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Individual differences moderate effects in an Unusual Disease paradigm: a within-subjects study using a psychophysical data collection approach

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Abstract

We investigate the impact of individual differences in risk-style and thinking-style on choice option characteristics in Tversky and Kahneman's famous Unusual Disease problem setting with a psychophysical data collection approach extending Mahoney et al. (2011). In addition to gain-loss frames, we varied the number of affected people, probabilities of surviving/dying, the type of disease, and the allotted time for making a decision. Framing effects were moderated by individual differences measured on five different scales. Moreover, the effects of disease type and probability to survive/die on risky choice frequencies were also affected by individual differences on all five scales; the effect of the number of affected people and time limits by some scales. The study further demonstrates that a psychophysical approach allows for varying defining choice characteristics and presenting them in a within-subjects design.

Keywords: Individual differences, Framing effects, Risky choice, Thinking-style, Risk-style, Psychophysics, Within-subjects design

1 Introduction

Since Tversky and Kahneman's (1981) seminal paper on framing, a vast number of studies have shown that decisions under risk are often influenced by the way the decision problem is presented. This phenomenon, known as framing effect, violates the normative principle of description invariance; that is, a decision must not depend on the way how it is presented. Presumably, the most famous and most applied example for framing risky choice alternatives is Tversky and Kahneman's (1981) Unusual Disease Problem.[1] The problem describes two

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[1]We use a more contemporary term without labeling the disease with a country or region of origin.

programs to combat a hypothetical disease that is expected to kill 600 people in either a positive or a negative frame. In the positive (negative) frame, 200 people can be saved (400 will die) for sure with program A (C), or 600 people will be saved (will die) with a probability of 1/3 (2/3) with program B (D). Most of the participants chose program A in the positive frame (72%) and program D in the negative frame (78%).

The effect of framing in Unusual Disease Problems was repeatedly demonstrated by more than 40 studies (see e. g., Kühberger et al., 1999; Kühberger, 1998; Levin et al., 1998, for meta-analytic reviews). In their meta-analysis of Unusual-disease-like studies, Kühberger et al. (1999) found that "framing remains the most important predictor" (Kühberger et al., 1999, p. 223), but other variables can also influence the choice between the programs. In addition to problem-describing characteristics such as probabilities, magnitude of outcome, problem domain, or different time constraints (see Diederich et al., 2018; Mahoney et al., 2011, for overviews), previous research considered individual characteristics to be moderators for risky choice framing effects (Kühberger, 1997). While some studies indicated that individual characteristics influence the strength of framing effects, for instance, risk-taking propensity (Fagley & Miller, 1990), cognitive ability (Stanovich & West, 1998), or rational and intuitive thinking-styles (Shiloh et al., 2002), many research failed to identify a significant relationship (Kühberger, 1997).

With a few exceptions (e. g., Bruine de Bruin et al., 2007; LeBoeuf & Shafir, 2003; Levin et al., 2002; Li & Liu, 2008; Mahoney et al., 2011; Parker & Fischhoff, 2005; Stanovich & West, 1998), the impact of individual characteristics on framing effects has been investigated with between-subjects designs: a particular decision problem is described by different frames and each participant responds to only one of these frames. The responses of all participants are then aggregated for the analysis. However, several researchers pointed out that a within-subjects design is more appropriate when investigating framing effects on the individual level (Aczel et al., 2018; Frisch, 1993; Mahoney et al., 2011). It allows analyzing individuals' susceptibility to framing effects based on certain individual characteristics.

A key challenge of within-subjects studies on framing effects is the transparency of framing manipulation. Once participants notice the similarity between frames, they may tend to give the same response in both frames (Aczel et al., 2018). The common way of dealing with this problem is adding intervening steps between the two frames, for instance, by inserting a temporal break (e. g., Levin et al., 2002; Parker & Fischhoff, 2005), inserting filling questions (e. g., LeBoeuf & Shafir, 2003; Li & Liu, 2008; Stanovich & West, 1998), or masking the frames by presenting different problems in random order (e. g., Frisch, 1993). However, framing effect sizes are often smaller in within-subjects studies than in between-subjects designs (Aczel et al., 2018; Piñon & Gambara, 2005). This difference is commonly explained with the higher transparency of within-subjects designs (Kahneman & Frederick, 2005), despite the efforts to reduce the similarity between frames.

To overcome these problems, Mahoney et al. (2011) introduced an alternative approach: The Unusual Disease Problem varied with respect to the specific disease, the number of

affected people, and probabilities of surviving/dying to create five unique choice problems. Each of these problems was framed as gain and loss, resulting in ten experimental choice situations to be answered by each participant.

Mahoney et al. measured individual differences in risk-styles and thinking-styles with different questionnaires: Stimulating Instrumental Risk Inventory (SIRI), Choice Dilemmas Questionnaire (CDQ), Risk Avoidance Scale (RAS), and Rational Experiential Inventory (REI). They found robust framing effects. However, their results did not support their hypotheses that risk- and thinking-styles moderate the framing effects.

The goal of the current study is the following. First, we seek to extend the study of Mahoney et al. (2011) by using a psychophysical approach. Instead of designing ten choice problems administered to 184 students, we vary the number of affected people and probabilities such that it results in 480 experimental trials administered to 55 participants. This approach had successfully been used in other framing studies (Diederich et al., 2020; Guo et al., 2017). Second, we further investigate individual differences in choice behavior by including the variables defining the choice problems as explanatory variables. We expect this to shed some light on the "suggestive evidence" provided by the Mahoney et al. (2011, p. 255) study.

2 Experiment

We reanalyzed data collected in Diederich et al. (2018). Similar to Mahoney et al. (2011), they used three different diseases embedded into two frames. Details on the number of affected people, probabilities, and response deadline variations are described in the following. For the current study, we elected scores on different personality scales to examine the influence of individual differences on choice behavior. Data can be found openly accessible on https://osf.io/3a8u6/.

2.1 Participants

Fifty-five undergraduates (26 female, 29 male) of the Jacobs University Bremen participated in two experiment sessions (age: 18 to 26 years; median=20; English speakers). See Diederich et al. (2018) for details.

2.2 Materials

Diederich et al. defined two major categories for the number of affected people, called Scope here. Condition Small included the values 20, 40, 60, and 80, flanked by ± 1; for condition Large, these numbers were multiplied by 100. The probabilities of surviving/dying were 0.3, 0.4, 0.6, and 0.7. For a given Scope, the 48 combinations (12×4) were framed as gains and losses, resulting in 96 test trials. In addition, 24 catch trials (twelve per frame) were constructed to assess accuracy and engagement in the task (for details see Diederich et al.,

2018), resulting in a total of 120 trials presented in one block. Furthermore, a block of trials was embedded in one of three diseases (Disease: Infectious, Leukemia, AIDS) with a response deadline of 1 or 3 seconds. The disease scenarios can be found in the Appendix.

2.3 Measures

We measured risk-styles with the SIRI (Zaleskiewicz, 2001), which is based on the reflection/impulsivity approach (e. g., Evans, 2008; Kahneman, 2003; Kahneman & Frederick, 2002). Zaleskiewicz (2001) distinguished between stimulating and instrumental risk-taking. Stimulating risk is associated with the enjoyment of risk and may lead to faster and less analytical decisions (impulsive). Instrumental risk-taking is motivated by reaching a goal. High instrumental risk-takers are expected to carefully analyze the characteristics and values of a risky choice (reflective). The SIRI is composed of two sub-scales, the stimulating-risk sub-scale (ST) and the instrumental-risk sub-scale (IN). Participants have to self-assess their attitudes to 17 statements (10 ST, 7 IN) using a 5-point Likert scale from 1 ("does not describe me at all") to 5 ("describes me very well"). In the current study, the reliability was α=.74 for the ST scale and α=.58 for the IN scale.

We measured thinking-styles with two different inventories. First, similarly to Mahoney et al. (2011), we used the Rational-Experiential Inventory, with the rational-analytic (RA) and the experiential-intuitive (EX) sub-scales (Pacini & Epstein, 1999), which is also based on the reflection/impulsivity approach. Experiential-intuitive thinking is characterized by rapid, holistic, and emotional thinking, whereas rational-analytic thinking is slow, analytic, and logical (Epstein, 1998). Participants rated all items on a 5-point Likert scale that ranged from 1 ("definitely not true of myself") to 5 ("definitely true of myself"). The reliability of RA and EX were α=.86 and α=.84, respectively.

Second, we included Actively Open-Minded Thinking (AOT) as an additional scale that goes "beyond the reflection/impulsivity construct" (Haran et al., 2013). Individuals with higher AOT values are often associated to be less susceptible to biases (Svedholm-Häkkinen & Lindeman, 2018) including framing effects (see e. g., Sá et al., 1999; West et al., 2008). The current study applied the 7-item short form of the AOT scale as used in Haran et al. (2013), who investigated the role of AOT in the acquisition, accuracy, and calibration of information. They found that AOT correlates with persistence and coherence. Participants rated all items on a 7-point Likert scale from 1 ("completely disagree") to 7 ("completely agree"). In the current study, the reliability of the AOT scale was α=.7.

The questionnaires as they were used in this study are found in Supplement S1.

2.4 Design and procedure

The study had a mixed design. Three diseases and two levels of Scope were paired to six combinations. Each subject was exposed to two different diseases, one with Small and the other with Large Scope. The remaining factors were balanced within subjects. Each

participant completed 480 trials in two sessions with two blocks of 120 trials, the first block of trials with a 3s deadline, the second with a 1s deadline. Note that within a given session, Disease and Scope conditions were the same. Participants had five-minute breaks between blocks and sessions.

The experimental trials started by showing the number of affected people for the corresponding trial. The subsequent screen showed the choice options (visualized by pie charts) and time limit for that particular trial. A response had to be made within the given time limit. The last screen provided feedback about the outcome of the choice. After offset of the screen, the next trial started (for details see Supplement S2 and Diederich et al., 2018). Participants filled the REI after the first session, the AOT before the second session, and the SIRI after the second session. Questions of each scale were presented in random order.

2.5 Data Processing and Statistical Methods

According to common practice in the individual risk-style and thinking-style literature (see e. g., Shiloh et al., 2002; Mahoney et al., 2011), we categorized participants according to their scores in each (sub)scale into three groups. As in Mahoney et al. (2011), the cut-off points were at 33% and 66% to create three groups of about equal sizes. In the following, we indicated the group affiliation of a participant for a specific scale by the *scale name* and the *first letter* of the respective category as suffix (**L**ow, **M**oderate, **H**igh), e. g., 'AOT_L'.

We evaluated data using descriptive statistics and generalized linear mixed models (GLMM) with random intercept variance across participants. For the statistical analysis, we used the computing environment R (version 4.0.3; packages: 'lme4', 'descr', 'psych', 'simr'; Aquino, 2018; Bates et al., 2015; Green & MacLeod, 2016; Revelle, 2020; R Core Team, 2018.[2]

All models included Frame (Loss; Gain), Scope of affected people, with categories Small (basic values: 20, 40, 60, 80) and Large (100 times the Small values), Probabilities of surviving/dying ($< .5$; $> .5$), Disease (Infectious disease; Leukemia; AIDS), and Time (1s; 3s limit) as explanatory variables. The first categories served as references. The dependent variable was, in all cases, the relative frequency of choosing the risky option. This model was executed separately for each of the five scales, that is, the sub-scales of the SIRI (ST and IN), the REI (RA and EX), and the AOT (main effects models). Furthermore, to investigate the relationship between a person's test score (group membership) and the impact of the explanatory variables on risky choice, we included two-way-interactions of group membership by each explanatory variable in the main effects models (interaction effects models). Finally, we performed group-wise modeling, that is, examining the effect of the explanatory variables on risky choice within each group. This method has been proposed as an alternative to interaction models (Holgersson et al., 2014). However, since conclusions

[2]Note that Mahoney et al. (2011) analyzed their data with an ANOVA approach. We use GLMMs since they have been shown to be more flexible, accurate, powerful, and suited for categorical data analysis (Kristensen & Hansen, 2004; Jaeger, 2008).

about group differences require further testing (Schepers, 2016) and the theoretical analysis has not yet been done for mixed models with more than two-sample comparisons, we include group-wise models here as intuitive post-hoc tests only.

A post-hoc sensitivity analysis indicating the smallest detectable effect sizes (using the R package "simr"; Green & MacLeod, 2016) is shown in Supplement S3.

3 Results

Of the 55 participants, 12 have been excluded due to catch trial failures. We included data from 43 participants (19 females) with a total of 16,432 trials in the analysis. In 51.1% of valid trials, the risky option was chosen. Overall, participants chose the risky option more often in loss trials (60.1%) than in gain trials (39.9%), indicating a framing effect (for details see Diederich et al., 2018). Probabilities and Scope had an impact on choice behavior: 1) The larger the probabilities in the scenario was the higher the proportion of the risky choice option, and 2) the fewer people were affected (Scope: Small), the higher the proportion of the risky choice option (for details see Diederich et al., 2018).

3.1 Individual differences

Individual scores varied across a wide range. Details and group memberships are found in Appendix (Table A1).

We found statistically significant correlations (Spearman's ρ) between the following scales: ST and IN (.411, p<.01), ST and RA (.378, p<.05), IN and RA (.380, p<.05), and IN and AOT (−.322, p<.05).

Of all scales, only the ST affected choice behavior. In particular, members of group ST_H chose the risky option more often than members of ST_L (57.7% vs. 44.7%; z=2.625, p<.01). Participants in ST_M chose the risky option in 50.7% of trials. Regardless of the scales, we found significant effects for Frame, Scope, and Probability, but not for Disease and Time limit in each main effects model (see Appendix Tables A2 – A6). In the following, we show all interaction effects, separate for each scale. Note that we interpret interactions even if the main effects were not significant. It is well possible that effects have canceled out due to the specific response behavior of different groups. For a more intuitive interpretation of the scale value influences, we included group-wise models in the Appendix (Tables A7 – A11).

3.1.1 Stimulating Instrumental Risk Inventory (SIRI)

Based on the statistical significance shown in Table 1, we interpret the interaction effects as follows: 1) Participants in group ST_H showed stronger framing effects than participants in ST_L. Specifically, members in ST_H chose the risky option in 44.6% of gain and 70.7% of loss trials, whereas members in ST_L chose the risky option in 36.2% of gain and 53.3%

TABLE 1: Generalized linear mixed models. Interactions: stimulating and instrumental risk-style.

Stimulating risk-style					Instrumental risk-style				
Fixed effects:	Est.	SE	z-value	p-value	Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.660	.268	−2.458	.014	(Intercept)	−.608	.266	−2.289	.022
ST_M	−.553	.382	−1.450	.147	IN_M	.510	.392	1.302	.193
ST_H	.750	.370	2.027	.043	IN_H	−.175	.375	−.467	.640
Frame(Gain)	−1.160	.075	−15.460	<.001	Frame(Gain)	−1.248	.073	−17.084	<.001
Scope(Large)	−.582	.084	−6.909	<.001	Scope(Large)	−.154	.071	−2.164	.030
Prob.(> .5)	2.835	.080	35.296	<.001	Prob.(> .5)	2.701	.077	34.932	<.001
Leukemia	−.215	.103	−2.083	.037	Leukemia	−.022	.092	−.237	.812
AIDS	−.513	.113	−4.546	<.001	AIDS	−.131	.099	−1.331	.183
Time(3s)	−.062	.072	−.861	.389	Time(3s)	−.016	.069	−.227	.821
ST_M×Frame	−.121	.108	−1.119	.263	IN_M×Frame	.015	.105	.144	.886
ST_H×Frame	−.435	.103	−4.202	<.001	IN_H×Frame	−.310	.104	−2.975	.003
ST_M×Scope	.731	.114	6.423	<.001	IN_M×Scope	−.086	.102	−.840	.401
ST_H×Scope	.670	.109	6.141	<.001	IN_H×Scope	.224	.099	2.268	.023
ST_M×Prob.	.330	.113	2.913	.004	IN_M×Prob.	.001	.111	.006	.995
ST_H×Prob.	−.436	.109	−4.019	<.001	IN_H×Prob.	.238	.108	2.204	.028
ST_M×Leukemia	.388	.152	2.557	.011	IN_M×Leukemia	−.525	.142	−3.693	<.001
ST_H×Leukemia	.263	.143	1.838	.066	IN_H×Leukemia	.176	.139	1.270	.204
ST_M×AIDS	.709	.150	4.722	<.001	IN_M×AIDS	−.503	.149	−3.387	.001
ST_H×AIDS	.387	.145	2.671	.008	IN_H×AIDS	.381	.132	2.894	.004
ST_M×Time	.306	.102	3.009	.003	IN_M×Time	.079	.100	.789	.430
ST_H×Time	.054	.098	.558	.577	IN_H×Time	.128	.097	1.320	.187
Random effects:		SD (Est.)			Random effects:		SD (Est.)		
Subject (Intercept)		.936			Subject (Intercept)		.970		

Note. Number of observations: 16,432, n=43

of loss trials. The framing effect was stronger in group IN_H (Gain: 40.1%; Loss: 64.0%) as compared to group IN_L (Gain: 40.6%; Loss: 59.0%). The group-wise models show a significant framing effect among all groups of ST and IN.

2) ST and IN moderated the effect of Scope on risky choices. The group-wise models suggest a significant effect of Scope on risky choice only for Group ST_L. In particular, members in ST_L chose the risky option in 48.4% of trials for Scope Small and in 41.0% of trials in Scope Large. For the IN scale, members of group IN_L and IN_M made more risky choices for Small (50.8% and 58.8%) than for Large (48.8% and 49.7%) Scope. No effect was observed for IN_H.

3) For Probabilities > .5, the risky option was chosen more often, whereas, for Probabilities < .5, the sure option was chosen more often. The proportion within each probability category, however, was different depending on group membership. Specifically, for Probabilities < .5, members of ST_H chose the risky alternative in 36.1% of the trials, whereas the proportion for the two remaining groups was considerably smaller (ST_M: 19.8%; ST_L:

20.8%). For Probabilities > .5, members of ST_L chose the risky alternative in 69.5% of the trials, whereas the proportion for the two remaining groups was significantly larger (ST_M: 80.5%; ST_H: 79.1%). For the IN scale, choice behavior was similar for groups IN_L and IN_M but different from group IN_H (for Probabilities > .5, proportions of risky option chosen: IN_H: 80.0%; IN_M: 76.4%; IN_L: 72.9%; for Probabilities < .5, proportions of risky option chosen: IN_H: 24.0%; IN_M: 27.0%; IN_L: 26.6%.

4) We found significant interaction effects between group memberships and Disease, in particular for ST_M and Leukemia, ST_M and AIDS, ST_H and AIDS, IN_M and Leukemia, IN_M and AIDS, and IN_H and AIDS. Disease showed no main effect when including the entire sample (Diederich et al., 2018), but it does when we consider subgroups with individual differences. The group-wise GLMM analysis (see Table A7 in the Appendix) indicates that individuals of group ST_L chose the risky option less often when the disease was Leukemia or AIDS as compared to the Infectious disease.[3]

Furthermore, the proportions of risky choices were lower for Leukemia and AIDS in group IN_M and higher for AIDS in IN_H than those for Infectious disease in the respective groups. No effect of diseases was found in group ST_M and IN_L. For detailed results refer to the group-wise GLMM analysis (see Table A7 and A8 in the Appendix) and the table of choice proportions in the Supplement (S5).

5) Finally, we found an interaction effect between ST_M and Time. The group-wise analysis revealed a significant effect of Time only for ST_M where individuals chose the risky option more often under the 3s (52.4%) as compared to 1s (48.9%) time constraint.

3.1.2 Rational Experiential Inventory (REI)

Results of the interaction effect analysis for RA and IN are shown in Table 2; results of the group-wise analysis are shown in the Appendix (Table A9 and A10).

1) We found stronger framing effects for group RA_M than for group RA_L. Specifically, for RA_L, the proportions of risky choices were 41.9% in gain and 59.9% in loss trials as compared to 39.4% and 62.2% for RA_M. Our analysis did not show any significant effect of EX on framing. The group-wise analysis revealed framing effects among all groups of RA and EX.

2) The effect of Scope on risky choices was different for the subgroups of RA. In particular, the group-wise analysis showed a significant effect only for members of RA_L: they made more risky choices for Small (54.0%) than for Large (47.8%) Scope. The interaction analysis showed no significant relationship between EX and the effect of Scope on risky choice.

[3]Note that we observed a discrepancy between the sign of the coefficient provided by the GLMM and choice proportions based on raw-data which occurred due to integration of subjects as random factor in the GLMM (see Simpson's paradox, Simpson, 1951, and related phenomena, Tu et al., 2008; details are shown in the Supplement S4).

TABLE 2: Generalized linear mixed models. Interactions: rational and experiential thinking-style.

Rational thinking-style					Experiential thinking-style				
Fixed effects:	Est.	SE	z-value	p-value	Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.413	.283	−1.457	.145	(Intercept)	−.908	.275	−3.305	<.001
RA_M	−.363	.38591	−.94	.347	EX_M	.699	.393	1.777	.076
RA_H	−.159	.417	−.381	.703	EX_H	.488	.382	1.278	.201
Frame(Gain)	−1.122	.072	−15.618	<.001	Frame(Gain)	−1.436	.077	−18.731	<.001
Scope(Large)	−.322	.077	−4.197	<.001	Scope(Large)	−.048	.076	−.634	.526
Prob.(> .5)	2.522	.076	33.389	<.001	Prob.(> .5)	3.004	.078	38.349	<.001
Leukemia	−.283	.116	−2.453	.014	Leukemia	.113	.110	1.024	.306
AIDS	−.137	.097	−1.408	.159	AIDS	.043	.093	.463	.644
Time(3s)	.059	.069	.852	.394	Time(3s)	.139	.070	1.973	.048
RA_M×Frame	−.586	.105	−5.587	<.001	EX_M×Frame	.157	.107	1.476	.140
RA_H×Frame	−.099	.104	−.948	.343	EX_H×Frame	.098	.105	.930	.352
RA_M×Scope	.354	.106	3.338	<.001	EX_M×Scope	−.188	.106	−1.776	.076
RA_H×Scope	.385	.106	3.616	<.001	EX_H×Scope	−.190	.108	−1.763	.078
RA_M×Prob.	.784	.111	7.090	<.001	EX_M×Prob.	−.338	.110	−3.065	.002
RA_H×Prob.	−.031	.108	−.290	.772	EX_H×Prob.	−.345	.109	−3.159	.002
RA_M×Leukemia	.320	.151	2.128	.033	EX_M×Leukemia	−.454	.156	−2.900	.004
RA_H×Leukemia	.396	.152	2.614	.009	EX_H×Leukemia	−.123	.145	−.845	.398
RA_M×AIDS	.089	.137	.648	.517	EX_M×AIDS	−.080	.138	−.577	.564
RA_H×AIDS	.136	.141	.966	.334	EX_H×AIDS	−.440	.136	−3.227	.001
RA_M×Time	.066	.097	.682	.495	EX_M×Time	−.258	.099	−2.597	.009
RA_H×Time	−.092	.100	−.918	.359	EX_H×Time	−.002	.098	−.023	.982
Random effects:		SD (Est.)			Random effects:		SD (Est.)		
Subject (Intercept)		1.010			Subject (Intercept)		.975		

Note. Number of observations: 16,432, n=43

3) Both RA and EX moderated the effect of Probabilities on risky choices. Participants chose the risky option more often for Probabilities > .5, and they chose the sure option more often for Probabilities < .5. As for the SIRI scales, the proportion within each probability category, however, was different depending on group membership. Specifically, for Probabilities < .5, members of RA_M chose the risky alternative in 23.4% of the trials, whereas the proportion for the two remaining groups was considerably larger (RA_L: 27.7%; RA_H: 27.0%). For Probabilities > .5, members of RA_L chose the risky alternative in 73.9% of the trials, whereas the proportion was larger for the two remaining groups (RA_M: 78.3%; RA_H: 76.8%). For the EX scale, choice behavior was similar between groups EX_M and EX_H but different from group EX_L (for Probabilities > .5, proportions of risky option chosen: EX_M: 76.0%; EX_H: 75.2%; EX_L: 78.2%; for Probabilities < .5, proportions of risky option chosen: EX_M: 28.0%; EX_H: 28.4%; EX_L: 20.9%).

4) We found significant interaction effects between group memberships and Disease, in particular between RA_M and Leukemia, RA_H and Leukemia, EX_M and Leukemia, and

EX_H and AIDS. Recall that no significant effect of Disease on risky choice was found in the main effects model (for details see Diederich et al., 2018). Again, the results show a relationship between individual differences and the impact of Disease on choice behavior. The group-wise analysis shows that individuals of RA_L chose the risky option less often in Leukemia (45.5%) than in Infectious disease problems (51.3%). No significant effects of Disease were found for the other RA groups. Furthermore, among the EX groups, we found significant effects of Disease for EX_M and EX_H. For EX_M, the proportions of risky choice were lower in Leukemia (49.8%) than in Infectious disease problems (53.5%). In EX_H, individuals made less risky choices in AIDS (51.9%) than in Infectious disease problems (52.3%).

5) Group membership and Time showed one significant interaction. Members of EX_L and EX_H chose the risky option more often under the 3s (50.6% and 52.9%) as compared to 1s (48.5% and 50.9%) time constraint. For EX_M, no significant effect of Time was observed (see Appendix, Table A10).

3.1.3 Actively Open-Minded Thinking scale (AOT)

Table 3 shows the interaction results when including AOT scores. The group-wise analysis is found in the Appendix (Table A11).

1) AOT membership moderated the framing effect, i. e., we observed a weaker framing effect for members of AOT_M as compared to the other groups. In particular, members of AOT_L chose the risky choice option in 37.5% of gain trials and 66.0% of loss trials. For AOT_M, the proportions were 40.8% and 52.1%, respectively; and for AOT_H, 43.6% and 66.0%, respectively.

2) There were no significant interactions between AOT and Scope.

3) For Probabilities $> .5$, the risky option was chosen more often, whereas for Probabilities $< .5$, the sure option was chosen more often. As for the other scales, the proportion within each probability category, however, was different depending on group membership. Specifically, for Probabilities $< .5$, members of AOT_L chose the risky alternative in 31.4% of the trials, and members of AOT_M and AOT_H in 20.1% and 26.3%, respectively. For Probabilities $> .5$, members of AOT_H chose the risky alternative in 83.3% of the trials, whereas the proportion was smaller for the two remaining groups (AOT_L: 72.0%; AOT_M: 72.8%).

4) We found a significant interaction only between AOT_M and AIDS. The group-wise analysis shows that individuals of AOT_L chose the risky option less often in AIDS (50.3%) than in Infectious disease problems (53.9%). No other interactions between Disease and AOT were found.

5) There were no significant interactions between AOT and Time.

Detailed information about conditional frequencies for each factor level and group membership are found in Supplement S5.

TABLE 3: Generalized linear mixed model. Interactions: actively open-minded thinking-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.102	.285	−.358	.720
AOT_M	−1.156	.404	−2.864	.004
AOT_H	−.364	.392	−.930	.353
Frame(Gain)	−1.565	.072	−21.753	<.001
Scope(Large)	−.073	.076	−.958	.338
Prob.(> .5)	2.092	.073	28.752	<.001
Leukemia	.010	.100	.096	.923
AIDS	−.265	.099	−2.681	.007
Time(3s)	.093	.068	1.376	.169
AOT_M×Frame	.808	.102	7.905	<.001
AOT_H×Frame	−.202	.109	−1.854	.064
AOT_M×Scope	−.034	.105	−.322	.747
AOT_H×Scope	.060	.116	.522	.601
AOT_M×Prob.	.771	.107	7.233	<.001
AOT_H×Prob.	1.417	.113	12.494	<.001
AOT_M×Leukemia	−.024	.143	−.171	.865
AOT_H×Leukemia	−.184	.145	−1.265	.206
AOT_M×AIDS	.426	.149	2.864	.004
AOT_H×AIDS	.207	.147	1.409	.159
AOT_M×Time	−.179	.098	−1.818	.069
AOT_H×Time	.057	.099	.580	.562
Random effects:	SD(Est.)			
Subject (Intercept)	.991			

Note. Number of observations: 16,432, n=43

4 Discussion and Conclusions

The current study investigated individual differences in choice behavior using a psychophysical data collection approach embedded primarily in a within-subjects design. A specific emphasis was put on framing effects in an Unusual Disease paradigm (Tversky & Kahneman, 1981), probing the results by Mahoney et al. (2011). We extended their study by including various variables that may influence risky choice behavior. In particular, additionally to gain and loss frames, we varied the number of people affected, the probability of surviving/dying, the type of diseases in the description, and deadlines for making a response. Similar to Mahoney et al. (2011), we included instruments for measuring risk-style and thinking-style, in particular, the Stimulating Instrumental Risk Inventory (SIRI) and the Rational-Experiential Inventory (REI). In addition, we included the Actively Open-Minded Thinking scale (AOT).

Comparing our results with those mainly obtained by Mahoney et al. (2011), we find the following: First, in contrast to Mahoney et al. (2011), who observed no impact of SIRI scores on risky choice behavior, the present study shows that individuals with high

stimulating risk-style scores chose the risky option more often than participants with low scores. Second, Mahoney et al. (2011) found no relationship between SIRI scores and the strength of the framing effect. Our results, however, show that both sub-scales of the SIRI, i. e., stimulating and instrumental risk, moderated the framing effect: Framing effects were stronger for individuals with high stimulating risk-style scores or high instrumental risk-style scores as compared to low risk-style scores. That is, regardless of whether the tendency to take higher risks is associated with fun (stimulating risk) or motivated by reaching a goal (instrumental risk), it enhanced the framing effect.

Third, Mahoney et al. (2011) did not find any relationship between rational thinking-style and framing effects. Similarly, Shiloh et al. (2002) and Stark et al. (2017) using a between-subjects design, observed no moderator effect of rational thinking-style on framing effect. Björklund & Bäckström (2008) found a negative correlation between rational thinking-style scores and susceptibility to framing effects (r=−.28). The current study found that rational-thinking style moderated the framing effect with the strongest effect for participants with moderate scores. There was no difference between low and high-score individuals.

Fourth, Mahoney et al. found that individuals with moderate experiential thinking-style scores chose the risky option more often than the other participants. Furthermore, for one specific decision problem, they found a stronger framing effect for individuals with high scores in experiential thinking. In contrast, here we found neither a main effect of experiential thinking on choice behavior nor a significant interaction between experiential thinking and framing. This ambiguous result reflects what has been observed in previous studies (e. g., Covey, 2014; LeBoeuf & Shafir, 2003; Stanovich & West, 2008; Stark et al., 2017). The contradictory evidence may have different reasons, and we can only speculate about it as systematic research is lacking. For instance, compositions of samples (e. g., undergraduates, graduates, or non-university participants) may lead to different cut-off points for membership categorization. That is, an experiential thinking score of 70 may have been categorized as high within one sample and low within another sample. Moreover, design-related differences and problem domain variations may influence choice behavior; an unusual problem description that challenges the participants' reliance on experience (Stark et al., 2017), may also be a possible explanation.

Finally, we found a relationship between AOT scores and the strength of framing effects. The effects for participants with moderate AOT scores were weakest among the three groups; the framing effect strength of individuals with low or high scores was about the same, contrary to prior findings (Sá et al., 1999; West et al., 2008). This finding asks for further research.

Mahoney et al. investigated the interaction between scale values and frames on risky choice behavior separate for each of the five health problems. Except for one (see above), they did not find any significant results. Note that the diseases, probabilities, and numbers of affected people were not systematically varied; therefore, any effect could not have been attributed to any variable. In our study, we tried to remedy this shortcoming by using a psy-

chophysical approach for data collection (many trials per participant, systematic variation of stimulus components; see e. g., Guo et al., 2017).

Using five different scales for measuring individual differences in risk- and thinking-styles, the results show that each scale moderated the effects of diseases and probabilities of surviving/dying on choice behavior. The effect of different numbers of affected people (Scope) on risky choice behavior was moderated by individual stimulating risk-style, instrumental risk-style, and rational thinking-style. The impact of time limits on risky choice was moderated by stimulating risk-style and experiential thinking-style.

The specific results are mixed: In some cases, individual differences produced different effect strengths depending on group membership. In other cases, we observed effects only for sub-groups or an inverted effect on risky choices in one group as compared to another group. For instance, Scope influenced choice behavior for individuals with low scores on stimulating risk-style but not for individuals with moderate and high scores. Another example is that the proportion of risky choices was higher for the AIDS than for the Infectious Disease scenario when individuals scored high on instrumental risk-style. However, it showed a reversed pattern for individuals with moderate scores, and no effect for individuals with low scores. We have no explanation for the differences, and further research is needed, especially since no comparison studies have been done so far.

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Appendix

Disease-Scenarios

"Infectious Disease": "Imagine that the German government is preparing for the outbreak of an unusual infectious disease, which is expected to kill many people. Two alternative programs to combat the disease have been proposed. Both programs have different consequences for different groups of people. Assume that the exact scientific estimates of the consequences of the programs are as described in each scenario".

A new agent to treat leukemia: "Imagine that scientists found a new agent to treat leukemia. Every year, leukemia kills many people. Two alternative substances to combat leukemia have been developed. Both substances can cause serious side effects that lead to death. Some groups of persons are more affected by the side effects than others. Assume that the exact scientific estimates of the consequences of the substances are as described in each scenario".

A new agent to treat AIDS: "Imagine that scientists found a new agent to treat AIDS. Every year, AIDS kills many people. Two alternative substances to combat AIDS have been developed. Both substances can cause serious side effects that lead to death. Some groups of persons are more affected by the side effects than others. Assume that the exact scientific estimates of the consequences of the substances on the different groups of people are as described in each scenario".

Groups of participants

TABLE A1: Trichotomized values of the scales and number of participants per group.

Scale	Low	Moderate	High
ST	13 – 24	25 – 28	29 – 37
N	14	14	15
IN	16 – 24	25 – 26	27 – 34
N	15	13	15
EX	56 – 71	72 – 79	80 – 99
N	14	14	15
RA	39 – 56	57 – 63	64 – 93
N	14	17	12
AOT	25 – 36	37 – 39	40 – 45
N	13	14	16

Note. N: Participants per group. Split at 33% and 66%. Standard deviations: 6.34 (ST), 3.01 (IN), 9.64 (EX), 11.85 (RA), and 4.44 (AOT).

Regression models, main effects models

Each main effects model analysis based on 16,432 observations; n=43.

TABLE A2: GLMM. Main effects: stimulating risk-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−1.004	.250	−4.011	<.001
ST_M	.413	.347	1.192	.233
ST_H	.896	.342	2.625	.009
Frame(Gain)	−1.343	.043	−31.484	<.001
Scope(Large)	−.102	.041	−2.524	.012
Prob.(> .5)	2.770	.045	62.187	<.001
Leukemia	−.083	.057	−1.451	.147
AIDS	−.087	.055	−1.574	.115
Time(3s)	.054	.040	1.339	.180
Random effects:	SD(Est.)			
Subject (Intercept)	.908			

Note. Number of observations:16,432, n=43

TABLE A3: GLMM. Main effects: instrumental risk-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.647	.260	−2.489	.013
IN_M	.141	.375	.376	.707
IN_H	.138	.361	.383	.702
Frame(Gain)	−1.343	.043	−31.482	<.001
Scope(Large)	−.102	.041	−2.521	.012
Prob.(> .5)	2.770	.045	62.182	<.001
Leukemia	−.084	.057	−1.477	.140
AIDS	−.088	.055	−1.586	.113
Time(3s)	.054	.040	1.339	.181
Random effects:	SD(Est.)			
Subject (Intercept)	.978			

Note. Number of observations:16,432, n=43

TABLE A4: GLMM. Main effects: rational thinking-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.611	.269	−2.273	.023
RA_M	.070	.357	.195	.845
RA_H	.098	.389	.252	.801
Frame(Gain)	−1.343	.043	−31.483	<.001
Scope(Large)	−.102	.041	−2.520	.012
Prob.(> .5)	2.770	.045	62.185	<.001
Leukemia	−.084	.057	−1.474	.141
AIDS	−.087	.055	−1.577	.115
Time(3s)	.054	.040	1.339	.181
Random effects:	SD(Est.)			
Subject (Intercept)	.980			

Note. Number of observations:16,432, n=43

TABLE A5: GLMM. Main effects: experiential thinking-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.663	.267	−2.480	.013
EX_M	.210	.372	.566	.571
EX_H	.110	.366	.300	.764
Frame(Gain)	−1.343	.043	−31.484	<.001
Scope(Large)	−.102	.041	−2.520	.012
Prob.(> .5)	2.770	.045	62.187	<.001
Leukemia	−.084	.057	−1.480	.139
AIDS	−.087	.055	−1.582	.114
Time(3s)	.054	.040	1.339	.181
Random effects:	SD(Est.)			
Subject (Intercept)	.977			

Note. Number of observations:16,432, n=43

TABLE A6: GLMM. Main effects: actively open-minded thinking-style.

Fixed effects:	Est.	SE	z-value	p-value
(Intercept)	−.536	.269	−1.991	.046
AOT_M	−.351	.368	−.953	.341
AOT_H	.250	.357	.701	.483
Frame(Gain)	−1.343	.043	−31.484	<.001
Scope(Large)	−.102	.041	−2.522	.012
Prob.(> .5)	2.770	.045	62.186	<.001
Leukemia	−.083	.057	−1.455	.146
AIDS	−.087	.055	−1.571	.116
Time(3s)	.054	.040	1.339	.181
Random effects:	SD(Est.)			
Subject (Intercept)	.948			

Note. Number of observations:16,432, n=43

Regression models, group-wise models

TABLE A7: GLMM. Participants grouped according to their individual stimulating risk-style.

	Stimulating risk-style											
	Low				Moderate				High			
Fixed effects:	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.
(Intercept)	−.656	.341	−1.923	.055	−1.198	.180	−6.669	<.001	.091	.253	.358	.720
Frame(Gain)	−1.165	.075	−15.481	<.001	−1.276	.077	−16.538	<.001	−1.595	.071	−22.327	<.001
Scope(Large)	−.589	.085	−6.958	<.001	.145	.076	1.897	.058	.088	.069	1.267	.205
Prob.(> .5)	2.846	.081	35.256	<.001	3.151	.080	39.378	<.001	2.398	.073	32.700	<.001
Leukemia	−.217	.104	−2.092	.037	.157	.111	1.419	.156	.048	.099	.483	.629
AIDS	−.530	.113	−4.674	<.001	.186	.099	1.891	.059	−.126	.091	−1.381	.167
Time(3s)	−.062	.072	−.863	.388	.243	.072	3.378	<.001	−.007	.066	−.108	.914
Random effects:	SD(Est.)				SD(Est.)				SD(Est.)			
Subject (Intercept)	1.222				.054				.928			

Note. Number of participants per group and number of observations: ST_L: n=14, obs.=5,351; ST_M: n=15, obs.=5,351; ST_H: n=15, obs.=5,730.

TABLE A8: GLMM. Participants grouped according to their individual instrumental risk-style.

	Instrumental risk-style											
	Low				Moderate				High			
Fixed effects:	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.
(Intercept)	−.608	.371	−1.637	.102	−.098	.265	−.371	.711	−.761	.123	−6.211	<.001
Frame(Gain)	−1.257	.073	−17.126	<.001	−1.231	.075	−16.339	<.001	−1.551	.074	−20.865	<.001
Scope(Large)	−.156	.071	−2.188	.029	−.239	.073	−3.272	.001	.073	.069	1.065	.287
Prob.(> .5)	2.716	.078	34.953	<.001	2.698	.081	33.500	<.001	2.922	.075	38.765	<.001
Leukemia	−.021	.093	−.230	.818	−.546	.108	−5.070	<.001	.119	.102	1.171	.242
AIDS	−.139	.099	−1.408	.159	−.634	.111	−5.712	<.001	.222	.087	2.570	.010
Time(3s)	−.016	.069	−.229	.819	.063	.072	.876	.381	.111	.067	1.651	.099
Random effects:			SD(Est.)				SD(Est.)				SD(Est.)	
Subject (Intercept)			1.359				.881				.340	

Note. Number of participants per group and number of observations: IN_L: n=15, obs.=5,733; IN_M: n=13, obs.=4,971; IN_H: n=15, obs.=5,728.

TABLE A9: GLMM. Participants grouped according to their individual rational thinking-style.

	Rational thinking-style											
	Low				Moderate				High			
Fixed effects:	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.
(Intercept)	−.414	.308	−1.342	.180	−.776	.302	−2.566	.010	−.562	.172	−3.274	.001
Frame(Gain)	−1.124	.072	−15.621	<.001	−1.713	.077	−22.346	<.001	−1.216	.075	−16.150	<.001
Scope(Large)	−.322	.077	−4.195	<.001	.032	.073	.433	.665	.062	.074	.840	.401
Prob.(> .5)	2.525	.076	33.348	<.001	3.313	.081	40.770	<.001	2.479	.077	32.206	<.001
Leukemia	−.284	.116	−2.451	.014	.038	.097	.388	.698	.102	.097	1.049	.294
AIDS	−.139	.097	−1.424	.154	−.048	.097	−.495	.620	−.013	.102	−.126	.899
Time(3s)	.059	.069	.852	.394	.125	.068	1.843	.065	−.032	.072	−.452	.651
Random effects:			SD(Est.)				SD(Est.)				SD(Est.)	
Subject (Intercept)			1.104				1,186				.495	

Note. Number of participants per group and number of observations: RA_L: n=15 , obs.=5,339 ; RA_M: n=14 , obs.=6,505 ; RA_H: n=12, obs.=4,588.

TABLE A10: GLMM. Participants grouped according to their individual experiential thinking-style.

	Experiential thinking-style											
	Low				Moderate				High			
Fixed effects:	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.
(Intercept)	−.898	.143	−6.275	<.001	−.208	.318	−.654	.513	−.421	.318	−1.325	.185
Frame(Gain)	−1.429	.077	−18.682	<.001	−1.281	.074	−17.250	<.001	−1.342	.072	−18.644	<.001
Scope(Large)	−.035	.076	−.463	.643	−.237	.074	−3.200	.001	−.240	.077	−3.133	.002
Prob.(> .5)	2.988	.078	38.239	<.001	2.671	.078	34.356	<.001	2.666	.076	34.849	<.001
Leukemia	.070	.110	.631	.528	−.342	.111	−3.077	.002	−.009	.094	−.090	.928
AIDS	.046	.092	.503	.615	−.037	.103	−.359	.720	−.401	.100	−4.005	<.001
Time(3s)	.138	.070	1.968	.049	−.119	.070	−1.701	.089	.137	.068	2.014	.044
Random effects:			SD(Est.)				SD(Est.)				SD(Est.)	
Subject (Intercept)			.419				1.120				1.185	

Note. Number of participants per group and number of observations: EX_L: n=14, obs.=5,356; EX_M: n=14, obs.=5,352; EX_H: n=15, obs.=5,724.

TABLE A11: GLMM. Participants grouped according to their individual actively open-minded thinking-style.

	Activel Open-Minded thinking-style											
	Low				Moderate				High			
Fixed effects:	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.	Est.	SE	z-val.	p-val.
(Intercept)	−.100	.184	−.543	.587	−1.259	.306	−4.117	<.001	−.468	.309	−1.512	.131
Frame(Gain)	−1.560	.072	−21.709	<.001	−.758	.073	−10.444	<.001	−1.772	.082	−21.609	<.001
Scope(Large)	−.073	.076	−.966	.334	−.107	.072	−1.485	.137	−.011	.087	−.120	.904
Prob.(> .5)	2.084	.073	28.691	<.001	2.864	.078	36.693	<.001	3.517	.088	40.187	<.001
Leukemia	.002	.099	.019	.985	−.015	.103	−.149	.882	−.176	.106	−1.658	.097
AIDS	−.261	.098	−2.646	.008	.158	.111	1.426	.154	−.055	.109	−.508	.612
Time(3s)	.093	.068	1.375	.169	−.085	.071	−1.200	.230	.151	.072	2.107	.035
Random effects:			SD(Est.)				SD(Est.)				SD(Est.)	
Subject (Intercept)			.602				1.070				1.166	

Note. Number of participants per group and number of observations: AOT_L: n=13, obs.=4,960; AOT_M: n=14, obs.=5,351; AOT_H: n=16 obs.=6,121

Supplementary materials

S1 Questionaires

SIRI

Stimulating risk scale
– If I play a game (e. g., cards) I prefer to play for money
– I enjoy risk-taking
– I often take Risk just for fun
– I takerisk only if it is absolutely necessary to achieve an important goal (−)
– I am attracted by different dangerous activities
– While taking risk I have a feeling of a very pleasant flutter
– I avoid activities whose results depend too much on chance (−)
– Gambling seems something very exciting to me
– In business one should take risk only if the situation can be controlled (−)
– I make risky decisions quickly without an unnecessary waste of time

Instrumental risk scale
– At work I would prefer a position with a high salary which could be lost to a stable position but with a lower salary
– To achieve something in life one has to take risks
– If there is a big chance to profit I take even very high risks
– To gain high profits in business one has to take high risks.
– If there was a big chance to multiply the capital I would invest my money even in the shares of a completely new and uncertain firm
– I willingly take responsibility in my work-place
– The skill of reasonable risk-taking is one of the most important managerial skills
A minus sign (−) denotes reverse scoring.

REI

Rationality scale
– I try to avoid situations that require thinking in depth about something (−)
– I'm not that good at figuring out complicated problems (−)
– I enjoy intellectual challenges
– I am not very good at solving problems that require careful logical analysis (−)
– I don't like to have to do a lot of thinking (−)
– I enjoy solving problems that require hard thinking
– Thinking is not my idea of an enjoyable activity (−)
– I am not a very analytical thinker (−)
– Reasoning things out carefully is not one of my strong points (−)

– I prefer complex problems to simple problems
– Thinking hard and for a long time about something gives me little satisfaction (−)
– I don't reason well under pressure (−)
– I am much better at figuring things out logically than most people
– I have a logical mind
– I enjoy thinking in abstract terms
– I have no problem thinking things through carefully
– Using logic usually works well for me in figuring out problems in my life
– Knowing the answer without having to understand the reasoning behind it is good enough for me (−)
– I usually have clear, explainable reasons for my decisions
– Learning new ways to think would be very appealing to me

Experientiality scale

– I like to rely on my intuitive impressions
– I don't have a very good sense of intuition (−)
– Using my gut feelings usually works well for me in figuring out problems in my life
– I believe in trusting my hunches
– Intuition can be a very useful way to solve problems
– I often go by my instincts when deciding on a course of action
– I trust my initial feelings about people
– When it comes to trusting people, I can usually rely on my gut feelings
– If I were to rely on my gut feelings, I would often make mistakes (−)
– I don't like situations in which I have to rely on intuition (−)
– I think there are times when one should rely on one's intuition
– I think it is foolish to make important decisions based on feelings (−)
– I don't think it is a good idea to rely on one's intuition for important decisions (−)
– I generally don't depend on my feelings to help me make decisions (−)
– I hardly ever go wrong when I listen to my deepest gut feelings to find an answer
– I would not want to depend on anyone who described himself or herself as intuitive (−)
– My snap judgments are probably not as good as most people's
– I tend to use my heart as a guide for my actions
– I can usually feel when a person is right or wrong, even if I can't explain how I know
– I suspect my hunches are inaccurate as often as they are accurate (−)

A minus sign (−) denotes reverse scoring.

AOT

– Allowing oneself to be convinced by an opposing argument is a sign of good character.
– People should take into consideration evidence that goes against their beliefs.
– People should revise their beliefs in response to new information or evidence.

– Changing your mind is a sign of weakness. (−)
– Intuition is the best guide in making decisions. (−)
– It is important to persevere in your beliefs even when evidence is brought to bear against them. (−)
– One should disregard evidence that conflicts with one's established beliefs. (−)
A minus sign (−) denotes reverse scoring.

S2 Display

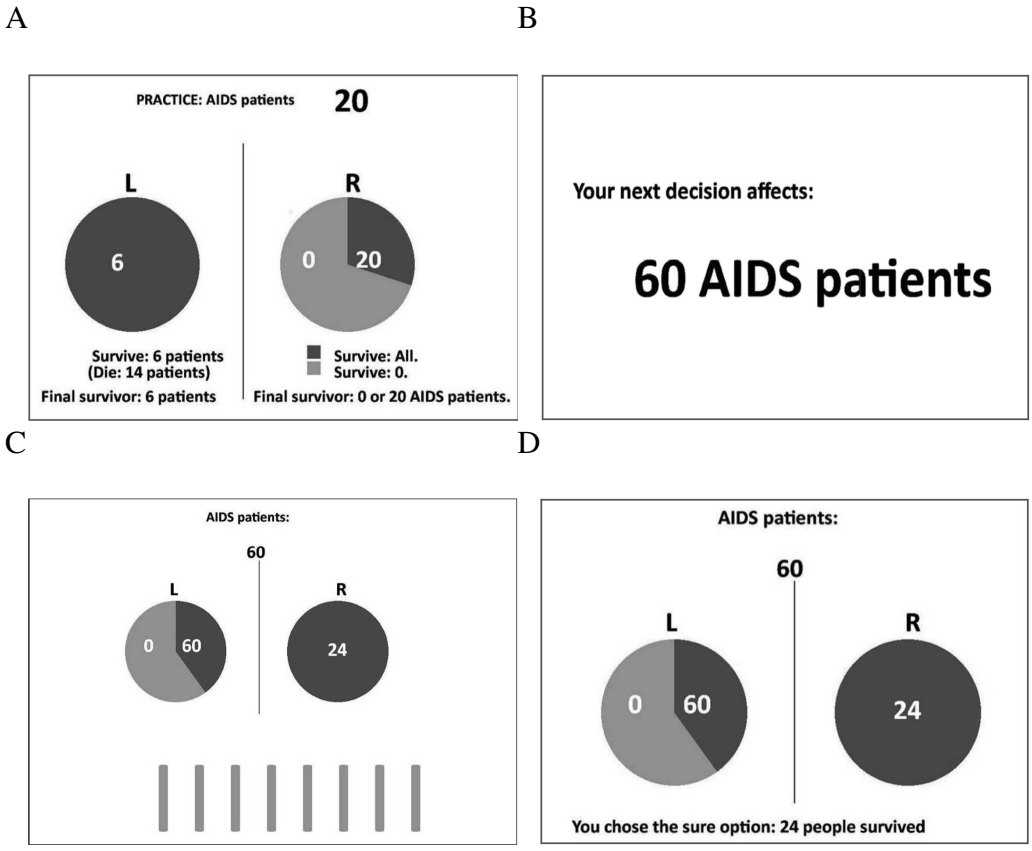

FIGURE S1: Example of a guided practice trial (A) and timeline for one trial in a gain frame (B–D). The screen displaying the initial amount was presented for 2.5 sec (B). The screen displaying the choice was presented for either 1s or 3s, depending on the experimental condition (C). The bars below the pie-charts indicate the available time for particular trials (speed by which the bars were removed). The feedback screen (D) was presented for 2.5 sec, in which the result of the current trial was announced. The conditions in this sample are disease type=AIDS; Scope=Small.

S3 Sensitivity analysis of interaction effects

We performed a post-hoc sensitivity analysis of the hypothesis-tests (GLMM, interaction effects models). Tables S1–S3 show the smallest detectable effect size (at a statistical power of .8 and an α of .05) for each interaction tested with the interaction effects models. For comparison, the table also shows the estimated regression coefficients provided by the interaction models. The smallest detectable effect sizes were estimated using 300 test simulation runs for each interaction effect. For simulations, we used the R package "simr" (Green & MacLeod, 2016).

TABLE S1: Sensitivity analysis of interaction effects. Stimulating and Instrumental risk-style.

Stimulating risk-style			Instrumental risk-style		
Interaction	Est.	Min. effect	Interaction	Est.	Min. effect
ST_M×Frame	−.121	−.289	IN_M×Frame	.015	.284
ST_H×Frame	−.435	−.287	IN_H×Frame	−.310	−.279
ST_M×Scope	.731	.323	IN_M×Scope	−.086	−.269
ST_H×Scope	.670	.313	IN_H×Scope	.224	.222
ST_M×Prob.(>.5)	.330	.310	IN_M×Prob.(>.5)	.001	.301
ST_H×Prob.(>.5)	−.436	−.317	IN_H×Prob.(>.5)	.238	.306
ST_M×Leukemia	.388	.387	IN_M×Leukemia	−.525	−.385
ST_H×Leukemia	.263	.336	IN_H×Leukemia	.176	.383
ST_M×AIDS	.709	.414	IN_M×AIDS	−.503	−.379
ST_H×AIDS	.387	.383	IN_H×AIDS	.381	.362
ST_M×Time(3s)	.306	.275	IN_M×Time(3s)	.079	.283
ST_H×Time(3s)	.054	.269	IN_H×Time(3s)	.128	.257

Note. Est.: Regression coefficients as provided by interaction models; Min. effect: Smallest detectable effect size at a statistical power of .8 and an α of .05.

TABLE S2: Sensitivity analysis of interaction effects. Rational and Experiential thinking-style.

Rational thinking-style			Experiential thinking-style		
Interaction	Est.	Min. effect	Interaction	Est.	Min. effect
RA_M×Frame	−.586	−.261	EX_M×Frame	.157	.313
RA_H×Frame	−.099	−.283	EX_H×Frame	.098	.287
RA_M×Scope	.354	.278	EX_M×Scope	−.188	−.298
RA_H×Scope	.385	.291	EX_H×Scope	−.190	−.308
RA_M×Prob.(>.5)	.784	.289	EX_M×Prob.(>.5)	−.338	−.314
RA_H×Prob.(>.5)	−.031	−.298	EX_H×Prob.(>.5)	−.345	−.326
RA_M×Leukemia	.320	.372	EX_M×Leukemia	−.454	−.419
RA_H×Leukemia	.396	.393	EX_H×Leukemia	−.123	−.383
RA_M×AIDS	.089	.378	EX_M×AIDS	−.080	−.388
RA_H×AIDS	.136	.384	EX_H×AIDS	−.440	−.391
RA_M×Time(3s)	.066	.265	EX_M×Time(3s)	−.258	−.254
RA_H×Time(3s)	−.092	−.281	EX_H×Time(3s)	−.002	−.263

Note. Est.: Regression coefficients as provided by interaction models; Min. effect: Smallest detectable effect size at a statistical power of .8 and an α of .05.

TABLE S3: Sensitivity analysis of interaction effects. Actively open-minded thinking-style

Actively open-minded thinking-style		
Interaction	Est.	Min. effect
AOT_M×Frame	.808	.289
AOT_H×Frame	−.202	−.311
AOT_M×Scope	−.034	−.294
AOT_H×Scope	.060	.311
AOT_M×Prob.(>.5)	.771	.306
AOT_H×Prob.(>.5)	1.417	.289
AOT_M×Leukemia	−.024	−.389
AOT_H×Leukemia	−.184	−.387
AOT_M×AIDS	.426	.406
AOT_H×AIDS	.207	.405
AOT_M×Time(3s)	−.179	−.281
AOT_H×Time(3s)	.057	.266

Note. Est.: Regression coefficients as provided by interaction models; Min. effect: Smallest detectable effect size at a statistical power of .8 and an α of .05.

S4 Linear regression model for group ST_L

The group-wise GLMM analysis indicates that individuals of group ST_L chose the risky option less often when the disease was Leukemia or AIDS as compared to the Infectious disease. However, we observed a discrepancy between the sign of the coefficient provided by the GLMM and the difference of choice proportions based on raw-data suggesting higher proportions of risky choices for AIDS (53%) as compared to the Infections disease (42%). This discrepancy occurred after we incorporated the subjects as random-effect in the GLMM. One phenomenon that describes such a discrepancy is known as the Simpson's paradox (Simpson, 1951). It is observed when "the relationship between two variables differs within subgroups compared to that observed for the aggregated data" (Tu et al., 2008, p. 2). We assume to observe a related phenomenon here.

Table S4 shows the results of the logistic regression analysis with the proportion of risky choices of individuals of group ST_L as dependent variable and Frame, Scope, Probability, Disease, and Time as independent variables. The result demonstrates that the coefficient for AIDS has a positive sign when subjects are not considered as random-effect in the regression model.

TABLE S4: Logistic regression. The effect of Frame, Scope, Probability, Disease, and Time on risky choice for individuals of group ST_L.

Coefficients	Est.	SE	z-value	p-value
(Intercept)	−1.007	.086	−11.685	<.001
Frame(Gain)	−.966	.067	−14.357	<.001
Scope(Large)	−.263	.071	−3.689	<.001
Prob.(> .5)	2.386	.069	34.720	<.001
Leukemia	−.018	.081	−.229	.819
AIDS	.553	.085	6.469	<.001
Time(3s)	−.048	.065	−.733	.464

Note. Generalized linear model (error distribution: binomial; link function: logit).

S5 Choice proportions

TABLE S5: Conditional choice proportions for each factor level and group membership.

		ST			IN			RA			EX			AOT		
		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Frame	Gain	36.2%	41.5%	44.6%	40.6%	42.0%	40.1%	41.9%	39.4%	41.6%	38.8%	42.2%	41.5%	37.5%	40.8%	43.6%
	Loss	53.3%	59.9%	70.7%	59.0%	61.5%	64.0%	59.9%	62.2%	62.4%	60.3%	61.9%	62.2%	66.0%	52.1%	66.0%
Scope	(×10)	48.4%	49.9%	57.0%	50.8%	53.8%	51.4%	54.0%	50.4%	51.6%	49.7%	53.2%	52.9%	53.1%	47.3%	55.1%
	(×1000)	41.0%	51.4%	58.3%	48.8%	49.7%	52.7%	47.8%	51.2%	52.4%	49.4%	50.9%	50.9%	50.5%	45.6%	54.6%
Prob.	$< .5$	19.8%	20.8%	36.1%	26.6%	27.0%	24.0%	27.7%	23.4%	27.0%	20.9%	28.0%	28.4%	31.4%	20.1%	26.3%
	$> .5$	69.5%	80.5%	79.1%	72.9%	76.4%	80.0%	73.9%	78.3%	76.8%	78.2%	76.0%	75.2%	72.0%	72.8%	83.3%
Disease	Infectious	42.3%	51.4%	60.3%	47.8%	59.0%	52.0%	51.3%	51.2%	53.5%	50.2%	53.5%	52.3%	53.9%	42.6%	56.6%
	Leukemia	40.7%	49.1%	60.0%	48.0%	49.3%	51.0%	45.5%	50.4%	52.1%	46.2%	49.8%	51.4%	50.0%	43.6%	55.2%
	AIDS	52.9%	51.1%	52.7%	55.1%	48.8%	52.9%	55.3%	50.9%	49.9%	51.5%	53.2%	51.9%	50.3%	53.3%	52.7%
Time	3s	44.3%	52.4%	57.8%	49.7%	52.2%	52.8%	51.3%	51.7%	51.6%	50.6%	51.1%	52.9%	52.5%	45.8%	55.8%
	1s	45.2%	48.9%	57.6%	49.9%	51.3%	51.2%	50.4%	50.0%	52.4%	48.5%	53.0%	50.9%	51.0%	47.1%	53.9%

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