A Compositional Pluralist Semantics for Extensional and Attitude Verbs

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Abstract We propose a new account of linguistic content that reconciles content-pluralism with compositionality. This is achieved by integrating truth-conditional content and attitude report content into a single notion of content. A parametrized version of this notion (with parameters for agents, times, and information states) serves as input to the compositional semantic machinery. By supplying different parameter-values to the parametrized contents of their complements, different verbs select for different components of the complement's integrated content. The resulting account explains the different substitution properties of extensional and attitude constructions and captures the role of agents' epistemic perspective in the determination of attitude content. The account improves upon other accounts of truth-conditional and attitude content (esp. two-dimensional semantics) by interpreting different occurrences of an expression—in extensional and in attitude embeddings—as objects of *the same* semantic type, and by explaining the substitution-resistance of attitudinal embeddings of extensional constructions.

Keywords Pluralism about linguistic content · Compositional interpretation · Intensional verbs · Attitude reports · Epistemic perspective · Two-dimensional semantics

1 Introduction

The notion of linguistic content lies at the core of research in semantics and the philosophy of language. This notion describes the context-dependent meaning of (utterances of) linguistic expressions that is used to capture the truth-conditional contribution of these expressions and to predict the entailment relations between these expressions (see Lewis 1970; Montague 1970). Many semantic theories today adopt some form of pluralism about linguistic content (see, e.g., Zimmermann 2012;

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Ciardelli and Roelofsen 2018; Potts 2005). These theories assume different kinds, or types, of linguistic content that serve as the contents of expressions in different contexts and that, hence, play different explanatory roles.

Among the different kinds of linguistic content are typically *truth-conditional content* and *attitude (report)*[1] *content*. Truth-conditional content is sometimes alternatively called *denotational content*, *intensions*, or *objective meaning*. Attitude content is sometimes called *epistemic content*, *information content*, or *subjective meaning*. Respectively, these two kinds of content capture agent-independent criteria for assigning truth-values to utterances (i.e. truth-conditional content) and agents' particular ways of grasping the truth-conditional content of these utterances (i.e. attitude content).

The distinction between truth-conditional and attitude content is often motivated by the observation that certain linguistic constructions resist the truth-preserving substitution of truth-conditionally equivalent expressions in their complements. Such constructions include *de dicto*-readings of clausal embeddings under attitude verbs like believe or hope. Constructions that exhibit this substitution-resistance are called *(hyper-)intensional constructions* and can be described as *cognitively opaque*.[2] They differ from *extensional*[3] constructions (e.g. embeddings under the verb indicate) that allow for such substitutions and are, hence, *cognitively transparent*.

The difference between extensional and attitude constructions is reflected in the possibility, or impossibility, of substituting DPs like sodium by their co-referential DPs (here: natrium) and, hence, of substituting (1a) by the truth-conditionally equivalent (1b): while this substitution is typically allowed in the complement of indicate (s.t. one can infer (2b) from (2a)), it is often disallowed in the complement of believe (s.t. one cannot generally infer (3b) from (3a)). The latter inference is blocked if the attitude complements have a different cognitive significance for the attitude subject (in (3): for Len).

(1) a. Sodium is a metal.
b. Natrium is a metal.

(2) a. The reaction indicates [$_{CP}$that sodium is a metal]. (**T**)
⇒ b. The reaction indicates [$_{CP}$that natrium is a metal]. (**T**)

[1] Because of our focus on *linguistic* content, we hereafter take attitude content to refer to the content of attitude *reports*, rather than to the content of the mental attitudes underlying these reports (see Hintikka 1969).

[2] Our notion of *cognitive opacity* differs from the familiar notion of (referential) opacity (see Quine 1953), which captures the sensitivity for truth-conditional, rather than for attitude content. Our notion of *cognitive transparency* differs from referential transparency, which captures the sensitivity for reference/extension. The difference between these notions is exemplified by the verb indicate, which creates a referentially opaque, but cognitively transparent context.

[3] We will hereafter use *extensional verb* (or *construction*) as a cover term for verbs (or constructions) that take *extensional* and for verbs (or constructions) that take *intensional* complements. Our use of this term is motivated by the common description of objectual attitude verbs as *intensional transitive verbs*.

(3) a. Len believes [$_{CP}$that sodium is a metal]. (**T**)

$\not\Rightarrow$ b. Len believes [$_{CP}$that natrium is a metal]. (**F**)

To explain the difference in substitutivity between (2) and (3), most pluralist theories about linguistic content (e.g. Chalmers 2006; Zimmermann 2012; Lappin 2015) interpret extensional verbs as expressions that select for the *truth-conditional* content of their complement and interpret attitude verbs as expressions that select for the *combined* (truth-conditional and *attitude*) content of their complement. However, these theories often yield a disunified semantics that interprets different occurrences of a complement—in extensional and in attitude embeddings—as objects of different types. As a result, these theories often resist an easy compositional formulation. However, given their intended role as an account of natural language content, this is highly problematic.

This paper outlines a new account of truth-conditional and attitude content, called *Integrated Semantics*, that solves the above problem by integrating truth-conditional and attitude content into a single notion of linguistic content. The account enables a uniform compositional treatment of extensional and attitude constructions that correctly predicts the substitution behavior of these constructions.

The paper is organized as follows: To show the need for an integrated account of truth-conditional and attitude content, we first describe the relation between truth-conditional and attitude content, review the most popular account of these two kinds of content (i.e. two-dimensional semantics), and identify some shortcomings of this account (in Sect. 2). The rest of the paper will be concerned with an incremental presentation of our alternative account of truth-conditional and attitude content, i.e. *Integrated Semantics*, and with a demonstration of the ability of this account to avoid the above shortcomings. To this aim, we first give an informal presentation of Integrated Semantics (in Sect. 3), which we subsequently turn into a compositional semantics for a small fragment of English containing extensional and attitude verbs (in Sect. 4, 5). The paper closes with a summary of our results and with pointers to future work.

2 Accounts of Truth-Conditional and Attitude Content

The distinction between truth-conditional and attitude content is anticipated by the different roles of Frege's notion of *sense* [German *Sinn*]. In (Frege 1892), the sense of an expression serves both to determine the denotation [*Bedeutung*] of this expression and to provide the linguistic content of this expression in indirect (e.g. attitude) contexts. The latter role is enabled by the fact that the sense of an expression contains the denotation's mode of presentation [*Art des Gegebenseins*; MoP] to the cognitive agent. Newer work in semantics captures the difference between the above roles by distinguishing, e.g., between truth-conditional content/reference and *guises* of this

content (see Heim 1998), between truth-conditional content and epistemic *roles* (see Perry 2012), between intensions and *intentions* (see Thomason 1980), and between objects and cognitive *concepts* (see Barsalou 1992).

The distinction between truth-conditional and attitude content is sometimes also captured by separating *hyperintensions* from Carnapian *intensions*: intensions of linguistic expressions are functions from indices (i.e. worlds, or world-time pairs) to the expressions' denotations at these indices (see Carnap 1988; Montague 1970). Intensions thus encode the expressions' truth-conditional content. Hyperintensions are objects with stricter identity-conditions than intensions that serve as the complements of attitude verbs, i.e. they play the role of attitude content. Hyperintensions typically take the form of structured contents (see Lewis 1970; Cresswell 1985), of sets of (im-)possible worlds/situations (see Muskens 1995; Zalta 1997), of unanalyzable primitives (see Thomason 1980; Pollard 2015), or of computational operations (see Moschovakis 2006; Lappin 2015).

2.1 The Relation Between Truth-Conditional and Attitude Content

Most theories of linguistic content assume some relation between truth-conditional and attitude content. This relation is suggested by Frege's assumption that the sense of an expression (*qua* MoP) determines the expression's denotation. The possibility of obtaining truth-conditional content from attitude content enables a compositional semantics for extensional and attitude verbs. However, this possibility is compromised by the fact that speakers' actual MoPs often underdetermine or misdetermine the expression's denotation. In particular, Kripke (1980) has observed that speakers often lack uniquely identifying information about the expression's denotation (s.t. their MoPs identify *other objects in addition to* the expression's denotation) or have false information about this denotation (s.t. their MoPs identify *a different object than* the expression's denotation).

To avoid the challenge from under- or misdetermination, many contemporary theories treat truth-conditional content as the 'default' kind of content and only introduce attitude content in response to special contextual triggers (e.g. occurrence in the complement of an attitude verb). However, this strategy causes a serious problem for the compositional interpretation of natural language: to enable the compositional interpretation of attitude reports, the linguistic content of the attitude complement (i.e. an *attitude* content) must, in some way, be obtainable from the kind of content that serves as input to the compositional machinery (here: a *truth-conditional* content). However, since attitude content is often richer than truth-conditional content, this is not generally possible.

2.2 *Attempts at (Re-)Connecting Truth-Conditional and Attitude Content*

In semantics and the philosophy of language, there have been some recent efforts towards a theory of truth-conditional and attitude content that avoids the dilemma between under- or misdetermination and non-compositionality. These efforts include two-dimensional semantics (see Kaplan 1989; Haas-Spohn 1995; Chalmers 2006; Zimmermann 2012), which interprets linguistic expressions as functions (Kaplanian *characters*) from contexts to intensions, i.e. as functions from contexts to *contents*. Contexts c are tuples containing the world w_c, time t_c, location l_c, and agent/speaker a_c of the context. Intensions are functions from indices to extensions. The intension of a character χ at a context c, $\lambda w \lambda t.\, \chi(c)(w, t)$, serves the role of truth-conditional content. The diagonal of a character χ, i.e. a function, $\lambda c.\, \chi(c)(w_c, t_c)$, from contexts to the character's extension at the context and the context's index, $\langle w_c, t_c \rangle$, serves the role of attitude content.

Two-dimensional semantics has been a remarkable success story. However, this semantics faces several problems regarding the compositional interpretation of attitude reports. These problems are identified below. We will see that each of these problems motivates a desideratum for an alternative, compositional theory of *integrated* (truth-conditional and attitude) content.

2.2.1 Problem 1: Empirical Adequacy

To explain the substitution behavior of attitude reports (see (3)), most theories of two-dimensional semantics (e.g. Lerner and Zimmermann 1991; Haas-Spohn 1995; Schlenker 2003) treat proper names and kind terms as indexical expressions whose truth-conditional content is determined by the utterance context. In virtue of this treatment, co-referential names/kind terms are assigned different characters. The interpretation of attitude verbs as relations to *characters* (or to *diagonals* of characters) and the identification of compositionality with compositionality of character[4] then explain the substitution failure in (3). However, without further—still underexplored—restrictions on the notion of character, the resulting semantics gives *trivial, inadequate truth-conditions* for attitude reports (see von Stechow and Zimmermann 2004).

[4] According to this principle, the character of a complex expression is a function of the characters of the expression's syntactic constituents and their mode of composition (see Westerståhl 2012). The adoption of this principle predicts the preservation of an expression's character under the substitution of same-character constituents.

2.2.2 Problem 2: Semantic Uniformity

To capture the different substitution properties of extensional and attitude constructions (e.g. (2) vs. (3)), some two-dimensional theories (esp. Chalmers 2006; see Lerner and Zimmermann 1991) vary the interpretation of expressions with the expressions' linguistic context: when an expression occurs in the complement of an attitude verb, it is interpreted as the *diagonal* of its character; otherwise, it is interpreted as its intension. However, this variation challenges the uniform interpretation of extensional verbs: since constructions like (2a) often lose their cognitive transparency in attitude embeddings (note the cognitive difference-for-Len between (1a) and (1b), and the resulting non-substitutivity of (2a) by (2b) in (4a)), extensional verbs require—next to their 'extensional' interpretation (on which they take intension-type complements)—a hyperintensional interpretation (on which they take diagonal-type complements). But this doubling seriously complicates their compositional interpretation (cf. Theiler et al. 2018; Liefke and Werning 2018).

(4) a. Len believes [that the reaction indicates [that sodium is a metal]]. (**T**)
$\not\Rightarrow$ b. Len believes [that the reaction indicates [that natrium is a metal]].(**F**)

2.2.3 Problem 3: Perspective-Dependence

The treatment of attitude reports in two-dimensional semantics is further challenged by the inability of this semantics to explain agent- and time-specific differences in the substitutivity of truth-conditionally equivalent complements (compare (3) and (5)). To account for these differences, some two-dimensional theories (e.g. Haas-Spohn 1995) relativize the diagonal of an attitude complement to the attitude subject (i.e. to the object at the origin of the causal chain of uses of the complement's name-constituent in the subject's language). However, apart from the need for further relativization (e.g. to the *time* of use; see the difference in substitutivity between (3)′ and (6), which assumes the cognitive identity-for-Len of (1a) and (1b) at the later point in time t_{k+1}), it is not clear how this relativization can be implemented in a *compositional* interpretation of attitude reports.

(5) a. Eve believes [$_{\text{CP}}$that sodium is a metal]. (**T**)
$\Rightarrow$ b. Eve believes [$_{\text{CP}}$that natrium is a metal]. (**T**)!
(3)′ a. Len believes (at t_k) [$_{\text{CP}}$that sodium is a metal]. (**T**)
$\not\Rightarrow$ b. Len believes (at t_k) [$_{\text{CP}}$that natrium is a metal]. (**F**)
(6) a. Len believes (at t_{k+1}) [$_{\text{CP}}$that sodium is a metal]. (**T**)
$\Rightarrow$ b. Len believes (at t_{k+1}) [$_{\text{CP}}$that natrium is a metal]. (**T**)!

2.3 Desiderata for an Account of Truth-Conditional and Attitude Content

The above problems suggest an alternative theory of truth-conditional and attitude content that has the following properties:

(P.1) The theory is *compositional* [cf. the problem of empirical adequacy]

(P.2) The theory gives *adequate truth- and entailment-conditions* for extensional and attitude constructions [cf. the problem of empirical adequacy]

(P.3) The theory enables a *uniform interpretation* of extensional and attitude constructions [cf. the problem of semantic uniformity]

(P.4) The theory *accommodates agents' epistemic perspective* on the entities in the domain of discourse [cf. the problem of perspective-dependence]

At present, there does not exist a theory of linguistic content that satisfies all of (P.1) to (P.4). However, such a theory is essential for the adequate compositional interpretation of natural language.

3 Integrated Semantics

Integrated Semantics [hereafter, IS] is a novel account of linguistic content that satisfies properties (P.1) to (P.4). This account is a version of two-dimensional semantics that obtains linguistic contents by applying meanings to contexts (here: to centered informational situations). In contrast to *contents* in two-dimensional semantics, contents in Integrated Semantics contain attitude content next to their familiar truth-conditional content. We call the relevant notion of content *integrated content*, abbreviated 'IC'. A parametrized version of this notion (with a parameter for centered informational situations; dubbed 'parametrized IC', or 'PIC') serves as input to the compositional semantic machinery. By supplying different centered situations to the PICs of their complements, different verbs select for different (truth-conditional, or integrated) components of their complement's IC. This selection explains the distinct substitution behaviour of the verbs' complements.

Below, we first introduce centered (informational) situations (in Sect. 3.1). We then give an initial presentation of IS. This presentation proceeds by describing the IC of sentences and proper names at a centered situation (in Sects. 3.2, 3.3).

3.1 Centered Informational Situations

Centered informational situations (or simply, *centered situations*) are ordered triples $\sigma^* := \langle \sigma, t_\sigma, a_\sigma \rangle$ consisting of an informational situation σ, a point in time t_σ, and

a cognitive agent a_σ.[5] Such triples represent the informational situation of a_σ at t_σ. Because of our particular use of such situations, we do not require that σ contains information about a_σ him-/herself.

Informational situations σ are world-level[6] correlates of information states. Such states are typically represented by sets of worlds (i.e. sets of those worlds that are compatible with the available information in this state). In virtue of the correspondence between situations and information states, every sentence that is true (or false) at all worlds in an information state is true (resp. false) in the corresponding situation. This is made possible by the partiality of situations: a sentence may be neither true nor false in a situation. The partiality of situations captures the informational imperfection of cognitive agents. To allow for the possibility of false information, we also consider impossible situations (see Zalta 1997).

The partial nature of informational situations induces a partial ordering on the set of situations. In particular, a situation σ_2 *includes* a situation σ_1 if σ_2 contains all information that is contained in σ_1. We call any situation that includes a situation an *extension* of that situation and identify the *maximal (consistent) extension* of a situation with a (possible) world extending this situation. We assume that every ordering of situations has a bottom element (called *the 'empty' situation*; denoted '†') an a top element (some world w). We assume a single empty situation.

As a consequence of the correspondence between informational situations and sets of worlds, situations have fairly coarse-grained identity conditions. For example, sentences that contain different co-referential or truth-conditionally equivalent expressions (e.g. (1a), (1b)) are true (or false) in the same situations. The 'enrichment' of informational situations by cognitive agents and points in time compensates for this shortcoming, as we will see below.

3.2 The Integrated Content of Sentences

We have mentioned above that a sentence's integrated content at a centered situation contains both truth-conditional and attitude content. To combine these two kinds of content into a single notion of 'integrated' content, Integrated Semantics identifies the integrated content of a sentence with the result of restricting the sentence's classical truth-conditional content at a centered situation (i.e. the set of worlds or situations in which the sentence is true) to smaller sets of situations that also encode the interpreter's salient description, guise, or MoP of the sentence's constituents at the time of interpretation. For (1a) and the centered situation $\sigma_0^* := \langle \sigma_0, t, a \rangle$ (where a is the sentence's interpreter), such a set is given in (7).

In what follows, we will use denotation brackets, $[\![\cdot]\!]$, as a notational device for the IS-interpretation of linguistic expressions. The PIC of the sentence Sodium is

[5] Centered informational situations are, thus, a variant of centered situations (see Stephenson 2010), which are ordered pairs of an agent and a world-part.

[6] Situations are thus objects of type s, not of the type of information states, $\langle s, t \rangle$.

a metal (i.e. (1a)) is then denoted by '⟦Sodium is a metal⟧'. The IC of this sentence at the centered situation σ_0^* is denoted by '⟦Sodium is a metal⟧(σ_0^*)' (see (7)). In (7), ⟦sodium⟧(σ_0^*) is the set of properties that captures a's MoP of sodium in σ_0 at t. This set is obtained from the IS-interpretation of the name sodium at σ_0^* (see Sect. 3.3) and enters the IC of (1a) through the sentence's compositional interpretation at σ_0^* (see Sect. 4). Below, we use σ as a variable over situations.

$$\begin{aligned} &[\![\text{Sodium is a metal}]\!](\sigma_0^*) \qquad (7)\\ = \ &\{\sigma \mid \underbrace{\text{sodium is a metal in } \sigma}_{\text{truth-cond'l content}} \ \&\ \underbrace{\text{sodium has all properties from } [\![\text{sodium}]\!](\sigma_0^*) \text{ in } \sigma\}}_{\text{attitude content (at } \sigma_0^*)} \end{aligned}$$

As a result of the coarse grain of situations (in particular, by the identification of sodium- and natrium- (i.e. Na-)containing situations), (7) is equivalent to (8):

$$\{\sigma \mid \text{Na is a metal in } \sigma \ \&\ \text{Na has all properties from } [\![\text{sodium}]\!](\sigma_0^*) \text{ in } \sigma\} \qquad (8)$$

The first restriction on the set from (7) (see the grey underbrace) identifies the *truth-conditional content* of (1a). The second restriction (see the black underbrace) identifies the *attitude content* of (1a) *at a's information state* σ_0 *at time* t. Since truth-conditional and attitude content perform different restrictions *on the same set* of situations, a sentence's IC is an object of the same type (i.e. a set of situations, type $\langle s, t\rangle$) as the truth-conditional and the attitude component of this IC. This enables the same-type interpretation of the occurrences of the verb indicate in (2a) and (4a). Integrated Semantics thus meets Desideratum (P.3).

Notably, by integrating an expression's (agent-*in*dependent) truth-conditional content with its (agent-*dependent*) attitude content, we do not suggest that linguistic agents know the expression's truth-conditional content: the agentive center of the situation σ_0^* may possess the information contained in (1a)'s attitude content at σ_0^* *without* thereby also possessing the information contained in (1a)'s truth-conditional content. For example, a may be unaware of the referential relation between the name sodium and the chemical element Na. In (7), the element Na only provides an 'external anchor' for the properties in the set ⟦sodium⟧(σ_0^*). While this anchor simplifies the representation of integrated content, nothing depends on it.

3.3 The Interpretation of Proper Names

In Integrated Semantics, proper names (e.g. sodium) are interpreted as intensional generalized quantifiers [*IQs*], i.e. as functions from centered situations to partial sets of properties of individuals. This interpretation is justified by the existence of a non-injective function, °, from IQs to individuals, s.t. we can obtain the referent of a name from the name's PIC. The non-injective nature of this function captures the intuitive semantic distinctness of co-referential names.

We illustrate the IS-interpretation of names through an example: assume that, in σ_1 at t_7, Len thinks of sodium as the reactive substance and of natrium as the silvery-white substance and that, in σ_4 at t_7, Eve thinks of both sodium and natrium as the silvery-white reactive metal. The IQs, $[\![\text{sodium}]\!]$ and $[\![\text{natrium}]\!]$, that serve as the PICs of the names sodium and natrium, then have the following values at $\sigma^*_{len} := \langle \sigma_1, t_7, len \rangle$ and $\sigma^*_{eve} := \langle \sigma_4, t_7, eve \rangle$:

$$\begin{aligned} [\![\text{sodium}]\!](\sigma^*_{len}) &= \{\text{is reactive}\} && \text{(9a)} \\ [\![\text{natrium}]\!](\sigma^*_{len}) &= \{\text{is silvery-white}\} && \text{(9b)} \\ [\![\text{sodium}]\!](\sigma^*_{eve}) &= \{\text{is reactive, is silvery-white, is a metal}\} && \text{(9c)} \\ &= [\![\text{natrium}]\!](\sigma^*_{eve}) \end{aligned}$$

On the basis of the above, (1a) and (1b) are interpreted as (10) and (11) by Len, and as (12) by Eve:

$$\begin{aligned} & [\![\text{Sodium is a metal}]\!](\sigma^*_{len}) && \text{(10)} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na has all properties from } [\![\text{sodium}]\!](\sigma^*_{len}) \text{ in } \sigma\} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na is reactive in } \sigma\} \\ \neq \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na is silvery-white in } \sigma\} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na has all properties of } [\![\text{natrium}]\!](\sigma^*_{len}) \text{ in } \sigma\} \\ = \; & [\![\text{Natrium is a metal}]\!](\sigma^*_{len}) && \text{(11)} \end{aligned}$$

$$\begin{aligned} & [\![\text{Sodium is a metal}]\!](\sigma^*_{eve}) && \text{(12)} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na has all properties of } [\![\text{sodium}]\!](\sigma^*_{eve}) \text{ in } \sigma\} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na is silvery-white and reactive in } \sigma\} \\ = \; & \{\sigma \mid \text{Na is a metal in } \sigma \;\&\; \text{Na has all properties of } [\![\text{natrium}]\!](\sigma^*_{eve}) \text{ in } \sigma\} \\ = \; & [\![\text{Natrium is a metal}]\!](\sigma^*_{eve}) \end{aligned}$$

The *difference* between the ICs of (1a) and (1b) at σ^*_{len} – and their *identity* at σ^*_{eve} – captures Len's and Eve's different epistemic perspectives on the referents of sodium and natrium, and explains the difference in substitutivity between (3) and (5). As a result, Integrated Semantics also meets Desiderata (P.2) and (P.4).

4 The Compositional Interpretation of VPs

We have suggested above that the attitude content of (1a) at σ^*_0 is obtained from the value-at-σ^*_0 of the IS-interpretation of the name sodium. The present section specifies the interpretation of the VP is a metal, which obtains the IC of (1a) from this value. To keep this specification as simple as possible—and to make the interpretation

of linguistic expressions reminiscent to the description of sentence-interpretations from the previous section –, we combine set-theoretic with lambda notation.[7] In the resulting 'mixed' notation, the PIC of (1a) is described as follows (cf. (8)):

$$\begin{aligned} & [\![\text{Sodium is a metal}]\!] \\ = \ & \lambda\sigma^*.\{\sigma \mid \text{Na is a metal in } \sigma \ \&\ \text{Na has all properties from } [\![\text{sodium}]\!](\sigma^*) \text{ in } \sigma\} \end{aligned} \tag{13}$$

We have mentioned in the previous section that the PICs of names are related to the names' individual referents through the non-injective function $^\circ$. This function allows us to render (13) as (14), where $^\circ$ is written in postfix notation (s.t. '$\boldsymbol{x}^\circ$' denotes $^\circ(\boldsymbol{x})$):

$$\begin{aligned} \lambda\sigma^*.\{\sigma \mid & [\![\text{sodium}]\!]^\circ \text{ is a metal in } \sigma \ \& \\ & [\![\text{sodium}]\!]^\circ \text{ has all properties from } [\![\text{sodium}]\!](\sigma^*) \text{ in } \sigma\} \end{aligned} \tag{14}$$

Axiom **Ax1** ensures the non-injectivity of $^\circ$. Below, we let $\boldsymbol{x}$ and $\boldsymbol{y}$ be variables over IQs.

$$\exists \boldsymbol{x} \exists \boldsymbol{y}\, [\boldsymbol{x}^\circ = \boldsymbol{y}^\circ \wedge \boldsymbol{x} \neq \boldsymbol{y}] \tag{Ax1}$$

Ax1 is instantiated by the relation between the PICs of sodium and natrium (in a standard model, given a standard interpretation function):

$$\text{Na} = [\![\text{sodium}]\!]^\circ = [\![\text{natrium}]\!]^\circ \wedge\ [\![\text{sodium}]\!] \neq [\![\text{natrium}]\!] \tag{15}$$

The PICs of the name sodium and of sentence (1a) (cf. (14)) then suggest the following interpretation of the VP be a metal (in (16)): (For simplicity, we treat this VP as a single lexical unit.)

$$\begin{aligned} & [\![\text{be a metal}]\!] \\ = \ & \lambda\boldsymbol{x}\lambda\sigma^*.\{\sigma \mid \boldsymbol{x}^\circ \text{ is a metal in } \sigma \ \&\ \boldsymbol{x}^\circ \text{ has all properties from } \boldsymbol{x}(\sigma^*) \text{ in } \sigma\} \end{aligned} \tag{16}$$

The above enables the compositional interpretation of (1a) at σ_0^* as follows:

$$\begin{aligned} & [\![[_{\text{DP}}\text{Sodium}][_{\text{VP}}\text{is a metal}]]\!](\sigma_0^*) \\ = \ & \lambda\boldsymbol{x}\lambda\sigma^*.\{\sigma \mid \boldsymbol{x}^\circ \text{ is a metal in } \sigma \ \& \\ & \qquad \boldsymbol{x}^\circ \text{ has all properties from } \boldsymbol{x}(\sigma^*) \text{ in } \sigma\}\big([\![\text{sodium}]\!]\big)(\sigma_0^*) \\ \equiv \ & \lambda\sigma^*.\{\sigma \mid [\![\text{sodium}]\!]^\circ \text{ is a metal in } \sigma \ \& \\ & \qquad [\![\text{sodium}]\!]^\circ \text{ has all properties from } [\![\text{sodium}]\!](\sigma^*) \text{ in } \sigma\}(\sigma_0^*) \\ \equiv \ & \lambda\sigma^*.\{\sigma \mid \text{Na is a metal in } \sigma \ \&\ \text{Na has all properties from } [\![\text{sodium}]\!](\sigma^*) \text{ in } \sigma\}(\sigma_0^*) \\ = \ & \{\sigma \mid \text{Na is a metal in } \sigma \ \&\ \text{Na has all properties from } [\![\text{sodium}]\!](\sigma_0^*) \text{ in } \sigma\} \end{aligned} \tag{17}$$

[7] The resulting 'mixed' notation is adopted, e.g., in (Ciardelli et al. 2017).

With the interpretation of names and VPs in place, we next turn to the interpretation of clausally complemented verbs in Integrated Semantics.

5 Extensional and Attitude Verbs in IS

We have seen in Sect. 1 that different clausally complemented verbs impose differently strong restrictions on the substitutivity of their complements. Integrated Semantics captures this difference by assuming that different verbs supply different centered situations to the PICs of their complements.[8] In particular, while extensional verbs like indicate typically[9] supply a designated centered situation (hereafter called *the 'empty' centered situation*, denoted by '$\dagger^*$') that contains the empty situation $\dagger$, attitude verbs like believe supply a contextually chosen centered situation that depends on the particular state or event described by the verb. Below, we first describe the interpretation of extensional verbs in IS (in Sect. 5.1). We then turn to the interpretation of attitude verbs (in Sect. 5.2) and of attitudinal embeddings of extensional verbs (in Sect. 5.3).

5.1 The Interpretation of Extensional Verbs

In Sect. 3.1, we have identified the 'empty' situation $\dagger$ as the bottom element in the partial ordering on situations, at which no sentence is true or false. As a result of this characterization, the set of properties that is associated with the name sodium at the centered situation $\dagger^*$ will be empty. This is captured in **Ax2**. Below, $\boldsymbol{x}$ and P are variables over IQs and properties, respectively.

$$\forall \boldsymbol{x}\,[\boldsymbol{x}(\dagger^*) = (\lambda P.\,\bot)] \qquad \textbf{(Ax2)}$$

The interpretation of the verb indicate is given below, where $\boldsymbol{p}$ is a variable over PICs[10]:

$$[\![\text{indicate}]\!] \;=\; \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*.\,\{\sigma \mid \boldsymbol{x}^\circ \text{ indicates } \boldsymbol{p}(\dagger^*) \text{ in } \sigma\} \qquad (18)$$

The above interpretation enables the compositional interpretation of (2a) at σ_0^* as follows:

[8] Since their interpretation thus influences the content of their complement, such verbs are Kaplanian *monsters* (see Kaplan 1989, Sect. VIII). The 'monstrous' interpretation of attitude verbs follows (Israel and Perry 1996) and (Schlenker 2003).

[9] This is not the case in attitudinal embeddings of such verbs, as we show in Sect. 5.3.

[10] In order to allow its application to the entire sentence, this interpretation stipulates a simplistic semantics for the DP the reaction (see Sect. 6).

$$
\begin{aligned}
& [\![\text{the reaction [indicates [that sodium is a metal]]}]\!](\sigma_0^*) \qquad (19)\\
= \; & \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*.\, \{\sigma \mid \boldsymbol{x}^\circ \text{ indicates } \boldsymbol{p}(\dagger^*) \text{ in } \sigma\} \; \big(\lambda \sigma'^*.\, \{\sigma' \mid \text{Na is a metal in } \sigma' \,\&\\
& \qquad \text{Na has all p'ties from } [\![\text{sodium}]\!](\sigma'^*) \text{ in } \sigma'\}\big)\big([\![\text{the reaction}]\!]\big)(\sigma_0^*)\\
= \; & \lambda \sigma^*.\, \big\{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \text{Na is a metal in } \sigma' \,\&\\
& \qquad \text{Na has all properties from } [\![\text{sodium}]\!](\dagger^*) \text{ in } \sigma'\} \text{ in } \sigma\big\}(\sigma_0^*)\\
= \; & \big\{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \underbrace{\text{Na is a metal in } \sigma'}_{\text{truth-cond'l content}} \,\&\\
& \qquad \underbrace{\text{Na has all properties from } [\![\text{sodium}]\!](\dagger^*) \text{ in } \sigma'\}}_{\text{attitude content (at } \dagger^*)} \text{ in } \sigma\big\}\\
= \; & \big\{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \underbrace{\text{Na is a metal in } \sigma'}_{\text{truth-cond'l content}}\} \text{ in } \sigma\}
\end{aligned}
$$

The above shows that the application of the IS-interpretation of the complement of indicate to the empty centered situation effectively *deletes* the attitude content of the complement. This reflects the fact that extensional verbs only select for the *truth-conditional* component of their complement. As a result of this selection, (2b) has the same PIC (and, hence, the same IC-at-σ_0^*) as (2a) (see (20)), such that the former can be substituted *salva veritate* for the latter.

$$
\begin{aligned}
& [\![\text{the reaction [indicates [that natrium is a metal]]}]\!](\sigma_0^*) \qquad (20)\\
= \; & \big\{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \text{Na is a metal in } \sigma' \,\&\, \text{Na has all}\\
& \qquad \text{properties from } [\![\text{natrium}]\!](\dagger^*) \text{ in } \sigma'\} \text{ in } \sigma\big\}\\
= \; & \big\{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \text{Na is a metal in } \sigma'\} \text{ in } \sigma\big\}
\end{aligned}
$$

5.2 *The Interpretation of Attitude Verbs*

In contrast to extensional verbs, attitude verbs obtain their complement's IC at a centered situation that is provided by a pragmatically given choice function (see von Heusinger 2013). This function selects, from the set of all centered situations, Σ^*, a centered situation whose situation-coordinate the ascriber of the attitude ascribes to the bearer of the attitude at the time of the ascription.

Since the attitude ascriber and the ascription-time are coordinates in the centered situation at which the attitude report is interpreted (hereafter, *the external (centered) situation*), the choice of the ascribed situation (i.e. of the *internal* (centered) situation) depends on the external situation. Since the standards of information vary with different attitudes (e.g. knowledge vs. belief), the choice of situation further depends on the particular state or event that is described by the attitude verb. Below, we represent these dependencies by superscripting the constant, f, for the choice function with the external situation, and by co-indexing this constant with the attitude verb. The resulting interpretation of the verb believe is given in (21).

$$[\![\text{believe}]\!] \;=\; \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*. \{\sigma \mid \boldsymbol{x}^\circ \text{ believes}^i\ \boldsymbol{p}(f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma\} \tag{21}$$

The compositional interpretation of (3a) at σ_0^* is given below:

$$\begin{aligned}
&[\![\text{Len [believes [that sodium is a metal]]}]\!](\sigma_0^*) && (22)\\
=\;& \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*. \{\sigma \mid \boldsymbol{x}^\circ \text{ believes}^i\ \boldsymbol{p}(f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma\}\ \big(\lambda \sigma'^*. \{\sigma' \mid \text{Na is a metal in}\\
&\qquad \sigma' \;\&\; \text{has all properties from } [\![\text{sodium}]\!](\sigma'^*) \text{ in } \sigma'\}\big)\big([\![\text{Len}]\!]\big)(\sigma_0^*)\\
=\;& \lambda \sigma^*. \big\{\sigma \mid \text{Len believes}^i\ \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\; \text{Na has all properties}\\
&\qquad \text{from } [\![\text{sodium}]\!](f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma'\} \text{ in } \sigma\big\}(\sigma_0^*)\\
=\;& \big\{\sigma \mid \text{Len believes}^i\ \{\sigma' \mid \underbrace{\text{Na is a metal in } \sigma'}_{\text{truth-cond'l content}} \;\&\\
&\qquad \underbrace{\text{Na has all p'ties from } [\![\text{sodium}]\!](f_i^{\sigma_0^*}(\Sigma^*)) \text{ in } \sigma'\}}_{\text{attitude content (at } f_i^{\sigma_0^*}(\Sigma^*))} \text{ in } \sigma\big\}
\end{aligned}$$

Assume that σ_0^* has as its agentive center an *accurate* attitude ascriber, such that $f_i^{\sigma_0^*}(\Sigma^*) = \sigma_{len}^*$ for i the index of Len believes, and $f_j^{\sigma_0^*}(\Sigma^*) = \sigma_{eve}^*$ for j the index of Eve believes (see Sect. 3.3). Then, the pairs of sentences from (3) and (5) are interpreted as (23) and (24), and as (25), respectively:

$$\begin{aligned}
&[\![\text{Len [believes [that sodium is a metal]]}]\!](\sigma_0^*) && (23)\\
=\;& \big\{\sigma \mid \text{Len believes}^i\ \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\\
&\qquad \text{Na has all p'ties from } [\![\text{sodium}]\!](f_i^{\sigma_0^*}(\Sigma^*)) \text{ in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& \big\{\sigma \mid \text{Len believes } \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\\
&\qquad \text{Na has all properties from } [\![\text{sodium}]\!](\sigma_{len}^*) \text{ in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& \big\{\sigma \mid \text{Len believes } \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\; \text{Na is reactive in } \sigma'\} \text{ in } \sigma\big\}\\
\neq\;& \big\{\sigma \mid \text{Len believes } \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\; \text{Na is silvery-white in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& [\![\text{Len [believes [that natrium is a metal]]}]\!](\sigma_0^*) && (24)
\end{aligned}$$

$$\begin{aligned}
&[\![\text{Eve [believes [that sodium is a metal]]}]\!](\sigma_0^*) && (25)\\
=\;& \big\{\sigma \mid \text{Eve believes}^j\ \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\\
&\qquad \text{Na has all p'ties from } [\![\text{sodium}]\!](f_j^{\sigma_0^*}(\Sigma^*)) \text{ in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& \big\{\sigma \mid \text{Eve believes } \{\sigma' \mid \text{Na is a metal in } \sigma' \;\&\\
&\qquad \text{Na has all properties from } [\![\text{sodium}]\!](\sigma_{eve}^*) \text{ in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& \big\{\sigma \mid \text{Eve believes } \{\sigma' \mid \text{Na is a metal, silvery-white, and reactive in } \sigma'\} \text{ in } \sigma\big\}\\
=\;& [\![\text{Eve [believes [that natrium is a metal]]}]\!](\sigma_0^*)
\end{aligned}$$

The above shows that—in contrast to the verb indicate—believe does not, in general, allow the truth-preserving substitution of truth-conditionally equivalent CPs in its complement. This is due to the fact that the internal situation at which the complement's IC is obtained preserves the attitude content of the complement of believe (see the black underbrace in (22)). As a result, the substitutivity of equivalent CPs only holds, in general, for CPs that have the same IC at all centered situations and, specifically, for CPs that also have the same attitude content at the particular centered situation at which the complement's IC is obtained. The latter case explains bearer-(and ascriber-)specific differences in the substitutivity of equivalent complements of attitude reports (see (P.4)).

5.3 Attitudinal Embeddings of Extensional Verbs

The interpretation of extensional and attitude verbs from the last two subsections enables the compositional interpretation of constructions containing these verbs (s.t. Integrated Semantics also meets Desideratum (P.1)). However, the interpretation of extensional complements at the situation $\dagger^*$ (see Sect. 5.1) fails to capture the substitution-resistance of truth-conditionally equivalent complements of extensional verbs that occur in attitude embeddings (see (4)). To compensate for this shortcoming, we also interpret the complements of extensional verbs at a contextually given centered situation. The IS-interpretation of the verb indicate from (18) is then replaced by the interpretation below:

$$[\![\text{indicate}]\!] \;=\; \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*.\, \{\sigma \mid \boldsymbol{x}^\circ \text{ indicates}^i\, \boldsymbol{p}\, (f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma\} \tag{26}$$

The identification of $f_i^{\sigma^*}(\Sigma^*)$ with the empty centered situation $\dagger^*$ if i is the index of an unembedded extensional verb (see **Ax3**) then captures the substitution-allowance of constructions like (2a) (in (33); see 19). The identification of $f_i^{[f_j^{\sigma^*}(\Sigma^*)]}(\Sigma^*)$ with $f_j^{\sigma^*}(\Sigma^*)$ if i is the index of an extensional and j the index of its embedding attitude verb (see **Ax4**) captures the substitution-resistance of constructions like (4a) (in (34)).

$$f_i^{\sigma^*}(\Sigma^*) = \dagger^* \quad \text{if } i \text{ is the index of an unembedded extensional verb} \qquad ((\mathbf{Ax3}))$$

$$f_i^{[f_j^{\sigma^*}(\Sigma^*)]}(\Sigma^*) = f_j^{\sigma^*}(\Sigma^*) \quad \text{if } i \text{ and } j \text{ are the indices of an extensional and an attitude verb, respectively} \qquad ((\mathbf{Ax4}))$$

$$[\![\text{the reaction [indicates [that sodium is a metal]]}]\!](\sigma_0^*) \tag{27}$$

$$= \{\sigma \mid \text{the reaction indicates}^i \{\sigma' \mid \text{Na is a metal in } \sigma' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](f_i^{\sigma_0^*}(\Sigma^*)) \text{ in } \sigma'\} \text{ in } \sigma\}$$

$$= \{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \text{Na is a metal in } \sigma' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](\dagger^*) \text{ in } \sigma'\} \text{ in } \sigma\}$$

$$= \{\sigma \mid \text{the reaction indicates } \{\sigma' \mid \text{Na is a metal in } \sigma'\} \text{ in } \sigma\}$$

$$[\![\text{Len [believes [that the reaction indicates [that sodium is a metal]]]}]\!](\sigma_0^*) \tag{28}$$

$$= \lambda \boldsymbol{p} \lambda \boldsymbol{x} \lambda \sigma^*. \{\sigma \mid \boldsymbol{x}^\circ \text{ believes}^i\ \boldsymbol{p}(f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma\} \big(\lambda \sigma_r^*. \{\sigma' \mid \text{the reaction indicates}^j \{\sigma'' \mid \text{Na is a metal in } \sigma'' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](f_j^{\sigma_r^*}(\Sigma^*)) \text{ in } \sigma''\} \text{ in } \sigma'\}\big)\big([\![\text{Len}]\!]\big)(\sigma_0^*)$$

$$= \lambda \sigma^*. \{\sigma \mid \text{Len believes}^i \big[\lambda \sigma_r^*. \{\sigma' \mid \text{the reaction indicates}^j \{\sigma'' \mid \text{Na is a metal in } \sigma'' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](f_j^{\sigma_r^*}(\Sigma^*)) \text{ in } \sigma''\} \text{ in } \sigma'\}\big](f_i^{\sigma^*}(\Sigma^*)) \text{ in } \sigma\}(\sigma_0^*)$$

$$= \{\sigma \mid \text{Len believes}^i \{\sigma' \mid \text{the reaction indicates}^j \{\sigma'' \mid \text{Na is a metal in } \sigma'' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](f_j^{[f_i^{\sigma_0^*}(\Sigma^*)]}(\Sigma^*)) \text{ in } \sigma''\} \text{ in } \sigma'\} \text{ in } \sigma\}$$

$$= \{\sigma \mid \text{Len believes}^i \{\sigma' \mid \text{the reaction indicates}^j \{\sigma'' \mid \text{Na is a metal in } \sigma'' \,\&\, \text{Na has all properties from } [\![\text{sodium}]\!](f_i^{\sigma_0^*}(\Sigma^*)) \text{ in } \sigma''\} \text{ in } \sigma'\} \text{ in } \sigma\}$$

The substitution-resistance of (4a) is then explained by the difference between $[\![\text{sodium}]\!](f_i^{\sigma_0^*}(\Sigma^*))$ and $[\![\text{natrium}]\!](f_i^{\sigma_0^*}(\Sigma^*))$. As a result, Integrated Semantics solves all of the problems of two-dimensional semantics from Sect. 2.2.

6 Conclusion and Future Work

We have shown that Integrated Semantics resolves the tension between composi-tionality (or uniformity of interpretation) and pluralism about linguistic content: the semantics provides a uniform interpretation of extensional and attitude verbs that predicts the substitution behavior of constructions containing these verbs and that captures the agent-dependent interpretation of attitude reports.

We have restricted our considerations in this paper to the integrated contents of proper names (as representatives for referential DPs) and have limited the interpretation of verbs and VPs to an update of the attitude content of the verbs' DP-arguments by the verbs' truth-conditional content. However, as is illustrated in (29), the substitutivity of equivalent

CPs in attitude reports may also depend on the attitude content of other syntactic CP-constituents (here: on the content of the constituent nouns groundhog and woodchuck).

(29) a. Eve believes [$_{CP}$that Phil is a groundhog]. (**T**)
$\not\Rightarrow$ b. Eve believes [$_{CP}$that Phil is a woodchuck]. (**F**)

Future work will extend the interpretation of verbs and VPs from Sect. 4 to a contextually determined interpretation that also respects the verbs' cognitive content, and will provide IS-interpretations of expressions from other syntactic categories.

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