Section A. General information

1a. Title

NØthing is Logical (NihiL): Neglect-zero effects in reasoning and interpretation

1b. Summary

When told that *you may stay* **or** *go*, you normally conclude that *you may stay* **and** *you may go*, contrary to the prescriptions of classical logic. This project investigates these and related cases of divergence between human and logical-mathematical reasoning and, challenging the canonical view, hypothesises that they are a straightforward consequence of a tendency in human cognition to neglect empty configurations. This tendency, which I call *neglect-zero*, connects to a general human preference for concrete (non-empty) over abstract (empty) representations, and follows from the expected difficulty of the cognitive operation of evaluating truths with respect to empty witness sets. Experimental findings in number cognition confirm this difficulty, which also explains the special status of the zero among the natural numbers.

In the project we will (i) define logics which model neglect-zero and rigorously isolate its effects on deductions and interpretation; (ii) run experiments to probe its role in cognition; and (iii) develop linguistic analyses to study its possible conventionalisation in natural language.

The novel hypothesis of a cognitive neglect-zero tendency, which can be suspended in some contexts but can also be conventionalised and therefore become obligatory in certain domains, will reshape our understanding of how semantics and pragmatics are integrated in ordinary language use and how human reasoning closely relates to but also differs from the logico-mathematical one. The development of explicit logics incorporating contextual and cognitive factors (both traditionally held to resist precise formalisations) is equally groundbreaking and will have implications for automated reasoning in AI applications.

1c. Public summary

Niets is LØgisch

Als je verteld wordt dat je mag gaan **of** blijven concludeer je dat je mag gaan **en** dat je mag blijven, wat tegenstrijdig is met de voorschriften van de klassieke logica. In dit project onderzoeken wij dergelijke gevallen van afwijking tussen menselijk en logisch-wiskundig redeneren met de nieuwe hypothese dat ze een rechtstreeks gevolg zijn van een neiging in de menselijke cognitie om lege representaties te negeren (*horror vacuüm*). We zullen logica's ontwikkelen die deze neiging samen met haar effecten op redeneren en interpretatie modelleren; en experimenten uitvoeren om de precieze voorspellingen van deze modellen te testen.

NØthing is Logical

When told that *you may stay* **or** *go*, you normally conclude that *you may stay* **and** *you may go*, contrary to the prescriptions of classical logic. This project investigates such cases of divergence between human and logical-mathematical reasoning and, challenging the canonical view, hypotheses that they are a straightforward consequence of a tendency in human cognition to neglect empty representations (*horror vacui*). We will develop logics which model this tendency and rigorously isolate its effects on deductions and interpretation; and experimentally test the precise predictions arising from these formalisations.

1d. Domain

- [x] Social Sciences and Humanities (SSH/SGW)
- [ ] Applied and Engineering Sciences (AES/TTW)
- [ ] Science (ENW)
- [ ] ZonMw

Section B. Scientific proposal

B1. Scientific quality

People draw conclusions that go beyond what is literally said. Since Grice's seminal work [Gri75], the relation between literal meaning (semantics, ruled by classical logic) and inferences based on language use (pragmatics) has been the subject of longstanding debate in philosophy and linguistics and important progress was made in the development of diagnostics to distinguish semantic from pragmatic inference, and in the formal derivation of the latter from general principles of conversation. This project challenges the canonical divide between semantics and pragmatics and sets out to explore inferences that, although diverging from classical logic, lack other defining properties of canonical pragmatic inference: they are often non-cancellable, are sometimes embeddable [Alo22], are acquired early [TRZC16], and their processing time can equal that of literal interpretations [CB14]. Primary examples of such inferences, which I will call *inferences of a 3rd kind (3K)*, are modal inferences triggered by existential/disjunctive constructions, including ignorance effects in *epistemic indefinites*[1] and *modified numerals*[2], and *free choice* (FC) inferences[3] where conjunctive meanings are unexpectedly derived from disjunctive sentences:

(1) You may go to the beach *or* to the cinema. ⇝ You may go to the beach *and* you may go to the cinema.

(2) Mr. X might be in Victoria *or* in Brixton. ⇝ Mr. X might be in Victoria *and* he might be in Brixton.

See Table 1 for further illustrations.

		pragm. derivable	cancel lable	non-embed.	proc. cost	acqui sition
Pragmatics	Conversational implicature A: Is J coming? B: She has to work ⇝ J is not coming	+	+	+	high	late
Semantics	Classical entailment I read some novels ⇝ I read something	−	−	−	low	early
3rd Kind	Epistemic Indefinites *Irgendjemand* hat angerufen ⇝ Speaker doesn't know who	+	−	+	?	?
	Modified Numerals Al has *at least two* degrees ⇝ Maybe two, maybe more	+	?	+	?	?
	FC disjunction You may do A *or* B ⇝ You may do A	+	?	?	low	early
	Scalar implicature I read some novels ⇝ I didn't read all novels	+	+	?	high	late

Table 1: Beyond Gricean paradise.

[1] [JT06, AOMB15, AP15]
[2] [GN07, AvO21]
[3] [Kam73, Zim00, Alo07]

The **novel hypothesis** at the core of this proposal is that 3K-inferences are neither the result of conversational reasoning [as in neo-gricean approaches, Sau04, Sim10], nor the effect of spontaneous optional applications of grammatical operators [as in the grammatical view of scalar implicatures, CFS11]. Rather they are a straightforward consequence of something else speakers do in conversation, namely, when interpreting a sentence, they create structures representing reality, pictures of the world [JL83] and in doing so they systematically neglect models which verify the sentence by virtue of some empty configuration [BSK19]. This tendency, which I call *neglect-zero*, connects to a general preference in human cognition for concrete (non-empty) over abstract (empty) representations [Pai65], and follows from the expected difficulty of the cognitive operation of evaluating truths with respect to empty witness sets. Models which verify a sentence by virtue of some empty set will be called *zero-models*.

As an illustration consider the following examples:

(3) Every square is black.

a. Verifier: [■, ■, ■]

b. Falsifier: [■, □, ■]

c. Zero-models: [ ]; [△, △, △]; [◊, ▲, ♠]

(4) Less than three squares are black.

a. Verifier: [■, □, ■]

b. Falsifier: [■, ■, ■]

c. Zero-models: [ ]; [△, △, △]; [◊, ▲, ♠]

The interpretation of (3) and (4) leads to the creation of structures representing reality, some verifying the sentence (the models depicted in (a)), some falsifying it (the models in (b)). The neglect-zero hypothesis states that zero-models, the ones represented in (c), are usually kept out of consideration. Zero-models are neglected because they are cognitively taxing. Findings from number cognition confirm this difficulty [RCMN16], which also explains the special status of the zero among the natural numbers [e.g., its late invention in human history, late emergence in human development, and special representation in the brain, Nie16]; the existential import effects operative in the logic of Aristotle (the inference from *every square is black* to *some square is black*) [AR02, Geu07]; and why downward-monotonic quantifiers (e.g., *less than* n *squares*) are more difficult to process than upward-monotonic ones (e.g., *more than* n *squares*) [BSK19]. Since empty witnesses encode the absence of objects, they are more detached from experience and therefore harder to conceive. The inference from the perception of absence to the truth of a sentence brings in additional costs, which results in a systematic dispreference for zero-models, a neglect-zero tendency. The **idea at the core of my proposal** is that 3K-inferences, just like Aristotelian existential import effects, are a consequence of such a neglect-zero tendency assumed to be operative among language users in ordinary conversations.

As shown in previous work of the applicant, team semantics [V07, YV17, Alo22] provides a perspicuous way to formally represent neglect-zero and to rigorously study its impact on reasoning and interpretation. Using a bilateral team-based modal logic, [Alo22] showed that neglect-zero derives FC inferences (when interpreting disjunctions speakers associate each disjunct with a non-empty possibility) and their cancellation under negation.

In the project we plan to further develop this research and (i) define logics which model neglect-zero and rigorously isolate its effects on deductions and interpretation (**WP-Logic**); (ii) run experiments to probe its role in human reasoning (**WP-Cognition**); and (iii) develop linguistic analyses to study its possible conventionalisation in natural language (**WP-Language**).

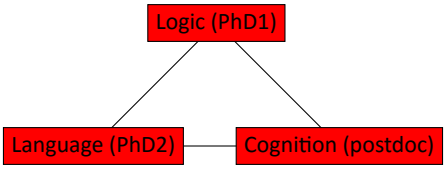
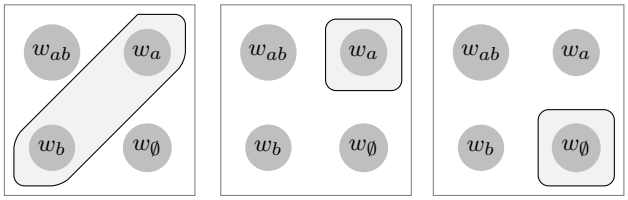


Figure 1: Work-packages and team members.

The **first objective** of this research is to give a principled explanation of how 3K-inferences and other neglect-zero effects relate to canonical pragmatic and semantic inferences [**WP-Language**] in the context of a general account of



(a) Verifier (b) Zero-model (c) Falsifier

Figure 2: Models for $(a \vee b)$.

human reasoning [**WP-Cognition**]. The **second objective** is to develop predictive models for neglect-zero effects, their suspension and conventionalisation [**WP-Logic**]. The **general strategy** is twofold: (i) define logics which model next to literal meanings (ruled by classical logic), also contextual and cognitive factors, and the additional inferences derived by their interplay; and (ii) experimentally test the predictions arising from these rigorous formalisations. Combining logical modelling, linguistic analyses and experimental methods we aim at an alternative architecture, beyond the semantics vs pragmatics vs cognition divides, where all these inferences find their natural place.

In what follows the objectives, hypotheses and planned activities of the three work-packages (WPs) are described in more detail.

WP-Logic

The **main goal** of WP-Logic is the development of non-classical logical systems where neglect-zero effects can be studied in a rigorous way. Our point of departure are the propositional and quantified versions of the Bilateral State-based Modal Logic (BSML) presented in [Alo22, AvO21].

The development of a logic deriving 3K-inferences is not a trivial task. Consider the case of FC inference. As mentioned above, sentences of the form *You may A or B* ($\Diamond(\alpha \vee \beta)$) are normally understood as implying *You may A* ($\Diamond\alpha$). The following, however, is not a validity in standard deontic logic [vW68].

(5) $\Diamond(\alpha \vee \beta) \rightarrow \Diamond\alpha$ [FC principle]

As [Kam73] pointed out, plainly making (5) valid, for example by adding it as an axiom, would not do because it would allow us to derive from $\Diamond a$ (*You may post this letter*) any other $\Diamond b$ (e.g., *You may burn it*):

(6)
1. $\Diamond a$ [assumption]
2. $\Diamond(a \vee b)$ [from 1, by classical reasoning]
3. $\Diamond b$ [from 2, by FC principle]

The source of the problem highlighted by (6) is, on our view, the mistaken attempt to explain FC facts purely in terms of truth-conditions. The core idea behind this project is that FC as well as other 3K-inferences are not truth-conditional effects but rather a direct consequence of a conversational factor, namely, that of the neglect-zero tendency. Inferences derived by such neglect-zero enrichments do not relate propositions but rather assertions and rejections [*speech acts*, Aus62, Sea69] and therefore might diverge from classical semantic entailments. For example, whenever A is *true*, A OR B is equally true [ADDITION], but it does not follow that whenever A is *assertable*, A OR B is equally assertable [FAILURE OF ADDITION]. To model such *conversational inferences*, [Alo22] developed BSML, a bilateral version of team-based modal logic. In team semantics, sentences are interpreted with respect to *sets* of evaluation points (teams) rather than single points. Classical modal logic models truth in possible worlds. BSML models assertion and rejection conditions in information states (sets of possible worlds). Operating at the level of speech acts rather than truth-conditions, BSML diverges from classical logic (e.g., validates FC inferences and invalidates addition), but only for neglect-zero enriched formulas (see Table 2).

The team-based nature of the system is crucial to formalise the neglect-zero tendency at the core of our proposal. In BSML, a state s supports a disjunction iff s is the union of two substates, each supporting one of the disjuncts. As an illustration consider the states represented in Figure 2. In these pictures w_a stands for a world where only a is true,

w_b only b, etc. The disjunction $(a \vee b)$ is supported by the first two states, but not by 2(c) because the latter consists of $w_\emptyset$, a world where both a and b are false. The state in 2(b) supports $(a \vee b)$, because we can find suitable substates supporting each disjunct: the state itself, supporting a, and the empty state, vacuously supporting b. State 2(b) is then an example of a *zero-model* for $(a \vee b)$, a model which verifies the formula by virtue of an empty witness.

Using tools from team semantics, we can define different notions of *neglect-zero enrichments* whose core effect is to disallow such zero-models: (i) *syntactically* via a pragmatic enrichment function $[\,]^+$ recursively defined in terms of NE (Non-Emptyness atom) [YV17], which requires non-empty supporting states (**BSML**$^+$); or (ii) *model-theoretically* by ruling out $\emptyset$ from the set of the possible states (**BSML***) [Alo22].

On both characterisations, we obtain that a state s supports a neglect-zero enriched disjunction iff s is the union of two *non-empty* substates, each supporting one of the disjuncts. Such enriched disjunctions thus require both their disjuncts to be live possibilities [Zim00, Geu05]. [Alo22] showed that in interaction with modalities neglect-zero enrichments derive FC inferences and their cancellation under negation.

In this framework, we can further model the global suspension of neglect-zero effects using **BSML**$^\emptyset$, the NE-free fragment of BSML, which behaves like classical modal logic. In **BSML**$^\emptyset$, which captures logico-mathematical reasoning, the empty state and more generally zero-models are allowed and play an essential role. Paraphrasing Whitehead, we can conjecture that the use of zero-models is only forced on us by the needs of cultivated modes of thought'.

> 'The point about zero is that we do not need to use it in the operations of daily life. No one goes out to buy zero fish. It is in a way the most civilized of all the cardinals, and its use is only forced on us by the needs of cultivated modes of thought.' (A.N. Whitehead quoted by [Nie16]).

We have then a pluralism of systems definable in variants of BSML whose predictions are compared in Table 2. Our conjecture is that these variants correspond to different interpretation strategies or reasoning styles people may adopt in different circumstances (e.g., ordinary conversation vs mathematical proof).

		BSML$^\emptyset$	**BSML**$^+$	**BSML***
FC inference	$\Diamond(\alpha \vee \beta) \models \Diamond\alpha \wedge \Diamond\beta$	-	+	+
FC cancellation	$\neg\Diamond(\alpha \vee \beta) \models \neg\Diamond\alpha \wedge \neg\Diamond\beta$	+	+	+
Negative FC	$\neg\Box(\alpha \wedge \beta) \models \neg\Box\alpha \wedge \neg\Box\beta$	-	-	+
Ignorance	$\alpha \vee \beta \models \Diamond\alpha \wedge \Diamond\beta$	-	+	+
Addition	$\alpha \models \alpha \vee \beta$	+	-	-
Contraposition	$\alpha \models \beta \Rightarrow \neg\beta \models \neg\alpha$	+	-	-

Table 2: Comparison variants BSML.

WP-Logic will have 3 phases. In phase 1, we will study the logical properties of these and other variants of BSML [Ant21] and further extend these systems with implication (e.g., to be able to study neglect-zero effects in conditionals [Sta75]). In phase 2, we will define BSML-style semantics (with weak negation) for logic programming [Doe94] with corresponding neural network models [SvL08, Lei18] needed for the theory developed in WP-Cognition. Finally, in phase 3, we will define dynamic [Vel96, HST18] and type-theoretic characterisations of (Q)BSML to arrive at compositional accounts of the phenomena addressed in WP-Language [CRT17, DR19].

WP-Language

Once it is established that neglect-zero impacts reasoning and interpretation, the question that arises is when this enrichment is operative and when it is not. As we discussed, logico-mathematical reasoning crucially relies on the availability of zero-models. Therefore *global* suspension of neglect-zero enrichments is possible, e.g., in the context of a mathematical proof. But do we also have *local* suspensions as, for example, would be predicted if $[\,]^+$-enrichment were a grammatical operation [like EXH in localist accounts of implicatures, Fox07, CFS11, BLF20]? [Alo22] argued that $[\,]^+$ is not a grammatical operation which can optionally apply but conjectured that we can have local neglect-zero effects but only if triggered by the semantics of certain expressions. More precisely, the **conjecture** is that neglect-zero can cause two kinds of effects:

(i) weak (i.e. cancellable) *global* effects, modelled by **BSML*** (BSML without $\emptyset$);

			BSML$^{\Diamond}$	**BSML***
Positive FC	$\Diamond(\alpha \vee \beta) \rightsquigarrow \Diamond\alpha \wedge \Diamond\beta$	**strong**	+	+
Negative FC	$\neg\Box(\alpha \wedge \beta) \rightsquigarrow \neg\Box\alpha \wedge \neg\Box\beta$	**weak**	-	+
Ignorance	$\alpha \vee \beta \rightsquigarrow \Diamond\alpha \wedge \Diamond\beta$	**weak**	-	+
Wide scope FC	$\Diamond\alpha \vee \Diamond\beta \rightsquigarrow \Diamond\alpha \wedge \Diamond\beta$	**?**	-	+

Table 3: Comparison **BSML$^{\Diamond}$** and **BSML*.**

(ii) more robust effects triggered by the conventional meaning of certain expressions, modelled by *local* applications of $[\,]^{+}$-enrichment.

The **main objective** of WP-Language is to further explore and experimentally test this conjecture by studying examples of possible conventionalisation of neglect-zero in the modal and nominal domains. The working hypothesis is that these conventionalisations are not lexical stipulations but rather emerge from the urge to communicate in an effective but learnable way.

Preliminary evidence for our conjecture comes from recent experiments attesting a difference in robustness between Positive FC (strong) vs Ignorance and Negative FC inferences (weak) [TBR19, MRSB21]. This contrast can be explained by assuming that modal verbs conventionalise neglect-zero effects, while disjunctions don't. Let **BSML$^{\Diamond}$** be an analysis which assumes an obligatory application of $[\,]^{+}$-enrichments in the scope of a modal (MAY/MUST $\mapsto$ $\lambda\alpha\Diamond/\Box[\alpha]^{+}$). **BSML$^{\Diamond}$** predicts a contrast between Positive FC (valid) vs Negative FC and ignorance inferences (both not valid). As shown in Table 3, **BSML$^{\Diamond}$**, modelling strong (i.e., obligatory) inferences, in combination with **BSML***, modelling global and weak (i.e., cancellable) effects, would give us a good match with [MRSB21, TBR19]'s experimental findings. To further confirm the hypothesis we plan to run experiments focusing on the case of wide scope FC, where the predictions of the two systems diverge but the empirical landscape is still unclear.

Other local cases of obligatory neglect-zero enrichments could be triggered by expressions in the nominal domain, e.g., universal quantifiers, leading to existential import presuppositions, and marked indefinites, in particular those of the epistemic kind [AOMB15]. Consider the following example of an overt cancellation of ignorance for plain disjunction, triggered by continuations like *Guess which!*:

(7) I was born in Tokyo or Kyoto. Guess which!

Epistemic indefinites like German *irgendein* are infelicitous in combination with such continuations [Has97, KS02, AP15]:

(8) *Irgendein* Student hat angerufen. #Rat mal wer?
Irgend-one student has called guess prt who?
Some student called – the speaker doesn't know who

We could account for this in quantified BSML assuming that epistemic indefinites trigger an application of $[\,]^{+}$-enrichments in their scope, which, with some additional assumptions, would derive their obligatory ignorance effect. Going back to the case of modal verbs, (9) is a typical case of overt FC cancellation:

(9) You may have coffee or tea. Guess which!

How can (9) be reconciled with the predictions of **BSML$^{\Diamond}$**? The difference between the epistemic indefinite (no overt cancellation possible) and the modal case is that for the latter, we can assume that the continuation (a sluice) forces a wide scope disjunction configuration [Fus19], and in that case the obligatory enrichment triggered by the modal would not lead to a FC inference: $\Diamond[\alpha]^{+} \vee \Diamond[\beta]^{+} \not\models \Diamond\alpha$. Wide scope FC effects would still be captured as cancellable/global neglect-zero effects (with restrictions): $\Diamond\alpha \vee \Diamond\beta \models_{BSML^{*}} \Diamond\alpha \wedge \Diamond\beta$.

These are only preliminary remarks. The goal of WP-Language is to further develop and test these ideas and, if disproven, develop alternative accounts of the experimentally established linguistic facts.

WP-Cognition

People often reason contrary to the prescriptions of classical logic. The **hypothesis** at the core of this project is that at least in part the divergence between human and logico-mathematical reasoning is due to a neglect-zero tendency.

While zero-models tend to be neglected in conversation, they play a crucial role in logico-mathematical reasoning. For example, the validity of the following classical deductions relies on the availability of zero-models (see Table 2):

(10) A. THEREFORE, A OR B.

(11) IF A THEN B. THEREFORE, IF NOT B THEN NOT A.

The **main goal** of WP-Cognition is to experimentally test this hypothesis with focus on reasonings with disjunction. In traditional ruled-based approaches, reasoning failures are explained by assuming that human reasoners resorts to non-classical rules [Was68, Bra78]. On our view, human reasoning cannot be studied abstracting from interpretation [SvL08]. Reasoning failures could result from perfectly classical reasoning acting upon non-standard interpretations of the premises or the conclusion [PM20]. On our hypothesis neglect-zero affects interpretation and therefore also reasoning. We will then start with experiments testing the impact of neglect-zero on interpretation (whether such effects are conventionalised or purely pragmatic is investigated in WP-Language).

Interpretation The cognitive difficulty of zero-models has been established experimentally in number cognition [Nie16], and also in semantics, but only in relation to the interpretation of quantifiers [BSK19]. Here we will test its impact on disjunctive and Aristotelian sentences. As an illustration of the kind of experiments we will run consider (12) and its possible models depicted in Figure 3.

(12) Every square is connected to a red or green triangle.

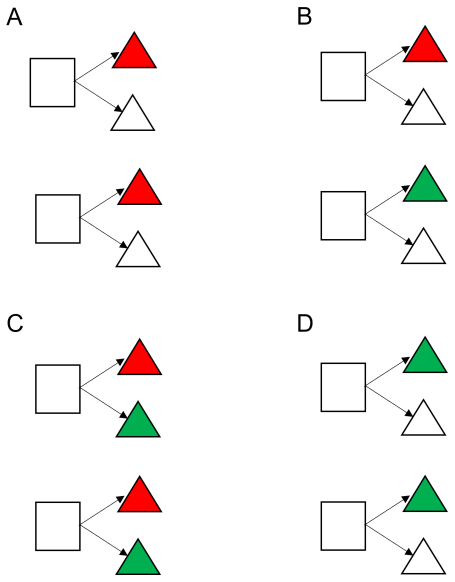


Figure 3: Four models for (12).

The upper left (A) and lower right (D) models, which are predicted to validate the sentence according to classical logic, are examples of zero-models in our team-based semantics. An experiment employing a picture-verification paradigm will be used to explore under which conditions (12) is judged true and if differences in availability/processing can be found between models ruled out by neglect-zero (A, D and zero-models with no squares) and those excluded by scalar reasoning (model C). An experiment showing no difference in availability/processing between zero-models and the rest would be a result disproving our hypothesis. We will run both behavioural and event-related potential (ERP) experiments, the former with both adults and children (3-5 years old). We expect more neglect-zero effects to arise in the preschool group. Our hypothesis for the ERP studies is that zero-models, since unexpected, should elicit distinctive/particular ERP components (e.g. N400).

Reasoning According to our hypothesis there are three kinds of reasonings:

(i) *Zero-free reasonings:* classically valid reasonings which don't rely on zero-models, e.g., *modus ponens* (If A then B; A. Therefore B);

(ii) *Zero-reasonings:* classically valid reasonings which rely on zero-models, for example (10)–(11) above;

(iii) *Neglect-zero fallacies:* classically invalid reasonings which however are validated if we neglect zero-models, e.g., ignorance, FC and existential import inferences.

The hypothesis that zero-models are cognitively taxing leads to various predictions (e.g., zero-reasonings are harder than zero-free reasoning; neglect-zero fallacies arise more easily in dual-task conditions). The main goals of this part are to develop a theory of human reasoning where these predictions can be made more precise; and test these predictions experimentally.

The difficulty of a reasoning can be tested in different ways: by checking whether their conclusions are spontaneously formulated; by presenting informants with full deductions and measure assessing time and/or the margin of errors; by a dual-task methodology [PM20]. Again we will run both behavioural (including dual-task) and ERP experiments [PGv$^+$10]. In the presence of an additional task, we expect zero-reasonings to cause more mistakes/take longer, while neglect-zero fallacies should be facilitated.

As for the theory, we plan to extend [SvL08] to study neglect-zero effects in disjunctive sentences. In model-based theories of reasoning, deductive reasoning depends on two main processes. First the premises are used to construct a model and then the validity of the conclusion is checked on this model. [SvL08] argued that subjects usually do not consider all models of the premises, but only *minimal* ones. To define minimal models they use logic programming, a formal logic, used in artificial intelligence and cognitive science, implementing a *closed-world* assumption (what is not known to be true is false). What could be a minimal model for a disjunction? Standard procedures yield two minimal models for $(a \vee b)$ one verifying only a and the other verifying only b [Sch05, AvR07]. This however would predict that human reasoners fail to draw FC inferences contradicting experimental findings [CB14]. Our strategy to solve this is to use teams in a logic programming framework (see WP-Logic) so that a disjunctive premise $a \vee b$ can lead to the construction of the non-zero minimal team $\{w_a, w_b\}$ rather than the minimal zero-models $\{w_a\}$ and $\{w_b\}$, which we conjecture are dispreferred.

Further evidence in favour of our neglect-zero hypothesis comes from addition (see (10)). A rule-based theory which assumes that human reasoners apply the rules of Natural Deduction would predict that if asked to formulate conclusions from premise A reasoners should mention A OR B. Past experiments however showed that people who are not trained in logic do not spontaneously produce the disjunction [JLBS92]. Classical model-based theories of reasoning which link the difficulty of a reasoning solely to the amount of models involved in the reasoning process also fail to account for this fact [JLBS92, QRJL19]. In these theories, the premise leads to the construction of a model validating A. But, classically, any verifier of A is also a verifier of A OR B and so by employing a single model the conclusion A OR B should in principle be available to the reasoner. Our neglect-zero hypothesis, instead, has a ready explanation of why this is not the case. A minimal verifier of A is also a verifier for A OR B but only if we allow the possibility of an empty witness for the second disjunct. Since a zero-model is involved we correctly predict that the inference is not spontaneously drawn.

We also plan to experimentally compare static and dynamic versions of our theory. In a dynamic version, in the case of multiple premises, we construct a minimal model for the first premise and then evaluate the remaining ones with respect to (minimal) updates of this model. In a static characterisation, instead, minimal models are constructed simultaneously for all premises. Only in the former can the ordering in the premises make a difference. In the experiments we will compare the following two versions of Disjunctive Syllogism:

(13) A OR B; NOT A. THEREFORE, B.

(14) NOT A; A OR B. THEREFORE, B.

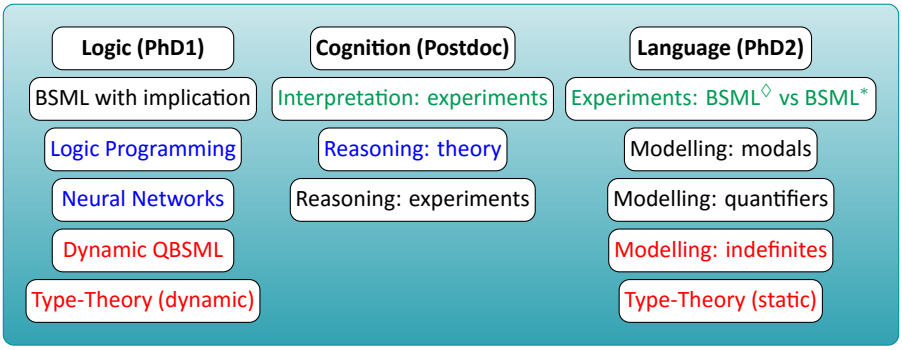
Our hypothesis combined with a dynamic implementation predicts a difference in complexity between (13) and (14). In (13), we construct a (non-zero) minimal model verifying A OR B; then we update it with NOT A (a simple eliminative update) and finally check if the resulting model verifies B. In (14), instead, the first premise leads to the construction of a minimal model verifying NOT A. Such a model can be updated to verify A OR B, but crucially the resulting model will be a zero-model for the disjunction, a model with an empty witness for the first disjunct. Since only (14) involves evaluation with respect to a zero-model we predict it to be harder than (13).

Summary of planned experiments

1. Interpretation of disjunctive and Aristotelian sentences
    - Picture-verification task (3-5-year-old children)
    - Picture-verification task (adults, dual-task, ERP)
2. Reasoning with disjunction (only adults, behavioural and ERP)
    - Zero-free vs zero-reasoning vs neglect-zero fallacies
    - Dynamic vs static: disjunctive syllogisms

Summary and conclusion

The following table summarises the activities of the work-packages and their interactions (same colour, except black, means related activities to be conducted in close collaboration):



The goal of the project is to place common departures from classical reasoning on a rigorous logical footing by defining **logics** that isolate the effect of zero-models in deductions and interpretations (1st column). This logical enterprise is supplemented by experiments probing the role of these models in **cognition** (2nd column), and by linguistic analyses studying their effects in natural **language**, enlarging the empirical scope to modals, quantifiers, and special indefinites (3rd column).

Nothing is logical. People don't reason according to classical logic rules. But the nothing (zero), whose difficulty to conceive is, as we conjecture, at the core of the illogicality of human behaviour, can itself be rigorously studied using logical methods. So even *nothing* is logical. By combining logical modelling, linguistic analyses and experimental methods we aim at a novel architecture, beyond the canonical divides, where cognitive and contextual aspects of human reasoning and communication can be studied in a rigorous and principled way.

B2. Embedding, organisation, and budget

2a. Project team composition

Main applicant

Title, first name, surname	Affiliation	Role
Dr Maria Aloni	University of Amsterdam (UvA), Institute for Logic, Language and Computation (ILLC)	project leader

Other team members

Title, first name, surname	Affiliation	Role
vacancy 1	University of Amsterdam, ILLC	PhD candidate (Logic)
vacancy 2	University of Amsterdam, ILLC	PhD candidate (Language)
vacancy 3	University of Amsterdam, ILLC	postdoc (Cognition)
Prof. Michiel van Lambalgen	University of Amsterdam, ILLC	advisor (cognition, reasoning)
Prof. Judith Rispens	University of Amsterdam, ACLC	advisor (cognition, ERP, acquisition)
Dr Jakub Szymanik	University of Amsterdam, ILLC	advisor (cognition, quantifiers)
Dr Floris Roelofsen	University of Amsterdam, ILLC	co-supervisor (language)
Prof. Donka Farkas	University of California, Santa Cruz, Linguistics	advisor (language, indefinites)
Dr Nick Bezhanishvili	University of Amsterdam, ILLC	co-supervisor (logic)
Dr Fan Yang	University of Helsinki, Mathematics and Statistics	advisor (logic, team semantics)
Dr Balder ten Cate	University of Amsterdam, ILLC	advisor (AI, logic programming, automated reasoning)
Dr Raffaella Bernardi	University of Trento, Information Engineering and Computer Science	advisor (AI, dialogue systems)
Dr Raquel Fernández	University of Amsterdam, ILLC	advisor (AI, dialogue systems)
Prof. Larry Moss	Indiana University, Mathematics	advisor (natural logic, automated reasoning)

2b. Selected output Main and Co-applicants

[1] Maria Aloni. *Logic and conversation: the case of free choice*. Manuscript 2022. Available at https://www.marialoni.org/resources/Aloni2022.pdf.

[2] Maria Aloni. Free Choice, Modals and Imperatives. In *Natural Language Semantics*, 2007, 15(1), pp. 65–94.

[3] Maria Aloni and Michael Franke. On the free choice potential of epistemic and deontic modals. In Ivano Caponigro and Carlo Cecchetto (eds) *From Grammar to Meaning: The spontaneous logicality of language*. 2013, Cambridge University Press.

[4] Maria Aloni. Individual Concepts in Modal Predicate Logic. In *Journal of Philosophical Logic*. 2005, 34(1), pp. 1–64.

[5] Maria Aloni and Paul Dekker. *Cambridge Handbook of Formal Semantics*. 2016, Cambridge University Press.

2c. Motivation of embedding, organisation and budget

The **research team** consists of the project leader (Aloni), two PhD candidates (WP-Logic, WP-Language) and one postdoc (WP-Cognition) and will have the support of renowned (international) advisers (full list in 2a). Different expertise

will be represented, as required by the interdisciplinary objectives of the project, including logic (Aloni, PhD1), semantics and pragmatics (Aloni, PhD2), and cognitive science, in particular the psychology of human reasoning (postdoc, advisors).

Team members will be hired using open selection procedures, as prescribed by UvA policy. PhD candidates and postdocs with the right profile can be easily found among the recent graduates of the MSc Logic (UvA-ILLC) and PhD programmes in Cognitive Science (ILLC, ENS-Paris, John Hopkins, Carnegie Mellon, Edinburgh).

The **project leader**, Maria Aloni, is an experienced researcher in semantics and philosophical logic with publications in Journal of Philosophical Logic, Linguistics and Philosophy, Natural Language Semantics, Journal of Semantics, Erkenntnis, Natural Language and Linguistic Theory, Synthese, Philosophical Quarterly and more. She also edited (with Dekker, 2016) the Cambridge Handbook of Formal Semantics and in 2001 her PhD thesis won the Beth Dissertation Prize. She further received VENI and VIDI grants and successfully supervised PhD students (3 completed, 4 ongoing), postdocs and other researchers. Since 2020, she is elected member of the Academia Europaea.

The proposal combines and expands on diverse topics Aloni investigated in the past. Its core idea was introduced in output [1] (see section 2b) currently under review and presented in invited lectures on numerous occasions. Of the other selected outputs, [2] and [3] directly relate to the project topic dealing with disjunction [2], indefinites [2,3] and conventionalisations of pragmatics [3]; [4] is a seminal paper investigating the logical foundation of conceptual covers, later employed in the analysis of epistemic indefinites, among others; and [5] is included as evidence of Aloni's international reputation and her ability to supervise large collaborative projects.

The project will be carried out at the **Institute for Logic, Language and Computation (ILLC)** at the UvA, which provides an ideal setting for the interdisciplinary research of the kind proposed. The project naturally fits within the ILLC research unit *Formal Semantics and Philosophical Logic*, but will benefit from collaborations also within other ILLC units (cognition, AI, mathematical logic), the ACLC-UvA (language & cognition) and the vast (international) network of the project leader.

The requested **budget** covers 5 months research leave for Aloni (31.000€) and the full-time salaries of postdoc (48 months, 170.000€) and 2 PhDs (48 months, 258.000€ each). We also reserved money for experiments (including research assistance, 12.500€), travel (8.000€) and 2 (hybrid) workshops (12.000€).

2d. Justification budget modules (if applicable)

2e. Money follows Cooperation (MfC)

B3. Scientific and/or societal impact

The principal goal of the project is theoretical/foundational: we want to understand the nature of human reasoning and communication; how cognitive and contextual factors impact deductions and interpretations; how natural language is shaped by the urge to communicate in an effective but learnable way. Our main hypothesis of a cognitive neglect-zero tendency, which can be suspended in some contexts, but can also be conventionalised and therefore become obligatory in certain domains, has the potential to reshape our understanding of how semantics and pragmatics are integrated in ordinary language use and how human reasoning closely relates to, but also differs from the logico-mathematical one. The development of explicit logics incorporating contextual and cognitive factors (both traditionally held to resist precise formalisations) is equally groundbreaking and opens up clear possibilities for knowledge utilization.

We expect our results to have **scientific impact** on different fields including Linguistics (semantics and pragmatics), Philosophy (philosophy of language, (philosophy of) logic, philosophy of mathematics), Mathematics (team logic, modal logic) and Cognitive Science (psychology of human reasoning, number cognition). For example, this research will lead to a radical shift of perspective in **semantics and pragmatics** where the discussion on pragmatic enrichment is nowadays dominated by the debate between grammatical and (neo)gricean accounts of implicatures, disregarding the impact of cognitive factors and the possibility of originally pragmatic effects to become conventionalised, both aspects at the core of our WP-Language. We also expect major impact on research in **psychology of human reasoning**. Our neglect-zero hypothesis has the potential to shed new light on several still unexplained experimentally established inference patterns, but also will produce new precise and interesting predictions asking for more experimental research. The fields of formal semantics/logic and psychology of reasoning have a common object of scrutiny, but use different methodologies

and have progressed almost completely in parallel in the past. Our project will contribute to fill this gap. To this aim we plan to invite scholars from both communities as speakers in our workshops, including pioneers of the logic-semantics-psychology interactions such as Bart Geurts (Nijmegen), Emmanuel Chemla and Salvador Mascarenhas (ENS-Paris) [not yet invited] and Michiel van Lambalgen (UvA, project advisor). To make our results accessible to the broad scientific community we further plan the following activities: (a) in the first trimester, we will launch the project website informing on project plans, activities and results (this will be an enhanced version of https://www.marialoni.org/Nihil); (b) project results will be submitted for presentation at the major conferences of the relevant fields; (c) we will organise two workshops, as mentioned above, with invited and selected presentations; (d) all data sets collected and produced within the project will be made available through open source platforms with links from the project website; (e) at the end, we will edit an open source volume collecting the main results of the project.

We further foresee three main areas of (long term) **societal impact** for our research:

(i) In WP-Logic we will develop logical systems combining closed-world reasoning and neglect-zero assumptions and following [SvL08] define neural network models of these systems [dLG98, Lei18]. Although the latter are idealisations primarily meant for modelling cognitive abilities, they will also have implications for **automated reasoning** and other AI applications. Our outputs (when combined with statistical methods) could be used to increase the accuracy of textual entailment systems [IM14, BPM15, Abz17] but also question answering or other dialogue systems [TGB22]. To explore these possibilities more concretely we will have a dedicated mid-term reflection session in year 2 where project results will be presented to our AI advisors (Raffaella Bernardi, Raquel Fernández, Balder ten Cate and Larry Moss). Recently there has been renewed interest in the goal of unifying statistical and symbolic methods in AI to arrive at more efficient, but also transparent and therefore accountable tools. This is an urgent issue we hope to be able to contribute to with our research.

(ii) Along the lines of Peterson *et al*'s training software for the false belief task [PSPP13], in the second part of the project, we will explore the possibility of developing training material for children with difficulties in abstract reasoning, which, we conjecture, might derive from a difficulty in constructing and manipulating zero-models. These training software will be in the form of **competitive reasoning games** and might be implemented as part of online training platforms (e.g., Oefenweb, in particular RekenTuin) but also as Apps or in robots engaged in human-robot communication. In year 3, we will design prototypes of these games in close collaboration with Michiel van Lambalgen and Judith Rispens (both project advisors), and decide, in consultation with the UvA coordinator of the TalentenKracht consortium, whether to apply for follow-up funding (50.000€, e.g., IXA Proof of Concept fund), for their realisation, which will be outsourced.

(iii) Difficult theoretical questions (what is the nature of human reasoning) but also complex societal problems can, on my view, only be properly addressed by combining insights and techniques from different disciplines. Therefore we need researchers with an interdisciplinary training who master tools from different fields and citizens with broad perspectives who can transcend the traditional boundaries between humanities (α), exact (β) and social (γ) sciences. With the aim to make diverse techniques available to students with different backgrounds we will prepare **videoclips** explaining a selection of the experimental and logical tools developed within the project. These videoclips will be freely accessible from the project website. With the aim to promote interdisciplinarity, in year 2 we will offer a MasterClass for **high-school students** on the topics of the project, presenting an example of a fruitful area of research where α, β and γ themes and methodologies are combined and students with different interests and talents can equally contribute. Both activities will be done in collaboration with the ILLC valorisation office, with whom Aloni already organised a successful MasterClass on Logic in 2017 (http://events.illc.uva.nl/MasterClass/Logica2017/).

Chosen impact focus:

- ☐ Scientific impact
- ☐ Societal impact
- ☑ Both scientific and societal impact

B4. Word count

Number of words in section B1 + B2c: 4464.
Number of words in section B3: 976.

B5. Reference list

[Abz17] Lasha Abzianidze. Langpro: Natural language theorem prover. In *Conference on Empirical Methods in Natural Language Processing*, 2017.

[Alo07] Maria Aloni. Free choice, modals and imperatives. *Natural Language Semantics*, 15:65–94, 2007.

[Alo22] Maria Aloni. Logic and conversation: the case of free choice. Under review, 2022.

[Ant21] Aleksi Anttila. The logic of free choice. axiomatizations of state-based modal logics. Master's thesis, ILLC, University of Amsterdam, 2021.

[AOMB15] Luis Alonso-Ovalle and Paula Menéndez-Benito. *Epistemic Indefinites*. Oxford University Press, 2015.

[AP15] Maria Aloni and Angelika Port. Epistemic indefinites and methods of identifications. In Luis Alonso-Ovalle and Paula Menéndez-Benito, editors, *Epistemic Indefinites*. Oxford University Press, 2015.

[AR02] Dorit Abush and Mats Rooth. Empty-domain effects for presuppositional and non-presuppositional determiners. In H. Kamp and B. Partee, editors, *Context Dependence in the Analysis of Linguistic Meaning*, pages 7–27. Brill, 2002.

[Aus62] John L. Austin. *How to do things with words*. Oxford University Press, 1962.

[AvO21] Maria Aloni and Peter van Ormondt. Modified numerals and split disjunction: the first-order case. Manuscript, ILLC, University of Amsterdam, 2021.

[AvR07] Maria Aloni and Robert van Rooij. Free choice items and alternatives. In G. Bouma, I. Kraemer, and J. Zwarts, editors, *Proceeding of the KNAW Academy Colloquium: Cognitive Foundations of Interpretaion*, pages 5–26. Edita KNAW, 2007.

[BLF20] Moshe E. Bar-Lev and Danny Fox. Free choice, simplification, and innocent inclusion. *Natural Language Semantics*, 28:175–223, 2020.

[BPM15] Samuel R. Bowman, Christopher Potts, and Christopher D. Manning. Recursive neural networks can learn logical semantics. In *Proc. of the 3rd Workshop on Continuous Vector Space Models and their Compositionality*, 2015.

[Bra78] M.D.S. Braine. On the relation between the natural logic of reasoning and standard logic. *Psychological Review*, 85:1–21, 1978.

[BSK19] Oliver Bott, Fabian Schlotterbeck, and Udo Klein. Empty-set effects in quantifier interpretation. *Journal of Semantics*, 36:99–163, 2019.

[CB14] Emmanuel Chemla and Lewis Bott. Processing inferences at the semantics/pragmatics frontier: disjunctions and free choice. *Cognition*, pages 380–396, 2014.

[CFS11] Gennaro Chierchia, Danny Fox, and Benjamin Spector. The grammatical view of scalar implicatures and the relationship between semantics and pragmatics. In Claudia Maienborn, Klaus von Heusinger, and Paul Portner, editors, *Semantics. An International Handbook of Natural Language Meaning*. de Gruyter, 2011.

[CRT17] Ivano Ciardelli, Floris Roelofsen, and Nadine Theiler. Composing alternatives. *Linguistics and Philosophy*, 40(1):1–36, 2017.

[dLG98] Artur S. d'Avila Garcez, Luís C. Lamb, and Dov M. Gabbay. *Neural-Symbolic Cognitive Reasoning*. Springer, 1998.

[Doe94] Kees Doets. *From Logic to Logic Programming*. MIT Press, 1994.

[DR19] Jakub Dotlačil and Floris Roelofsen. Dynamic inquisitive semantics: anaphora and questions. In *Proceedings of Sinn und Bedeutung 23*, 2019.

[Fox07] Danny Fox. Free choice and the theory of scalar implicatures. In Uli Sauerland and Penka Stateva, editors, *Presupposition and Implicature in Compositional Semantics*, pages 71–120. Palgrave MacMillan, Hampshire, 2007.

[Fus19] Melissa Fusco. Sluicing on free choice. *Semantics and Pragmatics*, 12, 2019.

[Geu05] Bart Geurts. Entertaining alternatives: disjunctions as modals. *Natural Language Semantics*, 2005.

[Geu07] Bart Geurts. Existential import. In Ileana Comorovski and Klaus von Heusinger, editors, *Existence: Semantics and syntax*, pages 253–271. Springer, 2007.

[GN07] Bart Geurts and Rick Nouwen. *At least* et al.: the semantics of scalar modifiers. *Language*, 83(3):533–559, 2007.

[Gri75] Herbert Paul Grice. Logic and conversation. In Peter Cole and Jerry Morgan, editors, *Syntax and Semantics, Volume 3: Speech Acts*, pages 41–58. Academic Pr, 1975.

[Has97] Martin Haspelmath. *Indefinite pronouns*. Oxford University Press, Oxford, 1997.

[HST18] Peter Hawke and Shane Steinert-Threlkeld. Informational dynamics of epistemic possibility modals. *Synthese*, 195, 2018.

[IM14] Thomas Icard and Larry Moss. Recent progress on monotonicity. In *Linguistic Issues in Language Technology*, 2014.

[JL83] Philip N. Johnson-Laird. *Mental Models*. Cambridge University Press, 1983.

[JLBS92] PN Johnson-Laird, RM Byrne, and W Schaeken. Propositional reasoning by model. *Psychological Review*, 99:418–439, 1992.

[JT06] Jacques Jayez and Lucia Tovena. Epistemic determiners. *Journal of Semantics*, 23:217–250, 2006.

[Kam73] Hans Kamp. Free choice permission. *Proceedings of the Aristotelian Society*, 74:57–74, 1973.

[KS02] Angelika Kratzer and Junko Shimoyama. Indeterminate pronouns: The view from Japanese. In *The proceedings of the Third Tokyo Conference on Psycholinguistics*, pages 1–25, 2002.

[Lei18] Hannes Leitgeb. Neural network models of conditional. In Sven Ove Hansson and Vincent F. Hendricks, editors, *Introduction to Formal Philosophy*, pages 147–176. Springer, Berlin, 2018.

[MRSB21] Paul Marty, Jacopo Romoli, Yasutada Sudo, and Richard Breheny. Negative free choice. *Semantics & Pragmatics*, 14(13), 2021.

[Nie16] Andreas Nieder. Representing something out of nothing: The dawning of zero. *Trends in Cognitive Sciences*, 20:830–842, 2016.

[Pai65] Allan Paivio. Abstractness, imagery, and meaningfulness in paired-associate learning. *Journal of Verbal Learning and Verbal Behavior*, 4:32–38, 1965.

[PGv+10] Judith Pijnackera, Bart Geurts, Michiel van Lambalgen, Jan Buitelaar, and Peter Hagoort. Exceptions and anomalies: An ERP study on context sensitivity in autism. *Neuropsychologia*, 48:2940–2951, 2010.

[PM20] Léo Picat and Salvador Mascarenhas. On the interplay between interpretation and reasoning in compelling fallacies. Manuscript under review, 2020.

[PSPP13] Candida C. Peterson, Virginia Slaughter, James Peterson, and David Premack. Children with autism can track others' beliefs in a competitive game. *Developmental Science*, 16(3):443–450, 2013.

[QRJL19] Ana Cristina Quelhas, Célia Rasga, and Philip Johnson-Laird. The analytic truth and falsity of disjunctions. *Cognitive Science*, 43, 2019.

[RCMN16] Araceli Ramirez-Cardenas, Maria Moskaleva, and Andreas Nieder. Neuronal representation of numerosity zero in the primate parieto-frontal number network. *Current Biology*, 26:1285–94, 2016.

[Sau04] Uli Sauerland. Scalar implicatures in complex sentences. *Linguistics and Philosophy*, 27:367–391, 2004.

[Sch05] Katrin Schulz. A Pragmatic Solution for the Paradox of Free Choice Permission. *Synthese*, 142:343–377, 2005.

[Sea69] John R. Searle. *Speech Acts*. Cambridge University Press, 1969.

[Sim10] Mandy Simons. A gricean view on intrusive implicatures. In Klaus Petrus, editor, *Meaning and Analysis: New Essays on H. Paul Grice,*, pages 138–169. Palgrave, 2010.

[Sta75] Robert Stalnaker. Indicative conditionals. *Philosophia*, 5(3):269–286, 1975.

[SvL08] Keith Stenning and Michiel van Lambalgen. *Human Reasoning and Cognitive Science*. The MIT Press, Cambridge, Massachusetts; London, England, 2008.

[TBR19] Lyn Tieu, Cory Bill, and Jacopo Romoli. Homogeneity or implicature: an experimental investigation of free choice. In *Proceedings of SALT 29*, pages 706–726, 2019.

[TGB22] Alberto Testoni, Claudio Greco, and Raffaella Bernardi. Artificial intelligence models do not ground negation, humans do. GuessWhat?! Dialogues as a case study. *Frontiers in Big Data*, 4, 2022.

[TRZC16] Lyn Tieu, Jacopo Romoli, Peng Zhou, and Stephen Crain. Children's knowledge of free choice inferences and scalar implicatures. *Journal of Semantics*, 33(2):269–298, 2016.

[V07] Jouko Väänänen. *Dependence Logic*. Cambridge University Press, Cambridge, 2007.

[Vel96] Frank Veltman. Defaults in Update Semantics. *Journal of Philosophical Logic*, 25:221–261, 1996.
[vW68] G.H. von Wright. *An Essay on Deontic Logic and the Theory of Action*. North Holland, 1968.
[Was68] P. C. Wason. Reasoning about a rule. *Quarterly Journal of Experimental Psychology*, 20:273–281, 1968.
[YV17] Fan Yang and Jouko Väänänen. Propositional team logics. *Annals of Pure and Applied Logic*, 168:1406–1441, 2017.
[Zim00] Ede Zimmermann. Free choice disjunction and epistemic possibility. *Natural Language Semantics*, 8:255–290, 2000.

B6. Work plan and planned deliverables

The following table summarises the project activities, planned deliverables and involvement of the team members. The same colour indicates related activities which will be carried out in close collaboration. The planned deliverables are further spelled out in Table 5. All journal articles will be in international journals considered first tier in their field. Other articles will appear in the proceedings of relevant highly-respected conferences. Outcomes can be coauthored.

		Aloni (PL)	**PhD1** (Logic)	**PhD2** (Language)	**Postdoc** (Cognition)
Y1		Preparatory work **[D1]**			
		Close supervision	Initial training &	Initial training &	
		& team building	Literature review	Literature review	
		Workshop 1 [D2]	Implication &	Experiments **[B1]**	Interpretation:
Y2			other extensions **[A1]**	& Data Analysis	experiments **[C1]**
		Close supervision	Logic **[A2]**	Modelling:	Reasoning:
		& outreach activities **[D3]**	Programming	modal domain **[B2]**	theory **[C2]**
		Midterm reflection AI [D4]	Neural network	Modelling:	Reasoning:
Y3		Close supervision	models **[A3]**	nominal domain	experiments **[C3]**
		& outreach activities **[D5]**	Dynamic	(quantifiers, **[B3]**	Data analysis
		Reasoning games **[D6]**	(Q)BSML **[A4]**	indefinites) **[B4]**	Recalibration **[C4]**
		Workshop 2 [D7]	Type-Theory	Type-Theory	
Y4		Integration	(dynamic) **[A5]**	(static) **[B5]**	
		& outreach activities	Dissertation	Dissertation	
			writing	writing	
Y5		Editing volume, Synthesis,			
		Repercussions **[D8]**			

Table 4: Work plan of the Nihil project.

no.	research outcomes	how published	when (month-year)
A1	Axiomatizations of variants of BSML with implication	in conference proceeding & journal article	12-Y1, 3-Y2
A2	Team semantics for Logic Programming	in conference proceeding	9-Y2
A3	Neural network models	journal article	3-Y3
A4	Dynamic (Q)BSML	in conference proceeding	9-Y3
A5	Type-theoretical (Q)BSML (dynamic)	journal article	3-Y4
B1	Results experiments on BSML* vs BSML$^\Diamond$	in conference proceeding & journal article	12-Y1, 3-Y2
B2	Linguistic analyses modal domain	in conference proceeding	9-Y2
B3	Linguistic analyses quantifiers	in conference proceeding & journal article	3-Y3, 6-Y3
B4	Linguistic analyses indefinites	in conference proceeding & journal article	9-Y3, 1-Y4
B5	Type-theoretical (Q)BSML (static)	journal article	3-Y4
C1	Results experiments neglect-zero effects on interpretation	in conference proceeding & journal article	9-Y1, 3-Y2
C2	Reasoning theory (first version)	in conference proceeding	9-Y2
C3	Results experiments neglect-zero effects on reasoning	in conference proceeding & journal article	3-Y3, 6-Y3
C4	Reasoning theory (final version)	journal article	9-Y3
D1	Project website	internet	3-Y1
D2	Workshop 1	online proceedings	12-Y1
D3	MasterClass high-school students	teaching material	6-Y2
D4	Mid-term reflection AI	internal report	12-Y2
D5	Videoclips	online teaching material	6-Y3
D6	Reasoning games	internal report	9-Y3
D7	Workshop 2	online proceedings	12-Y3
D8	Synthesis	edited volume	12-Y5

Table 5: Planned deliverables of the Nihil project.

Section C. Data management and ethical aspects

C1. Data management

1. Will data be collected or generated that are suitable for reuse?

Yes.

2. Where will the data be stored *during the research*?

During the course of the research project, the data will be stored using Research Drive, a data storage service in the cloud available for UvA research teams. Personal data will be anonymised and stored encrypted and only kept for as long as it is necessary for its purpose.

3. After the project has been completed, how will the data be stored for the long-term and how will the data be made available for use by third parties? For whom will the data be accessible?

After the completion of the research project, the data will be archived for a minimum of 10 years, at UvA/AUAS figshare, a system for safely storing, controlled sharing, and publication of research data. This facility complies with all applicable security regulations. Files are stored on ISO certified servers in Germany and can be accessed from any computer with an internet connection. The (anonymised) data will be publicly accessible together with the relevant metadata—according to the standards in the field—and other documentation that makes the data findable and verifiable. Data formats will be chosen in such a way that software sustainability is guaranteed.

4. Which facilities (ICT, (secure) archive, refrigerators or legal expertise) do you expect will be needed for the storage of data during and after the research? Are these facilities available?

ResearchDrive and the UvA/AUAS figshare repository are both available, free of charge, for researchers of the University of Amsterdam.

C2. Ethical aspects

	Not applicable	Not yet applied for	Applied for	Received
Approval from a recognised (medical) ethics review committee	☐	☑	☐	☐
Approval from an animal experiments committee	☑	☐	☐	☐
Permission for research with the population screening Act	☑	☐	☐	☐

If applicable, proof of approval will be sent to NWO before the start of the project.

Section D: Administrative details and statements

D1. Administrative details

Main Applicant

Title(s), initial(s), surname	Dr. MD Aloni
Institution	University of Amsterdam
Birth date	26/ 05/1969
Date PhD defence	25/01/2001
Position	associate professor
Type of appointment	fixed
End of contract date	–
Phone number	+310621964021
Email address for correspondence	m.d.aloni@uva.nl
Postal address for correspondence	Gerard Doustraat 214, 1073XB, Amsterdam

D2. Statements

☑ According to the formal eligibility criteria, the main and any co-applicants are no longer eligible as applicants in the NWO Talent Scheme (Vernieuwingsimpuls).

☑ The main applicant and any co-applicants have a paid appointment at one of the qualifying host institute(s) for the full duration of the application process and the project that is applied for.

☑ The main applicant and any co-applicants meet all other conditions for applicants listed in the call for proposals.

☑ By submitting this document I declare that I and all other individuals involved in this proposal satisfy the nationally and internationally accepted standards for scientific conduct as stated in the Netherlands Code of Conduct for Scientific Practice 2018 (Association of Universities in the Netherlands).

☑ By submitting this application form, I declare that I have discussed the final version of this proposal with all individuals or parties mentioned in this proposal as team members, collaborators, advisors and in any other role. All such individuals or parties mentioned are aware of and agree with their role and intended contribution to the project, should this be awarded funding.

☑ By submitting this document, I declare that I follow the NWO policy on data management.

☑ I have completed this form truthfully.

Name: Maria Aloni

Place: Amsterdam

Date: 14 February 2022