Numeral Modification and Framing Effects: *exactly* and *at most* vs *up to*

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Abstract

This study investigated modulation of risky-choice framing (RCF) and attribute framing (AF) effects by numeral modification. In Experiment 1, in which the numerals were modified with (the German equivalent of) *exactly* to enforce a precise reading, there were significant RCF and AF effects. Experiment 2 and 3 addressed the effects of (the German equivalents of) *at most* and *up to*. Both modifiers set an upper bound. Yet, they exhibit a sharp contrast in evaluative contexts. In Experiment 2, there was a significant interaction of modifier and frame for RCF, with a reversed framing effect for *at most* and a standard framing effect for *up to*. The modifier-by-frame interaction effect was replicated in Experiment 3 for AF. To explain framing effects with bare and modified numerals, we propose a semantic-pragmatic account in terms of salience and valence.

Keywords: framing effects; numeral modification; risky-choice framing; attribute framing

Introduction

The term *framing effect* refers to the well-established finding that choices and judgments are systematically affected by linguistic variation A frequently employed decision problem in framing research is the task to choose between two programs to combat a deadly disease expected to kill 600 people, with one program having a sure outcome and the other one a risky outcome (Tversky & Kahneman, 1981). Crucially, the outcomes are either presented in terms of number of lives saved or in terms of number of lives lost (see (1)).

(1) If Program 1 is adopted, (**sure option**)
[200 people will be saved] / [400 people will die].

If Program 2 is adopted, there is a (**risky option**)
[probability of 1/3 that 600 people will be saved, and a probability of 2/3 that no one will be saved] / [probability of 1/3 that no one will die, and a probability of 2/3 that 600 people will die].

The common finding is that the different framing of the options has an effect on participants' choices. In the *survive*-frame condition, participants tend to prefer the sure option (i.e., Program 1), whereas in the *die*-frame condition, they tend to disprefer it.

Framing effects are a robust finding; they have been demonstrated in numerous experimental studies for a variety of scenarios and judgment and decision tasks. For example, in a study by Duchon, Dunegan, and Barton (1989), participants were presented with a financial allocation scenario of an R&D manager being confronted with the request of a project team for additional funding. The previous performance of the team was either stated in terms of successful projects or in terms of unsuccessful projects (see (2)) and this frame manipulation was found to affect participants' ratings of their tendency toward rejecting or agreeing to the project team's funding request. Participants in the *successful*-frame condition indicated a stronger inclination to agree to the funding request than participants in the *unsuccessful*-frame condition.

(2) Of the projects undertaken by the team, [30 of the last 50 have been successful] / [20 of the last 50 have been unsuccessful].

Risky-Choice Framing and Attribute Framing

The financial-allocation problem is an example of attribute framing, whereas the deadly-disease problem in (1) is an example of risky-choice framing. In attribute-framing studies, the frame manipulation involves an attribute that is predicated to an entity or eventuality. Experimental tasks vary from judgements on a particular dimension to binary decisions. In risky-choice framing tasks, participants have to choose between two options in either of two variants. One option involves a single, sure outcome, whereas the other option is "risky", in that it involves two alternative outcomes. Findings from valence-rating studies suggest that risky-choice framing effects are not due to having to choose between a sure and a risky option but are driven by the evaluation of the sure option. Valence ratings were found to differ between the variants of the sure option but not between the variants of the risky option (Kühberger & Gradl, 2013; Peters & Levin, 2008). In light of this finding, risky-choice framing can be viewed as a complex variant of attribute framing.

Equivalence of Differently Framed Descriptions?

What is common to risky choice framing and attribute framing is the demonstration that ostensibly equivalent descriptions can lead to different decisions and evaluations depending on whether they are framed positively or negatively. One perspective on framing effects is to view them as evidence for irrationality in judgment and decision making under the

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assumption that they violate the principle of description invariance (e.g., Tversky & Kahneman, 1986). From a semantic-pragmatic perspective, violations of the principle of description invariance are not surprising. The pragmatic contribution of descriptively equivalent descriptions is not identical and even their semantic contribution may differ.

The usual justification for considering different descriptions equivalent is an arithmetic argument. Consider the example in (1). If 200 out of 600 people will be saved then the remaining 400 people will die from the disease and vice versa. However, this argument presupposes a precise reading of the numerals. While there is no established treatment of numerals, it is uncontroversial that bare numerals can receive different readings (e.g., Breheny, 2008; Carston, 1998; Geurts, 2006; Horn, 1972; Kennedy, 2015; Krifka, 2009). A numeral such as *200* may receive a precise ('exactly 200'), lower-bound ('at least 200'), upper-bound ('at most 200'), or approximate reading ('roughly 200').

Numeral Interpretation: Lower-bound reading?

As has been pointed out by Mandel (2014, 2015; see also Macdonald, 1986 and Kühberger, 1995), the readings participants of framing studies assign to the given numerals are critical with regard to the interpretation of framing effects. In his account, Mandel (2014) assumes a tendency to assign a lower-bound reading to the numerals. If true, then this would offer a parsimonious explanation of framing effects. Consider, for example, the deadly-disease problem. Under a lower-bound reading, the two description variants of the sure option do not have identical outcomes (at least 200 out of 600 will be saved ≠ at least 400 out of 600 will die). Moreover, and crucially, the number of lives to be saved is potentially higher in the positive frame than in the negative frame. That is, under a lower-bound reading, the *saved* variant is better than the *die* variant given the human conviction that the more lives saved/the fewer lives lost the better.

Experimental findings on numeral interpretation do not support the traditional view of a lower-bound core meaning of numerals (e.g., Huang & Snedeker, 2009; Marty, Chemla, & Spector, 2013). These findings appear to speak against the lower-bound reading account. Yet, further findings indicate that numeral interpretation is context-dependent (e.g., Musolino, 2004; Panizza, Chierchia, & Clifton, 2009). Possibly, scenarios such as the imminent outbreak of a deadly disease constitute contexts that bring about a tendency to a lower-bound reading of numerals. So far, however, there is no independent justification or evidence for this assumption.

Mandel (2014) reports three findings that provide support for his *lower-bound reading account*. First, when a precise reading was enforced via numeral modification (*exactly 200/400*) there was no framing effect. The second finding is that the majority of participants (64%) indicated a lower-bound interpretation in a numeral-interpretation assessment for the bare numerals in the original variants of the sure option. The third finding is that a standard framing effect was observed only for this subgroup of participants and not for those who indicated a precise or an upper-bound reading.

However, these findings do not provide unequivocal evidence for the lower-bound-reading account. With regard to the effect of enforcing a precise reading, there are conflicting results from experiments by Chick, Reyna, and Corbin (2016) and Simmons and Nelson (2013) which yielded significant framing effects when the numerals in the sure option were likewise modified with *exactly*. Regarding the numeral-interpretation findings, there is a methodological concern. The numeral-interpretation assessment immediately followed the task of choosing between the sure and risky option. Hence, the just-made choice might have influenced participants' indication of the numeral interpretation, e.g., in terms of a justification of the choice. To explore this issue, Claus (2022) conducted an experiment with distractor tasks in between the decision tasks and the assessment of the numeral interpretation. Most participants (79%) indicated that they interpreted the numerals with a precise reading. Moreover, a framing effect was observed for the subgroup of participants who indicated a non-precise reading of the numerals as well as for the subgroup of participants who indicated a precise reading.

The Role of Numeral Modification

Besides its parsimony, what distinguishes the lower-bound reading account from prominent other accounts of framing effects is, that it allows for predictions regarding the effects of numeral modification. Consistent with his account, Mandel (2014) found a stronger framing effect for numerals modified with *at least* compared with bare numerals.

Another account that predicts effects of numeral modification is the *alignment-assumption account* (Geurts, 2013), in which framing effects are attributed to diverging sets of semantic alternatives for differently framed descriptions. A decisive parameter in the account is the entailment pattern, i.e. upward- vs. downward entailing. In line with the account, Claus (2019) found that framing effects on evaluative ratings and on choice patterns disappeared when the numerals in the positive and negative frame were modified with the upward entailing modifier *more than* and the downward entailing modifier *fewer than*, respectively (*more than 200 people will survive / fewer than 400 people will die*).

The lower-bound reading account and the alignment assumption account are distinct alternatives to explain framing effects. Yet, they are not mutually exclusive. Moreover, they share predictions regarding numeral modification. Both accounts predict a reversed framing effect when the numerals are modified with *at least*, albeit for different reasons – because *at least* enforces an upper-bound reading vs because *at least* is downward entailing. Furthermore, framing effects with *exactly* are not only challenging for the lower-bound reading account but also for the alignment-assumption account, because *exactly* is neither upward nor downward entailing, but non-monotone (see Claus, 2022).

Present Study

The aim of the present study was to further investigate the effects of numeral modification on framing effects. Broadening the scope of previous studies, the present experiments

addressed two types of framing, risky choice framing and attribute framing. Experiment 1 involved a numeral modifier that enforces a precise reading and Experiment 2 and 3 juxtaposed two upper-bounded numeral modifiers. The experiments were conducted in German and were implemented as web-based experiments.

Experiment 1

Experiment 1 examined whether the occurrence of framing effects depends on the possibility of a lower-bound reading of the critical numerals. The numerals were modified with *genau*, the German equivalent of *exactly*. As mentioned above, previous findings on numeral modification with *exactly* from risky-choice framing studies are mixed. Mandel (2014) found no framing effect, whereas Simmons and Nelson (2013) and Chick et al. (2016) observed framing effects. To help clarify the mixed results, Experiment 1 included risky-choice framing and attribute framing.

Method

Participants All participants of the experiments reported in this paper were German native speakers and were recruited from the student population of Berlin and Potsdam. They gave informed consent for participation and participated in exchange for the chance to win € 25 in a raffle.

Fifty-two students (18 to 40 years, M = 26.41; 8 male) participated in Experiment 1. The data of four additional participants were excluded from the analyses; two of them were not native speakers of German and the other two recognized that the experiment was about framing effects.

Materials. The materials for the experimental trials consisted of a risky-choice framing scenario and an attribute framing scenario. There were two versions of each scenario, one with a positive frame and one with a negative frame.

For risky-choice framing, we adopted a variant of the deadly-disease scenario from Mandel (2014). The scenario pertains to a war zone, in which the lives of 600 individuals are at stake and with two response plans, a sure option and a risky option, see the German version and English translation in (3). There were two versions of the description of the options. The response plans' outcomes were stated either in terms of numbers of lives to be saved (positive frame) or in terms of number of lives to be lost (negative frame). The numerals in the sure option as well as the probability fractions in the risky option were modified with *genau* 'exactly'. Participants' task was to choose between the two response plans.

(3) Bei Anwendung von Plan A werden genau [200 Menschen gerettet werden] / [400 Menschen sterben].
Bei Anwendung von Plan B [werden mit einer Wahrscheinlichkeit von genau 1/3 600 Menschen gerettet werden und mit einer Wahrscheinlichkeit von genau 2/3 wird niemand gerettet werden] / [wird mit einer Wahrscheinlichkeit von genau 1/3 niemand sterben und mit einer Wahrscheinlichkeit von genau 2/3 werden 600 Menschen sterben].

'If Plan A is adopted, exactly [200 people will be saved] / [400 people will die].'
'If Plan B is adopted, there is a probability of exactly 1/3 [that 600 people will be saved, and a probability of exactly 2/3 that no one will be saved] / [that no one will die, and a probability of exactly 2/3 that 600 people will die].'

For attribute framing, we employed a variant of the financial allocation scenario as devised by Duchon et al. (1989). Participants had to imagine that they were managing an R&D department of a technology company and that one of the project teams has requested additional funding for an ongoing project. The frame manipulation pertained to the previous performance of the team, see (4). It was stated in terms of either number of successful projects (positive frame) or number of unsuccessful projects (negative frame). In both frame versions, the critical numeral was modified with *genau* 'exactly'. Participants' task was to indicate whether they would approve or reject the team's request for additional funding.

(4) Von den letzten 50 Projekte des Teams waren genau [30 erfolgreich] / [20 erfolglos].
'Of the team's last 50 projects, exactly [30 were successful] / [20 were unsuccessful].'

Design and Procedure For both, risky-choice and attribute framing, the factor FRAME was manipulated within-subject[1]. There were four experimental trials, corresponding to the two framing types and the two conditions, i.e., positive and negative frame. The order of the experimental trials for the two framing types and of the two conditions was counterbalanced.

The four experimental trials were separated by distractor trials. The first experimental trial was followed by a sequence of three word-naming trials. In each of these distractor trials, participants were asked to produce three words that start or end with a given chain of two to three letters. Subsequent to the second experimental trial, there were three sentence-acceptability tasks, in which participants were presented with a sentence and were asked to rate its acceptability, estimate its frequency in everyday language use, and suggest alternative wordings. The third and fourth experimental trials were followed by another sequence of word-naming trials and sentence-acceptability tasks, respectively.

Results and Discussion

Table 1 and 2 show the choice data for the risky-choice and attribute framing scenarios. The data were analyzed, separately for both types of framing, by using a generalized linear mixed model with a binomial logit function and with

[1] Note that Mandel (2014: Experiment 1) also employed FRAME as a repeated-measures factor and see Aczel, Szollosi, and Bago (2018) for arguments against objections regarding within-subject designs in framing studies.

participants as random factor and FRAME, as fixed factor with deviation coding (+.5, -.5). For both framing types, there was a significant main effect of FRAME, risky-choice framing: $b = 1.43$, $SE = .65$, $z = 2.22$, $p < .05$; attribute framing: $b = 15.43$, $SE = 4.23$, $z = 3.65$, $p < .001$.

These results indicate that enforcing a precise reading of numerals via modification with *genau* 'exactly' does neither preclude risky-choice nor attribute framing effects, providing additional evidence that framing effects are not bound to a lower-bound reading of numerals. As outlined above, this finding is challenging for the lower-bound reading account and the alignment-assumption account.

Table 1: Proportion of sure-option choices in the risky-choice framing trials of Experiment 1.

Frame	
Positive	Negative
51.9%	34.6%

Table 2: Proportion of approvals in the attribute framing trials of Experiment 1.

Frame	
Positive	Negative
92.3%	65.4%

Experiment 2

In Experiment 2 and 3, we juxtaposed the superlative numeral modifier *höchstens* and the directional numeral modifier *bis zu*, i.e., the German equivalents of *at most* and *up to*.

Both these modifiers set an upper bound, e.g., *at most 200* and *up to 200* convey that 200 is the maximum. Hence, if numeral interpretation and its consequences for the possible ranges of lives to be saved vs lost or successful vs unsuccessful projects is decisive, then one may expect a reversed framing effect with upper-bounded modifiers. With an upper-bound reading, the number of lives to be saved and the number of successful projects is potentially lower in the positive frame than in the negative frame.

However, *at most* and *up to* exhibit a sharp contrast in evaluative contexts (Blok, 2015; Qing, 2020; Schwarz et al. 2012), as shown in (5) for positive/negative evaluations of the differently framed descriptions of the sure option in the deadly-disease scenario.

(5) It is [good/bad] that [up to/at most] 200 people will be saved/400 people will die.

According to the linguistic analyses by Blok (2015), the superlative modifier *at most* but not the directional numeral modifier *up to* makes the complement set salient (the set of entities for which the predicate does not hold)[2]. This semantic difference may result in differences of the valence appraisal. Hence, if valence appraisal is decisive, different patterns for the two modifiers are expected.

To test the two opposing predictions, i.e., same vs different patterns for the two modifiers, we used a two-factorial design (FRAME x MODIFIER) and applied it to both types of framing in separate experiments. Experiment 2 involved risky-choice framing and Experiment 3 involved attribute framing.

Method

Participants One-hundred-and-one students (18 to 40 years, $M = 25.88$; 19 male) participated in Experiment 2. The data of four additional participants were excluded from the analyses because they were not a native speaker of German.

Materials For the experimental trials, the same risky-choice framing scenario as in Experiment 1 was used. There were two (FRAME: positive/negative) x two (MODIFIER: *bis zu* 'up to' / *höchstens* 'at most') versions of the description of the response plans, see the English translation in (6). The numerals in the sure option were modified with either *bis zu* 'up to' or *höchstens* 'at most'. In the risky option, the probability fractions were modified with *maximal* 'maximally' and *mindestens* 'at least', in such a way that the upper bound of the expected value of the risky options matched the outcome of the corresponding sure options.

(6) If Plan A is adopted, [up to/at most] [200 people will be saved] / [400 people will die].

If Plan B is adopted, there is a probability [of maximally 1/3 that 600 people will be saved, and a probability of at least 2/3 that no one will be saved] / [there is a probability of at least 1/3 that no one will die, and a probability of maximally 2/3 that 600 people will die].

Design and Procedure Experiment 2 employed a 2×2 mixed design with the factor MODIFIER (at most vs up to) as group factor and FRAME (positive vs negative) as repeated measures factor. Participants were randomly assigned to one of the two modifier conditions. The order of the experimental trials for the two frame conditions was counterbalanced. In between the two experimental trials, there were distractor tasks, i.e., three word-naming tasks and three sentence-judgment tasks, analogous to the distractor tasks in Experiment 1.

Results and Discussion

Table 3 shows the proportion of sure-option choices in the two frame conditions. For *bis zu* 'up to', there was the

[2] According to Blok (2015), the contrast between directional modifiers such as up to and other upper-bounded modifiers such as at most holds crosslinguistically. She obtained data for a variety of languages: Danish, Dutch, English, Farsi, French, German, Greek, Hebrew, Hungarian, Italian, Polish, Romanian, Russian, Spanish, and Turkish.

standard pattern of more sure-option choices in the positive-frame condition compared with the negative-frame condition. For *höchstens* 'at most', the pattern was reversed, i.e., more sure-option choices in the negative-frame condition compared with the positive-frame condition.

The choice data were analysed by generalized linear mixed modelling with a binomial logit function and with participants as random factor. The fixed factors were MODIFIER and FRAME, both with deviation coding (+.5, -.5). There was a significant interaction of MODIFIER and FRAME, b = -1.35, SE = .64, z = -2.09, p < .05 and no significant main effect, MODIFIER: b = .15, SE = .37, z = .40, p = .69; FRAME: b = .02, SE = .31, z = .07, p = .95.

Table 3: Proportion of sure-option choices in the risky-choice framing trials of Experiment 2.

	Frame	
	Positive	Negative
Bis zu 'up to'	59.2%	44.9%
Höchstens 'at most'	42.3%	55.8%

The significant interaction of MODIFIER and FRAME indicates that whether the upper bound of a quantity is expressed with *höchstens* 'at most' or with *bis zu* 'up to' can affect judgments and decisions. This finding points to the role of evaluative valence for the occurrence of framing effects.

Experiment 3

Experiment 3 was designed to investigate whether the findings of Experiment 2 for risky-choice framing could be replicated for attribute framing. We employed the same financial allocation scenario and the same choice task as in Experiment 1, but with varying the upper-bound modification of the numerals as in Experiment 2. In all other respects, the method of Experiment 3 was the same as in Experiment 2.

Method

Participants Ninety-four students (18 to 40 years, M = 26.15; 16 male) took part in Experiment 3. The data of six additional participants were excluded from the analyses because they were not native speakers of German (n = 3), did recognize that the experiment addressed framing effects (n = 2). or did not follow the instructions (n = 1).

Materials For the experimental trials, the same attribute framing scenario as in Experiment 1 was used. There were two (FRAME: positive/negative) x two (MODIFIER: *bis zu* 'up to' / *höchstens* 'at most') versions of the description of the team's performance, see the English translation in (7).

(7) Of the teams last 50 projects, [up to/at most] [30 were successful] / [20 were unsuccessful].

Design and Procedure Experiment 3 employed the same design and procedure as Experiment 2.

Results and Discussion

Table 4 shows the proportion of approvals in the financial allocation problem. The analysis corresponded to that employed for the choice data of Experiment 2 and revealed a significant interaction of MODIFIER and FRAME, b = -34.53, SE = 16.54, z = -2.09, p < .05 and no significant main effect, MODIFIER: b = 10.52, SE = 11.31, z = .93, p = .35; FRAME: b = 11.41, SE = 12.09, z = .94, p = .35.

Table 4: Proportion of approvals in the attribute framing trials of Experiment 3.

	Frame	
	Positive	Negative
Bis zu 'up to'	88.9%	68.9%
Höchstens 'at most'	67.3%	71.4%

Thus, as observed in Experiment 2 for risky-choice framing, the choice patterns for attribute framing in Experiment 3 differed for the two upper-bounded modifiers *bis zu* 'up to' and *höchstens* 'at most', providing additional support for the view that valence appraisal plays a crucial role in the emergence of framing effects.

Conclusions

The goal of our study was to gain further insights into the sources of framing effects by investigating the effects of numeral modification.

In Experiment 1, we addressed the effect of enforcing a precise reading via numeral modification, for which the existing evidence is mixed. For numerals modified with *exactly*, Mandel (2014) observed no framing effect whereas Chick et al. (2015) and Simmons & Nelson (2013) found a standard framing effect. In our Experiment 1, we replicated and extended the latter finding with a German translation equivalent of *exactly* and with two types of framing, i.e., there was a significant framing effect for numerals modified with *genau* for risky-choice and for attribute framing.

In Experiment 2 and 3, we juxtaposed the two modifiers *bis zu* 'up to' and *höchstens* 'at most'. Both are upper-bounded modifiers. Yet, they differ with respect to evaluative valence, as was illustrated above in (5). The results correspond to the difference in evaluative valence between the two modifiers, i.e., there was an interaction between modifier and frame for both, risky-choice framing and attribute framing.

The finding of a framing effect in Experiment 1 with enforcing a precise reading is challenging for the lower-bound reading account and cannot be explained within the alignment-assumption account as outlined above.

The findings of Experiment 2 and 3 are also challenging for other, prominent accounts of framing effects, e.g., prospect theory (e.g. Tversky & Kahneman, 1981), fuzzy-trace theory (e.g. Reyna & Brainerd, 1991), and the information leakage account (e.g. McKenzie & Nelson, 2003). However,

the findings could be captured in these accounts by positing additional assumptions that require further specification.

In prospect theory, positively and negatively framed information is represented as gains vs losses, respectively. To explain the present finding, one needs to assume that the presence and type of numeral modification affects whether information is represented as a gain or a loss. According to fuzzy-trace theory, the source of framing effects are coarse "gist" representations that do not contain numerical information. To account for the present findings, one could assume that numeral modifiers differentially affect gist representations or that with certain modifiers people are less likely to rely on gist representations but rather base their evaluation on verbatim representations. Within the information leakage account, it is assumed that people make the mechanistic inference that the given number is higher than a reference level, thereby mirroring the proposed tendency to cast descriptions in terms of the frame that involves an increased rate relative to a reference point. To capture the findings on numeral modification, one has to incorporate assumptions on modulatory effects of numeral modifiers on reference-point inferences.

In what follows, we propose a semantic-pragmatic account in terms of valence and salience to account for findings with bare and modified numerals. We start out from the assumption that the source of framing effects is that differently framed descriptions make different partial outcomes of a two-edged issue salient. Framing effects emerge if participants base their judgments on the immediate valence appraisal of the salient partial outcome. Different from other valence-based accounts (Tombu & Mandel, 2015; Wallin, Paradis, & Katsikopoulos, 2016), we operationalize valence as goal consistency, i.e., desirability in the context given. Hence, it is not the default affective valence of lexical items per se that is crucial. Consider the verb *die*. In the deadly-disease scenario, its default valence corresponds to the valence of the partial outcome of the sure option in terms of goal consistency, i.e., goal inconsistent. However, in the context of an antibacterial sanitation spray (e.g., *95% of bacteria die*), valence in terms of goal consistency is opposite. i.e., goal consistent.

Presumably, inferences with regard to goal consistency are routinely drawn during language comprehension, allowing for an immediate valence appraisal. If participants base their judgments and choices on that initial appraisal, framing effects are likely to occur.

Which of the two parts of a two-sided outcome is salient is not only determined by the given predicate but also hinges on other linguistic variables. One such variable is the presence of negation. Findings from studies on risky-choice framing indicate that negation reverses the valence of the predicate (Kühberger, 1995; Wallin et al., 2016; but see Yao, Wang, Peng, & Song, 2018).

The present study addressed the presence of numeral modification. We follow the distinction between positive and negative quantifiers by Sanford, Dawydiak, and Moxey (2007) within their psycholinguistic account of *quantifier focus effects* (see also Teigen, 2023 for a related concept, i.e., *directionally negative verbal probability expressions*). More specifically, we propose that with positive quantification (e.g., bare numerals, *more than n, up to n, at least n, exactly n*), what is salient is that the given predicate holds for some instances. In contrast, negative quantification (e.g., *at most n, fewer than n*) may make the complement set salient, i.e. that there are instances for which the predicate does not hold. Hence, reversed framing effects with negative quantifiers are attributed to a reversal of what is salient. Within this proposal, the diverging result patterns for *bis zu* 'up to' and *höchstens* 'at most' in the present experiments are ascribable to that *bis zu* 'up to' is positive and *höchstens* 'at most' is negative. However, more and different types of data are needed to pinpoint the decisive differences between modifiers such as *up to* and *at most*.[3] An obvious and potentially relevant difference lies in the direction of inferences of persuasive intentions (see Cummins & Franke, 2021).

Description variants in framing studies allow for a variety of pragmatic inferences. Hence, numeral modification may not only affect what is salient but also pragmatic inferences as part of controlled and analytic reasoning processes subsequent to the immediate valence appraisal. These inferences may include persuasive and argumentative inferences but also *how-many inferences* and inferences of the non-salient part of the two-sided outcome. All numeral modifiers may affect these pragmatic inferences with varying effects. Our proposal of a semantic-pragmatic account in terms of valence and salience could be interlinked with dynamic dual process models (e.g., Diederich & Trueblood, 2018) by relating the initial valence appraisal and subsequent deliberate inferences to processes in System 1 and System 2, respectively.

To conclude, there is a wide spectrum of accounts of framing effects. The different explanations are not necessarily mutual exclusive and presumably multiple factors are at play. The present study addressed the effects of numeral modification. Based on our findings, we proposed a semantic-pragmatic account of framing effects that links to psychological explanations and incorporates psycholinguistic insights from research on language comprehension. Clearly, the scope of the present study is restricted. However, the findings are promising for further investigations.

[3] To gain some insight whether or not the two modifiers differ with respect to assumptions on the range of possible values of the modified numerals, Experiment 2 and 3 included an assessment of participants' *how-many*-estimates of the modified numerals. We adopted a method employed by Cummins, Sauerland, and Solt (2012) and Hesse and Benz (2020). Participants were asked to indicate a range and a single number (e.g., *How many people do you think will be saved? Between __ and __, most likely __*). The estimates of the range boundaries did not differ between *bis zu* 'up to' and *höchstens* 'at most'. For the estimates of the most likely value, there was a significant difference, but only in the negative frame (with smaller numbers for *höchstens* than for *bis zu*). These results do not provide a simple alternative explanation for the findings of Experiment 2 and 3. To be sure, however, assessments of numeral interpretations are challenging with regard to methodological and theoretical concerns and are to be interpreted with caution.

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