./Jansen, L. (2011): Representing dispositions, *Journal of Biomedical Semantics* 2011, 2(Suppl 4):S4

Smith et al. (2005): Relations in Biomedical Ontologies. *Genome Biology* 2005 6:R46.

Spear, A. D. (2006): *Ontology for the 21st Century. An Introduction with Recommendations (BFO Manual)*, http://www.ifomis.org/bfo/documents/manual.pdf.

Vermaas, P. E. (2009): On Unification: Taking Technical functions as Objective (and Biological functions as Subjective, in: Krohs/Kroes (eds.) 2009, 70-87.

Vermaas, P./Houkes, W. (2003): Ascribing functions to Technical Artefacts: A Challenge to Etiological Accounts of Functions. *The British Journal for the Philosophy of Science*, 54, 261-89.

Wright, L. (1973): Functions. *The Philosophical Review*, 82, 139–168.