

Dynamic Risk Perceptions in Times of Avian and Seasonal Influenza Epidemics: A Repeated Cross-Sectional Design

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Infectious diseases pose a serious threat to humans. Therefore, it is crucial to understand how accurately people perceive these risks. However, accuracy can be operationalized differently depending on the standard of comparison. The present study investigated accuracy in risk perceptions for three infectious diseases (avian influenza, seasonal influenza, common cold) using three different standards for accuracy: Social comparison (self vs. others' risk perceptions), general problem level (risk perceptions for diseases with varying threat levels), and dynamic problem level (risk perceptions during epidemics/seasons vs. nonepidemic/off-season times). Four online surveys were conducted using a repeated cross-sectional design. Two surveys were conducted during epidemics/seasons of avian influenza, seasonal influenza, and common cold in 2006 ($n = 387$) and 2016 ($n = 370$) and two surveys during nonepidemic/off-season times for the three diseases in 2009 ($n = 792$) during a swine flu outbreak and in 2018 ($n = 422$) during no outbreak of zoonotic influenza. While on average participants felt less at risk than others, indicating an optimistic bias, risk perceptions matched the magnitude of risk associated with the three infectious diseases. Importantly, a significant three-way interaction indicated dynamic accuracy in risk perceptions: Participants felt more at risk for seasonal influenza and common cold during influenza and cold seasons, compared with off-season times. However, these dynamic increases were more pronounced in the perceived risk for others than for oneself (optimistic bias). The results emphasize the importance of using multiple approaches to assess accuracy of risk perception as they provided different information on how accurately people gauge their risk when facing infectious diseases.

KEY WORDS: Accuracy; dynamic; infectious diseases; optimistic bias; risk perception

1. INTRODUCTION

The year 2018 marked the 100th anniversary of one of the most catastrophic public health crises in modern history; the 1918 influenza pandemic

known colloquially as “Spanish flu”. In September 2018 Michael Osterholm, the director of the Center for Infectious Disease Research and Policy (CIDRAP), issued a seemingly counterintuitive warning that people are more vulnerable to an influenza pandemic today than they were 100 years ago. His evaluation is based on the consideration of the effectiveness of vaccines, population density and crowding, globalization and economic disruption (Voelker, 2018). As of the writing of the article, the coronavirus (SARS-CoV-2 and the associated disease COVID-19) outbreak revealed the vulnerability

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to infectious diseases worldwide. The coronavirus outbreak underscores the need to study the perception of infectious risks as it varies across times of low and high prevalence. In this respect, the present study examined dynamic risk perceptions in times of avian and seasonal influenza epidemics.

One of the most serious infectious diseases is seasonal influenza. Current estimates suggest that seasonal influenza alone kills up to 650,000 people every year (Iuliano et al., 2018; World Health Organization [WHO], n.d.-b), with 5% to 10% of the world's adults infected annually (WHO, n.d.-c), and up to 10 million infections in Germany every year (Robert Koch Institute [RKI], 2019). Moreover, people can be infected with avian, swine, and other zoonotic influenza viruses, which can cause diseases ranging from mild conjunctivitis to severe pneumonia and even death (WHO, n.d.-a). Specifically, avian influenza, which is also called "bird flu," is one of the major infectious threats in the 21st century, generating an epidemic in 2003, which spread from Asia to Africa and Europe (WHO, n.d.-a). Highly pathogenic avian influenza (HPAIV) also emerged in Germany (HPAIV/H5N1; Arbeitsgemeinschaft Influenza, 2012) in 2006, when the present study was launched, and reemerged 10 years later in 2016/2017 (subtypes *HPAIV/H5N8* and *H5N5*; Buda et al., 2017). Given that influenza viruses are constantly mutating (antigenic shift), the public needs to be informed and protected against both seasonal influenza epidemics and out-of-season outbreaks.

Despite the long history of research on risk perceptions, there has been substantial debate on how people perceive and respond to risks, and why they do so (e.g., Douglas, 1996; Finkel, 2008; Glendon & Clarke, 2016; Weber & Morris, 2010; Weinstein, 2003; Wilkinson, 2001; Wilson, Zwickle, & Walpole, 2019). A prominent approach in research on risk perception is the psychometric paradigm (e.g., Slovic, Fischhoff, & Lichtenstein, 1985; see also, Slovic, 2000, and the critical review by Sjöberg, Moen, & Rundmo, 2004), which provides insight into the accurateness of risk perception in laypeople. Consistently, a bias of laypeople's perceptions of risk was observed (compared with experts) in the way they overrate risk associated with catastrophic, infrequent, and involuntary events, and underrate risk associated with familiar, frequent, and voluntary events. However, people's "rank order" of risks is accurate in relation to objective risk assessments (Slovic, 2000; Slovic, Fischhoff, & Lichtenstein, 1980; Weinstein, 2000). This means, that people allocate distinct risks to different

hazards, suggesting an awareness that some risks are more likely to affect them than others. De Zwart, Veldhuijzen, Richardus, and Brug (2010) corroborated these findings with respect to infections related to influenza viruses, showing that participants felt more vulnerable toward a common cold than avian influenza. However, while the psychometric paradigm has been very helpful for making comparisons across hazards, it is limited in capturing risk perceptions of a specific hazard that vary intra- and interindividually (Sjöberg et al., 2004).

From a psychological perspective, people must not only be aware of an existing health risk ("general risk perception") such as an influenza epidemic, but must also feel personally at risk ("personal risk perception") in order to take preventive actions (Renner & Schupp, 2011; Renner, Gamp, Schmäzle, & Schupp, 2015). Specifically, the effective management of infectious disease risk largely depends on prevention and the adoption of precautionary behaviors in the population (e.g., Betsch et al., 2012; Brug, Aro, & Richardus, 2009; Renner & Reuter, 2012; Rubin, Potts, & Michie, 2010; WHO, 2018). Numerous studies have shown that personal risk perception is an essential motivational trigger for preventive behavior change (Gaube, Lermer, & Fischer, 2019; Renner & Schupp, 2011). The relations between perceived risk and protective behavior have been revealed by a meta-analysis on three different measures of risk perception and their relation to vaccination behavior (Brewer et al., 2007). These associations ranged from $r = 0.16$ for perceived severity to $r = 0.26$ for perceived likelihood. Effects of similar magnitude were found in a meta-analysis that solely included experimental studies. The authors concluded, that heightening perceived likelihood changed subsequent intentions ($d+ = 0.31$) and behavior ($d+ = 0.23$; Sheeran, Harris, & Epton, 2014). The authors of this review and meta-analysis use the term risk perception and perceived likelihood interchangeably and state that "risk perceptions refer to people's beliefs about their vulnerability to danger or harm. Typically, risk perceptions are assessed by participants' judgments of the likelihood of experiencing negative outcomes (e.g., "How likely are you to become obese in the future?")" (Sheeran et al., 2014, p. 512). Measures of perceived severity or more affective/intuitive measures such as worry may capture partly overlapping but also unique variance (Sheeran et al., 2014). Here, the perception of infectious disease risks considers conceptually distinct levels of risk perception examining the question

of how accurately people perceive the risk at the “personal” and “general” level of risk focusing on the perceived likelihood of experiencing a hazard.

In addition, social comparison allows people to be overly optimistic with regard to the perception of future health risks. Specifically, a large body of evidence reveals that people see lower risk when gauging their own personal risk than when gauging the risk faced by others, indicating an optimistic bias (Renner & Schupp, 2011; Shepperd, Klein, Waters, & Weinstein, 2013; Siegrist & Árvai, 2020; Weinstein, 1980). Evidence has also been found for optimistically biased perceptions of risk of influenza virus-related infections. During the H1N1 (“swine flu”) outbreak in 2009, German survey respondents felt on average less at risk than others (Renner & Reuter, 2012). Similar findings also emerged in Chinese and U.S. samples in 2010, also indicating social inaccuracy (Han, Zhang, Chu, & Shen, 2014; Xu & Peng, 2015).

Dynamic changes in risk perception according to changes in problem levels are another indicator for the accuracy of personal risk perceptions (Loewenstein & Mather, 1990). For instance, tracking the 2009 H1N1 pandemic over the course of a year revealed a substantial correspondence between perceived risk and objective influenza activity (Gidengil, Parker, & Zikmund-Fisher, 2012; see also Rubin *et al.*, 2010; but see De Zwart *et al.*, 2010). Similar findings have been reported for severe acute respiratory syndrome (SARS) in Hong Kong (Lau, Yang, Tsui, & Kim, 2003; Leung *et al.*, 2005) and swine flu in Germany (Reuter & Renner, 2011). Notably, we are not currently aware of data linking the objective problem level of seasonal influenza and its corresponding perceived risk. However, seasonal influenza is presumably the prototypical exemplar for influenza (Bishop, 1991), as it varies over periods with high or low risk.

Taken together, there are different ways to measure how accurately people perceive their personal risk, which might not necessarily converge to a consistent overall pattern (Ferrer & Klein, 2015). Previous research in the field of influenza virus-related diseases has assessed the accuracy of risk perceptions either with regard to objective levels of threat (i.e., general problem level accuracy) or by comparing perceived risk for oneself to others’ risk (i.e., social accuracy; De Zwart *et al.*, 2010; Ibuka, Chapman, Meyers, Li, & Galvani, 2010; Xu & Peng, 2015). Thus, the accuracy of risk perceptions has previously been determined by comparing perceived personal risk with measures of perceived others’ risk (i.e., social accuracy) or by comparing objective risk assessments

to perceived risks (i.e., general problem level accuracy). Moreover, there has been little research on the dynamic response of risk perceptions to changes in problem levels over multiple diseases, and depending on the presence and absence of epidemics (i.e., dynamic problem level accuracy). In addition, it remains unclear whether dynamic changes occur equally for the perceived risk for both the self and others. As the different measures of risk perception tap into distinct aspects of accuracy in perceptions, a more comprehensive assessment can offer a better understanding of how people gauge their risk when confronted with an outbreak of zoonotic influenza.

1.1. The Present Study

The present study examined the accuracy of personal risk perceptions for three different infectious diseases, namely avian influenza, seasonal influenza, and the common cold, using three different indicators for accuracy: (i) social accuracy (perceived personal vs. others’ risk), (ii) general problem level accuracy (rank order in risk perceptions across diseases), and (iii) dynamic problem level accuracy (dynamic response of risk perceptions to epidemics/seasons vs. nonepidemic/off-season times).

While we predicted an optimistic bias, that is, that risk perception would be lower for the self in comparison to others, we examined the hypothesis that the optimistic bias varies in strength across three different infectious diseases.

Objective data (the number of confirmed cases) showed that the rank order of the three infectious diseases was consistent across the four waves that were assessed, with the common cold posing the highest, seasonal influenza an intermediate, and avian influenza the lowest risk of infection (Bayer *et al.*, 2014; RKI, 2019, 2020). Based on previous findings (Slovic, 2000; Weinstein, 2000), we predicted that general problem level accuracy would reflect the respective rank order between the three diseases consistently in all four waves.

According to dynamic problem level accuracy, people should adjust their risk perception to changes in the objective risk levels. Hence, we tested the hypothesis of dynamic accuracy assuming higher risk perceptions for the infectious diseases during times of increased objective risk. The objective risk for both avian and seasonal influenza and the common cold was high during the 2006 and 2016 waves and low during the 2009 and 2018 waves. In 2009, however, the survey was conducted during the outbreak

of swine flu in Germany. Since this was a different influenza virus, comparisons between the 2009 and 2018 waves allow to reveal possible generalization effects on infectious diseases. Furthermore, we also examined whether risk perception for the self and others differed in their degree of dynamic changes, which would indicate differential dynamic accuracy.

2. METHOD

2.1. Procedure and Sample

Data was collected via four cross-sectional online surveys in 2006, 2009, 2016, and 2018. The language used in all surveys was German. The surveys in 2006 (March 27th–May 15th) and 2016 (November 24th–January 15th) were conducted in close temporal coincidence to outbreaks of avian influenza in Germany. The assessment time spans also overlapped with the season for seasonal influenza, which is commonly between January and April in Germany (RKI, 2019), and the common cold, which is most prevalent during autumn and winter (RKI, n.d.). The survey in 2009 (July 21st–October 22nd) was conducted during the outbreak of swine flu in Germany, but neither avian nor seasonal influenza was prevalent at that time in Germany. Finally, the survey in 2018 (May 09th–June 13th) was conducted during a time span with a low infection risk for both avian and seasonal influenza, and the common cold. Overall, the three infectious diseases of interest for the current study (i.e., avian influenza, seasonal influenza, and common cold) were prevalent in 2006 and 2016. While risk was low for the three diseases in 2009 and 2018, a swine flu outbreak occurred in 2009.

Using the snowball technique, participants were invited to the study via an official press release from the university (cf. Cameron, Sherman, Marteau, & Brown, 2009; Jones & Salathé, 2009; Renner & Reuter, 2012; Van, McLaws, Crimmins, MacIntyre, & Seale, 2010). Participation was completely voluntary, and the participants did not receive any compensation, except for the survey conducted in 2018 in which the participants were invited to take part in a draw to win one of 20 Amazon vouchers, each valued 10 Euro. The University ethics committee approved the questionnaire. The study was carried out in accordance with the provision of the World Medical Association Declaration of Helsinki. Before starting the questionnaire, participants read a description of the study procedures, were informed about the expected

duration of participation, and that they could withdraw at any time without negative consequences. All participants consented to participate in this study by starting the online survey after being fully informed about the study.

In total, $N = 3,066$ participants were recruited via email. Of these, 1,095 participants were excluded due to missing data ($n = 348$ had missing values on all variables; $n = 530$ had missing values on all six risk perception variables; $n = 188$ had missing values on one to five risk perception variables) or because they were under the age of 18 years ($n = 29$).

The final study sample comprised $N = 1,971$ participants (63.2% female) with an age range between 18 years and 86 years ($M = 33.86$, $SD = 12.37$). The majority were German citizens (92.4%) and had a university-entrance diploma (“Abitur”) or more than 19 years of education (77.1%). Compared with the general population of Germany, the study sample was 10.4 years younger (Statistisches Bundesamt, 2017), comprised 12.2% more females (Statistisches Bundesamt, 2018), and 45.2% more people with a university-entrance diploma (Statistisches Bundesamt, 2020). As Table I shows, participants across the four waves differed significantly in terms of age $F(3, 1964) = 65.21$, $p < 0.001$, $\eta^2 = 0.09$, gender $\chi^2(3) = 11.68$, $p = 0.009$, $V = 0.08$, and education $\chi^2(3) = 53.28$, $p < 0.001$, $V = 0.17$. Post-hoc tests (Bonferroni) indicated that participants in the 2009 wave were significantly older than the other three samples, all p 's ≤ 0.010 , and the participants from the 2016 wave were significantly younger than the remaining samples, all p 's < 0.001 . The gender ratio did not differ significantly across the four waves, except for the one in 2018, which encompassed more women than in 2006 and 2009, all p 's ≤ 0.05 . Education levels were significantly higher in 2006 and 2016, compared with 2009 and 2018, all p 's ≤ 0.05 .

The study sample was significantly older than the drop-out sample ($M_{study} = 33.86$, $SD = 12.37$ vs. $M_{drop-out} = 29.41$, $SD = 11.52$), $t(1353.73) = 8.67$, $p < 0.001$, $d = 0.37$ and differed in gender distribution $\chi^2(1) = 4.95$, $p = 0.026$, $V = 0.04$, with 56.5% females in the drop-out sample and 63.2% in the study sample. Education levels were equally high in both samples, $\chi^2(1) = 0.20$, $p = 0.651$. On average, participants in the study sample perceived their personal risk for seasonal influenza as significantly lower compared with the drop-out sample ($M_{study} = 3.18$, $SD = 1.43$ vs. $M_{drop-out} = 3.69$, $SD = 1.55$), $t(2037) = -2.90$, $p = 0.004$, $d = 0.34$. However, the study and drop-out sample did not differ significantly regarding the other

Table I. Participants' Characteristics ($N = 1,971$)

Measure	Wave 2006 ($n = 387$)	Wave 2009 ($n = 792$)	Wave 2016 ($n = 370$)	Wave 2018 ($n = 422$)	Statistics
Gender n (%)					$\chi^2(3) = 11.68, p = 0.009, V = 0.08$
Female	231 (59.7)	486 (61.4)	233 (63.0)	296 (70.1)	
Male	156 (40.3)	303 (38.3)	137 (37.0)	126 (29.9)	
Age M (SD)	34.8 (11.9)	37.2 (13.6)	26.9 (10.3)	32.9 (9.2)	$F(3, 1964) = 65.21, p < 0.001, \eta^2 = 0.09$
Education level n (%)					$\chi^2(3) = 53.28, p < 0.001, V = 0.17$
Full-time training finished ≤ 19 years	46 (11.9)	219 (27.7)	57 (15.4)	116 (27.5)	
Abitur/full-time training finished > 19 years	335 (86.6)	568 (71.7)	311 (84.1)	305 (72.3)	

Note: Number of participants might vary due to missing values.

five risk perception variables, $t(218.39) \leq |-1.52|$, all p 's ≥ 0.130 .

2.2. Measures

Measures assessing personal and others' risk perception were assessed within online surveys which were adjusted across measurement points to assess perceptions and protective behavior in relation to the avian influenza outbreaks (2006 and 2016); swine flu (2009); and avian and seasonal influenza (2018).

2.2.1. Personal Risk Perception (Self)

The participants were asked to estimate their absolute likelihood of becoming infected with (i) avian influenza (bird flu), (ii) seasonal influenza, and (iii) the common cold, on a scale from (1) "very unlikely" to (7) "very likely" with (4) "moderately likely" as the middle alternative; "How likely do you think you are to get infected with (*bird flu/normal flu [influenza]/common cold*) this year?" (see also, Renner & Reuter, 2012).

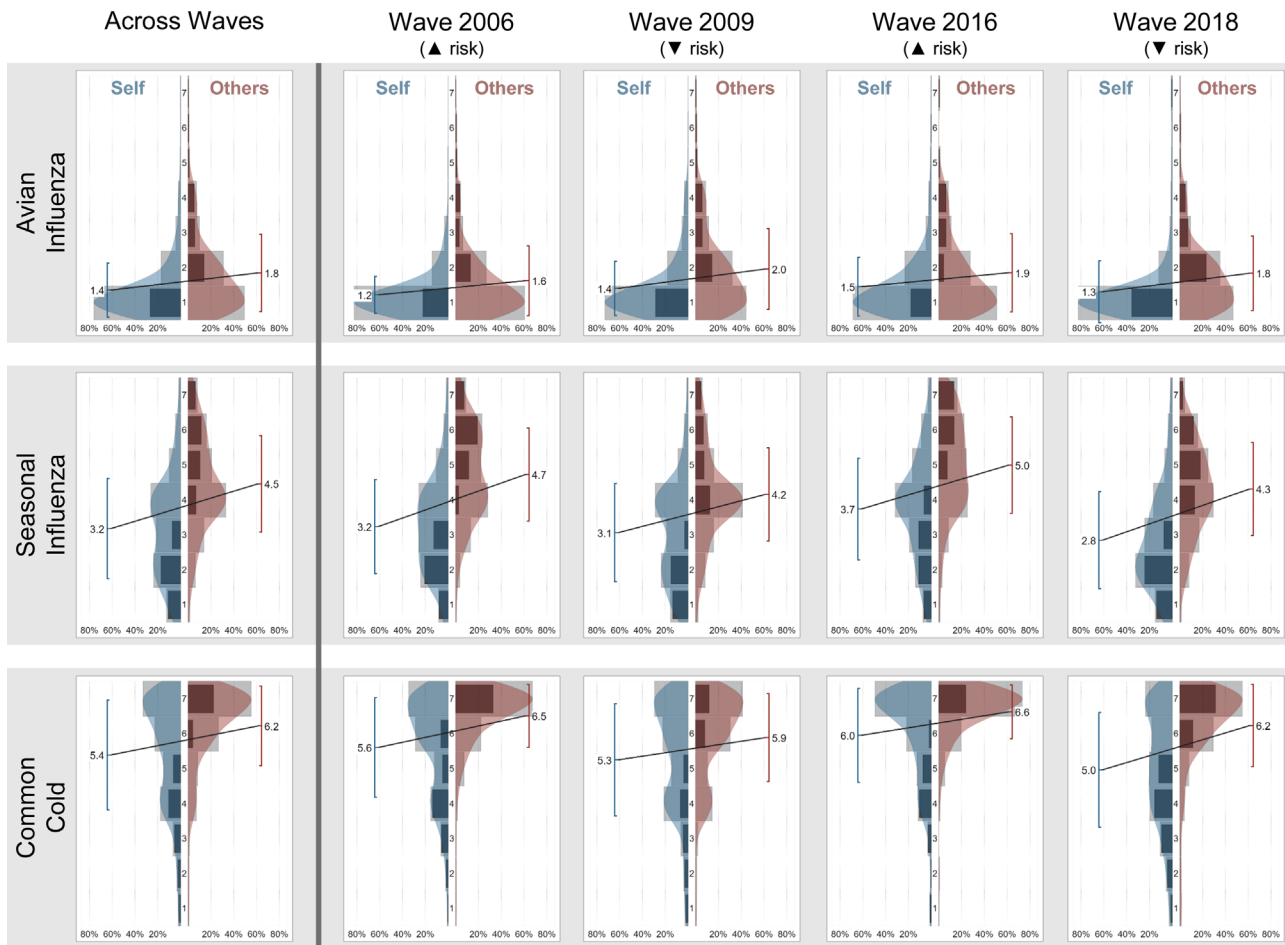
2.2.2. Others' Risk Perception (Others)

They were also asked to estimate the infection likelihood for an average person of their age and sex, "How likely is it in your opinion, that an average person of your age and sex gets infected with (*bird flu/normal flu [influenza]/common cold*) this year?," using the same seven-point rating scale.

2.3. Analytic Procedure

Statistical analysis was performed using IBM SPSS Statistics 25. Mixed measure ANOVAs were computed to test the research questions. Within the main model, interaction and simple main effects were calculated, where appropriate. Furthermore, post-hoc tests with Bonferroni corrections were conducted. The align-and-rank data for a nonparametric ANOVA procedure (ARTool; Wobbrock, Findlater, Gergle, & Higgins, 2011) and Kruskal-Wallis tests were used to secure the reported findings in the result section, confirming main and interaction effects. Due to brevity reasons, only parametric test results are reported.

v-Plots were created to visualize and compare the data distributions for the different infectious diseases, as well as for the personal and others' risk perception across the waves (Debbeler, Gamp, Blumenschein, Keim, & Renner, 2018; see, Blumenschein et al., 2020 for a detailed description). Fig. 1 depicts 15 v-plots that show the similarities and differences between multiple distribution properties. Each v-plot displays a histogram in light gray which shows the relative frequency of each response category for the respective variable. In addition, inner difference-histograms in dark gray depict the difference between risk perceptions for the self and other in each response category. To facilitate visual comparisons between the two distribution shapes, a smoothed density distribution on top of the histogram supports the visual comparison of the overall distributions. Mean and standard deviation are shown on the left/right side of the respective v-plots. Mean levels are connected via a black line



Note: Values range from (1) “very unlikely” to (7) “very likely.” Mean risk perception across the waves is depicted in the left column. Levels of objective risk for all three infectious diseases are stated above the right columns (▲ “High risk” = epidemics/seasons of avian influenza, seasonal influenza, and the common cold in 2006 and 2016; ▼ “Low risk” = nonepidemic/off-season times for avian influenza, seasonal influenza, and the common cold in 2009 and 2018; please note that a swine flu outbreak occurred in 2009, in 2018 no outbreak of zoonotic influenza occurred). Smoothed density distributions (red/blue shape) show the type of distribution, histograms (light gray) depict the relative frequency of each response category, difference histograms (dark gray) highlight the differences in each response category, means and standard deviations are depicted as lines in red/blue above the distributions. Mean values are connected via a black line for comparison.

Fig 1. Risk perception for three infectious diseases (avian influenza, seasonal influenza, and the common cold) at four waves split for self and others.

to facilitate the comparison of the mean levels of two distributions. The online tool to create v-plots is publicly available at <https://v-plot.dbvis.de>.

3. RESULTS

The v-plots in Fig. 1 depict the distributions of risk perceptions for the self and others in relation to the three infectious diseases and four waves (see also Table II). The column on the left encompasses

the average risk perception across all measurement points. Visual comparisons of the risk perception show marked differences depending on the judgement target (self–other) and disease (common cold, seasonal influenza, and avian influenza).

Personal risk perceptions are constantly lower than risk perceptions for others, indicating an optimistic bias. This is reflected (i) by the central tendency marked by the black line that is systematically lower on the left side, compared with the

Table II. Means and Standard Deviations of Risk Perception (Self Vs. Others) for Three Infectious Diseases at Four Waves

Measure	2006		2009		2016		2018	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
	[95% CI]		[95% CI]		[95% CI]		[95% CI]	
Self								
Avian	1.22	0.53	1.40	0.78	1.45	0.84	1.31	0.89
Influenza	[1.17, 1.27]		[1.35, 1.46]		[1.37, 1.54]		[1.22, 1.39]	
Seasonal	3.24	1.34	3.06	1.41	3.74	1.46	2.85	1.39
Influenza	[3.10, 3.37]		[2.96, 3.16]		[3.59, 3.89]		[2.71, 2.98]	
Common	5.60	1.43	5.25	1.61	5.95	1.35	4.96	1.64
Cold	[5.46, 5.75]		[5.14, 5.36]		[5.82, 6.09]		[4.81, 5.12]	
Others								
Avian	1.62	1.00	1.96	1.16	1.85	1.12	1.84	1.07
Influenza	[1.52, 1.72]		[1.88, 2.04]		[1.74, 1.97]		[1.73, 1.94]	
Seasonal	4.73	1.33	4.16	1.33	4.99	1.38	4.31	1.33
Influenza	[4.59, 4.86]		[4.06, 4.25]		[4.85, 5.14]		[4.18, 4.44]	
Common	6.51	0.90	5.89	1.26	6.62	0.77	6.23	1.18
Cold	[6.42, 6.60]		[5.80, 5.98]		[6.55, 6.70]		[6.12, 6.35]	

Note: *M* = mean; *SD* = standard deviation; CI = confidence interval.

right side and, (ii) by the different smoothed density distributions as the blue compared with the red distributions are more shifted to the lower end of the scale. Notably, an optimistic bias was most pronounced for seasonal influenza. The inner difference-histograms (in dark gray depicting the difference between risk perceptions for the self and others in each response category) show consistently for all diseases and waves that most participants saw themselves less at risk as compared with their peers.

Furthermore, general problem level accuracy is clearly visible by comparing the smoothed density distributions for the three diseases: The peak of the risk perception distributions for avian influenza are at the lower end of the scale, for seasonal influenza in the middle of the scale, and for the common cold at the upper end of the scale.

Also, dynamic accuracy is evident as the smoothed density distributions during times of increased objective risk for common cold and seasonal influenza (wave 2006 and 2016) show an upward shift compared with off-season times (wave 2009 and 2018), indicating a global rather than a localized effect. Also comparing where the black lines cross the scale, a pattern of higher–lower–higher–lower can be observed for seasonal influenza and the common cold across the four waves.

Since the study followed a repeated cross-sectional design, a 2 “target” (self vs. others) \times 3 “disease” (avian influenza vs. seasonal influenza vs. common cold) \times 4 “wave” (2006 vs. 2009 vs. 2016 vs. 2018) repeated measure ANOVA was conducted to test the

differences in risk perception for the three different infectious diseases at the four different measurement points, with the first two factors as within factors and the latter factor as a between factor.

3.1. Social Accuracy: Perceived Personal Versus Others’ Risk

The $2 \times 3 \times 4$ ANOVA yielded a significant main effect for the factor “target”, $F(1, 1967) = 1,696.23$, $p < 0.001$, $\eta_p^2 = 0.46$, reflecting that, on average, the participants felt at lower risk than their average peers ($M_{self} = 3.31$, $SD = 0.94$ vs. $M_{peer} = 4.18$, $SD = 0.82$; see also *v*-plots in Fig. 1). The difference observed between perceptions of risk to self and others indicates a substantial optimistic bias, and so a clear lack of social accuracy. Furthermore, a significant “target \times disease” interaction effect emerged, $F(2, 3934) = 249.14$, $p < 0.001$, $\eta_p^2 = 0.11$, indicating differences in the extent of the optimistic bias relating to the disease. As Fig. 1 (left row) depicts and a simple main effect analysis of “target” within “disease” showed, the strongest optimistic bias occurred for seasonal influenza, followed by the common cold, and then avian influenza, $F(1, 1967) = 1,486.92$, 668.71 , and 405.26 , respectively, all p ’s < 0.001 .

3.2. General Problem Level Accuracy: Rank Order in Risk Perceptions Across Diseases

In addition, the $2 \times 3 \times 4$ ANOVA yielded a significant main effect for “disease”,

$F(2, 3934) = 9,766.21, p < 0.001, \eta_p^2 = 0.83$, indicating pronounced differences in risk perception for the three different infectious diseases (see also Fig. 1, left row). Specifically, in accordance with the objective risk rank order within and across the four assessment periods, the perceived risk of infection in descending order was (i) the common cold ($M = 5.81, SD = 1.17$), (ii) seasonal influenza ($M = 3.82, SD = 1.20$), and (iii) avian influenza ($M = 1.60, SD = 0.82$), indicating rank order accuracy. Fig. 1 furthermore depicts that risk perceptions for seasonal influenza and the common cold varied more than for avian influenza.

3.3. Dynamic Problem Level Accuracy: Dynamic Response of Risk Perceptions to Epidemics/Seasons Versus Nonepidemic/Off-Season Times

Furthermore, the $2 \times 3 \times 4$ ANOVA yielded a significant main effect for “wave”, $F(3, 1967) = 46.06, p < 0.001, \eta_p^2 = 0.07$, and a significant “wave \times disease” interaction effect, $F(6, 3934) = 30.25, p < 0.001, \eta_p^2 = 0.04$, indicating dynamics in risk perception across waves which varied depending on the type of the infectious disease.

To follow up on the observed two-way interaction “wave \times disease,” a simple main effects analysis of “wave” within “disease” was calculated. This showed that risk perceptions differed as a function of assessment time for all three infectious diseases: avian influenza, $F(3, 1967) = 9.53, p < 0.001, \eta_p^2 = 0.01$, seasonal influenza $F(3, 1967) = 44.65, p < 0.001, \eta_p^2 = 0.06$, and the common cold, $F(3, 1967) = 45.42, p < 0.001, \eta_p^2 = 0.06$.

For avian influenza, the participants showed a lower risk perception in 2006 ($M = 1.42, SD = 0.66$) compared with the other three measurement points (all M 's ≥ 1.57 , all SD s ≥ 0.83), all p 's ≤ 0.050 . No other significant differences between waves were observed, all p 's ≥ 0.158 . Thus, overall, perceived risk for getting infected with avian influenza was rather stable across time and did not fluctuate during the two avian influenza outbreaks in 2006 and 2016.

For seasonal influenza, the participants reported on average significant higher risk perceptions in 2006 and 2016, when seasonal influenza was prevalent, compared with off-season times in 2009 and 2018 ($M_{2006} = 3.98, SD = 1.09, M_{2016} = 4.37, SD = 1.24$ vs. $M_{2009} = 3.61, SD = 1.17, M_{2018} = 3.58, SD = 1.15$), all p 's < 0.001 . Moreover, seasonal influenza risk per-

ceptions during off-season times in 2009 and 2018 did not differ significantly, $p = 1.0$. Overall, risk perceptions for seasonal influenza indicated dynamic accuracy.

The participants similarly reported significantly higher risk perceptions for catching a common cold during the common cold seasons in 2006 and 2016, as compared with off-season times in 2009 and 2018 ($M_{2006} = 6.06, SD = 0.97, M_{2016} = 6.29, SD = 0.92$ vs. $M_{2009} = 5.57, SD = 1.25, M_{2018} = 5.6, SD = 1.18$), all p 's ≤ 0.001 . Again, at the two off-season time points, risk perceptions for the common cold did not differ significantly, $p = 1.0$. Hence, common cold risk perceptions reflected season and off-season times, which indicates dynamic accuracy.

3.4. Differential Effects in Dynamic Accuracy: Perceived Personal Versus Others' Risk Across Waves

The $2 \times 3 \times 4$ ANOVA yielded a significant two-way interaction effect for “wave \times target”, $F(3, 1967) = 13.52, p < 0.001, \eta_p^2 = 0.02$, and a significant three-way interaction for “wave \times disease \times target”, $F(6, 3934) = 11.40, p < 0.001, \eta_p^2 = 0.02$, indicating dynamics in risk perception across waves, depending on the type of the infectious disease and judgment target (self vs. others).

A first approach to complement the significant “wave \times disease \times target” interaction is to consider diseases separately to detect differences in social accuracy across waves within disease type. Simple effect analyses yielded a significant “wave \times target” interaction, with $F(3, 1967)$ for avian influenza = 3.40, $p = 0.017, \eta_p^2 = 0.01$, seasonal influenza = 9.34, $p < 0.001, \eta_p^2 = 0.01$, and common cold = 20.07, $p < 0.001, \eta_p^2 = 0.03$. Thus, the degree of optimistic bias or social accuracy varied across waves within diseases.

The three-way interaction was also analyzed by calculating “wave \times disease” interactions and their corresponding main effects for risk perceptions for the self and others, respectively, to follow up on these differential dynamic changes. Simple effect analyses within risk perceptions for the self and others yielded a significant “wave \times disease” interaction, $F(6, 3934) = 17.44, p < 0.001, \eta_p^2 = 0.03$, and $F(6, 3934) = 32.99, p < 0.001, \eta_p^2 = 0.05$, respectively. Thus, for both judgment targets, dynamic changes occurred across waves depending on the disease type, mirroring the dynamic accuracy effect across judgment targets described above. Overall, however,

the effect was more pronounced for others than for personal risk perceptions.

3.4.1. Personal Risk Perception

Within personal risk perception, the main effect for “wave” reached statistical significance for avian influenza, seasonal influenza, and the common cold, $F(3, 1967) = 7.38, 29.82, \text{ and } 32.19, \eta^2 = 0.01, 0.04, \text{ and } 0.05$, respectively, all p 's < 0.001 . Post-hoc analysis again showed that personal risk perception for avian influenza was relatively stable across waves, with significantly lower average values in 2006 ($M = 1.22, SD = 0.53$) compared with 2009 ($M = 1.4, SD = 0.78$) and 2016 ($M = 1.45, SD = 0.84$), all p 's $\leq .001$. No other significant effects were found, all p 's ≥ 0.056 . Personal risk perception for seasonal influenza was significantly higher during season times in 2006 ($M = 3.24, SD = 1.34$) and 2016 ($M = 3.74, SD = 1.46$) than in the off-season times in 2018 ($M = 2.85, SD = 1.39$) and 2009 ($M = 3.06, SD = 1.41$), all p 's < 0.001 , except for risk perceptions in 2006 and 2009, which did not differ significantly, $p = 0.277$. Similarly, for the common cold, the participants felt more at risk in season than in off-season times, 2006 ($M = 5.6, SD = 1.43$), 2016 ($M = 5.95, SD = 1.35$) versus 2009 ($M = 5.25, SD = 1.61$) and 2018 ($M = 4.96, SD = 1.64$), all p 's ≤ 0.001 .

3.4.2. Others' Risk Perception

Within others' risk perceptions, a main effect for “wave” occurred for all three diseases (avian influenza, seasonal influenza, and the common cold: $F(3, 1967) = 8.11, 40.01, 49.91; \eta^2 = 0.01, 0.06, 0.07$, respectively, all p 's < 0.001). Post-hoc tests revealed a lower others' risk perception for avian influenza in 2006 ($M = 1.62, SD = 1.0$) compared with 2009 ($M = 1.96, SD = 1.16$), 2016 ($M = 1.85, SD = 1.12$) and 2018 ($M = 1.84, SD = 1.07$), all p 's ≤ 0.036 . No other effects were significant, all p 's ≥ 0.384 . Others' risk perception for seasonal influenza and the common cold showed dynamic accuracy, with average peers rated as more at-risk during season times in 2006 and 2016 than during off-season times in 2009 and 2018. Others' risk perceptions for seasonal influenza in 2006 ($M = 4.73, SD = 1.33$) and 2016 ($M = 4.99, SD = 1.38$) versus 2009 ($M = 4.16, SD = 1.33$) and 2018 ($M = 4.31, SD = 1.33$), all p 's < 0.001 . Others' risk perceptions for common cold in 2006 ($M = 6.51, SD = 0.90$) and 2016 ($M = 6.62, SD = 0.77$) versus 2009 (M

$= 5.89, SD = 1.26$) and 2018 ($M = 6.23, SD = 1.18$), all p 's ≤ 0.002 .

4. DISCUSSION

The present study surveyed four samples in Germany during times of zoonotic and seasonal influenza epidemics over a course of 12 years. To our knowledge, this repeated cross-sectional study is the first to involve multiple surveys of this type over different zoonotic epidemics and epidemics/seasons versus nonepidemic/off-season times.

4.1. Accuracy of Risk Perceptions: A Matter of the Comparison Standard

How to assess risk perception is an enduring challenge for research, since the different measures that can be utilized reflect different meanings, research aims, and traditions across disciplines such as health psychology, public health, economics, decision science, and sociology (e.g., Brewer et al., 2007; Cano & Salzberger, 2017; Renner & Schupp, 2011; Wilson et al., 2019). In the present study, the accuracy of risk perception is examined with respect to objective data, social comparison processes, and responding to dynamic changes in level of risk.

Data for all three infectious diseases revealed an optimistic bias rather than social accuracy, since the participants believed that they were less at risk of becoming infected with a virus than others. Importantly, the bias was highly robust across diseases and times of immediate threat. Conversely, risk perceptions for the self and for others were sensitive to differences in levels of objective risk. Risk perceptions showed consistent general problem level accuracy, as risk perceptions for avian influenza, seasonal influenza, and the common cold matched the objective hazard rank order. Specifically, the common cold poses the highest infection risk (Bayer et al., 2014), followed by seasonal influenza, since up to 10 million people in Germany are infected with this disease every year (RKI, 2019). In contrast, there have never been any human avian influenza infections in Germany (RKI, 2020). As shown in Fig. 1 (left panel), the distribution of risk ratings reflected this rank order, with pronounced mean differences between infectious diseases. Moreover, risk perceptions for the self and others waxed and waned with the epidemics/seasons versus nonepidemic/off-season times of seasonal influenza and the common cold, implying dynamic accuracy. However, dynamic accuracy was not shown

for avian influenza. Overall, these findings suggest that answers to the question of how accurately risk is perceived depend on the respective comparison standard.

The concurrence found in the present study between social inaccuracy and general problem level accuracy was also observed by De Zwart et al. (2010) in a sample taken in the Netherlands during the avian influenza epidemic in 2006/2007. Using different standards for assessing the accuracy of risk perception, as in the present study, perceived vulnerability reflected both the hazard rank order between avian influenza and the common cold and an optimistic bias for the former. Interestingly, even in times of an avian influenza epidemic, the perceived risk of catching avian influenza was low in both an absolute sense and compared with diseases such as the common cold. The results converge with the distinction made by Shepperd et al. (2013) between unrealistic comparative optimism, where people expect that negative outcomes are less likely to occur for oneself than for others, and unrealistic absolute optimism, where people's risk assessments are unrealistically positive when compared with an objective criterion such as actuarial risk assessments or actual outcomes. Accordingly, on average the participants demonstrated unrealistic comparative optimism while being realistic in comparison to objective standards. Hence, people are mistaken about different things and commit different errors (see also, Jefferson, Bortolotti, & Kuzmanovic, 2017; Renner et al., 2015).

4.2. Social Inaccuracy of Risk Perceptions: For Others, It Will be Worse

The present results replicate numerous findings on the "optimistic bias" or "unrealistic optimism", showing a consistent pattern of seeing others as being more at risk than oneself across both time and type of disease (Brewer et al., 2007; Shepperd, Pogge, & Howell, 2017). Thus, during times of heightened threat such as seasonal influenza epidemics, people might acknowledge higher levels of risk, but they still feel less vulnerable than others.

It has been argued that the pervasiveness of an optimistic bias in risk perceptions might be due to methodological conundrums, and thus overstated (see, Shepperd et al., 2017). Accordingly, one might argue that "scale attenuation", the limited scale range used to assess risk perceptions, might have contributed to the observed effects (Harris & Hahn,

2011). The v-plots in Fig. 1 show that while risk perceptions for avian influenza and the common cold were skewed toward the opposite ends of the rating scales, all the distributions reflect a considerable variance. Thus, while overestimation of the observed optimistic bias due to attenuation effects is possible, this reasoning seems unlikely.

The fact that the participants harbored a pessimistic outlook for others may represent a mechanism by which they maintain a comparatively optimistic outlook for themselves, despite realizing that health-related risks do increase with changing threat levels. This might satisfy a need for accuracy by acknowledging more objective risk at an absolute level, while serving motivational self-protective or self-enhancing needs by simultaneously maintaining a pessimistic view of others (Armor & Taylor, 1998; Renner & Schupp, 2011; Taylor & Shepperd, 1998). People take their objective disadvantages into account when making judgments, but they also discount them to some extent. This leads to a practical conclusion: Risk communication that only provides information about the individual's risk may have less impact than risk communication that provides additional information about the risk faced by an average peer. People may need both kinds of information to locate their risk status more accurately.

Although an optimistic bias may be beneficial insofar as it can promote positive affect and motivational needs (Taylor & Brown, 1988), it may also inhibit the motivation to adopt preventive behaviors. Importantly, the optimistic bias was most pronounced for seasonal influenza as compared with avian influenza or the common cold, and this remained unchanged even during the high-risk seasons in 2006 and 2016. Considering that drops in life expectancy in Germany observed in 2016/2017 have been linked to the increased mortality caused by influenza epidemics (Nowossadeck, von der Lippe, & Lampert, 2019), it is highly important to shed light on the construction of risk perception during influenza epidemics. Thus, there is a recurrent need for health campaigns informing the public about forthcoming influenza epidemics and the adoption of preventive health behaviors to cross the Rubicon from being aware of a health risk to feeling personally at risk. In this respect, debiasing interventions to reduce the optimistic bias revealed significant effects in 64% of the studies available for meta-analysis (Ludolph & Schulz, 2017). Accordingly, it seems relevant to determine the potential of successful intervention

strategies to reduce optimistic bias in the domain of seasonal influenza and other infectious diseases (Greening, Chandler, Stoppelbein, & Robison, 2005; Rose, 2011).

4.3. Dynamic Accuracy in Risk Perceptions: Commonalities and Differences Between Infectious Diseases

Most commonly, accuracy is assessed by determining the relationship of risk perception and objective risk estimates across multiple sources of risk at one measurement point in time (Siegrist, 2014). However, given that influenza risk shows recurrent patterns of peaks and troughs, and the finding that feeling personally at risk increases protective health behavior (Liao, Wong, & Fielding, 2013; Renner & Reuter, 2012; Reuter & Renner, 2011), the within-risk accuracy of risk perception seems most relevant from a public health perspective, that is, whether people hold distinct and accurate risk perceptions for specific risks. Tracking the dynamics of risk perception to the 2009 H1N1 pandemic over the course of one year, Gidengil *et al.* (2012) observed a close relationship between risk perception and objective risk estimates. Similar findings regarding the short-term accuracy of risk perceptions and infection rates have been observed for SARS (Lau *et al.*, 2003; Leung *et al.*, 2005). Here, we extended this repeated cross-sectional approach to study risk dynamics by assessing three types of infectious diseases, including seasonal influenza, and four waves which varied in objective risk for infectious diseases. In general, risk perceptions reflected the waxing and waning of objective infection risks for seasonal influenza and the common cold. Furthermore, there was a swine flu outbreak during the 2009 wave, revealing no hint for the spreading or generalizations of risk perceptions from an unrelated infectious disease on seasonal influenza or the common cold. Overall, the findings lend further support to the notion that risk perceptions of seasonal influenza and the common cold are grounded in reality.

In contrast, risk perceptions of avian influenza did not track objective risk estimates. Interestingly, similar findings of low-risk perceptions regarding avian influenza were observed in the Netherlands in 2006 (De Zwart *et al.*, 2010) as well as in China in 2013/2014 (Cui, Liao, Lam, Liu, & Fielding, 2017). However, it is uncertain whether these findings should be seen as inaccurate risk perceptions or, alternatively, as an accurate response to available risk

information, at least in European countries. Specifically, during the 2006 wave, which coincided with an avian pandemic, while human infections of H5N1 occurred worldwide, there were none reported in Germany. During the 2016 epidemic, there were no human infections of H5N8 worldwide. This contrasts with the occurrence of animal infections in 2006 and, to a much larger extent, during the 2016 outbreak in many European countries, including Germany (Brown *et al.*, 2017). While future research is necessary, these considerations suggest that rather than reflecting inaccurate risk perceptions, the findings observed for avian influenza may indicate that risk perception is based primarily on geographic proximity and human infection rates, which are directly related to the objective risk of infection (see also, Ibuka *et al.*, 2010).

It has been suggested that risk perception should be seen within a larger social, cultural, and economic context (Glendon & Clarke, 2016; Pidgeon, Kasperson, & Slovic, 2003; Slovic, 1992; WHO, 2002). In a pioneering study on risk dynamics, Loewenstein and Mather (1990) related objective measures of various risks to the accuracy of public perceptions of these risks, that is, numbers of news articles and survey questions over several years, and even decades, for some risks. Results were complex, with a close correspondence between the trajectory of public risk perception and objective risk estimates for some risks, that is, crime, inflation, and unemployment, but not for others, that is, Herpes. In addition, there was some evidence for panic responses associated, with AIDS and Herpes showing a temporary rise in perceived risk, which exceeded objective risk levels. Media coverage of infectious diseases over the past two decades included pronounced peaks associated with avian, SARS, and H1N1 pandemics, which possibly amplified the risk perceptions associated with infectious diseases over time. Interestingly, spanning a time range of 12 years, there seems to be no gross change, that is, panic or sustained shifts, in risk perceptions for the infectious diseases sampled in the present study. However, it should be noted that the present study was not designed for this purpose and is therefore of limited use in addressing this issue.

4.4. Limitations

The main limitation of this study is that it used a repeated cross-sectional design to examine dynamic changes in the perceived risk of infectious diseases. Although this design permits comparisons between

different points in time, a longitudinal study would be preferable for investigating the dynamics of risk perception (Siegrist, 2014).

In addition, since the four survey samples differed from each other in certain characteristics (age, gender, and education), sample selection bias should be taken into account when generalizing the results. Furthermore, the possibility that the different compositions of the samples led to the observed patterns in risk perception cannot be excluded. Although the different samples largely matched each other in terms of age and gender, the level of education varied across waves and was in general higher compared with the German population. Thus, generalizability of the present results is limited by education level and associated numerical literacy and results should be replicated with representative samples. Furthermore, generalizability of the study results might also be limited by recruiting participants through a snowball technique that might have caused a systematic self-selection bias.

When comparing the drop-out to the study sample, a difference in perceived risk emerged. Specifically, the study sample expressed lower personal risk perception for seasonal influenza. Thus, there might be the possibility that we underestimated the population's risk perception. However, the difference between the mean levels was comparatively small. Furthermore, there were neither differences between the drop-out and the study sample for the remaining five risk perception variables nor any difference for avian flu and common cold, indicating a nonselective dropout in this regard.

Participants might have differed in their interpretation of the provided risk perception rating scale (e.g., Wallsten, Budescu, Rapoport, Zwick, & Forsyth, 1986) adding some measurement error. However, the consistency of the results across the four waves and the observed ranking accuracy suggest a general high reliability of the results.

5. Conclusion

The current study investigated three different measures of accuracy that provided different information on how people gauge their risk in the face of infectious diseases. Specifically, data revealed accurate risk perceptions, as people accurately allocated different levels of risk to the different infectious diseases (i.e., general problem level accuracy) and responded to changes in objective risk for seasonal influenza and common cold (i.e., dynamic prob-

lem level accuracy). However, while risk perceptions fluctuated with the current threat level, people still maintained their belief that the threat is worse for others (i.e., social inaccuracy) and thus biased risk perceptions were revealed. Hence, the results of the present study support the importance of using multiple measures to fully assess the accuracy of risk perceptions. Specifically, evidence for dynamic accuracy suggests that public health campaigns might be able to capitalize on the dynamics of the perceived risk of seasonal influenza to maximize protective behaviors during times of higher objective risk. Furthermore, the study suggests that avian influenza is conceptualized in a different way to seasonal influenza and the common cold, which should be taken into consideration in public health campaigns. Future research should further enhance on elaborating the overall picture of the dynamics of risk perception, by including multiple measures when investigating the dynamics. For instance, the changing magnitude of the optimistic bias during the emergence and development of a pandemic, like the current COVID-19 pandemic, and investigating personal and general risk perceptions separately, would reveal important insights on whether perceived risk matches the current objective risk (as indicated by active cases) and whether personal or rather general risk perceptions are adapted accordingly.

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REFERENCES

- Arbeitsgemeinschaft Influenza. (2012). Abschlussbericht der Influenzasaison 2006/07 [Final report of the influenza season 2006/07]; Aviare Influenza in der Saison 2006/07 [Avian influenza in the 2006/07 season]. Retrieved from https://edoc.rki.de/bitstream/handle/176904/3435/Abschlussbericht_2007.pdf

- Armor, D. A., & Taylor, S. E. (1998). Situated optimism: Specific outcome expectancies and self-regulation. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 30, pp. 309–379). San Diego, CA: Academic Press.
- Bayer, C., Remschmidt, C., an der Heiden, M., Tolksdorf, K., Herzhoff, M., Kaersten, S., ... Buchholz, U. (2014). Internet-based syndromic monitoring of acute respiratory illness in the general population of Germany, weeks 35/2011 to 34/2012. *Euro Surveillance*, 19(4), 20648. <https://doi.org/10.25646/1743>
- Betsch, C., Brewer, N. T., Brocard, P., Davies, P., Gaissmaier, W., Haase, N., ... Stryk, M. (2012). Opportunities and challenges of web 2.0 for vaccination decisions. *Vaccine*, 30(25), 3727–3733. <https://doi.org/10.1016/j.vaccine.2012.02.025>
- Bishop, G. D. (1991). Understanding the understanding of illness: Lay disease representations. In J. A. Skelton & R. T. Croyle (Eds.), *Contributions to psychology and medicine. Mental representation in health and illness* (pp. 32–59). New York, NY: Springer US.
- Blumenschein, M., Debbeler, L. J., Lages, N. C., Renner, B., Keim, D. A., & El-Assady, M. (2020). V-plots: Designing hybrid charts for the comparative analysis of data distributions. *Computer Graphics Forum*, 39(3), 565–577. <https://doi.org/10.1111/cgf.14002>
- Brewer, N. T., Chapman, G. B., Gibbons, F. X., Gerrard, M., McCaul, K. D., & Weinstein, N. D. (2007). Meta-analysis of the relationship between risk perception and health behavior: The example of vaccination. *Health Psychology*, 26(2), 136–145. <https://doi.org/10.1037/0278-6133.26.2.136>
- Brown, I., Mulatti, P., Smietanka, K., Staubach, C., Willeberg, P., Adlhoeh, C., ... Verdonck, F. (2017). Avian influenza overview October 2016–August 2017. *EFA Journal*, 15(10), 261. <https://doi.org/10.2903/j.efsa.2017.5018>
- Brug, J., Aro, A. R., & Richardus, J. H. (2009). Risk perceptions and behaviour: Towards pandemic control of emerging infectious diseases: International research on risk perception in the control of emerging infectious diseases. *International Journal of Behavioral Medicine*, 16(1), 3–6. <https://doi.org/10.1007/s12529-008-9000-x>
- Buda, S., Prahm, K., Preuß, U., Gau, P., Schweiger, B., Biere, B., ... Haas, W. (2017). Bericht zur Epidemiologie der Influenza in Deutschland Saison 2016/17 [Report about the epidemiology of influenza in Germany season 2016/17]: Aviäre Influenza [Avian influenza]. Retrieved from <https://edoc.rki.de/bitstream/handle/176904/3633/2017.pdf>
- Cameron, L. D., Sherman, K. A., Marteau, T. M., & Brown, P. M. (2009). Impact of genetic risk information and type of disease on perceived risk, anticipated affect, and expected consequences of genetic tests. *Health Psychology*, 28(3), 307–316. <https://doi.org/10.1037/a0013947>
- Cano, S., & Salzberger, T. (2017). Measuring risk perception. In G. Emilien, R. Weitkunat, & F. Lüdicke (Eds.), *Consumer perception of product risks and benefits* (Vol. 3, pp. 191–200). Cham, Germany: Springer International Publishing.
- Cui, B., Liao, Q., Lam, W. W. T., Liu, Z. P., & Fielding, R. (2017). Avian influenza A/H7N9 risk perception, information trust and adoption of protective behaviours among poultry farmers in Jiangsu Province, China. *BMC Public Health*, 17(1), 463. <https://doi.org/10.1186/s12889-017-4364-y>
- De Zwart, O., Veldhuijzen, I. K., Richardus, J. H., & Brug, J. (2010). Monitoring of risk perceptions and correlates of precautionary behaviour related to human avian influenza during 2006–2007 in the Netherlands: Results of seven consecutive surveys. *BMC Infectious Diseases*, 10, 114. <https://doi.org/10.1186/1471-2334-10-114>
- Debbeler, L. J., Gamp, M., Blumenschein, M., Keim, D., & Renner, B. (2018). Polarized but illusory beliefs about tap and bottled water: A product- and consumer-oriented survey and blind tasting experiment. *Science of the Total Environment*, 643, 1400–1410. <https://doi.org/10.1016/j.scitotenv.2018.06.190>
- Douglas, M. (1996). *Risk and blame: Essays in cultural theory*. London, UK: Routledge.
- Ferrer, R., & Klein, W. M. (2015). Risk perceptions and health behavior. *Current Opinion in Psychology*, 5, 85–89. <https://doi.org/10.1016/j.copsyc.2015.03.012>
- Finkel, A. M. (2008). Perceiving others' perceptions of risk: Still a task for Sisyphus. *Annals of the New York Academy of Sciences*, 1128, 121–137. <https://doi.org/10.1196/annals.1399.013>
- Gaube, S., Lermer, E., & Fischer, P. (2019). The concept of risk perception in health-related behavior theory and behavior change. In M. Raue, B. Streicher, & E. Lermer (Eds.), *Perceived safety: A multidisciplinary perspective* (Vol. 50, pp. 101–118). Cham, Germany: Springer International Publishing.
- Gidengil, C. A., Parker, A. M., & Zikmund-Fisher, B. J. (2012). Trends in risk perceptions and vaccination intentions: A longitudinal study of the first year of the H1N1 pandemic. *American Journal of Public Health*, 102(4), 672–679. <https://doi.org/10.2105/AJPH.2011.300407>
- Glendon, A. I., & Clarke, S. (2016). *Human safety and risk management: A psychological perspective* (3rd ed.). Boca Raton, FL: CRC Press.
- Greening, L., Chandler, C. C., Stoppelbein, L., & Robison, L. J. (2005). Risk perception: Using conditional versus general base rates for risk communication. *Journal of Applied Social Psychology*, 35(10), 2094–2122. <https://doi.org/10.1111/j.1559-1816.2005.tb02211.x>
- Han, G. K., Zhang, J. M., Chu, K. R., & Shen, G. (2014). Self-other differences in H1N1 flu risk perception in a global context: A comparative study between the United States and China. *Health Communication*, 29(2), 109–123. <https://doi.org/10.1080/10410236.2012.723267>
- Harris, A. J. L., & Hahn, U. (2011). Unrealistic optimism about future life events: A cautionary note. *Psychological Review*, 118(1), 135–154. <https://doi.org/10.1037/a0020997>
- Ibuka, Y., Chapman, G. B., Meyers, L. A., Li, M., & Galvani, A. P. (2010). The dynamics of risk perceptions and precautionary behavior in response to 2009 (H1N1) pandemic influenza. *BMC Infectious Diseases*, 10, 296. <https://doi.org/10.1186/1471-2334-10-296>
- Iuliano, A. D., Roguski, K. M., Chang, H. H., Muscatello, D. J., Palekar, R., Tempia, S., ... Mustaqim, D. (2018). Estimates of global seasonal influenza-associated respiratory mortality: A modelling study. *Lancet*, 391(10127), 1285–1300. [https://doi.org/10.1016/S0140-6736\(17\)33293-2](https://doi.org/10.1016/S0140-6736(17)33293-2)
- Jefferson, A., Bortolotti, L., & Kuzmanovic, B. (2017). What is unrealistic optimism? *Consciousness and Cognition*, 50, 3–11. <https://doi.org/10.1016/j.concog.2016.10.005>
- Jones, J. H., & Salathé, M. (2009). Early assessment of anxiety and behavioral response to novel swine-origin influenza A(H1N1). *PloS One*, 4(12), e8032. <https://doi.org/10.1371/journal.pone.0008032>
- Lau, J. T. F., Yang, X., Tsui, H., & Kim, J. H. (2003). Monitoring community responses to the SARS epidemic in Hong Kong: From day 10 to day 62. *Journal of Epidemiology & Community Health*, 57(11), 864–870. <https://doi.org/10.1136/jech.57.11.864>
- Leung, G. M., Ho, L. M., Chan, S. K. K., Ho, S. Y., Bacon-Shone, J., Choy, R. Y. L., ... Fielding, R. (2005). Longitudinal assessment of community psychobehavioral responses during and after the 2003 outbreak of severe acute respiratory syndrome in Hong Kong. *Clinical Infectious Diseases*, 40(12), 1713–1720. <https://doi.org/10.1086/429923>
- Liao, Q., Wong, W. S., & Fielding, R. (2013). Comparison of different risk perception measures in predicting seasonal influenza vaccination among healthy Chinese adults in Hong Kong: A prospective longitudinal study. *PloS One*, 8(7), e68019. <https://doi.org/10.1371/journal.pone.0068019>
- Loewenstein, G., & Mather, J. (1990). Dynamic processes in risk perception. *Journal of Risk and Uncertainty*, 3(2), 155–175. <https://doi.org/10.1007/BF00056370>

- Ludolph, R., & Schulz, P. J. (2017). Debiasing health-related judgments and decision making: A systematic review. *Medical Decision Making, 38*(1), 3–13. <https://doi.org/10.1177/0272989x17716672>
- Nowossadeck, E., von der Lippe, E., & Lampert, T. (2019). Entwicklung der Lebenserwartung in Deutschland – aktuelle Trends [Progress of life expectancy in Germany - current trends]. *Journal of Health Monitoring, 4*(1). <https://doi.org/10.25646/5869>
- Pidgeon, N., Kasperson, R. E. & Slovic, P. (Eds.), (2003). *The social amplification of risk*. Cambridge, UK: Cambridge University Press.
- Renner, B., Gamp, M., Schmäzle, R., & Schupp, H. T. (2015). Health risk perception. In J. D. Wright (Ed.), *International encyclopedia of the social & behavioral sciences* (2nd ed., pp. 702–709). Oxford, UK: Elsevier.
- Renner, B., & Reuter, T. (2012). Predicting vaccination using numerical and affective risk perceptions: The case of A/H1N1 influenza. *Vaccine, 30*(49), 7019–7026. <https://doi.org/10.1016/j.vaccine.2012.09.064>
- Renner, B., & Schupp, H. (2011). The perception of health risks. In H. S. Friedman (Ed.), *The Oxford handbook of health psychology* (pp. 639–666). New York, NY: Oxford University Press.
- Reuter, T., & Renner, B. (2011). Who takes precautionary action in the face of the new H1N1 influenza? Prediction of who collects a free hand sanitizer using a health behavior model. *PloS One, 6*(7), e22130. <https://doi.org/10.1371/journal.pone.0022130>
- Robert Koch Institute. (n.d.). Allgemeine Informationen [General information]: Erkältungen [Common colds]. Retrieved from <https://grippeweb.rki.de/Info.aspx>
- Robert Koch Institute. (2019). Influenza: Häufig gestellte Fragen und Antworten zur Grippe [Frequently asked questions and answers about flu]. Retrieved from https://www.rki.de/SharedDocs/FAQ/Influenza/FAQ_Liste.html?nn=2370434
- Robert Koch Institute. (2020). Zoonotische Influenza [Zoonotic influenza]: RKI zu humanen Erkrankungen mit aviärer Influenza (Vogelgrippe) [RKI about human cases of avian influenza (bird flu)]. Retrieved from <https://www.rki.de/DE/Content/InfAZ/Z/ZoonotischeInfluenza/Vogelgrippe.html>
- Rose, J. P. (2011). Debiasing comparative optimism and increasing worry for health outcomes. *Journal of Health Psychology, 17*(8), 1121–1131. <https://doi.org/10.1177/1359105311434051>
- Rubin, G. J., Potts, H. W. W., & Michie, S. (2010). The impact of communications about swine flu (influenza A H1N1v) on public responses to the outbreak: Results from 36 national telephone surveys in the UK. *Health Technology Assessment, 14*(34), 183–266. <https://doi.org/10.3310/hta14340-03>
- Sheeran, P., Harris, P. R., & Epton, T. (2014). Does heightening risk appraisals change people's intentions and behavior? A meta-analysis of experimental studies. *Psychological Bulletin, 140*(2), 511–543. <https://doi.org/10.1037/a0033065>
- Shepperd, J. A., Klein, W. M. P., Waters, E. A., & Weinstein, N. D. (2013). Taking stock of unrealistic optimism. *Perspectives on Psychological Science, 8*(4), 395–411. <https://doi.org/10.1177/1745691613485247>
- Shepperd, J. A., Pogge, G., & Howell, J. L. (2017). Assessing the consequences of unrealistic optimism: Challenges and recommendations. *Consciousness and Cognition, 50*, 69–78. <https://doi.org/10.1016/j.concog.2016.07.004>
- Siegrist, M. (2014). Longitudinal studies on risk research. *Risk Analysis, 34*(8), 1376–1377. <https://doi.org/10.1111/risa.12249>
- Siegrist, M., & Árvai, J. (2020). Risk perception: Reflections on 40 years of research. *Risk Analysis, 40*(S1), 2191–2206. <https://doi.org/10.1111/risa.13599>
- Sjöberg, L., Moen, B.-E., & Rundmo, T. (2004). Explaining risk perception: An evaluation of the psychometric paradigm in risk perception research (No. 84). Retrieved from <https://api.semanticscholar.org/CorpusID:201601374>
- Slovic, P. (1992). Perception of risk: Reflections on the psychometric paradigm. In S. Krimsky & D. Golding (Eds.), *Social theories of risk* (pp. 117–152). New York, NY: Praeger.
- Slovic, P. (2000). *The perception of risk*. London, UK: Earthscan Publications.
- Slovic, P., Fischhoff, B., & Lichtenstein, S. (1980). Facts and fears: Understanding perceived risk. In R. C. Schwing & W. A. Albers (Eds.), *Societal risk assessment* (pp. 181–216). Boston, MA: Springer US.
- Slovic, P., Fischhoff, B., & Lichtenstein, S. (1985). Characterizing perceived risk. In R. W. Kates, C. Hohenemser, & J. X. Kasperson (Eds.), *Perilous progress: Managing the hazards of technology* (pp. 91–125). Boulder, CO: Westview.
- Statistisches Bundesamt. (2017). Pressemitteilung Nr. 197 vom 13. Juni 2017 [Press release No. 197 from 2017 June 13]. Retrieved from https://www.destatis.de/DE/Presse/Pressemitteilungen/2017/06/PD17_197_12411.html
- Statistisches Bundesamt. (2018). Zahl der Woche Nr. 10 vom 6. März 2018 [Number of the week No. 10 from 2018 March 6]. Retrieved from https://www.destatis.de/DE/Presse/Pressemitteilungen/Zahl-der-Woche/2018/PD18_10_p002.html
- Statistisches Bundesamt. (2020). Bevölkerung nach Bildungsabschluss in Deutschland [Population according to educational attainment in Germany]. Retrieved from <https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Bildungsstand/Tabellen/bildungsabschluss.html>
- Taylor, K. M., & Shepperd, J. A. (1998). Bracing for the worst: Severity, testing, and feedback timing as moderators of the optimistic bias. *Personality and Social Psychology Bulletin, 24*(9), 915–926. <https://doi.org/10.1177/0146167298249001>
- Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: A social psychological perspective on mental health. *Psychological Bulletin, 103*(2), 193–210. <https://doi.org/10.1037/0033-2909.103.2.193>
- Van, D., McLaws, M. L., Crimmins, J., MacIntyre, C. R., & Seale, H. (2010). University life and pandemic influenza: Attitudes and intended behaviour of staff and students towards pandemic (H1N1) 2009. *BMC Public Health, 10*, 130. <https://doi.org/10.1186/1471-2458-10-130>
- Voelker, R. (2018). Vulnerability to pandemic flu could be greater today than a century ago. *Journal of the American Medical Association, 320*(15), 1523–1525. <https://doi.org/10.1001/jama.2018.12966>
- Wallsten, T. S., Budescu, D. V., Rapoport, A., Zwick, R., & Forsyth, B. (1986). Measuring the vague meanings of probability terms. *Journal of Experimental Psychology: General, 115*(4), 348–365. <https://doi.org/10.1037/0096-3445.115.4.348>
- Weber, E. U., & Morris, M. W. (2010). Culture and judgment and decision making: The constructivist turn. *Perspectives on Psychological Science, 5*(4), 410–419. <https://doi.org/10.1177/1745691610375556>
- Weinstein, N. D. (1980). Unrealistic optimism about future life events. *Journal of Personality and Social Psychology, 39*(5), 806–820. <https://doi.org/10.1037/0022-3514.39.5.806>
- Weinstein, N. D. (2000). Perceived probability, perceived severity, and health-protective behavior. *Health Psychology, 19*(1), 65–74. <https://doi.org/10.1037/0278-6133.19.1.65>
- Weinstein, N. D. (2003). Exploring the links between risk perceptions and preventive health behavior. In J. Suls & K. A. Wallston (Eds.), *Social psychological foundations of health and illness* (pp. 22–53). Malden, MA: Blackwell Publishing Ltd.
- Wilkinson, I. (2001). *Anxiety in a risk society*. London, UK: Routledge.
- Wilson, R. S., Zwickle, A., & Walpole, H. (2019). Developing a broadly applicable measure of risk perception. *Risk Analysis, 39*(4), 777–791. <https://doi.org/10.1111/risa.13207>
- Wobbrock, J. O., Findlater, L., Gergle, D., & Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. In D. Tan, G. Fitzpatrick, C.

- Gutwin, B. Begole, & W. A. Kellogg (Eds.), *Proceedings of the 2011 annual conference on human factors in computing systems - CHI '11* (pp. 143–146). New York, NY: ACM Press.
- World Health Organization. (n.d.-a). Influenza: Avian and other zoonotic influenza. Retrieved from http://www.who.int/influenza/human_animal_interface/en/
- World Health Organization. (n.d.-b). Influenza: Burden of disease. Retrieved from http://www.who.int/influenza/surveillance_monitoring/bod/en/
- World Health Organization. (n.d.-c). International travel and health: Seasonal influenza. Retrieved from https://www.who.int/ith/diseases/influenza_seasonal/en/
- World Health Organization. (2002). The world health report 2002: Reducing risks, promoting healthy life. Retrieved from http://www.who.int/whr/2002/en/whr02_en.pdf?ua=1
- World Health Organization. (2018). Influenza (seasonal): Prevention. Retrieved from [https://www.who.int/news-room/factsheets/detail/influenza-\(seasonal\)](https://www.who.int/news-room/factsheets/detail/influenza-(seasonal))
- Xu, J., & Peng, Z. (2015). People at risk of influenza pandemics: The evolution of perception and behavior. *PloS One*, *10*(12), e0144868. <https://doi.org/10.1371/journal.pone.0144868>