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ORIGINAL RESEARCH

Default meanings: language's logical connectives between comprehension and reasoning

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Abstract

Language employs various coordinators to connect propositions, a subset of which are "logical" in nature and thus analogous to the truth operators of formal logic. We here focus on two linguistic connectives and their negations: conjunction *and* and (inclusive) disjunction *or*. Linguistic connectives exhibit a truth-conditional component as part of their meaning (their semantics), but their use in context can give rise to various implicatures and presuppositions (the domain of pragmatics) as well as to inferences that go beyond semantic/pragmatic properties (the result of reasoning processes). We provide a comprehensive review of the role of the logical connectives in language and argue that three sets of factors—semantic, pragmatic, and those related to reasoning—are separate and separable, though some details may differ cross-linguistically. As a way to showcase the argument, we present two experiments in language comprehension in Spanish wherein pragmatic content was minimised and reasoning processes neutered, thus potentially highlighting what might be the default meanings of the connectives under study. In Experiment 1 we show that the conjunctive reading of inclusive disjunction is available in positive contexts other than in syntactically intricate cases such as downward entailing and free choice contexts, contrary to what has been claimed in the literature. In Experiment 2 we show that negated conjunctions and disjunctions in Spanish can easily receive the same interpretation when contrasted against the same context and, moreover, that these interpretations match those avail-

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able in English, despite claims from the literature that linguistic connectives and local negation interact differently in English and Romance languages.

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1 Introducing the connectives

The world's languages exhibit various ways to connect clauses, the smallest grammatical units that directly express a proposition (Haiman and Thompson, 1988). One such way is through the employment of "coordinators" like *and* and *or*, which generate so-called "compound" sentences. Such sentences involve each compound clause being of equivalent grammatical status, and therefore independent of each other (Haspelmath, 2004). Thus, for example, the sentence *the triangle is blue and the circle is red*, where the coordinator *and* connects two clauses at the same grammatical level. Compound sentences exemplify one central way of linguistically expressing complex propositions (or thoughts): one in which two atomic propositions are entertained "side-by-side", with the connection mediated by a coordinator. As such, coordinators tap some of the core properties of our linguistic and conceptual knowledge, and therefore a study of how compound sentences are put together and understood should provide key insight into some of the central properties of both language and thought. Indeed, combining two or more thoughts is a central feature of cognition (Frege, 1963; Fodor, 1975).

In this paper, we shall concern ourselves with the "logical" uses of a number of linguistic coordinators. It is noteworthy that out of the various lexical items that natural languages offer for connecting two clauses—e.g., *and*, *because*, *but*, *or*, etc.—a small handful exhibit logical properties. Such coordinators can behave like the connectives (or sentence operators) of formal logic—they are, so to speak, language's logical connectives. There is plenty of discussion in the literature as to how many logical connectives there are in language, their cross-linguistic distribution, and how they are acquired [see Gazdar and Pullum (1976), Horn (2012), and Crain et al. (2000) for discussion]. We shall set these topics aside and will instead concentrate on the comprehension of two wide-spread logical connectives and their negations: conjunction *and* and disjunction *or*.[1]

We shall start this study by providing a comprehensive account of language's logical connectives, including a discussion of some of the supposedly different ways in which coordinators and negative operators combine in English and Romance languages. We will then show how some aspects of our theoretical perspective can be put to the test and will in fact present two experiments in language comprehension to that effect, both conducted in Spanish, as a possible paradigmatic case of Romance languages, and both meant to challenge well-established predictions from the literature, as we shall discuss. In the remainder of this section, then, we will describe the

[1] We will not say much about the syntax of coordinating structures, a rather thorny issue in itself, as our interest lies on the semantics (and pragmatics) of compound sentences; we shall employ examples and materials that are, in principle, free of "syntactic" complications [for remarks on the syntax of compound sentences, see Progovac (2000) and Hoeksema (2000)].

Table 1 Truth tables for conjunction and inclusive and exclusive disjunctions, given propositions P and Q

P	Q	$\wedge$	$\vee$	$\vee_e$
T	T	T	T	F
T	F	F	T	T
F	T	F	T	T
F	F	F	F	F

main characteristics of linguistic connectives, while in the following section we will review previous experimental evidence on the connectives, highlighting important methodological considerations and, following from these considerations, our claim that linguistic and non-linguistic properties can to some extent be teased apart in a psychological investigation of how language's logical connectives are interpreted and used, the issue Sect. 3 shall be devoted to.

The reference to formal logic is meant quite literally. In the propositional strand of logic, scholars have analysed both how propositions combine with each other and what constitutes their meaning [see, e.g., Quine (1941)]. In particular, logicians assign truth values to sentences in order to account for their meaning, a proposition being either true (T) or false (F) depending on whether it accurately describes an aspect of the world or not. If we limit our attention to the combination of two sentences and the two possible truth values, we can construct "truth tables" for each compound sentence in the following way.[2]

First, we place two propositions, P and Q, side-by-side along with all the possible combinations of the two truth values, one per proposition, thus yielding four possible lines, as in the first two columns in Table 1 above: True-True, True-False, False-True, False-False. We then assign one of the two truth values—(T)rue or (F)alse—to each line, and the resulting column of four values, e.g. T F F F, would constitute a possible truth table, the 'purpose of [such] tables…to give a certain kind of meaning to certain constants [the connectives]' (Strawson, 1952, p. 69).

In the case of the connectives that interest us here, the meaning of conjunction *and* ($\wedge$, in logic) has it that the compound sentence is true only when both clauses are true (i.e., T F F F), whereas disjunction *or* could in principle be associated to two different truth tables, in accordance to two types of disjunction from formal logic. If the meaning of disjunction is inclusive ($\vee$), then the compound sentence is true when either one of the two clauses is true as well as when both of them are true (viz., T T T F). If the meaning is instead exclusive ($\vee_e$), then the compound sentence is true only if one of the two clauses is true, but not when both of them are (that is, F T T F). The truth tables for these three connectives are shown in Table 1.

So it is in formal logic, and the suggestion here is that the meaning of natural language connectives is also established by truth tables, a proposal that is somewhat muddied by the fact that linguistic expressions are typically context sensitive (Chier-

[2] We shall use the terms clause, sentence, and proposition more or less interchangeably in this paper, but nothing of substance hinges on this particular choice. Further, we shall ignore how propositions are put together (i.e., generated, as a linguist would put it), but this is obviously an important factor too [see Collins (2011) for some comments].

chia, 2004, 2013). Thus, whilst it is certainly the case that linguistic expressions that employ logical connectives must have a core truth-conditional component as part of their meaning, what's usually referred to as the semantics of such linguistic expressions (von Fintel and Matthewson, 2008), their use in context can give rise to such pragmatic phenomena as implicatures and presuppositions. These pragmatic effects can result in what appear to be non-logical uses of the connectives, and sometimes obfuscate the logical meaning altogether (Klinedinst and Rothschild, 2012; Haspelmath, 2004). Thus, *and* is often used to signal more than simply a union of two sentences, whilst *or* is typically equivocal between exclusive and inclusive disjunction.

In any case, the (semantic) meaning of the connectives should not be confused with the pragmatic uses they can be put to. The pragmatic effects that arise in language use are often mitigated, and sometimes even eliminated, in various ways, often unearthing the logical interpretation in doing so. In some cases, the syntactic details of the relevant linguistic expressions play a role in either triggering or constraining the pragmatic effects (Chierchia, 2006), whilst in other cases such effects can be cancelled either by the context or by adding further linguistic material to the sentences. In the case of cancellable implicatures, the pragmatic effects are said to be defeasible, as Grice (1989) termed it, thereby establishing that such uses are not part of the actual semantics of the expressions.[3]

In order to illustrate, consider the following sentences, adapted from the literature (Gazdar and Pullum, 1976; Crain, 2012):

(1) The bomb was tested and the earth was not destroyed (conjunction)
(2) David ordered pizza or he ordered pasta (disjunction)
(3) David didn't order pizza or pasta (negation of disjunction)

The sentence (1) implies a temporal as well as a causal relation between the two clauses instead of the union of two independent propositions, which is what logic would mandate. However, the implicature of causation/temporality (a generalised conversational implicature) can be cancelled by adding *but I don't know if these events are related* to the end of the sentence, bringing the interpretation of the overall expression in line with what logical conjunction ought to yield (as mentioned, the overall context may also cancel the implicature).

In the case of (2), which at first sight favours an "exclusive" reading—that is, David ordered one or the other, but not both—the sentence actually receives an "inclusive" interpretation when the disjunction is placed under negation: (3) means that David didn't order pizza *and* that he didn't order pasta. This runs counter to what a logician would expect if the linguistic connective *or* were a case of exclusive disjunction, as the negation of an exclusive disjunction should return a "both or neither" reading (the so-called logical biconditional). That language's *or* does not behave as an exclusive disjunction under negation has been taken as evidence that it is instead intrinsically inclusive and that the exclusive readings arise because of an implicature of exclusivity

[3] Not all non-logical uses of the connectives can be put down as pragmatic effects—connectives can often function simply as discourse linkers, for instance—but here we are only interested in cases where the pragmatically derived interpretations closely track the logical meanings. There has been some discussion on how to analyse the *prima facie* non-logical uses of the connectives, but this goes beyond the scope of this study [see Cohen (1971) for a critical view, and the response from Gazdar (1979); cf. Posner (1980)].

the hearer computes. In (2), the implicature may possibly originate from the belief that pasta and pizza are main courses and thus one would order one or the other for a meal but not both, a factor that we shall take into consideration later on (we also note that the exclusivity implicature is different to the generalised kind mentioned in the previous paragraph).

How does the hearer come to the exclusive reading of disjunction? According to a Gricean way of looking at this issue, in interpreting a sentence such as *Joe or Bill will turn up* a hearer does not usually compute what we shall term "the conjunctive reading" available to inclusive disjunction—namely, that both Joe and Bill will turn up (the true-true, TT, interpretation)—because the speaker did not utter *Joe and Bill will turn up* and therefore such a reading is deemed to be false by the person doing the interpreting. In this case, the hearer "enriches" the meaning of (inclusive) disjunction to an exclusive reading on the (double) assumption that such an interpretation is more informative and speakers aim to maximise a message's informativity.[4]

Crucial to our purposes is the fact that *and* and *or* share the conjunctive TT reading. As *and* and *or* overlap in truth values, they form a scale; that is, the truth values of *and* are a subset of those of *or*, yielding a subset/superset relation: *and* $\subseteq$ *or*, simplifying somewhat. As a result, the comprehension of disjunctive sentences gives rise to implicatures that are scalar in nature. That is, in interpreting a disjunctive sentence the hearer has to work out which interpretation within the *and–or* scale applies in a given situation: from the three potential state of affairs of inclusive disjunction to the two of exclusive disjunction and the single one of the conjunctive reading.[5]

The syntactic structure of a given sentence can sometimes constrain the available interpretations. The so-called downward entailing contexts are a clear case in this respect, as these are linguistic contexts that can block the implicature of exclusivity. We encountered such a context before in the form of the negation of a disjunction—*John did not order pasta or pizza*—which yielded a conjunctive reading. In general, downward entailing contexts licence inferences from sets to subsets, as in the sentence *John did not buy a car*, which entails that John did not buy a *red* car (the set of cars obviously includes the subset of red cars). As such, these contexts are naturally related to the superset/subset relationship between *and* and *or*; in the case of the *and–or* scale, downward entailing contexts favour the subset interpretation exemplified by the conjunctive reading of disjunction.[6]

[4] The reason that exclusive disjunction is more informative than inclusive disjunction lies on the fact that its truth table has two true values, for three of inclusive disjunction, and thus exclusive disjunction applies to two possible state of affairs instead of three. As such, the truth values of exclusive disjunction is a subset of the truth values of inclusive disjunction. In what follows, and in order to be consistent with our terminology, when we talk of inclusive disjunction we shall always have the three possible true values in mind, whilst when we intend to discuss some of the subset truth values of inclusive disjunction we shall use the phrase "the conjunctive reading (of disjunction)" for the TT interpretation and the phrase "the exclusive readings (of disjunction)" for the TF/FT interpretations.

[5] There is an extensive literature on scalar implicatures, but the important point to note here is that there's plenty of evidence for the claim that scales are often computed in actual, real-time language comprehension [see, for a recent review of the experimental evidence, Breheny (2019)].

[6] Other downward entailing contexts are shown in examples (i–iii) below, where the exclusivity implicature is blocked and the conjunctive reading is available in each case, as we explicitly state in the first example. This is further exemplified in the so-called restrictor position of a quantifier like *every*, i.e. the quantifier's

The general state of affairs suggests two questions worthy of an experimental investigation. Firstly, does disjunction ever receive a conjunctive interpretation in positive contexts or does such an interpretation only ever unambiguously arise in downward entailing contexts and in other, more intricate cases? The conjunctive reading of disjunction in positive contexts is supposed to only arise in a restricted set of examples, but the experimental evidence on this point is, as we shall show in the next section, equivocal. Crucially, a conjunctive reading in unexceptional positive contexts would constitute a clear demonstration that disjunction is indeed truly inclusive, and that would be a noteworthy result.

Secondly, do language's conjunction and disjunction behave like their logical counterparts under negation? We have seen that *or* behaves like inclusive disjunction under negation in English, while negated conjunctive sentences involve some rather complex judgements as to how to interpret them, and this raises some interesting questions vis-à-vis the negation of disjunction. Namely, the negation of logic's conjunction operator yields a truth table with three true values—three possible situations the respective compound sentence would apply to—whereas the negation of logic's disjunction yields a single true value, and these interpretations are not always easy to obtain in the linguistic counterparts, in any language. The picture is complicated further by the claim that these interpretations are not available in Romance languages, an issue that is also part of this study, considering that the experiments were conducted in Spanish (there appear to be no such complications in the case of conjunction and disjunction in positive contexts, at least in European languages; we'll come back to this issue in the Conclusion). Consider the following sentences in order to clarify:

(4) The triangle is not blue and red
(5) The triangle is not blue or red

(4) is the negation of a conjunction and (5) the negation of a disjunction, but what do these sentences mean, exactly? As mentioned, (5), a negated disjunction, seems to behave like its counterpart in logic and ought to be understood as a conjunction of two negated clauses, as paraphrased in (6) below. In this respect, English accords to one of De Morgan's well-known logical laws, shown in (7).

(6) The triangle is not blue and it is not red
(7) $\neg(P \vee Q) \Longleftrightarrow \neg P \wedge \neg Q$

Footnote 6 continued
first argument, another downward entailing context. Thus, the exclusive reading arises in (v) but does not in (iv), as in the latter the disjunction is in the quantifier's restrictor [see Chierchia et al. (2001), for more details].

(i) Paul does not like John or Bill *entails* that Paul doesn't like John and Paul doesn't like Bill
(ii) Paul is stronger than John or Bill
(iii) If John or Bill go to the gym, Paul goes swimming
(iv) Every student who wrote a paper or made a presentation received a good grade
(v) Every student wrote a paper or made a presentation

Another relevant case involves the so-called free choice/permission sentences, such as *you're allowed to eat cake or ice cream*, which can be paraphrased as *you're allowed to eat cake and you are allowed to eat ice cream*. In this case the conjunctive reading arises from the modal verb, but we defer to Zimmermann (2000) for the details [the example itself is taken from Singh et al. (2016)]. Sauerland et al. (2015) use the terms isotone and antitone to refer to these set-subset relations, but this is by-the-by.

(8) $\neg(P \wedge Q) \Longleftrightarrow \neg P \vee \neg Q$
(9) The triangle is not blue or it is not red

How about the negation of a conjunction, however? According to another well-known De Morgan law, this one shown in (8), a negated conjunction derives into a disjunction of two negated clauses, and thus (4) should be understood as in (9). The latter judgement is harder to obtain than the negation of a disjunction, if at all available. One possible difficulty arises from the (inclusive) disjunction the De Morgan law returns in this case, thus establishing that the truth table of a negated conjunction is composed of three true values (for one single true value of a negated disjunction). It is easy to see how a negated conjunction returns a conjunctive reading—i.e., a conjunction of two negated clauses—but obtaining the disjunctive interpretation, when one of the two clauses may not be the case but the overall sentence remains true, is not as straightforward. Such a reading may be available with the right intonation on the connective *and* in order to draw the right contrast (in addition to an accommodating context), but this certainly requires some effort, it is not certain to be accessible, and it is clearly not the default reading.[7]

Accordingly, an obvious hypothesis to probe may well be that a negated conjunction ought to be more difficult to understand than a negated disjunction; or as Seuren (2006) puts it, that a negated conjunction is not immediately interpreted as a disjunction of negated clauses in the same way that a negated disjunction *is* often quickly interpreted as a conjunction of negated clauses (p. 131). Seuren offers an explanation in terms of the amount of computation required, where a negated conjunction requires a great deal more than a negated disjunction—roughly speaking, because three true values need to be computed in one case, but a single one in the other. This general prediction has received some support from the perspective of reasoning when negated compound sentences of this kind are presented as premises to a problem-solving situation. Khemlani et al. (2012b, a), for instance, empirically evaluated this prediction within the *mental model* theory of reasoning and found that a negated conjunction was indeed harder to reason with than a negated disjunction. We shall explain our own approach to this prediction in the following section, where we will draw a distinction between comprehending/interpreting compound sentences and reasoning with them, a distinction that is central to our purposes.

In addition, there is the aforementioned issue regarding the cross-linguistic analysis of how linguistic connectives behave under negation. It has been claimed, in particular in a number of recent studies by Pagliarini and colleagues (Pagliarini et al., 2018, 2021), that negated conjunctions and disjunctions behave differently in Romance languages than they do in other language families, English being a relevant contrasting case here [this position is partly based on Szabolcsi (2002); Szabolcsi and Haddican

[7] It is worth adding that the examples in (4) and (5) are clausal reduced, in contrast to *the triangle is not blue and the circle red* and *the triangle is not blue or the circle red*, which are full clauses (with some verb reduction), and though it would be preferable to employ full clauses in a study that probes the logical properties of compound sentences, on a par with what is actually the case in logic, the linguistic, "full" versions of negated conjunctions and disjunctions are rather awkward and difficult to understand. As described in the next sections, where we present our two experiments, we used full versions of conjunctions and disjunctions in positive contexts, which is unproblematic in language, but reduced versions in the case of negated conjunctions and disjunctions.

(2004), who report some cross-linguistic, but certainly preliminary, data on the matter]. In particular, a sentence such as *Mary didn't invite Lucy or John for dinner* is supposed to be ambiguous between two readings in English—viz., between *Mary didn't invite Lucy or she didn't invite John for dinner* and *Neither Lucy nor John were invited to dinner by Mary*—in a way that its counterpart in French is claimed not to be (Nicolae, 2017). That is, though the French sentence *Marie n'a pas invité Lea ou Jean à diner* (Marie has not invited Lea or Jean for dinner) can apparently be understood as an exclusive disjunction (i.e., Marie didn't invite Lea or she didn't invite Jean for dinner), the conjunctive interpretation under negation, a neither/nor reading, is argued to be doubtful, if at all available. As Pagliarini et al. (2018, 2021) describe the general state of affairs, in languages such as English and German clausal negation takes scope over the connectives *and* and *or*, whereas in languages such as Italian, Catalan or Mandarin, the situation is reversed, thus yielding the putatively different interpretations.

This is argued to follow from the cross-linguistic study of polarity, according to which in Romance languages connectives such as *and* and *or* are positive polarity items (PPIs) and thus are interpreted outside of the scope of negation—that is, within the same clause such connectives take scope over negation instead than the other way around, as is the case in English and other Germanic languages [see Pagliarini et al. (2018), for discussion of the relevant linguistic literature as well as some experimental evidence on this, which we discuss briefly in fn. 9]. Accordingly, in Romance languages a negated conjunction would only be true when both clauses are false, whilst a negated disjunction would be true when only one of the clauses is true. Contrary to what is claimed to be the case in English, in Romance languages a negated conjunction does not license a disjunction of two negated clauses and a negated disjunction would not allow a conjunctive reading.

We find this very doubtful and clearly in conflict with our own grammatical judgements; moreover, and whilst we understand the linguistic analyses and appreciate the theoretical repercussions, there is little actual empirical evidence for these interpretations, which are quite specific indeed—no wide-ranging surveys or questionnaires seem to have been conducted, and the cross-linguistic evidence reported in Szabolcsi (2002); Szabolcsi and Haddican (2004), the main source Pagliarini and colleagues reference, mostly derives from informal judgements of fellow colleagues and the like. Part of our experimental investigation was in fact set up to evaluate some of these claims, especially the assertion that a negated disjunction cannot return a conjunctive reading in Romance languages (the claim that negated conjunctions in Romance languages are hard or even impossible to interpret as a disjunction of two negated clauses appears to be true of English too, as mentioned, but we shall not engage with this contingency here).

As a way to lend support to our judgements, we consulted some of the analyses the first author has conducted on Italian examples of negated conjunctions and disjunctions.[8] A corpus analysis of two large databases, CHILDES, a corpus of language acquisition data, and *La Repubblica*, an Italian newspaper, found numerous examples of negated conjunctions and disjunctions with the intended conjunctive interpretation

[8] These analyses were conducted in collaboration with Prof. Maria Teresa Guasti from University Milano-Bicocca, who we thank here. Though this short study was done in Italian, the results could be applicable to other Romance languages—our own judgements in Spanish are certainly in line with the results of the questionnaires.

(in each case). In order to confirm these intuitions, twenty *prima facie* unequivocal examples of each type of sentence were selected and a short questionnaire was run with native speakers of Italian to evaluate the requisite interpretations. These interpretations were confirmed in every single case and as a result we regard the conjunctive reading of negated conjunctions/disjunctions as clearly possible, if not in fact entirely unexceptional, in (at least some) Romance languages. We certainly expect participants to have no trouble accessing these readings in Spanish in an experimental task.[9]

All things considered, then, the second issue under investigation in this study will aim to evaluate a number of interrelated issues. To wit: Are negated conjunctions and disjunctions in language understood as their counterparts in logic? Do Romance languages such as Spanish differ from English regarding these very readings? And finally, though in this case the evidence we will provide will be more indirect, does a negated conjunction demand more processing load from the language comprehension system than a negated disjunction?

We shall evaluate our two research questions—on inclusive disjunction, and on negated conjunctions/disjunctions—from the perspective of language comprehension, which is a slightly different approach from what has usually been the case in the literature on logical connectives. In the next section we describe some of the previous work on the use of *and* and *or* and their negations, which for the most part has centred on evaluating how experimental participants draw conclusions from sentences that employ these connectives. We shall argue that slightly different cognitive mechanisms are involved in linguistically processing compound sentences and in reasoning with them, giving rise to different predictions and in fact to different kinds of evidence (and data). Sect 3, in turn, reports two experiments in Spanish, both of which were designed to minimise pragmatic content and block reasoning processes; the first experiment is centred on the question of whether disjunction is ever interpreted conjunctively in positive contexts, whilst the second is devoted to the (double) issue of whether language's conjunction and disjunction are interpreted like their logical counterparts under negation, and whether Spanish and English return the same kind of readings. The final section discusses the results by putting them into the right context and brings an end to the overall discussion by introducing a number of related research questions (and by alluding to some further results, soon to be published).

[9] We should stress that we do not deny that the other interpretations are possible, though some seem very hard to compute to us (in particular, again, a negated conjunction as a disjunction of negated clauses). Pagliarini and colleagues, for instance, have obtained an exclusive reading of a negated disjunction in Italian (Pagliarini et al., 2018) and Catalan (Pagliarini et al., 2021), *prima facie* lending support for their take on how scope relations vary between Romance languages and English, but we should point out that the context in these experiments was not unbiased and the set-up seems to have disfavoured the conjunctive reading (the task involved foodstuffs and the act of feeding an animal puppet, which may have made the choice of one foodstuff out of two the more natural interpretation for sentences such as *the cat didn't eat the carrot or the pepper* in both Italian and Catalan). We would argue that negated conjunctions/disjunctions are ambiguous in both English and Romance languages and they may well differ as to what the preferred/default interpretations are, but the purported dispreferred reading in each case may not be altogether absent or unavailable. We suspect a better account of the cross-linguistic differences, such as they are, may be available, but this is beyond the scope of this paper.

2 A theoretical split: comprehension vs. reasoning

The claim that the semantics of natural language connectives is truth-theoretic is now pretty much the received opinion [see Horn (2012), for a review]. It is not the only possible view, however. Some scholars, especially those working with the *mental logic* model of reasoning, a theory that posits that much of human reasoning is based on implementing a set of inference schemas, have in the past argued that the meaning of the connectives is determined by the inferences in which they appear [see, for instance, O'Brien and Bonatti (1999)]. Loosely connected to "inferential role semantics" (Block, 1986) as well as to certain strands of formal logic, this stance has focused on the so-called rules of introduction and elimination for the connectives. These are rules that establish how the connectives can be used in deductive reasoning and are part of Gerhard Gentzen's "calculus of natural deduction", a particular framework mental logic theorists have often made reference to [e.g., Braine (1978, p. 1)]. Also known as inference rules, introduction/elimination rules have featured in many mental logic studies.

Thus we find Braine and Rumain (1981), an experimental study on how children and adult reason with disjunction. Four tasks were devised for this purpose with children ranging from the age of 5 to 10 as well as with college students. In the first task, blocks of different shapes and colours would be presented to participants, who were required to select the right objects by responding to two types of commands, both of which were meant to allow for what Braine and Rumain called a set-union interpretation, which were always presented in the following order: "give me all the green things or give me all the round things" (intended set-union interpretation: things that are both green and round) and "give me all those things that are either blue or round" (set-union interpretation: things that are both blue and round). In this task, Braine and Rumain found that the majority of participants chose one category only with each command, and typically the first one that was mentioned—e.g., green things for the command "give me all the green things or give me all the round things". Regarding the so-called set-union interpretation, only some of the adults would entertain it, marginally so, and only with the second type of command (viz., with "give me all those things that are either blue or round").

The second task evaluated how participants dealt with contradictions and tautologies, but we will not discuss it here. In the third task, an experimenter would describe the contents of an open and visible box by using sentences such as "either there's a horse or there's a duck in the box", and participants had to confirm whether the statement was (either) true or false. In this task, where the either/or sentence would be used with all possible truth values (that is, TT, TF, FT, FF), the results were threefold: i) all participants considered the compound sentence false when both clauses were false (FF); ii) most children preferred the TT reading to the mixed forms TF and FT readings, suggesting they treated disjunction as if it were a conjunction, even though the either/or form wouldn't in principle allow for this reading; and iii) most adults considered the mixed TF/FT forms to be true but varied as to whether they considered the TT interpretation valid or not, suggesting that most adults interpreted this type of disjunction exclusively rather than inclusively (though, again, the either/or phrasing should have signalled an exclusive reading).

Finally, the fourth task, composed of seven reasoning problems, required participants to draw an inference about the contents of a closed box based on the information they were given, which acted as premises. This task evaluated the use of inference rules directly, as it involved situations in which participants had to "reason with alternatives". Thus, in a situation in which premises *p or q* and *not-q* were presented, the participants would be expected to conclude that *p* by applying an elimination rule for the disjunction, also known as the disjunctive syllogism (Braine and Rumain, 1981, p. 47). In this task, which evaluated the participants' command of 7 different inference rules, all participants did well with all of them.

All together, Braine and Rumain took their results to establish that the meaning of the connectives is determined by its inferential role rather than by truth conditions, but this conclusion is not well supported. In fact, such a perspective draws too close a bond between the meaning of the connectives (in either formal logic or language) and the rules of inference in which the connectives can partake; after all, the inference rules may be triggered in a reasoning task in a way they need not be, or would not be, in simply computing a linguistic interpretation. This is reflected in the methods and tasks employed in Braine and Rumain (1981). The first thing to note, in fact, is that some of these tasks vary considerably in nature, and so would the mental representations and processes at play in each case. Task 1 involved following a number of commands and manipulating tangible objects, while in task 3 a sentence and a visual scene are presented and the participant is asked to judge whether the sentence describes the scene appropriately, a set-up that is not significantly different from many current experiments in psycholinguistics, including our own. Task 4 is more different still, as participants had to explicitly employ different rules of inference presented as linguistic material; that is, participants were required to process the linguistic material first and then reason with it, which is to say that some sentences were in fact presented as premises to an argument and the expectation was that participants would draw a number of conclusions from these sentence-premises. Thus, task 4 would engage language comprehension as well as whatever representations and processes are operative in reasoning, be these those of mental logic (Braine and O'Brien, 1998), mental models (Johnson-Laird, 2010), Bayesianism (Oaksford and Chater, 2007), or else.

We have already argued that interpreting sentences with connectives implicates combining semantic and pragmatic factors, which we showed to be separable. We now add that reasoning with sentences that contain connectives would commit further factors still, such as biases and heuristics (Tversky and Kahneman, 1974), processing speed (Anderson, 1992), the availability (or not) of inference rules (Johnson-Laird and Yang, 2008), and possibly many others, and all these factors are certainly independent, and in fact also separable, from the more properly linguistic. If anything, Braine and Rumain are conflating factors that are more or less independent of each other.

The separation between the meaning of the connectives and the pragmatic uses as well as non-linguistic inferences they can give rise to is more readily appreciated these days by mental logic practitioners [e.g., in Cesana-Arlotti et al. (2018)], and this specific issue *has* received more attention recently, especially in studies that sit at the intersection of theories of meaning and theories of reasoning [Mascarenhas and Koralus (2015), is a case in point, to which we will come back, briefly, *infra*]. The intermixing of linguistic and non-linguistic properties is an unfortunate shortcoming

of the Braine and Rumain (1981) study; it is also a difficult one to avoid, as compound sentences employing connectives can give rise to multiple interpretations, and given specific experimental conditions, the supposition that there is a problem to work out—that there is an interpretation to favour, and that there is something to do with it—may easily arise for participants. As we shall discuss, this is a methodological issue at heart and great care needs to be employed as to not employ materials or a set-up that trigger reasoning processes. Such a situation can easily transpire in studies that are more psycholinguistic in outlook as well, in fact. In order to exemplify what is stake, we now move to a discussion of two particular works on the connectives—namely, Paris (1973) and Chevallier et al. (2008)—which will provide the necessary contrast (and background) to our own study.

Consider Paris (1973) first, a work that employed a verification task with four groups of children aged between 7 and 16 years as well as with 19-year-old college students. Participants would be shown a slide depicting a scene for 15-20 seconds along with a verbal description containing a coordinator and would be then asked to judge whether the description of the scene was (either) true or false. Paris employed eight different coordinators (e.g., *and*, *or*, *but*, *if…then*, etc.), which he called connectives, and his intention was to probe whether participants were sensitive to the logical relations he identified with these coordinators. In order to do so, Paris showed all participants every connective with the four, possible truth values (as depicted in the slides) and coded responses as percentages of errors, where an error was a non-logical interpretation.[10]

Paris found that all groups (both children and adults) demonstrated near perfect performance with conjunction *and*, whereas the overall picture with disjunction is more varied. In particular, most participants appear to have treated disjunction *or* inclusively in that the three true values (TT, TF, and FT) of disjunction were accepted for disjunctive sentences in general, though the youngest children (the group of 7-year-olds) only accepted the conjunctive (TT) interpretation and older participants, especially college students, preferred the exclusive reading of disjunction (the mixed forms TF and FT). The last result certainly accords well with the Gricean view on the comprehension of disjunction outlined earlier as well as with subsequent experimental evidence. Adult participants are presumably more sensitive to pragmatic factors than children, and thus are more likely to compute the exclusivity implicature of disjunctive sentences. That is, though there is some evidence that children from the age of 6 are adult-like in being able to derive (some) scalar implicatures (Foppolo et al., 2012), computing such implicatures involves representing a number of situations against a background of alternatives (3 situations for inclusive disjunction, 2 for exclusive disjunction, 1 for conjunction), and the construction of these alternative representations should be easier for adults (Gualmini et al., 2001). This is an important point for our study, as we will employ a modified version of Paris's paradigm and we will aim to

[10] Only a handful of the coordinators Paris employed are considered clear examples of binary logical connectives nowadays—the conditional *if…then* is not one of them, for instance [see Gazdar and Pullum (1976) and Kratzer (1986)]—and thus we will only discuss the results Paris obtained with *and* and *or*. We should note, further, that like Braine and Rumain (1981), Paris included the structure "either…or…" in his experiment, sometimes called a complex disjunction in the literature (Nicolae, 2017; Tieu et al., 2017) and thus not a *binary* connective on a par with simple disjunction *or* [it in fact exemplifies a so-called correlative connective (Horn, 2012)], and this connective should not allow for a conjunctive reading, as alluded to earlier, as the either/or phrasing ought to be a pretty strong marker of an exclusive interpretation.

control for pragmatic factors so that the exclusive readings are not disproportionally preferred any more than they may already be.[11]

The case of Chevallier et al. (2008) is a more intricate one, this an experimental study that centres on the issue of how much time participants are given to process disjunctions, which the authors claim to be a key factor. This framework starts with the Gricean expectation that the literal meaning of disjunction is inclusive while the exclusive reading is the result of enrichment; what Chevallier et al. (2008) add to this is the relevance-theoretic perspective that whether a disjunction is interpreted inclusively or exclusively may depend on how much time one is allowed to process them (or put in more relevance-theoretic terms, on how much processing effort is expended to do so, which in the context of an experiment this translates on how much time participants are given to process a sentence). However, the actual task Chevallier et al. (2008) employed seems to be partly language comprehension, partly problem-solving, a situation we have noted can often ensue in the case of the connectives, especially when there might be an indication in the set-up, the task itself or the materials, that logical relations are being probed, and this is what we think took place in this case.

Participants would be shown a string such as *table* (pseudo- and non-words were also used), followed by a description of the strings, such as *there is an A or a B* (note the connective), and then they would be asked whether the description was true or not. Participants were exposed to the four truth values of conjunctions and (inclusive) disjunctions across three conditions that manipulated the temporal component in one way or another: in the *fast-word* condition the string would appear for one second and then be replaced by the description; in the *normal* condition the string would appear on its own first and after one second the description would appear below it; and in the *extra-time* condition the presentation would be similar to that of the *normal* condition but participants were made to wait three seconds before they could respond. According to the results of their experiment 1, the most relevant one for our purposes, the percentage of correct answers to the conjunctive reading of disjunction (the TT value), the datum Chevallier et al. (2008) themselves highlight, was 80 in the *fast-word* condition, for 75 and 52 in the *normal* and *extra-time* conditions, respectively (correct answers to the mixed forms TF-FT were high in each condition, as we stress below, while performance on the conjunctions was near perfect, as expected).

Chevallier et al. (2008) take these data to suggest that the first interpretation that arises in the processing of a disjunction, and thus the literal meaning, is the inclusive one, as evidenced by the fact that when participants are given three seconds to process the descriptions they tend to reject the TT reading for disjunctive sentences. Chevallier

[11] It is worth adding that Paris (1973) seems to have been the first study to report that young children only accept the conjunctive TT interpretation for disjunction *or*, surprisingly dismissing the mixed TF/FT forms [as stated, Braine and Rumain (1981), reported a similar result, but the use of either/or sentences in their study raises more questions than it answers]. Paris speculated that children may have fixated on the auditory and visual information and actually disregarded the connective *or* and the logical relations it marks—that is, these children might have checked whether the individual sentences matched the figures or not, ignoring the connective mediating between them. Recent results suggest that children's performance is not equivocal in this respect (Singh et al., 2016; Tieu et al., 2017); children *do* go through a phase in which disjunction is understood conjunctively only. Our study won't add anything to the study of language acquisition, but we will keep in mind the (methodological) point regarding what strategies participants may be employing when exposed to disjunctive compound sentences in a task of this nature.

et al. (2008) are certainly right to focus on the TT reading as a marker for whether participants treat disjunction inclusively or not (the acceptance of the mixed forms is not in doubt), but the overall data seem to point to a general preference for the exclusive interpretation of disjunction in general, much as Paris (1973) had reported. Indeed, the percentage of correct answers to the TF-FT forms were 82-82, 92-94, and 95-92 in the *fast-word*, *normal*, and *extra-time* conditions, respectively, and what is noticeable overall is not so much the decrease of percentage of correct responses for the TT interpretation across conditions, the datum Chevallier et al. (2008) fixate on (recall, 80-75-62), but the fact that the responses to the mixed forms are pretty much the same in the *normal* and *extra-time* conditions while the percentage of correct answers is lower in the *fast-word* condition for *every* reading. Indeed, in the *fast-word* condition the responses to TT, TF and FT are almost identical, and this might well be an artefact of the manipulation itself rather than a reflection of the speed at which the values of an inclusive disjunction are typically processed. It seems to us that the *normal* condition ought to be regarded as a baseline against which performance on the other two conditions should be measured. In this sense, what the data would indicate is a preference for the mixed forms in both the *normal* and *extra-time* conditions—and thus a preference to an exclusive interpretation—and a ceiling effect of sorts in the *fast-word* condition [Chevallier et al. (2008) don't provide pair comparisons for the different responses, and this is unfortunate]. This is not to say that disjunction is not interpreted inclusively *tout court*—the performance on the *normal* condition is certainly testament to that—, but all in all this result is not as striking as Chevallier et al. (2008) believe—a preference for the exclusive reading of disjunction in general seems to be a more accurate description of the overall results.

More importantly, as mentioned, the kind of task Chevallier et al. (2008) employed appears to bridge the gap between a purely psycholinguistic phenomenon (including the processing of both semantics and pragmatics) and processes that involve some kind of problem-solving (and therefore reasoning), and this factor may well go some way towards explaining the data. Contrary to the setting presented in Paris (1973), the scene as well as the sentence describing the scene employed in Chevallier et al. (2008) are hardly natural or neutral (within the strictures of a laboratory setting, anyway); after all, presenting a string of characters on a screen is not very representative of a typical use of language in context and this may be triggering an alertness in participants of a different nature to what is usually the case in a language comprehension task. In addition, the sentence that is then presented as a "description" of the string is not describing any scene per se, but more appropriately it is referring to an attribute of the string, which is left open for evaluation in a way that is not the case in a classic picture/sentence matching task (that is, it is the evaluation of whether the sentence matches the scene that is slightly different). We would argue, in fact, that a description such as *there is an A or a B* is a *leading* sort of sentence, and in this particular context it may well lead participants to believe they are facing a puzzle of some kind, with the expectation that the puzzle requires a resolution. The fact that participants were required to undertake the same task at different speeds may also have contributed to the suspicion that it was participants' problem-solving abilities that were being put to the test.

Relatedly, earlier on we mentioned Mascarenhas and Koralus (2015) as an example of a study that explicitly focuses on these very factors and some of the issues they discuss might apply here. According to Mascarenhas and Koralus (2015), in a problem-solving task the presence of a premise containing a disjunction typically raises the question of which disjunct is in fact true—that is, it can give rise to a "disjunction elimination" strategy, a rule of inference of the kind Braine and Rumain (1981) had employed in their study and which might well constitute a reasoning bias or heuristic in human reasoning. We would say that the set-up in Chevallier et al. (2008) is indeed conducive to regarding the opening sentence as a kind of a premise rather than simply as a description of a scene. If so, it should not be surprising, given the specific amount of time participants had to spend thinking about their responses in some conditions, that they would consider the opening sentence as introducing a problem-solving task of sorts, and in these terms, that they might have considered rejecting one of the disjuncts as a result. And if this is the case, then the data Chevallier et al. (2008) report in the *extra-time* condition might well be the result of a reasoning process and not solely a case of language comprehension, a circumstance that also appears to be true, though perhaps in a lesser degree, in the *normal* condition (as mentioned, the *fast-word* condition probably reflects the noted ceiling effect). What might have happened here, then, is a case of disjunction elimination, which is certainly common enough in decision-making inferences, as suggested by Mascarenhas and Koralus (2015) and reported in Braine and Rumain (1981), discussed *supra* [cf. Rips (1994), who argues that human reasoning processes only use elimination rules when it comes to the connectives, supporting the claim that disjunction elimination may be a reasoning bias/heuristic].[12]

Overall, the data in Paris (1973) and Chevallier et al. (2008), the two studies that to our knowledge have more clearly obtained the result that in some cases adult participants assign a conjunctive interpretation to disjunction in positive contexts, in addition to the exclusive readings, are not entirely compelling or robust. Chevallier et al. (2008) were on the right track in their focus on the conjunctive reading as the unambiguous proof that disjunction is inclusive, while Paris (1973) certainly employed an experimental technique that is apt to tracking psycholinguistic factors properly. What was lacking in both studies was the right *design*; the use of all truth values of a great number of coordinators in the case of Paris (1973), and all truth values of conjunction and disjunction in addition to time constraints and an odd task in the case of Chevallier et al. (2008), seems to have resulted in rather convoluted sets of data and the wrong sets of contrasts. That said, we shall keep these two studies in mind for the remainder of this paper, as our own set of experiments develop and improve upon some of the ideas and data from these two studies.

There are two main theoretical splits at hand here, then, which we intend to exploit in our study. Firstly, there is a split between the semantics of the connectives and their use in context (their pragmatics). And secondly, there is a split between the (linguistic) comprehension of the connectives, which will include both semantic and pragmatic

[12] There might be independent reasons to doubt the relevance-theoretic account in any case, as Chevallier et al. (2008) themselves are aware of and discuss. The exclusivity implicature is so common that it need not be the result of a temporal inferential process in many, if not most, cases, no matter how fast such an implicature might be computed [and Chevallier et al. (2008) might be too optimistic in this respect anyway].

factors, and reasoning with them, which will involve further factors (biases, heuristics, processing speed, etc.). The employment of the connectives in a problem-solving task would involve whatever reasoning systems the mind makes use of in addition to the language comprehension system proper, whilst the language comprehension system may well behave rather differently depending on whether extensive pragmatic information is present or not (such as a context, speakers' intentions, etc.).

Our study keeps these distinctions squarely in mind, and in doing so will highlight the rather different predictions that derive therefrom, as demonstrated in our experiments. We present two experiments below, both of which were designed so that the task was exclusively a language comprehension one. Experiment 1 probes the availability of the conjunctive reading of disjunction in positive contexts by contrasting conjunction and disjunction against the same context as well as by tightly constraining the pragmatic information available to participants. Experiment 2 contrasts two sets of predictions on the effect(s) of negating conjunctions and disjunctions: one set deriving from a cross-linguistic perspective, the other from a language processing perspective.

3 Experimental evidence

Our own framework is centred on the contingency that conjunction and disjunction can in principle describe the same sort of (visual) scene (in both Spanish and English, and possibly in many other languages). Given that conjunction and disjunction share a truth value, in both positive and negative contexts, what we have called the conjunctive reading, we constructed an experimental setting in which the same kind of scene is presented with both conjunctive and disjunctive compound sentences. As mentioned, we used a modified version of Paris's paradigm in which both the graphics and sentences employed were more neutral in an attempt to control for pragmatic and non-linguistic factors. Participants would initially be shown a graphic depicting one/two geometrical figures in various colours. A sentence describing the graphic would be played soon after, and once the audio file had finished the graphic would be replaced by a yes/no question. The question simply asked whether the sentence matched the graphic that had been presented, rather than whether the sentence was true or not, and would remain on the screen for the remainder of the trial, until participants responded. We used four different types of figures—circles, triangles, squares, and diamonds—which could appear in four different colours (or combinations of these): blue, green, red, and yellow. We recorded participants' yes-no responses as well as the time each participant took to answer each question. The yes-no responses constitute the main data, while the response times (RTs) provided complementary information.

The two experiments were designed so that we could probe whether the default interpretations for the requisite compound sentences align closely with the expected logical readings, and we hypothesised that this would be the case. In the next two subsections, we will describe the experiments in more detail and report the results we obtained, which confirmed the predictions.

3.1 Experiment 1

We took advantage of two factors in the design of our experiments. The first factor is based on the possibility of minimising, or neutralising, the sort of context that participants are exposed to in a psycholinguistic experiment run in a laboratory. In the case of Experiment 1, where our interest lied on the conjunctive reading of *or* and the aim was to avoid the exclusivity implicature, we ran a set of experiments with little meaningful context. Our working assumption was that if the exclusive reading is the result of pragmatic effects, then it ought to be possible to block such an interpretation by eliminating the state of affairs that usually gives rise to these effects. We have already mentioned that scalar implicatures do not tend to arise in downward entailing contexts [as long as the non-linguistic context is unbiased, we should add, as discussed in fn. 9; see, moreover, Chierchia et al. (2004)]. What we did here was devise a situation in which scalar implicatures would be by default absent, which ought to be possible to do in an appropriately designed experiment [as Chierchia (2004, p. 51) has speculated]. We do not mean to say that all pragmatic factors would be nullified in such conditions, or indeed every possible implicature; but we did set out to disfavour the exclusivity implicature.

The second factor is not unrelated; it in fact complements the first. Though the literature suggests, as we have seen, that the conjunctive reading of disjunction is typically only possible in positive contexts in some rather intricate syntactic structures, some perfectly normal and *prima facie* simpler sentences appear to be less prone to yielding the exclusivity implicature than others. Thus, whilst the sentence *David ordered pasta or he ordered pizza* does give rise to an exclusive reading, plausibly from the noted general knowledge that both pasta and pizza are main meals and thus one would order just one of them, a sentence such as (10) does not appear to have the same import.

(10) The triangle is blue or the circle is red
(11) The triangle is blue or red

In (10), the contrast between the objects in each clause, along with the quality ascribed to each—a blue triangle in one case, a red circle in the other—seems to block the interpretation that the state of affairs is one in which there is one object or the other but not both—that is, the conjunctive reading appears to be available. The situation is different in (11), a type of sentence that exhibits clausal reduction, and where the exclusivity reading is more marked—there is but one object and two colours, and the sentence implies that its colour is either blue or red but not both. In the terms we used earlier, sentence (11) would have to be interpreted against a background of *fewer* alternatives than sentence (10) (i.e., the two alternatives of exclusive disjunction against the three of inclusive disjunction). In this experiment, then, we used sentences with full clauses, much as is the case in logic (we'll take a different approach in Experiment 2, as anticipated in ft. 7, *supra*).

We made use of these two factors—the absence of context, and the role of specific sentences in yielding the exclusivity reading—in order to probe how the processing system parses sentences with disjunction *or*. In addition, and crucially, we contrasted the conjunctive reading of disjunction with the processing of a conjunctive sentence

by employing the same kind of scenes for each type of sentence. This was done on the Gricean assumption that in such a situation participants would be less likely to accept the conjunctive reading of disjunction given the availability of conjunction, but if they did accept such a reading the result would be the more compelling and we would have succeeded in neutralising the pragmatic effects that give rise to the exclusivity interpretation. Our general prediction for Experiment 1 was that disjunction could be interpreted conjunctively in such positive contexts, without the interference of a confusing design or intricate syntactic contexts. The goal was to unearth the conjunctive reading of disjunction in a clearer and more unequivocal manner than had been the case in either Paris (1973) or Chevallier et al. (2008), thus unambiguously proving that language's disjunction is indeed inclusive. Thus, participants would be exposed to the same sort of graphic in each condition (viz., two figures), but the type of sentence they would hear would differ. In one condition, participants would hear a compound sentence with conjunction (condition *and*), which would describe the graphic perfectly, and in the other they would hear a compound sentence with disjunction (condition *or*), which would also describe the graphic accurately, but just in case the disjunction is interpreted as an inclusive disjunction and the conjunctive, TT reading is accessed and accepted. Such a design, moreover, should make any predictions from a reasoning perspective moot, most notably the expectation that disjunction elimination becomes operative when disjunctive sentences are presented as premises to a problem, which should not be the case here.

We hypothesised that participants' performance would be almost perfect in the *and* condition, whereas for the *or* condition we predicted that participants would accept the conjunctive reading in many cases, and certainly above chance. The latter prediction is based on the two factors we set out to exploit: the lack of a biased context towards an exclusive reading, and the use of full clausal compounds using shapes and colours, thus drawing a significant contrast between figures and colours, which should minimise the exclusivity reading further. The prediction remains a rather strong one, however. The implicature of exclusivity is a fairly robust phenomenon, plausibly arising very frequently in daily usage [Morris (2008), provides some evidence for this conjecture], and given the noted contrast with the conjunction condition, it would not be odd for participants to reject the conjunctive reading for a disjunctive compound sentence —that is, to favour the exclusive readings. Regarding response times, and though this measure involved a counter that started after the question was presented, and therefore ought to be treated with care, we predicted that participants would be faster in responding to the question they faced in the case of conjunctions, as it should be simpler, or more direct, to judge that the corresponding state of affairs applies in this condition than in the *or* condition. As mentioned, participants need only compute one true value for conjunctions, for a maximum of three for inclusive disjunctions, and this ought to be reflected in the response times.

In fact, response times offer an additional control for our hypotheses. The appropriate comprehension of conjunctive sentences requires that each conjunct be processed, while in the case of disjunctions participants could simply focus on the first disjunct, confirm that it is true for the graphic that has been presented, and thus settle on the conclusion that the overall sentence is true, regardless of the truth or falsity of the second disjunct (this would certainly mean that an exclusive reading of disjunction

is preferred). If participants were to follow such an approach for disjunctions, then response times for disjunctions ought to be faster than for conjunctions (this is a comparison between processing one disjunct and processing two conjuncts); but if this is not the case, as we have hypothesised, then this would constitute further evidence for the expectation that participants are indeed computing the conjunctive reading of disjunction.[13]

3.1.1 Method

Participants. 20 psychology students (4 male, 16 female) from the Rovira i Virgili University (Tarragona, Spain) participated in this and the next experiment for course credit. The order of presentation was counterbalanced so that half of the participants would carry out Experiment 1 first and then move on to Experiment 2 after a short break, while the other half would start with Experiment 2 and then complete Experiment 1 after the same sort of break. The mean age was 23 years, and participants had no known hearing impairments. All were native speakers of Spanish.

Materials. Two variants of biclausal, declarative Spanish sentences were constructed, corresponding to two experimental conditions. In one condition, the connective *and* mediated between the two clauses, whilst in the other condition the clauses were connected by the connective *or*. Each clause ascribed a single colour to a single geometrical figure; we used four different colours (blue, yellow, red, and green) and four different figures (circles, squares, triangles, and diamonds). Each condition was composed of 10 sentences, each exemplified below.

And condition: El círculo es azul y el cuadrado es amarillo (the circle is blue and the square is yellow)
Or condition: El círculo es azul o el cuadrado es amarillo (the circle is blue or the square is yellow)

20 more sentences were constructed to act as fillers. The fillers were similar to the experimental sentences, except that each clause was individually negated. That is, we used 10 conjunctions of two negated clauses, and 10 disjunctions of two negated clauses. The following are examples of each type: *el rombo no es rojo o el círculo no es amarillo* (the diamond is not red or the circle is not yellow), and *el rombo no es azul y el círculo no es verde* (the diamond is not blue and the circle is not green). The addition of filler sentences was meant to provide some variability in the materials participants were exposed to, as is common in studies of psycholinguistics. We used all four colours and all four geometrical figures in both experimental and filler sentences. The sentences were recorded in stereo with a normal but subdued intonation by a native, male speaker of the Spanish language using the Praat software on a Windows-operated computer. We paid particular attention to the connectives in the recordings in order to make sure that they were always unstressed; a stressed disjunction, in particular, could have signalled an exclusive reading and this needed to be avoided and kept as neutral as possible. A further 8 practice sentences were created, four of which were similar to the experimental items (two per experimental condition) and

[13] We thank one of the reviewers for bringing our attention to this point.

four were like the fillers (two conjunctions, two disjunctions). No feedback on the responses was provided during the practice session and there was no training of any kind; the aim of the practice session was to familiarise participants to the kind of task and materials they would face in the experimental session. 48 graphics depicting two figures side by side were created with Microsoft PowerPoint, each figure presented in one colour only. The figures in the graphics always matched the figures mentioned in the sentences, though there was some variability as to whether the colours always matched, as explained below. The order of presentation of colours and figures in both the graphics and the sentences was randomised and counterbalanced to ensure that participants attended and interpreted the whole sentence.[14]

Procedure. The design of the experiment was a within-participants, within-items factorial with two experimental conditions, and therefore two experimental lists were created. As participants were exposed to every experimental condition, they acted as their own controls (in a within-participant design, each participant serves as their own baseline, as what is effectively compared is their performance to two different experimental conditions). Each version was arranged according to a Latin square (blocking) design so that the items were randomised within and between blocks. Participants were randomly assigned to one of the two lists. The experiment was designed and run with the Experimental Builder software (SR Research Ltd.) and administered in a sound-proof laboratory with low to normal illumination in which a maximum of four subjects at a time would be tested. Participants were sat in front of a computer screen and were told to hold a computer mouse with their dominant hand. Each trial started with a fixation point, which was replaced by a graphic showing two coloured geometrical figures side by side. After 500 ms. a sentence was presented over headphones binaurally, and when it finished the graphic on the screen would be replaced with the question 'does the sentence match the graphic you have just seen?'. Participants were instructed to use the mouse to answer either 'yes' or 'no' by clicking on the respective boxes on the screen, presented just below the question. A simplified version of the experimental procedure appears in Fig. 1. Participants were told to be quick, but to avoid rushing and/or answering randomly. Once participants clicked on the chosen box, the question would be replaced by an instruction stating that the next trial would be presented upon pressing the space bar, giving subjects control over the rate at which the items were presented. The experimental session consisted of a total of 40 items and the Experiment Builder software was used to measure and record the yes/no responses as well as the response times. Response times were measured from the moment the question appeared on the screen. The session lasted around 15 minutes. Participants were expected to choose a 'yes' response predominantly in the conjunction condition and in many cases, at least above chance level, in the disjunction condition. This would be the case if the conjunctive reading of disjunction was accepted for the most part, which of course was not a given. In any case, we designed the filler items so that the expected response from participants was a 'no', though this was also based on the assumption that the sentences would be appropriately understood, which was also not assured. We did this in order to introduce some variability in the responses

[14] Details of the materials as well as the raw data of this and the next experiment can be found at: https://osf.io/ygn5s.

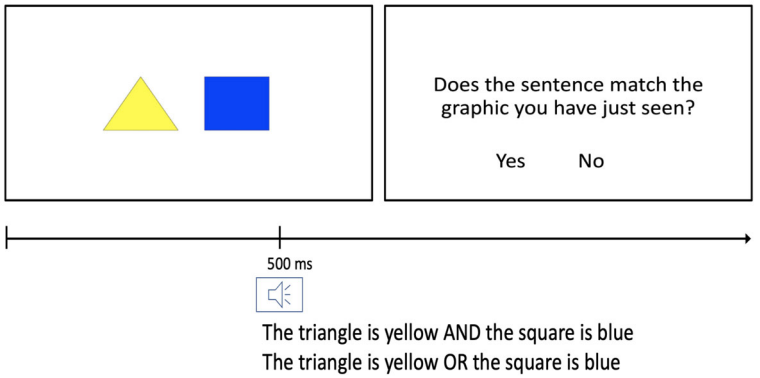

Fig. 1 Procedure of Experiment 1 (the text has been translated from Spanish)

Table 2 Experiment 1

Condition	Data	
	Yes/no (% of 'no-responses')	RTs
And	0.75 (3.3)	703.6 (248.5)
Or	10 (18.7)	990.3 (431.1)

Responses and response times per condition (percentage of 'no' answers and mean RTs, with standard deviations in parentheses)

that were required, even though responses to the disjunction condition could very well have been mostly 'no', suggesting a preference for an exclusive interpretation from participants. This meant that in the case of the fillers the colours mentioned in the sentences did not match the colours that appeared in the graphics, as alluded to earlier.

3.1.2 Results

The responses and response times of the 20 subjects were collected with the Experiment Builder programme. The data were organised according to experimental condition. The analysis of the yes/no responses and response times was carried out with the SPSS package (IBM, US). Table 2 collates responses and response times per condition. The yes/no responses are presented as percentage of 'no' answers, indicating an error of interpretation in the case of the conjunction condition and an exclusive interpretation in the case of the disjunction condition.

As can be observed in Table 2, participants recorded very few 'no' answers. Responses to both conditions were certainly above chance and thus were not random (chance is typically settled at around the 50% mark). This was certainly expected for the *and* condition, where the percentage of such responses is negligible (less than 1%) and performance thus near perfect. It was also the case in the *or* condition, as participants chose a 'no' answer, thus preferring an exclusive interpretation, only ten percent

of the time, a much lower score than we had expected. Thus, participants accepted the conjunctive reading of disjunction in a positive context, even when contrasted to conjunction, and in a great proportion, though unsurprisingly less often than in the case of conjunction. Regarding response times, participants were faster in answering in the *and* condition than in the *or* condition. Pair comparisons per participants and per items, which were carried out to test for statistical differences between the means of the two conditions, showed that these differences were all significant in this experiment: between the percentages of 'no' answers to each condition ($t_1(19) = -2.3$, $p < .05$; $t_2(19) = -14.0$, $p < .001$), and between the RTs to each condition ($t_1(19) = -3.3$, $p < .01$; $t_2(19) = -4.5$, $p < .001$).

Additionally, an analysis of the responses to the fillers shows that participants recorded very few 'yes' answers (the expected response was a 'no'), as the percentage of errors was only 1.5%, while the average response time to these sentences was 917.02 ms. As argued in the Discussion section below, this information provides complementary confirmation for our hypotheses.

3.2 Experiment 2

Experiment 2 exploited the same two factors as Experiment 1, and here too we focused on the fact that negated conjunctions and disjunctions share one true value in logic as well as in potentially many languages—in this case a conjunctive, neither/nor reading—though in this case there was not quite the same kind of contrast to draw between the two conditions, for negated conjunctions and disjunctions in language do not form a scale in quite the same way that conjunction and disjunction do, considering that it is not clear that the potential three true values of negated conjunctions (the superset) are in fact accessible in language, let alone easily. In this case, a Gricean account of how the relevant interpretations are computed is not applicable, though the claim that the neither/nor reading in Spanish is more accessible for negated conjunctions than it is for negated disjunctions is obviously relevant. Naturally, the usual caveat of whether participants would compute this interpretation for each sentence type applies in this experiment too; as in Experiment 1, the compound sentences could in fact give rise to various interpretations. Unlike Experiment 1, though, we employed reduced clausal sentences instead of full sentences, as the full versions of negated compound sentences are rather awkward in language and this would introduce further complications (see fn. 7, *supra*, as well as the methodology section below for examples of the materials). This meant employing slightly different graphics too, which now represented a single geometrical figure presented in two colours (e.g., a graphic representing a green and yellow triangle would be paired to a sentence such as *the triangle is not red and/or blue*).

This experiment, in addition, was also meant to probe the question of whether the neither/nor reading is available in Spanish for negated conjunctions and, especially, for negated disjunctions, contrary to what the literature suggests. As discussed earlier, negated conjunctions and disjunctions seem to behave like the relevant De Morgan laws from logic in English, whilst Romance languages are argued to not quite follow this pattern as they are said to reverse the scope relations between local negation and

the connectives—connectives in Romance languages are positive polarity items and therefore take scope over negation. If so, in Spanish a negated conjunction would not license a disjunction of negated clauses and the neither/nor reading would be the only possible reading, while negated disjunctive sentences would not be understood as a conjunction of two negated clauses, but instead would *only* elicit a reading in which one single clause could be true. We have already argued that this take on things is not well supported and that there are various reasons to believe that the "English" interpretations are also available in (at least some) Romance languages. As stated earlier, we suspect that negated conjunctions are probably ambiguous in both English and Spanish, even if we find the disjunctive reading supposedly available rather difficult to obtain, while in the case of negated disjunctions we have our doubts that these sentences are actually ambiguous, in either English and Spanish, and our assumption will be that the neither/nor reading is the default interpretation in both languages (if not actually the only one, in fact).

Experiment 2 was designed with the aim of evaluating this very assumption, and though we hypothesised that the conjunctive reading would be available to our participants for both types of sentences, it is unclear that either sentence would be favoured over the other as an expression of the neither/nor reading—and certainly not in the way that conjunction and disjunction could be so confronted in positive contexts. Thus, we expected that participants would register 'yes' answers for both conditions for the most part, and certainly above chance. Similarly to Experiment 1, though, the typology of 'no' answers would indicate rather different preferences in each case; a preference for an interpretation other than the conjunctive in the case of negated conjunctions, and a preference for a disjunctive reading in the case of negated disjunctions, thus offering some support to the cross-linguistic perspective.

In addition to the cross-linguistic angle, Experiment 2 too exploited the distinction between comprehending/interpreting compound sentences and reasoning with them, but this time under negation. In this case our overall approach allowed us to offer a different take on the import of the "obvious hypothesis" that negated conjunctions may be more difficult to understand than negated disjunctions. The import of such a hypothesis is not as broad as it appears to be. In fact, from the perspective of language comprehension rather than from the view of reasoning or problem-solving, we predicted that it was unlikely that there would be many differences in performance between the two conditions, as our set-up doesn't call on participants to consider what follows from the sentences that are presented to them. If our predictions regarding what the default readings are prove to be correct, then the percentage of responses might turn out to be rather similar between the two conditions, and so might be the response times to the comprehension question. As stressed, in our opinion the neither/nor reading is the default reading for both negated conjunctions and disjunctions in Spanish and this would be the first interpretation the language comprehension system computes —plausibly the only one, given that it is the interpretation that the graphics immediately support, thereby blocking (or at the very least, not triggering) any of the other interpretations that negated conjunctions and disjunctions potentially allow. The literature on how ambiguous sentences are comprehended is a good illustration of the general situation we envisioned: the end-product when processing ambiguity is always a single interpretation, irrespectively of the disambiguating that is carried out,

word-by-word, during the comprehension of any given sentence [see, for instance, van Gompel and Pickering (2007)]. We expected that a similar situation would apply here.

These predictions follow, in part, from the use of the two factors that have animated most of our investigation: the use of an unbiased context and experimental materials that are apt for the task at hand. In such conditions, the language comprehension system would return an interpretation right away for each type of sentence, and similarly so. In the setting we constructed, moreover, the relevant sentences are not presented as premises, nor are inferential roles or any other construct central to reasoning processes obviously triggered—these other contingencies are not relevant or operative here. Thus, the question of whether participants compute the full truth tables of each compound sentence (recall, three true values in one case, one in the other, if the Spanish sentences behave like the counterparts from logic), and whether this has an effect on the time and effort needed to do so, should also be moot in Experiment 2.

3.2.1 Method

Participants. The same as in Experiment 1, as noted above.

Materials. 20 monoclausal, negative Spanish sentences were constructed for this experiment. Each sentence mentioned a geometrical figure, two colours, and comprised a connective. 10 sentences were negated conjunctions and 10 were negated disjunctions, the two conditions of this experiment, as shown below.

Not And condition: El círculo no es azul y amarillo (the circle is not blue and yellow)
Not Or condition: El círculo no es azul o amarillo (the circle is not blue or yellow)

20 graphics to accompany the experimental sentences were created depicting one single geometrical figure, always presented in two different colours. The order of the colours in both the sentences and the graphics was randomised and counterbalanced so that participants had to attend to the whole sentence before computing the entire interpretation. The colours of the graphics never matched the colours mentioned in the sentences in order to target a neither/nor reading. Thus, participants were expected to choose 'yes' as the most common response, with the usual caveat that this required having access to the conjunctive reading of both kinds of compound sentences, especially in the case of negated disjunctions in a Romance language such as Spanish. The filler items were similar to the experimental items from Experiment 1, except that in this case the expected answer was for the most part 'no' (if these, also, were interpreted correctly, of course). Filler items were biclausal, declarative sentences (10 conjunctions, 10 disjunctions) and the graphics depicted two figures side by side, each figure presented in a single colour, and which did not match the colours mentioned in the sentences. All other details are as in Experiment 1, and here too participants acted as their own controls.

Procedure. The same as in Experiment 1, with the single change that in the case of the experimental items the graphics shown to participants depicted a single figure instead of two, and each figure was presented in two different colours instead of in just one, as shown in the simplified representation of the procedure in Fig. 2.

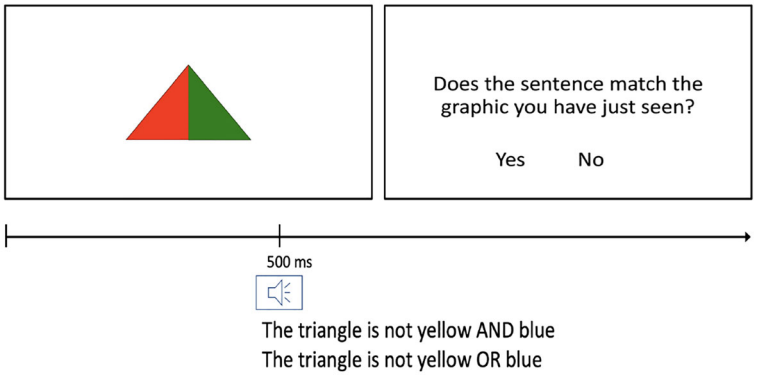

Fig. 2 Procedure of Experiment 2 (the text has been translated from Spanish)

Table 3 Experiment 2

Condition	Data	
	Yes/no (% of 'no-responses')	RTs
Not And	3.5 (7.2)	1469.4 (669.0)
Not Or	4 (5.9)	1489.2 (710.9)

Responses and response times per condition (percentage of 'no' answers and mean RTs, with standard deviations in parentheses)

3.2.2 Results

The responses and response times were treated and analysed exactly as in Experiment 1, as shown in Table 3. Participants registered very few 'no' answers, and the percentages of responses in each condition were similar this time. Responses were above chance in this case too. Participants did not seem to have any problems entertaining the specific reading we had targeted—the neither/nor interpretation—of, indeed, understanding negations of conjunctions/disjunctions in general. Regarding response times, participants were equally fast in both conditions, as the RTs to each condition were also similar. Pair comparisons per participants and per items showed that the slight differences between the two conditions were not significant, in terms of either the percentages of responses ($t_1(19) = -.49$, n.s.; $t_2(19) = -.49$, n.s.) or RTs ($t_1(19) = -.18$, n.s.; $t_2(19) = -.11$, n.s.).

As for the filler sentences, there were very few 'yes' answers (the expected response was 'no'), which amounted to 2% in terms of percentage of errors, and the average response time was 1140.21 ms (we will come back to this below).

3.3 Discussion

All the predictions turned out to be correct, and this is certainly significant, as there were good linguistic and non-linguistic reasons for such hypotheses to not have been supported. In Experiment 1, we did not use any of the linguistic contexts in which disjunction typically yields a conjunctive (TT) reading and participants were shown the same scenes with both conjunctions and disjunctions, which might have given rise to a Gricean inference that disjunction needed to be interpreted exclusively in such circumstances. And yet participants accepted the conjunctive reading of disjunction in a positive context other than in downward entailing contexts and some of the others we have chronicled here. This is especially noteworthy for two reasons. First, the result is not common; as discussed earlier, to our knowledge there are two studies that report a similar outcome (Paris, 1973; Chevallier et al., 2008), and neither is unequivocal or especially persuading. Secondly, the fact that these participants accepted the conjunctive reading of disjunction when contrasted to conjunctive sentences is pretty strong evidence in favour of the claim that language's *or* is definitely inclusive—that the conjunctive reading of disjunction is readily available.

Crucially, we can be sure that participants processed conjunction and disjunction appropriately and that they didn't ignore the connectives and simply focused on whether the figures and colours on display matched those mentioned in the sentences, the sort of non-linguistic strategy mentioned in fn. 11, *supra*. The most important datum in this respect is the response percentages. Performance on the *and* condition was near perfect, as expected, while the percentage of 'yes' responses on the *or* condition, though high, would plausibly have been higher still had a non-linguistic, feature-matching method been employed. As a matter of fact, a *perceptual* procedure that merely tracked the match-up of figures and colours would have been fairly straightforward to implement in this experiment, though this was theoretically unlikely to begin with. As Fodor (1983) argued long ago, and has been stressed again recently (Ferreira and Nye, 2018), language comprehension is a compulsory kind of mental process—given a linguistic input, the language processing system cannot but be activated—and this is surely magnified in the peculiar setting of a laboratory, where participants are sat in front of a computer screen and are presented with sentences aurally over a set of headphones. In such circumstances, it is hard to see how participants could subdue an unconscious mental process such as linguistic processing in favour of a more explicit, perceptual course of action.[15]

In any case, and as Mandelbaum (2018) discusses in the case of an experiment in which participants had to match one visual feature (viz., shape) between two stimuli, such perceptual processes are nearly error-free and response times to questions similar in kind to the one we asked in our experiment can be incredibly fast—and certainly

[15] A laboratory setting is also a rarefied sort of environment and experimental tasks such as ours don't make for entirely felicitous contexts from a pragmatic point of view, but this is neither here nor there, as we were interested in the literal meaning participants would assign to compound sentences (their semantics), as we have stressed.

faster than what is typically the case in a language comprehension task.[16] If our experiment had been treated as if it were (mostly) a perceptual task, the result would have been much higher response rates (in the case of the *or* condition) and much faster response times in both conditions (and in both experiments), and this is not what we observe. Participants did pay attention to the connectives and indeed processed them fully, and we believe this was in part due to the careful design we implemented; recall, in particular, that the order of colours and figures was counterbalanced in both the sentences and graphics and this would have contributed to participants having to attend to the sentences fully.

Participants' performance on the filler sentences offers complementary support for such a conclusion (this is also the case in Experiment 2). As reported, the percentage of errors to filler sentences was very low (1.5%) and thus closer to what was observed in the *and* condition (0.75%) than what was obtained in the *or* condition (10%). In terms of response times, however, performance on the *or* condition and on the fillers was rather similar (990 ms for the former, 917 for the latter), whereas in the *and* condition participants were much faster (700 ms). This is not entirely surprising given the characteristics of filler sentences, which were similar in kind to the experimental sentences of the *or* condition; filler sentences were disjunctive compound sentences with a negation on each clause (e.g., *the diamond is not red or the circle is not yellow*), thus also potentially specifying three state of affairs (namely, the three true values of inclusive disjunction). As noted earlier, response times constituted an offline and complementary measure, but it is still a relevant datum and indeed the results on the experimental and filler sentences, when put together, support the inference that participants did attend to the sentences appropriately. Had this not been the case, we would have observed a different pattern of results, both in terms of percentage of errors and response times; namely, both measures would have exhibited a much narrower range in each case—there would have been, that is, a much more uniform performance across all treatments, the experimental and the filler alike—and this is not what transpired. Nor, therefore, should there be any worry that participants might have habituated to the expected responses we had identified ('yes' for experimental sentences, 'no' for filler sentences), as these expectations simply reflected what we had hypothesised would be the default readings and participants certainly hadn't received any feedback or training on the matter; moreover, in the case of both the *or* condition and the fillers, the expected response was not the only possible, or correct, interpretation.[17]

More importantly still, and to come back to the main hypotheses of Experiment 1, participants' performance differed in the *and* and *or* conditions, both in terms of percentage of responses and in response times, and even though these differences were not of a great magnitude, they proved to be statistically significant. In this sense, and despite the fact that both kinds of compound sentences received the same interpretation, participants exhibited a slight preference for the *and* condition (this is especially significant given the way prosody was controlled for). Indeed, performance was better in the *and* condition than in the *or* condition, as both the percentage of 'no' responses

[16] The results reported in Lobina et al. (2018) is a case in point, as this study offers clear experimental evidence on the differences in performance between perceptual and language comprehension processes, as well as some relevant comments on the Fodorian claim regarding the obligatoriness of language processing.

[17] We thank the reviewers for pressing us to clarify this issue.

and the response times were lower in the *and* condition. Finally, the fact that in this experiment the conjunctive reading of disjunction was preferred over the exclusive, TF-FT readings strongly suggests not only that the exclusivity implicature did not arise, but also, that reasoning processes were not operative either, given that a heuristic such as "disjunction elimination" did not materialise. All in all, the interpretations we were interested in were properly tracked.

In Experiment 2, for its part, there were two outstanding questions: whether a Romance language such as Spanish would allow the readings languages such as English yield on negations of conjunctions and disjunctions, and whether participants' performance would be different in each condition, perhaps suggesting that they entertained multiple interpretations of these sentences as they processed them, which in turn might have been a sign that a potential reasoning process had taken place, in contrast to a situation in which participants compute a single interpretation, the expectation from a language comprehension perspective. Regarding the latter question first, and as we explained earlier, we designed the experiments so that there wasn't any suggestion that the sentences functioned as some sort of premises which participants had to evaluate and draw conclusions from (i.e., reason with). Instead, we expected that participants would reach one interpretation, and fairly quickly; the opposite could certainly have resulted in participants thinking through what the sentences meant and entailed, potentially spending more time with one of the conditions than with the other, but this was not observed. As for the issue of whether Spanish would license the same readings as English, and just as we did in Experiment 1, we targeted the one reading that negated conjunctions and disjunctions share—the conjunctive, neither/nor reading—by providing a graphic that represented this very interpretation. Given that both conditions were contrasted against the same context and the conjunctive reading was only available, supposedly for Spanish, in the case of the negation of a conjunction, the set-up of this experiment was conducive to evaluating whether such a reading would be accessed and accepted for negated disjunctions as well.

The data here also suggest that participants paid attention to the connectives and processed them adequately. Percentage of correct responses was high for each condition, but not as high as it would be expected if participants had used the kind of non-linguistic strategy we have discussed (that is, merely inspecting whether the figures and colours in the graphics and the sentences matched, regardless of the connectives). In the case of response times, these too were higher than what a perceptual task would have produced, and it is furthermore significant that these were manifestly higher in this experiment than in Experiment 1, which is not entirely surprising, as negated sentences are more taxing to process than positive sentences [see, for early evidence on this now well-established datum, Wason (1959)]. As for Experiment 1, performance on the filler sentences provides further support for this conclusion. In Experiment 2, filler sentences were similar in kind to the experimental sentences of Experiment 1 (i.e., they were positive sentences such as *the circle is blue and the square is yellow*), and this had an effect on how performance on the fillers compared to the performance on the experimental items, which were all negated compound sentences. In the case of the percentage of errors, this value was marginally lower for filler sentences (2% for filler sentences to no more than 4% for the experimental), but the response times for filler sentences were much lower (1140 ms for the fillers to no less than 1460 for

the experimental), and this suggests a qualitative difference (that is, that the sentences were treated differently).

The proviso regarding the complementary nature of response times still applies, but the contrast between the experimental and filler sentences, and indeed between the two experiments, is nonetheless noteworthy and constitutes further indication that participants did indeed process the sentences appropriately (in the case that concerns now, the negated compound sentences of Experiment 2). All the other methodological considerations we have discussed in the analysis of Experiment 1 are of course also relevant in this case (viz., the expected performance of a perceptual strategy, the mandatoriness of language processing, etc.); we here add a reminder that our participants carried out both experiments in a single session, and given that the order of presentation was counterbalanced, this should have also contributed to neutralising any potential perceptual strategy as well.

According to the results, then, participants interpreted negated conjunctions and disjunctions in Spanish in the way they are understood in English and just as the noted De Morgan laws from formal logic mandate (at least in part, of course; we targeted one single truth value in each case). That is, negated conjunctions were understood conjunctively and negated disjunctions were also interpreted as conjunctions of two negated clauses. Indeed, the percentage of 'no' answers, indicative of an interpretation other than the conjunctive, was rather low in either condition (no more than 4%), and this suggests that the targeted interpretations were properly tracked in Experiment 2 as well. Such data run counter to various positions from the literature. Firstly there is that part of the literature which claims that a negated disjunction in Romance languages is not interpreted conjunctively but as an exclusive disjunction (i.e., one or the other, but not both). In this respect, our results indicate that the logical connectives of Spanish, and of possibly other Romance language, especially Italian, are not, in fact, PPIs; in addition, the results may also show that the default reading of a negated disjunction in Spanish is the conjunctive neither/nor interpretation, but we do not wish to press this claim injudiciously. The data also run counter, at least in part, to claims in the reasoning/problem-solving literature that a negated conjunction ought to be more difficult to understand than a negated disjunction. This did not prove to be the case, given that even though the percentage of responses to negated conjunctions was slightly better than to negated disjunctions and response times were also slightly faster (with the proviso on the latter, *passim*), these differences were not statistically significant and thus participants showed no preference for either sentence type when it comes to accepting a neither/nor reading (though we suspect that a better measure to assess processing difficulty in general can be found). In any case, and finally, there is no evidence that participants found these sentences especially difficult to process or understand, other than what may be the case when negation is involved.

4 Conclusion and forthcoming issues

The aim of this study was to unearth the default meanings of the coordinators *and* and *or* qua logical connectives in a Romance language by analysing their interpretation in both positive and negative linguistic contexts. The readings we obtained closely

matched those of the equivalent truth operators from formal logic, and we would argue this was the result of the methodological framework we employed. Our results owe much to our methodology and experimental materials. The employment of geometrical figures and colours, along with the task the participants faced, appears to have resulted in a suitably neutral context that avoided some of the pragmatic effects associated with the connectives as well as the possible non-linguistic effects that reasoning with the connectives can give rise to (post-linguistic effects, in effect).

In this sense, we succeeded in targeting various separate, and indeed separable, components of the mind: semantic and pragmatic knowledge, on the one hand, and the language comprehension system and whatever mental systems are in charge of reasoning, on the other—or at least as much as it is possible to do. Regarding the linguistic factors, we do not claim that this methodology can target semantic knowledge directly, though we are confident that the task and design were insulated from at least some of the most central pragmatic factors, in this case the exclusivity implicature of disjunction. Indeed, these experiments did not aim to evaluate whether, and how, participants can entertain the full truth tables of the compound sentences they were exposed to (the four truth values); we instead focused on the accessibility of what we had hypothesised would be the default meanings of the sentences we manipulated given a specific context—namely, the one true value given a particular visual representation. We also did not aim to establish what the scope relations between negation and the connectives *and* and *or* actually are in Spanish (or in English), which we regard as an open question, as alluded to in fn. 9, *supra* (though we certainly have been critical of Pagliarini and colleagues on this point). Instead, we claimed that in language the default meaning of negated conjunctions and disjunctions was the conjunctive, neither/nor reading, and that such a reading was available in both Spanish and English, contrary to some claims in the literature.

Likewise regarding language comprehension and reasoning; it may be hard to draw a line between these two phenomena sometimes, but a picture-matching task with no leading questions or suggestions that the task is a puzzle of some kind (and where participants would be prompted to think through their answers), may be as close to doing this as it is, again, possible to do. Put together, we wager that such a framework is rather apt to unearthing the default meanings of many types of sentences employing logical connectives, and this includes working out which linguistic coordinators actually behave logically, and in which languages. Possible cross-linguistic variability certainly needs to be better evaluated, and we have shown how this issue could be approached in the case of the scope of local negation vis-à-vis conjunction and disjunction. As we have seen, we did not find many dissimilarities between English and Spanish interpretations of compound sentences, but the situation may be different in other, non-European languages [Mauri (2008), offers some relevant information in this respect].

Another outstanding question our approach may be fruitfully applied to (*has* been applied to) has to do with the number of logical connectives that have been lexicalised in the world's languages. According to formal logic, there are sixteen possible binary connectives, but the consensus in linguistics and philosophy is that only two or three linguistic coordinators behave like logical operators, and not all of these are present in all of the world's languages. A significant amount of work has been devoted to working

out why natural languages exhibit a small number of connectives (mostly conjunction and disjunction; negation is not a binary connective, but a unary operator), some of the proposals on offer pragmatic in nature (Horn, 2012), others not at all (Katzir and Singh, 2013), while others yet incorporate a historical component (Hoeksema, 1999). From a psycholinguistic viewpoint, an interesting question is whether any of the unlexicalised connectives can be acquired or learned in an especially-designed experiment. After all, some of the unlexicalised connectives, "alternative denial" most prominently—or Sheffer stroke (*nand*), which stands for the negation of the conjunction operator and thus yields a "not both…and…" reading—seem easily entertainable in the mind, perhaps in some logic-like, conceptual system [a *language of thought* in the sense of Fodor (1975)].

This points to another theoretical split, this time between the lexicalisation of conceptual connectives and the learnability of invented words corresponding to concepts of unlexicalised logical connectives [see, as an example of this split, but with unlexicalised determiners as a case study, Hunter et al. (2011)]. Though there might be reasonable grounds for why most connectives go unlexicalised, there is no apparent reason for why (m)any of the unlexicalised connectives could not be learned in an experiment. The latter question broaches the issue of how language and thought relate, as it suggests the existence of connectives that are conceptual in nature rather than linguistic. We have undertaken some work on these issues with the very framework we have outlined and applied here, this time in combination with the *visual world* paradigm, and shall give an account of it anon.

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References

Anderson, M. (1992). *Intelligence and development*. Oxford: Blackwell Publishers.

Block, N. (1986). Advertisement for a semantics for psychology. *Midwest Studies in Philosophy, 10*, 615–78.

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

Braine, M. D. S., & O'Brien, D. P. (Eds.). (1998). *Mental logic*. Mahwah, NJ: Lawrence Erlbaum.

Braine, M. D. S., & Rumain, B. (1981). Development of comprehension of "or": Evidence for a sequence of competencies. *Journal of Experimental Child Psychology, 31*, 46–70.

Breheny, R. (2019). Scalar implicatures. In C. Cummins & N. Katsos (Eds.), *The Oxford handbook of experimental semantics and pragmatics* (pp. 39–61). Oxford: Oxford University Press.

Cesana-Arlotti, N., Martín, A., Téglás, E., Vorobyova, L., Cetnarski, R., & Bonatti, L. L. (2018). Precursors of logical reasoning in preverbal human infants. *Science, 359*, 1263–1266.

Chevallier, C., Noveck, I. A., Nazir, T., Bott, L., Lanzetti, V., & Sperber, D. (2008). Making disjunctions exclusive. *The Quarterly Journal of Experimental Psychology, 61*(11), 1741–1760.

Chierchia, G. (2004). Scalar implicatures, polarity phenomena, and the syntax/pragmatics. In A. Belletti (Ed.), *Structures and beyond* (pp. 39–103). Oxford: Oxford University Press.
Chierchia, G. (2006). Broaden your view: Implicatures of domain widening and the "Logicality" of language. *Linguistic Inquiry, 37*(4), 535–590.
Chierchia, G. (2013). *Logic in grammar*. Oxford: Oxford University Press.
Chierchia, G., Crain, S., Guasti, M. T., Gualmini, A., & Meroni, L. (2001). The acquisition of disjunction: Evidence for a grammatical view of scalar implicatures. In A. H. J. Do, L. Domínguez, & A. Johansen (Eds.), *Proceedings of the 25th Annual Boston University Conference on Language Development* (pp. 157–168). Sommerville, MA: Cascadilla Press.
Chierchia, G., Guasti, M. T., Gualmini, A., Meroni, L., Crain, S., & Foppolo, F. (2004). Semantic and pragmatic competence in children's and adults' comprehension of "or". In I. A. Noveck & D. Sperber (Eds.), *Experimental pragmatics* (pp. 283–300). New York: Palgrave Macmillan.
Cohen, L. J. (1971). Some remarks on Grice's views about the logical particles of natural language. In Y. Bar-Hillel (Ed.), *Pragmatics of natural language* (pp. 50–68). Dordrecht: Reidel.
Collins, J. (2011). *The unity of linguistic meaning*. Oxford: Oxford University Press.
Crain, S. (2012). *The emergence of meaning*. Cambridge: Cambridge University Press.
Crain, S., Gualmini, A., & Meroni, L. (2000). The acquisition of logical words. *Logos and Language, 1*(1), 49–60.
Ferreira, F., & Nye, J. (2018). The modularity of sentence processing reconsidered. In R. G. De Almeida & L. R. Gleitman (Eds.), *On concepts, modules, and language* (pp. 63–86). Oxford: Oxford University Press.
Fodor, J. A. (1975). *The language of thought*. Cambridge, MA: Harvard University Press.
Fodor, J. A. (1983). *The modularity of mind*. Cambridge, MA: Bradford Books/The MIT Press.
Foppolo, F., Guasti, M. T., & Chierchia, G. (2012). Scalar implicatures in child language: Give children a chance. *Language Learning and Development, 8*, 365–394.
Frege, G. (1963). Compound thoughts. *Mind, 72*(285), 1–17. Originally published in 1923.
Gazdar, G. (1979). *Pragmatics: Implicature, presupposition, and logical form*. New York: Academic Press.
Gazdar, G. & Pullum, G. (1976). Truth-functional connectives in natural language. In S. Mufwene, C. A. Walker, & S. B. Steever (Eds.), *Papers from the Twelfth Regional Meeting of the Chicago Linguistic Society* (pp. 220–234). Chicago, IL: Chicago Linguistic Society.
Grice, P. H. (1989). *Studies in the way of words*. Cambridge, MA: Harvard University Press.
Gualmini, A., Crain, S., Meroni, L., Chierchia, G., & Guasti, M. T. (2001). At the semantics/pragmatics interface in child language. In R. Hastings, B. Jackson, & Z. Zvolenszky (Eds.), *Proceedings of SALT XI* (pp. 231–47). Ithaca, NY: Cornell University.
Haiman, J., & Thompson, S. A. (Eds.). (1988). *Clause combining in grammar and discourse*. Amsterdam: John Benjamins Publishing Company.
Haspelmath, M. (2004). Coordinating constructions. In M. Haspelmath (Ed.), *Coordinating constructions* (pp. 3–39). Amsterdam: John Benjamins Publishing Company.
Hoeksema, J. (1999). Blocking effects and polarity sensitivity. In J. Gerbrandy, M. Marx, M. de Rijke, & Y. Venema (Eds.), *JFAK: Essays dedicated to Johan van Benthem on the occasion of his 50th birthday* (pp. 1–13). Amsterdam: Amsterdam University.
Hoeksema, J. (2000). Negative polarity items: Triggering, scope, and c-command. In L. Horn & Y. Kato (Eds.), *Negation and polarity* (pp. 115–146). Oxford: Oxford University Press.
Horn, L. R. (2012). Historie d'*O: Lexical pragmatics and the geometry of opposition. In J. Y. Beziau & G. Payette (Eds.), *The square of opposition: A general framework for cognition* (pp. 394–426). Bern: Peter Lang AC.
Hunter, T., Lidz, J., Wellwood, A. & Conroy, A. (2011). Restrictions on the meaning of determiners: Typological generalisations and learnability. In E. Cormany, S. Ito, & D. Lutz (Eds.), *Proceedings of SALT, XIX* (pp. 223–238). Ithaca, NY: Cornell University.
Johnson-Laird, P. N. (2010). Against logical form. *Psychologica Belgica, 50*(3–4), 193–221.
Johnson-Laird, P. N., & Yang, Y. (2008). Mental logic, mental models, and simulations of human deductive reasoning. In R. Sun (Ed.), *The Cambridge handbook of computational psychology* (pp. 339–58). Cambridge: Cambridge University Press.
Katzir, R., & Singh, R. (2013). Constraints on the lexicalization of logical operators. *Linguistics and Philosophy, 36*, 1–29.

Khemlani, S., Orenes, I. & Johnson-Laird, P. N. (2012a). Negating compound sentences. In N. Miyake, D. Peebles, & R. Cooper (Eds.), *Proceedings of the 34th Annual Meeting of the Cognitive Science Society* (pp. 575–580). Austin, TX: Cognitive Science Society.

Khemlani, S., Orenes, I., & Johnson-Laird, P. N. (2012b). Negation: A theory of its meaning, representation, and use. *Journal of Cognitive Psychology, 24*(5), 541–59.

Klinedinst, N., & Rothschild, D. (2012). Connectives without truth tables. *Natural Language Semantics, 20*, 137–175.

Kratzer, A. (1986). Conditionals. In A. M. Farley, P. Farley, & K. E. McCollough (Eds.), *Papers from the Parasession on Pragmatics and Grammatical Theory* (pp. 115–135). Chicago, IL: Chicago Linguistic Society.

Lobina, D. J., Demestre, J., & García-Albea, J. E. (2018). Disentangling perceptual and psycholinguistic factors in syntactic processing: Tone monitoring via ERPs. *Behavior Research Methods, 50*, 1125–1140.

Mandelbaum, E. (2018). Seeing and conceptualizing: Modularity and the shallow contents of perception. *Philosophy and Phenomenological Research, 97*(2), 267–283.

Mascarenhas, S. & Koralus, P. (2015). Illusory inferences: Disjunctions, indefinites, and the erotetic theory of reasoning. In D. C. Noelle, et al. (Eds.), *Proceedings of the 37th Annual Meeting of the cognitive Science Society* (pp. 1541–1546). Austin, TX: Cognitive Science Society.

Mauri, C. (2008). *Coordination relations in the languages of Europe and beyond*. Berlin: Mouton de Gruyer.

Morris, B. J. (2008). Logically speaking: Evidence for item-based acquisition of the connectives and & or. *Journal of Cognition and Development, 9*, 67–88.

Nicolae, A. C. (2017). Deriving the positive polarity behavior of plain disjunction. *Semantics and Pragmatics, 10*, 1–21.

Oaksford, M., & Chater, N. (2007). *Bayesian rationality: The probabilistic approach to human reasoning*. Oxford: Oxford University Press.

O'Brien, D. P., & Bonatti, L. L. (1999). The semantics of logical connectives and mental logic. *Cahiers de Psychologie Cognitive/Current Psychology of Cognition, 18*(1), 87–97.

Pagliarini, E., Crain, S., & Guasti, M. T. (2018). The compositionality of logical connectives in child Italian. *Journal of Psycholinguistic Research, 47*, 1243–1277.

Pagliarini, E., Reyes, M. A., Guasti, M. T., Crain, S., & Gavarró, A. (2021). Negative sentences with disjunction in child language. *Language Acquisition, 28*, 153–165.

Paris, S. G. (1973). Comprehension of language connectives and propositional logical relationships. *Journal of Experimental Child Psychology, 16*, 278–291.

Posner, R. (1980). Semantics and pragmatics of sentence connectives in natural language. In J. Searle, F. Kiefer, & M. Bierwisch (Eds.), *Speech act theory and pragmatics* (pp. 169–203). Dordrecht: Reidel.

Progovac, L. (2000). Coordination, c-command, and 'logophoric' n-words. In L. Horn & Y. Kato (Eds.), *Negation and polarity* (pp. 88–114). Oxford: Oxford University Press.

Quine, W. V. O. (1941). *Elementary logic*. Cambridge, MA: Harvard University Press.

Rips, L. (1994). *The psychology of proof*. Cambridge, MA: The MIT Press.

Sauerland, U., Tamura, A., Koizumi, M., & Tomlinson, J. M., Jr. (2015). Tracking down disjunction. In M. Otake, S. Kurahashi, Y. Ota, K. Satoh, & D. Bekki (Eds.), *New frontiers in artificial intelligence; JSAI-isAI 2015* (pp. 109–121). Cham: Springer.

Seuren, P. A. M. (2006). The natural logic of language and cognition. *Pragmatics, 16*(1), 103–138.

Singh, R., Wexler, K., Astle-Rahim, A., Kamawar, D., & Fox, D. (2016). Children interpret disjunction as conjunction: Consequences for the theory of scalar implicature. *Natural Language Semantics, 24*(4), 305–352.

Strawson, P. F. (1952). *Introduction to logical theory*. London: Methuen & Co., Ltd.

Szabolcsi, A. (2002). Hungarian disjunctions and positive polarity. *Approaches to Hungarian, 9*, 1–22.

Szabolcsi, A., & Haddican, B. (2004). Conjunction meets negation: A study in cross-linguistic variation. *Journal of Semantics, 21*(3), 219–249.

Tieu, L., Yatsushiro, K., Cremers, A., Romoli, J., Sauerland, U., & Chemla, E. (2017). On the role of alternatives in the acquisition of simple and complex disjunctions in French and Japanese. *Journal of Semantics, 34*(1), 127–152.

Tversky, A., & Kahneman, D. (1974). Judgment under certainty: Heuristics and biases. *Science, 185*(4157), 1124–31.

van Gompel, R. P. G., & Pickering, M. J. (2007). Syntactic parsing. In M. Gareth Gaskell (Ed.), *The Oxford handbook of psycholinguistics* (pp. 289–307). Oxford: Oxford University Press.

von Fintel, K., & Matthewson, L. (2008). Universals in semantics. *The Linguistic Review, 25*, 139–201.
Wason, P. C. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology, 11*(2), 92–107.
Zimmermann, T. E. (2000). Free choice disjunction and epistemic possibility. *Natural Language Semantics, 8*, 255–290.