Ratio format shapes health decisions: The practical significance of the "1-in-X" effect

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All data sets, R code and materials used in this research are available at: https://osf.io/u69jq/.

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Abstract

Prior research found that "1-in-X" ratios led to higher and less accurate subjective probability than "N-in-X*N" ratios or other formats even though they featured the same mathematical information. It is unclear, however, whether the effect transfers into health decisions and the practical significance of the effect is undetermined. Based on previous findings and risk communication theories, we hypothesised that the "1-in-X" effect would occur and transfer into relevant decisions. We also tested whether age, gender and education differences would moderate the "1-in-X" effect on decision-making. We conducted three well-powered experiments (n = 1912) using a sample from the general adult UK population to test our hypotheses, estimated the effect and excluded a possible methodological explanation for such a transfer. In hypothetical scenarios, participants decided whether to travel to Kenya given the chance of contracting malaria (Experiment 1) and whether to take recommended steroids given the side effects (Experiments 2 and 3). Across the experiments, we replicated a small-to-medium "1-in-X" effect on the perceived probability, Hedge's g = -0.36, 95% CI [-0.47, -0.24], z = -6.18, p < .001 and found a small effect on subsequent decisions, OR = 1.32, 95% CI [1.10, 1.59], z = 2.99, p = .003. The perceived probability fully mediated the effect of the ratio format on decision. Age, gender and education did not moderate the "1-in-X" effect on decision. We argue that a high prevalence of "1-in-X" ratios in medical communication makes these small changes clinically relevant. Therefore, to communicate information accurately, "1-in-X" ratios should not be used or at least used cautiously in medical communication.

Keywords: "1-in-X" effect, subjective probability, risk communication, medical decisions

When making informed decisions about our health, an accurate perception of probabilistic information is critical. For instance, one can decide against taking steroids if the probability of experiencing side effects seems too high. Previous research studied the factors that shape subjective probabilities [1, 2]. As part of this research programme, recent studies found that “1-in-X” probability ratios (e.g., 1 in 10) consistently yielded higher subjective probabilities than the same probability magnitudes expressed as “N-in-X*N” ratios (e.g., 10 in 100) or percentages (e.g., 10%). This effect has been labelled the “1-in-X” effect [3]. The effect has been demonstrated with negative and positive outcomes, using various scenarios, replicated in different populations, and using different languages [3-5]. It has also been tested in an ecologically valid setting [6]. Based on this research, some called for the ratio to be eliminated from medical communication [7, 8]. “1-in-X” ratios are consistently higher than other numerical and pictorial formats [3-5] and lead to a larger overestimation of the probability compared with “N-in-X*N” ratios when using objective numerical scales [9]. This means that probability estimation is biased by “1-in-X” ratios.

It remains unclear whether the “1-in-X” effect has any practical significance – whether the effect on probability perception transfers into decisions. This is important to establish because “1-in-X” ratios are currently the most prevalent ratio format used in medical communication [10]. Indeed, the majority of family physicians used this format to communicate the risks associated with prenatal screening to pregnant women [10]. Both decision-making theories and risk communication theories assume that the probability of an event (e.g., probability of a side effect) affects decisions involving this event (e.g., taking a medicine) [11, 12]. Preliminary evidence also indicated that the format of probability ratios affected the decisions expressed as a likelihood of action [9]. However, two drawbacks prevented us from drawing firm conclusions from this evidence: (i) the decision measure followed the probability question, thus inviting an order effect and (ii) the decision measure

was continuous, which does not reflect the dual nature of decisions (e.g., accepting a treatment or not).

The Present Experiments

The present manuscript details three experiments aimed at tackling the issue of the "1-in-X" effect on health-related decisions. We had four main goals. First, we aimed to replicate the "1-in-X" effect in different scenarios. Second, we investigated whether the different ratios affected decisions presented as dichotomous choices: we used the decision to travel to Kenya considering the risk of contracting malaria (Experiment 1) and the decision to take steroids considering their side effects (Experiments 2 and 3). Whereas the former decision was based on a scenario used in the "1-in-X" effect literature [3, 5], the latter decision was based on ecologically valid materials taken from the UK's National Health Service website [13]. We also considered the possibility that the effect on decision could be a methodological artefact – and that it might occur due to providing an explicit probability rating. We therefore manipulated the presentation order of the measures (Experiments 1 and 2). Third, we tested whether the subjective probability would mediate the effect on the subsequent decision (Experiments 1-3). Finally, we tested whether people of different ages, genders or educational backgrounds were more sensitive to the effect of ratio format on decision. For that purpose we worked with a large sample of the UK adult population (overall n = 1912). We were interested in these relationships because prior research linked these variables with risk perception, health literacy and numeracy [14-16], even though such links were not detected specifically for the "1-in-X" effect. [5, 9]

We tested three main hypotheses and one research question. First, we expected that the "1-in-X" effect would affect the subjective probabilities across various health-relevant scenarios. Second, we expected that the "1-in-X" effect would affect health-related decisions.

Third, we expected that the effect would be mediated by the subjective probability perception. Finally, we explored the role of gender, age and level of education as possible moderators of the "1-in-X" effect on decision.

Experiment 1

Method

Participants and Design. We aimed to recruit at least 597 participants in order to detect a small effect ($OR = 1.71 \approx 10\%$ change from 0.2 to 0.3), while using a logistic regression and assuming $\alpha = .05$, $1 - \beta = .80$, and a two-sided test [17]. Therefore, 605 participants were recruited from an online panel (Prolific Academic) and completed a questionnaire. Only those participants who were at least 18 years old, resided in the UK and – to assure the quality of responses [18] – had an approval rating of more than 90% were eligible to participate. The participants were paid £1 for completing a 12-minute questionnaire which also featured a problem-solving task unrelated to the research reported here. Participants were mostly women (69.1%), the majority of whom had completed high school (38.2%) or held an undergraduate degree (41.2%). Their ages ranged from 18 to 84 years ($M = 36.0$, $SD = 11.7$ years). The sample consisted of managers and working professionals (25.8%), unemployed individuals, including students and homemakers (23.5%), and workers in sales and offices (12.6%), services (7.3%) or in another occupation.

In a 2(ratio: "1-in-X" vs "N-in-X*N") × 2(response order: probability first vs. decision first) between-subjects design, participants assessed the subjective probability of contracting malaria while travelling to Kenya and decided whether or not to maintain or cancel their booking.

Materials and Procedure. After providing informed consent, participants read a scenario describing a hypothetical situation in which they had booked a trip to Kenya [3]. In the scenario they learnt that the risk of contracting malaria during their trip was around 8%, described either with a "1-in-X" ratio (1 in 13) or an "N-in-X*N" ratio (10 in 130). Participants expressed their subjective probability of contracting malaria on an 11-point Likert scale (anchored as *1: extremely low, 11: extremely high*). On the same page, they reported their decision to cancel the trip (or not) on a dichotomous Yes/No scale. The response options were randomised (see Supplementary Materials for the exact wording). The presentation order of the probability and decision questions was counterbalanced. Participants then answered questions concerning their age, gender, level of education and occupation before being debriefed.

We followed the APA ethical guidelines when conducting all three experiments. We have reported all the experiments, measures, manipulations and exclusions. All data sets, R code and materials are available at: https://osf.io/u69jq/.

Results and Discussion

We found that participants provided higher probability estimates in the "1-in-X" condition than in the "N-in-X*N" condition and that this was the case regardless of the order of presentation of the questions (Figure 1, panel A). The observed "1-in-X" effect was statistically significant, $F(1, 601) = 24.52$, $p < .001$, $\eta_p^2 = 0.04$, whereas the main effect of order and the interaction term were not, $F(1, 601) = 3.60$, $p = .058$, $\eta_p^2 = 0.01$; $F(1, 601) = 0.81$, $p = .369$, $\eta_p^2 < 0.01$, respectively. Thus, we replicated the "1-in-X" effect on the subjective perception of the probability reported in the prior research [3, 5].

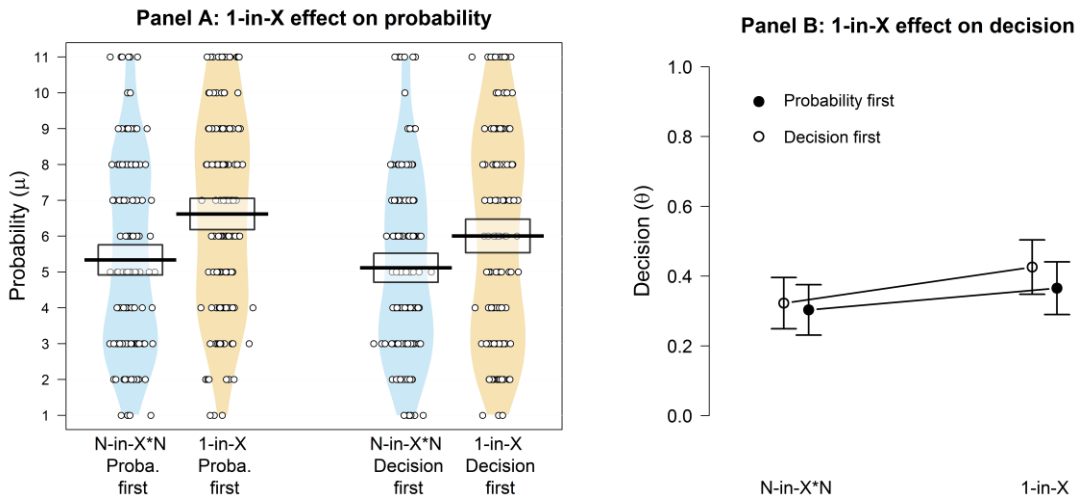

Figure 1: Effect of ratio format and presentation order on the perceived probability expressed as the risk of contracting malaria on an 11-point verbal Likert scale, (Panel A) and related decision expressed as a proportion of decision to cancel the trip to Kenya (Panel B).

Note. Panel A: Horizontal lines represent means, boxes represent 95% confidence intervals, beans represent smoothed densities, and circles represent individual responses.
Panel B: Dots represent proportion point estimates and bars represent 95% confidence intervals.

More participants decided to cancel their trip when the risk of contracting malaria was presented as a "1-in-X" ratio than an "N-in-X*N" ratio. This effect was slightly stronger when participants made their decision before providing a probability estimate rather than after (Figure 1, panel B). The interaction between the format and presentation order did not add significantly to the main effect model, $\chi^2(1) = 0.24$, $p = .626$, so only the main effect model was considered further. In this model, we found a significant effect of the ratio format, $OR = 1.45$, 95% CI [1.04, 2.04], $z = 2.19$, $p = .029$ and a non-significant effect of the order, $OR = 1.20$, 95% CI [0.86, 1.68], $z = 1.06$, $p = .289$.

To test the mediation hypothesis, we used a recommended analytical strategy using the macro PROCESS that relies on bootstrapped intervals [19, 20]. The total effect of the

ratio format on decision, $c = 0.37$, $z = 2.18$, $p = .029$, was fully mediated by the perceived probability, since the indirect effect was significant (i.e., bootstrapped CIs did not contain zero), $ab = 0.41$, 95% CI_{BCa} [0.24, 0.59] and the direct effect was substantially reduced and no longer significant, $c' = 0.01$, $z = 0.03$, $p = .977$. Hence, the ratio format affected decision-making, and this was not caused by an order effect in the tasks. We further established that the effect on decision was fully mediated via perceived probability, which is consistent with the prior literature on risk perception and with decision theories [12]. It is important to note that the mediation analysis does not account for the whole variability in the decision-making variable, instead, it accounts for the variability in decision-making caused by the ratio format manipulation.

Age, gender and education level did not moderate the effect of the format on decision in three separate logistic regression models Age (mean-centred) did not significantly affect decision and did not significantly interact with the format, $OR = 1.01$, 95% CI [0.99, 1.03], $z = 0.68$, $p = .495$; $OR = 0.99$, 95% CI [0.97, 1.02], $z = -0.46$, $p = .643$, respectively. Gender (dummy-coded) did not significantly affect decisions and did not significantly interact with the format, $OR = 0.75$, 95% CI [0.44, 1.28], $z = -1.07$, $p = .285$; $OR = 1.24$, 95% CI [0.60, 2.55], $z = 0.59$, $p = .554$, respectively. Education level (recoded here as the dummy-coded variable – 0: completed high school education or lower education, $n = 239$, vs. 1: bachelor degree or higher education, $n = 366$) did not significantly affect decisions and did not significantly interact with the format, $OR = 1.21$, 95% CI [0.74, 2.00], $z = 0.76$, $p = .445$; $OR = 0.68$, 95% CI [0.34, 1.36], $z = -1.09$, $p = .275$, respectively. We did not find evidence to support the fact that people of different ages, genders or educational levels would be more (or less) prone to the probability format affecting their decisions.

Experiment 2

In Experiment 1, we demonstrated that the ratio format affected the perceived probability which then had an impact on decision. In Experiment 2, we wanted to extend the robustness of the demonstration to a more realistic and complex health scenario. Therefore, we devised a scenario closely mimicking a situation of risk communication to a patient using wording from the NHS UK website describing side effects of a recommended drug (prednisolone).

Method

Participants and Design. The same a priori stopping rule was used as in Experiment 1 (i.e., at least 597 participants to detect a small effect). A different sample of 605 participants was recruited from an online panel (Prolific Academic). We used the same eligibility criteria as in Experiment 1. Participants were mostly women (69.6%), the majority of whom had either finished high school (37.9%) or held an undergraduate degree (43.3%). Their ages ranged from 18 to 68 years (M = 35.6, SD = 11.6 years). The sample consisted of managers and working professionals (25.5%), unemployed individuals, including students and homemakers (24.6%), workers in sales and offices (12.9%), in services (6.3%) or in another occupation.

In a 2(ratio: "1-in-X" vs "N-in-X*N") × 2(response order: probability first vs. decision first) between-subjects design, participants assessed the subjective probability of a steroid's side effect and decided whether or not they would adhere to the medication.

Materials and Procedure. After providing informed consent, participants read a scenario describing a hypothetical situation in which they suffered from a reactive form of arthritis and their family physician suggested taking prednisolone to manage their symptoms (see Supplementary Materials). They also learnt that the risk of experiencing side effects such as

depression and hallucinations while taking prednisolone was around 5%, described either as a “1-in-X” ratio (1 in 20) or an “N-in-X*N” ratio (5 in 100). In order to appear as realistic as possible, the scenario text was adapted from the NHS website and the prednisolone leaflet. Curiously, while the NHS website reported the risk to be 1 in 20, the prednisolone leaflet described the risk as 5 in 100. Participants assessed their subjective probability of experiencing these side effects on an 11-point Likert scale, (“In your opinion, when taking prednisolone, the probability of experiencing changes in your mental state, such as depression or hallucinations, is…”, anchored as *1: extremely low*, *11: extremely high*). They also reported their decision as to whether they would take the medication regularly (or not) on a dichotomous Yes/No scale, (“Given that the probability of experiencing changes in your mental state, such as depression or hallucinations, is 1 in 20 [5 in 100] when taking prednisolone, would you regularly take this medication?”) The options were randomised and the presentation order of the two questions was systematically counterbalanced. Participants then reported their age, gender, level of education and occupation, and were debriefed.

Results and Discussion

We observed substantial variations in probability perception according to the ratio format – the "1-in-X" format led to higher probability perception compared with the "N-in-X*N" format, whereas the probability varied minimally according to the presentation order (Figure 2, panel A). The observed "1-in-X" effect was statistically significant, $F(1, 601) = 45.25$, $p < .001$, $\eta_p^2 = 0.07$, whereas the main effect of order and the interaction with the main effect of ratio format were not, $F(1, 601) = 0.13$, $p = .723$, $\eta_p^2 < 0.01$; $F(1, 601) = 0.14$, $p = .705$, $\eta_p^2 < 0.01$, respectively. Thus, we replicated the findings from Experiment 1 concerning the significant "1-in-X" effect and the non-significant effect of order on probability perception.

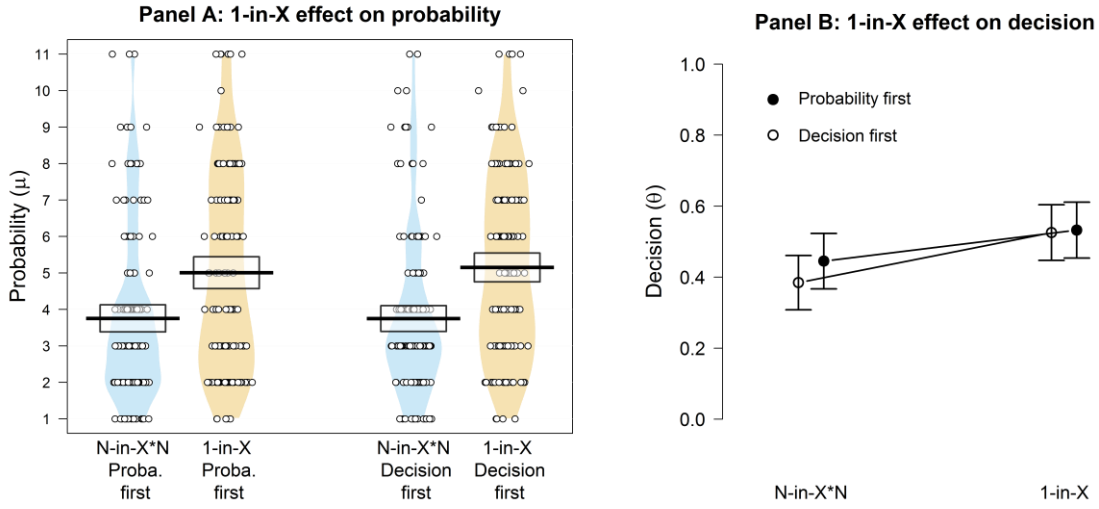

Figure 2: *Effect of ratio format and presentation order on the perceived probability expressed as the risk of experiencing side effects on an 11-point verbal Likert scale, (Panel A) and related decision expressed as a proportion of decisions not to take prednisolone (Panel B).*

Note. Panel A: Horizontal lines represent means, boxes represent 95% confidence intervals, beans represent smoothed densities and circles represent individual responses.

Panel B: Dots represent proportion point estimates and bars represent 95% confidence intervals.

Participants decided not to take the medication (0: to take prednisolone, 1: not to take prednisolone) more often when the risk was presented in the "1-in-X" format compared with the "N-in-X*N" format, the effect of which was slightly more pronounced in the decision-first condition (Figure 2, panel B). In the main effect model (adding an interaction term did not significantly increase explained variance, $\chi^2(1) = 0.48$, $p = .486$), we found a significant effect of the format, *OR* = 1.61, 95% CI [1.17, 2.22], $z = 2.89$, $p = .004$ and a non-significant effect of the order, *OR* = 0.87, 95% CI [0.63, 1.20], $z = -0.86$, $p = .391$.

The total effect of format on decision, $c = 0.47$, $z = 2.88$, $p = .004$, was fully mediated by the perceived probability, because the indirect effect was significant (i.e., bootstrapped CIs did not contain zero), $ab = 0.38$, 95% CI_{BCa} [0.24, 0.55]. The direct effect was substantially reduced and no longer significant, $c' = 0.13$, $z = 0.74$, $p = .457$. Yet again we found the "1-in-X" effect on probability and decision-making. The effect on decision was fully mediated via probability perception.

Age, gender and education level (using the same approach and recoding as in Experiment 1) did not moderate the effect of the ratio format on decision, nor did they directly impact the decision to adhere to the treatment. Age (mean-centred) did not significantly affect decision and did not significantly interact with the format, *OR* = 1.02, 95% CI [1.00, 1.04], $z = 1.91$, $p = .057$; *OR* = 0.99, 95% CI [0.96, 1.02], $z = -0.73$, $p = .468$, respectively. Gender (dummy-coded) did not significantly affect decisions and did not significantly interact with the format, *OR* = 1.42, 95% CI [0.85, 2.40], $z = 1.31$, $p = .189$; *OR* = 0.89, 95% CI [0.48, 1.99], $z = -0.05$, $p = .958$, respectively. Education level (recoded here as a dummy-coded variable – 0: completed high school education or lower education, $n = 238$, vs. 1: bachelor degree or higher education, $n = 367$) did not significantly affect decisions and did not significantly interact with the format, *OR* = 1.25, 95% CI [0.78, 2.01], $z = 0.93$, $p = .351$; *OR* = 0.76, 95% CI [0.39, 1.46], $z = -0.83$, $p = .405$, respectively. Thus, we did not

find evidence that people of different ages, genders or education levels would be more (or less) prone to the format affecting their decision-making process.

Experiment 3

In Experiment 3, we aimed to replicate the effect of the ratio format on probability perception and decision in a sample balanced in terms of gender and with more variance in age and education, using different ratios (1 in 20 vs. 10 in 200) and with delayed presentation of the decision-making question (i.e., presented on a subsequent page). This aimed to test the robustness of the effect on decision-making, specifically whether the effect on decision is dependent on mental representations of risk stored in short-term memory as is often the case in real-life decisions. Since we found no order effects on probability and decision, we presented the measures in a fixed order: the main variable of interest – decision-making – was always presented first and the probability question second.

Method

Participants and Design. A similar power consideration was applied to define an a priori stopping rule as in the previous experiments. A sample of 831 participants was recruited from a different online panel to that of Experiments 1 and 2 (Bilendi) which was part of a larger study investigating other health-related topics. The sample composition roughly matched the composition of the UK adult population in terms of age, gender, education and living area. Only those participants who were at least 18 years old, resided in the UK, and answered all the dependent variable questions were included in the final sample. Since we did not have control over the quality of responses, we measured the time people took to read the scenario and excluded those who were rushing – i.e., those who read the scenario in less than 8.9 seconds, which was a third of the median time required for reading the scenario. This was an a priori exclusion rule that is part of the standard operating procedures of the lab and is

applied consistently in other papers [21]. The final sample was composed of 702 participants: 52.8% women, 46.4% men and 0.6% transgender or gender variant, 1 missing answer; 28.3% completed a GCSE, 15.5% an A-level and 34.7% a degree, whereas others held an apprenticeship (3.6%), some other qualification (13.3%) or no qualification at all (4.6%). The participants' ages were measured in age categories (in years) to facilitate the quota sampling: 18-24 (3.6%), 25-34 (13.4%), 35-44 (20.2%), 45-54 (21.2%), 55-64 (19.9%) and 65-74 (21.1%); four participants did not provide this information. The sample consisted of full-time workers (38.2%), retired people (26.8%), unemployed (13.4%), part-time workers (11.4%) and students (1.6%); six participants did not provide this information.

In a simple between-subjects design, in which we manipulated ratio ("1-in-X" vs "N-in-X*N"), participants decided whether or not they would adhere to the medication and assessed the subjective probability of a steroids' side effect.

Materials and Procedure. After providing informed consent, participants answered socio-demographic questions and some questions that were irrelevant to the reported research. They then read the same prednisolone scenario as in Experiment 2. The risk of experiencing side effects such as depression and hallucinations was described either as a "1-in-X" ratio (1 in 20) or an "N-in-X*N" ratio (10 in 200). On a separate page, participants reported their decision as to whether they would take the medication regularly (or not) using the same questions and scales as in Experiment 2; the options were presented in a random order. On the next page, participants assessed their subjective probability of experiencing the side effect using the same wording and scale as in Experiment 2. Participants were then debriefed.

Results and Discussion

We observed that the "1-in-X" ratio increased the perceived probability only slightly compared with the "N-in-X*N" condition (Figure 3, panel A). The observed "1-in-X" effect was not statistically significant, $F(1, 700) = 2.71$, $p = .100$, $\eta_p^2 = 0.004$.

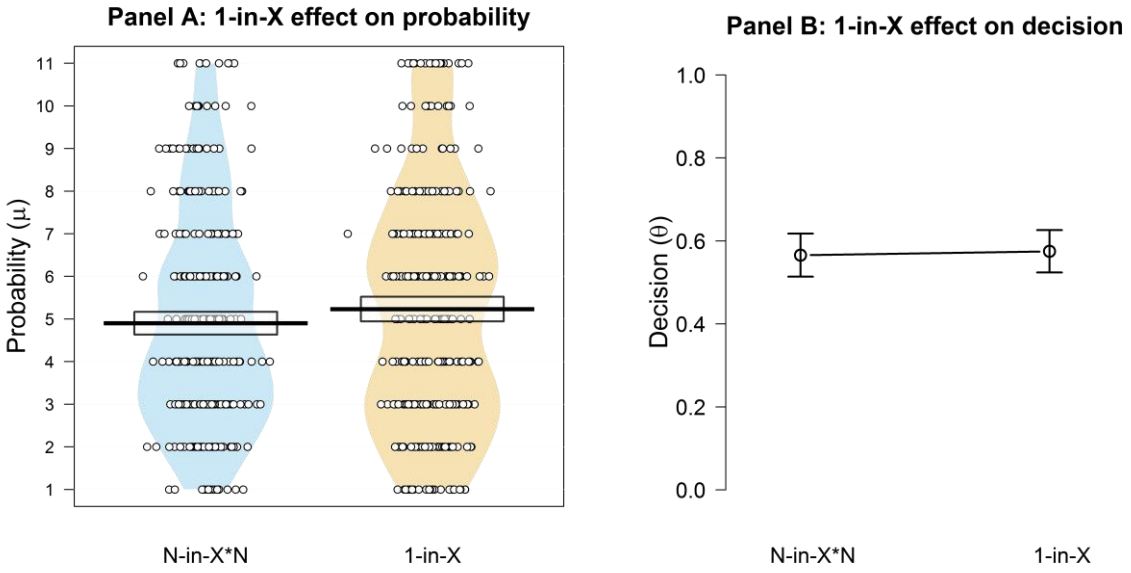

Figure 3: *Effect of ratio format on the perceived probability expressed as the risk of experiencing side effects on an 11-point verbal Likert scale, (Panel A) and related decision expressed as a proportion of decisions not to take prednisolone (Panel B).*

Note. Panel A: Horizontal lines represent means, boxes represent 95% confidence intervals, beans represent smoothed densities and circles represent individual responses.
Panel B: Dots represent proportion point estimates and bars represent 95% confidence intervals.

We found that the "1-in-X" ratio caused only a small increase in the proportion of decisions not to take prednisolone (0: to take prednisolone, 1: not to take prednisolone) compared with the "N-in-X*N" ratio (Figure 3, panel B). We found a non-significant effect of the format, $OR = 1.04$, 95% CI [0.77, 1.40], $z = 0.25$, $p = .802$ (i.e., the direction was consistent with the "1-in-X" effect). Since we did not find a statistically significant or

substantial effect we did not run a mediation analysis of the "1-in-X" effect on decision via probability perception.

Neither age nor gender moderated the effect of the format on decision, whereas education level did moderate the magnitude of the effect. Age (treated as a scale variable here and mean-centred prior analysis) did not significantly affect decision and did not significantly interact with the format, *OR* = 1.16, 95% CI [1.00, 1.35], *z* = 1.96, *p* = .050; *OR* = 1.02, 95% CI [0.83, 1.26], *z* = 0.22, *p* = .825, respectively. Gender (dummy-coded; excluding a few answers in the other categories) did not significantly affect decisions nor interact with the format, *OR* = 1.32, 95% CI [0.86, 2.03], *z* = 1.27, *p* = .203; *OR* = 0.90, 95% CI [0.49, 1.64], *z* = -0.35, *p* = .725, respectively. Education level (dummy coded; 0: lower education level – no qualification, apprenticeship, GCSE; 1: higher education level – 2+ A-levels and degree+; other qualification was excluded since it is a mixed category) did not significantly affect decisions but did significantly interact with the format, *OR* = 1.30, 95% CI [0.81, 2.09], *z* = 1.07, *p* = .283; *OR* = 0.50, 95% CI [0.26, 0.96], *z* = -2.09, *p* = .036, respectively. Those with lower levels of education were more prone to the "1-in-X" effect than those with higher education levels for whom the effect was in the opposite direction. Thus, age and gender did not interact with the format in their effect on decision-making, whereas education level did.

Data Synthesis: Estimating the "1-in-X" Effect on Probability and Decision

To summarise the "1-in-X" effect on subjective probability and decision across the experiments reported here (see Table 1 for summary), we computed an internal meta-analysis using fixed and random effect models with the R package metafor [22]. We found a small-to-medium and statistically significant "1-in-X" effect on perceived probability across the three experiments using a fixed effect model, Hedge's *g* = -0.36, 95% CI [-0.47, -0.24], *z* = -6.18, *p* < .001 (a random effect model yielded a similar conclusion, *g* = -0.36, 95% CI[-0.60, -0.11]).

We found a small "1-in-X" effect on health decision across the three experiments using a fixed effect model, *OR* = 1.32, 95% CI [1.10, 1.59], $z = 2.99$, $p = .003$ (a random effect model yielded similar results, *OR* = 1.33, 95% CI [1.02, 1.74]). The odds of mitigating the risk – by *cancelling* a trip or by *not* adhering to a treatment – were 24% more likely when the risk was quantified as a "1-in-X" ratio than when the risk was quantified as an "N-in-X*N" ratio. When we pooled the data from the three experiments, we found an approximate 12% absolute risk difference (414/951 vs. 537/961), which means that being exposed to the "1-in-X" ratio brought 12 excess decisions to mitigate the risk per 100 decisions compared with the "N-in-X*N" ratio.

Table 1: Effect of ratio manipulation on the perceived probability and related decisions (Experiment 1: cancelling a trip abroad; Experiments 2 and 3: not taking the recommended medicine).

	Probability		Decision	
	"N-in-X*N"	"1-in-X"	"N-in-X*N"	"1-in-X"
	M (*SD*)	*M* (*SD*)	%	%
Experiment 1	5.2 (2.6)	6.3 (2.8)	30.8	39.3
Experiment 2	3.8 (2.3)	5.1 (2.6)	41.2	53.0
Experiment 3	4.9 (2.5)	5.2 (2.8)	56.6	57.6

General Discussion

In three well-powered experiments, we found that "1-in-X" ratios led to higher probability perception compared with "N-in-X*N" ratios. The overall "1-in-X" effect was small-to-medium sized. Critically, "1-in-X" ratios altered the subsequent health decisions:

more people cancelled the trip abroad to remedy the risk of contracting an illness (Experiment 1) and more people did not adhere to the recommended treatment considering the risk of experiencing side effects (Experiment 2; but not significantly so in Experiment 3); the overall effect size was small. The effect on decision cannot be explained as a methodological artefact, i.e. as an expressed consequence of making a probability judgment prior to making a decision, given that we did not find that the order of the questions mattered (Experiments 1 and 2). The format effect on decision was fully mediated by the perceived probability of contracting the illness (Experiment 1) or experiencing side effects (Experiment 2). Socio-demographic indicators – age, gender and education – did not moderate the effect on decision with the exception of a higher sensitivity to the “1-in-X” effect for those less educated (Experiment 3). Our findings are consistent with prior research that demonstrated the “1-in-X” effect on probability perception [3-5]. The effect size is similar to that found in the recent meta-analysis which included some null findings [5]. The “1-in-X” effect on decisions and its mediation via subjective probability is consistent with prior evidence on the link between probability and decision [1, 12] and is also aligned with current theories of decision-making, in which perceived probability along with perceived utility are expected to determine decision-making such as the prospect theory [11].

To draw up the practical implications of our findings, we need to interpret the small effect on decision identified here in terms of practical significance. However, before drawing any conclusion, we need to cover two important caveats of our research: one concerning the size of the effect and one concerning the context in which such interpretations are made. First, the effects generally reported in the literature are inflated [23] because of a bias favouring the publication of significant results, which might distort our perception of effect size. Here, we have transparently reported all of the three studies we conducted to assess the practical significance of the “1-in-X” effect, hence we believe that our estimate of the effect

size does not suffer from such a distortion. Due to the high prevalence of “1-in-X” ratios in health communication, the small effect on decision can have a big cumulative effect [10]. Second, we have considered a context of informed decision-making where the objective is to communicate the information as accurately as possible. However, there might be different contexts such as health change and persuasion, in which practitioners might wish to emphasise the risks and therefore use “1-in-X” ratios.

Bearing these caveats in mind, we need to pay further consideration to the costs and benefits associated with the change of formats following the framework of determining a sufficiently important difference [24]. Given the small but cumulative harmful effect that the “1-in-X” ratios can bring to patients, and considering the fact that there is virtually no cost involved in changing the format, we believe that the ratio should be used sparsely. This conclusion is aligned with the calls to abandon “1-in-X” ratios [8].

One possible limitation in our research is whether or not we can trust the conclusion since we have presented mixed findings (two out of three experiments were significant). First, by conducting an internal meta-analysis, we demonstrated that the effect is present and statistically significant. Second, the mixed findings are far more common than they are reported. We can calculate the support for the null and alternative hypothesis in our research [25]. The probability of two out of three studies being significant, given the assumption that the alternative hypothesis is true (while having 80% power) is 38.4% and only 0.7% given the assumption that the null hypothesis is true (while having 5% alpha). The likelihood ratio (LR) then compares how well the two hypotheses predict the data; in this case LR = 0.384/0.007 = 55, which indicates that the observed results are around 55 times more likely to occur under the assumption that the alternative hypothesis is true rather than under the assumption that the null hypothesis is true [25]. Another limitation of our studies is that we focused on hypothetical decisions. Future research should focus on the impact of ratios on

actual rather than hypothetical decisions. The evidence available so far pinpoints the fact that there are no big differences in the perceived probability between hypothetical and actual situations of probability assessment in different studies [3, 6, 26], which indicates that we can expect to observe similar findings in real life as we have found in hypothetical situations. Finally, the current research does not address the issue of the psychological processes underlying the “1-in-X” effect. Future research should clarify these processes and test proposals suggested in prior research such as gist interpretation [8], ease of imagination [4], or association with severity and its subsequent overestimation [10].

To conclude, we found that “1-in-X” ratios led to higher subjective probability perception compared with “N-in-X*N” ratios. This difference drove the changes in decisions. We also found that people of different ages, genders or education levels were not more prone to these changes. Due to the high prevalence of “1-in-X” ratios, the relatively small effect of these ratios grows into a cumulative effect on decision-making, which might obscure informed decision-making. As there are minimal costs associated with the format use, health communicators wanting to promote accurate risk perceptions should use “N-in-X*N” ratios instead.

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Supplementary Materials

Experiment 1: Materials

Kenya Scenario

Imagine that you have booked a trip to Kenya and you now learn that the risk of being infected by malaria during your trip to Kenya is 1 in 13 [10 in 130].

Questions

Given this risk, would you cancel your trip to Kenya?

- ❍ No
- ❍ Yes

In your opinion, the probability of being infected by malaria during your trip to Kenya is . . .

	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Note. In the "1-in-X" condition, 1 in 13 ratio was used, whereas in the "N-in-X*N" condition, 10 in 130 ratio was used (shown in squared brackets here). The order of the questions was systematically counterbalanced.

Socio-demographic questions

What is your age?

[Participants selected one option out of the range of values between 18 and 100]

What is your gender?

- ❍ Male
- ❍ Female

What is your occupation?

- ❍ Management, professional, and related
- ❍ Service
- ❍ Sales and office
- ❍ Farming, fishing, and forestry
- ❍ Construction, extraction, and maintenance
- ❍ Production, transportation, and material moving
- ❍ Government
- ❍ Retired
- ❍ Unemployed (including students and homemakers)
- ❍ Other

Which of the following best describes your highest achieved education level?

- ❍ Less than High School
- ❍ Finished High School
- ❍ Undergraduate Degree
- ❍ Master's Degree
- ❍ Doctoral (PhD) or Professional (JD, MD) Degree

Experiment 2: Materials

Prednisolone Scenario

Please imagine that you have developed a condition called reactive arthritis. Reactive arthritis causes inflammation (redness and swelling) in various places in the body. It usually develops following an infection, and in most cases clears up in a few months without causing long-term problems. Your symptoms include joint pain, tenderness and swelling, lower back pain, swelling of your fingers and watery eyes. Due to your stomach condition, you're unable to use ibuprofen which is usually used for treatment. Your GP suggests instead that you take a steroid medication: prednisolone. Your GP tells you that the probability of experiencing changes in your mental state, such as depression or hallucinations, associated with taking prednisolone is 1 in 20 [5 in 100].

Questions

Given that the probability of experiencing changes in your mental state, such as depression or hallucinations, is 1 in 20 [5 in 100] when taking prednisolone, would you regularly take this medication?

❍ No
❍ Yes

In your opinion, when taking prednisolone the probability of experiencing changes in your mental state, such as depression or hallucinations, is:

	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Note. In the "1-in-X" condition, 1 in 20 ratio was used, whereas in the "N-in-X*N" condition, 5 in 100 ratio was used (shown in squared brackets here). The order of the questions was systematically counterbalanced. The materials were adjusted from the NHS website.

Socio-demographic questions

What is your age?

[Participants selected one option out of the range of values between 18 and 100]

What is your gender?

- ❍ Male
- ❍ Female

What is your occupation?

- ❍ Management, professional, and related
- ❍ Service
- ❍ Sales and office
- ❍ Farming, fishing, and forestry
- ❍ Construction, extraction, and maintenance
- ❍ Production, transportation, and material moving
- ❍ Government
- ❍ Retired
- ❍ Unemployed (including students and homemakers)
- ❍ Other

Which of the following best describes your highest achieved education level?

- ❍ Less than High School
- ❍ Finished High School
- ❍ Undergraduate Degree
- ❍ Master's Degree
- ❍ Doctoral (PhD) or Professional (JD, MD) Degree

Experiment 3: Materials

Instruction

Now, you are going to read a hypothetical scenario concerning your health, in which you will be asked to make a health-related decision. Please note that the general information provided in the scenario are actual information taken from NHS.

Prednisolone Scenario

Please imagine that you have developed a condition called reactive arthritis. Reactive arthritis causes inflammation (redness and swelling) in various places in the body. It usually develops following an infection, and in most cases clears up in a few months without causing long-term problems. Your symptoms include joint pain, tenderness and swelling, lower back pain, swelling of your fingers and watery eyes. Due to your stomach condition, you're unable to use ibuprofen which is usually used for treatment. Your GP suggests instead that you take a steroid medication: prednisolone. Your GP tells you that the probability of experiencing changes in your mental state, such as depression or hallucinations, associated with taking prednisolone is 1 in 20. [10 in 200].

Questions

Given that the probability of experiencing changes in your mental state, such as depression or hallucinations, is 1 in 20 [10 in 200] when taking prednisolone, would you regularly take this medication?

❍ No
❍ Yes

In your opinion, when taking prednisolone the probability of experiencing changes in your mental state, such as depression or hallucinations, is:

	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Note. In the "1-in-X" condition, 1 in 20 ratio was used, whereas in the "N-in-X*N" condition, 10 in 200 ratio was used (shown in squared brackets here). The order of the questions was fixed: the probability question always followed the decision question. The materials were adjusted from the NHS website.

Socio-demographic questions

To which gender identity do you most identify?

- ❍ Male
- ❍ Female
- ❍ Transgender male
- ❍ Transgender female
- ❍ Gender variant/Non-conforming
- ❍ I do not wish to answer this question

What is your type of occupation?

- ❍ Full-time
- ❍ Part-time
- ❍ Self-employed
- ❍ Student
- ❍ Unemployed
- ❍ Retired

What is your highest level of education?

- ❍ GCSE
- ❍ 2+ A-level
- ❍ Degree+
- ❍ Apprenticeship
- ❍ Other Qualification
- ❍ No Qualification

How old are you?

- ❍ 18-24
- ❍ 25-34
- ❍ 35-44
- ❍ 45-54
- ❍ 55-64
- ❍ 65-74