

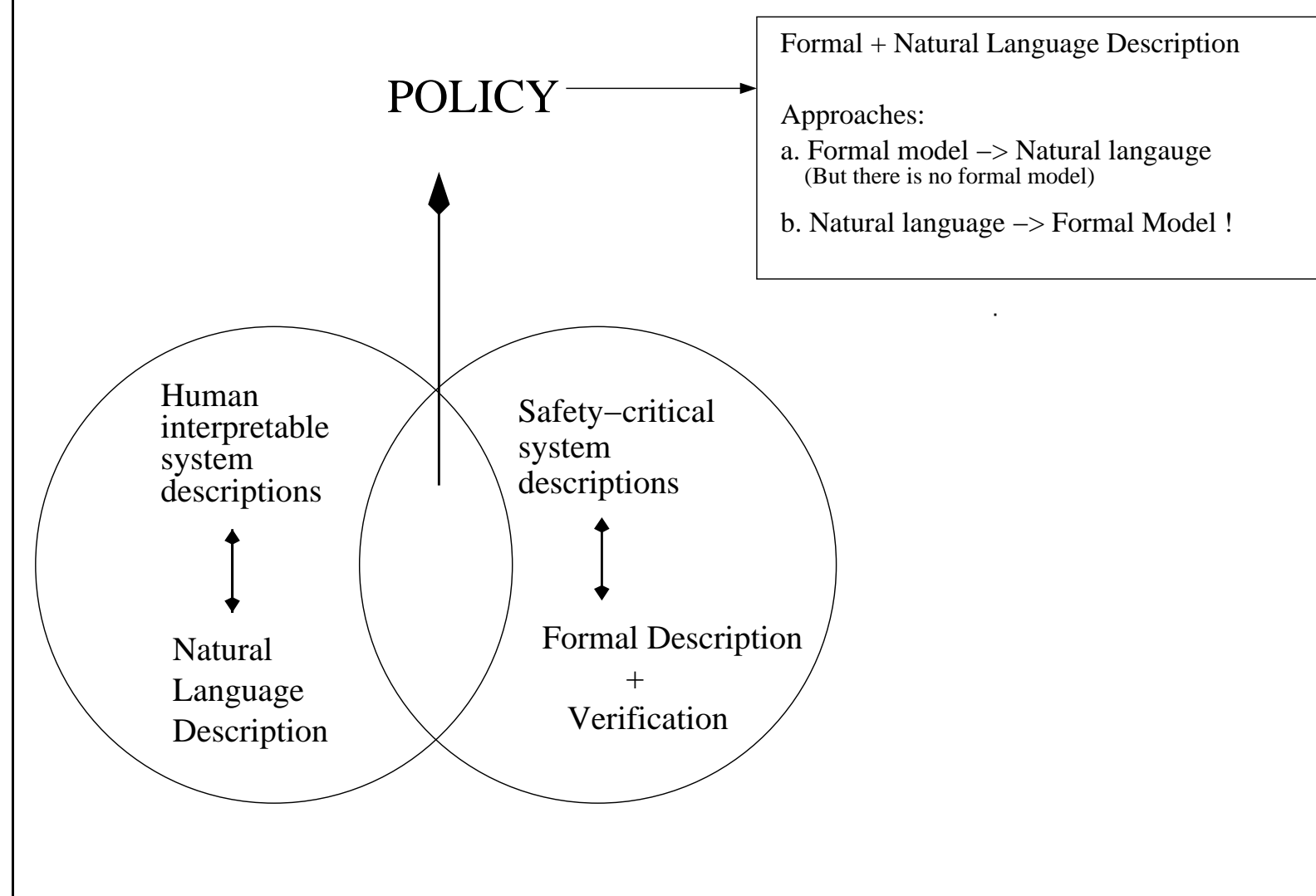
Extracting Traceable Formal Models from Natural Language Policy

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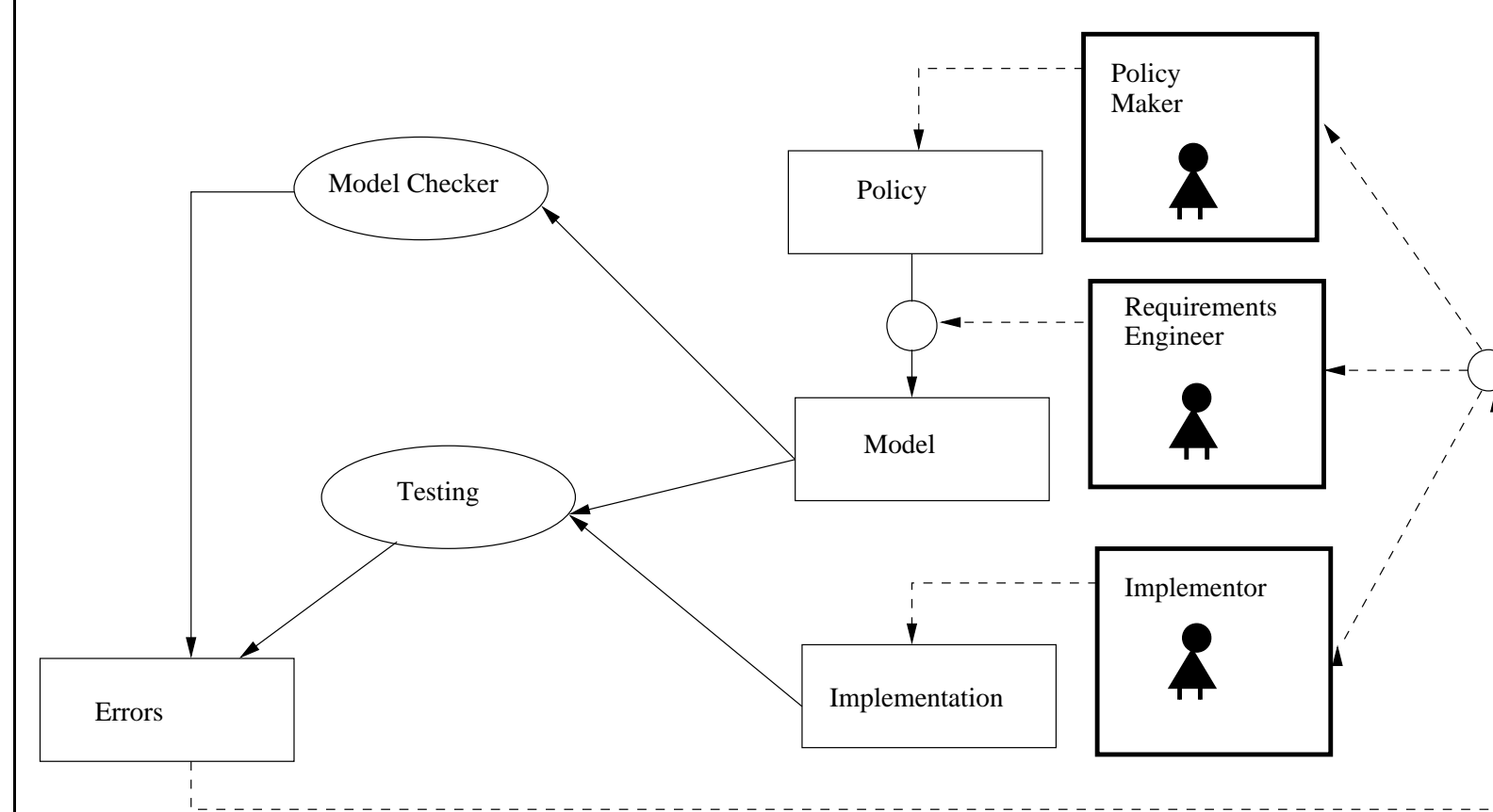
Motivation



Goals

- Test an organization's implementation of policy
- Check if policy is consistent

An Environment for Policy in Natural and Formal Languages



Case Study - FDA CFR

The Food and Drug Administration's Code of Federal Regulations. Excerpt from FDA CFR 610.40:

- (1) a. Except as specified in paragraph (1c) of this section, you, an establishment that collects blood or blood components, must test each donation of human blood or blood component intended for use in preparing a product, including donations intended as a component of, or used to prepare, a medical device, for evidence of infection due to the following communicable disease agents:
 - i. Human immunodeficiency virus, type 1;
 - ii. Human immunodeficiency virus, type 2;
 - iii. Hepatitis B virus;
 - iv. Hepatitis C virus;
 - v. Human T-lymphotropic virus, type I; and
 - vi. Human T-lymphotropic virus, type II.
- b. To test for evidence of infection due to communicable disease agents designated in paragraph (1a) of this section, you must use screening tests that the Food and Drug Administration (FDA) has approved for such use, in accordance with the manufacturer's instructions. You must perform one or more such tests as necessary to reduce adequately and appropriately the risk of transmission of communicable disease.
- c. You are not required to test donations of Source Plasma for evidence of infection due to the communicable disease agents listed in paragraphs (1a-v) and (1a-vi) of this section.

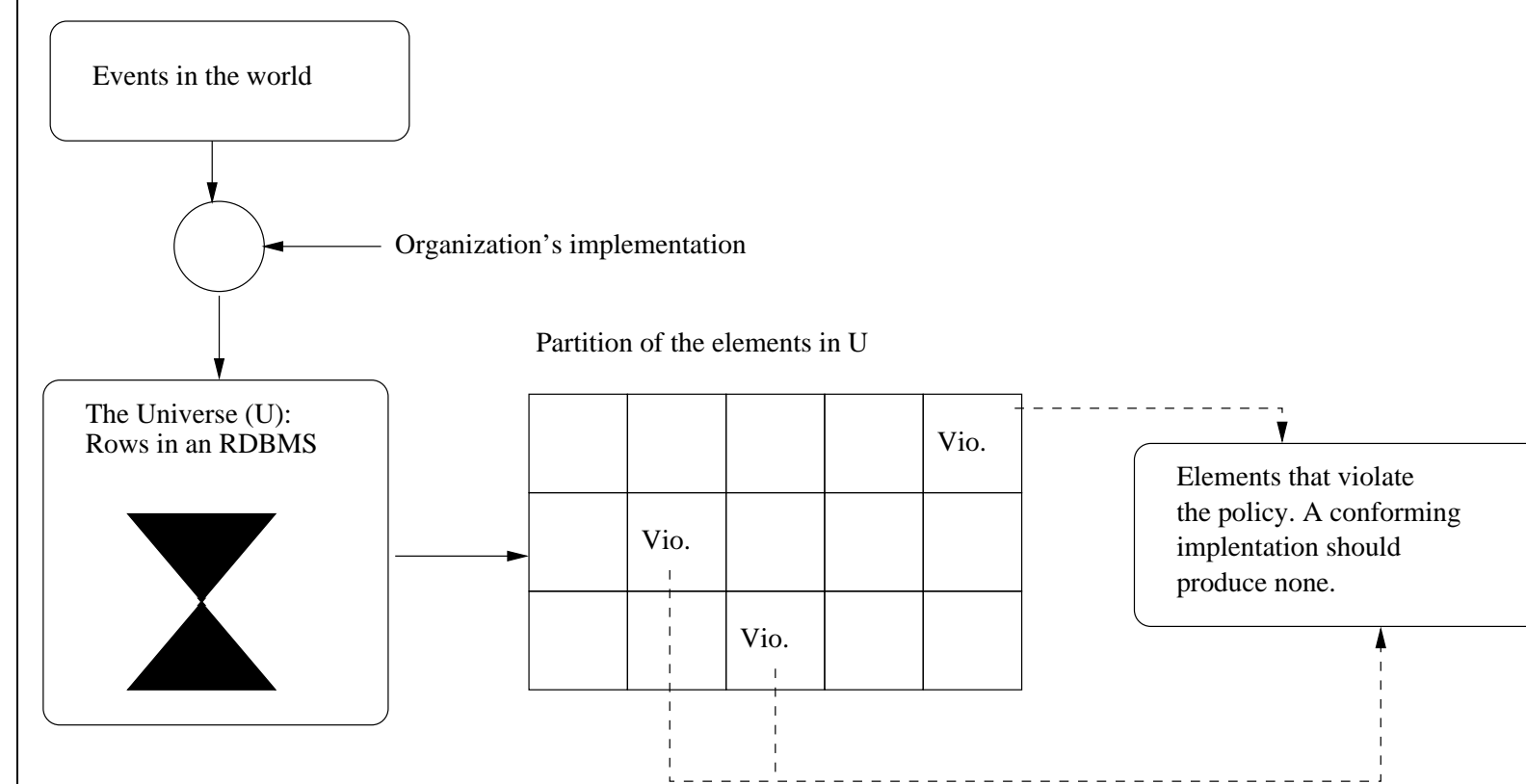
Set-based semantics

We think of a policy document as describing a set. For (1), this can be thought of as *a set of donations*. We call this set **the universe** and denote it by \mathcal{U} . We do not assume any apriori knowledge of \mathcal{U} but we do assume that it is finite. For the CFR 610.40 it would be the set of donations handled by a particular organization.

Specifically, what policy tells us is which elements in \mathcal{U} violate it. Thus, given a policy document \mathcal{D} and $x \in \mathcal{U}$ the formal model we aim to construct will check if x is in conformance with the policy or in violation of it. We denote the set of elements which violate \mathcal{D} by \mathcal{V} . Note that $\mathcal{V} \subseteq \mathcal{U}$ and the set of elements which conform to \mathcal{D} is $\mathcal{U} - \mathcal{V}$. Here are examples of elements in \mathcal{U} in CFR 610.40:

- d_1 = A donation that has been tested for diseases (1a-i) to (1a-vi) with an FDA approved screening test. $d_1 \in \mathcal{U} - \mathcal{V}$.
- d_2 = A donation of blood that has not been tested for (1a-v). $d_2 \in \mathcal{V}$

The Model

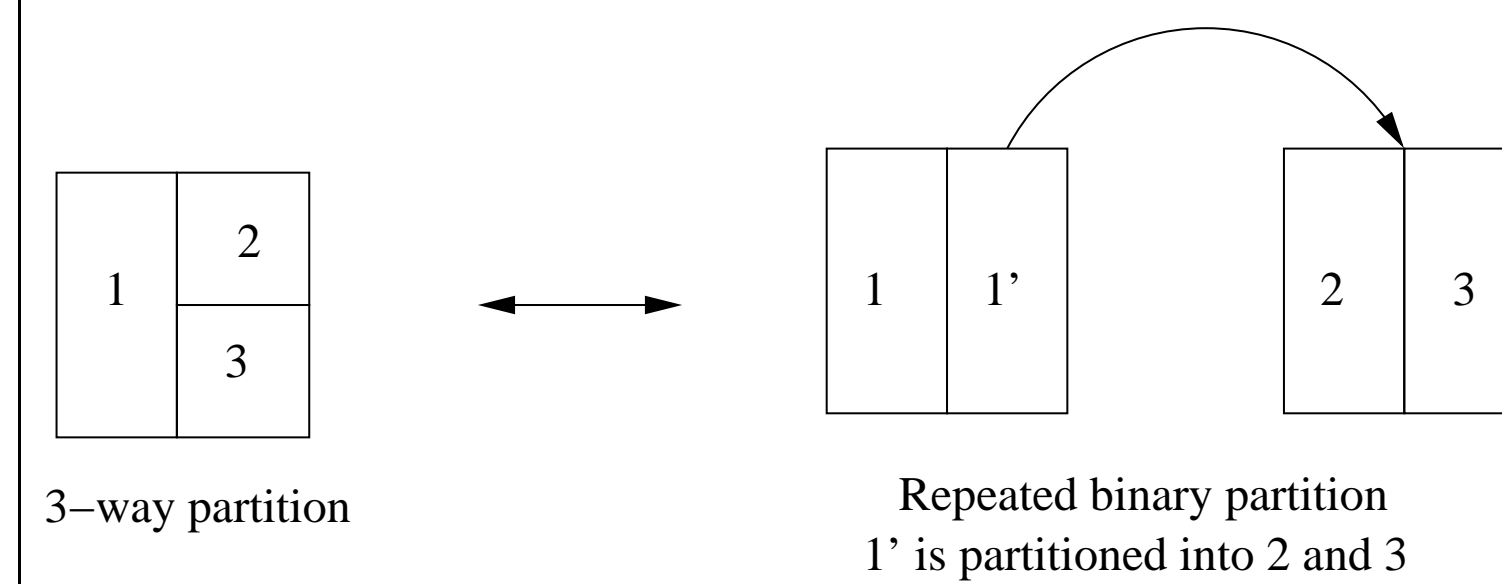


Extraction Procedure

1. Compute the partitions of \mathcal{U} by assigning semantic interpretations to appropriate natural language predicates.
2. Certain partitions computed in step 1 will be dependant on other partitions. These are assigned an interpretation using other partitions.
3. Finally, boolean formulas over the columns of a table in an RDBMS corresponding to \mathcal{U} are specified for each partition

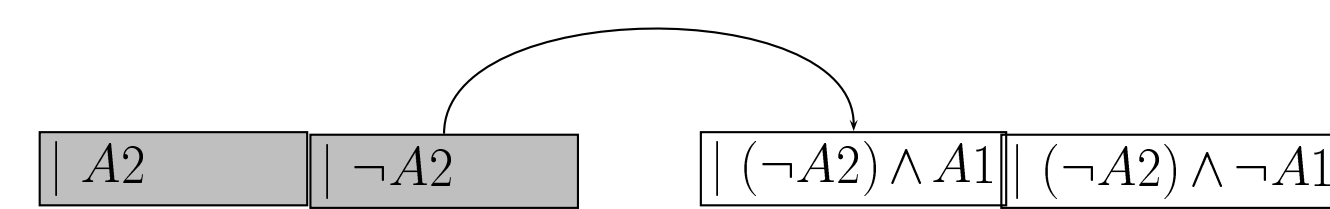
Repeated binary partitioning

An n-way partition can be thought of as a binary partition repeated $n - 1$ times. Initially there is just 1 partition, and at step i , a partition obtained at step $i - 1$ is split into two partitions. Each step is the result of a semantic interpretation assigned to a natural language predicate.



Natural language predicates that partition \mathcal{U}

One class of predicates that can be used to partition \mathcal{U} are **discourse connectives**. For example, the only sentence in paragraph (1a), is of the form *Except A2, A1* where *except* is a discourse connective, which partitions \mathcal{U} as shown in the figure.

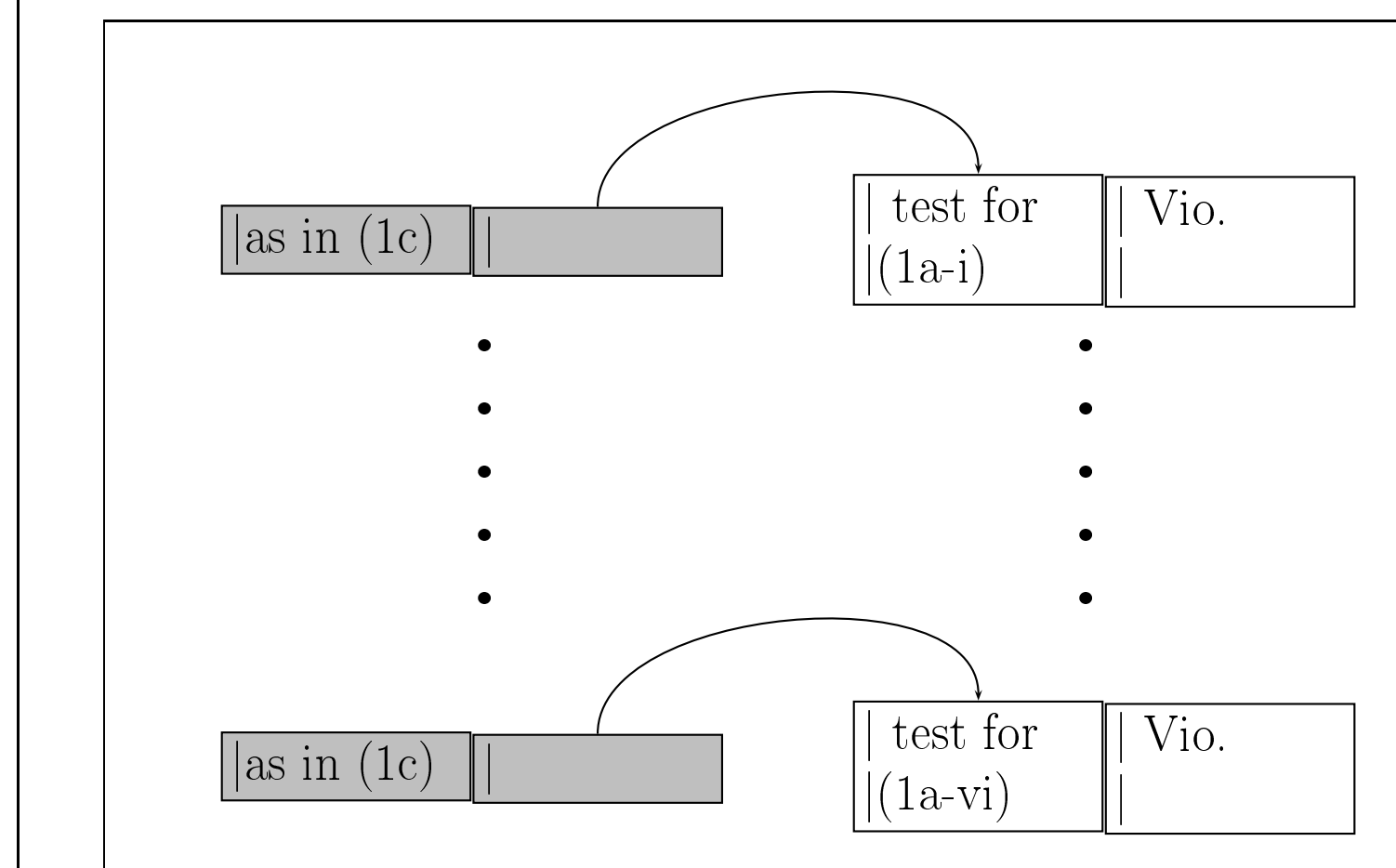


Local Formulas = $\{A2, \neg A2, A1, \neg A1\}$

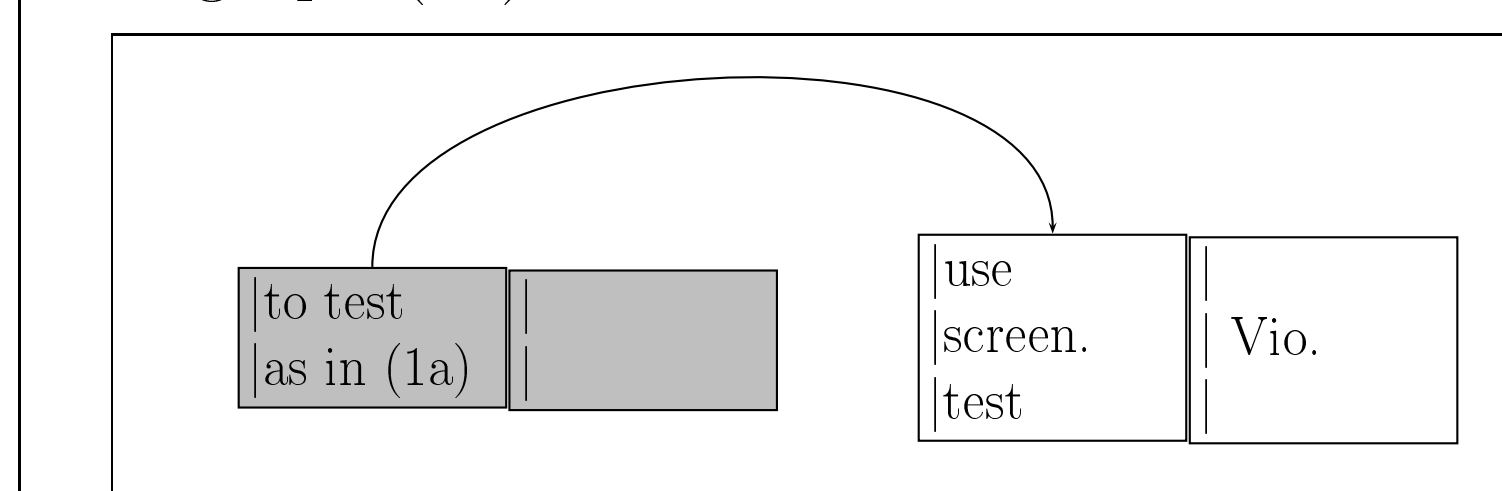
Partition Formulas = $\{A2, \neg A2, (\neg A2) \wedge A1, (\neg A2) \wedge \neg A1\}$

In the figures that follows only the local formulas $A2$, and $A1$ are shown.

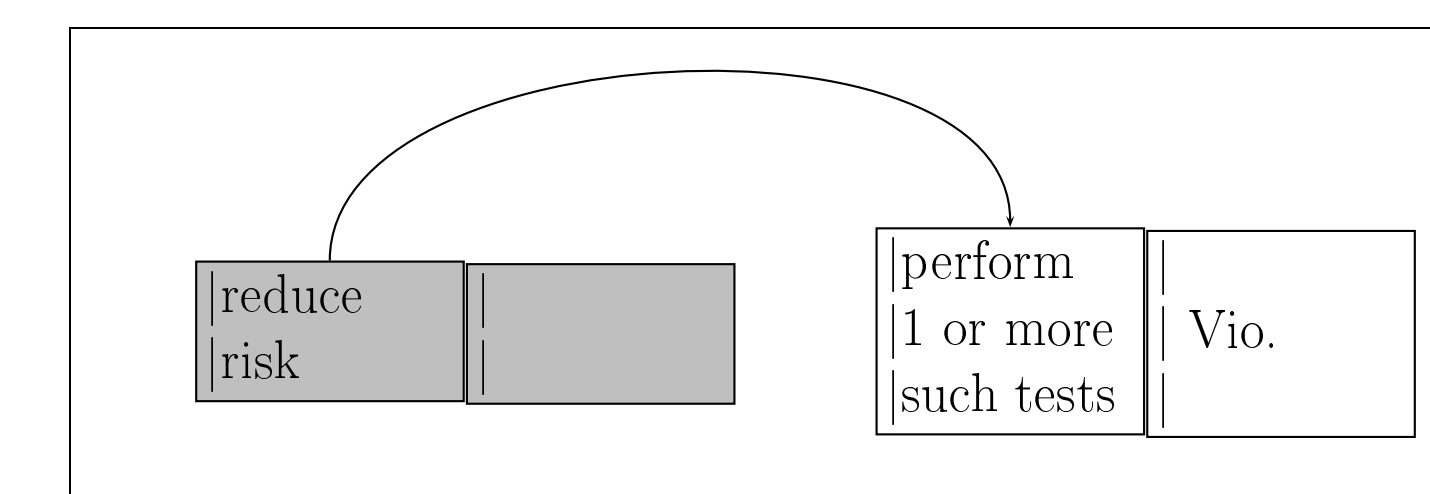
Partitions of \mathcal{U} for CFR 610.40



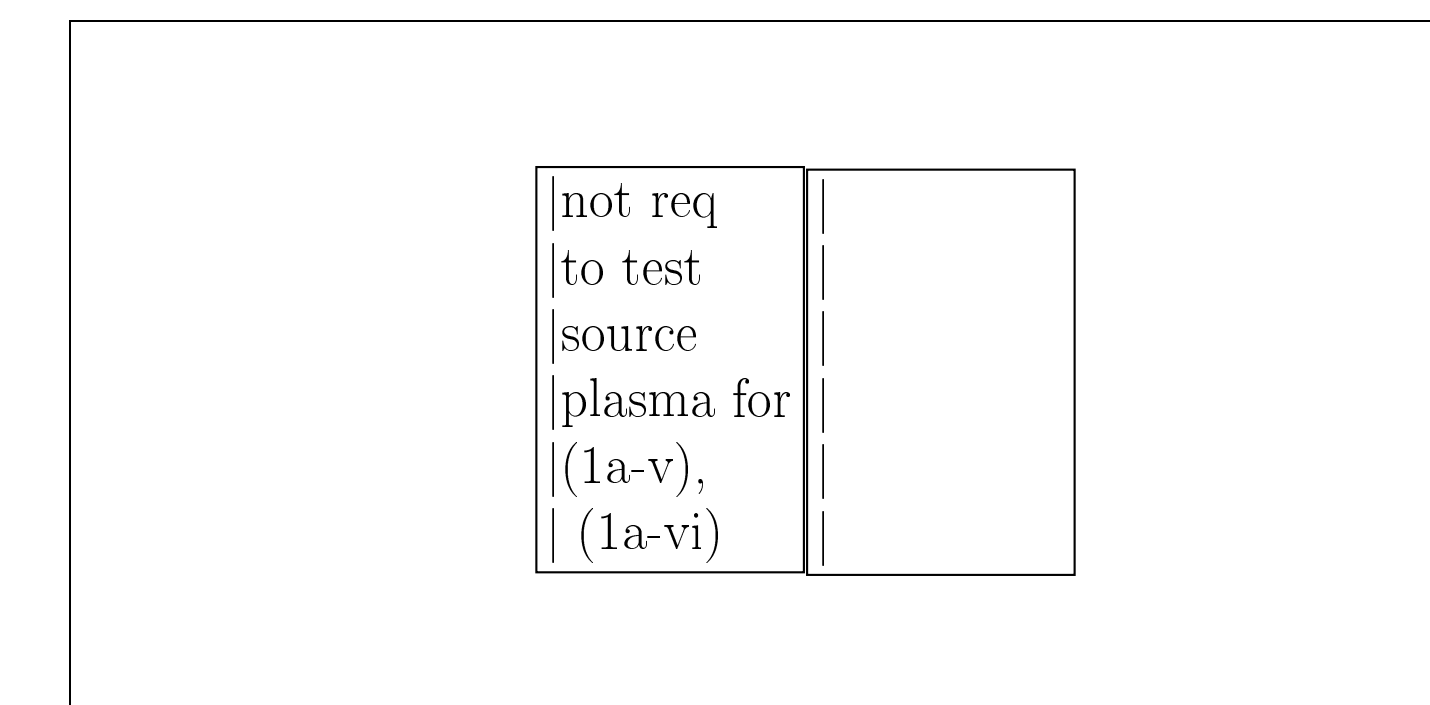
Paragraph (1a), Sentence 1, Connective - *except*



Paragraph (1b), Sentence 1, Connective - *in order*



Paragraph (1b), Sentence 2, Connective - *in order*



Paragraph (1c), Sentence 1, No connective

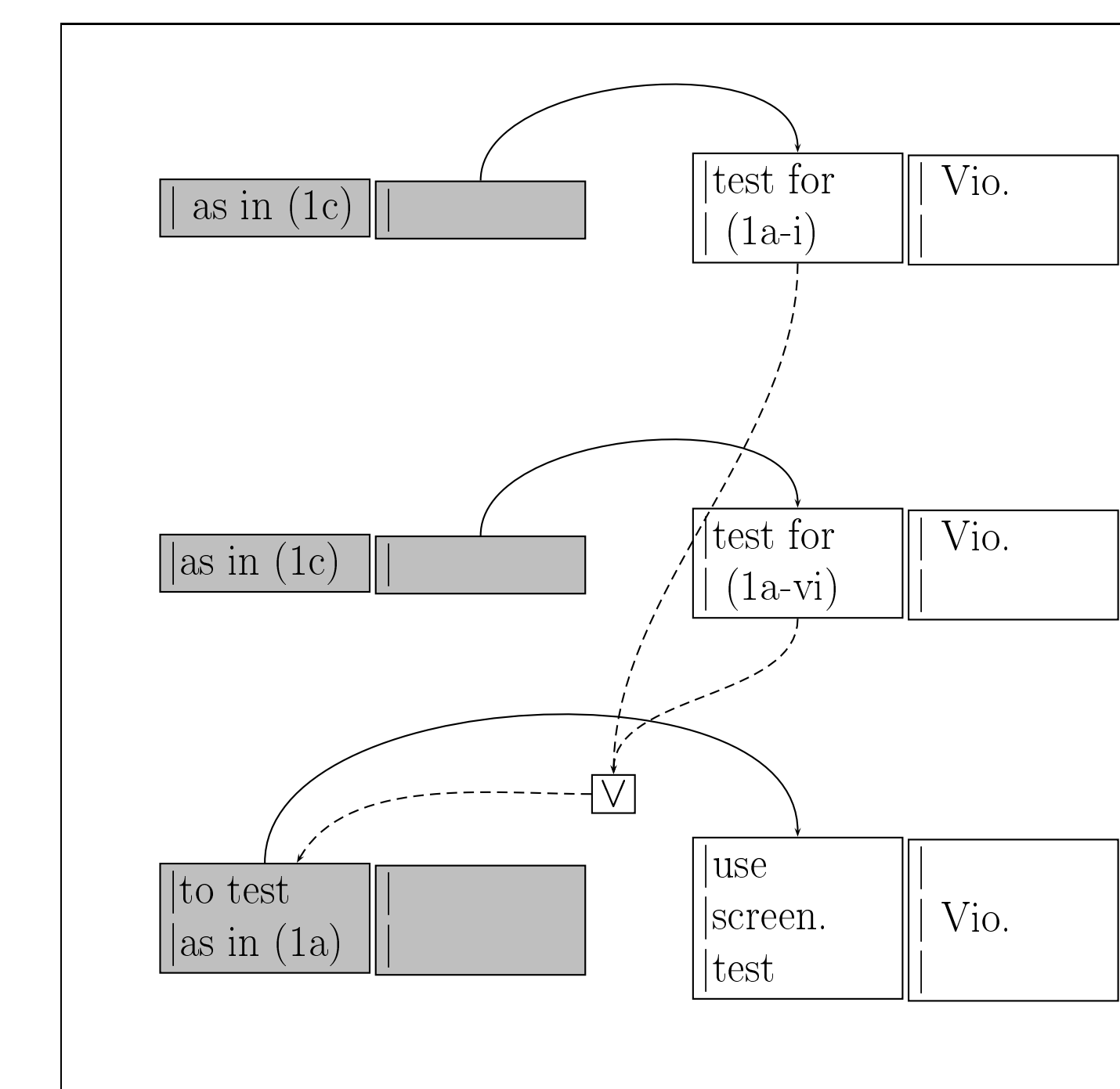
Composing the interpretation of Δ -partitions

In this step, we attempt to compose the interpretation of partitions with *explicit references to other partitions*. We call these partitions Δ -partitions as they *derive* a significant portion of their interpretation from other partitions of \mathcal{U} . There are 3 Δ -partitions in (1) corresponding to the clauses:

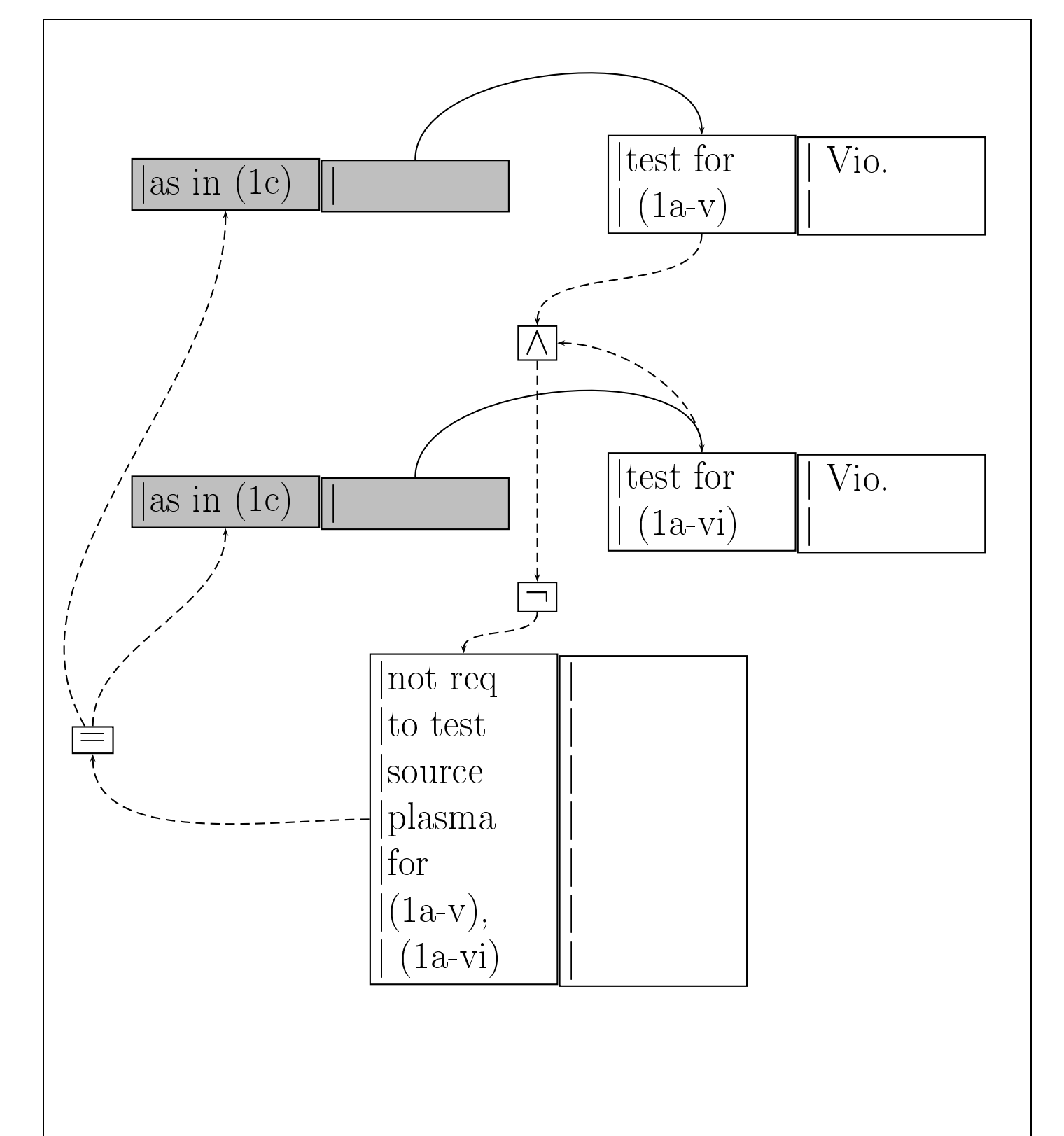
A. as specified in paragraph (1c) of this section

B. To test for evidence of infection due to communicable disease agents designated in paragraph (1a) of this section

C. You are not required to test donations of Source Plasma for evidence of infection due to the communicable disease agents listed in paragraphs (1a-v) and (1a-vi) of this section



Composing the interpretation for Δ -partition B. Dotted arrows signify that only *local formulas* are used.



Composing the interpretation for Δ -partitions A, and C. Dotted arrows signify that only *local formulas* are used

Database table for \mathcal{U}

Column(s)	Value space	Interpretation
tf(1a-i) ... tf(1a-vi)	B	true \Leftrightarrow test for (1a-i) ... (1a-vi) respectively, are carried out.
st	B	true \Leftrightarrow for all tests carried out, a screening test was used.
rr	B	true \Leftrightarrow risk has been reduced for the transmission of any disease
nt(1a-i) ... nt(1a-vi)	N	number of tests carried out for (1a-i) ... (1a-vi)
apsp	B	true \Leftrightarrow is a donation of source plasma and applying permission not to test

Local formulas

Formula Id(s)	Formula(s)	Clause(s)
$\phi_{1.1} \dots \phi_{6.1}$	tf(1a-i) ... tf(1a-vi)	you must test for (1a-i) ... you must test for (1a-vi)
$\phi_{1.2} \dots \phi_{4.2}$	false	as specified in (1c)
$\phi_{5.2}, \phi_{6.2}$	ϕ_9	as specified in (1c)
$\phi_{7.1}$	st	you must use a screening test
$\phi_{7.2}$	$\bigvee_{i=1}^6 \phi_{i.1}$	To test as in (1a)
$\phi_{8.1}$	$\bigwedge_{i=1}^6 (\neg tf_i \vee (nt_i \geq 1))$	you must perform 1 or more tests
$\phi_{8.2}$	rr	To reduce risk of transmission of disease
ϕ_9	$apsp \wedge \neg(\phi_{5.1} \wedge \phi_{6.1})$	You are not required to test source plasma for (1a-v) and (1a-vi)

Current status and future work

We have completed a detailed case study, involving the entire CFR 610.40, part of which is presented here. Experiments to automatically extract the partitions of \mathcal{U} are underway. We are also investigating other predicates like *only* which can be used to partition \mathcal{U} . Further work is needed on composing the interpretation Δ -partitions before appropriate algorithms and user interfaces can be designed.