A rule violation account for the reading of negated general disjunctions
referring to definite narrow-scope sets of objects

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Abstract

In the psychology of propositional reasoning and psycholinguistics, few previous studies have investigated how people read the negation of a general disjunction referring to a definite narrow-scope set of objects (*for a set with limited objects, it is not true that xs are p or q*). We develop some alternative accounts for the negation. The original and revised mental model theory make contradictory predictions for the negation. The probabilistic violation account interprets it as the probabilistic violation of the general disjunction by introducing nonnegligible exceptions. A rule violation account based on the default rule reading of generics in psycholinguistics interprets it as the rule violation of the general disjunction by introducing exceptions. Four experiments investigated the reading of negated general disjunctions referring to definite narrow-scope sets in possibility and truth judgment tasks. Participants' possibility and truth judgments provide convergent evidence that a negated general disjunction is consistent with only sets containing $\neg p \neg q$ cases regardless of whether other cases are present or not. This implies that people tend to understand the general disjunction as the deterministic universal rule, and interpret the negated general disjunction as the qualitative violation of the rule by introducing exceptions. These findings favor the rule violation account over the other accounts. The present overall response pattern is consistent with the default universal rule interpretation of generic sentences referring to definite narrow-scope sets predicted by the relativity principle in psycholinguistics that reading generics as probabilistic or deterministic is relative, depending on background knowledge or contexts. The relative reading of general disjunctions is beyond existing simple deterministic and probabilistic accounts of compound propositions in propositional reasoning.

Keywords: negated general disjunctions; negation; generics; the rule violation account; the relativity principle

1. Introduction

A current dispute in reasoning about disjunctions is how people interpret negated disjunctions, that is, what is the meaning of a negated disjunction? For example, consider negations such as, for a card, (1) *it is not true that the card is round or red*, and for a pack of cards, (2) *it is not true that cards are round or red*. Here, the former is the negation of a singular disjunction referring to a single object, whereas the latter is the negation of a general disjunction referring to a set of objects. A general disjunction is a disjunctive rule constraining a set of objects or instances, and so has generality, which a singular disjunction does not have. Previous studies on negated singular disjunctions found that the negation of a singular disjunction, $p \text{ or } q$, mentally implies that only $\neg p \neg q$ is possible but each of $p \neg q$, $\neg p q$, and $p q$ is impossible (Khemlani, Orenes, & Johnson Laird, 2012, 2014; Macbeth et al., 2013, 2014). This finding was explained in the mental model theory (Khemlani, et. al., 2012, 2014). However, these studies neglected negations of general disjunctions. Yin, et. al. (2020) investigated how participants generated possible cases for a negated general disjunction (e. g, *it not true that a card is round or it is red*). They found that the majority of participants listed $\neg p \neg q$, $p \neg q$ and $\neg p q$ as possible, whereas the minority of participants listed $p q$ as possible. This response pattern differs from that the response pattern of negated singular disjunctions in the previous studies. This suggests that the reading of negated general disjunctions may be more complex than the reading of negated singular disjunctions.

The reading of the negation of a general disjunction involves the reading of the general disjunction and the reading of its negation, and so concerns current main disputes in the psychology of propositional reasoning. Existing main accounts of propositional reasoning imply different predictions for the meanings of negated general disjunctions, and so investigating the reading of negated general disjunctions can distinguish between these accounts. Moreover, general

disjunctions belong to generic language in psycholinguistics (Carlson, & Pelletier, 1995; Karczewski, Wajda, & Poniak, 2020; Lazaridou-Chatzigeorgaki, Stockall, & Katsos, 2019; Leslie & Adam, 2022; Tessler & Goodman, 2019). Thus, how people understand negated general disjunctions reflects the interaction of disjunctions, genericity, and negation, and so is a common concern of the psychology of propositional reasoning and psycholinguistics. Current research aims to investigate the common concern.

In this paper, we use disjunctions in the inclusive sense that the two disjuncts of a disjunctive sentence, p or q , can both be true, because in classic logic the inclusive sense is the general meaning of a typical disjunction in which there is no inferential knowledge connection between the two disjuncts and so both are independent and can be true at the same time. In natural language, p or q may be exclusive or inclusive, depending on background knowledge or context (Evans, & Newstead, 1980; Fillenbaum, 1974; Quelhas & Johnson-Laird, 2017; Khemlani, et., al., 2018; Newstead, et., al., 1984; Noveck, et., al., 2002). For example, the disjunctions such as *babies are male or female*, *balls are metal or plastic*, are obviously exclusive because in each disjunction the two disjuncts are on the same dimension, whereas the disjunctions such as *babies are fat or female*, *balls are white or plastic*, are obviously inclusive because in each disjunction the two disjuncts are on different dimensions. For the latter sentences, a question whether the conjunction of the two disjuncts in a given disjunction is possible or impossible, can determine whether people read the disjunction as inclusive or exclusive. This question was investigated in current four experiments.

There are two ways of investigating the qualitative reading of negated general disjunctions: possibility and truth questions. Possibility questions include two kinds. One is the case possibility question that asks people to indicate whether each of four cases (pq , $p\neg q$, $\neg pq$, and $\neg p\neg q$) is individually possible or impossible given a negated general disjunction. The other is the set

possibility question that asks people to indicate whether a set of objects consisting of one or more of the four cases is possibly or impossibly the unknown set of objects for which a negated general disjunction holds. A truth question asks people to judge whether a negated general disjunction, *not* (p or q), holds or not given a set of objects, which consists of one or more of the four cases. There are 15 possible sets, which are shown in Table 1. For example, in a task, given a pack of cards consisting of some of the four cases (round red cards, round non-red cards, non-round red cards, and non-round non-red cards), people are asked whether the negated disjunction (*it is not true that cards are round or red*) holds or not. See the complete task with all sets in Appendix A. We call the latter two kinds of questions set questions. In set questions, whether a set contains one type of four cases (pq , $p\neg q$, $\neg pq$, and $\neg p\neg q$) determines whether the corresponding case is possible in the set. Thus, the components of the set determine the corresponding possibilities allowed by the set.

The reading of a negated general disjunction referring to a definite set of objects (for example, for a pack of cards, *it is not true that cards are round or red*) is mediated by the interpretation of the general disjunction. There are two interpretation questions. The first question is whether people interpret a general disjunction (cards are round or red) as the universal disjunction (all cards are round or red). In both English and Mandarin, whether the reading of a generic term such as a bare noun without quantifiers (e.g., *cards* and *cats*) is definite (referring to a kind or a unique set of objects) or indefinites (referring to some existential objects) depends on context or background knowledge (Cohen, 2022; Dayal & Saĝ, 2020; Krifka, 2004; Le Bruyn, de Swart, & Zwarts, 2017; Leslie & Adam, 2022; Sterken, 2015, 2017; Tessler & Goodman, 2019). Consider two statements: “Ducks can swim”, and “In the lake ducks are swimming.” In the former, the subject refer to the kind “*ducks*” and so is definite. In the latter, the subject refer to some existential individuals and so is indefinite. Moreover, the definite reading of a generic bare noun may be a probabilistic majority

generalization with exceptions or a deterministic universal rule without exceptions, depending on background knowledge or contexts. Reading generics as probabilistic or deterministic is relative.

We propose this relativity principle as the basis of current research, and illustrate it as follows.

“Ducks can swim” is a majority generalization of the typical property “can swim” of the kind *ducks* although some ducks can not swim (Rooij & Schulz, 2020). “Ducks are birds” is a universal rule that all ducks are birds. The definite reading of a bare noun referring to a unique limited (narrow-scope) set may be universal in some contexts. Consider the statement “In our class students are right-handed.” Here, the generic term (students) is universal in that it refers to all the students in our class. Similarly, in the statement “for a pack of cards, *it is true that cards are round or red*”, *cards* should refer to all the cards in the pack, and so is universal. Moreover, according to two pragmatic maxims in Grice’s pragmatics (1976): the quantity maxim that a speaker should make contribution as informative as is required, and the quality maxim that a speaker try to make contribution one that is true, pragmatically the disjunction expresses all known alternative states of cards in the pack, and so the predicate of the disjunction is predicated of all the cards in the pack. This also implies that the subject of the general disjunction is universal. Generally, a disjunctive sentence that is the combination of a generic term as the subject and the disjunction as the predicate is more likely to imply the universal reading of the generic term than a simple sentence with only one of the two disjuncts in the disjunction. Consider the following two statements:

(3) Soldiers are right-handed.

(4) Soldiers are right-handed or left-handed.

(3) is a majority generalization that describes the majority of soldiers, whereas (4) is a universal rule that pragmatically summarizes all known alternative states of soldiers in question. In (4), the number of soldiers as the subject equals the sum of the number of right-handed soldiers and the

number of left-handed soldiers. The quantificational domain of the two alternatives is restricted to the quantificational domain of the subject. Thus, the general disjunction is a default rule without exceptions that exhausts all known alternative states of soldiers. The rule interpretation of general disjunctions is suggested by the exhaustivity implicature of disjunctions in psycholinguistics (Gotzner, Barner, & Crain, 2020). It is also suggested by the proposal that generics are universal by default (Nickel, 2010) and express a *default rule* (Leslie, 2017; Krifka, 1987; Gelman, 2010). This is a type of inference rule that allows for exceptions (Cohen, 2022). For example, we may assume that *Ravens are black* means by default that any raven is black, but we are ready to retract this conclusion if we learn that there is an albino raven. Thus, people are more likely to read the same generic term *Soldiers* as universal in (4) than in (3). The default rule reading of generics is confirmed by the generic overgeneralization effect found in some previous studies that people tend to overgeneralize from the truth of a generic (e. g., “tigers are striped”) to the truth of the corresponding universal statement (“all tigers are striped”) (Cimpian, et al., 2010; Karczewski, Wajda, & Poniat, 2020; Lazaridou-Chatzigoga, Stockall, & Katsos, 2019; Leslie, Khemlani, & Glucksberg, 2011). Overall, according to the relativity principle that the reading (probabilistic versus deterministic) of generics depends on background knowledge or contexts, we predict that for a general disjunction referring to a definite narrow-scope set with limited objects, people will be more likely to read the generic term as universal, and the general disjunction as a default universal rule. The default universal rule is relative to the definite narrow-scope set of objects referred to by the general disjunction. The relative universalization indicates the Yes answer to the first question.

In the Yes answer to the first question, the second question is whether the universal disjunction means the uniform interpretation that all cards are uniform in that *all cards are round non-red cards* or *all cards are non-round red cards* or *all cards are round red cards*. The NO answer implies the

non-uniform interpretation that all cards may not be uniform and so *some cards are round non-red cards or some cards are non-round red cards or some cards are round red cards*. We predict that people will interpret the universal disjunction as the non-uniform interpretation by default due to that the non-uniform interpretation is highly probable and so is more accessible according to the probability heuristic proposed by Chater & Oaksford (1999). In the uniform interpretation (UI) of the general disjunction, the negation of *all cards are round or red* logically implies that all cards are non-round non-red, and so means that only non-round non-red cards are possible and so must be present. In the non-uniform interpretation, the negation implies that *not all cards are round or red*, which further implies that the pack of cards must contain some non-round non-red cards regardless of whether there are other types of cards. Experiment 1 investigated the two interpretation questions.

1.1. *Theoretical accounts and predictions for negated general disjunctions*

There are three potential accounts for the reading of negated general disjunctions: classical predicate logic, the original and revised mental model theory (Khemlani, Orenes, & Johnson Laird, 2012; Khemlani, Byrne, & Johnson-Laird, 2018), the probabilistic approach (Cruz, Baratgin, Oaksford, & Over, 2015; Cruz, Over, & Oaksford, 2017; Elqayam & Over, 2013; Evans & Over, 2004; Oaksford & Chater, 2009; Politzer & Baratgin, 2016). These existing accounts do not explicitly specify the reading of negated general disjunctions. According to the essential ideas of these accounts, we develop their specifications and predictions of the reading of negated general disjunctions. Although in mental logic (Braine & O'Brien, 1998) there is a mental predicate logic that addresses reasoning about quantifiers in sentences, the mental-predicate logic does not address negated general disjunctions.

In classical propositional logic (DeMorgan, 1847; Suppes & Hill, 1992) and Rips' (1994)

Psychology of Proof (PSYCOP), DeMorgan's law 2 states that *not (p or q)* is equivalent to *(not p) and (not q)*. Thus, *not (p or q)* holds if and only if *not p and not q* hold, that is, *p* and *q* are both false. DeMorgan's law 2 is applicable to negated singular disjunctions without quantifiers, but not negated general disjunctions with quantifiers. For example, for a card, *it is not true that the card is red or round* is equivalent to *the card is non-red and non-round*.

In the uniform interpretation (UI) of general disjunctions, *it is not true that cards are red or round* means *it is not true that all cards are red or round*. The latter sentence means *it is not true that all cards are round non-red cards or all cards are non-round red cards or all cards are round red cards*, resulting in *all cards are non-round non-red*. Here, we can treat all cards as a set, and so the negation means *it is not true that the set of cards is red or round*. According to DeMorgan's law 2, this sentence means that *the set of cards is non-round non-red*, that is, *all cards are non-round non-red*. Generally, in the uniform interpretation (UI), *not (p or q)* means *not p and not q*. In classical logic, this means that $\neg p \neg q$ is possible, but it is uncertain whether each of $p \neg q$, $\neg p q$, and $p q$ is possible or not. Thus, the uniform interpretation does not imply definite possibility implications. Conversely, *not (p or q)* holds only when it is the case that *not p and not q*. See the prediction in Table 1.

In classical predicate logic, a quantifier negation rule is $\sim(x) Fx :: (\exists x) \sim Fx$, that is, "Not all are" is equivalent to "Some are not" (Hurley & Watson, 2018, p. 495). According to this rule, *it is not true that all xs are p or q* is equivalent to *not all xs are p or q*, that is, *some xs are not p and not q*. However, classical predicate logic does not address the interpretation question how people interpret generic sentences without the quantifier *all*, such as *cards are red or round*. According to the above two pragmatic maxims and the default rule interpretation of generics in psycholinguistics, we predict that the reading of a general disjunction referring to a definite narrow-scope set of objects

will be the deterministic universal disjunction without exceptions. Thus, *it is not true that cards are red or round* is equivalent to *it is not true that all cards are red or round*, and so is equivalent to *not all cards are red or round*, which is equivalent to *some cards are non-red and non-round* according to the quantifier negation rule. Overall, *it is not true that xs are p or q* is equivalent to *some xs are not p and not q*. We call this account the rule violation account (RVA) because it treats the negation of a general disjunction as violating the universal disjunctive rule by introducing exceptions to it. This account is based on the conjunction of the default universal rule interpretation of generic sentences referring to definite narrow-scope sets predicted by the relativity principle in psycholinguistics and the quantifier negation rule in classical predicate logic. It predicts the deterministic universal rule reading of general disjunctions referring to definite narrow-scope sets like the present tasks.

Table 1

Theoretical predictions for truth judgments in set questions where different cases are equiprobable.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
pq					pq	pq	pq		pq	pq	pq				pq
$p \neg q$		$p \neg q$		$p \neg q$	$p \neg q$		$p \neg q$	$p \neg q$		$p \neg q$			$p \neg q$		$p \neg q$
$\neg pq$			$\neg pq$	$\neg pq$		$\neg pq$	$\neg pq$	$\neg pq$	$\neg pq$			$\neg pq$			$\neg pq$
								$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$
UI	F	F	F	F	F	F	F	F	F	F	F	F	F	T	F
RVA/PVA	F	F	F	F	F	F	F	T	T	T	T	T	T	T	T

Notes: T = true, denoting that the disjunction is true; F = false, denoting that the disjunction is false.

According to RVA, for a set of cards, *it is not true that cards are round or red* implies that there are some non-round non-red cards in the set of cards regardless of whether there are other cards in

the set of cards. Thus, in any set containing non-round non-red cards (columns 8-15 in Table 1) the negated general disjunction holds. Conversely, the truth of the negated general disjunction implies that any set containing non-round non-red cards is possible regardless of whether there are other cards in the set. Overall, the truth of a negated general disjunction is consistent with any set containing $\neg p \neg q$ cases, but not sets excluding $\neg p \neg q$ cases (columns 1-7 in Table 1). See these predictions in Table 1. Moreover, for case possibility questions, RVA predicts that a true general disjunction mentally implies that each of $p \neg q$, $\neg pq$, and pq is possible but $\neg p \neg q$ is impossible due to that it semantically violates the general disjunction, and the negated general disjunction mentally implies that each of $p \neg q$, $\neg pq$, and pq is possible, but $\neg p \neg q$ must be present.

The mental model theory (MMT) implies a contradictory prediction for the reading of negated general disjunctions because in MMT, the deterministic interpretation of unnegated compound propositions (such as conditionals and disjunctions) implied by the semantic compatibility principle of MMT is inconsistent with the complement interpretation of negations of compound propositions. We specify the contradictory prediction as follows.

MMT postulates that the core meaning of a compound proposition refers to the set of possibilities allowed by it (Johnson-Laird, 2001; Johnson-Laird & Byrne, 2002, p 650). Possibilities represent possible states of affairs that are *semantically compatible* with a compound proposition, whereas impossibilities are states of affairs that are *semantically incompatible* with a compound proposition (Johnson-Laird, 2001). This semantic compatibility principle is the basis of MMT. Possibilities envisaged by people form mental models, and each mental model represents a possibility. There are two versions of MMT as follow. “The previous version of The mental model theory [MMT1] postulated that people understand compound propositions by constructing models representing the disjunctive alternatives to which they refer” (Khemlani, Byrne, & Johnson-Laird, 2018, p. 4). In

MMT1, an inclusive disjunction is regarded as true when at least one of the three cases ($p \neg q$, $\neg p q$, and $p q$) is actual; otherwise, it is false (Johnson-Laird & Byrne, 2002, p. 651). A true inclusive disjunction implies the disjunction of possibilities allowed by it (Johnson-Laird, 2001; Johnson-Laird & Byrne, 2002). In the new theory [MMT2], “the meanings of compound propositions, such as conditionals (*if*) and disjunctions (*or*), unlike those in logic, refer to conjunctions of epistemic possibilities that hold in default of information to the contrary” (Johnson-Laird, Khemlani, & Goodwin, 2015; Khemlani, Byrne, & Johnson-Laird, 2018, p. 1).

Although most existing literature of MMT focuses on singular compound propositions referring to singular objects or events, proponents of MMT have not defined compound propositions as singular compound propositions in both MMT1 and MMT2. In the framework of MMT, the semantic compatibility principle is applicable to singular and general compound propositions. It implies the deterministic interpretation of true general conditionals and disjunctions where exceptions are impossible. Introducing the possibility of exceptions to a general conditional or disjunction implies that the general compound proposition is not true and so is negated. This is confirmed by some studies on general conditionals (e. g., *if a card is round then it is red*) referring to sets of objects or events (Goodwin, 2014; Ragni, Kola, & Johnson-Laird, 2018).

According to the deterministic interpretation of MMT, a true general disjunction (*cards are round or red*) disallows exceptions such as non-round non-red cards, and so is equivalent to the universal statement (*all cards are round or red*). Thus, the negation of the general disjunction (*It is not true that cards are round or red*) means that there are exceptions (non-round non-red cards) in the set of cards regardless of whether there are other types of cards. This implies that each of the four types of cards is possible for the negated general disjunction. Generally, *not (p or q)* implies that $\neg p \neg q$, $p \neg q$, $\neg p q$, and $p q$ are all possible, and *not (p or q)* is consistent with any set containing $\neg p \neg q$ cases in

column 8-15 in Table 1.

However, the above deterministic interpretation of negated general disjunctions is not consistent with the complement interpretation of negation in MMT1 that “the core meaning of negation refers to the complement of the set to which the unnegated sentence, clause, or constituent refers” (Khemlani, Orenes, & Johnson Laird, 2012, p. 11). In MMT1, the negation of a compound sentence implies the complement of the set of possibilities of the compound sentence. We call this account the complement interpretation of negations. In this account, *p or q* means possibly $p \neg q$ or possibly $\neg pq$ or possibly pq , and so *not (p or q)* means the negation of the disjunction of the three possibilities, that is, the complement (possibly $\neg p \neg q$) of the set of the three possibilities. Thus, *not (p or q)* implies that only $\neg p \neg q$ is possible, and $p \neg q$, $\neg pq$, and pq are all impossible, and *not (p or q)* is consistent with only the set $\{\neg p \neg q\}$. Thus, *it is not true that xs are p or q* is equivalent to *All xs are not p and not q*. For example, *it is not true that cards are round or red* means *all cards are non-round and non-red*. This prediction by the complement interpretation of negation isn’t consistent with the deterministic interpretation of negated general disjunctions in MMT.

In MMT2, *p or q* means the conjunction of the three possibilities allowed by the disjunction, that is, *possibly $p \neg q$ and possibly $\neg pq$ and possibly pq* . Thus, *not (p or q)* means that not all the three possibilities hold, resulting in that at least one of the three cases ($p \neg q$, $\neg pq$, pq) is not possible. This prediction by negating the conjunction of possibilities isn’t consistent with the deterministic interpretation of negated general disjunctions in MMT that *not (p or q)* is consistent with any set containing $\neg p \neg q$ cases.

In summary, the deterministic interpretation of general disjunctions predicted by the semantic compatibility principle in MMT is inconsistent with the interpretations of negating sets of possibilities of general disjunctions predicted by MMT1 and MMT2. Overall, theoretically MMT

isn't self-consistent, and so is unable to make a consistent prediction for the reading of negated general disjunctions. Thus, MMT is not a valid account for negated general disjunctions, and so current empirical research does not test it.

The probabilistic approach (PA) emphasizes uncertain interpretations of propositions and focus on probabilistic reasoning from uncertain premises with the manipulation of probabilities of premises (Cruz, 2020; Oaksford & Chater, 1998, 2009). It assumes two basic principles of probabilistic reasoning (Cruz, 2020). One is the principle of probabilistic validity that a one-premise inference is valid when the probability of its conclusion is higher than or equal to the probability of its premise; otherwise, it is invalid (Baratgin & Politzer, 2016; Cruz et al., 2015). The other is the principle of probabilistic coherence that the probabilities of premises and conclusions are coherent if and only if they conform to the axioms of probability theory (Coletti & Scozzafava, 2002; Pfeifer, 2013; Pfeifer & Sanfilippo, 2017). To our knowledge, in the probabilistic approach there is no extant specification of negations of general disjunctions. The present tasks investigate the qualitative reading of certain negated general disjunctions, that is, people are asked to judge whether what cases are possible or impossible given a certain negated general disjunction, or whether a negated general disjunction holds given the set of objects referred to by it. These tasks do not require probability judgments of conclusions, and so are not appropriate to test the two principles of PA. Thus, current research does not aim to test the two principles.

The present tasks can test the uncertain interpretation of propositions assumed by PA that the reading of propositions should be probabilistic (tolerating few exceptions), but not deterministic (tolerating no exceptions) (Cruz, et al., 2015; Oaksford & Chater, 1998, 2009; Pfeifer & Sanfilippo, 2017). Oaksford & Chater (1998, 2009) argues that “Any everyday rule, such as *birds fly*, *if you put money in the coke machine, you get a coke*, and so on, succumb to indefinitely many exceptions,

such as ostriches, penguins and broken or empty coke machines,” and “human everyday reasoning in particular, is best viewed as solving probabilistic, rather than logical, inference problems.”

Typically, it interprets a conditional assertion (*if p then q*) as the subjective belief indicated by a high subjective conditional probability (may not be the highest, 1), $P(q/p)$, and so treats conditional rules as exceptions-tolerating (Oberauer, & Wilhelm, 2003; Over, 2020; Skovgaard-Olsen, 2020).

Oaksford & Chater (2009, p. 106) argued a probabilistic semantics: *If p then q* conditionals are assumed to express that the conditional probability $P(q/p)$, is high, arriving at some threshold such as .9. Moreover, Cruz, et al. (2015) showed evidence for the probabilistic reading of disjunctions in natural language. It is noteworthy that most evidence for the probabilistic reading of propositions, takes propositions about natural categories referring to indefinite sets of objects where category boundaries are indefinite and numbers of category members are unlimited (e.g., *Birds fly*). However, RVA predicts that the reading of general propositions referring to definite sets with limited objects like the present tasks will be deterministic, according to the relativity principle of reading generics as probabilistic or deterministic.

Like the probabilistic reading of general conditionals by PA, we develop a probabilistic account for negated general disjunctions in the present tasks. In particular, people should interpret a general disjunction (*p or q*) as highly probable (may not be the highest, 1), that is, $P(p \text{ or } q)$ is high enough to exceed a probabilistic threshold (e. g, .99) of acceptance. When exceptions are available to a highly probable general disjunction, the general disjunction tolerates exceptions and so is true. When exceptions are not available to the general disjunction, $P(p \text{ or } q)$ is equal to 1 by default and so *p or q* is true. When $P(p \text{ or } q)$ is lower than the probabilistic threshold, the disjunction will be judged not true, that is, it will be negated. Conversely, the negation of the general disjunction implies that $P(p \text{ or } q)$ is lower than 1 or the probabilistic threshold of acceptance, and so there must

be probabilistically nonnegligible exceptions ($\neg p \neg q$) to the general disjunction. We call this account the probabilistic violation account (PVA) of negated general disjunctions. In this account, $P(p \text{ or } q) = P(p \neg q) + P(\neg p q) + P(pq)$. Here, P denotes probability.

For truth judgments about a general disjunction with frequency information, PVA makes the unique predictions that when $P(p \text{ or } q)$ increases in the interval around the probabilistic threshold of the general disjunction, its acceptance rate will increase, but its rejection rate will decrease. Experiment 4 tested this prediction. For truth judgments about general disjunctions where in a set different types of cases are equiprobable by setting the same frequency, PVA has the same prediction as RVA. Experiment 3 tested this prediction.

For case possibility judgments about true general disjunctions without frequency information of the four cases in Experiment 2, PVA has the same prediction as RVA. In the absence of available exceptions, a true general disjunction ($p \text{ or } q$) implies that $P(p \text{ or } q)$ is equal to 1 by default, and so $\neg p \neg q$ is impossible but $p \neg q$, $\neg p q$, and pq are all possible; and the corresponding negation implies that $P(p \text{ or } q)$ is less than 1, and so $\neg p \neg q$ must be present but each of $p \neg q$, $\neg p q$, and pq may be present.

In summary, for the negation of a general disjunction referring to a definite narrow-scope set, UI, RVA, and PVA make the different predictions shown in Table 1. RVA interprets the negation as the rule violation of the general disjunction by introducing exceptions such as $\neg p \neg q$ cases. It predicts that in Table 1 the eight sets containing $\neg p \neg q$ cases are all consistent with the negated general disjunction and so should equally elicit dominant acceptance responses in truth questions, regardless of whether $p \neg q$, $\neg p q$ and pq cases are present in these sets. Thus, the complete set $\{p \neg q, \neg p q, pq, \neg p \neg q\}$ and the complementary set $\{\neg p \neg q\}$ should not differ in acceptance responses. PVA interprets the negation as the probabilistic violation of the general disjunction by introducing

nonnegligible exceptions. For set questions where different cases are equiprobable, it has the same predictions as RVA. For set questions where different cases are not equiprobable, it has the different prediction.

1.2. *The overview of the present experiments*

We conducted four experiments to investigate how people read negated general disjunctions referring to definite narrow-scope sets. Experiment 1 investigated how participants interpreted unnegated and negated general disjunctions. Experiment 2 investigated case possibility judgments for unnegated and negated general disjunction. Experiment 3 aimed to test the predictions in Table 1. Finally, we tested the prediction for truth judgments of PVA in Experiment 4 where $P(p \text{ or } q)$ was manipulated.

In each experiment, we reported how we determined our sample size, all manipulations, and all measures in the study. All materials are available in the section of *design and materials*. All data for the study are available on OSF (Wang & Liang, 2022). We presented all the codes for the study as supplementary materials.

2. **Experiment 1**

2.1. *Method*

2.1.1. *Participants*

Sample size was determined classically (Machin, et al., 2011). In Experiment 1 with a within-group design, a power analysis indicated that 30 participants in total would be required to detect a discordant proportion ratio sum of .56 with a power of 90%. We aimed for at least 80 participants. A total of 86 college students (38 men, 48 women) from Shaanxi Normal University participated in the experiment. They had not yet taken any logic course. The four experiments received ethical

approval from the Shaanxi Normal University Human Research Ethics Committee, and all of the participants signed a written consent form.

2.1.2. *Design and materials*

Experiment 1 was a paper-and-pencil questionnaire study that investigated how participants read unnegated and negated general disjunctions. We used a within-subjects (unnegated versus negated general disjunctions) design where problems 1 and 2 concerned the reading of unnegated and negated general disjunctions, respectively. There were two questionnaires with the same problem design but different topics, which were between-subjects. One was about balls (*it is not true that balls are white or plastic*), and the other was about tourists (*it is not true that tourists wear glasses or blue shirts*). Each questionnaire was presented on a sheet. Here we illustrate the questionnaires with the following questionnaire with the topic of tourists, which are translated from the original Chinese version.

Instruction

Please answer the following items in the given order. Please tick your answers.

Problem one

There is a large tourist group. For the tourists, it is true that tourists wear glasses or blue shirts. For the tourists in the group, is it (true not true) that all the tourists wear glasses or blue shirts?

Problem two

There is a large tourist group. For the tourists in the group, it is not true that tourists wear glasses or blue shirts. Please answer the following questions according to the premise.

Conclusion 1: Not all the tourists wear glasses or blue shirts. (Yes No)

Conclusion 2: All the tourists don't wear glasses and all the tourists don't wear blue shirts. (Yes No)

Conclusion 3: The group of tourists must contain tourists who don't wear glasses and blue shirts, regardless of

whether it contains other types of tourists. (Yes No)

Conclusion 4: All the tourists don't wear glasses or all the tourists don't wear blue shirts. (Yes No)

In problem 1, the general disjunction was true in the absence of available exceptions and so $P(p \text{ or } q)$ was equal to 1. This implied that $\neg p \neg q$ cases were impossible by default and so the general disjunction was equivalent to the corresponding universal disjunction. The interpretation question investigated whether participants read the general disjunction (*xs are p or q*) as the universal disjunction (*All xs are p or q*).

In Problem 2, a general disjunction is not true and so $P(p \text{ or } q)$ was less than 1. Participants were asked whether some propositional interpretations as conclusions follow from the given negated disjunction (*It is not true that xs are p or q*). There were four candidate interpretations: (1) *Not all xs are p or q* (the quantifier-negation interpretation); (2) *All xs are not p and all xs are not q* (the dual-negation interpretation); (3) *The set of xs must contain $\neg p \neg q$ cases, regardless of whether it contains other types of cases* (the violation interpretation); (4) *All xs are not p or all xs are not q* (the clause-negation interpretation). RVA and PVA both predicted interpretations (1) and (3).

2.1.3. Procedure

We conducted the experiment in a quiet classroom. Every participant received a questionnaire on a sheet of paper and a pen to fill it out. They took about 5 minutes to complete the questionnaire.

2.2. Results and discussion

The two topics (tourists and balls) showed no obvious differences in performance. Thus, the results were collapsed across the two topics. In general disjunctions, 77% of participants read a general disjunction as the corresponding universal disjunction, whereas only 23% of participants did not. There was decisive evidence that the former was higher than the latter, as revealed by a Bayesian binomial test ($BF_{10} = 3286725$). Thus, most participants showed the default rule

interpretation of general disjunctions.

In negated general disjunctions, most participants interpreted a negated general disjunction (*it is not true that xs are p or q*) as (1) *Not all xs are p or q*, and (3) *The set of xs must contain $\neg p \neg q$ cases, regardless of whether it contains other types of cases*, but not (2) *All xs are not p and all xs are not q*, and (4) *All xs are not p or all xs are not q*. The acceptance rates of (1) and (3) were 76.6% and 83.7% respectively. The acceptance rates of (2) and (4) were 34.9% and 22.1% respectively. In each of interpretations (1), (3), and (4), a Bayesian binomial test revealed there was decisive evidence that affirmative and negative answers showed obvious differences (an interval summary of the three Bayes factors was $3.28 \times 10^6 < BF_{10} < 4.11 \times 10^{14}$). In interpretation (2), a Bayesian binomial test revealed there was positive evidence that affirmative and negative answers showed obvious differences ($BF_{10} = 8.15$). These results showed the violation interpretation of negated general disjunctions, which implied that they interpreted general disjunctions as not uniform. This result disfavours the uniform interpretation of general disjunctions. The overall propositional interpretation of negated general disjunctions favours the prediction of RVA and PVA over UI.

In summary, most participants showed the deterministic interpretation of general disjunctions, and the rule violation interpretation of negated general disjunctions by introducing exceptions to general disjunctions. These findings favour RVA and PVA over UI.

3. Experiment 2

3.1. Method

3.1.1. Participants

Experiment 2 with a within-group design had the same power analysis as Experiment 1. A total of 86 college students (35 men, 45 women) from Shaanxi Normal University participated in the

experiment. They had never taken a course in logic before.

3.1.2. Design and materials

Experiment 2 was a paper-and-pencil questionnaire study that used a within-subjects design to investigate how participants made modal judgements about unnegated and negated general disjunctions. There were two within-subjects problems: Problem one about unnegated general disjunctions, and Problem two about negated general disjunctions. Problem one was the baseline problem, and Problem two was the target problem. Participants first completed the baseline problem, then the target problem. There were two questionnaires with the same problem design but different topics, which were between-subjects. One was about balls (*it is not true that balls are white or plastic*), and the other was about tourists (*it is not true that tourists wear glasses or blue shirts*). Each questionnaire was presented on a sheet. Here we illustrate the questionnaires with the following questionnaire with the topic of tourists, which are translated from the original Chinese version.

Instruction

Please answer the following items in the given order. Please tick your answers.

Problem one

There is a large tourist group. For the tourists in the group, it is true that tourists wear glasses or blue shirts. Please answer the following questions according to the premise.

1. Do you think that the group of tourists (must may cannot) contain tourists not wearing glasses and blue shirts?
2. Do you think that the group of tourists (must may cannot) contain tourists wearing glasses and blue shirts?
3. Do you think that the group of tourists (must may cannot) contain tourists not wearing glasses but wearing blue shirts?

4. Do you think that the group of tourists (must may cannot) contain tourists wearing glasses but not blue shirts?

Problem two

There is a large tourist group. For the tourists in the group, it is not true that tourists wear glasses or blue shirts.

Please answer the following questions [identical to the above four questions] according to the premise.

Here are the four questions identical to the above four questions, and so we omit them.

In the baseline problem, the general disjunction was true in the absence of available exceptions and so $P(p \text{ or } q)$ was equal to 1. This implied that $\neg p \neg q$ cases were impossible by default and so the general disjunction was equivalent to the corresponding universal disjunction. Each modal question asked whether the set of elements under the general disjunction (must may cannot) contain each of the four cases ($p \neg q$, $\neg pq$, pq , and $\neg p \neg q$). The three accounts (RVA, PVA, and UI) all predicted that the set may contain $p \neg q$, $\neg pq$, and pq , but cannot contain $\neg p \neg q$. The exclusive reading of the general disjunction ($p \text{ or } q$) predicted that the set may contain $p \neg q$ and $\neg pq$, but cannot contain pq and $\neg p \neg q$. The inclusive reading of the general disjunction predicted that the set may contain $p \neg q$, $\neg pq$, and pq , but cannot contain $\neg p \neg q$.

In the target problem, the general disjunction was not true and so $P(p \text{ or } q)$ was less than 1. This implied that $\neg p \neg q$ cases must be present in the set. Each modal question asked whether the set of elements (must may cannot) contain each of the four cases ($p \neg q$, $\neg pq$, pq , and $\neg p \neg q$). RVA and PVA both predicted that the set must contain $\neg p \neg q$ but may contain each of $p \neg q$, $\neg pq$, and pq , and so $\neg p \neg q$ cases would elicit stronger modal judgments than the other three cases. UI predicted that the set cannot contain each of $p \neg q$, $\neg pq$, and pq , but must contain $\neg p \neg q$. The exclusive reading of the general disjunction ($p \text{ or } q$) predicted that pq and $\neg p \neg q$ are both exceptions to the general

disjunction and the negated general disjunction implies introducing pq or $\neg p\neg q$ to the set, resulting in that pq and $\neg p\neg q$ may both be present in the set and so both would show no differences in modal judgments. The inclusive reading of the general disjunction (p or q) predicted that only $\neg p\neg q$ cases are exceptions to the general disjunction and the negated general disjunction implies introducing $\neg p\neg q$ cases to the set, resulting in that pq cases may be present in the set but $\neg p\neg q$ cases must be present in the set and so $\neg p\neg q$ cases would elicit stronger modal judgments than pq cases.

Overall, the three accounts all predicted that the negated general disjunction would elicit more “must contain” judgments of $\neg p\neg q$ cases than the unnegated general disjunction.

3.1.3. Procedure

The procedure was similar to that in Experiment 1.

3.2. Results and discussion

The two topics (tourists and balls) showed no obvious differences in performance. Thus, the results were collapsed across the two topics. The overall results are shown in Table 2.

Table 2

The overall results (percentages) in Experiment 2

	General disjunctions				Negated general disjunctions			
	$p\neg q$	$\neg pq$	pq	$\neg p\neg q$	$p\neg q$	$\neg pq$	pq	$\neg p\neg q$
must	16.3	16.3	3.5	1.2	4.7	3.5	1.2	66.3
may	82.6	82.6	90.7	12.8	62.8	64	62.8	27.9
cannot	1.2	1.2	5.8	86	32.6	32.6	36	5.8

In general disjunctions, most participants judged that each of $p\neg q$, $\neg pq$, and pq was possible, but $\neg p\neg q$ is impossible. We compared $\neg p\neg q$ cases with each of the other cases using Bayesian ordinal

model in R (Kruschke, 2015, p. 672) where the response variable was ordinal in that modal belief was increasing from response “cannot” to “may” to “must”. There was decisive evidence that $\neg p \neg q$ cases elicited lower modal judgments than each of the other cases ($4.01 \times 10^8 < BF_{10} < 7.76 \times 10^{13}$). Most participants judged pq possible, showing the inclusive reading of general disjunctions that p and q can both be true. Thus, judging $\neg p \neg q$ impossible showed the deterministic reading of general disjunctions. The overall response pattern favours the common prediction of RVA and PVA.

In negated general disjunctions, the majority of participants judged that the set under a negated general disjunction must contain $\neg p \neg q$ cases, but may contain each of $p \neg q$, $\neg pq$, and pq cases. We compared $\neg p \neg q$ cases with each of the other cases using the same Bayesian ordinal model in R as the above model. There was decisive evidence that $\neg p \neg q$ cases elicited stronger modal judgments than each of the other cases ($1.18 \times 10^8 < BF_{10} < 4.96 \times 10^{11}$). $\neg p \neg q$ cases elicited stronger modal judgments than pq cases, as was consistent with the prediction of the inclusive reading of the general disjunction. These results were consistent with the violation interpretation found in the interpretation questions. The overall pattern of modal judgments favours the prediction of RVA and PVA over UI.

Moreover, there was decisive evidence that $\neg p \neg q$ cases elicited stronger modal judgments in negated general disjunctions than in general disjunctions ($BF_{10} = + \text{infinity}$). These results were consistent with the violation interpretation found in the interpretation questions. There was strong evidence that each of $p \neg q$, $\neg pq$, and pq cases elicited weaker modal judgments in negated general disjunctions than in general disjunctions ($4.98 \times 10 < BF_{10} < 4.36 \times 10^3$). This was due to the pattern of individual differences in negated general disjunctions: About one third of participants judged that the set cannot contain each of $p \neg q$, $\neg pq$, and pq cases, whereas more than 60% of participants judged that the set may contain each of $p \neg q$, $\neg pq$, and pq cases.

In summary, most participants showed the deterministic reading of general disjunctions, and the rule violation interpretation of negated general disjunctions by introducing exceptions to general disjunctions. The latter finding is consistent with the finding in Experiment 1 that most participants interpreted a negated general disjunction (*it is not true that xs are p or q*) as (3) *The set of xs must contain $\neg p \neg q$ cases, regardless of whether it contains other types of cases*. Both findings favour RVA and PVA over UI.

4. Experiment 3

Experiment 2 revealed that a negated general disjunction implies that $\neg p \neg q$ must be present but $p \neg q$, $\neg pq$, and pq may be present. Thus, each of the latter three cases is possible. However, this does not imply that each of these three possibilities is required by the negated general disjunction. Thus, Experiment 2 underdetermines whether each of the three possibilities is required by the negated general disjunction. To investigate this question, Experiment 3 used set questions to test the predictions in Table 1. In particular, if whether one case is present or absent in a set determines whether the general disjunction is true or not, the case and its possibility is required by the negated general disjunction. Otherwise, both are unrequired.

4.1. Method

4.1.1. Participants

Experiment 3 with a within-group design had the same power analysis as Experiment 1. A total of 104 college students (51 men, 53 women) from Shaanxi Normal University participated in the experiment. They had never taken a course in logic before.

4.1.2. Design and materials

Experiment 3 was a paper-and-pencil questionnaire study with a set true judgment task. For

example, in a task, participants were asked to judge whether a negated disjunction (*it is not true that cards are round or red*) holds for a set consisting of some of the four cases (round red cards, round non-red cards, non-round red cards, non-round non-red cards). There were two problems with different materials, sets of cards and sets of balls, with two negated disjunctions: *it is not true that cards are round or red*; *it is not true that balls are blue or plastic*. The two problems were between-subjects. Each problem contained 15 items, corresponding to the 15 sets in Table 1, which were counterbalanced. In each set, different cases had the same frequency 10 and so were objectively equiprobable. The complete task with the example problem as the card problem is presented in Appendix A translated from the original Chinese version.

In Experiment 3, sets in columns 1, 5, 6, and 7 were inclusive sets in that they contained inclusive cases pq but not cases $\neg p \neg q$. These four sets could test whether the reading of the general disjunction was inclusive or exclusive. The exclusive reading of the general disjunction would be contradictory to these inclusive sets. Thus, the negation of the exclusive reading may imply the inclusive reading that inclusive cases pq were allowed. Accordingly, these four inclusive sets would imply that the negated general disjunctions hold. If participants did not accept the negated general disjunctions in these inclusive sets, this would imply the inclusive reading.

4.1.3. Procedure

In each experiment, the procedure is identical to that in Experiment 1, except that participants took about 10 minutes to complete the questionnaire.

4.2. Results and discussion

The two problems with different materials, cards and balls, showed no obvious differences in possibility judgments. Thus, the results were collapsed across the two problems. The overall results of both experiments are shown in Table 3.

Most participants did not accept the negated general disjunctions in the four inclusive sets, and so they showed the inclusive reading of the general disjunctions. Most participants accepted the negated disjunctions in each key set containing $\neg p \neg q$ cases, but rejected them in each set excluding $\neg p \neg q$ cases. This suggests that only $\neg p \neg q$ cases are required for a negated disjunction.

Table 3

The overall results (percentages) of truth judgments in Experiment 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	pq				pq	pq	pq		pq	pq	pq				pq
		$p \neg q$		$p \neg q$	$p \neg q$		$p \neg q$	$p \neg q$		$p \neg q$			$p \neg q$		$p \neg q$
			$\neg pq$	$\neg pq$		$\neg pq$	$\neg pq$	$\neg pq$	$\neg pq$			$\neg pq$			$\neg pq$
								$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$	$\neg p \neg q$
Holds	34	52	48	32	40	38	41	82	73	79	72	83	79	82	70
Doesn't hold	66	48	52	68	60	63	59	18	27	21	28	17	21	18	30

We analysed these binomial data using Bayesian bernoulli model (logistic regression) (Bürkner, 2017) in R, in which the set was the independent variable. For the prior, we used a standard weakly informative scaled t -distribution, $t(\text{df} = 7, \text{mean} = 0, \text{sd} = 2.5)$ (the standard prior for such analyses recommended in the rstanarm package in R).

We first compared each of the seven non-key sets with the corresponding key set containing $\neg p \neg q$ cases, e.g. the set containing only pq cases, with the set containing only pq and $\neg p \neg q$ cases. There was decisive evidence that each key set containing $\neg p \neg q$ cases elicited more acceptance responses than the corresponding non-key set excluding $\neg p \neg q$ cases ($1.09 \times 10^2 < BF_{10} < 6.11 \times 10^7$). Next we compared the key set $\{\neg p \neg q\}$ in column 14, with each of the seven remaining key sets in columns 8 to 13 and column 15. We found no evidence that acceptance responses differed between the key set $\{\neg p \neg q\}$ and each of the other key sets ($0 < BF_{10} < 1$). Most participants

equally often accepted the negated disjunctions in the eight key sets containing $\neg p \neg q$ cases.

In summary, the overall pattern of truth judgments shows that people accept a negated general disjunction in sets containing $\neg p \neg q$ cases, but not in sets excluding $\neg p \neg q$ cases. Thus, whether a set includes $\neg p \neg q$ cases determines whether the negated disjunction holds. Only $\neg p \neg q$ cases are required by the negated disjunction, and so only the possibility of $\neg p \neg q$ is required by it. These findings are consistent with the prediction of RVA and PVA over UI.

5. Experiment 4

In Experiment 3, the findings of truth judgments are unable to distinguish between RVA and PVA due to that we did not manipulate $P(p \text{ or } q)$ and $P(\neg p \neg q)$. In Experiment 4 we further manipulated $P(p \text{ or } q)$ and $P(\neg p \neg q)$ to distinguish between RVA and PVA.

Method

5.1. *Participants*

Experiment 4 with a within-group design had the same power analysis as Experiment 1. A total of 154 college students (66 men, 88 women) from Shaanxi Normal University participated in the experiment. They had never taken a course in logic before.

5.1.2. *Design and materials*

Experiment 4 was a paper-and-pencil questionnaire study based on a set-based truth judgment task with the manipulation of probability of exceptions. In this task, participants were asked to judge whether a general disjunction (*Balls were green or plastic*) and its opposing conjunction (*Balls were not green and not plastic*) were individually true or not for each of 5 sets with frequency information shown in Table 4. The five problems corresponding to the five sets constituted a booklet in which each problem was separately presented on a small piece of paper. Problem 0/1000

containing pq cases but not $\neg p\neg q$ exceptions were absent, was designed to examine whether the reading of the general disjunction was inclusive or exclusive. Judging the general disjunction true would imply the inclusive reading, whereas judging it not true would imply the exclusive reading. The four problems with exceptions were the target problems that can test whether the reading of the general disjunction and its negation was probabilistic. The instruction on the first page is as follows: “Please complete the following problems by the presentation order of these problems. Please tick your answers.” One example problem translated from the original Chinese version is as follows:

There is a box of 1000 balls. It is known that the composition of the box of balls is as follows:

300 green plastic balls
300 non-green plastic balls
300 green non-plastic balls
100 non-green non-plastic balls

For these balls, is it (True Not true) that balls were green or plastic?

For these balls, is it (True Not true) that balls were not green and not plastic?

Table 4.

The frequency information of the four cases and the results (percentages) in Experiment 4

problems	$p\neg q$	$\neg pq$	pq	$\neg p\neg q$	$P(p \text{ or } q)$	$P(\neg p\neg q)$	<i>xs are p or q</i>		<i>xs are not-p and not-q</i>	
							True	Not true	True	Not true
100/1000	300	300	300	100	.9	.1	33.8	66.2	29.2	70.8
10/1000	330	330	330	10	.99	.01	33.1	66.9	32.5	67.5
3/1000	333	333	331	3	.997	.003	34.4	65.6	29.9	70.1
1/1000	333	333	333	1	.999	.001	36.4	63.6	28.6	71.4
0/1000	333	333	334	0	1	0	78.6	21.4	18.8	81.2

Notes: The representation of problems is $\neg p\neg q$ frequency / the sum of the four truth table cases.

One presentation order of the five problems was as follows: problems 100/1000, 10/1000, 3/1000, 1/1000, 0/1000. The other presentation order was as follows: problems 1/1000, 3/1000, 10/1000, 100/1000, 0/1000. Thus, the four target problems were counterbalanced. For the four target problems with high $P(p \text{ or } q)$ and low $P(\neg p \neg q)$, $P(p \text{ or } q)$ increased from 900/1000 to 999/1000, as probability of exceptions decreased from 100/1000 to 1/1000. This design aimed to investigate whether the reading of a general disjunction (balls were green or plastic) with few exceptions ($\neg p \neg q$) (problems 1/1000 and 3/1000) would be probabilistic. If participants adopted the probabilistic violation reading of negation, negation rate of the general disjunction would decrease as $P(p \text{ or } q)$ increased, and meanwhile the opposing proposition (balls were non-green and non-plastic) would be negated due to low $P(\neg p \neg q)$. If participants adopted the rule violation reading of negation, negation rate of the general disjunction would not vary with $P(p \text{ or } q)$ and $P(\neg p \neg q)$, and participants would negate it when any number of exceptions were introduced, and meanwhile they would also negate the opposing proposition due to low $P(\neg p \neg q)$. In the situation with high $P(p \text{ or } q)$ and low $P(\neg p \neg q)$, the probabilistic violation reading would lead to that the general disjunction would receive more acceptances than the opposing proposition, whereas the rule violation reading would lead to that it and its opposing proposition would equally often be negated, that is, the two could not both be true. Thus, RVA made the unique prediction that the negation of the general disjunction would imply violating the disjunction rule by introducing any number of exceptions, but not its opposing proposition, that is, the negation and the opposing proposition of the general disjunction could take different truth values.

4.1.3. Procedure

The procedure is identical to that in Experiment 1.

5.2. Results and discussion

The overall results are shown in Table 4. In problem 0/1000 containing pq cases but not exceptions, most participants accepted the general disjunction as true, but negated the opposing proposition as not true. In each of the two propositions, a Bayesian binomial test revealed there was decisive evidence that affirmative and negative answers showed obvious differences ($BF_{10} = 1.31 \times 10^{15}$, 1.44×10^{20} , respectively). The dominant acceptance of the general disjunction implied that they read it as inclusive.

In each target problem with exceptions, each of the two propositions received more negations than acceptances, and the majority of participants negated both the two propositions regardless of the number of exceptions. The acceptance of the general disjunction with the inclusive reading in problem 0/1000 implied that its negation in each target problem with pq cases is not due to the exclusive reading of it. Moreover, in each target problem with exceptions, we compared the general disjunction and its opposing proposition using Bayesian bernoulli model (logisitic regression) (Bürkner, 2017) in R. There was positive evidence that participants equally often negated the general disjunction and its opposing proposition, and there was no obvious difference between negations of both ($5.8 < BF_{01} < 25$). Thus, the negation of the general disjunction did not imply its opposing proposition. For the four target problems with high $P(p \text{ or } q)$ and low $P(\neg p \neg q)$, we compared problem 1/1000 with each of the other three target problem using Bayesian bernoulli model (logisitic regression) (Bürkner, 2017) in R. There was positive evidence that negation (or acceptance) rate of the general disjunction did not vary with $P(p \text{ or } q)$ and $P(\neg p \neg q)$ ($16 < BF_{01} < 25$), and there was positive evidence that negation (or acceptance) rate of the opposing proposition with low $P(\neg p \neg q)$ did not vary with $P(p \text{ or } q)$ and $P(\neg p \neg q)$ ($16 < BF_{01} < 25$). The former finding is consistent with the prediction of RVA, but not the prediction of PVA. The overall response pattern of the general disjunction and its opposing proposition showed that participants preferred to the rule

violation reading over the probabilistic violation reading of the negated general disjunction, and the negation of the general disjunction did not imply its opposing proposition. Thus, these findings favour RVA over PVA.

6. General discussion

6.1. *The summary of the present results*

In Experiment 1, the finding of the universal interpretation of general disjunctions is consistent with the previous finding of the generic overgeneralization effect of simple sentences. This suggests that the default rule interpretation of generics is applicable to general compound sentences referring to definite sets. In the absence of available exceptions, people tend to interpret a general disjunction as the universal disjunction, showing the deterministic interpretation; and the negated general disjunction as violating the rule by introducing exceptions to the general disjunction. Overall, people show the default rule interpretation of general disjunctions referring to definite narrow-scope sets, and the rule violation interpretation of negations of general disjunctions.

For case possibility judgments in Experiment 2, the majority of participants judged that the set under a general disjunction cannot contain $\neg p \neg q$ cases, showing the default rule interpretation. They judged that the set under a negated general disjunction must contain $\neg p \neg q$ cases, but may contain each of $p \neg q$, $\neg pq$, and pq cases. In other words, $\neg p \neg q$ cases are necessary but $p \neg q$, $\neg pq$, and pq cases are all possible for the negated general disjunction. This finding is congruent with the previous finding that given a negated general disjunction (e. g, there is a pack of cards. For the cards, *it not true that a card is round or it is red*), the majority of participants listed the possibilities of $\neg p \neg q$, $p \neg q$ and $\neg pq$, whereas the minority of participants listed the possibility of pq (Yin, et. al., 2020). In the latter finding, that only the minority of participants listed pq as possible may be due to

the ambiguity that *a card* in the disjunction may refer to a particular card but not any card in the pack, and so pq is intuitively impossible for the particular card referred to by the negated disjunction. In the present finding, the corresponding negated general disjunction took the generic form: *it not true that cards are round or red*. In this form, the general disjunction clearly refers to cards rather than a particular card. The reference ambiguity no longer exists, and so the majority of participants judged pq cases possible in the pack of cards.

In Experiment 3, in the condition that different cases are equiprobable, a negated general disjunction holds in each key set containing $\neg p \neg q$ cases regardless of whether other cases are present, but not in each set excluding $\neg p \neg q$ cases. Thus, the negated general disjunction requires only $\neg p \neg q$ cases, but not the other cases, and so it requires only the possibility of $\neg p \neg q$, but not the other possibilities. These findings favor the prediction of RVA and PVA over UI.

In Experiment 4, when $P(p \text{ or } q)$ increased from 900/1000 to 999/1000, “true” judgments about the general disjunction did not increase with $P(p \text{ or } q)$, and participants negated the general disjunction with the probability of 999/1000. Some skeptics may argue that $P(p \text{ or } q) = 999/1000$ is still lower than the probabilistic threshold of acceptance, which may be 9999/10000, 99999/100000, etc. If this is the case, the probabilistic account may be unfalsifiable. Intuitively, 999/1000 is empirically a very high probability. The negation of the general disjunction with this high probability should reasonably imply the deterministic interpretation (not tolerating exceptions), as predicted by RVA. Thus, the present result disfavors the prediction of PVA that the general disjunction with the very high probability (999/1000) should be judged true. Overall, set-based truth judgments favor the rule violation reading over the probabilistic violation reading of negated general disjunctions, and a negated general disjunction (*It is not true that Balls were green or plastic*) does not imply the opposing proposition (*Balls were not green and not plastic*).

In summary, the four experiments provide convergent evidence for the rule violation interpretation of negated general disjunctions referring to definite narrow-scope sets. RVA can best explain the present findings. The present overall response pattern is consistent with the default universal rule interpretation of generic sentences referring to definite narrow-scope sets predicted by the relativity principle in psycholinguistics that reading generics as probabilistic or deterministic is relative, depending on background knowledge or contexts.

6.2. Theoretical implications in psycholinguistic research on generic language

In both possibility and truth judgments, people show the deterministic reading (tolerating no exceptions) of general disjunctions referring to definite narrow-scope sets. They tend to understand a general disjunction such as “Tourists wear glasses or blue shirts” as the universal disjunction “All tourists wear glasses or blue shirts”, showing the default rule interpretation. Thus, possibility and truth judgments are symmetrical at the core meaning of generic disjunctions. This finding is different from the previous finding of the asymmetry of generic simple sentences referring to indefinite sets: participants interpreted novel generics such as “Lorches have purple feathers” as referring to nearly all lorches (often reaching 100%), but they judged the same novel generics to be true given a wide-scope range of prevalence levels (e.g., even when only 10% or 30% of lorches had purple feathers) (Cimpian, Brandone, & Gelman, 2010). In interpreting given generic propositions, general disjunctions referring to definite sets and simple generic simple sentences referring to definite sets can both elicit the default rule interpretation without exceptions. This implies that whether given generic propositions are compound or simple sentences could make no differences to interpretations of given generic propositions. The difference in truth judgment shows that people are more likely to read a general disjunction referring to a definite narrow-scope set as

the default rule over the narrow-scope set, whereas people are more likely to read a generic simple sentence referring to a definite wide-scope set as the majority generalization over the wide-scope set. This difference may be due to the interaction of the two factors: type of sentences (whether generic sentences are compound or simple sentences) and type of sets (whether sets in question are narrow or wide-scope). As is suggested by the relativity principle, when a general disjunction refers to a definite narrow-scope set with limited members, it probably means a default universal rule without exceptions that exhausts all known alternative states in question; when a general disjunction refers to a definite wide-scope set with unlimited members (such as a natural kind), it probably means a majority generalization with exceptions. For example, when sheep refer to the natural kind *sheep* without a definite category boundary, the statement “Sheep are black or white” is intuitively a majority generalization with exceptions such as gray sheep, that is, most sheep are black or white. When sheep refer to a definite narrow-scope set such as the sheep in a village, the statement “In our village, sheep are black or white” is intuitively a universal rule without exceptions, that is, every sheep is black or white. The narrow-scope set of sheep in the latter statement is a subset of the wide-scope set of sheep in the former statement, and so the wide-scope set is statistically more likely to contain exceptions than the narrow-scope set. Thus, the latter statement is more likely to be a universal rule than the former statement. Overall, whether a general disjunction means a deterministic universal rule or a probabilistic majority generalization depends on whether the general disjunction refers to a narrow-scope set or a wide-scope set. This relativity principle implies that there should be the interaction of type of sentences and type of sets. The relative reading (deterministic or probabilistic) of general disjunctions is consistent with the relativity view in psycholinguistics that the reading of generic simple sentences depends on context or background knowledge (Cohen, 2022; Dayal & Sağ, 2020; Krifka, 2004; Le Bruyn, de Swart, & Zwarts, 2017;

Leslie & Adam, 2022; Sterken, 2015, 2017; Tessler & Goodman, 2019). Future research could investigate the interaction of type of sentences and type of sets on the reading of generics.

It is noteworthy that the relativity principle means that all things being equal, a generic sentence more likely means the probabilistic majority generalization in a wide-scope set than in a narrow-scope set. The distinction between wide-scopes and narrow-scopes is relative. In other words, the wider a set is, the more likely the generic sentence referring to the set is to mean the probabilistic majority generalization. When referring to a definite set, the generic sentence more likely means the probabilistic majority generalization when the scope of the set is relatively wider, because statistically the wider-scope set is more likely to contain exceptions. For example, the statement “In Australia, sheep are black or white” more likely means a probabilistic majority generalization than the statement “In our village, sheep are black or white”. The latter statement more likely means a deterministic universal rule. Moreover, when generic sentences refer to definite natural kinds, background knowledge can mediate the reading of generic sentences. For example, the statement “sheep are black or white” more likely means a probabilistic majority generalization than the statement “sheep are male or female”, which more likely means a deterministic universal rule. This is due to the background knowledge that the former disjunction fails to exhaust all alternatives in terms of color, whereas the latter disjunction exhausts all alternatives in terms of gender. Overall, in the relativity principle, scopes of sets and background knowledge both affect the reading of generic sentences. We for the first time propose that scopes of sets affect the reading of generic sentences.

The rule violation interpretation of negated general disjunctions is consistent with the theory of alternatives in linguistics that negating an affirmative sentence means producing alternatives to the affirmative sentence and so the negation of the affirmative sentence means alternatives to it (Repp & Spalek, 2021). According to the rule violation interpretation, *it is not true that all xs are p or q* is

equivalent to *some xs are not p and not q*. *Some xs are not p and not q* is the alternative to the affirmative disjunction. In particular, the negation of a general disjunction holds in each key set containing $\neg p \neg q$ cases regardless of whether other cases are present, but not in each set excluding $\neg p \neg q$ cases. Each key set containing $\neg p \neg q$ cases in which the negated general disjunction holds is an alternative to the affirmative sets without $\neg p \neg q$ cases referred to by the affirmative general disjunction. The key difference between the alternative sets and the affirmative sets is that the alternative sets contains exceptions ($\neg p \neg q$ cases) to the affirmative general disjunction, but the affirmative sets do not.

6.3. Theoretical implications in the psychology of propositional reasoning

The finding of the rule violation interpretation of negated general disjunctions is consistent with the previous finding that people tend to negate a singular disjunction (e. g., *the card is round or red*) as false when the possibility of $\neg p \neg q$ is introduced to the referred object of the singular disjunction regardless of whether there are other possibilities (Wang & Zheng, 2021). Thus, both negated singular and general disjunctions means the rule violation interpretation by introducing the possibility of exceptions to unnegated disjunctions.

The rule violation interpretation of negated general disjunctions parallels the previous finding that most participants judged a general conditional, *if p then q* (e. g., *if a card is round then it is red*), false in a set containing $p \neg q$ cases where the four truth-table cases (pq , $p \neg q$, $\neg pq$, and $\neg p \neg q$) were equiprobable by default (Wang & Yao, 2018). That the general conditional is false is equivalent to that the general conditional is not true, that is, the negation of the general conditional. This implies that people interpret the negation of a general conditional as the violation of the general conditional rule by introducing exceptions ($p \neg q$ cases). Overall, people interpret the

negation of a general compound sentence as the violation of the general rule by introducing exceptions, but not the complement of the set of possibilities referred to by the general compound sentence. Negating a general compound sentence means violating the general rule rather than negating the set of possibilities under the general rule. This refutes the semantic complement interpretation of negated compound sentences postulated by MMT1 (Khemlani, Orenes, & Johnson Laird, 2012, 2014).

The results of Experiment 4 with the manipulation of $P(p \text{ or } q)$ and $P(\neg p \neg q)$ further show that people tend to read the negation of a general disjunction referring to a definite narrow-scope set as the qualitative rule violation over the quantitative probabilistic violation of the general disjunction. The qualitative rule violation interpretation of the negation implies that the general disjunction disallows exceptions, and the negation of it requires exceptions to it. This finding favors RVA over PVA of general disjunctions referring to definite narrow-scope sets.

According to the relativity principle in psycholinguistics that the reading of generics depends on background knowledge or contexts, PVA is more likely to be applicable to negated general disjunctions referring to definite wide-scope sets such as natural kinds than those referring to definite narrow-scope sets. This is illustrated by the above example about sheep where whether the reading of “sheep are black or white” is deterministic or probabilistic depends on whether sheep refer to a narrow-scope set such as the sheep in “our village” or the natural kind *sheep* with the wide-scope set. The statement “In our village, sheep are black or white” is more likely to be a deterministic universal rule without exceptions, and introducing exceptions to the general disjunction implies the negation of it. The statement “Sheep are black or white” where sheep refer to the whole natural kind *sheep* is more likely to be a probabilistic majority generalization tolerating negligible exceptions, and the negation of it requires introducing a considerable proportion of

exceptions to the general disjunction such that $P(p \text{ or } q)$ is lower than the probabilistic threshold of accepting it.

In the psychology of propositional reasoning, existing accounts of general compound propositions such as general conditionals and disjunctions divide into two opposing camps: the deterministic interpretation (MMT) and the probabilistic interpretation of general compound propositions. Both camps fail to take account of the relativity principle of reading generics in psycholinguistics and so are one-sided and absolute. The probabilistic approach can explain the probabilistic majority generalization of generic sentences in psycholinguistics, but not the deterministic universal rule interpretation of generic sentences such as “if a duck lays eggs then it is female” and “Ducks are male or female”. MMT can explain the deterministic universal rule interpretation of generic sentences, but not the probabilistic majority generalization of generic sentences in psycholinguistics. The relativity principle shows that reading generics as probabilistic or deterministic is relative, depending on background knowledge or contexts. The relative reading of generic sentences implies that there is no single interpretation of all generic sentences, and so is beyond the existing one-sided accounts of general compound propositions. This suggests that the psychology of propositional reasoning should incorporate the relativity principle of reading generics in psycholinguistics.

7. Conclusion

The present four experiments investigated how people understand negations of general disjunctions referring to definite narrow-scope sets in both truth and possibility questions. In both truth and possibility judgments people tend to read a general disjunction referring to a definite narrow-scope set as a deterministic universal rule, and read the negation of the general disjunction as the qualitative violation of the rule by introducing exceptions, showing the deterministic rule

violation reading of the negated general disjunction. These findings favor the rule violation account over the other accounts. Thus, negating a general disjunction implies violating the default universal rule represented by it, but not negating the set of possibilities referred to by it. The present overall response pattern is consistent with the default universal rule interpretation of generic sentences referring to definite narrow-scope sets predicted by the relativity principle of reading generics in psycholinguistics. The relative reading of general disjunctions is beyond existing simple deterministic and probabilistic accounts of compound propositions in propositional reasoning.

References

- Braine, M. D. S., & O'Brien, D. P. (Eds.). (1998). *Mental logic*. Mahwah: Erlbaum.
- Braine, M. D. (1998). Steps toward a mental-predicate logic. In *Mental logic* (pp. 281-340). Psychology Press.
- Chater, N., & Oaksford, M. (1999). The probability heuristics model of syllogistic reasoning. *Cognitive Psychology*, 38, 191-258.
- Carlson, G. N., & Pelletier, F. J. (Eds.). (1995). *The generic book*. University of Chicago Press.
- Cohen, A. (2022). Genericity. <https://doi.org/10.1093/acrefore/9780199384655.013.326>
- Cimpian, A., Brandone, A. C., & Gelman, S. A. (2010). Generic statements require little evidence for acceptance but have powerful implications. *Cognitive science*, 34(8), 1452-1482.
- Cruz, N. (2020). Deduction from uncertain premises? In *Logic and Uncertainty in the Human Mind* (pp. 27-41). Routledge.
- Cruz, N., Baratgin, J., Oaksford, M., & Over, D. E. (2015). Bayesian reasoning with ifs and ands and ors. *Frontiers in Psychology*, 6, 192. Doi: 10.3389/fpsyg.2015.00192
- Cruz, N., Over, D. E., & Oaksford, M. (2017). The elusive oddness of *or*-introduction. In G.

- Gunzelmann, A. Howes, T. Tenbrink, & E. J. Davelaar (Eds.), *Proceedings of the 39th Annual Conference of the Cognitive Science Society* (pp. 663-668).
- Dayal, V., & Sağ, Y. (2020). Determiners and bare nouns. *Annual Review of Linguistics*, 6, 173-194.
- DeMorgan, A. (1847). *Formal logic or the calculus of inference necessary and probable*. London, England: Taylor & Walton.
- Elqayam, S., & Over, D. E. (2013). New paradigm psychology of reasoning: an introduction to the special issue edited by Elqayam, Bonnefon, and Over. *Thinking & Reasoning*, 19, 249-265.
- Evans, J. St. B. T., Handley, S. J., & Over, D. E. (2003). Conditional and conditional probability. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 321–335.
doi:10.1037/0278-7393.29.2.321
- Evans, J. S. B., & Newstead, S. E. (1980). A study of disjunctive reasoning. *Psychological research*, 41(4), 373-388.
- Evans, J. St. B. T., Over, D. E., & Handley, S. J. (2005). Suppositions, extensionality and conditionals: A critique of The mental model theory of Johnson-Laird & Byrne (2002). *Psychological Review*, 112, 1040–1052.
- Fillenbaum, S. (1974). Or: Some uses. *Journal of Experimental Psychology*, 103(5), 913.
- Gelman, S. A., & Pelletier, F. J. (2010). Generics as a window onto young children's concepts. *Kinds, things, and stuff: Mass terms and generics*. New York: Oxford University Press. 100-120.
- Goodwin, G. P. (2014). Is the basic conditional probabilistic? *Journal of Experimental Psychology: General*, 143(3), 1214–1241.
- Gotzner, N., Barner, D. and Crain, S. (2020). 'Disjunction triggers exhaustivity implicatures in 4-to 5-year-olds: Investigating the role of access to alternatives', *Journal of Semantics* 37(2), 219-245.

- Grice, H. Paul, (1967). Logic and conversation, in D. Davidson and G. Harman (eds.) 1975, *The Logic of Grammar*, Encino: Dickenson, pp. 64–75.
- Handley, S. J., Evans, J. St. B. T., & Thompson, V. A. (2006). The negated conditional: A litmus test for the suppositional conditional? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32, 559–569.
- Hurley, P. J., & Watson, L. (2018). A Concise Introduction to Logic. 13th edition. *Cengage Learning, Stamford, CT*.
- Johnson-Laird, P. N. (2001). Mental models and deduction. *Trends in cognitive sciences*, 5(10), 434-442.
- Johnson-Laird, P. N., & Byrne, R. M. J. (2002). Conditionals: A theory of meaning, pragmatics, and inference. *Psychological Review*, 109, 646–678.
- Johnson-Laird, P. N., Khemlani, S. S., & Goodwin, G. P. (2015). Logic, probability, and human reasoning. *Trends in cognitive sciences*, 19(4), 201-214.
- Karczewski, D., Wajda, E., & Poniak, R. (2020). Do all storks fly to Africa? Universal statements and the generic overgeneralization effect. *Lingua*, 246, 102855.
- Kass, R. E., & Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association*, 90, 773-795.
- Khemlani, S. S., Byrne, R. M., & Johnson-Laird, P. N. (2018). Facts and possibilities: A model-based theory of sentential reasoning. *Cognitive science*, 42(6), 1887-1924.
- Khemlani, S., Orenes, I., & Johnson-Laird, P. N. (2012). Negation: A theory of its meaning, representation, and use. *Journal of Cognitive Psychology*, 24(5), 541-559.
doi:10.1080/20445911.2012.660913
- Khemlani, S., Orenes, I., & Johnson-Laird, P. N. (2014). The negations of conjunctions,

- conditionals, and disjunction. *Acta Psychologica*, 151, 1-7. doi:10.1016/j.actpsy.2014.05.004.
- Krifka, M. (1987). *An outline of genericity* (Technical Report SNS-Bericht 87-25 Seminar für natürlich-sprachliche Systeme). Tübingen University.
- Krifka, M. (2004). Bare NPs: Kind-referring, indefinites, both, or neither? In R. B. Young & Y. Zhou (Eds.), *Proceedings of the 13th Conference on Semantics and Linguistic Theory* (pp. 180–203). CLC Publications, Cornell.
- Kruschke, J. (2015). *Doing Bayesian data analysis*. New York: Academic Press.
- Lazaridou-Chatzigoga, D., Stockall, L., & Katsos, N. (2019). Contextualising generic and universal generalisations: quantifier domain restriction and the generic overgeneralisation effect. *Journal of Semantics*, 36(4), 617-664.
- Le Bruyn, B. S. W., de Swart, H. E., & Zwarts, J. (2017). Bare nominals. *Oxford Research Encyclopedia of Linguistics*. DOI: 10.1093/acrefore/9780199384655.013.399
- Leslie, S. J. (2007). Generics and the structure of the mind. *Philosophical Perspectives*, 21, 375–403.
- Leslie, S. J., Khemlani, S., & Glucksberg, S. (2011). Do all ducks lay eggs? The generic overgeneralization effect. *Journal of Memory and Language*, 65(1), 15-31.
- Leslie, S. J., & Adam, L. (2022). Generic Generalizations, *The Stanford Encyclopedia of Philosophy*. <https://plato.stanford.edu/archives/fall2022/entries/generics/>.
- Macbeth, G., Razumiejczyk, E., Crivello, M., Bolzán, C., Girardi, C., & Campitelli, G. (2014). Mental models for the negation of conjunctions and disjunctions. *Europe's Journal of Psychology*, 10, 135–149.
- Macbeth, G., Razumiejczyk, E., Crivello, M. C., Fioramonti, M., & Pereyra Girardi, C. I. (2013). The shallow processing of logical negation. *Psychology and Behavioral Sciences*, 2(5), 196-201.

- Machin, D., Campbell, M. J., Tan, S. B., & Tan, S. H. (2011). *Sample size tables for clinical studies*. John Wiley & Sons.
- Newstead, S. E., Griggs, R. A., & Chrostowski, J. J. (1984). Reasoning with realistic disjunctives. *The Quarterly Journal of Experimental Psychology*, 36(4), 611-627.
- Nickel, B. (2010). Generically free choice. *Linguistics and philosophy*, 33(6), 479-512.
- Noveck, I. A., Chierchia, G., Chevaux, F., Guelminger, R., & Sylvestre, E. (2002). Linguistic-pragmatic factors in interpreting disjunctions. *Thinking & Reasoning*, 8(4), 297-326.
- Oaksford, M., & Chater, N. (2009). Precis of Bayesian rationality: The probabilistic approach to human reasoning. *Behavioral and Brain Sciences*, 32(01), 69-84.
- Oberauer, K. & Wilhelm, O. (2003). The meaning(s) of conditionals: Conditional probabilities, mental models and personal utilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 680-693.
- Over, D. E. (2020). The development of the new paradigm in the psychology of reasoning. In *Logic and Uncertainty in the Human Mind* (pp. 243-263). Routledge.
- Pfeifer, N. (2013). The new psychology of reasoning: A mental probability logical perspective. *Thinking & Reasoning*, 19(3-4), 329-345.
- Pfeifer, N., & Sanfilippo, G. (2017). Probabilistic squares and hexagons of opposition under coherence. *International Journal of Approximate Reasoning*, 88, 282-294.
- Politzer, G., & Baratgin, J. (2016). Deductive schemas with uncertain premises using qualitative probability expressions. *Thinking & Reasoning*, 22, 78-98.
- Quelhas, A. C., & Johnson-Laird, P. N. (2017). The modulation of disjunctive sentences. *The Quarterly Journal of Experimental Psychology*, 70(4), 703-717.
- Ragni, M., Kola, I., & Johnson-Laird, P. N. (2018). On selecting evidence to test hypotheses: a

- theory of selection tasks. *Psychological Bulletin*, 144(8).
- Repp, S., & Spalek, K. (2021). The role of alternatives in language. *Frontiers in Communication*, 6, 682009. doi: 10.3389/fcomm.2021.682009.
- Rooij, R. V., & Schulz, K. (2020). Generics and typicality: a bounded rationality approach. *Linguistics and Philosophy*, 43(1), 83-117.
- Rips, L. J. (1994). *The psychology of proof*. Cambridge, MA: MIT Press.
- Suppes, P., & Hill, S. (1992). *First course in mathematical logic*. Mineola, NY: Dover Publications.
- Skovgaard-Olsen, N. (2020). Relevance and conditionals: A synopsis of open pragmatic and semantic issues. In *Logic and Uncertainty in the Human Mind* (pp. 192-206). Routledge.
- Sterken, R. K. (2015). Generics in context. *Philosopher's Imprint*, 15(21).
- Sterken, R. K. (2017). The meaning of generics. *Philosophy Compass*, 12(8), e12431.
- Tessler, M. H., & Goodman, N. D. (2019). The language of generalization. *Psychological review*, 126(3), 395.
- Wang, M., & Liang, L. (2022). The raw datasets of Experiments 1-4. <https://osf.io/zyjqs/files/>
- Wang, M., & Yao, X. (2018). The dual reading of general conditionals: The influence of abstract versus concrete contexts. *Quarterly Journal of Experimental Psychology*, 71(4), 859-869.
- Wang, M., & Zheng, L. (2021). Does the inclusive disjunction really mean the conjunction of possibilities? *Cognition*, 208, 104551. doi: 10.1177/17470218221089331.
- Yin, P., Sun, J., & Wang, M. (2020). The relative difficulty of negations of conjunctions and disjunctions—a mental model perspective. *Cognitive Processing*. doi: 10.1007/s10339-020-01004-3.

Appendix A

There are fifteen boxes of balls below. Each box contains the set of some balls in a parenthesis. Please judge whether the underlined statement for each item is true or false. Please answer the following items in the given order. Please tick your answers.

- (1) There is one box of balls {ten blue plastic balls, ten blue non-plastic balls, ten non-blue plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (2) There is one box of balls {ten blue plastic balls, ten blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (3) There is one box of balls {ten blue plastic balls, ten non-blue plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (4) There is one box of balls {ten blue plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (5) There is one box of balls {ten blue non-plastic balls, ten non-blue plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (6) There is one box of balls {ten blue non-plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (7) There is one box of balls {ten non-blue plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold)..
- (8) There is one box of balls {ten blue plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (9) There is one box of balls {ten blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (10) There is one box of balls {ten non-blue plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (11) There is one box of balls {ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).
- (12) There is one box of balls {ten blue plastic balls, ten blue non-plastic balls, ten non-blue plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).

(13) There is one box of balls {ten blue plastic balls, ten blue non-plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).

(14) There is one box of balls {ten blue plastic balls, ten non-blue plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold).

(15) There is one box of balls {ten blue non-plastic balls, ten non-blue plastic balls, ten non-blue non-plastic balls}. For the box of balls, the statement “it is not true that balls are blue or plastic” (holds doesn’t hold)..