Formal Ontology in Information Systems
S. Borgo et al. (Eds.)

doi:10.3233/978-1-61499-910-2-113

The Identity of Dispositions

Adrien BARTON[a,1], Olivier GRENIER[a], Ludger JANSEN[b] and Jean-François ETHIER[a,1]
[a] *GRIIS, Université de Sherbrooke, Quebec, Canada*
[b] *Ruhr University Bochum, Germany*

Abstract. Clear criteria for the identity of dispositions are still lacking, and this has been presented as one of the main challenge raised by such entities. It is of prime importance to identify or distinguish dispositions such as diseases or risks. This article first introduces conventional ways to refer to a disposition (such as “fragility”) and canonical ways (such as “disposition to break in case of a strong shock”). This raises the issue of how should exactly be defined a “disposition **d** to *R* when *TR*”, where *R* is a realization specification and *TR* a trigger specification. Two ontological frameworks are distinguished. The first framework, which has been largely used so far in the literature on dispositions, interprets **d** as a disposition which can only be triggered by instances of *TR*, and can only be realized by instances of *R*. The second, new framework introduces the notion of “minimal trigger” and “maximal realization”, and interprets *TR* as a parent class of a class of processes that have as part a minimal trigger, and *R* as a parent class of a class of processes that are parts of a maximal realization. We then discuss several criteria of identity, including the criterion according to which two dispositions are identical iff they have the same categorical basis, the same class of minimal triggers and the same class of maximal realizations. We show on several examples that the second framework avoids the disposition multiplicativism that is introduced by the first framework.

Keywords. Disposition, Identity, Causality, Trigger, Realization, Multiplicativism.

1. Introduction

Dispositions are entities such as fragility, inflammability, solubility, or vulnerability to poison, which can be triggered by some process, leading to a realization process. They may exist even if they are not realized or even triggered: I am vulnerable to arsenic even if I never ingest any arsenic in my life. Dispositions are causal properties, and for this reason, they are of central importance for scientific ontologies. They have been used to formalize diseases [1], risks [2], or probabilities [3]. A formalization of dispositions has been proposed in the framework of the Basic Formal Ontology (BFO) [4], and a theory of mereology of dispositions has been sketched [5].

However, dispositions have some disturbing characteristics. A common worry is that there are many of them: dispositions are often identified with causal powers (the capacity of an entity to cause some effect), and the world is replete with causal powers. Their identity is one of the main argument that has been raised against the relevance of

[1] Corresponding authors, GRIIS, Université de Sherbrooke, 2500 Boulevard de l'Université, Sherbrooke, QC J1K 2R1, Canada; E-mails: adrien.barton@gmail.com; ethierj@gmail.com. We thank Barry Smith and three reviewers for useful comments. AB and OG acknowledge financial support by the CIHR-funded Quebec SPOR Support Unit.

dispositions in applied ontologies: as stated by Guarino [6], “the difficulty of distinguishing one disposition from another […] is a good evidence of their problematic status”. Moreover, in some cases, what we would identify as one causal power seems to give rise to several dispositions. For example, OGMS, the Ontology for General Medical Science [1], formalizes a disease as a disposition realized by the whole disease course, the latter being composed by several pathological processes. But does it mean that there is another disposition realized by each of those pathological processes? If yes, we have a case of “disposition multiplicativism”. Another example concerns risks, which have been identified with dispositions [2]. Consider a person with atrial fibrillation who has a risk to have a stroke. Obviously, the probability of his risk of stroke over 6 months is different from the probability of his risk of stroke over 12 months; but does it mean that he has two dispositions, one risk at 6 months, and another risk at 12 months? This leads to a question about the identity of dispositions: what are the conditions for two dispositions to be identical (that is, for them to be the same entity)?

This article will analyze this question. The next part will distinguish a disposition from its categorical basis. A third part will differentiate two ways to refer to dispositions, and analyze how to specify the triggers and realizations of a disposition, contrasting the framework accepted so far, labelled here “ONLY”, with a new framework labelled “PARTHOOD”. A fourth part will argue that PARTHOOD is more ontologically economical than ONLY. A conclusion will follow.

Next to standard first-order logic, we will make use of the Manchester Syntax [7] for the Web Ontology Language (OWL), which is a description language for ontologies based on Description Logics. Terms for universals will be italicized and terms for particulars will be written in bold. If **a** and **b** are particulars, **a**+**b** is defined as the mereological sum of **a** and **b**. Similarly, if *A* and *B* are classes or universals, *A*+*B* is defined as the class of mereological sums of one instance of *A* and one instance of *B*.

2. Dispositions and their categorical bases

2.1. Formalization of dispositions in BFO

Our ontological framework builds on a model of dispositions (and processes) proposed in the context of the Basic Formal Ontology (BFO) [8], but should be adaptable to other upper ontologies. BFO defines a disposition as a realizable entity “that exists because of certain features of the physical makeup of the independent continuant that is its bearer” ([2], p. 178). To be realized in a process, a disposition needs to be triggered by some other process: for example, $\mathbf{strong\_shock_0}$ can trigger the disposition $\mathbf{fragility_0}$ of $\mathbf{glass_0}$ ($\mathbf{fragility_0}$ **has_trigger** $\mathbf{strong\_shock_0}$, or $\mathbf{strong\_shock_0}$ **trigger_of** $\mathbf{fragility_0}$) which is then realized by $\mathbf{glass_0\_breaking}$ ($\mathbf{fragility_0}$ **has_realization** $\mathbf{glass_0\_breaking}$ or $\mathbf{glass_0\_breaking}$ **realization_of** $\mathbf{fragility_0}$) – where **has_trigger** and **has_realization** are primitive relational predicates for causal relations.

2.2. What are categorical bases?

The fragility of a glass exists because of a certain molecular structure of this glass. The inflammability of a match exists because of its chemical constitution. Whatever constitutes a disposition is sometimes called the “causal basis” of the disposition [9]. There are several proposals concerning the nature of causal bases. For one, BFO [8] introduces the "material basis" of a disposition as a material entity. E.g., the morphine contained in opium is the material basis of opium's dormitive virtue, and my weak eye muscle is the material basis of my short-sightedness. The material basis of a disposition is a material entity. This, however, cannot always capture finely enough the causal structure relevant for a disposition. Imagine a glass whose molecular structure makes it both fragile and electrically resistive: the material basis of both its fragility and its electrical resistivity is the whole glass – but because of different properties. Therefore, following Röhl & Jansen [4], we introduce the notion of "categorical basis", which is a quality (or a sum of qualities) of the disposition bearer. The categorical basis of the glass fragility is the sum of qualities of the glass that make it fragile, and the categorical basis of its electrical resistivity is the sum of qualities of the glass that make it electrically resistive. Thus, the notion of categorical basis enables a finer identification of the specific causal factors underlying a disposition.

2.3. Are categorical bases the same entities as dispositions?

Aiming at parsimony, it is tempting to identify dispositions with their categorical bases. Guarino [6] argues in favor of the identification, as the "truth-maker of the property *being fragile* seems to be the same as the truth-maker of the property *having a certain crystalline structure*." Prior, Pargetter & Jackson [9] argue against this identification, but their arguments rely on the ontological hypothesis that properties exist only as types, or universals, and other debatable hypotheses about the nature of identity between types. Mumford [10] replies to them that dispositions and categorical bases are different at type level, but the same at token level, i.e., that categorical terms and dispositional terms are just two ways to refer to the same entity at the token level.

There is, however, a good reason not to subscribe to this token-identity thesis, as dispositional and categorical tokens seem to satisfy different relations. For example, one can define mereological relations on dispositions [5], such that a disposition of $\mathbf{glass_0}$ to break-or-crack has as proper parts a disposition to break and a disposition to crack; however, the categorical basis of the disposition of $\mathbf{glass_0}$ to break and the categorical basis of the disposition of $\mathbf{glass_0}$ to crack are not proper parts of the categorical basis of the disposition of $\mathbf{glass_0}$ to break-or-crack. Those three bases are rather identical.

In contrast, imagine that the *very same* qualities underlie the fragility and electrical resistivity of $\mathbf{glass_0}$ – and, thus, that we cannot distinguish the categorical basis of its fragility from the categorical basis of its electrical resistivity. Still, we can distinguish fragility (as a disposition to break) from electrical resistivity (as a disposition to block electric current). Therefore, we have good reasons not to identify dispositions with their categorical basis.

3. Defining trigger specification, realization specification and bearer

3.1. Conventional and canonical dispositions: definitions

We need to distinguish two ways to refer to dispositions [11]. *Conventional descriptions* are terms or phrases regimented in common language or scientific discourse, such as "fragility" of "solubility" not explicitly referring to their triggers or realizations. In contrast, *canonical descriptions* explicitly describe a disposition in terms of their triggers and realizations. For example, "a disposition to *R* when *TR*" is characterized by the trigger specification *TR* and the realization specification *R* (we will call the association of a trigger specification and a realization specification a "track"). Consider a magnet **magnet$_0$**, and let *Attraction* be the class of attraction processes between two magnets, *Repulsion* the class of repulsion processes between two magnets, *Unlike poles approach* the class of processes during which two magnets are approached with opposite poles facing, and *Like poles approach* the class of processes during which two magnets are approached with similar poles facing. Then, examples of canonical dispositions include the single-track **attraction_power$_0$** of **magnet$_0$** to *Attraction* when *Unlike poles approach*, its single-track **repulsion_power$_0$** to *Repulsion* when *Like poles approach*, and its multi-track **attraction_and_repulsion_power$_0$** to *Attraction* when *Unlike poles approach* and to *Repulsion* when *Like poles approach*. Following the above-mentioned theory of mereology among dispositions [5], the following parthood relations (named "**mod-part_of**") obtain between these three canonical dispositions:

- **attraction_power$_0$ mod-part_of attraction_and_repulsion_power$_0$**
- **repulsion_power$_0$ mod-part_of attraction_and_repulsion_power$_0$**

Put differently, **attraction_and_repulsion_power$_0$** is a mod-complex (that is, a disposition with a proper mod-part) that has two possible pathways, or modes, of being realized: via **attraction_power$_0$** or via **repulsion_power$_0$**.

Canonical descriptions are typically useful to analyze the structure of dispositions referred to by conventional names. For example, we might analyze the conventional disposition **magnetism$_0$** of **magnet$_0$** by stating that it is identical with a canonical multi-track disposition to *Attraction* when *Unlike poles approach* and to *Repulsion* when *Like poles approach*. We will here deal with canonical dispositions that are sure-fire, i.e., that are invariably realized when triggered [4], and for which there are no masks, i.e., no entities blocking the process that would otherwise lead from a trigger to a realization, like a cushion would mask the breaking of **glass$_0$** [11]. As we will see, there are two non-equivalent ways to formalize canonical dispositions: ONLY and PARTHOOD.

3.2. Defining canonical dispositions

3.2.1. ONLY: A first framework for canonical dispositions

Following Röhl & Jansen [4], we consider first a single-track disposition **d** that has **x** as a bearer, *R* as its realization specification and *TR* as its trigger specification, and which can thus be described as "a disposition **d** of **x** to *R* when *TR*"; and we will ignore the distinction between "trigger" and "background conditions". A trigger specification and a realization specification are formalized as follows:

(ONLY TR_{Class}) **d** is a disposition with the trigger specification *TR* iff
(*TR* SubClassOf *Process*) and (**d has_trigger** only *TR*).

(ONLY R_{Class}) **d** is a disposition with the realization specification *R* iff
(*R* SubClassOf *Process*) and (**d has_realization** only *R*).

The last clause of (ONLY TR_{Class}) can be rephrased as '(**trigger_of** value **d**) SubClassOf *TR*', where '**trigger_of** value **d'** (abbreviated in the following '**trigger_of d**') is the class whose instances **tr** are such that '**tr trigger_of d**', that is, the class of triggers of **d**. Analogously, the last clause of (ONLY R_{Class}) can be rephrased as '(**realization_of** value **d**) SubClassOf *R*', where '**realization_of** value **d**' (abbreviated in the following '**realization_of d**') is the class whose instances **r** are such that '**r realization_of d**', that is, the class of realizations of **d**. The two conditions (ONLY $\mathrm{TR}_{\mathrm{Class}}$) and (ONLY $\mathrm{R}_{\mathrm{Class}}$) can be translated into first-order logic by quantifying over instances:

(ONLY $\mathrm{TR}_{\mathrm{Instance}}$) **d** has the trigger specification *TR* iff for all **tr**:
(**tr instance_of** *TR* → **tr instance_of** *Process*) and
(**d has_trigger tr** → **tr instance_of** *TR*)

(ONLY $\mathrm{R}_{\mathrm{Instance}}$) **d** has the realization specification *R* iff for all **r**:
(**r instance_of** *R* → **tr instance_of** *Process*) and
(**d has_realization r** → **r instance_of** *R*))

However, such a reading would be insufficient in an ontology in which we would quantify over actual entities only. As a matter of fact, any disposition **d** that is never triggered and never realized would trivially satisfy these two conditions. So, for example, if **glass$_0$** is never hit by a strong shock during its history, we could state that its **disposition_to_break$_0$** has the trigger specification *Heart_beating* and has the realization specification *Headache*, or any other unrelated processes. Therefore, the quantification above should hold as a matter of necessity: the right-hand side in (ONLY $\mathrm{TR}_{\mathrm{Instance}}$), for example, should be read as holding that *necessarily* any trigger of **d** is an instance of *TR* (and any instance of *TR* is an instance of *Process*). This would mean that **disposition_to_break$_0$** *could only* be realized by a breaking process, and *could only* be triggered by a strong shock. Such a reading is implicit in (ONLY $\mathrm{TR}_{\mathrm{Class}}$), if we accept the distinction drawn between classes and sets by Johansson [12]: a set is identified by its members, whereas the identity of a class goes beyond its actual instances. We consider that this holds for all classes, including fully defined ones. Thus, a class such as '**trigger_of d**' share some similarities with the "terminological units" (as defined in [13]), as they might have no extension in the actual world. In the following, we will call "ONLY" the framework composed by the conjunction of (ONLY $\mathrm{R}_{\mathrm{Class}}$) and (ONLY $\mathrm{TR}_{\mathrm{Class}}$).

In general, not any instance of a trigger specification *TR* would trigger **d**. For example, not every instance of *Strong_shock* would trigger **disposition_to_break$_0$**: clearly, an instance of *Strong_shock* in which **glass$_0$** does not participate would not trigger this disposition. For the same reason, not any instance of a realization specification *R* would be a realization of **d**. This means that in general, we do not have '(**trigger_of d**) EquivalentTo *TR*', nor '(**realization_of d**) EquivalentTo *R*'. It is important, that is, to distinguish a trigger specification (resp. realization specification) for a disposition from its class of actual triggers (resp. class of actual realizations).

One could suggest that any instance of *TR in which **b** participates* is a trigger of **d** (and that any instance of *R in which **b** participate* is a realization of **d**). But this must also be rejected. As a matter of fact, **glass$_0$** could participate in a *Strong_shock* in a way different from the one intended – for example, by being used as a tool to hit a more fragile **glass$_1$** that would break, while **glass$_0$** would remain intact. Therefore, if we want to find a trigger specification such that every instance of this class would trigger **d**, and a realization specification such that every instance of this class would realize **d**, we should define them by referring to the particular(s) involved. For example, we could define **disposition_to_break$_0$** as a disposition to ***glass$_0$**_Breaking* when

*Strong_shock_on_**glass**$_0$* (which are both defined classes, rather than universals). We will call this a *full specification* of a disposition:

> (FULL SPECIFICATION) The phrase "a disposition to *Rfull* when *TRfull*" is a full specification of **d** iff:
> *TRfull* EquivalentTo (**trigger_of d**) and *Rfull* EquivalentTo (**realization_of d**)

3.2.2. Disposition multiplicativism in ONLY

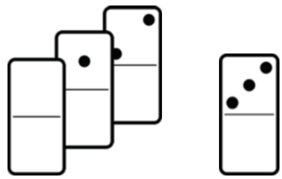


Figure 1. Domino configuration 1

Consider three dominos, **domino$_0$**, **domino$_1$** and **domino$_2$**, which are placed in a line from left to right (cf. the left part of configuration 1 in Figure 1), such that if we push **domino$_0$** to the right (the class of such processes is named "$Push_{\rightarrow 0}$"), it will fall ($Fall_{\rightarrow 0}$) and push **domino$_1$**, that will fall ($Fall_{\rightarrow 1}$) and push **domino$_2$** that will fall ($Fall_{\rightarrow 2}$). More precisely, we define for i $\in \{0, 1, 2\}$:

$Push_{\rightarrow i}$ $=_{\text{def}}$ a process during which **domino$_i$** is pushed to the right in configuration 1.

- $Fall_{\rightarrow i}$ $=_{\text{def}}$ a process during which **domino$_i$** falls to the right onto the floor in configuration 1.

According to those definitions, $Fall_{\rightarrow 0}$ SubClassOf $Push_{\rightarrow 1}$, because the process during which **domino$_0$** falls to the right in the configuration 1 is a process during which **domino$_1$** is pushed to the right. Similarly, $Fall_{\rightarrow 1}$ SubClassOf $Push_{\rightarrow 2}$. (Of course, it would not be the case if the domino configuration was different from configuration 1; this configuration should therefore be seen as a background condition for the dispositions mentioned below – and, as suggested earlier, is here integrated into the trigger.)

Consider, e.g., the following four dispositions: 1) $\mathbf{d}_{\rightarrow 0;\rightarrow 2}$ to $Fall_{\rightarrow 2}$ when $Push_{\rightarrow 0}$ 2) $\mathbf{d}_{\rightarrow 0;\rightarrow 1,2}$ to $Fall_{\rightarrow 1,2}$ when $Push_{\rightarrow 0}$ (where $Fall_{\rightarrow 1,2}$ is the class of falls of **domino$_1$** and fall of **domino$_2$** where the former causes the latter) 3) $\mathbf{d}_{\rightarrow 0;\rightarrow 0,1,2}$ to $Fall_{\rightarrow 0,1,2}$ when $Push_{\rightarrow 0}$ 4) $\mathbf{d}_{\rightarrow 0;\rightarrow 0,2}$ to $Fall_{\rightarrow 0,2}$ when $Push_{\rightarrow 0}$. According to ONLY, those four dispositions are different from each other, as they do not have the same classes of realizations. Suppose for example that **domino$_0$** is pushed, causing a chain of falls of **domino$_{0,1,2}$** (= **domino$_0$+domino$_1$+domino$_2$**) named **fall$_{0,1,2}$**; then **fall$_{0,1,2}$** is a realization of $\mathbf{d}_{\rightarrow 0;\rightarrow 0,1,2}$, but it is not a realization of $\mathbf{d}_{\rightarrow 0;\rightarrow 1,2}$ nor a realization of $\mathbf{d}_{\rightarrow 0;\rightarrow 2}$.

Suppose now that **domino$_3$** is also next to **domino$_0$** as in figure 1. Consider the following dispositions: $\mathbf{d}_{\rightarrow 0;\rightarrow 0}$ to $Fall_{\rightarrow 0}$ when $Push_{\rightarrow 0}$; and $\mathbf{d}_{\rightarrow 0,3;\rightarrow 0}$ to $Fall_{\rightarrow 0}$ when $Push_{\rightarrow 0}$+$Push_{\rightarrow 3}$. According to ONLY, those two dispositions are different from each other, as they do not have the same class of triggers. For example, if **domino$_0$** is pushed (during the process **push$_0$**) at the same time as **domino$_3$** (during the process **push$_3$**), then **push$_0$** is a trigger of $\mathbf{d}_{\rightarrow 0;\rightarrow 0}$, but **push$_0$+push$_3$** is not. For the same reasons, $\mathbf{d}_{\rightarrow 3;\rightarrow 3}$ and $\mathbf{d}_{\rightarrow 0,3;\rightarrow 3}$ are different.

Thus, ONLY commits to a relatively strong form of disposition multiplicativism. We will now discuss an alternative, more economical ontological framework.

3.2.3. PARTHOOD: A second framework for canonical dispositions

One might want to endorse a more encompassing conception of triggers and realizations of a disposition than the one implied by ONLY. We might accept that whenever a disposition **d** is triggered by a process **tr**, it is also triggered by processes having **tr** as a part; for example, the mereological sum of a strong shock on $\mathbf{glass_0}$ and John's heart beating (or any other unrelated process) is also a trigger of $\mathbf{disposition\_to\_break_0}$; or in Figure 1, $\mathbf{push_0}$+$\mathbf{push_3}$ is also a trigger of $\mathbf{d}_{\to 0;\to 0}$. Similarly, we might say that whenever **d** is realized by a process **r**, it is also realized by processes that are parts of **r**; e.g., any part of the breaking of $\mathbf{glass_0}$ caused by a strong shock would also be a realization of $\mathbf{disposition\_to\_break_0}$; or, in Figure 1, $\mathbf{fall_0}$ and $\mathbf{fall_{1,2}}$ are also realizations $\mathbf{d}_{\to 0;\to 0,1,2}$.

Formally, this could be expressed by stating that a process that would have as part a trigger of **d** is a trigger of **d**, and a process that would be a part of a realization of **d** is a realization of **d**:

(HAS-PART$_{TR}$)
(*Process* and (**has_part** o **trigger_of d**)) SubClassOf (**trigger_of d**)

(PART-OF$_R$)
(*Process* and (**part_of** o **realization_of d**)) SubClassOf (**realization_of d**)

(HAS-PART$_{TR}$) clearly implies that some parts of the trigger might not play any causal role in leading the disposition to be realized. What causally matters in the mereological sum of a strong shock on $\mathbf{glass_0}$ and my heart beating in triggering $\mathbf{disposition\_to\_break_0}$ is only the strong shock. Actually, what causally matters might even be only a proper part of the strong shock, such as the final part of the shock, during which is applied a pressure above a threshold value P_1 – let's call the class of such processes *Pressure>P$_1$*_$\mathbf{glass_0}$. This leads to define the class of minimal triggers of **d**: the class of triggers of **d** for which no proper part is a trigger of **d**. Therefore, we can define the class of minimal triggers of **d** named "*TRmin*(**d**)" as follows:

(TRMIN) *TRmin*(**d**) EquivalentTo
[(**trigger_of d**) and not (**has_proper_part** o **trigger_of d**)]

Similarly, we can define the class *Rmax*(**d**) of maximal realizations of **d** as follows as realizations of **d** who are not proper parts of another realization of **d**:

(RMAX) *Rmax*(**d**) EquivalentTo
[(**realization_of d**) and not (**proper_part_of** o **realization_of d**)]

Intuitively, an instance **trmin** of *TRmin*(**d**) is a smallest part of a trigger of **d**, such that the interaction of **trmin** with the categorical basis of **d** is enough to cause a realization of **d**. Similarly, an instance **rmax of** *Rmax*(**d**) is a largest whole that has a realization of **d** as part, such that there is an instance **trmin** of *TRmin*(**d**) whose interaction with the categorical basis of **d** causes **rmax** (or, put differently, it is the mereological sum of all processes that are caused by the interaction of **trmin** and **b**). Note that when we use the word "caused", we do not only mean "proximally caused", but also "distally caused": that is, if there is a causal chain due to the categorical basis of **d** which is triggered by **trmin**, then the whole causal chain of events belongs to the realization **rmax** of **d**. However, if some process is caused by the interaction not only of the categorical basis of **d** and **trmin**, but also by other factors, then it is not a part of **rmax**.

Reciprocally, by application of (HAS-PART$_{TR}$) and (PART-OF$_{R}$), the triggers of **d** are exactly the processes that have as part a minimal trigger of **d**, and the realizations of **d** are exactly the processes that are a part of a maximal realization of **d**:

(TRIGGER) (**trigger_of d**) EquivalentTo
[*Process* and (**has_part** some *TRmin*(**d**))]

(REALIZATION) (**realization_of d**) EquivalentTo
[*Process* and (**part_of** some *Rmax*(**d**))]

Note that we chose here to speak of a class of minimal triggers, and of classes of triggers which have as parts those minimal triggers; but alternatively, we might have reserved the term "triggers" for the minimal triggers, and called processes that include those triggers "over-triggers" (in which case, if **ot** is an over-trigger of **d**, then there is a part **t** of **ot** such that **d has_trigger t**). The choice between both vocabularies has no real ontological import, so we will chose the first option to be in the continuity of Röhl & Jansen [4] model and other later works that built on it.

In this framework, a disposition is characterized by its classes of minimal triggers and maximal realizations. However, it is still possible to characterize a disposition by its trigger specification and realization specification in order to describe, for example, that **disposition_to_break$_0$** is a disposition to *Breaking* when *Strong_shock*. A trigger specification *TR* of a disposition **d** is any class of processes that has a subclass *TR'* whose instances all have as part some minimal trigger of **d**:

(HAS-PART$_{TRMIN}$) A disposition **d** has a trigger specification *TR* iff:
TR SubClassOf *Process*, and there is a class *TR'* such that:
TR' SubClassOf *TR* and *TR'* SubClassOf (**has_part** some *TRmin*(**d**)).

For example, according to (HAS-PART$_{TRMIN}$), **disposition_to_break$_0$** has the trigger specification *Strong_shock* because *Strong_shock* is a parent class of *Strong_shock_on_***glass$_0$**, whose instances all have as part an instance of *Pressure>P$_1$_on_glass$_0$* (that is, a minimal trigger of **disposition_to_break$_0$**).

Similarly, we can define a realization specification of a disposition **d** as any class of process such that any maximal realization of **d** has as part some element of this class:

(PART-OF$_{RMAX}$) A disposition **d** has a realization specification *R* iff:
R SubClassOf *Process*, and there is a class *R'* such that:
R' SubClassOf *R* and *Rmax*(**d**) SubClassOf (**has_part** some *R*').

E.g., according to (PART-OF$_{RMAX}$), **disposition_to_break$_0$** has the realization specification *Breaking* because *Breaking* has as subclass **glass$_0$**_*Breaking*, and every maximal realization of **disposition_to_break$_0$** has as part an instance of **glass$_0$**_*Breaking*.

We will call "PARTHOOD" the framework composed by the assumptions (HAS-PART$_{TR}$), (PART-OF$_{R}$), (HAS-PART$_{TRMIN}$) and (PART-OF$_{RMAX}$). The two different ontological frameworks ONLY and PARTHOOD thus both define what is a trigger specification and a realization specification – though, as we will see, a disposition is more finely characterized by its full specification in ONLY, and by its classes of minimal triggers and realizations in PARTHOOD. We will now specify the maximal realizations on a few domino examples.

3.3. Specifying the maximal realization: Domino examples

On the domino example in Figure 1, $TRmin(\mathbf{d}_{\to 0;\to 1})$ might be the application of a momentum above M_0 on $\mathbf{domino_0}$; let's call it $Minimal\_push_{\to 0}$. We have seen above that an instance *Rmax* is the mereological sum of all processes that are caused by the interaction of a minimal trigger **trmin** and the categorical basis of $\mathbf{d}_{\to 0;\to 1}$. So what would be $Rmax(\mathbf{d}_{\to 0;\to 1})$? To answer this, we need to specify further $\mathbf{d}_{\to 0;\to 1}$, as it has been so far ambiguously defined. We can first define $\mathbf{d}_{\to 0;\to 1}{}^{do0,1,2}$ as the disposition to $Fall_{\to 1}$ when $Push_{\to 0}$ inhering in $\mathbf{domino_{0,1,2}}$. But we can also define $\mathbf{d}_{\to 0;\to 1}{}^{do0,1}$ as the disposition to $Fall_{\to 1}$ when $Push_{\to 0}$ inhering in $\mathbf{domino_{0,1}}$ only. The interaction of $Push_{\to 0}$ with the categorical basis of $\mathbf{d}_{\to 0;\to 1}{}^{do0,1,2}$ borne by $\mathbf{domino_{0,1,2}}$ will cause an instance of $Fall_{\to 0,1,2}$. However, the interaction of an instance of $Push_{\to 0}$ with the categorical basis of $\mathbf{d}_{\to 0;\to 1}{}^{do0,1}$ borne by $\mathbf{domino_{0,1}}$ will only cause an instance of $Fall_{\to 0,1}$. Thus, $Rmax(\mathbf{d}_{\to 0;\to 1}{}^{do0,1,2}) = Fall_{\to 0,1,2}\_caused\_by\_Push_{\to 0}$ (where the latter is a subclass of $Fall_{\to 0,1,2}$, when those falls are caused by an instance of $Push_{\to 0}$) and $Rmax(\mathbf{d}_{\to 0;\to 1}{}^{do0,1}) = Fall_{\to 0,1}\_caused\_by\_Push_{\to 0}$.

Therefore, $\mathbf{d}_{\to 0;\to 0,1,2}{}^{do0,1,2}$, $\mathbf{d}_{\to 0;\to 0,2}{}^{do0,1,2}$, $\mathbf{d}_{\to 0;\to 1,2}{}^{do0,1,2}$, $\mathbf{d}_{\to 0;\to 0,1}{}^{do0,1,2}$, but also $\mathbf{d}_{\to 0;\to 2}{}^{do0,1,2}$, $\mathbf{d}_{\to 0;\to 1}{}^{do0,1,2}$ and $\mathbf{d}_{\to 0;\to 0}{}^{do0,1,2}$ all have the same class of maximal realization, namely $Fall_{\to 0,1,2}\_caused\_by\_Push_{\to 0}$: the class of realizations systematically depends on the categorical basis and the class of minimal triggers. To determine whether these dispositions are identical, though, we will need a criterion of identity between dispositions, that we will devise in the next section.

4. Criteria of identity for dispositions

We will now formulate several identity criteria for disposition instances, and evaluate whether they are acceptable in ONLY or PARTHOOD. We will first discuss single-tracks dispositions, and then turn to multi-tracks dispositions.

4.1. Identity of single-track dispositions

4.1.1. Identification by trigger and realization specifications

Consider the disposition $\mathbf{d_0}$ inhering in **b** to *R* when *TR*, and the disposition $\mathbf{d_1}$ inhering in **b'** to *R'* when *TR'*. What are the necessary conditions for $\mathbf{d_0}$ and $\mathbf{d_1}$ being identical? A first necessary condition is that **b** and **b'** are identical: since dispositions are specifically dependent continuants, two dispositions cannot be identical if they inhere in two different bearers. More specifically, we could impose that the categorical basis **cat** of **d** and the categorical basis **cat'** of **d'** are identical. This in turn implies that **b** and **b'** are identical, since **cat inheres_in b** and **cat' inheres_in b'**, and a quality instance inheres in only one bearer. A first, natural candidate criterion of identity would be:

(ID_1) A disposition with basis **cat** to *R* when *TR* and a disposition with basis **cat'** to *R'* when *TR'* are identical iff:
cat and **cat'** are identical, *R* and *R'* are identical, and *TR* and *TR'* are identical.

This is, however, not a sound criterion of identity. As a matter of fact, let *R#* be any parent class of *R* such that *R#* SubClassOf *Process*, and *TR#* any parent class of *TR* such that *TR#* SubClassOf *Process*. Then, whether we accept ONLY or PARTHOOD, it is easy to see that a disposition to *R* when *TR* is also a disposition to *R#* when *TR#*.

4.1.2. Do we need to specify the bearer or the categorical basis in identity criteria?

A second proposal would be that two dispositions are identical iff they have the same class of triggers and the same class of realizations (that is, if they have the same full specification):

(ID_2) **d** is identical to **d'** iff [(**trigger_of d**) EquivalentTo (**trigger_of d'**) ∧ (**realization_of d**) EquivalentTo (**realization_of d'**)]

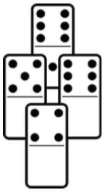


Figure 2.

However, we can construct in ONLY a counter-example to (ID_2) illustrated by the domino arrangement in Figure 2. If $\mathbf{domino_4}$ is pushed to the right, then it falls on both $\mathbf{domino_5}$ and $\mathbf{domino_6}$, which both falls on $\mathbf{domino_7}$, making it fall. However, even if only $\mathbf{domino_5}$ or $\mathbf{domino_6}$ would fall, $\mathbf{domino_7}$ would fall. Then, there are two causal chains from $Push_{\rightarrow 4}$ to $Fall_{\rightarrow 7}$ – one involving $Fall_{\rightarrow 5}$, and the other involving $Fall_{\rightarrow 6}$. In ONLY, one could distinguish two dispositions with the same class of triggers and realizations: the disposition $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,5,7}$ to $Fall_{\rightarrow 7}$ when $Push_{\rightarrow 4}$ due to the first causal chain; and the disposition $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,6,7}$ to $Fall_{\rightarrow 7}$ when $Push_{\rightarrow 4}$ due to the second causal chain. Clearly, these two dispositions are not identical, as they do not have the same bearer: the first one can disappear (if $\mathbf{domino_5}$ would disappear) while the second one still exists, and vice versa. However, they have the same class of triggers $Push_{\rightarrow 4}$, and the same class of realizations $Fall_{\rightarrow 7\_caused\_by\_Push\rightarrow 4}$; that is, they have the same full specification. Thus, (ID_2) is false in ONLY.

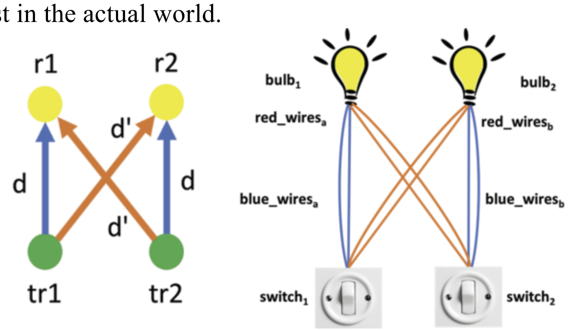
However, Figure 2 is not a counter-example of (ID_2) if we accept PARTHOOD: in such a case, $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,5,7}$ and $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,6,7}$ do not have the same class of realizations. For example, an instance of $Fall_{\rightarrow 5}$ caused by an instance of $Push_{\rightarrow 4}$ would belong to **realization_of** $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,5,7}$, but not to **realization_of** $\mathbf{d}_{\rightarrow 4;\rightarrow 7}^{do4,6,7}$. We did not find any real-world counter-example to (ID_2) in PARTHOOD, but they are theoretically possible.

4.1.3. Identification by class of triggers, class of realizations and categorical basis

This leads us to (ID_3), according to which two dispositions are identical if they have the same class of triggers, the same class of realizations *and the same categorical basis*:

(ID_3) **d** is identical to **d'** iff ∃**cat** (**d has_basis cat** ∧ **d' has_basis cat**)
∧ [(**trigger_of d**) EquivalentTo (**trigger_of d'**)]
∧ [(**realization_of d**) EquivalentTo (**realization_of d'**)]

However, we can construct a theoretical model of two different dispositions **d** and **d'** that would have the same categorical basis, the same class of triggers (with instances **tr1** and **tr2**) and the same class of realizations (with instances **r1** and **r2**), as pictured on figure 3a. Let us introduce the ternary relation **real** such that **real**(tr_1,**d**,r_1) iff r_1 is the realization of **d** when it is triggered by tr_1. This figure 3a represents the following relationships: **real**(tr_1,**d**,r_1); **real**(tr_2,**d**,r_2); **real**(tr_1,**d'**,r_2); and **real**(tr_2,**d'**,r_1). Such a structure would provide a counter-example to (ID_3). However, it is not clear that such a model would exist in the actual world.



Figures 3a and 3b.

Consider for example the scenario pictured in Figure 3b, in which two switches are each connected to two light bulbs by different wires, such that switching either $\mathbf{switch_1}$ or $\mathbf{switch_2}$ (or both) would be enough to light up both $\mathbf{bulb_1}$ and $\mathbf{bulb_2}$. Consider now the disposition for both bulbs to light up when both switches are switched up whose categorical basis include $\mathbf{blue\_wires_a}$ and $\mathbf{blue\_wires_b}$, and the other disposition for both bulbs to light up when both switches are switched up whose categorical basis include $\mathbf{red\_wires_a}$ and $\mathbf{red\_wires_b}$. Then, both dispositions do not have the same categorical basis, and, thus, Figure 3b does not present a counter-example to (ID_3).

However, scenarios like Figure 3a are at least theoretically possible. Therefore, we can suggest the following criterion of identity, according to which two dispositions are identical iff they have the same basis, and any process that triggers the first disposition into a realization does trigger the second disposition into the very same realization, and vice versa:

(ID_4) **d** is identical to **d'** iff: ∃**cat** (**d has_basis cat** ∧ **d' has_basis cat**)
∧ ∀**r** ∀**t** (**real**(**tr**,**d**,**r**) ⇔ **real**(**tr**,**d'**,**r**))

Again, the reading of this quantification should be modal (otherwise, two dispositions with the same basis that would never be triggered would trivially be identical). We suggest that (ID_4) is the correct criterion of identity for disposition instances. For all practical purposes, however, (ID_3) seems to be usable until a convincing real-world counter-example is found.

(ID_3) and (ID_4) show, as we stated in section 2.3, that a disposition should not be identified with its categorical basis. As a matter of fact, according to both criteria, two dispositions can have the same categorical basis but still be different, in case they have different classes of triggers or different classes of realizations.

4.1.4. Identification by classes of minimal triggers and maximal realizations

Within PARTHOOD, we can show that the following criterion (ID_3') is equivalent to (ID_3) by applying (TRIGGER), (REALIZATION), (TRMIN) and (RMAX):

(ID_3') **d** is identical to **d'** iff: ∃**cat** (**d has_basis cat** ∧ **d' has_basis cat**)
∧ (*TRmin*(**d**) EquivalentTo *TRmin*(**d'**))
∧ (*Rmax*(**d**) EquivalentTo *Rmax*(**d'**))

Finally, as suggested during the analysis of the domino example in subsection 3.3, the class of maximal realizations *Rmax*(**d**) of a disposition systematically depends on its class of minimal triggers *TRmin*(**d**) and its categorical basis. Therefore, the following criterion of identity (ID_3'') is also equivalent to (ID_3) and (ID_3'):

(ID_3'') **d** is identical to **d'** iff: ∃**cat** (**d has_basis cat** ∧ **d' has_basis cat**)
∧ *TRmin*(**d**) EquivalentTo *TRmin*(**d'**)

4.2. Identity of multi-track dispositions

The former criteria apply only to single-track dispositions. Some dispositions, however, are multi-tracks, having several single-track dispositions as mod-parts. Classically, two entities are identical iff they have the same proper parts (PP):

x is identical to y iff ∀w (PPwx ⇔ PPwy)

This criterion can be adapted to multi-track dispositions by stating that two multi-track dispositions are identical iff they have the same mod-parts:

(ID_5) If **d** and **d'** are mod-complexes, then **d** is identical to **d'** iff:
∀ **d''** (**d'' proper_mod-part_of d** ⇔ **d'' proper_mod-part_of d'**)

4.3. Avoiding disposition multiplicativism

Now that we have criteria of identity for the two frameworks ONLY and PARTHOOD, we can evaluate them by applying them to the examples mentioned in section 3. We had seen that according to ONLY, and independently of any criterion of identity we endorse, dispositions such as $\mathbf{d}_{\rightarrow 0;\rightarrow 2}{}^{do0,1,2}$, $\mathbf{d}_{\rightarrow 0;\rightarrow 1,2}{}^{do0,1,2}$, $\mathbf{d}_{\rightarrow 0;\rightarrow 0,1,2}{}^{do0,1,2}$, $\mathbf{d}_{\rightarrow 0;\rightarrow 0,2}{}^{do0,1,2}$ are all distinct disposition instances, as they all have different classes of realizations. However, if we accept PARTHOOD and (ID_4) – or any other acceptable criterion of identity mentioned above – they are all identical to each other. We had also seen that according to ONLY, $\mathbf{d}_{\rightarrow 0;\rightarrow 0}$ and $\mathbf{d}_{\rightarrow 0,3;\rightarrow 0}$ are different disposition instances, as they have different classes of triggers; however, in PARTHOOD with (ID_4), they are identical. PARTHOOD would thus be able to limit disposition multiplicativism.

5. Discussion and conclusion

We have distinguished two ways to refer to dispositions: the conventional terms like "fragility", and canonical terms like "disposition to *R* when *TR*", where *TR* is a trigger specification and *R* is a realization specification. We have proposed two ontological frameworks for the interpretation of canonical specifications: the framework ONLY, that has been endorsed until now in most of the applied ontology literature on dispositions; and the new framework PARTHOOD. The latter introduces minimal triggers, which are the smallest processes that would trigger a disposition, and maximal realizations, which are the largest processes that would realize a disposition. We have seen that PARTHOOD largely avoids the disposition multiplicativism that is implied by ONLY; for this reason, the former may be preferred when ontological parsimony is desired.

Regardless of whether we accept ONLY or PARTHOOD, any single-track disposition is a disposition to *Process* when *Process* – that is, *Process* is always both a trigger specification and a realization specification (but not, of course, a class of triggers or a class of realizations). If a speaker wants to refer to a disposition **d**, it would be a very unspecific characterization of **d** to state that it is a disposition to *Process* when *Process*, and an interlocutor could not identify which disposition the speaker has in mind. Although a trigger specification and a realization specification do not usually point to a unique disposition instance, the interlocutor can sometimes identify the disposition relying on the pragmatics of communication. So, for example, when the speaker mentions the disposition of $\mathbf{glass_0}$ to *Breaking* when *Strong_shock*, the interlocutor can understand that what is referred to is the disposition with full specification "disposition to $\mathbf{glass_0}$_*Breaking* when *Strong_shock_on*_$\mathbf{glass_0}$", although this was not explicitly specified [14]. But to avoid misunderstanding when mentioning a disposition, the speaker can refer to a disposition instance by providing a full specification of it (in the framework ONLY) or a specification of its classes of minimal triggers and maximal realizations (in the framework PARTHOOD). In some rare cases, it might even be necessary to specify the categorical basis of the disposition; and if the categorical basis and a list of trigger–realization associations (in both ONLY and PARTHOOD), or a categorical basis and a specification of the class of minimal triggers (in PARTHOOD) are provided, then it is possible to identify dispositions unambiguously, according to the criteria of identity (ID_4) or (ID_3''). In general, the more specific the trigger and realization specifications are, the more likely the disposition is going to be correctly identified by the interlocutor.

Note also that in our framework, the bearer of a disposition does not participate in all realizations. Indeed, the bearer of $\mathbf{d}_{\rightarrow 0;\rightarrow 2}^{do,1,2}$, which is $\mathbf{domino_{0,1,2}}$, does not participate in $Fall_{\rightarrow 2\_due\_to\_a\_push\rightarrow 0}$ (a subclass of $Fall_{\rightarrow 2}$) which is the class of realizations of $\mathbf{d}_{\rightarrow 0;\rightarrow 2}^{do0,1,2}$ according to ONLY, and a subclass of the class of realizations of $\mathbf{d}_{\rightarrow 0;\rightarrow 2}^{do0,1,2}$ according to PARTHOOD (unless one would consider that whenever **x part_of y** and **x participates_in r**, then **y participates_in r**, but this would imply that the whole universe participates in any process, which would probably lead to a too broad theory of participation). Instead, we might suggest the axiom according to which the bearer of a disposition always participates in any of its maximal realizations.

In the PARTHOOD framework, it can be very useful to identify a disposition by its minimal triggers and maximal realizations, when we are interested in determining the causal factors with a high precision. However, the description of a disposition by a trigger specification and a realization specification can also be very useful, when we do not know what are the exact causal factors of some effect, and how far their effects extend. The usefulness of minimal triggers and maximal realizations depends on the domain of applications, and whether we want to describe triggers and realizations in a more fine-grained or coarse-grained way. Consider dispositions such as *Fragility* of a *Glass*, which can have as trigger instances of *Fall_glass* or of *Heavy_object_put_on_glass*. Such triggers will be more useful when we deal with, e.g., data concerning handling or shipment of the glasses. But when we deal with, e.g., engineering specifications, we would be more interested in the minimal triggers of *Fragility*, such as instances of $Pressure{>}P_1\_on\_glass$.

Some aspects need to be examined in future work. First, our analysis of disposition identity could be combined with the mereology of dispositions [5] and applied, e.g., to biomedical dispositional entities such as predispositions to diseases, to diseases themselves, or medical risks. A second question concerns the diachronic identity of dispositions – namely: what makes that a disposition **d** at time t and a disposition **d** at time t' are the same entity? Third, the connection between dispositions and causality needs more elaboration, so that the informal characterization of *TRmin* and *Rmax* that has been proposed here could be more systematically spelled out.

References

[1] R.H. Scheuermann, W. Ceusters, B. Smith, Toward an ontological treatment of disease and diagnosis, in: *Proc. 2009 AMIA Summit Transl. Bioinforma.*, San Francisco CA, 2009, pp. 116–120.

[2] A. Barton, L. Jansen, A. Rosier, J.-F. Ethier, What is a risk? A formal representation of risk of stroke for people with atrial fibrillation, in: *Proc. 8th Int. Conf. Biomed. Ontol.*, Newcastle, UK, in press, pp. 1–6.

[3] A. Barton, A. Burgun, R. Duvauferrier, Probability assignments to dispositions in ontologies, in: M. Donnelly, G. Guizzardi (Eds.), *Proc. 7th Int. Conf. Form. Ontol. Inf. Syst. FOIS2012*, IOS Press, Amsterdam, 2012, pp. 3–14.

[4] J. Röhl, L. Jansen, Representing dispositions, *Journal of Biomedical Semantics* **2** (2011), S4.

[5] A. Barton, L. Jansen, J.-F. Ethier, A taxonomy of disposition-parthood, in: A. Galton, F. Neuhaus (Eds.), *Proc. Joint Ontol. Workshop 2017*, CEUR Workshop Proceedings, 2018, pp. 1–10.

[6] N. Guarino, BFO and DOLCE: So Far, So Close..., *Cosmos + Taxis* **4** (2017), 10–18.

[7] M. Horridge, P.F. Patel-Schneider, OWL 2 web ontology language manchester syntax, *W3C Working Group Note* (2009).

[8] R. Arp, B. Smith, A.D. Spear, *Building Ontologies with Basic Formal Ontology*, The MIT Press, 2015.

[9] E.W. Prior, R. Pargetter, F. Jackson, Three theses about dispositions, *American Philosophical Quarterly* **19** (1982), 251–257.

[10] S. Mumford, *Dispositions*, Oxford University Press, 1998.

[11] S. Choi, M. Fara, Dispositions, *The Stanford Encyclopedia of Philosophy* (2016).

[12] I. Johansson, Four Kinds of ‘Is_A’ Relation, in: K. Munn, B. Smith (Eds.), *Appl. Ontol. Introd.*, Ontos, 2008, pp. 235–254.

[13] S. Schulz, M. Brochhausen, R. Hoehndorf, Higgs Bosons, Mars Missions, and Unicorn Delusions: How to Deal with Terms of Dubious Reference in Scientific Ontologies, in: *Proc. 2nd Int. Conf. Biomed. Ontol. ICBO 2011*, CEUR Workshop Proceedings, 2011, pp. 183–189.

[14] L. Jansen, On Ascribing Dispositions, in: Max Kistler, Bruno Gnassounou (Eds.), *Dispositions and Causal Powers*, Aldershot: Ashgate, 2007, pp. 161-177.