Formal Thought Disorder and Logical Form: A Symbolic Computational Model of Terminological Knowledge

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Abstract

Although formal thought disorder (FTD) has been for long a clinical label in the assessment of some psychiatric disorders, in particular of schizophrenia, it remains a source of controversy, mostly because it is hard to say what exactly the "formal" in FTD refers to. We see anomalous processing of terminological knowledge, a core construct of human knowledge in general, behind FTD symptoms and we approach this anomaly from a strictly formal perspective. More specifically, we present here a symbolic computational model of storage in, and activation of, a human semantic network, or semantic memory, whose core element is logical form; this is normalized by description logic (DL), namely by $\mathcal{CL}$, a DL-based language – Conception Language – designed to formalize conceptualization from the viewpoint of individual cognitive agency. In this model, disruptions in the rule-based implementation of the logical form account for the apparently semantic anomalies symptomatic of FTD, which are detected by means of a $\mathcal{CL}$-based algorithmic assessment.

Key words: Formal Thought Disorder (FTD); Terminological Knowledge; Syntax-Semantics Interface; Description Logic; Conception Language

1 Introduction

1.1 A Controversial Label in Clinical Settings

There is a psychiatric label that has for long now puzzled clinical practitioners and scientists alike: We speak here of the clinical label *formal thought disorder* (FTD)

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and the cause of the puzzlement seems to be the large number of symptoms, many apparently not related, that are seen as revealing its presence to the clinician, but the plethora of conditions that can exhibit it also contributes to this vexing confusion. Indeed, the symptoms believed to be revelatory of FTD range from poverty of speech (limited or absent spontaneous speech) to an unrestrainable "word salad," and while psychotic conditions such as schizophrenia and mania often display signs of FTD, many other, non-psychotic, conditions do so, too, to some significant extent (e.g., brain tumors, dementia, Alzheimer's disease, etc.) (Roche et al., 2015); this picture is further blurred by the fact that FTD might be (partly) an effect of antipsychotic medication (e.g., Malinowski et al., 2018). In other words, the diagnosis in clinical settings of FTD is neither reliable nor valid.

The current edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association, 2013), the *vade mecum* of the psychiatric practitioners, does not improve on this unsatisfactory state of affairs. To begin with, the DSM-5 vacillates between seeing FTD as a thought or a speech disorder, calling it "Disorganized thinking (speech)" [sic] and introducing its (short) definition as follows: "*Disorganized thinking (formal thought disorder)* is typically inferred from the individual's speech" (DSM-5, p. 88). The circularity pointed out by, among others, Rochester & Martin (1979, p. 6), that "thought disorder is when talk is incoherent [a]nd talk is incoherent when the thought is disordered" is obvious. Secondly, from the profusion of symptoms considered in the literature, only three are seen in the DSM-5 as relevant for the diagnosis of FTD: derailment or loose associations, tangentiality, and incoherence or "word salad."[1] (We shall use the abbreviation DTI for this trio.) In particular, the fact that "semantic anomalies" are included in the symptoms of FTD seems to be unaccounted for in the common understanding of the adjective *formal* as referring to form alone, and this is precisely where we contribute to a theoretical clarification of FTD as a thought disorder reflected in speech production (and understanding).

1.2 A Way Out of the Controversy: Taking *Formal* in a Strictly Formal Sense

Despite these issues the correct specification of *formal* can make the label FTD clinically relevant, i.e., reliable and valid. That is, there indeed seems to be a disorder of thought that concerns its *formal processes* and can be described – and, ideally, explained – from a *formal perspective*, with *formal tools*. This depends, of course, on a definition of *formal with respect to thought*, a subject of research that has already a long tradition, namely from the perspective of logic (e.g., Braine, 1990; Braine & O'Brien, 1998; Evans, 2002; Inhelder & Piaget, 1955; Johnson-Laird & Yang, 2008; Rips, 1994; Stenning & van Lambalgen, 2008; Wason, 1968).

In general terms, what are commonly seen as the "thought, language, and communication (TLC) disorders" (cf. Andreasen, 1979; 1986) or, as the current edition of the DSM-5 puts it, the "disorganized thinking (speech)" symptom in the diagnosis of schizophrenia, can be theoretically approached from the (largely cognitivist) viewpoint of a *logical form* rooting in a *syntax of thought*. More specifically, we hypothesize

[1] See Andreasen (1979) for the eighteen "canonical" symptoms of FTD. McKenna & Oh (2005) provides a comprehensive discussion of these symptoms.

that what are commonly seen as the semantic anomalies of FTD that account for a *dyssemantic hypothesis* of thought disorder (McKenna & Oh, 2005, Chapter 7) are not so much *semantic*, but rather *syntactic*: In our view, they reflect an impairment in the storage in, and activation of, concepts in human semantic networks; these *conceptual processes* are governed by syntactic rules and we accordingly call this *the dyssyntactic hypothesis*. Besides being naturally amenable to formalization, these processes are also naturally computational, and this coupling *formalization-computation* already constitutes a well-established paradigm in cognitive modeling, to wit, *declarative/logic-based cognitive modeling* (e.g., Bringsjord, 2008). We integrate our model, which we call *the dyssyntax model*, in this paradigm (Badie & Augusto, 2022).

1.3 What Our Model Is and Is Not

In the present article, we go by the maxim "first things first" and begin by (A) circumscribing FTD from a theoretical viewpoint as an impairment of both symbolic storage and activation over a semantic network, the cognitive construct that underlies human terminological knowledge, and (B) by providing a symbolic computational means to assess it accordingly. This is the core of our model, which will address further computational aspects (e.g., tree-based search), as well as possibly neuronal correlates, in future work. Ours is a *symbolic* model, because it considers the elements of human mentation, such as concepts and beliefs, to be (atomic or complex) *symbolic structures* or to be describable/expressible as such. In normal conditions, these symbolic structures may correspond to well-formed strings of atomic symbols, grammatically called *words* and *sentences* – *concepts* and *beliefs*, respectively, in a more cognitive perspective – formalizable by means of logical formulas (e.g., Fodor & Pylyshyn, 1988). These are rather *larger-grained*, or *digital*, representations and the processes associating them into complex semantic structures can be optimally described by as large-grained representations and operations as the ones of logic (vs. the *finer-graded*, or *analog*, processes and/or representations of connectionist models).[2]

Additionally, this is a *computational* model inasmuch as (1) it takes human thinking to be information processing and, as such, subject to spatial-temporal constraints that impose more or less severe limitations on the fluency and accuracy of thought processes and their verbal expression in specific contexts (e.g., Scheutz, 2002; Sun, 2009), (2) it can be implemented in, or simulated by, a (physical) model of computation, which typically requires some formalism and algorithmic approaches (e.g., Augusto, 2021b; 2022b). To put it in other words and from the increasingly relevant viewpoint of knowledge (Augusto, 2020c), we propose here a model of *knowledge representation* that accounts for FTD as an impairment in the human processing of knowledge, in particular of *terminological knowledge* (Badie, 2018a-b; 2020a-b). By focusing on terminological knowledge, we restrict information processing to verbal processing and we work largely within computational cognitive linguistics (e.g., Edelman, 2007; Edelman & Waterfall, 2007):[3] Our model explains how computationally impletementable

[2]See Augusto (2018) for the pairs *representation – process* and *analog – digital*. As stated in this reference, these pairs need (much) further work to be carried out on them, but we think that the sketchy conception we currently have of them already provides good working elements. We remark, *en passant*, that some connectionist models are not even capable of representing the binary operation of exclusive OR.

[3]The label "computational cognitive linguistics" appears not yet clearly to circumscribe a field of

rule-based deficits in the storage and retrieval of terminological constructs (i.e. lexical items but also concepts) produce samples of speech that are characteristic of FTD.

The above summary of our model excludes a few features that we think it is important to make clear: (*i*) Ours is not a model of language, let alone discourse, understanding and/or processing – we are only interested in formal features of terminological knowledge processing as they are revealed in speech production, and this excludes other aspects (of speech) such as phonology, morphology, pragmatics, etc.; (*ii*) this means that our understanding of "formal" is very strict, namely related to symbolic logic, and it is not to be taken in the sense used in formal semantics in linguistics (e.g., Portner & Partee, 2002); (*iii*) by the term "impairment," we do not mean to imply that there is something like (a) "mental disorder"; this is indeed a controversial expression (see, e.g., Bolton, 2008) that we are keen to avoid. (On the other hand, we explicitly associate FTD with a "thought disorder," a label that indicates a cognitive approach to thought processes rather than to mentation in general (e.g., Hart & Lewine, 2017); in this perspective, it is obvious that FTD must be taken as a deficit, as the shared conceptualization that characterizes human communication fails, frequently to a significant extent, with negative consequences for the subject in terms of social relations and the ability to find and secure a job (e.g., Roche et al., 2015).); (*iv*) as said above, FTD symptoms are exhibited in many conditions, and we do not associate this deficit specifically with schizophrenia (but because this association is prevalent in the literature we often use the terms "schizophrenia" and "schizophrenic" in our own model, without for that intending a clinical meaning.[4]); (*v*) this is not a complex model, and it may even be seen as naïve, but it is in line with the models of thinking and reasoning cited above (this said, we call the reader's attention to the fact that the simplicity of logic can be quite deceptive). Last but not least, (*vi*) our objective is not to offer a new method of diagnosis of FTD. We are well aware that the adoption of new diagnostic measures typically involves the replacement of available ones based on significantly better values being demonstrated for several criteria and parameters, such as diagnostic-efficiency statistics, sensitivity, specificity, and positive and negative predictive power, and we do not see our algorithmic assessment based on $\mathcal{CL}$ as justifying such a procedure.

Elaborating further on this last point, ours is a model in the cognitive-science tradition, meant to clarify theoretical aspects rather than to provide diagnostic measures, the objective of psychiatric models (e.g., Tyrer, 2013); these are highly constrained by, among others, social and commercial factors (e.g.. Kecmanovic & Hadzi-Pavlovic, 2010), a feature that contrasts with the essentially theoretical interest of models in cognitive science, in which the form of mental representations has been a core subject since the very inception of this field (e.g., Johnson-Laird, 1980). Given the highly philosophical nature of the concept *mental representation*, models in cognitive science aim at explanatory approximations rather than descriptive phenomenologies that

research, despite its use in the cited works.

[4]For instance, the influential *Kaplan & Sadock's Comprehensive Textbook of Psychiatry* (Sadock et al., 2017) defines FTD as follows: "Disturbance in the form of thought rather than the content of thought; thinking characterized by loosened associations, neologisms, and illogical constructs; thought process is disordered, and the person is defined as psychotic. Characteristic of schizophrenia." As a matter of fact, these authors associate thought disorder with schizophrenia: "Any disturbance of thinking that affects language, communication, or thought content; the hallmark feature of schizophrenia" (Sadock et al., 2017).

work as the fundament of psychiatric diagnostic tests. In the present model, we aim solely to show that the "formal" in FTD can be modeled strictly formally, namely via description logics, and by "assessing" we do not mean "clinical evaluation," but "identification by formal means," instead, of defective processes in terminological knowledge. On the one hand, we do not really expect clinicians to learn $\mathcal{CL}$ and diagnose patients by means of our algorithmic procedure, though it would be interesting and informative were this to actually take place; on the other hand, we think that learning our model in some depth would facilitate an understanding of FTD from the information processing viewpoint. In a cognitive-science experimental setting, which typically allies psychology and AI (especially of the symbolic kind; Augusto, 2021a), we think it would be interesting to implement our model in a computing machine that mimics FTD in humans.

1.4 Organization of the Article

This article is organized as follows. We begin by providing the reader with some historical notes on the clinical understanding and assessment of FTD (Subsection 2.1) and an elaboration on the dyssemantic hypothesis (2.2); we contrast the latter with our dyssyntactic hypothesis in 2.3, a discussion that comprises two sub-topics, to wit, the syntax-semantics interface (2.3.1) and syntactic rules over semantic networks (2.3.2). In Section 3, we put the *formal* in FTD, for which we provide both the theoretical background on which our model is based (3.1) and a logical account of categorization and association of thought processes recruited in terminological knowledge (3.2); this latter Subsection comprises a Sub-subsection (3.2.1) on set theory and description logic, and two Sub-subsections on how description logic formalizes the process of terminological categorization (3.2.2) and association (3.2.3). Section 4 is where we elaborate on the dyssyntax model as a formal account of FTD (4.1) based on the conception language $\mathcal{CL}$ (4.2), a combination that allows for assessing FTD with a computational. In this context, we not only give our algorithmic assessment (4.3.1), but also provide some remarks on the expected contribution of the Web Ontology Language (OWL) for our model. We end, in Section 5, with the usual conclusions and future work.

2 FTD, Speech, and a Sketch of the Dyssyntactic Hypothesis

2.1 Some Historical Notes

The interest in the evolution of our understanding of thought disorders (e.g., Bentall, 2006; Collin et al., 2016; Jablensky, 2010; Parnas, 2011; Thomas, 2001) and in particular of FTD (e.g., Jerónimo et al., 2018) has recently reemerged in the literature, likely motivated by the feeling that our comprehension of this and other thought disorders is not satisfactory because we got lost in the thread at some point. Aspects of speech – including or even primarily respecting meaning – were early on seen as a salient symptom of thought disorder in schizophrenia. E. Kraepelin, the first to isolate schizophrenia (he called it *dementia praecox*) as a clinical condition from a variegated cluster of symptoms, called the diagnostician's attention to *akataphasia*, or "derailments in the *expression of thought* in speech" (Kraepelin, 1896/1919, p. 70). This was characterized by the failure to find an expression appropriate for one's thought (*displacement paralogia*) or by letting one's speech "fall" into unrelated channels (*derailment paralogia*), which caused a gliding off of the expression of thought into intrusive side-ideas (e.g., "a suspended appetite"; "a voluntary disease of the eyes") resulting often in nonsensical speech.

Soon after this, E. Bleuler, to whom modern psychiatry owes the label "schizophrenia," saw the *loosening of associations* as one of the fundamental symptoms of this condition. In this "alteration of thinking, feeling, and relation to the external world which appears nowhere else in this particular fashion" (Bleuler, 1911/1950, p. 9), deficits at both the ideational and conceptual levels were seen to result in overall bizarre and faulty associations often concomitant with blocking, splitting of ideas, pressure of thoughts, and other disturbances that gave an envelope of illogicality and bizarreness to the patients' speech.

Many later theories centered also in aspects of speech to define FTD, some explicitly focusing on meaning: For instance, Cameron (1938, 1944) spoke of *asyndesis*, or *asyndetic thinking*, as the inability to preserve conceptual boundaries in thought disorder, which could co-occur with *metonymic distortion* (or *word approximations*) and an *interpenetration of themes*; Fish (1962) saw a *disturbance of conceptual thinking* at the root of the disorder; and Chapman and colleagues (Chapman et al., 1964) spoke of a *semantic bias*, or preference for a specific meaning, to explain the mismatch between speech and context in FTD. In large measure, speech became the focus of FTD assessment and diagnosis, with tests being developed to a lesser or greater extent around the semantic side of verbal expression, as in the Present State Examination (Wing et al., 1974), in Harrow and Quinlan's (1985) exploration of what they saw as bizarre-idiosyncratic thinking, in the Communication Deviance Index (Docherty et al., 1996), in the Thought and Language Index (Liddle et al., 2002), and, most influentially, in Andreasen's (1979, 1986) comprehensive Thought, Language, and Communication (TLC) Scale, which became an important diagnostic tool in the DSM III (American Psychiatric Association, 1980) – to name but a few.

More recently, the literature of schizophrenia studies exhibited an explosion of works on the role and aspects of language in FTD that is now virtually a field of its own with theories and hypotheses being profusely produced and defended (see, e.g., McKenna & Oh, 2005). Many are based on models of normal speech production, with the help of which levels/modules responsible for grammatical encoding, concept retrieval, context sensitivity, and even monitoring of one's speech are indicated (but typically not explained) as being at the root of FTD (see, e.g., Bachman & Cannon, 2005). Computational-based quantitative models have also been developed (e.g., Elvevåg et al., 2007; Maher et al., 2005) and the neurophysiological aspects of FTD are now also an active field of research, namely from the viewpoint of the neurobiological correlates (e.g., Cavelti et al., 2018; Chen et al., 2021; Leube et al., 2008; Wensing et al., 2017) and even of genetics (Levy et al., 2010). Despite all these and other diverse approaches, which account for the large number of models and theories (see Roche et al., 2015), our understanding of FTD is still limited.

2.2 The Dyssemantic Hypothesis

The apparent predominance of "semantic anomalies," in particular, has motivated theories and models implicating disruptions in semantic memory, an important element in some models of speech (see below). To be sure, patients with FTD often consistently make semantic mistakes. These include the failure to identify correctly (give a name to) objects of the world (e.g., wrong nouns; neologisms; naming many objects with one same, more or less adequate, word), the generation and attribution of inadequate properties (e.g., "owls have blades"; "admirals have fins"), the failure to distinguish words from non-words, the inability to form coherent sets of objects, etc. (See, e.g., Levy et al., 2010; McKenna & Oh, 2005; Vogel et al., 2009.) Additionally, reaction times in lexical and semantic tasks, as well as in memory tasks involving semantic material, are commonly longer than those of controls, suggesting that semantic memory is structurally impaired (e.g., Tamlyn et al., 1992).

Importantly, subjects showing these "semantic anomalies" are not otherwise grossly intellectually impaired with a frequency that indicates that the processing of lexical/verbal or even purely conceptual representations may independently go wrong, apparently leaving the processing of other representations (e.g., motor representations) by and large untouched (see, e.g., Bowie & Harvey, 2005; Clare et al., 1993; Tamlyn et al., 1992). In the light of this, a profusion of studies has focused on semantic memory, and McKenna and Oh (2005) came up with the label "the dyssemantic hypothesis" to cover it.

Taking Quillian's *hierarchical model of semantic memory* (e.g., Collins & Quillian, 1969; Quillian, 1967, 1969) and Collins and Loftus' *spreading activation model of semantic processing* (Collins & Loftus, 1975) as plausible explanations of storage and activation processes involving lexical/conceptual representations, it can be hypothesized that FTD is a structural semantic memory problem, an activation one, or both.[5] For instance, semantic activation models appear to account satisfactorily for well-established psychological phenomena such as semantic priming (see, e.g., Ferrand & New, 2004) and word expectancy (Kuperberg & Jaeger, 2016). In fact, there is evidence supporting all these hypotheses (see, e.g., Arne et al., 2016; Cavelti et al., 2018; Doughty et al., 2008; Laws et al., 1998; Laws et al., 2000; Leeson et al., 2006), which suggests that structure and activation in semantic memory are interdependent features. In this context, errors in *categorization* such as overinclusiveness (the inability to keep to a single specific context or frame of reference), and wrong, often bizarre and/or nonsensical, *associations*, seen as prompters of an array of symptoms of FTD, such as derailment, incoherence, circumstantiality, etc., have been hypothetically attributed to, for instance, hyper-priming, or increased semantic priming, i.e., increased spreading activation in semantic memory (see Pomarol-Clotet et al., 2008, for a review and meta-analysis), and/or to a semantic memory impairment (see Doughty & Done, 2009, for a review and meta-analysis).

[5] Combined, they can be seen as constituting the *network activation model of semantic memory* or, more shortly, *semantic (network) activation model*. As a matter of fact, rather than a combination, Collins & Loftus (1975) *revised* the original model in the sense of relaxing its strict hierarchical structure.

2.3 A Sketch of the Dyssyntactic Hypothesis

2.3.1. The syntax-semantics interface

Information has two sides to it, to wit, syntax and semantics, and its processing is (simultaneously) syntactic and semantic in the case of human cognition. As seen, FTD is believed to be a disorder of thought as expressed by disorders in speech. It is thus in principle justified that hypotheses on FTD should focus on the relation between thought *in general* (i.e., cognition) and natural language processing. The dyssemantic hypothesis concentrates on semantic memory as a basis for language and speech processes alone, neglecting the fact that it might just be a part of a larger information processing network in which many elements, though symbolic and/or conceptual, may not be strictly linguistic; moreover – or as a consequence of this –, it ignores the fact that semantics is but the *other* of the two sides of human information processing. From an information-processing view of human cognition, cognitive processes are regimented by both syntactic and semantic rules and operations. Thus, according to this view that is commonly and generally referred to as (*classical*) *cognitivism* or also as *computationalism*, symbolic(-based) cognitive phenomena must be analyzed from *both* a syntactic *and* a semantic viewpoints (see, e.g., Augusto, 2014; Fodor, 1975; Fodor & Pylyshyn, 1988; see also Hanna, 2006, Chapter 4).

However, although semantics is in important ways determinating of syntax (for instance, the symbol structures "8" and "9" call forth processes – and the associated syntactic rules – such as counting, adding, multiplying, etc., but not, say, scratching, eating, opening, etc.; see Augusto, 2014), syntax is *primary* in the sense that computational processes need not achieve a full semantic expression in order for cognition and behavior at large to occur. This is very likely the case in reflex behavior in coma and in the persistent vegetative state, but also in the vast number of processes, lower- and higher-level alike, that account for the label "unconscious cognition" (Augusto, 2010; 2013; 2016). In this perspective, *formal* manipulation – as with respect to *symbols*, whether atomic or structures thereof – is always giving of meaning,[6] but under certain conditions (e.g., time constraints, stimulus complexity or degradation, life-support relevance or survival urgency, etc.) the syntactic side of the cognitive process may prevail. The dual-system account of the human cognitive architecture attributes this to the *System 1*, which is essentially unconscious and is more tolerant of pressure, degradation, or corruption than its dual *System 2*, believed to be largely conscious (see Augusto, 2018).

Semantic networks taken from a more formal perspective are now emerging in the literature (e.g., Badie & Augusto, 2022; Nettekoven et al., 2022). We, too, consider semantic networks and models based thereon to be an adequate formal means to represent human semantic memory (see Fig. 1), which is the construct that underlies our terminological knowledge, i.e. our knowledge of lexical items and/or concepts and the way they are interrelated. But in this view, any cognitive process regimented by computational constraints, though in principle also essentially semantic, is first and foremost syntactic, with errors or deficits in this side of the process being reflected in semantic anomalies; in fact, recent studies point in the direction of overall reduced linguistic complexity in FTD (e.g., Çokal et al., 2018). Because there is a – hypo-

[6] A notoriously controversial claim (see, e.g., Chomsky 1957; see also the debate around the Chinese Room Argument: Chalmers 1996; Cole 2009; Dennett 1987; Searle 1980).

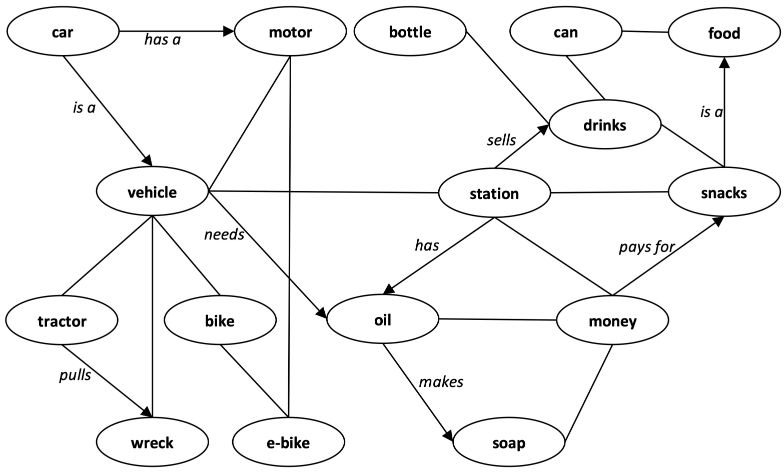

Figure 1: A (fragment of a) semantic network whose core category is "Filling Station." The nodes are labeled with concepts and the arcs (arrows) are labeled with binary roles; unlabeled arcs indicate non-specific association between two concepts.

thetically innate – "syntax of thought (in general)," with possibly many and diverse modules sharing (parts of) the same syntax responsible for mental representations, primarily syntactic processes may be generalized or global even when appearing localized. In fact, there are experimental results that support the hypothesis that the semantic anomalies said to be characteristic of FTD frequently co-occur with dysexecutive and other syntactic-like deficits (McKenna & Oh, 2005).

2.3.2. Syntactic rules over semantic networks

Our starting point is a representationalist theory of mind, according to which human mentation is based on *(mental) representations*, i.e. conceptual atoms/structures that can refer to objects in the world even when they are not present or available for direct perception. For instance, one can think of a bar of soap while traveling in the metro, possibly because one needs to buy one when going to the supermarket later that same day. Hence, the atomic concept soap can be retrieved from storage in a semantic network in association with other concepts such as supermarket, shower, etc. Although unlikely or uncommonly, one may retrieve the concept soap in association with, say, animal_fat, if one knows about tallow_soap.[7] This is so because the retrieval of concepts is carried out by a cognitive agent that has a direct relation – need, wish, belief, etc. – with the concepts stored in their semantic memory. We see this as a task of storage and search in a semantic network that can be adequately modeled as symbolic computation, namely at the knowledge level of cognition (see, e.g., Augusto, 2021a). Summing up, we assume here that thinking, or cognizing at large, is *representing*, and the thought processes are conveniently (if not veridically) dis-

[7] The relation between concepts and words (or lexical items) is an open question, despite its clear formulation as early as in Saussure (1916). In particular, the fact that there are humans who behave largely normally while appearing not to understand verbal language (see below) poses a problem. Here, we assume that a concept like soap has usually a corresponding lexical item (the word "soap").

tinguishable into the *formation*, *categorization*, *association*, and further *combination* of mental representations in general (vs. domain-specific). This assumption can be referred to as *cognitivism* (e.g., Fodor, 1975; Fodor & Pylyshyn, 1988).

Given the above theoretical grounds and in the light of available empirical observations – for instance, associative agnosia, but not apperceptive agnosia, seems to be a characteristic of schizophrenia, with patients showing impairments in recognition and identification of visual stimuli (e.g., Gabrovska et al., 2002) –, we can hypothesize that the basic thinking process of the formation of representations is unimpaired in schizophrenia, with deficits beginning at the levels of categorization and association. On the other hand, corroborating the isolation of these two thought processes is evidence reported suggesting that reasoning proper is largely or wholly unaffected in schizophrenia (e.g., Ho, 1974; Watson & Wold, 2006; Williams, 1964).[8]

The hypothesis that the onus of FTD in schizophrenia – and possibly, by generalization, in other clinical conditions – falls upon the processes of categorization and association is further supported by the fact that categorization and association processes in general (vs. specifically conceptual or linguistic) seem to be affected: For instance, categorization of specific timbre features appears to be impaired in schizophrenia (e.g., Micoulaud-Franchi et al., 2011), and latent inhibition and blocking, normal phenomena observable at the level of association of stimuli in conditioning, seem to be absent or deficient in patients with schizophrenia (e.g., Escobar et al., 2002).

Traditionally – and perhaps naturally –, it is believed that thought finds an exceptional expression in natural language productions (rather than in other forms of behavior or action), a stance known as the *language of thought hypothesis* (see Fodor, 1975; Fodor & Pylyshyn, 1988). Whether natural language and speech in particular are exceptional expressions of thought is a debatable matter (see, e.g., Gleitman & Papafragou, 2005), but, be it as it may, speech is a good instance of a symbolic(-based) cognitive process involving substantial computational constraints: In order to achieve its communicating ends it must be fluent, requiring high precision and attention to contextual cues under strict time limitations. Importantly, the semantic consequences of this highly regimented processing are not only immediate, but also obvious for the averagely proficient user of a natural language.

Grounded on the above, the *dyssyntactic hypothesis* postulates that the semantic anomalies exhibited in FTD are "surface" manifestations of the syntactic aspects or sides of something like a "language of thought," namely in those that are well expressed in natural language productions; more specifically, it postulates that these anomalies occur largely in the processes of the categorization and association of mental representations, of which concepts and lexical items present exceptional observational characteristics.

The categorization and association of semantic material are thought processes that implicate a long-term semantic memory. However, we are here assuming that memory per se is not what is primarily impaired in patients with FTD, in the sense that they might have a specific memory deficit or dysfunction in storing and/or retrieving mnemic material, namely of the biographical (e.g., amnesia) or conceptual/lexical

[8] As a matter of fact, where commonsense and logic conflict, patients with schizophrenia seem to fare better than controls, with formal rules being less frequently violated by them (Owen et al., 2007). However, evidence is conflicting; see, for instance, the studies by Garety & Hemsley (1994), and by Mujica-Parodi et al. (2000).

kind (e.g., agnosia), which commonly has a biological etiology (traumatic brain injury, malformation, degenerative disease, etc.). Moreover, we are not (yet) assuming that there is an anatomical localization for disorders in the categorization and association processes, as do hypotheses related to executive function that commonly attribute the symptoms of FTD to frontal or frontal-parietal/temporal lobe dysfunction (e.g., Horn et al., 2012; Kerns & Berenbaum, 2002, 2003; McGrath, 1991; Nakamura et al., 2008; Stirling et al., 2006). In the context of the dyssyntactic hypothesis, terms such as *storage* and *retrieval* refer more immediately to, respectively, the rule-governed, syntax-based, processes of "finding a place" for a concept or word in a semantic network and of activating elements or parts of such a network. In computational jargon, we speak here of storage and search, the hallmarks of computational models of cognition (e.g., Augusto, 2021a; Newell & Simon, 1976).

3 Putting the *Form* in Thought: Logical Form

3.1 Theoretical Background: (Classical) Cognitivism, Representations, and Forms and Manipulations of Representations

Above, we identified cognitivism as the theoretical label that captures the relationships between representationalism and computationalism as theories of mind or cognition. (*Classical*) *cognitivism* (e.g., Fodor & Pylyshyn, 1988) allows us to explain why and how *form is more than just syntax, entailing also a semantic side*, by means of the postulation of *symbols* as entities the experience of whose manipulation in *structures* is capable of eliciting other behaviors or experiences (see Augusto, 2014). In this perspective, laid out in some measure in Newell (1980), *meaning* (also: *designation*, *reference*, *aboutness*, etc.) just is this eliciting, or the interpretation of the symbols that makes it so that having a symbol – i.e., mentally representing something by means of a symbol (structure) – is tantamount to having the thing designated for the purposes of a specific process or behavior. More prosaically, for instance, to run away from a lion all one needs is to represent the symbols "lion" or "lion running towards me," regardless of whether there actually is a lion running towards one and one sees it, one does not see it but is told that it is the case that a lion is running towards one, or one imagines or hallucinates the lion and its running towards one. Let D_1 denote the world description "There is a lion running towards me." and D_2 do so for "I should be running away as fast as possible." Then the well-formed thought $D_1 \rightarrow D_2$, where the symbol "$\rightarrow$" denotes the material conditional in (propositional) logic "if ... then", can be said to be meaningful – and rightly so!

Thus, semantically, we can speak of *symbols* or *symbol structures*, such as *concepts* and *descriptions*, and when natural language is concerned (i.e., when there are symbols that have a name), we can also speak of *words*. In syntactic terms, we have *rules* for symbols or for operations with symbols. The implementation of these rules gives the manipulation of symbols a particular form that is identical to, or in some more or less close way resembles, the *inferential laws* of logic, reason why we can by and large speak of this as *logical form* (e.g., Braine, 1990; Braine & O'Brien, 1998; Evans, 2002; Inhelder & Piaget, 1955; Johnson-Laird & Yang, 2008; Rips, 1994; Stenning & van Lambalgen, 2008; Wason, 1968).

A more sophisticated way to put this is to speak of this logical form as intermediating – in the sense that it instantiates – between deep and surface structures of natural language productions, where the surface structures are "mediately behind" acoustic-phonetic speech productions (a phonological form) and the deep structures are constitutive of (though probably not identical to) a "universal grammar" not bound to any specific natural language, but at the root of them all (Chomsky, 1965; Berwick & Chomsky, 2016). Importantly, the surface structures mediate or instantiate the phonological form, and are thus in some way connected to the sensorimotor apparatus. This entails that the logical form appears to be shared by other (representational) systems or modules belonging to the same cognitive apparatus or architecture, and thus might contribute to, or even be responsible for, the binding of the various cognitive processes into *unified representations*. In this adaptation, or novel interpretation, of the Minimalist Program (see, e.g., Chomsky, 1995), syntax is the set of all the formal rules that instantiate equally a thought and all the transformations that intermediate between a thought and its oral (or written) production, including its syntactic construction in a restricted, grammatical, sense.

In this view, syntax is clearly not domain specific, and what syntax and semantics share is the logical form, not so much in the sense that they have the same form (though this is also true; see Augusto, 2014), but in the sense that it is the form that is instantiated syntactically that determines the meaning of the structured forms (linguistic productions, but also gesturing, moving, perceiving stimuli, etc.). The fundamental hypothesis here is that this formal manipulation has access to both/either the conceptual and/or the lexical representations that constitute an individual's terminological knowledge and that one of its tasks is precisely to give the interface between both kinds of representations a specific form and structure;[9] the former specifies the *internal constitution of representations*, the latter is the dynamically organized *semantic network* where they are stored and activated. These two components are interdependent in the sense that the internal constitution of complex representations, namely propositions, reflects the storage and activation processes of the semantic network. The *logical form* is this interdependence.

3.2 The Logical Form of Categorization and Association

3.2.1 Set theory and description logic

We assume that set theory and modern symbolic logic, or more precisely, *standard* set theory and *description logic* (DL), are adequate means to model – i.e. describe/express – formally categorization and association processes in a semantic network. One can hypothesize that *truly* naïve set theory is an innate human ability to cognize reality,

[9]It is important to remark that this interface may be empty, as is suggested by (episodic) clinical conditions in which the patients exhibit normal motor behavior prompted by conceptual cues while being unable to understand or produce strictly verbal constructs; for instance, the patient shows no appropriate verbal reaction to the word "chair" when shown a picture of one, but knows – and even partly verbalizes the fact – that they are sitting on one. This suggests that the concept chair is largely preserved even when the word "chair" is inaccessible (see, e.g., Lecours & Joanette, 1980). In our model, we assume that this interface is not only not empty, but it largely is the very semantic network.

without which it would be impossible to talk of "normal" cognition.[10] DL, in turn, is well known for its ability to model terminological knowledge (e.g., Baader et al., 2008), an ability that is attributable to its tight relation to set theory from the perspective of semantics. In effect, and briefly, the DL connectives for conjunction ($\sqcap$), disjunction ($\sqcup$), and negation ($\neg$) are *interpreted* as the set-theoretic operations of intersection ($\cap$), union ($\cup$), and complementation or difference ($\setminus$, $-$). Additionally, via this interpretation DL has the ability to express the set-theoretic relations of identity ($=$) and inclusion ($\subseteq$) by means of the connectives "$\equiv$" and "$\sqsubseteq$", respectively. Let us agree that the core of DL is constituted by *concepts*, namely by both assertional and terminological descriptions thereof. Briefly, we have:[11]

Fundamental assertional descriptions of concepts. The concept descriptions "a is a A_1"[12] and "b is a A_2" (where a and b are two individual symbols and A_1 and A_2 are two atomic concepts) are formally represented by $A_1(a)$ and $A_2(a)$, respectively. This is interpreted as $a \in A_1$ and $b \in A_2$, where "$\in$" denotes the set-theoretic relation of membership. In addition, the role description "a and b are related together by means of r" (where a and b are two individual symbols and r is an atomic role) is formally represented by $r(a, b)$. This is interpreted as $(a, b) \in r$, where "(a, b)" is an ordered pair.

Fundamental terminological descriptions of concepts. Let A_1 and A_2 be two atomic concepts and r_1 and r_2 two atomic roles. There are four fundamental terminological descriptions in DL: (a) The *concept equivalence* $A_1 \equiv A_2$ expresses the fact that A_1 and A_2 are semantically equivalent (i.e. are equal). (b) The *role equivalence* $r_1 \equiv r_2$ expresses the property that r_1 and r_2 are semantically equivalent (i.e. are equal). (c) The *concept subsumption* $A_1 \sqsubseteq A_2$ expresses the property that A_1 is subsumed under A_2; in other words, A_1 is the *sub-concept* of A_2. (d) The *role subsumption* $r_1 \sqsubseteq r_2$ expresses the fact that r_1 is subsumed under r_2; in other words, r_1 is the *sub-role* of r_2.

The reader will have noticed that DL syntax is based on the finite set of logical constants $Cons = \{\neg, \sqcap, \sqcup, \sqsubseteq, \equiv\}$, which we extend with $\{\top, \bot\}$, where the *top concept* "$\top$" and the *bottom concept* "$\bot$" respectively represent the logical concepts of tautology and contradiction.[13] DLs are further constructed over the following non-logical symbols that we shall collect in a set Γ: (1) *Individual symbols*, which are constant symbols and the instances of concepts; (2) *Concepts*, which correspond to a distinct, conceptual, entity and can be regarded to be equivalent to unary predicates in standard predicate logic; and (3) *Roles*, which are either *relations* or *properties*, and can be interpreted to be equivalent to binary predicates in standard predicate logic.[14] (1) - (3) are constructed over the elements of the Roman alphabet together with the auxiliary elements of $\gamma = \{<, >\}$, known as *conceptual identifiers*.

The syntax of DLs is strongly based on concepts and their interrelationships. The

[10] This is actually a very old theory if we replace the word "set" by, say, "idea" as used in Plato or "category" as used in Aristotle or Kant.

[11] See the formal details in Badie & Augusto (2022).

[12] More correctly, "a is a A_1." For simplicity, we omit final marks in descriptions, as well as grammatical features (e.g. "is a A" instead of "is an A").

[13] This is actually a subset of $Cons_{DL}$, which includes also $\{\rightarrow, \forall, \exists\}$, superfluous for our model. Below, we shall use "$\top$" and "$\bot$" also as denoting the truth values "true" and "false," respectively.

[14] $P(x)$ and $Q(x, y)$ are examples of a unary and a binary predicate, respectively. See Augusto (2019) for a comprehensive discussion of all the terms of standard (predicate) logic used in this paper; see Augusto (2022) for computational implementations thereof.

logical structures of DL are fundamentally describable based on atomic symbols, of which there are three kinds: (i) *individuals* (e.g., *bob*, *blue*, *pasta*), (ii) *atomic concepts* (e.g., <*Person*>, <*Color*>, <*Food*>), and (iii) *atomic roles* (e.g., <*hasMother*>, <*hasColor*>, <*isA*>). Atomic symbols are the elementary descriptions from which we inductively build complex *concept* (and *role*) *descriptions* based on concept (and role) constructors (which are the elements of *Cons*). We call any specific collection $\Sigma = \{$individual, atomic concept, atomic role$\}$ a *signature*. For example, considering (i) individual ::= *blue*, (ii) atomic concept ::= <*Blue*>, and (iii) atomic role ::= <*isBlue*>, the collection $\Sigma_{blue} = \{$*blue*, <*Blue*>, <*isBlue*>$\}$ constitutes a signature to talk formally about the concept `blue` in DL.

In the framework of DL, the complex concept (and role) descriptions are $\neg C_1$ (and $\neg R_1$), $C_1 \sqcap C_2$ (and $R_1 \sqcap R_2$), $C_1 \sqcup C_2$ (and $R_1 \sqcup R_2$), and $C_1 \equiv C_2$ (and $R_1 \equiv R_2$), where C_1 and C_2 stand for two (complex) concept descriptions, and R_1 and R_2 represent two (complex) role descriptions. In order to express the logical, and semantic, structure of complex descriptions we focus on (complex) concept descriptions. Let $C_{i=1,2}$ denote a DL formula constituted by a complex concept description; then $\neg C_i$, $C_1 \sqcup C_2$, $C_1 \sqcap C_2$, and $C_1 \equiv C_2$ are also DL formulas.

Many more connectives can be conceived for a particular DL logic, but these (actually, only a part of these) suffice to express a vast number of thought processes that can be expressed by means of concept descriptions, i.e., meaningful declarative concept descriptions. *Meaningfulness* is here associated with a bivalent semantics of *truth* and *falsity* in which a concept description cannot be simultaneously true and false (the classical principle of non-contradiction; PNC) and must be either true or false (a principle known as bivalence and usually confused with the classical law of excluded middle, LEM, according to which either C or $\neg C$ is true). Formally speaking, $C_i \sqsubseteq \top$ expresses that the concept description C_i is subsumed under the logical concept <*Truth*>. Therefore, $C_i \sqsubseteq \top$ means that C_i is true. Also, $C_i \sqsubseteq \bot$ expresses that the concept description C_i is subsumed under the logical concept <*Falsity*>. Therefore, $C_i \sqsubseteq \bot$ means that C_i is false.

Here, <*Truth*> and <*Falsity*> are defined as two logical concepts. At this point, we wish to make it clear that "regular" atomic concepts (e.g., <*Book*>, <*Green*>, <*Girl*>) are not (logically and) semantically interpretable in DL.[15] In fact, independently they do not have any logical value in a formal description. However, the logical concepts <*Truth*> and <*Falsity*> are independently interpretable in any formal description. We here take this bivalent semantics to be by and large adequate for the analysis of descriptive thought processes involved in (non-quantified) declarative speech productions (e.g., "The girl rides her red bike", "The cat is on the mat", "It often rains in November"), which for formal ends we see as (world) descriptions.

3.2.2 Categorization of conceptualizations and its formalization in DL

It is plausible that when we mentally construct (i.e. *form*, trans*form*, and re*form*) a concept or a lexical (i.e. linguistic/symbolic/numerical) item, as well as factual descriptions related to it, in order to conceptualize and interpret it we store it in a long-term memory subsystem (*semantic memory*) not only in a way that must

[15] But they are semantically interpretable in $\mathcal{CL}$; for this aspect below we extend semantic interpretations to atomic concepts in DL.

be organized or structured, so as to be cognitively advantageous – what E. Rosch (1978) saw as the first general and basic principle of *category formation*, to wit, the *principle of cognitive economy*, stating the function of a *category system* –, but also veridical, in the sense that it adequately maps the structure of the world into an individual's semantic memory; this is roughly Rosch's second general and basic principle, to wit, the *principle of perceived world structure*; Rosch, 1978) (see also Badie, 2017a-b; 2018a). In particular, there are two well-documented findings in cognitive psychology that strongly suggest this rule-governed and veridical character of semantic memory: (*a*) semantic material is differentially available (see below), and (*b*) recent presentation, even masked, degraded, and/or subliminally, of an item speeds subsequent access to (i.e., primes) that item and facilitates or activates semantically related items (see, e.g., Tulving & Schacter, 1990).

Because the perceived world has a very large – potentially infinite[16] – number of objects, Rosch's two principles ally to explain how we store, in a computationally optimal way, our knowledge of the world: In an extremely *cognitively economical structure* that provides the maximum of information with the least cognitive effort by mapping the perceived world as closely or veridically as possible. Theoretically, this might imply that set theory and DL are characterized by some form of *forcing* that allows us to speak of "normalcy" in categorization systems.[17] The practical importance of this is that we are in principle capable of categorizing more or less different entities, even those encountered for the first time, in useful time by computing the within-class similarities that account for the basic-level classes. For instance, suddenly confronted with a *<ChargingLion>*, it is vital that one classify it as such, rather than as *<BigCat>*, *<Feline>*, or *<Animal>* – and certainly not as *<Pet>*! Thus, the psychological significance of this is that one should more quickly come up with the atomic concept *<Lion>* (formalizing the basic-level concept lion taken as a mental representation) in comparison to the atomic concept *<Animal>*, or to the more-specified concept *<BigCat>*, or even to *<WildAnimal>*. Formally, we indicate this correct interpretation as

$$(<\mathit{Lion}> \sqsubseteq <\mathit{ChargingLion}>) \sqsubseteq <\mathit{Truth}>$$

And we write simply *<Lion>*. If, however, one categorizes a charging lion as, say, *<Pet>*, then we indicate this wrong interpretation as

$$(<\mathit{Lion}> \sqsubseteq <\mathit{Pet}>) \sqsubseteq <\mathit{Falsity}>$$

and write $<\mathit{Lion}_{\perp}>$ to indicate that the concept *<Lion>* has been wrongly categorized and thus is a wrong or faulty conceptualization. (Hence, we use the subscript "$\perp$" as the identifier for faulty conceptualization.)

In fact, there is *empirical* evidence that seems to corroborate Rosch's two principles and their concretization in the basic-level category. In a series of experiments, Rosch and colleagues (Rosch et al., 1976) verified that reaction times to identify whether

[16] If we consider cognitive creativity (a.k.a. imagination) and also delusional/hallucinatory perception.

[17] In effect, DL is syntactically based on modal logic, which has a forcing interpretation (Blackburn et al., 2007; see Augusto, 2020b, Section 4.4 for a briefer discussion). This, and set-theoretic forcing interpretations, we hypothesize, may in turn be tightly related to the postulation of a universal grammar.

displayed images matched or did not match a given category were significantly lower when the category was a basic-level one. Also, basic-level categories appear to be the first to be learned by children; this is suggested by the observation that concrete nouns are the first to emerge in their utterances (e.g., Hills et al., 2009). Etc. (See Rosch et al., 1976, for an abundance of further studies and results thereof.) Given this empirical observation that equates with a parameter of normalcy or regularity in human cognition, instances such as $<\mathit{Lion}_{\perp}>$ must be attributed to either "normal" isolated miscategorizations (e.g., for lack of attention or unfamiliarity with an object) or idiosyncratic miscategorizations.

3.2.3 Association of conceptualizations and their formalization in DL

Further psychological significance applies, now at the level of *retrieval*: For instance, when asked if a car is a vehicle, one should answer "Yes," and this without taking too long; and when asked if a bike is a vehicle, one should, again, answer "Yes," though perhaps a slightly longer reaction time will be expected, because, after all, the individual bike is already a wee more distant from the concept <*Vehicle*> than from <*Car*> in the sense that this latter concept intermediates between both <*Bike*> and an instance of the concept <*Vehicle*>. Further, not all vehicles are electrical, and because, as a matter of fact, only a very few are so, the answer to the question "Are bikes electrical vehicles?" will require a much longer reaction time for the interrogated subject to give perhaps the wise answer "It depends on the bike" or "I don't know." That is to say that, contrary to the case of the concepts <*Car*> and <*Tractor*>, which are undoubtedly connected to the concept <*Vehicle*> (which is constructed based on the individual vehicles), the super-concept <*ElectricalVehicle*> may or may not be so. In the same way, the concept <*Vehicle*> may or may not be connected to sub-concepts such as <*Sledge*> or <*Skateboard*>.

Two aspects are important in the above: Firstly, formed, transformed, and reformed concepts find their place in semantic memory in a cluster of closely related concepts – which, as seen, can be either sub-concepts or super-concepts.[18] This clustering is what we can call *conceptual relatedness* or *semantic similarity*, following Collins and Loftus (1975).[19] But, and secondly, this conceptual relatedness is, of course, not the same for all concepts (and, subsequently, for their instances) in a specific class; for example, for an older driver not much versed in autonomous vehicles, a regular car is *more* a vehicle than an autonomous car is (see above the question of degrees of exemplarity or typicality). We can thus think of *semantic distance* as the shortest path between two concepts in someone's semantic network. Figure 1 shows (a fragment of) one such network.

As said above, a semantic network is a formal means to represent semantic memory, or terminological knowledge broadly conceived. In effect, a semantic network is defined as a (directed) graph whose nodes are concepts or individuals, and the edges

[18] We are here assuming – against the motivation of Collins and Loftus (1975)? – that semantic networks just are full-scale hierarchical category systems in which semantic relatedness expresses better (but does not replace) the two dimensions of the latter.

[19] This is the *spreading activation* theory, or model, of human semantic memory developed mainly by Quillian and Collins (e.g., Collins & Quillian 1969; Quillian 1967, 1969). In what follows, we will ally elements of this model with the logical connectives in a more explicit way than, for instance, in Collins & Loftus (1975).

may be labeled by roles (see Fig. 1). This makes their alliance with DL extremely adequate. An important point to bear in mind with regard to semantic networks, and which appears almost all too obvious, is that we normally do not include concepts (as well as their instances) in non-related classes; moreover, when retrieving a concept, we normally activate only related concepts (in other words: we *associate* semantically related concepts) and inhibit (*dissociate*) semantically unrelated ones. Some forms of expression relying on "semantic oddity," such as poetry, play with this: For instance, metaphor combines concepts that are not normally associated (e.g., "He is a devil."), creating a surprise or novelty effect in the reader/listener.

The retrieval of information in computing systems has a well-studied logic-algebraic foundation (e.g., Dominich, 2008); from the viewpoint of computationalism as a theory of cognition and taking the brain as a computing "machine" (e.g., Husbands et al., 2008), we believe that human agents use by and large the same operations. In logical terms, we retrieve symbol structures by making conjunctions and disjunctions that can be said to be rule-governed and logical because they comply, generally, with the two pillars of classical logic briefly mentioned above, the PNC, expressed by the DL formula "$\neg(D \sqcap \neg D)$", where D is a description, stating that contradictory descriptions cannot both be true of any one and the same entity at the same time, and the LEM, expressed in DL by "$D \sqcup \neg D$", according to which either what is stated (or predicated) of any one and the same entity is true or its negation is. Interpreted in DL semantics, these (conceptual and logical) principles are subsumed under the top concept "$\top$" because their interpretation is always subsumed under the logical concept <*Truth*>: By assigning to D a truth value *true* (and by classifying a concept description under $\top$) when $\neg D$ has a truth value *false* (and, as a negation of a concept description, is subsumed under the bottom concept "$\bot$"), we can construct truth tables that provide an interpretation as far as the truth-assignment of these principles is concerned (see Fig. 2).[20]

D	$\neg D$	$\rho(\neg D)$
$\top$	$\bot$	$\bot$
$\bot$	$\top$	$\top$

D_1	D_2	$D_1 \sqcap D_2$	$\rho(D_1 \sqcap D_2)$	$D_1 \sqcup D_2$	$\rho(D_1 \sqcup D_2)$
$\top$	$\top$	$\top$	$\top$	$\top$	$\top$
$\top$	$\bot$	$\bot$	$\bot$	$\top$	$\top$
$\bot$	$\top$	$\bot$	$\bot$	$\top$	$\top$
$\bot$	$\bot$	$\bot$	$\bot$	$\bot$	$\bot$

Figure 2: Truth tables for DL adapted for descriptions $D_{(i)}$, their negation, association, and disjunction. $\rho(D)$ denotes the retrieval of some description D.

Further, let us designate retrieval of concepts by the Greek letter ρ. Then we say that we retrieve a description D correctly/wrongly according to the truth-table of DL for negation augmented as in Fig. 2. Furthermore, because concept retrieval is connected to concept *activation* (in the sense that for an individual concept to be

[20]For simplicity, we make the truth values *false* and *true* coincide with the bottom and top concepts, respectively.

retrieved it must first be activated in the semantic network), the augmented truth table for classical negation expresses the fact that when we activate an individual concept (e.g., $<\mathit{Sweet}>$), we deactivate (or inhibit) its negation or opposite (e.g., $<\neg \mathit{Sweet}>$ or $<\mathit{Sour}>$, respectively).

This formalizes the retrieval of descriptions one at a time in terms of (augmented) DL. Let us now see how two descriptions (and no more, for simplicity and clarity only) are logically associated or dissociated in retrieval: The conjunction of two descriptions is correctly activated when both should be activated (for instance, for semantic relatedness, and/or for cultural and/or contextual cues; e.g., the English expression "bread and butter," formalizable in DL as $<\mathit{Bread} \sqcap \mathit{Butter}>$, and the common association "wine and bar," formalizable as $<\mathit{Wine} \sqcap \mathit{Bar}>$, etc.), while their disjunction is correctly activated when both or at least one of them is to be activated (e.g., "walk or stop" = not-walk at a streetlight, $<\mathit{Walk} \sqcup \neg \mathit{Walk}>$). On the contrary, the conjunction of two descriptions should be inhibited when one or both should not be activated (for the same reasons), and their disjunction should be inhibited when none should be activated. For instance, $<(\mathit{Lion} \sqcap \mathit{Play})_{\perp}>$ is commonly the case, as is $<(\mathit{Liquor} \sqcap \mathit{Drive})_{\perp}>$, too.

As a matter of fact, the *context* plays here a central role. For instance, the association $<(\mathit{Queen} \sqcap \mathit{HorseRide})>$ of the individual concepts $<\mathit{Queen}>$ and $<\mathit{HorseRide}>$ is admissible in the context of, say, a horse race or hunting, but in the context of a chess game $<(\mathit{Queen} \sqcap \mathit{HorseRide})_{\perp}>$ is likely to be the case. In the same way, if attacked by a charging lion a cognitive agent will be expected to disjointly associate the individual concepts $<\mathit{Fight}>$ or $<\mathit{Flight}>$ as $<(\mathit{Fight} \sqcup \mathit{Flight})>$; on the contrary, $<(\mathit{Fight} \sqcup \mathit{Flight})_{\perp}>$ will be the case for a cognitive agent that feels threatened without reason. This is the same as to say that an association should be inhibited when, if in a conjunction, one or both concepts are not related to the context or class at issue (given the cultural and/or contextual cues), and if in a disjunction, none of the individual concepts is related to the context or class at issue. When retrieving one individual concept at a time, one should not simultaneously retrieve it together with its negation or opposite (cf. PNC); one should activate either it or its negation/opposite (cf. LEM).

What we now have is a powerful formal tool, provided by (standard) set theory and (augmented) DL, of description/expression of the logical form of the thought processes of classification and association of conceptual and/or terminological representations. Summing up, of any (atomic or complex) concept C, we have either $<C>$ (abbreviating $<C_{\top}>$) or $<C_{\perp}>$ in case C has the correct logical form or the incorrect logical form, respectively, it being the case that $<\ldots_{\top}>$ or $<\ldots_{\perp}>$, while denoting correct/meaningful or faulty/meaningless conceptualizations, actually depend on the application of rules on a semantic network that, in turn, are triggered by the agent's perception of the context. Importantly, DL can be used to express the cognitive processes of categorization and association as inferential processes in a conservative way, i.e. by respecting the inference rules of classical logic (Table 1).[21]

[21] In Table 1, the symbol "$\models$" denotes logical consequence, namely of the semantic type. See Augusto (2020b) for a comprehensive discussion of this central concept of formal logic.

Table 1: Rules of inference and their classical account in DL. (D_1 and D_2 stand for two concept descriptions. The formal expression "$\models D$" is read "D is meaningful" (also: holds or is true); on the contrary, "$\not\models D$" denotes that D is meaningless (also: does not hold or is false). "Iff" is read "if and only if".)

DL-Based Inference Rule	**DL-Based Account**	
Conjunction Introduction ($\sqcap I$): $\dfrac{D_1 \quad D_2}{D_1 \sqcap D_2}$	If $D_1 \sqsubseteq \top$ and $D_2 \sqsubseteq \top$, then conjoin D_1 and D_2; in effect, $\models D_1 \sqcap D_2$ iff $\models D_1$ and $\models D_2$.	Otherwise, $(D_1 \sqcap D_2) \sqsubseteq \bot$; in effect, $\not\models D_1 \sqcap D_2$ iff $\not\models D_1$ or $\not\models D_2$.
Disjunction Introduction ($\sqcup I$): $\dfrac{D_1}{D_1 \sqcup D_2}$ $\dfrac{D_2}{D_1 \sqcup D_2}$	If $D_1 \sqsubseteq \top$, disjoint D_1 and D_2 whether $D_2 \sqsubseteq \top$ or $D_2 \sqsubseteq \bot$, and vice-versa, if $D_2 \sqsubseteq \top$, ...; $\models D_1 \sqcup D_2$ iff $\models D_1$ or $\models D_2$.	Otherwise, $\not\models D_1 \sqcup D_2$ iff $\not\models D_1$ and $\not\models D_2$.
Negation Introduction ($\neg I$): $\dfrac{\begin{matrix}(D)\\ \bot\end{matrix}}{\neg D}$	If D leads to $\bot$, then negate D: $\models \neg D$ iff $\not\models D$.	We always have: $\not\models \bot$
Negation Elimination ($\neg E$): $\dfrac{\neg D \quad D}{\bot}$	Negating D while keeping D leads to $\bot$; in effect, we have $\models D$ iff $\not\models \neg D$.	PNC always holds: $\not\models (D \sqcap \neg D)$

4 The Dyssyntax Model

4.1 Formal Account of FTD as "Schizophrenic Retrieval"

From a logical perspective, subjects who have been diagnosed with FTD not only frequently disrespect the rules of composition and inference of classical logic (Fig. 2; Table 1), but they actually appear to go against them in what can be seen as a pattern. Because this pattern appears to be most frequent in schizophrenia we shall refer to it as the "schizophrenic pattern." In effect, schizophrenia patients tend to activate simultaneously antonyms (Chaika, 1974; Spitzer et al., 1993; see Schreber, 1903/2000, for first-hand evidence), sometimes with such obvious antynomy as that of "yes" and "no" (e.g., Laffal et al., 1956). As for conjunction and disjunction, the pattern is to see the conjunction of opposites as correct, and the disjunction of false disjuncts as also unproblematic. Figure 3 shows this pattern for activation or retrieval (denoted by ρ), but it is hypothesized that this might be so also for storage (denoted by σ).

Regardless of the etiology – whether at storage or retrieval (possibly both) – we propose a means to assess FTD via a computational analysis of speech (but also written) samples that takes all the above discussion in consideration. For this end, the Conception Language $\mathcal{CL}$ will be our main tool.

D	$\neg D$	$\rho^*(\neg D)$
$\top$	$\bot$	$\top$
$\bot$	$\top$	$\bot$

D_1	D_2	$D_1 \sqcap D_2$	$\rho^*(D_1 \sqcap D_2)$	$D_1 \sqcup D_2$	$\rho^*(D_1 \sqcup D_2)$
$\top$	$\top$	$\top$	$\bot$	$\top$	$\bot$
$\top$	$\bot$	$\bot$	$\top$	$\top$	$\bot$
$\bot$	$\top$	$\bot$	$\top$	$\top$	$\bot$
$\bot$	$\bot$	$\bot$	$\top$	$\bot$	$\top$

Figure 3: Truth tables adapted for descriptions and their negation, association, and disjunction in "schizophrenic retrieval" (in gray), denoted by $\rho*$, where ρ is a mapping from descriptions to the Boolean truth-value set $V_{Bool} = \{\top, \bot\}$.

4.2 Conception Language $\mathcal{CL}$

DL has been shown to provide an adequate formal means to represent the categorization and association of concepts in a semantic network. However, we must in fact speak of *individual* semantic networks, because no two human semantic networks are exactly the same, despite the forcing aspect of both set theory and DL briefly mentioned above. In effect, every human cognitive agent constructs a partly idiosyncratic or specific semantic network that reflects their individual conceptualization of the world, which, in turn, depends on the individuals they encounter daily and on other aspects such as cultural biases, epistemes, etc. To express this idiosyncrasy we employ here what we call *Conception Language* ($\mathcal{CL}$), a DL-based language which is conceived precisely for modeling terminological knowledge and representing the agents' associated conceptions of the world (Badie, 2018a-b; 2020a-b).

By assuming that concepts are distinct representational phenomena/entities that are construed by cognitive agents in a particular state of awareness, a possible interpretation is that concepts can be identified with the *contents* in, for example, linguistic expressions (which are basically in the form of words), formal expressions (which are basically in the form of symbols and special characters), and/or numerical expressions (which are in the form of numbers) by becoming manifested in the form of the agents' *conceptions.* Let Ag stand for some agent. $\mathcal{CL}$ is syntactically defined based on (1) Ag's *conceptions* (which are equivalent to Ag's conceptions of [their mental] concepts) and on (2) Ag's *conception's effects* (which are equivalent to Ag's conceptions of [their mental concepts] roles), as well as based on (3) *singulars* (which are equivalent to Ag's conceptions of various individuals in the world). For example, John's conception of the concept $<Car>$ is symbolically represented by the conception $<{}^{John}Car>$. Also, his conception of the role $<isCar>$ is regarded as his conception's effect and is representable by $<{}^{John}isCar>$. In addition, his conception of some individual *car* is represented by the singular ${}^{John}car$. Conceptions, effects, and singulars are respectively denoted by C, E, and s in $\mathcal{CL}$. In addition, $\mathcal{CL}$ is capable of applying the relations of membership (of a singular under some conception of an agent) as well as of subsumption (of some conception of an agent under their other conceptions). $\mathcal{CL}$ can also support the conjunction (of two, or more, conceptions [of an agent]), disjunction (of two, or more, conceptions), and negation (of some conception).

Importantly, $<Car>$ and $<^{John}Car>$ stand for the general concept of car and for John's specific conception of car, the same distinction being applicable for effects and singulars. Based on the described formalism, *conception descriptions* are terminologically analyzable in the following way: Any conception description can fundamentally be understood to be in the forms of *conception equality* (formally: $^{Ag}C_1 \equiv {}^{Ag}C_2$), *conception subsumption* ($^{Ag}C_1 \sqsubseteq {}^{Ag}C_2$), *conception's effect equality* ($^{Ag}E_1 \equiv {}^{Ag}E_2$), *conception's effect subsumption* ($^{Ag}E_1 \sqsubseteq {}^{Ag}E_2$), *conception assertion* ($^{Ag}C(s)$), and *conception's effect assertion* ($^{Ag}E(s_1, s_2)$). From a deeper logical perspective, an *Ag*'s semantic interpretation of (as well as their inferencing based on) their conception of within-concept relationships can fundamentally be prompted by their atomic conception(s) of within-concept, proximity, relationships (based on similarities, prototypicality, and/or representativeness or exemplarity). In effect, at every storage and retrieval step (which takes place in a particular state of awareness of *Ag*), *Ag* conceptualizes, interprets and (deductively or inductively) infers the attributes of concepts (as well as of classes of various singulars), both vertically and horizontally, establishing relations among super- and sub-ordinate categories in a semantic network.

Figure 4 is a sub-ontology of the ontology of conception representation in terminological systems using $\mathcal{CL}$, a construct elaborated on in Badie (2020a). This Figure shows the specification of possible conceptualization of agents' conceptions in our $\mathcal{CL}$-based logical system.

4.3 Assessing FTD with a $\mathcal{CL}$-Based Computational Implementation

Briefly put, $\mathcal{CL}$ provides us with a logical language for what can be called "agent specification," the individual(ized) speech of an agent by means of which this agent's productions can be compared to some standard terminological knowledge. This comparison, in turn, constitutes an assessment with respect to FTD. In effect, the valuations $<^{Ag}C> \sqsubseteq <Truth>$ and $<^{Ag}C> \sqsubseteq <Falsity>$ for some agent *Ag* are determined by $< C > \sqsubseteq <Truth>$ and $< C > \sqsubseteq <Falsity>$ for the larger community of which *Ag* is a member (for instance, if *Ag* is a North-American individual, then $< C >$ is valuated according to the typical terminological knowledge of English-speaking North-Americans). This is what we call *shared conceptualization* in the context of semantic knowledge (e.g., Augusto, 2022). (Below we discuss this in some more detail.) We are now ready to demonstrate how to apply $\mathcal{CL}$ in our model, in order to assess FTD as a formally-describable singularity over a semantic memory.

4.3.1 The $\mathcal{CL}$-based assessment algorithm

As seen above, by means of DL and $\mathcal{CL}$, it is possible to valuate the conceptions of individual agents as being meaningful or meaningless (also: true or false), it being the case that this formal valuation effectively equates with a valuation of normalcy or singularity (also: abnormality). For instance, let us consider the individual conception

$$<^{Ag}Lion> \sqsubseteq <^{Ag}Pet>$$

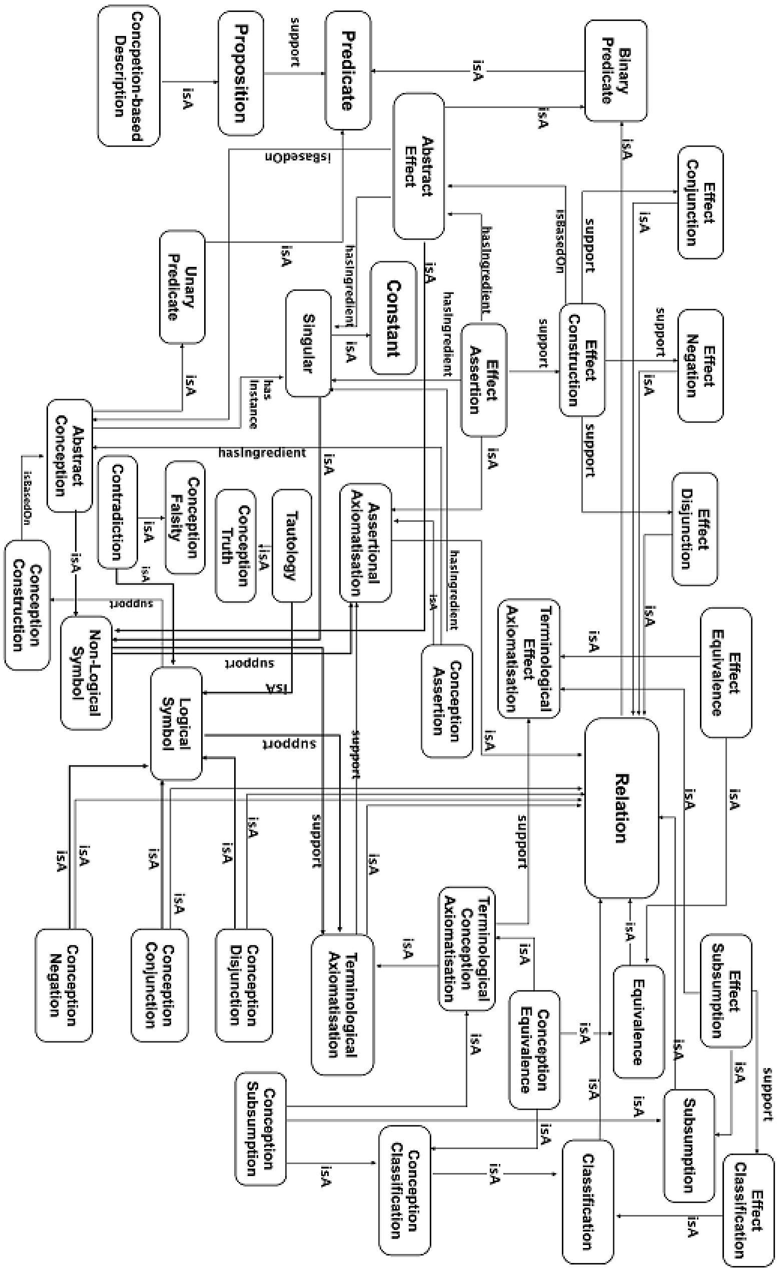

Figure 4: A schematic ontology for logical-terminological descriptions of agents' conceptions in *CL*.

by some agent. While the conception $<Lion> \sqsubseteq <Pet>$ may in principle be acceptable (say, for some agent John who has a pet lion), in which case we write

$$\begin{gathered} <^{John}Lion_{\top}> \sqsubseteq <^{John}Pet_{\top}> \\ \equiv \\ <^{John}Lion_{\top}> \sqsubseteq \top \\ \equiv \\ <^{John}Lion_{\top}> \end{gathered}$$

it is not so for Brenda, who, say, believes that any lion is a pet. Hence, we write

$$\begin{gathered} <^{Brenda}Lion_{\bot}> \sqsubseteq <^{Brenda}Pet_{\bot}> \\ \equiv \\ <^{Brenda}Lion_{\bot}> \sqsubseteq \bot \\ \equiv \\ <^{Brenda}Lion_{\bot}> \end{gathered}$$

to indicate that Brenda's conception of lion or pet (or both) deviates from the normal categorization. In the same way, we write

$$< \ (<^{Brenda}Lion> \sqcap <^{Brenda}Play>)_{\bot} \ >$$

to indicate that Brenda's association of lion and play is abnormal or singular. Equally if Brenda produces the conception that "You can grop with lions," because "grop with" is a neologism or a non-word (formally: $<GropWith> \sqsubseteq \emptyset$) we also write $<^{Brenda}GropWith(Lion)_{\bot}>$.

If we apply this in an algorithmic way (see Fig. 5)[22] to a sufficiently long sample of spontaneous or prompted speech production, we have a reliable formal tool to assess FTD by the amount of $< ._{\bot} >$, namely in a ratio to normally shared conceptions, to be found in the "translation" of the sample into $\mathcal{CL}$.[23] This formal tool is reliable because it can cover not only the aspects considered in DTI, but all the other aspects considered in the literature and mentioned above.[24] In effect, even if we think that the *loosening of conception association*, most immediately identifiable with the D and I of DTI (but also obviously with the T), is the culprit of FTD, we believe that the reduction by the DSM-5 to DTI is too drastic, leaving aside symptoms that do indeed, in our view, contribute to an assessment of FTD as it is accounted for in our dyssyntax model.

The algorithm is *conservative* but *not* classical, as the valuation for negation, conjunction, and disjunction in which there is an indeterminate truth value, denoted by "?", follows the truth tables of Bochvar's logic known as external system, in which this indeterminacy is simply identified with falsity (see Fig. 6). In other words, we have the truth-value set $V_{Bochvar} = \{\bot, ?, \top\}$ but treat "?" as "$\bot$". We account for

[22] $|F|$ denotes the cardinality of the set F, i.e. the number of its elements.

[23] We need yet to establish this ratio, but it seems that at least 30% of abnormal or singular conceptions will be required for an assessment of (mild) FTD.

[24] Note that we speak here of a *formal* tool and not of a *clinical* tool. In effect, we take DTI to be aspects of individual speech productions that deviate linguistically and conceptually from normalcy when interpreted via $\mathcal{CL}$ in our dyssyntax model, i.e. they are not seen as clinical symptoms without further ado. This said, we believe these two perspectives – the formal and the clinical one – may possibly coincide, but this will require further work in the dyssyntax model.

```
% Input:  A set F₀ of formalized conceptual descriptions by a specific
     agent of the basic forms <α>, <¬α>, <(α ⊓ β)>, <(α ⊔ β)>

% Output:  A set F* of valuated formalized conceptual descriptions


while |Fᵢ| > 0, i = 0,...,k, do:
    if <α> ⊑ ⊤ , then print <α>⊤, else print <α>⊥;
    if <(¬α)> ⊑ ⊤, then print <(¬α)>⊤, else print <(¬α)>⊥;
    if <(α ⊓ β)> ⊑ ⊤, then print <(α ⊓ β)>⊤, else print <(α ⊓ β)>⊥;
    if <(α ⊔ β)> ⊑ ⊤, then print <(α ⊔ β)>⊤, else print <(α ⊔ β)>⊥;
end when F_{k+1} = ∅ and |F*| = |F₀|.
```

Figure 5: The algorithm (in pseudocode) for the $\mathcal{CL}$-based FTD assessment of a speech sample. It is assumed that printed formulas are removed from the input set F (such that we have $|F_j| = |F_i| - 1$ for $j = i + 1$) and are sent to the output set F^*.

this choice by claiming that indeterminacy is the same as meaninglessness, in logical terms, a feature that plays a central role in the assessment of FTD.[25]

D	$\neg D$
$\top$	$\bot$
?	$\top$
$\bot$	$\top$

$D_1 \sqcap D_2$	$\top$	?	$\bot$
$\top$	$\top$	$\bot$	$\bot$
?	$\bot$	$\bot$	$\bot$
$\bot$	$\bot$	$\bot$	$\bot$

$D_1 \sqcup D_2$	$\top$	?	$\bot$
$\top$	$\top$	$\top$	$\top$
?	$\top$	$\bot$	$\bot$
$\bot$	$\top$	$\bot$	$\bot$

Figure 6: Bochvar's conservative non-classical truth tables for the truth-value set $V_{Bochvar} = \{\top, ?, \bot\}$ adapted for the DL connectives for negation, conjunction, and disjunction.

We apply the assessment algorithm in Figure 5 to the following speech sample (source: Andreasen, 1986) attributable, for a correct application of $\mathcal{CL}$, to an agent called Emma.[26] For convenience, we isolate Emma's descriptions:

> (D_1) They're destroying too many cattle and oil just to make soap. (D_2) If we need soap when you can jump into a pool of water, and then when you go to buy your gasoline, my folks always thought they should, get pop but the best thing to get, is motor oil, and, money. (D_3) May may as well go there and, trade in some, pop caps and, uh, tires, and tractors to grup, car garages, so they can pull cars away from wrecks, is what I believe in. (D_4) So I didn't go there to get no more pop when my folks

[25] See Augusto (2020a) for Bochvar's and other three-valued logics with an indeterminate truth value and for logical accounts of meaninglessness.

[26] We think it is relevant to use here samples of speech that have been assessed as exhibiting FTD in the standard clinical literature. In our model, for some of these – e.g., the sample here considered – this assessment is not corroborated. From a psychiatric viewpoint, it might be argued that our model lacks sensitivity, but we prefer this to false positives.

said it. (D_5) I just went there to get a ice-cream cone, and some pop, in cans, or we can go over there to get a cigarette."

We call the reader's attention to the fact that Emma's speech appears to be centered in the category "filling station," of which we give a fragmentary semantic network in Figure 1 above. She refers to a specific filling station with the deictic "there." This remark is crucial, because $\mathcal{CL}$ inherits the semantics of DL, which is based on an *interpretation* carried out over the elements of a *domain of discourse*, so an agent's productions must always be assessed with this aspect in mind (see Badie & Augusto, 2022, for details). Importantly, and as shown in Figure 1, the domain can be further divided into sub-domains (in this case, for instance, "supermarket").

To simplify, we omit the superscript Emma and present the formalized conceptual descriptions by Emma as already assessed (denoted by $\widetilde{D_i}$) by the algorithm above:

$$(\widetilde{D_1}) \qquad <(((\mathit{Cattle} \sqcap \mathit{Oil})_\top \sqcap \mathit{Destroy})_\top \sqcap \mathit{Soap})_\top >_\top$$

$$(\widetilde{D_2}) \qquad <\neg(\mathit{Soap} \sqcap (\mathit{WaterPool} \sqcap \mathit{Jump})_\top)_\top \sqcup$$
$$((\mathit{Gasoline} \sqcap \mathit{Pop} \sqcap \mathit{MotorOil} \sqcap \mathit{Money})_\top \sqcap \mathit{Get}_\bot)_\bot >_\top$$

$$(\widetilde{D_3}) \qquad <(((\mathit{PopCap} \sqcap \mathit{Tire} \sqcap \mathit{TractorToGrup} \sqcap \mathit{CarGarage})_? \sqcap \mathit{TradeIn})_\bot \sqcap$$
$$((\mathit{Car} \sqcap \mathit{Wreck})_\top \sqcap \mathit{PullAwayFrom})_\top) >_\bot$$

$$(\widetilde{D_4}) \qquad <(\mathit{FolksForbid} \sqcap \neg \mathit{Go})_\top >_\top$$

$$(\widetilde{D_5}) \qquad <((\mathit{IceCreamCone} \sqcap \mathit{PopInCans} \sqcap \mathit{Cigarette})_\top \sqcap \mathit{Get})_\top >_\top$$

Some remarks: D_2 is formalized as $<(\alpha \to \beta)> \equiv <(\neg\alpha \sqcup \beta)>$. D_3 is valuated as false because "to grup" is a neologism or a non-word; this makes it that the whole conjunction is meaningless, and thus the main conjunction is false, by application of Bochvar's truth table for conjunction.

We can actually simplify our algorithm as in Figure 7 with ease of human reading in view, so that the output of the assessment of Emma's sample is the multiset[27]

$$\{1, 1, 0, 1, 1\}$$

corresponding to the assessment of descriptions D_1 through D_5. It is immediately obvious that abnormal descriptions account for only 20% of Emma's speech, for which reason we disagree with Andreasen (1986), as well as with Kuperberg (2010), who unhesitatingly produce a diagnosis of FTD. To be sure, DTI is prevalent in Emma's sample *at the surface*: Emma's reply is tangential to the question asked (her opinion on current political issues like the energy crisis), and there is an overall *apparent* loosening

[27] A multiset is a set in which repeated elements are allowed and enumerable.

```
% Input:  A set F0 of formalized conceptual descriptions by a specific
     agent of the basic forms <α>, <¬α>, <(α ⊓ β)>, <(α ⊔ β)>

% Output:  A multiset F* of Boolean values


while |Fi| > 0, i = 0,...,k, do:
    if <α> ⊑ ⊤ , then print 1, else print 0;
    if <(¬α)> ⊑ ⊤, then print 1, else print 0;
    if <(α ⊓ β)> ⊑ ⊤,then print 1, else print 0;
    if <(α ⊔ β)> ⊑ ⊤, then print 1, else print 0;
end when Fk+1 = ∅ and |F*| = |F0|.
```

Figure 7: The simplified algorithm. It is assumed that formulas whose Boolean value has been printed are removed from the input set F (such that we have $|F_j| = |F_i|-1$ for $j = i+1$) and the corresponding values are sent to the output multiset F^*.

of associations; this, together with neologisms, gives the sample an *appearance* of incoherence that, together with some grammatical mistakes, makes the assessor ready to pronounce a case of FTD. However, if one concentrates on *logical* form alone, which accounts for the *deep structure* of Emma's speech, and keeps the domain of discourse in mind, one might not be so willing or ready to pronounce such an assessment, at least until further, longer samples are subjected to the assessment algorithm.

4.3.2 $\mathcal{CL}$ and the Web Ontology Language (OWL)

Without the presence of the symbol "$\sqsubseteq$", our algorithm would be just the classically conservative truth tables for negation, conjunction, and disjunction of Bochvar's three-valued logical system referred to as *external*. The obvious question now is: Who/What determines the valuations for set inclusion? At present, we must rely on the common-sense knowledge of the human implementers of the algorithm. This, of course, is not optimal from the viewpoint of computational cognitive linguistics, and we need access to terminological databases or repositories that are as complete as possible for specific languages, communities, and even domains in the sense that they can provide us with probabilities of interest.[28] For the latter, ontologies will provide an adequate resource; for the former, we will require extensive digitalized corpora. With such resources at hand, we will be able to check automatically for degrees of sharedness, or the degrees to which a concept is normally included in a certain domain of discourse (e.g., $<(<Oil> \sqsubseteq <Soap>)_{0.22}>_{\top}$, because the inclusion relation is verified to hold to a degree of, say, 22%) or the degree to which two concepts are normally shared (e.g., $<(<Lion> \sqcap <Play>)_{0.06}>_{\bot}$, because the shared degree of association of these concepts is below 15%; or $<(<Lion> \sqcap <Grop>)_{0.00}>_{\bot}$, because the word "grop" was not found in the resources). At present, we have no such resources other than the existing ontologies, but it is expectable that in a not-so-far future OWL services

[28] We have forthcoming work in this subject. We anticipate that this will require fuzzy DLs.

and databases will provide us with complete corpora. Because, just like $\mathcal{CL}$, OWL is essentially DL-based, it will be just a matter of adapting minimally these resources, so that assessors can access them for strictly formal support in the assessment of FTD. After all, the measuring tool of FTD is the degree to which given samples of speech deviate from normal sharedness, in the belief that this deviation reflects essentially a syntactic impairment in human semantic networks or terminological knowledge bases.

5 Conclusions and Further Work

In this paper, we present a novel model for semantic memory, or terminological knowledge, that can assess speech samples for the condition known for long in the psychiatric literature as formal thought disorder (FTD). Although this condition clearly points to the form of thought, until now this form had not been identified and rigorously defined. We see it as the logical form associated with the (*deep*) processes of storage and retrieval in a semantic network, describable by description logic (DL) and specifiable for individual cognitive agents by the DL-based Conceptual Language $\mathcal{CL}$.

This is a symbolic computational model, because it considers concepts and/or words as symbol structures that are manipulated – i.e. formed, transformed, and reformed – by computational operations that do not depend on the will of the subject but are largely automatic and unconscious. When these operations are defective in specific ways they impact on the (*surface*) of speech productions as semantic dysfunctions when, in fact, the dysfunction is at the (deep) level of the syntax of thought. We accordingly call this *the dyssyntax model*, based on a *dyssyntax hypothesis*.

The onus of FTD, in this model, falls on the processes of categorization and association in semantic networks. We see these as corresponding to negation, conjunction, and disjunction as defined in DL. It thus appears justified to assess singularities or irregularities in speech production with respect to these operations. While this could be automatically implemented by some conservative non-classical truth tables (we choose Bochvar's tables for his three-valued external logic system), the human assessor has a crucial rule in determining the accordance or discordance of an agent's descriptions with the rest of the community with respect to set inclusion. To make of this an unbiased and reliable assessment, we predict that Web Ontology Language (OWL) services will be shortly so comprehensive and developed that they can be used for this end, which is possible given that OWL is, just like $\mathcal{CL}$, DL-based.

How to implement this will constitute a large part of our work in this model. Future work will focus also on the computational aspects of categorization and association in semantic networks, predictably by studying them from the viewpoint of (search) trees. The theoretical aspect of forcing in set theory and DL, only too briefly touched upon in this paper, also requires a deeper research, and we are keen to carry it out.

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