



HAL
open science

Investigating Functions in BFO from the Viewpoint of Extrinsic Dispositions

Fumiaki Toyoshima, Adrien Barton, Jean-François Ethier

► **To cite this version:**

Fumiaki Toyoshima, Adrien Barton, Jean-François Ethier. Investigating Functions in BFO from the Viewpoint of Extrinsic Dispositions. 6th Workshop on Foundational Ontology (FOUST 2022) @ The 8th Joint Ontology Workshops (JOWO 2022), International Association for Ontology and its Applications (IAOA), Aug 2022, Jönköping, Sweden. paper 5. hal-03919178

HAL Id: hal-03919178

<https://hal.science/hal-03919178>

Submitted on 2 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Investigating Functions in BFO from the Viewpoint of Extrinsic Dispositions

Fumiaki Toyoshima¹, Adrien Barton^{2,1} and Jean-François Ethier¹

¹ GRIIS, Université de Sherbrooke, 2500 Boulevard de l'Université, Sherbrooke, QC, J1K 2R1, Canada

² IRIT, CNRS, Université de Toulouse, 118 Route de Narbonne, F-31062 Toulouse Cedex 9, Toulouse, France

Abstract

We take initial steps towards a meticulous analysis of functions (including the so-called “use function”) within a recently proposed, unifying dispositional framework for realizable entities in Basic Formal Ontology (BFO). Our approach to function is strikingly characterized by an ontology of “extrinsic dispositions”, which are realizable entities outside the BFO category of disposition. This work helps to articulate multiple possible senses of the term “function” within BFO and to deepen the understanding of the present BFO dispositional theory of function.

Keywords

function, Basic Formal Ontology (BFO), disposition, role, realizable entity, extrinsic disposition, use function

1. Introduction

Function (in its non-mathematical sense) is an entity that is central to a wide range of domains such as biology, engineering, and sociology. Paradigmatic examples of functions include the function of the heart to pump blood and the function of this screwdriver to turn screws. The nature of function nonetheless remains nebulous from an ontological perspective [1][2].

In this short paper we will explore the notion of function in the upper ontology Basic Formal Ontology (BFO) [3][4]. There are some thorny questions concerning the current BFO view that function is a special kind of disposition [5]. A first question is whether, according to BFO’s dispositional account, the function of Mary’s heart is a function to pump blood in *her body* (but not in anybody’s else, even if it is transplanted into another body), or a function to pump blood in any body to which it would be connected? Which BFO category (*inter alia* of realizable entity) do these different senses of “function” correspond to? A second question is the ontological status of the so-called “use function” in BFO, such as the use function of this chair to help to reach for something? We will briefly address such issues by leveraging a recently proposed, unifying dispositional framework for realizable entities in BFO that involves so-called “extrinsic dispositions” [6].

The paper is organized as follows. Section 2 provides preliminaries. Section 3 examines the status of function within this unifying dispositional framework for realizable entities in BFO. Section 4 investigates the notion of the so-called “use function”. Section 5 offers discussion *vis-à-vis* related work. Section 6 concludes the paper with a brief remark on future work.

2. Preliminaries

2.1. BFO and its dispositional account of function

The BFO upper ontology [3][4] includes the top-level distinction between continuants (which persist over time) and occurrents (which extend through time), the former being further divided into

The Eighth Joint Ontology Workshops (JOWO’22), August 15-19, 2022, Jönköping University, Sweden

EMAIL: toyo.fumming@gmail.com (A. 1); adrien.barton@irit.fr (A. 2); ethierj@gmail.com (A. 3)

ORCID: 0000-0002-4690-1221 (A. 1); 0000-0001-5500-6539 (A. 2); 0000-0001-9408-0109 (A. 3)



© 2022 Copyright for this paper by its authors.
Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

CEUR Workshop Proceedings (CEUR-WS.org)

independent continuants and dependent continuants. As for continuants, a specifically dependent continuant is a dependent continuant that depends (existentially) on at least one independent continuant. A quality is a specifically dependent continuant that does not require any further process in order to be realized (e.g. color, shape, and mass). A realizable entity is a specifically dependent continuant that inheres in some independent continuant and is of a type such that some instances thereof are realized (or activated) in processes of a correlated type. Note that this process of activation or realization is not the same as the process of being brought into existence: for example, the fragility of some mineral can be brought into existence by this mineral being heated and cooled; but it will be realized by this mineral breaking when hit. As for occurrents, a process is an occurrent that exists in time by occurring, has temporal parts, and depends on at least one independent continuant as participant (e.g. the process of blood pumping).

A disposition is: “A realizable entity (...) that exists because of certain features of the physical makeup of the independent continuant that is its bearer” ([3], p. 178). It is also characterized as an “internally grounded realizable entity”: if a disposition ceases to exist, then we can conclude that the physical makeup of the bearer has changed. Exemplars of dispositions include fragility (the disposition to break when pressed with force) and solubility (the disposition to dissolve when put in a solvent).

A function is a disposition of a bearer with a specific kind of historical development [5]. In more detail: “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 of how it came into being — either through natural selection (in the case of biological entities) or through intentional design (in the case of artifacts)” ([3], pp. 102-103). This hierarchy of realizable entities is visualized in Figure 1 (note that a realizable entity is “externally grounded” if and only if it is not internally grounded).

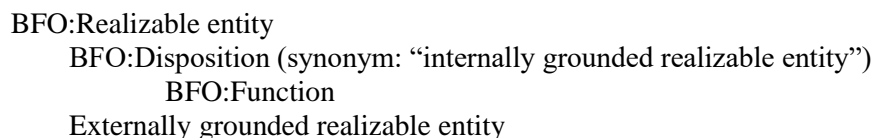


Figure 1: A hierarchy of realizable entities in BFO

2.2. A unifying dispositional framework for realizable entities in BFO

We will deploy Toyoshima et al.’s [6] unifying dispositional framework for realizable entities in BFO. It is built upon McKittrick’s [7] pragmatic and very broad conception of dispositions (which she calls “dispositional pluralism”) and an enriched theory of dispositions in BFO that has been elaborated in compliance with Röhl & Jansen’s [8] and Barton et al.’s [9] works. The pivotal idea is that multifarious realizable entities (including dispositions in BFO) can be understood as dispositions in McKittrick’s pluralist sense of the term.

Construed as a disposition in this pluralist sense, a realizable entity can be realized in some process and to be realized in a process, a realizable entity needs to be triggered by another process. A realizable entity has some “categorical basis”: roughly, a quality or sum of qualities of the bearer that render(s) the realizable entity causally relevant to its realization. For instance, the fragility of this glass can be realized in a process of glass-breaking, it can be triggered by a process of pressing the glass with sufficient force, and it has as categorical basis some specific molecular structure of the glass: the glass is fragile and can be broken because of the causal import of this molecular structure (for details, see Toyoshima et al.’s [6] discussion on the causal import of realizable entities).

To clarify dispositions in BFO, we will postulate — somewhat, if not perfectly, in Toyoshima et al.’s [6] spirit — that a realizable entity being internally (respectively: externally) grounded amounts to that realizable entity being intrinsic (respectively: extrinsic) (refer to Röhl & Jansen [1] for an alternative interpretation of realizable entities being internally/externally grounded). To be more specific, we will introduce the distinction between “intrinsic dispositions” and “extrinsic dispositions” (where the term “disposition” is used in McKittrick’s pluralist sense) and assume that an intrinsic (respectively: extrinsic) disposition in McKittrick’s terms is synonymous with an internally

(respectively: externally) grounded realizable entity in BFO's terms. Consequently, BFO:dispositions are identical to intrinsic dispositions in our McKittrick-style terminology.

The distinction between intrinsic and extrinsic dispositions is based on the distinction between intrinsic and extrinsic properties. The latter distinction is notoriously difficult to define explicitly, but the basic idea is that a property instance is intrinsic if it inheres in its bearer purely in virtue of the way its bearer is and it is extrinsic if it inheres in its bearer (at least partially) in virtue of the way the world that is external to the bearer is [10]. Paradigmatic examples of intrinsic and extrinsic dispositions include, respectively, the intrinsic disposition \mathbf{d}_{in} of this key (say \mathbf{key}_1) to open any instance of the type $Lock_2$ and the extrinsic disposition \mathbf{d}_{ex} of \mathbf{key}_1 to open this particular lock (say \mathbf{lock}_2), where \mathbf{lock}_2 is an instance of $Lock_2$. From a pluralist point of view, \mathbf{d}_{in} is intrinsic because \mathbf{key}_1 can open any instance of the type $Lock_2$ as long as \mathbf{key}_1 does not change intrinsically, while \mathbf{d}_{ex} is an extrinsic disposition because it is borne in virtue of the existence of \mathbf{lock}_2 , which is external to \mathbf{key}_1 and whose structure might change (in which case \mathbf{key}_1 would not be able to open \mathbf{lock}_2 anymore, and \mathbf{d}_{ex} would cease to exist). We can also say that \mathbf{d}_{in} is an "intrinsic dependee" [6] of \mathbf{d}_{ex} , where an intrinsic dependee is an intrinsic disposition which some extrinsic disposition depends on (technically: "relies on" [6]). Note that any extrinsic disposition has at least one intrinsic dependee.

Finally, we will provide a list of subtypes of categorical basis of realizable entities (see Figure 2). There are two kinds of categorical bases of a realizable entity: the "internal basis" and the "external basis" of this realizable entity. An internal basis inheres in the bearer of the realizable entity, whereas an external basis inheres in some entity that is external to (mereologically speaking: that does not overlap with) the bearer. To illustrate them with an example taken from Barton et al. [11], consider a match that would get burnt if scratched in the presence of oxygen. We can distinguish two closely related, but different realizable entities. First: the realizable entity (say \mathbf{rm}_{int}) of this flammable match to get burnt when scratched and surrounded by oxygen. This realizable entity \mathbf{rm}_{int} would *continue* to exist absent oxygen: \mathbf{rm}_{int} has as internal basis some quality of the match but it does not have as external basis the concentration of oxygen molecules surrounding the match (more generally, it has no external basis). The presence of oxygen molecules around the match, instead, is part of the *background condition* [8]: roughly, a necessary condition for the realization of the disposition. Second: the realizable entity (say \mathbf{rm}_{ext}) of the same match to get burnt when scratched *simpliciter*. This realizable entity \mathbf{rm}_{ext} would *cease* to exist absent oxygen: indeed, the match cannot get burnt if there is no oxygen, so in such a situation, \mathbf{rm}_{ext} would not exist. The entity \mathbf{rm}_{ext} has as internal basis some quality of the match and as external basis the concentration of oxygen molecules surrounding the match. To summarize: when the match is placed in an environment without oxygen, \mathbf{rm}_{int} exists, but \mathbf{rm}_{ext} does not exist; and when the match is placed in an environment with oxygen, both \mathbf{rm}_{int} and \mathbf{rm}_{ext} exist.

- Categorical basis (which renders the realizable entity causally relevant to its realization)
- Internal basis (which inheres in the bearer)
- External basis (which inheres in something that is external to the bearer)

Figure 2: A list of subtypes of categorical basis

3. Function in BFO

We begin by considering the realizable entity \mathbf{r}_1 of Mary's heart to pump blood in the human body in general, to wit, in any instance (such as Mary's body) of the type *Human body*. Quite importantly, \mathbf{r}_1 is an intrinsic disposition, as it still exists when Mary's heart is transplanted into another person's body, for example. In addition, \mathbf{r}_1 can be triggered by a process of Mary's heart being physically connected to a human body, it has as internal basis some quality of Mary's heart, and it has no external basis. We can plausibly take \mathbf{r}_1 to be a function in BFO: it is the function of Mary's heart to pump blood *in the human body* (whether in Mary's body or in another person's).

One can identify two realizable entities that are different from but closely related with \mathbf{r}_1 , and that are both realized by the heart pumping blood in *Mary's* body (but not in anyone's body). The first one, \mathbf{r}_2 , is analogous with \mathbf{rm}_{int} . It is the realizable entity of the heart pumping blood in *Mary's* body when it is connected to *Mary's* body. This realizable entity always exists when the heart exists — even when,

for example, the heart is placed outside Mary’s body during some cardiac surgery. The second one, r_3 , is analogous with rm_{ext} . It is the realizable entity of the heart pumping blood in Mary’s body *simpliciter* (that is, it does not need any special trigger to be realized — or said differently, it is constantly triggered). This realizable entity would cease to exist absent the physical connection of Mary’s heart with her body. As distinct from r_1 and r_2 , r_3 is an extrinsic disposition because it is borne in virtue of the existence of this particular human body (namely Mary’s body — to be precise, parts of her body) which is external to Mary’s heart. For that matter, r_3 has as external basis the connection between Mary’s body and her heart (by which we mean a quality that is external to Mary’s heart and ensures that it is connected to Mary’s body). When Mary’s heart is physically connected to another person’s, then it is r_1 , but neither r_2 nor r_3 , that can be realized in a process of Mary’s heart pumping blood in that person’s body. We can think of r_2 and r_3 as functions of Mary’s heart to pump blood in Mary’s body only. The entity r_2 is an intrinsic disposition and can thus be considered as a BFO: function. But r_3 is not a BFO: disposition, as it is not an intrinsic disposition, and thus *a fortiori* it is not a function in BFO, where BFO: function is a subtype of BFO: disposition (see Section 5 for discussion about whether r_3 — as well as another similar realizable entity to appear below — constitutes a counterexample to the current BFO dispositional account of function).² Differences among three realizable entities r_1 , r_2 and r_3 are shown in Table 1.

Table 1
Differences among realizable entities r_1 , r_2 , and r_3

	intrinsic or extrinsic disposition	external basis	trigger / background condition	realization
r_1	intrinsic disposition	none	the heart being connected to a person’s body	pumping blood in this person’s body
r_2	intrinsic disposition	none	the heart being connected to Mary’s body	pumping blood in Mary’s body
r_3	extrinsic disposition	the connection between Mary’s body and her heart	any process	pumping blood for Mary’s body

4. What is “use function”?

We move onto the notion of use function, as it remains largely unexplored in the BFO context (which we will touch on in Section 5). The basic idea is that a use function is a function that is ascribed to something in virtue of an intentional agent’s usage of that thing for her use purpose. Use functions are usually reckoned to be borne by (technical) artifacts [12]: e.g. the use function of this chair to help to reach for something. But non-artifacts can also have use functions: e.g. the use function of my nose to hold glasses and the use function of this pair of sticks in the woods to help eating. (We remark as an aside that non-artifacts with use functions may be sometimes called “naturefacts” [13].)

To investigate use function, we will employ the following driving scenario. At time t_0 , Sam sees a pair of sticks in the woods. At time t_1 , she forms the intention to use this pair of sticks (say ps_1) to help her eating. At time t_2 , she actually uses ps_1 to help her eating. We take it for granted that Sam is an intentional agent, that she did not know about the existence of ps_1 before t_0 , that nobody else finds ps_1 in the woods or intends to use ps_1 to help eating.

First of all, consider ps_1 at time t_0 . Since use function is in nature allied with an agent’s intentional usage, ps_1 has no use function at this time because there is no intention to use ps_1 to help eating. However, we can think of at least one realizable entity that is borne by ps_1 at time t_0 (as well as later) and that is related to the use function of ps_1 to help Sam’s eating, as this use function comes into being later than time t_0 . It is the realizable entity rs_1 of ps_1 to move objects when manipulated in a certain way

² We can consider the relationship between the two functions r_1 and r_2 from the perspective of their etiological element, although the etiological aspect of BFO: functions goes beyond the scope of our investigation. We are assuming that both r_1 and r_2 are functions because their bearer (namely the heart) come into being through natural selection, based on the idea that a heart is “built” (for lack of a better term) to help an organism to maintain homeostasis and controlled exchanges with the outside world for this organism. Under this assumption, r_1 and r_2 may emerge at the same time. But suppose, for the sake of argument, that we could “grow” a heart out of stem cells without planning that it would pump blood in a given individual. In this thought-experimental scenario, this “growing heart” comes into being through intentional design and thus the disposition r_1 would be indeed a function (namely a function to pump blood in any human’s body); whereas the disposition to pump blood in Mary’s body r_2 , which comes into existence at the same time as r_1 , becomes a function to pump blood in Mary’s body at a later time, when the heart is redesigned to be transplanted into Mary’s body.

(namely, the way we usually use a pair of sticks). Notably, **rs₁** is an intrinsic disposition, as it exists even before Sam sees **ps₁** in the woods. Additionally, **rs₁** can be triggered by a process of **ps₁** being moved in a certain way, it has as internal basis some quality of **ps₁**, and it has no external basis.

Consider next **ps₁** at time t_1 , where Sam intends to use **ps₁** to help her eating without actually using it for that use purpose. According to a first, broad understanding of use function, merely intending to use something for the user’s use purpose (even without actually using it) suffices to attribute to that thing the associated use function. Thus, at time t_1 (and later), **ps₁** has the broad use function to help Sam’s eating. We can characterize this use function as the realizable entity **rs₂** of **ps₁** to help Sam’s eating such that **rs₂** can be realized in a process of **ps₁** bringing food into Sam’s mouth and it can be triggered by a process of **ps₁** being moved in a certain way.

Unlike **rs₁**, **rs₂** is an extrinsic disposition because it is borne in virtue of the existence of Sam’s intention, which is external to **ps₁**, such that **rs₁** is an intrinsic dependee of **rs₂**: intuitively, **ps₁** can bring food into Sam’s mouth because of its capability to move something. In addition, **rs₂** has some external basis because it owes its existence partly to Sam’s intention to use **ps₁** to help her eating. One way of analyzing this external basis of **rs₂** is to assume, following Toyoshima et al. [14], that intention is roughly a disposition (in the pluralist sense) to actions that emerges from the complex interactions among various beliefs and desires. Given this dispositional account of intention, we can think that the external basis of **rs₂** is the internal basis of Sam’s intention to use something to help her eating. Differences between **rs₁** and **rs₂** are shown in Table 2.

We will finally consider **ps₁** at time t_2 , where Sam actually uses **ps₁** to help her eating. According to a second, narrow understanding of use function, it is not enough to merely intend to use something for a use function to come into being: a thing has a use function (in the narrow sense) only when the user *actually* uses that thing for her use purpose. Thus, at time t_2 (but not earlier), **ps₁** has the narrow use function to help Sam’s eating. One simple way to formalize this use function is to think of it as “**rs₂** when Sam actually uses **ps₁** to help her eating”, based on the idea that a broad use function becomes also a narrow use function when the user actually uses the thing for her use purpose. That is to say, **rs₂** is an instance of the type *Broad use function* between t_1 and t_2 , and becomes also an instance of the type *Narrow use function* at time t_2 .³

Table 2
Differences between realizable entities **rs₁** and **rs₂**

	intrinsic or extrinsic disposition	external basis	trigger/background condition	realization
rs₁	intrinsic disposition	none	ps₁ being manipulated in a certain way	ps₁ moving a thing
rs₂	extrinsic disposition	the categorical basis of Sam’s intention to use ps₁ to help her eating	ps₁ being manipulated in a certain way	ps₁ bringing food into Sam’s mouth

5. Discussion and related work

We will provide discussion by focusing on realizable entities **r₃** and **rs₂**, as they are not BFO:functions but may be seen as functions in their substantive sense. To consider their status in BFO more carefully, we introduce the BFO category of role: “a realizable entity that (1) exists because the bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be (optionality), and (2) is not such that, if this realizable entity ceases to exist, then the physical make-up of the bearer is thereby changed (external grounding)” ([3], pp. 99-100). Therefore, a role amounts to an optional and externally grounded realizable entity. Examples of roles include the role of being a student and the role of this heart to being a plastinated prop in a museum display.

³ Note that this raises the issue of when a realizable entity gets and stops having a broad use function. If Sam uses the stick to bring some food in her mouth, and then stops using them for a few seconds in order to chew her food, do the sticks stop having a broad use function during that time? That is, during that time, **rs₂** would still be an instance of *Narrow use function*, but would not be an instance of *Broad use function*? (we thank an anonymous reviewer for this remark). This conclusion might be avoided by endorsing a definition of “use” that has a large enough temporal window (Sam “uses” the sticks during her whole meal, even when she is only chewing her food). Alternatively, if one is uncomfortable with this back and forth into instantiating *Broad use function*, this might be an argument in favor of sticking to narrow use functions only, as **rs₂** remains an instance of *Narrow use function* even when Sam stops temporarily using the sticks to chew her food (since she intends to use them to bring food to her mouth again).

Since we equate the type *Externally grounded realizable entity* with the type *Extrinsic disposition*, if r_3 is optional, then it is a role in BFO (and similarly so for rs_2). Although the BFO notion of optionality remains to be defined precisely, we can think that use functions are roles in BFO: for instance, ps_1 has rs_2 merely because it finds itself in the situation in which Sam intends to use it to help her eating (and thus rs_2 is optional). As a matter of fact, Spear et al. [5] and Röhl & Jansen [1] submit that use function is a role in BFO. Besides, “the role of a stone in marking a boundary” is cited as an example of a role in BFO ([3], p. 100) and this role can be taken as a use function.

Let us now turn to r_3 : is r_3 optional (and thus a role in BFO) or non-optional? To tackle this question, it will be useful to examine the optionality of rs_2 . Given the BFO sense of optionality (refer to Röhl & Jansen [1] for an alternative interpretation of optionality), it means that rs_2 exists in virtue of the circumstances in which ps_1 does not have to be: those in which Sam intends to use ps_1 to help her eating. In other words, rs_2 owes its existence partly to the *external* fact that Sam intends to use ps_1 to help her eating. This may turn out to be equivalent to the statement that rs_2 has as *external* basis the internal basis of Sam’s intention to use something to help her eating. This line of reasoning can yield the general hypothesis that a realizable entity is optional if (or perhaps more strongly: if and only if) it has some external basis. Given this hypothesis, r_3 is optional (and is a role in BFO).

As for r_2 , it is a BFO:disposition and thus might be seen as a function (as it arguably satisfies the etiological requirement of a BFO:function). It is thus important, when introducing a BFO:function, to clarify whether one has in mind an entity like r_1 or r_2 .

6. Conclusion

We analyzed the notion of function within a recently proposed, unifying dispositional framework for realizable entities in the BFO upper ontology. We distinguished different closely related entities falling into BFO:function (r_1 and r_2) and argued that when introducing a BFO:function, one needs to clarify which of those is referred to. We also argued that there can be some realizable entities (r_3 and rs_2) that we may think of as functions but that fall outside the purview of the current BFO dispositional account of function because they can be characterized as extrinsic dispositions. We also contended that use functions can be generally formalized as extrinsic dispositions.

In the future we will further this line of inquiry into a BFO-based ontology of function. Examples of the tasks to be grappled with include a meticulous analysis of the etiological element of the BFO notion of function and a more sophisticated clarification of the BFO notion of optionality (especially in connection with the external basis of a realizable entity, as we briefly discussed in Section 5). It is also worthwhile to formulate and compare possible views with different implications for the present BFO theory of function. One prominent view is the “revisionary view”, which would both expand the extent of *Function* in BFO to cover such realizable entities as r_3 and/or rs_2 (for thoughts, see Artiga’s [15] remark on “a pluralist view on functions” that is compatible with BFO⁴ and his claim that a satisfactory theory of function should capture “the distinction between *having a function* and *functioning as*” — chairs for sitting and chairs for helping to reach for something, to borrow one of his illustrative examples — the latter being intimately related to use function). Another major view is the “conservative view”, which would keep the same extent for *Function* in BFO by explaining why some entities are commonly called “functions”, although they are not BFO:functions (for this line of reasoning, see Spear et al.’s [5] and Röhl & Jansen’s [1] opinion that the BFO theory of function does not need to cover use function). Finally, by advancing our approach to function, we plan to examine a long-standing controversy over whether the current BFO dispositional account of function can account for malfunctioning [1][2][5].⁵

⁴ Artiga [15] (p.98) states: “Spear and colleagues [by which he means Spear et al. [5]] admit that their proposal is not supposed to exhaust all possible categories that should be included in the taxonomy, so if different accounts turn out to capture different senses of function, further branches could be added to it (...). Thus, in principle BFO is fully compatible with a pluralist view on functions. For instance BFO could include a $Function_1$ category at the same level of *Disposition* and *Role* and a $Function_2$ category as a subtype of *Disposition*. Obviously, that option would be less parsimonious, but it might be in position to accommodate more cases. In any case, it seems to be an alternative worth considering.”

⁵ FT acknowledges financial support by the SPOR Canadian Data Platform (CIHR). We thank two anonymous reviewers for their helpful feedback.

7. References

- [1] Röhl J, Jansen L. Why functions are not special dispositions: an improved classification of realizables for top-level ontologies. *J Biomed Semant.* 2014;5, 27. <https://doi.org/10.1186/2041-1480-5-27>
- [2] Jansen L. Functions, malfunctioning, and negative causation. In: Christian A, Hommen D, Retzlaff N, Schurz G, eds. *Philosophy of science.* Springer;2018:117-135.
- [3] Arp R, Smith B, Spear AD. *Building Ontologies with Basic Formal Ontology.* Cambridge, MA: MIT Press; 2015.
- [4] Otte JN, Beverley J, Ruttenberg A. BFO: Basic Formal Ontology. *Appl Ontol.* 2022;17(1):17-43. doi:10.3233/AO-220262.
- [5] Spear AD, Ceusters W, Barry S. Functions in Basic Formal Ontology. *Appl Ontol.* 2016;11(2):103-128. doi:10.3233/AO-160164
- [6] Toyoshima F, Barton A, Jansen L, Ethier, JF. Towards a unified dispositional framework for realizable entities. In: Brodaric B, Neuhaus F, eds. *Proceedings of the 12th International Conference on Formal Ontology in Information Systems (FOIS 2021).* IOS Press;2021:13-17.
- [7] McKittrick J. *Dispositional pluralism.* Oxford University Press; 2018.
- [8] Röhl J, Jansen L. Representing dispositions. *J Biomed Semant.* 2011;2, S4. <https://doi.org/10.1186/2041-1480-2-S4-S4>
- [9] Barton A, Grenier O, Jansen L, Ethier JF. The identity of dispositions. In: Borgo S, Hitzler P, Kutz O, eds. *Proceedings of the 10th International Conference on Formal Ontology in Information Systems (FOIS 2018).* IOS Press;2018:113-125.
- [10] Marshall D, Weatherson B. Intrinsic vs. extrinsic properties. In: Zalta EN, ed. *The Stanford Encyclopedia of Philosophy.* Spring 2018 ed. Available from: <https://plato.stanford.edu/archives/spr2018/entries/intrinsic-extrinsic/>
- [11] Barton A, Rovetto R, Mizoguchi R. Newtonian forces and causation: a dispositional account. In: Garbacz P, Kutz O, eds. *Proceedings of the 8th International Conference on Formal Ontology in Information Systems (FOIS 2014).* IOS Press;2014:157-170.
- [12] Borgo S, Franssen M, Garbacz P, Kitamura Y, Mizoguchi R, Vermaas PE. Technical artifacts: an integrated perspective. *Appl Ontol.* 2014;9(3-4):217-235. doi:10.3233/AO-140137
- [13] Hilpinen R. Artifact. In: Zalta EN, ed. *The Stanford Encyclopedia of Philosophy.* Winter 2011 ed. Available from: <https://plato.stanford.edu/archives/win2011/entries/artifact/>
- [14] Toyoshima F, Barton A, Grenier O. Foundations for an ontology of belief, desire and intention. In: Brodaric B, Neuhaus F, eds. *Proceedings of the 11th International Conference on Formal Ontology in Information Systems (FOIS 2020).* IOS Press;2020:140-154
- [15] Artiga, M. New perspectives on artifactual and biological functions. *Appl Ontol.* 2016;11(2):89-102. doi:10.3233/AO-160166