Separating the availability and accessibility of *de re* and *de dicto*

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Abstract. The *de re*/*de dicto* ambiguity captures the intensional referential properties of DPs. Formal frameworks (e.g. the scope-based theory, the situation pronoun theory, etc.) have actively relied on nuanced judgments data to model the different semantics under *de re* and *de dicto* readings. Nevertheless, inconsistent judgments suggest informal judgment collection method is insufficient. We reported three controlled experiments to systemize the truth-value judgment pattern of *de re/de dicto* readings. Via two quantitative metrics of the judgment distribution, we distinguished two concepts (*reading availability* vs. *reading accessibility*) that capture whether the reading is licensed by the semantics of the grammar and whether the reading can be easily obtained under a random context. We concluded that while our data support the availability in the grammar for both the *de re* and *de dicto* readings, *de re* readings overall exhibited bimodal judgments and had lower accessibility rate while the accessibility rate of *de dicto* was at ceiling; the *de re* accessibility decreased given more *de re* terms in the proposition and was also affected by the DP's syntactic position as well as idiosyncratic contexts. More broadly, the experimental results support the advantage of including quantitative data collection for nuanced semantic judgments.

Keywords. *de re/de dicto* ambiguity; truth-value judgment; quantitative method

1. Introduction. The sentence *Sue wants to marry a plumber* has two interpretations, described as the *de re*/*de dicto* ambiguity. Under the *de re* interpretation, the sentence is true if there is a plumber in the actual world that Sue wants to marry, even if Sue might not know he is a plumber. Under the *de dicto* reading, the sentence is true if Sue wants to marry whoever is a plumber and that she does not have to have a particular person in mind. In natural language semantics, this *de re*/*de dicto* interpretation captures DP referential properties in intensional domains[1]. In general, *de re* DPs pick out specific individuals in the actual world and for propositional attitude reports, the attitude holder needs not commit to the referential association between the linguistic expression and the individual entity. On the other hand, the referential association between *de dicto* DPs and its mapping entity only exist in the possible worlds

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[1] As early as Aristotle, *de re*/*de dicto* related linguistic phenomena have been observed and discussed. Yet this pair of Latin term was not intensively applied until the Medieval period by Thomas Aquinas. The adoption of the terms in philosophy and linguistics was initiated by Frege, Russell, and Quine but the current sense of *de re* and *de dicto* is far away from and not intuitively related to the literal meaning of the terminology (*de re*: 'of the thing', *de dicto*: 'of what is said') (von Fintel & Heim, 2011). Therefore, it is clearer to introduce the *de re*/*de dicto* distinction via a contextualized example. For more details of terminology development, see Keshet and Schwarz (2019).

introduced by the intentional operator, and consequently, the association might not hold true in the actual world.

This paper examines current judgment collection methods that provide empirical semantic judgment for formal frameworks and reports three experiments with the goal to highlight the necessity of getting quantitative judgments for nuanced semantic readings. The first section lays out the theoretical framework, pinpoints inconsistent judgments in the literature, discusses the adequacy of judgment gathered from armchair intuitions, and raises the motivation for a quantitative approach. The second section reports the results of three controlled truth-value judgment experiments that tested whether English speakers could get both *de re* and *de dicto* readings of designed sentences which theoretically admit both readings. Given the observed judgment variation, the final section provides a unifying account that addresses both the mode and the variation of semantic judgments.

Based on the judgment data, we distinguish two concepts around the nuanced semantic readings: the reading availability and the reading accessibility. The availability of one reading of one proposition is assumed to be determined by the proposition's truth condition which is derived from the intrinsic grammar and the compositional rules. Depending on the truth conditions and the context where the proposition is evaluated, the availability has a binary outcome which corresponds to its truth-value. On the other hand, the reading accessibility refers to the easiness for native speakers to arrive at the claimed reading in a natural linguistic context (e.g. reading, communication, etc.). It is a continuous variable – low reading accessibility indicates a large variation in the truth-value judgment. It can be caused by the meaning sophistication, grammatical complexity of the proposition, confounding and distractive information in the context, or the heterogenous language processing behavior of the speakers. We expect these two terms to account for the observed judgment patterns of *de re* and *de dicto* readings. We refer the readers to the experiment and conclusion sections for more discussion.

1.1. A BRIEF OVERVIEW OF CURRENT THEORETICAL FRAMEWORKS. There have been various semantic frameworks that aim to formalize the two readings of DPs and generate accurate predictions for reading availability given multiple linguistic environments. These include the scope-based theory (Elliott, 2020; Keshet, 2008, 2011), the intensional variable theory (Percus, 2000), the presupposition projection theory (Romoli & Sudo, 2009), and the concept generator approach (Charlow & Sharvit, 2014).

The traditional scope-based theory posits that in the logical form *de re* DPs need to outscope the intensional operator to achieve the reading assigned in the actual world (see Cresswell & von Stechow, 1982; Fodor, 1970; Russell, 1905 among others). Yet this LF movement could alter the quantificational relation between this DP and the intensional operator and diverge nontrivially from the intended reading (as shown in (1)).

(1)   If [everyone in this room]*de re* is outside, it would be empty.
       LF: [every x in this room in w_0]
           [if [x were outside in w_1] [the room would be empty in w_1]]

       a. Intended meaning:
       For everyone in this room, if all of them are outside, it would be empty.
       b. # LF meaning:
       For every x in this room, if x is outside, it would be empty (which is not logical because it implies that anyone in this room going outside will make this room empty).

Percus (2000) proposes the situation pronoun solution to escape the scope theory paradox. Specifically, the situation pronoun of a given structure is taken as an unpronounced intensional variable that works as a variable over possible worlds. It is bound by a higher lambda abstractor to avoid the random world index assignment. In this way, DPs can attain the *de re* interpretation via the logical binding of intensional variables while remaining *in-situ*, as shown in (2).

(2)   If [everyone in this room]*de re* were outside, it would be empty.
       LF: λw_0 [$_{S1}$ if [$_{S2}$ λw_1 [$_{S3}$ everyone in this room in w_0 were outside in w_1]
                      [it would be empty in w_1]]]

Nevertheless, this silent pronoun approach is beset by overgenerated predictions that do not seem to be realized by natural language (see Percus, Keshet (2008), and Romoli and Sudo (2009) for possible constraints based on the binding relation in order to curb the overgeneration).

       In contrast to a situation pronoun account, Keshet (2008) proposes *split intensionality* which is based on the traditional scope-based theory with the employment of a type-shifting operator ^. This operator not only turns an extensional argument to an intensional one, but also takes on the functionality of assigning different world indices to its upper and lower regions in the LF. Consequently, the operator ^ shoulders the responsibility of assigning intensional readings to local linguistic segments and leaves the intensional operator (e.g. *if* in this case) in charge of the quantificational force assignment. Thus, DPs can be interpreted *de re* once they are raised above ^ while remaining in the scope of the intensional operators (as shown in (3)).

(3)   If [everyone in this room is outside]*de re*, it would be empty.
       LF: [if [**everyone in this room λ_1 ^ t_1** were outside] [this room would be empty]]

In addition to this challenge, phenomena like the wide scope indefinites and the conflict between quantificational force and *de re*/*de dicto* scope readings among multiple quantifiers brought up by Bäuerle (1983) are all being actively tested under the theory of *split intensionality* and its offspring in Keshet (2011) and (Elliott, 2020).

       In addition to the scope-based theories and the intensional variable theory, Romoli and Sudo (2009) propose accounting for *de re*/*de dicto* disambiguation via presupposition projection resolution. In this approach, *de re* readings are obtained when the presupposition is resolved globally, and *de dicto* readings are obtained when it is resolved locally. Sentence (4) is an example for this approach when the DP is a definite description.

(4)   John thinks that the president is smart.
       a. *de re*: $\exists!x$: **president(x)** and John thinks that ιx[president(x)] is smart
       b. *de dicto*: John thinks that $\exists!x$: **president(x)** and ιx[president(x)] is smart

       Additional semantic strategies have also been applied to model readings in more intricate linguistic structures. For example, the concept generator *G* has been proposed to address the *bound de re* reading under a multiple-guise scenario in (5) where inside the embedded attitude complement, the QNP *every female student* is interpreted *de re*, the co-indexed possessive pronoun *her* is *de re*, and the NP possessee *mother* is *de dicto* (Charlow & Sharvit, 2014).

(5)   John believes that every female student$_i$ likes her$_i$ mother.
       LF: John believes-w_0
          [$\lambda_8 \lambda_9 \lambda_1$ [every female student-w_0
                  [λ_2[[$G_8 t_2$]-w_1 likes-w_1 [G_9 her$_2$]-w_1 mother-w_1]]]]

Truth condition of a *multiple-guise scenario*:
"John comes into contact with every actual female student more than once, and each actual female student appears each time in a different guise, but in John's mind the mapping between women and guises is one-to-one. If other words, if the same woman appears in two different guises, John fails to recognize this and thinks he came into contact with two different women." (p.3)

For example, like (5), neither the scope-based approach nor the basic situation variable approach is sufficient to model different possible world indices for a pair of binding DPs inside a single embedded proposition (cf. Cresswell & von Stechow, 1982).

This brief sketch, with cases from (1) to (5), illustrates how theories rely on new pieces of linguistic data to evolve. Importantly, those linguistic data are not only made of a single proposition, but also its truth-value judgment from linguists based on the corresponding context. This is what Tonhauser and Matthewson (2015) claim as the "complete" profile of linguistic data and, of course, the heart of research on natural language meaning.

1.2. THE NEED FOR QUANTITATIVE RESEARCH. While the truth-value judgments of *de re*/*de dicto* interpretation, or in other words, the availability or unavailability of certain reading is the basis for theory development, two obstacles might keep theorists from obtaining accurate judgments.

Firstly, inconsistent judgments exist in the literature about the same DP structure in nearly identical linguistic environment. For instance, von Fintel and Heim (2011) employ sentence (6) to argue that some cases exhibit genuine ambiguity of *de re* and *de dicto* interpretation. While they claim that *your abstract* in (6) can be both *de re* and *de dicto* under appropriate contexts, Nelson (2019) points out that the embedded DP *her brother* in (7), which has the same internal DP structure as *your abstract*, cannot be interpreted *de re*.

(6) John believes that [your abstract]*de re/de dicto* will be accepted.

　　a. *de re* truth condition:
　　John reviewed an amazing abstract and thought that it will be accepted. The speaker of this belief report has the additional knowledge that the abstract is written by the addressee "you" and thus utters (6).

　　b. *de dicto* truth condition:
　　Suppose the addressee "you" is a famous linguist and John knows that no matter what abstract you write it will be accepted. John might not know the specific content of the abstract or even which abstract is yours, but based on his general belief and knowledge, your abstract will be accepted.

　　　　　　　　　　　　　　　　　　　　　　　　　　(von Fintel and Heim 2001:157)

(7) # Sally believes that [her brother]*de re* is happy.

　　(Supposed) *de re* truth condition:
　　Sally hears a person laughing outside on the street who happens to be her brother. She believes that the person is happy, even though Sally does not recognize the person is her brother.

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Nelson argues that the belief holder *Sally* does not conceive in her mental state the target subject (i.e. Sally's brother in real world) as what the embedded DP describes. Nelson stands in the perspective of the belief holder and argues that *de re* should not be available, while von

Fintel and Heim advocate *de re* as a natural language phenomenon. These two underlying rationales bring forward different judgments. In order to see whether Nelson's reasoning is representative, it helps to gather judgment data from a representative pool of native speakers. Furthermore, some might argue that it could also be some idiosyncratic linguistic features, e.g. *your* vs. *her*, or the inanimate vs. animate possessees, that result in the unexpected inconsistency in judgment. Yet we could not commit to these hypotheses without carefully controlling these factors and collecting judgments using quantitative methods.

A second example of judgment inconsistency can be seen in Charlow and Sharvit (2014). As pointed out in their own paper, for the very sentence (5), Ezra Keshet notes that the possessee *mother* is more natural under a *de re* reading while the authors claim that it leans more towards the *de dicto* reading. Although the authors further prove that the reading assignment of *mother* does not theoretically affect the core of *bound de re* readings, this is a clear case where trained linguists can also hold disagreeing judgments.

Furthermore, real-life instances can also provide data not already captured by theoretical prediction. In theory, cardinal DPs cannot be interpreted *de re* (Keshet, 2008; Musan, 1995; Romoli & Sudo, 2009). Yet sentence (8), which is a real-life utterance collected at an economic conference reported on *Language Log* by Liberman (2005), goes against this theoretical prediction.

(8)　　U.S. forces in Iraq have intentionally killed [12 journalists]*de re/de dicto*.

　　a. *de re* truth condition:
　　There were 12 journalists killed by the U.S. forces in an attempt but the forces did not know the people they killed were journalists.

　　b. *de dicto* truth condition:
　　The U.S. forces targeted journalists and killed 12 of them intensionally.

(Liberman on October 23, 2005)

According to the speaker's paraphrase after the conference, the cardinal DP *12 journalists,* which is embedded by the intensional adverb *intentionally*, does have the *de re* reading. Therefore, it is possible that the theoretical prediction of the cardinal DP reading is generalized out of limited empirical data, but more rigorously speaking, we have no ground for claiming this until we gather more judgments from varying sentence items with cardinal DPs.

Given cases discussed above, judgment inconsistency may simply result from idiosyncratic noises or speaker variability which would not change what we know about *de re*/*de dicto* so far. But sceptic voices may utilize the inconsistency to challenge the grammatical groundings and the intrinsic reading availability for *de re* and *de dicto*. Fortunately, given the prevalence of crowdsourcing tools that make collecting quantitative data much easier than before, it is optimal to design standard methods that provides reliable linguistic data to achieve a fine-grained understanding of the judgment distribution. For example, with a minimal-pair design, we can pinpoint the exact culprit that contributes to reading unavailability; with the control of contexts, we can eliminate distractive effects from discourse information; and with judgments from multiple speakers, we can minimize individual biases resulting from different linguistic backgrounds, etc. (see supporting views from Tonhauser and Matthewson (2015), Davidson (2020), Gibson and Fedorenko (2010) among others). For these reasons, quantitative empirical evidence via standardized procedures can provide data for a certain phenomenon which is, in Tonhauser and Matthewson's (2015) terms, "complete, stable, and replicable."

A subsequent urge for adopting a quantitative data collection method is that outside linguistics, research in other relevant fields (e.g. philosophy, psychology, law) tend to claim that when a sentence can be interpreted both *de re* and *de dicto*, the *de re* one is preferred, indicating that a *de re* reading is easier to obtain and more accessible to readers. For example, Jaszczolt (1997) claims that the referential property of definite noun phrases is more salient in communication and thus argues for a "default *de re* reading". Her claim finds its allies both in the realm of cognitive science, developmental psychology (Apperly & Butterfill, 2009; Apperly & Robinson, 2003; Low & Watts, 2013; Mitchell et al., 1996; Robinson & Apperly, 2001) and in the legal settings as well (Anderson, 2013).

According to various findings from the psychology experiments, when the participant and the experiment protagonist both receive the identity information of an object but the protagonist remains partially ignorant of the object's certain properties, both children and adult participants fail to utilize the properties only known to the protagonist to refer to the object when put into the protagonist's shoes. These observations hinge on theory of mind and foster an egocentrism or reality bias explanation. The easiness of accessing information in actual reality but not others' mental status supports the "default *de re*" hypothesis.

When it comes to the legal settings, Anderson (2013) reports a prevalent inadequacy in statutory interpretation due to first the failure to recognize the *de re*/*de dicto* ambiguity in a statute's literal text and then the bias toward the *de re* reading. An example is reading the definition of genocidal intent in (9) during the trials conducted by International Criminal Tribunal for Rwanda.

(9)   Genocidal intent: "intent to destroy a racial, ethnical, religious, or national group".

a. *de re* truth condition:
There exists some X that is in fact a national, ethnic, racial or religious group, and the perpetrator intended to destroy X.

b. *de dicto* truth condition:
Perpetrator intends to destroy some group as "an ethnic group" (or as "a national group", or as "a racial group", or as "a religious group").

On one hand, holding a *de re* interpretation would lead to a rigorous and even dogmatic examination of whether the suffered Tutsi group belongs to one of the four groups defined in the statute. On the other hand, the *de dicto* reading would encourage more examination on whether the perpetrating Hutu group regards Tutsi as one of the four. Despite this ambiguity, the early ICTR proceedings were dominated by debates about the first group identity issue. Even though the *de dicto* highlight was ultimately brought up in this specific case, there were still other cases where the ruling was based on a *de re* interpretation.

While the interdisciplinary tendency suggests a *de re* preference, such a preference has not been suggested within linguistics, nor has there been much investigation of which reading is systematically easier to access and what are the affecting factors. By varying contextual information, providing multiple judgment response options, and collecting judgments from multiple native speakers, experimental linguistic studies can offer clearer views on these issues.

Despite the need for more carefully controlled experiments in natural language semantics, there has not been any experimental work that we are aware of that directly looks at the availability and the accessibility of *de re*/*de dicto* readings in truth-value judgment tasks. While Hackle et al. (2009) studies *transparent* versus *opaque* readings in intentional transitive

predicates using online reading times and gathers evidence supporting the scope-based theory over the situation pronoun approach, their finding— QRed transparent DPs facilitate the processing of the following ACD site—does not directly speak to the judgment problems we introduced above. Therefore, our study fills the gap by providing a simple experimental template that systematically explores the reading availability/accessibility as a starting point of this research program.

1.3. RESEARCH GOAL. We aim to set up a benchmark for systematically obtaining stable, replicable, and transparent judgments of *de re/de dicto* readings and define the quantitative metrics to represent the availability and accessibility of the two readings across carefully controlled contexts.

2. Experiment one. Given the above-mentioned judgment inconsistency and the debated asymmetry between *de re* and *de dicto* accessibility, Exp.1 asked whether *de re* and *de dicto* readings are equally available and accessible to native English speakers given highly controlled contexts that in theory allow both readings.

2.1. PARTICIPANTS. 120 adult speakers of native English were recruited in our study through Amazon's Mechanical Turk. They received a $2 compensation after finishing the experiment.

2.2. MATERIALS AND DESIGN. The experiment was essentially a truth-value judgment task where participants processed the context and gave their judgment about a target sentence based on the context. There were four contexts in total for each participant (context example in Table 1, full experiment materials in Appendix 1) each of which had a protagonist holding an attitude towards a newly encountered object.

CONTEXT

Julie is one of the judges of an ongoing poetry competition. The best poem that she has read so far is an extremely intriguing poem about the ocean. She believes that this poem will win the competition. Julie remembers being told that Nicole, one of the best-known poets, submitted a poem about the ocean to the competition. Therefore, Julie concludes that this poem must be written by Nicole and the first prize will be going to her. However, this poem was actually written by Elizabeth, a younger and lesser-known poet. It is just a coincidence that the two poets wrote about the same topic.

JUDGMENT QUESTION

According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement.

Target Sentence I:
Julie believes that **Elizabeth's poem** will win the competition. (*de re*)
Target Sentence II:
Julie believes that **Nicole's poem** will win the competition. (*de dicto*)

Table 1: Example context in Exp.1

There were two terms in the contexts that described the target object. The protagonist (e.g. *Julie*) associated one term *X* (e.g. *Nicole's poem*) to the target object. But in reality, *X* was not correct and the correct descriptive term *Y* (e.g. *Elizabeth's poem*) was not known by the protagonist. This scenario led to a *de dicto* reading if the wrong term *X* was used in reporting the protagonist's belief and a *de re* one if the correct term *Y* was used. Note that the critical terms we used were definite NPs in the structure of *someone's belonging*. So, technically speaking, the designed *de dicto* reading was not purely *de dicto* because this *de dicto* term picked up an individual entity in the actual world and diverged from the pure *de dicto* sense where the protagonist believes that whichever entity that is *someone's belonging* will, for example, win the competition. Though this juxtaposition of *de re* and *de dicto* readings was closer to the *transparent* and *opaque* readings of DPs, the underlying design rationale was to keep the contexts and sentences for each reading as similar as possible to each other (e.g. simply a switch in proper names, for example) to prevent uncontrolled contextual factors from affecting the judgments.

Under this design and given a designated context, both readings were true predicted by theories (Romoli & Sudo, 2009; von Fintel & Heim, 2011). Therefore, the null hypothesis was that participants should be able to access both readings equally successfully. If the null hypothesis were not met, further explanations would be needed.

For each scenario, the participants were presented with one of the two target sentences and were asked to drag a slider bar to show to what extent they agree or disagree with the sentence. The two ends were labeled "highly agree" (score 100) and "highly disagree" (score −100). The slider always started from the middle labeled "uncertain" (score 0). After the participants dragged the slider to wherever that made the most sense, a judgment score was recorded. One of the advantages of a slider bar is that the continuous judgment score displays increased granularity than binary options or Likert scales. It also has greater sensitivity to reveal the existence of a potential interpretation that would otherwise stay concealed owing to the strong binary or categorical implication in other designs (Marty et al., 2020).

Furthermore, three filler sentences were additionally provided to elicit participants' judgment. Based on the context, one was definitely correct, one was definitely wrong, and the last one was uncertain. Successful judgments of these three sentences indicate the participants were attentive and thus eligible for inclusion in the data analysis.

The experiment had a within-subject design with fully counterbalanced item display. Each participant read four scenarios each coupled with four sentences. Two of the four scenarios were randomly chosen for the *de re* condition and the other two for the *de dicto* condition. We created six lists to achieve a Latin Square design. The participants were randomly assigned to one of the six lists. The order of four stories was randomized, so was the order of the four sentences within each scenario. The position of the "highly agree" label was also counterbalanced as a between-subject control. This treatment was to eliminate the confounding factor that participants might show a bias of dragging the slider to a particular direction. The entire survey was created on Qualtrics and distributed through Amazon's Mechanical Turk[2].

2.3. RESULTS. We analyzed only the participants whose judgment for the correct/wrong filler was at least 75%. 115 participants (95.8%) were retained for the analysis.

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[2] The full experiment survey on Qualtrics can be accessed through the following link:
https://harvard.az1.qualtrics.com/jfe/form/SV_01UTaqO9hkkAcGF

Figure 1 shows that the judgment distribution of the *de re*/*de dicto* sentences among all contexts. While judgments for *de dicto* readings were overwhelmingly accented to in the "highly agree" range, judgments for *de re* readings were bimodal—although more than half of the judgments were agreed with, another large proportion went to the "disagree" edge. Furthermore, *de re* judgments were also more scattered and distributed across the scale, resulting in more intermediate judgments on each side.
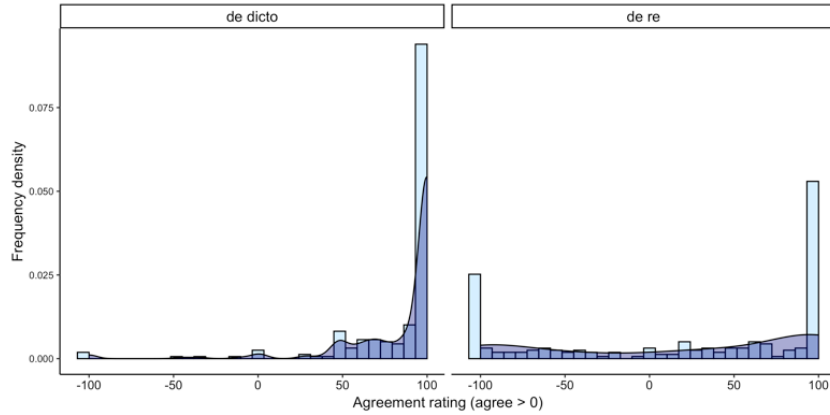

Figure 1: Histogram distribution of truth-value judgments

We further analyzed the proportion of agreement along with the four contexts, assuming that treating the agreement as a binary variable was appropriate based on its non-normal distribution. In Figure 2, the proportion of agreement for *de dicto* judgments were at ceiling for all tested scenarios while *de re* judgments exhibited larger variability across the four conditions with a unanimous lowering effect ($\chi^2 = 79.13$, df = 1, p < .001).
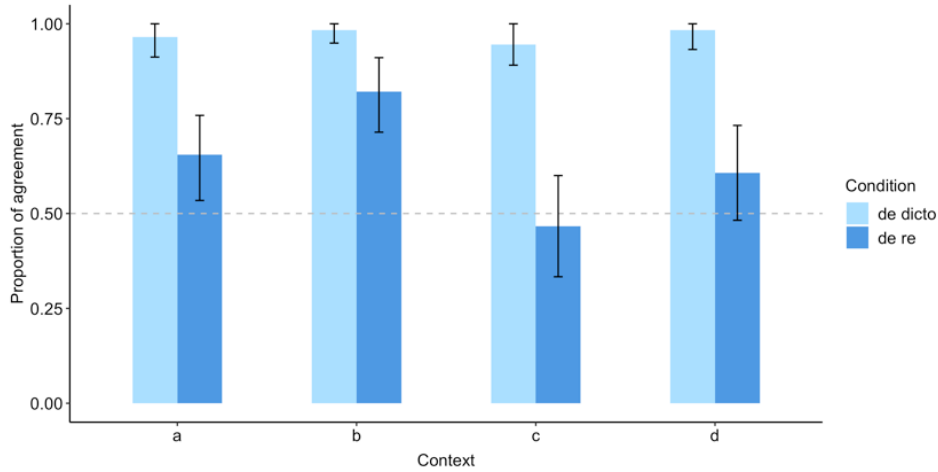

Figure 2: Proportion of agreement based on condition and context[3]

The visually observed effects of *de re*/*de dicto* manipulation and the context were confirmed in a mixed-effects logistic regression analysis (using R package *lme4*). By treating both the *de re*/*de dicto* conditions and the context condition as sum-encoded fixed effects with a random intercept on participant, the *de re* condition was significantly less likely to be agreed upon

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[3] The error bars represent 95% confidence intervals of the agreement proportion sampled via bootstrapping.

compared with the average agreement rate for a random trial (β = -1.61, SE = 0.23, p < .001); additionally, context B had a significantly higher agreement rate (β = 0.96, SE = 0.30, p = .001) while context C accrued a significantly lower agreement rate (β = -0.81, SE = 0.24, p < .001)[4]. The reason to treat context as a fixed effect rather than a random effect was that the contextual effect was also of theoretical interests and that the number of the contexts (N = 4) was not eligible as a random effect.

Furthermore, we explored whether the accessibility of a certain reading exhibits inter-subject differences in these two conditions, with Table 2 displaying the number and proportion of participants organized by their judgment behavior. Given that each participant only judged two trials under each reading condition, it is clear that a preponderance of participants agreed with both *de dicto* readings while the judgment pattern for *de re* was distinctively allocated in the three groups. The fact that 36.5% of the participants only liked one *de re* trial out of two suggests that the failure to obtain the *de re* reading is not merely a group effect and that certain contextual item might play a role in the accessibility of *de re*.[5]

# of Participants	Agree with 0 trial	Agree with 1 trial	Agree with 2 trials	Total
de re	21 (18.3%)	45 (36.5%)	52 (45.2%)	115
de dicto	0 (0.0%)	7 (6.1%)	108 (93.9%)	115

Table 2: Proportion of participants by the judgment behavior

DISCUSSION. By setting up contexts that theoretically allow both *de re* and *de dicto* readings and eliciting native speakers' judgments, we found that while *de dicto* readings were unanimously agreed upon, *de re* readings exhibited bimodal judgments with larger variations across contexts and speakers. While more than 50% of *de re* readings was agreed which supports the availability of *de re*, the disagreement proportion suggests non-trivial factors that affect the accessibility of *de re*. The varying agreement rate of *de re* across the four contexts (suggested by Figure 2) as well as the outstanding proportion of participants who only agreed with one *de re* trial (suggested by Table 2) suggest that idiosyncratic contextual factors affect the accessibility of *de re*. More specifically, the salience of the *de re* DPs in the context, participants' attentiveness to the information flow, and the general naturalness of the setting could all be impactful and await further investigation.

In a post hoc analysis, we found that one feature of the judgment pattern aligns with one existing theoretical prediction, which we did not make a corresponding prediction prior to the experiment. More specifically, the difference in *de re* agreement rates in context A and B versus context C and D supports the Nested DP Constraint proposed by Romoli and Sudo (2009) (10).

(10)   Nested DP Constraint[6]
a. In a nested DP structure [DP1 … […DP2…]], when DP2 is *de dicto*, a *de re* DP1 renders the reading unavailable.
b. # Mary thinks [[the wife]*de re* of [the president]*de dicto*] is nice.

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[4] The syntax of the model is "logit(agree) ~ condition + context + (1|subject)". The reason of using the sum-encoding method was that there is no designed baseline control group to compare against and that it produces more reliable results for interaction terms. We also ran another model "logit(agree) ~ condition * context + (1|subject)" but didn't find significant improvement from the reported one. Please see Appendix 3 for the full statistical report.

[5] Thanks to Alexander Göbel for pointing to an inter-speaker investigation.

[6] See the same observation in Sauerland (2014)

In our study, the target DPs in all of the four scenarios were in the structure of [DP$_2$ ['s DP$_1$]] (e.g., *Nicole's poem*). Contexts A and B manipulated the *de re* and *de dicto* reading of the entire proposition by alternating DP$_2$ (e.g., *Nicole's poem* vs. *Elizabeth's poem*) while DP$_1$ was held true both in the actual world and in the belief holder's mental world. In contrast, context C and D achieved the manipulation by alternating DP$_1$ (e.g., *Haley's brother* vs. *Haley's husband*) while DP$_2$ was held true in both worlds. According to Romoli and Sudo, in context C and D, when DP$_2$ is held in both worlds, the *de re* DP$_1$ would be unavailable. This is consistent with the relatively low agreement rate on the *de re* condition in context C and D compared with that in context A and B (P(agree | C/D = *de re*) = 53.4%, P(agree| A/B = *de re*) = 73.7%, χ^2 = 9.30, df = 1, p = .002). Although this observation should be further confirmed with controlled experiments to ensure that the effect can be attributed to the nested DP structure, we claim our observation is the first experimental support for Romoli and Sudo's Nested DP Constraint.

3. Experiment two & three. While Exp.1 presented the judgment distribution on a single *de re*/*de dicto* manipulation with an additional highlight on the contextual effect, Exp.2 and 3 continued asking whether the accessibility distinction of the two readings as well as the contextual effect extend to other DP structures or more sophisticated propositions. We were driven by this motivation to study the nuanced case of *bound de re* observed in Charlow and Sharvit (2014), their example in (5) repeated here in (11).

(11)   John believes that every female student$_i$ likes her$_i$ mother.
        LF: John believes-w_0
             [$\lambda_8\,\lambda_9\,\lambda_1$ [every female student-w_0
                        [λ_2[[$G_8\,t_2$]-w_1 likes-w_1 [G_9 her$_2$]-w_1 mother-w_1]]]]

        Truth condition of a *multiple-guise scenario*:
        "John comes into contact with every actual female student more than once, and each
        actual female student appears each time in a different guise, but in John's mind the
        mapping between women and guises is one-to-one. If other words, if the same woman
        appears in two different guises, John fails to recognize this and things he came into
        contact with two different women." (p.3)

The crucial *bound de re* renders both the QNP *every female student* and the possessive pronoun *her* the *de re* reading. The reading of *mother* is less deterministic for the theory, but since there were stated inconsistent judgments among linguists (Keshet vs. Charlow & Sharvit), it is also worth investigating. Since there are three critical nominal expressions embedded in the belief report, in order to compare the accessibility of *bound de re* ([*every female student*]$_{de\ re}$, [*her*]$_{de\ re}$, [*mother*]$_{de\ dicto}$) with other readings and determine the reading alternation of which segment influences the accessibility the most, it is necessary to manipulate both the *de re* and the *de dicto* readings for all three segments. Furthermore, since *their mother* can be construed as a nested DP, varying the reading of *mother* could also help replicate the results in Exp.1 that is relevant to Romoli and Sudo's Nested DP Constraint. Therefore, Exp.2 and 3 stacked the two readings for each of the three nominal expressions and constructed a 2 X 2 X 2 design.

3.1. PARTICIPANTS. In Exp.2, 160 participants finished the tasks for a $2 compensation from Amazon's Mechanical Turk. After applying the same data trimming criterion as in Exp.1, data

from 127 participants (79.38%) remained for analysis. As for Exp.3, 120 participants out of 128 (93.75%) who finished the tasks remained for the analysis[7].

3.2. METHODS. We split the 2 X 2 X 2 design into two experiments by treating the *de re*/*de dicto* assignment of QNP as a between-experiment manipulation (QNP was *de re* in Exp.2 and *de dicto* in Exp.3) so that the possessive pronoun and the possessee, serving two within-subject manipulations, took either *de re*/*de dicto* reading within one experiment. Focusing on a 2 X 2 within-subject manipulation eliminated the necessity of participants reading more than four stories.

Within each experiment, the crucial design for each trial follows Exp.1 by positing a context story and a target sentence to gauge participants' judgments. The most significant difference is that while Exp.1 held each context for both conditions constant and only varied the target sentence to test either readings, Exp.2 and 3 held the tested sentence constant across the 2 X 2 design and manipulated the textual information so that there were four variations for each context and each variation theoretically admits one reading out of the 2 X 2 reading matrix (since it is unnatural to set a context that allows both *de re* and *de dicto* readings of the possessive pronoun). Another modification used in Exp.2 and 3 was that since the multiple-guise setting requires a protagonist to encounter the same group of people twice and to assign them disparate descriptive terms each time, we had illustrative pictures accompany the text to facilitate the information tracking procedure. Please refer to Table 3 as an example and Appendix 2 for full experiment materials in the *bound de re* condition. Other than the mapping between contexts with target readings, Exp.2 and 3 had the same randomization, counterbalance, and filler design as Exp.1[8].

CONTEXT
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As a photographer, John likes to rearrange his collections of photographs now and then. One day, he encounters two sets of photos. In the first set, there are three ladies and each is holding a baby. John naturally believes that each of the babies is being held by their mother.

In the second set, three young adults are each wearing a T-shirt with a "2018" logo. John naturally believes that they were graduating students in the year 2018. John also notices that, interestingly, each of the young adults shares a similar smile to one of the ladies in the first photo set. He tries to recall if there is a connection between the young

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[7] The lower inclusion rate in Exp.2 was because those participants were recruited on weekends and the online implementation made it more challenging to gather good data on weekends.

[8] The full experiment survey on Qualtrics can be accessed through the following link:
https://harvard.az1.qualtrics.com/jfe/form/SV_a3Edy4DmQbahUKV

adults and the ladies but memory fails him.

   As a matter of fact, what John fails to recall is three pieces of information. (1) The young adults in the second set of photos were the babies in the first set. They've grown up! (2) The ladies in the first set are actually the babies' grandmother. The three young adults inherit their smile from their grandma who is mistakenly believed by John to be their mother. (3) The second set of photos were taken not in the graduation ceremony but when the three adults were volunteering for an academic conference in 2018.

   Despite the fact that John doesn't remember the correct relationship between the ladies in the first set of photos and the young adults in the second set and that he has several pieces of incorrect information, John spends quite some time appreciating these photos.

JUDGMENT QUESTION

According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement.

Target sentence: Looking at his photos, John believes that [every conference volunteer]_{de re} in the second set has the same smile as [their]_{de re} [mother]_{de dicto}.

Table 3: The canonical *bound de re* scenario in Charlow & Sharvit (2014)

3.3. RESULTS. Figure 3 shows via histogram the agreement distribution from "highly disagree" (-100) to "highly agree" (100) of the target sentences by the *de re/de dicto* reading assignment of the QNP, the possessive pronoun, and the possessee. Consistent with findings in Exp.1, judgments tend to gather around both ends of the scale. Crucially, judgment for the *bound de re* case in the bottom left graph shows that while a salient proportion of the judgments is on the disagreement end, the majority lies on the agreement end. This clearly shows that *bound de re* is available. Yet compared with the control condition with three *de dicto* terms in the bottom right graph, *bound de re* was less likely to find agreement by participants (judging from the height of the vertical bar on the very end) and attained more intermediate judgments along the slider.

   Figure 4 shows the agreement proportion of the eight conditions. By visually looking at the bars, the second column out of eight represents the canonical *bound de re* condition whose

agreement rate is slightly above the chance level. Overall, the *de re* condition of the possessee has a clearly lower agreement rate (around 0.5) than the *de dicto* condition ($\chi^2 = 23.63$, df = 1, p < .001). Figure 5 displays the agreement proportion by both the condition manipulations and the contexts. A visual examination shows a clear contextual effect because of the conspicuous lowering agreement rate for readings in the fourth context. Apart from the fourth context, the *bound de re* reading in the other three contexts was well above the chance level, indicating that *bound de re* was largely available but its accessibility was moderated by idiosyncratic post-semantic reasons. The peculiarity of the fourth context was neither expected nor designed because before the experiments all the materials were checked for the naturalness and soundness by the author, the advisor, and one native English consultant.
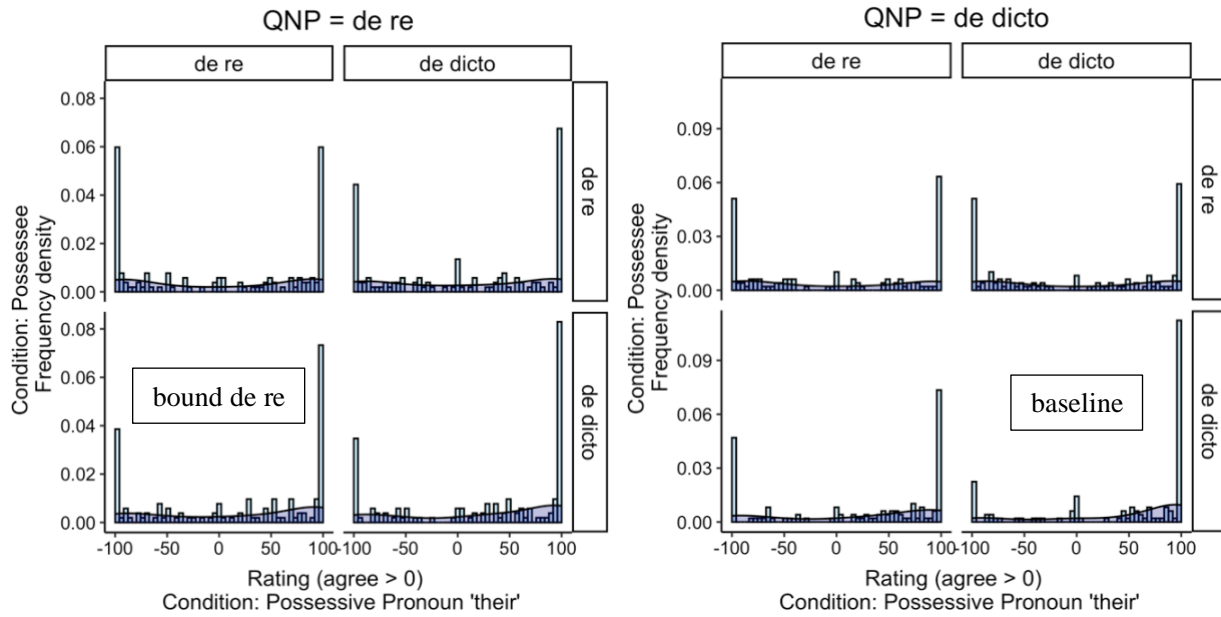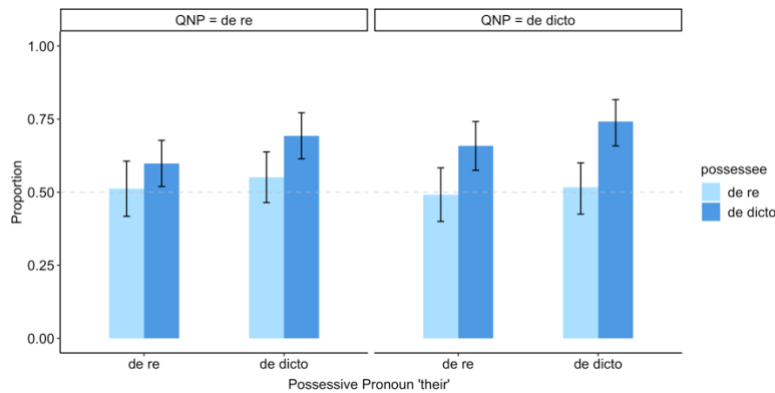

Figure 3: Agreement distribution in Exp.2 & 3

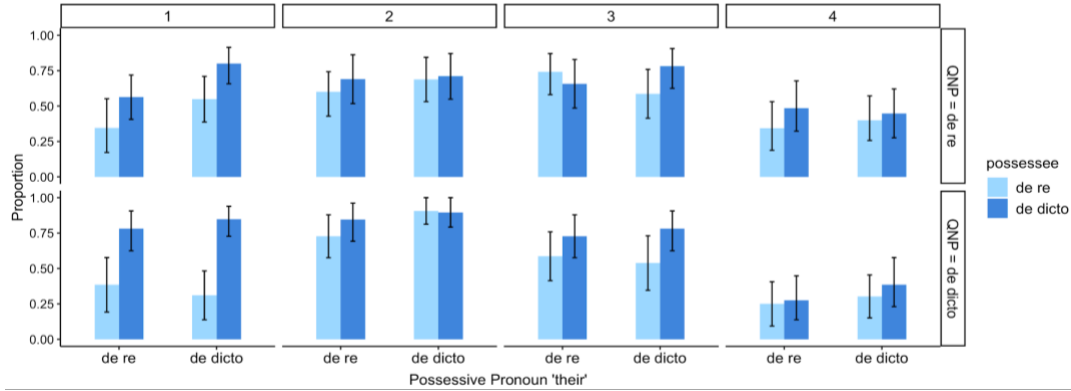Figure 4: Agreement proportion by condition[9]

Figure 5: Agreement proportion among conditions and stories[10]

The effects of *de re/de dicto* manipulation on agreement were further analyzed using a logistic mixed-effects model. The maximal model had one random intercept for participants and three fixed-effects variables to indicate the *de re/de dicto* assignment of the three nominal terms. The fourth fixed-effect variable was the story plus an interaction term between the story and each of the three nominal terms[11]. All the fixed effects were sum-coded.

The results show that while *de re* QNPs did not significantly affect the probability of agreement (β = -0.06, SE = 0.10, p = .561), *de re* possessive pronouns (β = -0.19, SE = 0.08, p = .02) and *de re* possessees (β = -0.42, SE = 0.08, p < .001) did significantly lower the agreement rate. Compared with the average agreement rate across the four stories and controlling the reading assignments of the three terms, story two (β = 0.96, SE = 0.15, p < .001) and three (β = 0.41, SE = 0.14, p = .003) were more likely to be agreed upon. The interaction terms reveal more about which reading manipulation was the most effective under which context. Compared with the average agreement rate for the *de re* QNP condition, story two had a significant lower rate (β = -0.50, SE = 0.15, p < .001). Compared with the average agreement rate for the *de re* possessee condition, story one had a significantly lower rate (β = -0.54, SE = 0.15, p < .001).

3.4. DISCUSSION. Exp.2 and 3 tested the accessibility of *de re* and *de dicto* in the *bound de re* phenomenon. We confirmed that the canonical *bound de re* structure ([QNP]*de re*, [Possessive pronoun]*de re*, [Possessee]*de dicto*) was available but its accessibility was lower than the control condition where all the three terms were *de dicto*. Generally speaking, Exp.2 and Exp.3 replicated the finding of Exp.1 in showing that *de re* was less accessible than *de dicto* by its lower agreement rate. But the accessibility of *de re* also depended on the nominal term's syntactic features – the effect of *de re/de dicto* variation on the agreement rate was significantly salient for possessees but nearly negligible for QNPs. Furthermore, the general pattern of reading accessibility was also influenced by specific contexts.

The strong effect of reading difference on the possessee doesn't entirely support Keshet's observation that a *de re* possessee is more felicitous; it is, on the other hand, in line with the

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[10] The error bars represent 95% confidence intervals of the agreement proportion sampled via bootstrapping.

[11] The syntax of the model is "logit(agree) ~ (QNP + pronoun + possessee)*story + (1|subject)". We've also fitted another model "logit(agree) ~ QNP + pronoun + possessee + story + (1|subject)" but the anova() test showed the former one outperformed the latter. The reason to take story as a fixed effect was that (1) Figure 5 exhibits an obvious disparity of the agreement pattern among the four contexts—treating the story as a fixed effect can perform post hoc tests for which context differs from the other; (2) the limited story item makes it statistically inappropriate for a random effect. Please refer to Appendix 3 for the full statistical report.

nested DP theory proposed by Romoli and Sudo (2009). The lack of effect for QNPs echoes with numerous observations in theoretical work that both *de re* and *de dicto* readings for QNPs are felicitous (e.g. Keshet, 2008; May, 1978; Romoli & Sudo, 2009 among others). Going back to the claim of *bound de re* in Charlow and Sharvit (2014), these two experiments prove informative in confirming that *bound de re* is available, though with varying accessibility compared with other readings tested in this experiment.

4. General discussion. In a series of three experiments, we provided quantitative evidence of the availability and accessibility of *de re* and *de dicto* readings both in simple attitude propositions and more complex structures. In Exp.1 where the given contexts admitted both interpretations, our data support a picture in which both readings were available but the accessibility of the two readings differ: *de dicto* readings were always accessible but the accessibility of *de re* was bimodal. In Exp. 2 and 3 where the complex contexts were controlled to admit only a single interpretation, we found the judgments were strongly bimodal. In general, the more *de re* DPs a sentence contained, the lower agreement rate the sentence had. At the same time, the syntactic position of the *de re* DP also affected its accessibility. Furthermore, across all three experiments, the accessibility of *de re*/*de dicto* readings was affected by unplanned idiosyncratic contexts.

4.1. THE QUANTITATIVE METRICS OF AVAILABILITY AND ACCESSIBILITY. To better interpret the judgment distributions in the three experiments, we bring up the concept of reading availability and reading accessibility which characterize the features of the judgment distribution. We assume that one designated reading is available when it is agreed by more than 50% of the judgments in an experimental setting. In another word, if the mode of judgments of a certain reading clusters around "highly agree" in our study, we regard this reading available. Reading availability also corresponds with the statistic term "representativeness": a reading is available when a representative group of native speakers agree with this reading. It would also be equivalent to the fact that the grammar of this language licenses this reading, if we assume that grammar is by itself a representative set of rules that characterizes how a language work among the native speakers. We take the term "reading availability" to connect a theoretical notion that the grammar licenses the reading with an empirical metric that more than half of the sampled speakers agree with this reading.

In contrast, we regard the accessibility of a certain reading as another concept which presupposes the availability of that reading and further asks how easy it is to obtain that reading given a random context or scenario. Reflected on a judgment distribution, the reading accessibility is concerned with the degree of variation that does not align with the mode, i.e. the "agree" label: if there is great variability, the probability of one participant judging the reading to be true decreases and thus the accessibility is reduced. Under the linguistic context, a reading's accessibility could be determined by factors related to language comprehension or contextual factors irrelevant of the critical experimental design.

We argue that this pair of terms serves an effective linking hypothesis to map the behavioral distribution gathered in experiments to appropriate interpretation of the tested reading: once the availability of a certain reading is attested in quantitative experiments, the reading can function as empirical evidence to facilitate theory development, while the variation of the judgment can be attributed to factors irrelevant to the reading itself.

4.2. MODELING THE AVAILABILITY OF *DE RE* AND *DE DICTO*. In this section we discuss possible formal models for the *de re* and *de dicto* readings that were found to be available in our

experiments. As the *bound de re* readings have been modeled in Charlow & Sharvit (2014), this subsection focuses on the readings from Exp.1. In particular, since what Exp.1 tested was technically the *de re* reading and the non-canonical *de dicto* reading (dubbed as "partial *de dicto* reading" here), we illustrate them and by contrast incorporate the modeling of the pure *de dicto* reading as well.

We begin with a scope-based theory to characterize the meaning difference between the three target readings. As shown in the logical forms from (12) to (14), two crucial features at play are (a) the scopal interaction between the intensional quantifier *believe* and the two properties that refer to the embedded subject and (b) the definiteness of this embedded subject.

(12)   *de re*: Julie believes that [Elizabeth's poem]$_{de\ re}$ will win.

$\lambda w_0 \exists!x[poem_{w0}(x) \wedge author_{w0}(Elizabeth)(x) \wedge \forall w[BEL_{w0}(Julie, w) \rightarrow [win_w(x)]]](w_0) = 1$ iff there is a particular x such that it is a poem and written by Elizabeth in world w_0. In all the possible worlds w that represent what Julie believes in world w_0, x wins the competition in w.

(13)   *partial de dicto*: Julie believes that [Nicole's poem]$_{de\ dicto}$ will win.

$\lambda w_0 \exists!x[poem_{w0}(x) \wedge \forall w[BEL_{w0}(Julie, w) \rightarrow [author_w(Nicole)(x) \wedge win_w(x)]]](w_0) = 1$ iff there is a particular x such that it is a poem in world w_0 and in all the possible worlds w that represent what Julie believes in world w_0, x is written by Nicole in w and x wins the competition in w.

(14)   *pure de dicto*: Julie believes that [Nicole's poem]$_{de\ dicto}$ will win.

$\lambda w_0 \forall w[BEL_{w0}(Julie,w) \rightarrow \exists x[poem_w(x) \wedge author_w(Nicole)(x) \wedge win_w(x)]] (w_0) = 1$ iff in all the possible worlds w that represent what Julie believes in world w_0, there is an x such that it is a poem in world w and written by Nicole and x wins the competition in w.

By modeling the DP *somebody's poem* as a conjunction of two properties and varying the scope interaction between each property and the intentional quantifier, we controlled which world these two properties were evaluated in. The *de re* reading has the two properties scope out of *believe* because both are evaluated in the actual world; the *partial de dicto* reading has the property of x being written by Nicole in the scope of *believe*, establishing the association between this property with the possible world that represents what Julie believes. These two LFs also highlight the definiteness property of x by the quantificational symbol ∃!, which corresponds to the story setting that the DP picks up a specific entity that is seen by the belief holder in the real world. In contrast, the *pure de dicto* means that Julie believes whichever poem is written by Nicole will win the competition. It preserves the canonical constraints of *de dicto* reading: the DP is evaluated in the possible world and it does not pick up specific individuals in the actual world.

Under a scope-based approach to these three readings, one can see how a reading could be easily altered from one to another in our stories just by manipulating the scope of various DPs. The fact that the *de re* LF and the *partial de dicto* LF just differ from each other by the possible world in which, say, the authorship property of the poem is evaluated also makes it easy to manipulate the contexts in our experiment. This minimal difference in the context also allows us to minimize the influence of theoretically irrelevant contextual information on the judgment of the tested readings.

Despite the clarity of the scope approach, its limitation in modeling sentences with multiple embeddings due to the clause island restrictions requires a modified and updated approach. Specially, we need to readdress the outscoping transparency in both the *de re* and the *partial de dicto* reading[12].

To model the *partial de dicto* reading when $\lambda w.poem_w(x)$ needs to be moved within the scope of *believe*, we resort to world indices for possible world designation and an extended interpretation supplied by the context for the intensional descriptive expression. In (15), *Nicole's poem* corresponds to $\lambda w.poem_w(x)$ and $\lambda w.author_w(Nicole)(x)$ saturated by the belief world index w. It also takes an additional feature $\lambda w_0 [see_{w_0}(Julie)(x)](w_0)$ to consolidate Julie's association with the poem.

(15) *partial de dicto*

$\lambda w_0 \forall w [BEL_{w_0}(Julie, w) \longrightarrow win_w(\iota x[poem_w(x) \wedge author_w(Nicole)(x) \wedge see_{w_0}(Julie)(x)])](w_0) = 1$ iff for all possible worlds w that represent what Julie believes in world w_0, there is one unique x such that Julie saw x in w_0 and believes that this x, which is Nicole's poem in w, will win the competition in w.

This approach in dealing with *partial de dicto* can be abstracted in (17). It provides an additional contextual semantics $Q_{w'}(x)$ to the canonical interpretation of intensional definite descriptions in (16). Often times, this contextually salient property is anchored in the current world or in the preceding context before the intensional content is introduced, and thus could supply an anaphoric flavor to the descriptive terms.

(16) Canonical interpretation of intensional definite descriptions
      The P $= \lambda w.\iota x\, P_w(x)$

(17) Extended interpretation of intensional definite descriptions
      The P $= \lambda w.\iota x\, P_w(x) \wedge Q_{w'}(x)$ where Q and w' are contextually supplied

Even so, this approach might not successfully cover the *de re* case in (18). This is because while constraints in (16) and (17) stipulate that the property P should be supplied by the literal information of the definite descriptions and the Q should be supplied by the context, one linguistic segment cannot be P and Q simultaneously. In (18), $author_{w_0}(Elizabeth)(x)$ is supplied by the literal information of *Elizabeth's poem* and yet its world index does not match that of $\lambda w.poem_w(x)$ but that of the contextually salient property. The dual function of this segment $author_{w_0}(Elizabeth)(x)$ goes against the original stipulation and thus the LF in (18) is just suboptimal.

(18) *de re*
      ?? $\lambda w_0 \forall w [BEL_{w_0}(Julie, w) \longrightarrow win_w(\iota x[poem_w(x) \wedge author_{w_0}(Elizabeth)(x) \wedge see_{w_0}(Julie)(x)])] (w_0) = 1$ iff for all possible worlds w that represent what Julie believes in world w_0, there is one unique x such that x was written by Elizabeth and seen by Julie in w_0; Julie believes that this poem x will win the competition in w.

Despite the failed attempt to model *de re*, the contextually salient property proposed by (17) is indicative of another approach. It highlights an associative relation between the belief holder

and the target object and further formalizes this associative relation as a concept held by the belief holder about the target object which is generated under a specific scenario. Subsequently, a concept generator *G* proposed by Charlow and Sharvit (2014) can be the solution here.

A concept generator *G* is a function of type <e, <s, e>> that maps entities to concepts, as elaborated in (19). Subsequently, the *de re* reading could be modeled as (20) where the definite description of *Elizabeth's poem* is used to pick up the individual target entity for *Julie* to form a concept.

(19) $\lambda x\, \lambda w.\, G_y(x)(w)$ = G is a concept generated by entity *y* about entity *x* in world *w*.

(20) $\lambda w_0 \forall w\ [BEL_{w0}(Julie, w) \rightarrow win_w(G_{Julie}(\iota x[poem_{w0}(x) \wedge author_{w0}(Elizabeth)(x)])(w))](w_0)$
= 1 iff for all possible worlds *w* that represent what Julie believes in world w_0, Julie forms a concept *G* towards a specific individual *x* that is Elizabeth's poem in world w_0; furthermore, *x* will win the competition in world *w*.

Moreover, since one can form multiple concepts of the same <mark>emtity</mark> under multiple scenarios, we can also quantify over the possible concept generators and select the one that is made suitable by the context. The treatment is in (21).

(21) $\lambda w_0 \exists G[Suitable_{w0}(G, Julie) \wedge \forall w\ [BEL_{w0}(Julie, w) \rightarrow win_w(G_{Julie}(\iota x[poem_{w0}(x) \wedge author_{w0}(Elizabeth)(x)])(w))]](w_0)$ = 1 iff
(a) $Suitable_w(G, Julie) = G_{Julie}(x)(w')$ is a suitable concept for Julie in *w* such that for any *x* and any *w'*, $G(x)(w')$ is a reliable description of *x* in *w'*;
(b) for all possible worlds *w* that represent what Julie believes in world w_0, Julie forms a suitable concept *G* towards a specific individual *x* that is Elizabeth's poem in world w_0; furthermore, *x* will win the competition in world *w*.

So far, we have explored the scope-based approach, an extended intensional interpretation for definite descriptions, and the concept generator approach to model the crucial readings we tested in Exp.1. We end up taking the formal models in (14), (15), and (21) to represent the readings of *pure de dicto*, *partical de dicto*, and *de re* of the *poem* example.

4.3. ACCOUNTING FOR THE *DE RE* ACCESSIBILITY VARIATION. After modeling the availability of *de re* and *de dicto* readings, this section accounts for the varying accessibility The bimodal distribution of *de re* calls for an explanation and two tentative factors interacting with each other could provide useful insight.

The first one is concerned with a contextual setup of *de re* and *de dicto* readings as well as the participants' processing strategy. Across the three experiments, every story setup contains all the information that admits both the *de re* reading and the *de dicto* reading. Information supporting a *de re* reading was descriptive terms held true in the actual world but unknown by the belief holder; in contrast, information supporting a *de dicto* reading was descriptive terms for the same entity which was held true in the belief holder's mind. The sharp contrast of information evaluated in two parallel worlds could be well tracked by the participants. Consequently, when their incremental comprehension starts from, for example, *Julie believes that…*, there is chance that they only attend to what *Julie* believes and subsequently to descriptive terms held true in *Julie*'s belief world. A *de dicto* DP naturally matches what the belief holder believes and thus is highly agreed upon. But encountering a *de re* DP whose referential relation to the entity is not held in *Julie*'s mind and does not follow the logic continuity established by *Julie believes that* could incur an abrupt surprise in processing and

raises disagreement (as the case in example (7) raised by Nelson (2019)). Participants who were sensitive to the contrast between actual world information and the information held true in the belief holder's mind could be actively utilizing the Theory of Mind ability and reasoning with perspective shifting (e.g. Apperly & Butterfill, 2009; Low & Watts, 2013; Wimmer & Perner, 1983). Further experiments should aim to show that eliminating the contrastive information in the context raises the *de re* agreement rate in order to support the explanatory claims laid out here.

The second factor is idiosyncratic contexts which can influence the reading accessibility in a post hoc manner that is hard to control. Take as an example the third story in Exp.1 (noted as Exp.1–3 in the following text) and the fourth story in Exp.2 and 3 that exhibited peculiarly lower accessibility pattern than the cohort stories. Intuitively, there could be some irrelevant semantic or world knowledge information in those idiosyncratic contexts that hinder the access of *de re* reading. Zooming in to Exp.1–3, the *de re* term is *Haley's husband* and the *de dicto* term is *Haley's brother* and the story involves someone mistaking Haley's husband for her brother. Since this type of instance is rather salient in real life, it might be easier to catch the contrast. The same goes to Exp.2–4 when the salient contrast is between *bank robbers* and *school teachers* for the same group of people. While processing these two specific cases involve a world knowledge regarding the similarity of the two critical DPs, we need to set up controlled experiments to test whether this hypothesis is a real significant factor.

Apart from the discussion of potential factors for lower accessibility for *de re*, our findings also suggest that Jaszczolt (1997)'s "default *de re*" claim or the *de re* preferences in the legal settings are at least not attested in our own contexts. Even though our paradigm does not speak directly to this "default *de re*" claim by asking participants for their immediate interpretations of an ambiguous sentences, the bimodal distribution and the low agreement rate for *de re* readings throughout Exp.1 to 3 do suggest that accessing *de re* readings could be challenging under a certain number of contexts.

4.4. IMPLICATION ON QUANTITATIVE METHODOLOGIES IN FORMAL SEMANTICS. Both the bimodal distribution of *de re* reading and the underlying contextual factor call for a reevaluation of the traditional data collection methods adopted in theoretical work and advocate more quantitative methods. For extremely nuanced reading, judgments could easily vary or even exhibit inconsistency in the literature. The inconsistency could either indicate that the reading is not available, or the reading is not accessible because of the peripheral factors like idiosyncratic contexts, the speakers' linguistic training background, and their cognitive biases. Take the idiosyncratic contexts as an example. Imagine a linguist starts to investigate the *de re*/*de dicto* distinction only in the context of the third story in Exp.1 (noted as Exp.1–3). She would be more likely to arrive at a conclusion that *de re* is unavailable without looking at other contexts. Similarly, if she looked into the *bound de re* situation in Exp.2/3–4, there would be an even smaller chance for her to support the availability of *bound de re*.

All of these distractive factors need to be set aside before we reach the conclusion of reading availability. To do this, the existing informal judgment collection method is not sufficient and understanding the distribution of judgments across a number of speakers among various contexts becomes crucial. We argue that systematic experimental methodologies can not only help distinguish the availability and the accessibility of ambiguous readings like *de re*/*de dicto* ambiguities, but also create complete and reliable judgment data that are replicable and directly referenceable by the following work. Given that, our study was simple and robust, suggesting

that in order to test the contextual effect, getting even just a little bit experimental by choosing a handful of contexts and participants can lead to worthwhile gains(Davidson, 2020).

4.5. LIMITATION AND FUTURE DIRECTION. For our crucial analysis about the availability and accessibility of *de re*/*de dicto* readings, we assume that (1) our sampled participants shared the same grammar of English and (2) when a sentence is genuinely ambiguous, one reading is more salient than the other for reasons like frequency, linguistic experience, etc. These assumptions could be falsified with further investigation.

The phenomenon of lower accessibility for *de re* only applies to *de re* definite phrases in the subject position of the complement clause embedded under the attitude verb *believe*. The observation of *de re*/*de dicto* judgment for other structures might be different from our major claim.

For future studies, it would be informative to test whether the contextual contrast of *de re* and *de dicto* information influences *de re* accessibility. That is, if there is no contrastive term such as *Nicole's poem* vs. *Elizabeth's poem* but just one *de re* term unknown to the belief holder, what would be agreement rate for *de re* statement? If the rate goes higher, then at least we can argue that the contrastive information held true in the real world versus in the belief world explains away the low accessibility of *de re*.

Additionally, to provide direct evidence as a reply to the "default *de re*" claim, it would be helpful to see whether speakers show a preference to choose the *de re* reading if the two sentences are presented simultaneously to participants in a force choice task. Furthermore, to pinpoint the exact contextual factors that influence reading judgment, it would be useful to look into the discrepancy between the tested contexts, construct the subcategories of these contextual factors, and use independent experiments to verify their role in influencing reading judgment.

5. Conclusion.   Through a series of three experiments to investigate participants' judgments of the *de re*/*de dicto* ambiguities, we highlight the concepts of availability and accessibility for testing psychosemantic ambiguities. We conclude that while in this case, there is evidence for both readings to be available above chance in simple scenarios as well as in more sophisticated *bound de re* readings, the accessibility of *de dicto* was high and the accessibility of *de re* was bimodal. The accessibility of *de re*/*de dicto* readings was also affected by the *de re/de dicto* readings of other DPs in the proposition, the DPs' syntactic position, and idiosyncratic properties of the contexts. We also use this study to advocate a quantitative approach to collect nuanced semantic judgment data for theoretical development.

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Appendix 1: Materials for Exp.1

STORY A
Context
Julie is one of the judges of an ongoing poetry competition. The best poem that she has read so far is an extremely intriguing poem about the ocean. She believes that this poem will win the competition. Julie remembers being told that Nicole, one of the best-known poets, submitted a poem about the ocean to the competition. Therefore, Julie concludes that this poem must be written by Nicole and the first prize will be going to her. However, this poem was actually written by Elizabeth, a younger and lesser-known poet. It is just a coincidence that the two poets wrote about the same topic.
Instruction
According to this story, please use the slider bars to indicate to what extent you agree or disagree with the following four statements.

[S1] *de dicto*	**[S1]** *de re*
Julie believes that Nicole's poem will win the competition.	Julie believes that Elizabeth's poem will win the competition.

[S2] definitely right
Elizabeth is a young poet.

[S3] definitely wrong
Elizabeth and Nicole met each other and decided that they will both write poems about the ocean.

[S4] not sure
Julie will also be the judge for the poetry competition next year.

STORY B
Context
Mr. and Mrs. Johnson have two high school girls, Annie and Grace. One day, Mrs. Johnson finds a wrapped present lying on the front porch of their house. A note on the box says: "From your secret admirer". Mrs. Johnson remembers that one day she saw Annie's classmate Mike standing in front of their house for a long time without knocking at the door. She also remembers being told that Annie is very popular in her class, so she concludes that Mike sent the gift to Annie. It turns out that Mike did send the gift, but to Grace. Grace and Mike met each other in a book club, and Mike has admired Grace since then.
Instruction
According to this story, please use the slider bars to indicate to what extent you agree or disagree with the following four statements.

[S1] *de dicto*	**[S1]** *de re*
Mrs. Johnson believes that Annie's gift was sent by Mike.	Mrs. Johnson believes that Grace's gift was sent by Mike.

[S2] definitely right
When Mrs. Johnson finds the present, it is lying on the front porch with a note on it.

| **[S3] definitely wrong** |

Grace and Mike knew each other from jazz band.
[S4] not sure   The gift was wrapped in pink paper.

STORY C
Context   Susan works at a hospital. She is responsible for checking in visitors whose relatives and friends are in the maternity ward. One day, a man comes to Susan and asks to visit Haley. His surname is the same as Haley's and they both have beautiful blond hair. Susan remembers Haley saying that she has a brother, so Susan concludes that this man is Haley's brother. Since Haley will deliver the little baby soon, Susan also thinks that the man will accompany Haley for a while. Yet, it turns out that this man is not Haley's brother but instead, Haley's husband. Haley took her husband's surname, and they both have blond hair.
Instruction   According to this story, please use the slider bars to indicate to what extent you agree or disagree with the following four statements.

[S1] *de dicto* Susan believes that Haley's brother will accompany her for a while.	**[S1]** *de re* Susan believes that Haley's husband will accompany her for a while.

[S2] definitely right   Haley is receiving medical care in the maternity ward.
[S3] definitely wrong   Susan thinks the man is related to Haley because of his brown hair.
[S4] not sure   The man is bringing a bouquet of daisies to Haley.

STORY D
Context   Alice and Tracy live in the same apartment and always help each other with daily errands. One day, Tracy is gathering up their laundry and she finds an apron with a large coffee stain lying on the sofa. Tracy remembers Alice saying that she usually wears her favorite apron when she cooks and the other day she spilled a cup of coffee while cooking. Tracy thus concludes that what she found is Alice's favorite apron and it needs to be washed. As a matter of fact, however, what Tracy found is Alice's spare apron, not her favorite one. Alice's favorite apron was already in the laundry at the time when she spilled the coffee onto her spare apron.
Instruction   According to this story, please use the slider bars to indicate to what extent you agree or disagree with the following four statements.

[S1] *de dicto* Tracy believes that Alice's favorite apron needs to be washed.	**[S1]** *de re* Tracy believes that Alice's spare apron needs to be washed.

[S2] definitely right   Alice usually wears an apron when she cooks.
[S3] definitely wrong

The apron with a large coffee stain was lying on the table when Tracy discovered it.
[S4] not sure
Tracy altogether gathered three pounds of laundry.

Appendix 2: Basic Materials for Exp.2 & 3

STORY A

Context

    As a photographer, John likes to rearrange his collections of photographs now and then. One day, he encounters two sets of photos. In the first set, there are three ladies and each is holding a baby. John naturally believes that each of the babies is being held by their mother.

    In the second set, three young adults are each wearing a T-shirt with a "2018" logo. John naturally believes that they were graduating students in the year 2018. John also notices that, interestingly, each of the young adults shares a similar smile to one of the ladies in the first photo set. He tries to recall if there is a connection between the young adults and the ladies but memory fails him.

    As a matter of fact, what John fails to recall is three pieces of information. (1) The young adults in the second set of photos were the babies in the first set. They've grown up! (2) The ladies in the first set are actually the babies' grandmother. The three young adults inherit their smile from their grandma who is mistakenly believed by John to be their mother. (3) The second set of photos were taken not in the graduation ceremony but when the three adults were volunteering for an academic conference in 2018.

    Despite the fact that John doesn't remember the correct relationship between the ladies in the first set of photos and the young adults in the second set and that he has several pieces of incorrect information, John spends quite some time appreciating these photos.

Instruction

According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement.

| |
|---|
| **[S1]** *de re + de re + de dicto*
 Looking at his photos, John believes that [every conference volunteer]*de re* in the second set has the same smile as [their]*de re* [mother]*de dicto*. |
| **[S2] definitely right**
 John is a photographer who likes to rearrange his photos now and then. |
| **[S3] definitely wrong**
 In the first set of photos, each of the babies is being held by their father. |
| **[S4] uncertain**
 The three young adults in the second set of photos went to Penn State University for undergraduate education. |

STORY B

Context
 	
     Thomas is a new delivery person in a flower shop. Today is his first workday and he needs to deliver three flower bouquets to three customers named Jesse, Taylor, and Alex. Looking at the flowers, Thomas believes that the fresh buds are very pretty. However, the first day of work makes Thomas nervous. He wonders whether these three female customers would love their flowers -- Thomas believes the customers are female under his impression that flowers usually are delivered to women.
 	
     Interestingly, each time when Thomas is about to leave a flower bouquet at its recipient's door, he encounters a young man jogging on the sidewalk. After a brief greeting, every young man starts to appreciate the beauty of that flower bouquet, making Thomas believe that they really love it.
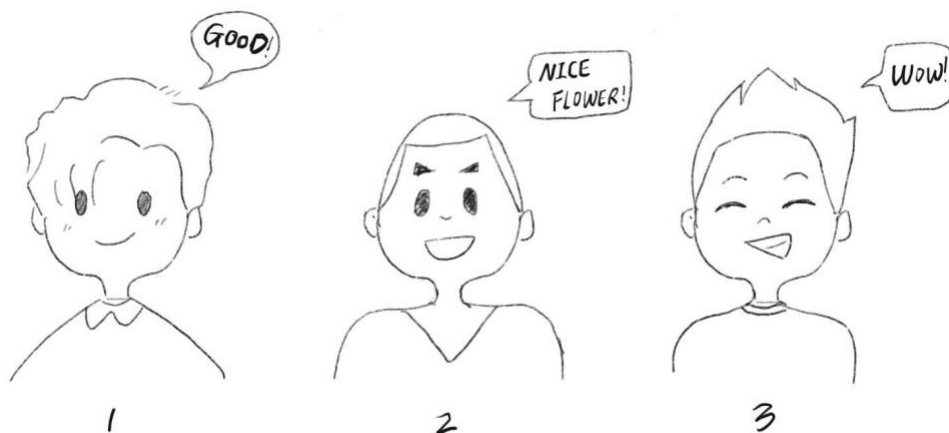
As a matter of fact, Thomas hasn't figured out the whole situation. (1) The young men he encounters are actually Jesse, Taylor, and Alex respectively -- they were each returning from their morning exercise and thus didn't show up at the door to receive the flower. Thomas doesn't recognize this and mistakenly believes that his customers are female. (2) The flowers are actually artificial which are mistakenly believed by Thomas to be fresh. The flower shop is famous for making artificial flowers that look like fresh ones. Thomas couldn't tell the difference due to the lack of experience.

Fortunately, even though Thomas has several pieces of incorrect information, the flowers are still very much enjoyed!

| Instruction |
| --- |
| According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement. |
| **[S1]** *de re + de re + de dicto*
After having delivered the flowers, Thomas believes that [every male customer]*de re* that he saw really loves [their]*de re* [fresh flower bouquet]*de dicto*. |
| **[S2] definitely right**
Today is the first workday for Thomas. |
| **[S3] definitely wrong**
Thomas correctly understands what is going on during his delivery trip. |
| **[S4] uncertain**
The flower bouquets will be used to decorate the kitchens in the recipients' houses. |

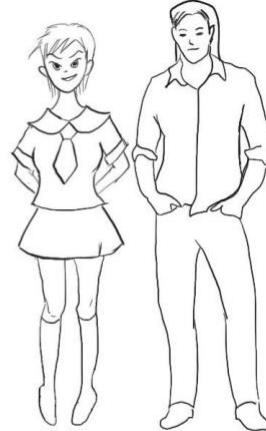| STORY C |
| --- |
| **Context**
    Kaitlyn works as a DJ at a music club. One afternoon, when she is preparing the music, she notices three guys in handsome outfits walking into the club, each accompanied by a girl in a school uniform. Judging from their intimate interactions, Kaitlyn believes that these guys are the girls' boyfriends. |
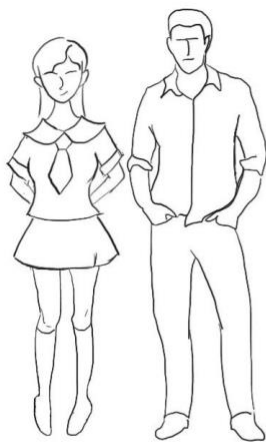
club entrance   club entrance   club entrance

When night comes and the routine dance battle begins, Kaitlyn notices the three handsome guys again, this time each competing against a beautiful lady in a fancy evening dress. They've battled for several rounds, which makes Kaitlyn believe that the beautiful ladies really enjoy battling with those guys.

VS   VS   VS

Dance floor   Dance floor   Dance floor

As a matter of fact, Kaitlyn doesn't totally get what is going on. (1) The three dancing ladies are actually the same girls in uniform that Kaitlyn saw at the entrance – the club lighting, the ladies' drastically different dressing style, and their heavy make-up kept Kaitlyn from realizing who they are. (2) These ladies are actually actresses who were wearing the school uniform as a costume. It turns out that they just finished an acting audition where they played high school girls. (3) The handsome guys are actually the ladies' brothers who are mistakenly believed by Kaitlyn to be the ladies' boyfriends.

The situation is that the three pairs of siblings have gone to the music club to celebrate the sisters' success in getting an audition. Of course, it is hard for Kaitlyn to get all of the information right.

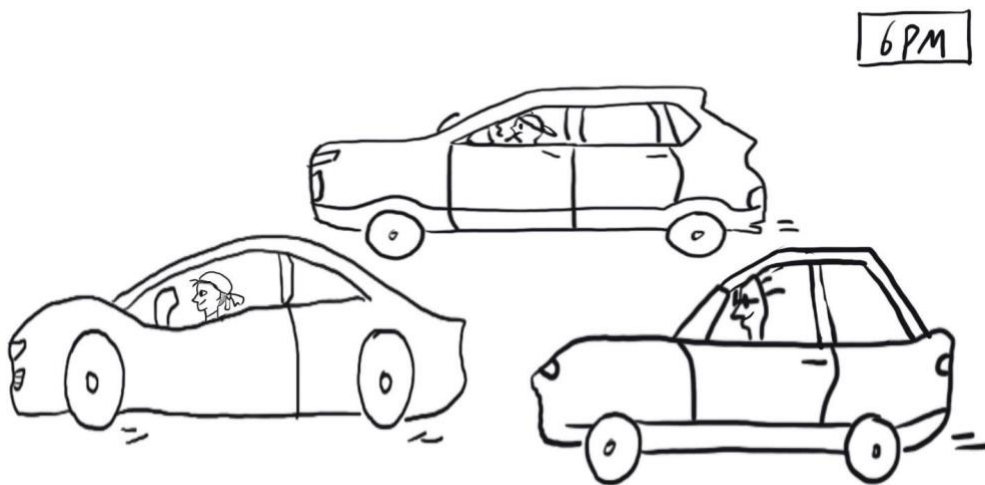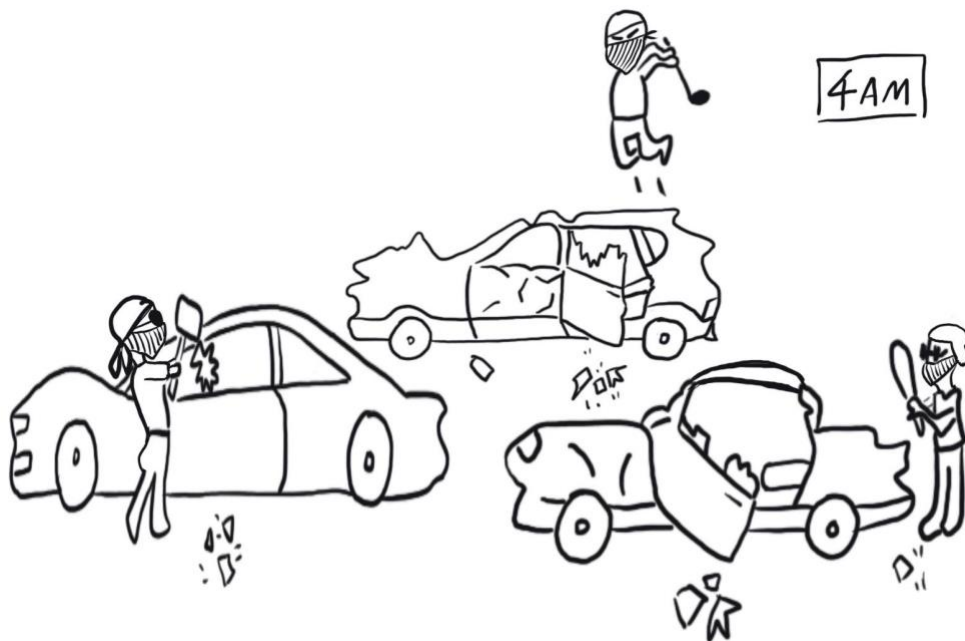| |
|---|
| **Instruction** |
| According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement. |
| **[S1]** *de re + de re + de dicto* |
| Looking at the dancing scene, Kaitlyn believes that [every actress]*de re* that she saw really enjoys battling with [their]*de re* [boyfriend]*de dicto*. |
| **[S2] definitely right** |
| There is a dance battle at night in the music club. |
| **[S3] definitely wrong** |
| The three handsome guys are not involved with the dancing. |
| **[S4] uncertain** |
| The dancing ladies are wearing pink dresses. |

STORY D
Context
Chris runs a grocery store near a school. One day at 6 pm, he notices three young men driving three cars and pulling over at the school. Seeing the three men entering the school, Chris believes that they are the school teachers. Chris also notices that the cars look quite fancy, and thus he naturally believes that they are sports cars.   At 4 am, Chris is suddenly alerted by some violent noise. He sees three strange people wearing face masks, smashing the three cars, and destroying the car plates. Witnessing this level of violence and intent to destroy the cars, Chris calls 911 to report the crime.

As a matter of fact, Chris does not get the whole picture of what is going on. (1) The three violent people are actually the three young men who Chris saw driving the cars at 6 pm – their face masks keep Chris from recognizing them. (2) The three men are not teachers but bank robbers! They want to destroy their crime vehicles before running away. (3) Moreover, the cars are not sports cars as mistakenly believed by Chris. They are actually ordinary sedans with a similar appearance to sports cars.

Therefore, what looks like a case of vandalism is actually a more serious bank robbery!

Instruction
According to this story, please use the slider bar to indicate to what extent you agree or disagree with the following statement.

[S1] *de re + de re + de dicto*
Looking at the dancing scene, Kaitlyn believes that [every actress]*de re* that she saw really enjoys battling with [their]*de re* [boyfriend]*de dicto*.

[S2] definitely right
Chris runs a grocery store near a school.

[S3] definitely wrong
Instead of calling 911, Chris calls the local government to report the violent scene.

[S4] uncertain
The three men robbed four million dollars in total.

Appendix 3: The statistical report for Exp.1–3

1. Experiment 1

Full model estimates for logistic mixed-effects regressions predicting the agreement probability

MODEL SYNTAX: logit(agree) ~ condition + context + (1|subject)				
Fixed effects	ß	SE	z-value	p-value
Intercept	2.314	0.272	8.503	< 0.001
de re	-1.610	0.226	-7.096	< 0.001
Story A	0.014	0.252	0.054	0.957
Story B	0.962	0.300	3.210	0.001
Story C	-0.818	0.245	-3.341	0.001
Random effects		Variance	SD	
Subject Intercept		0.741	0.861	
Number of observations: 460, number of participants: 115				

2. Experiment 2 & 3

Full model estimates for logistic mixed-effects regressions predicting the agreement probability

MODEL SYNTAX: logit(agree) ~ (QNP + pronoun + possessee)*story + (1|subject)				
Fixed effects	ß	SE	z-value	p-value
Intercept	0.420	0.171	2.452	0.0142
QNP *de re*	0.074	0.171	0.434	0.664
Pronoun *de re*	-0.348	0.168	-2.073	0.039
Possessee *de re*	-0.956	0.175	-5.450	< 0.001
Story B	1.068	0.237	4.497	< 0.001
Story C	0.516	0.219	2.349	0.019
Story D	-1.155	0.222	-5.193	< 0.001
QNP*re* : B	0.487	0.233	2.091	0.037
QNP*re* : C	-0.156	0.218	-0.713	0.476
QNP*re* : D	-0.382	0.217	-1.755	0.079
Pronoun*re* : B	0.073	0.247	0.295	0.768
Pronoun*re* : C	0.368	0.251	1.468	0.142
Pronoun*re* : D	0.210	0.234	0.897	0.370
Possessee*re* : B	0.781	0.272	2.873	0.004
Possessee*re* : C	0.627	0.220	2.844	0.004
Possessee*re* : D	0.753	0.259	2.905	0.004
Random effects		Variance	SD	
Subject Intercept		1.182	1.087	
Number of observations: 988, number of participants: 247				