

**Risk Perception and Behavior**  
**Related to Changing Health Risks**

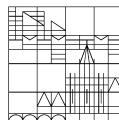
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## Table of Contents

<b>Vorveröffentlichungen der Dissertation .....</b>	<b>I</b>
<b>Table of Contents .....</b>	<b>II</b>
<b>Summary .....</b>	<b>V</b>
<b>Zusammenfassung .....</b>	<b>VIII</b>
<b>General Introduction .....</b>	<b>1</b>
Assessment of Health Risks.....	2
Assessment of Perceived Risk.....	3
Accuracy of Perceived Risk.....	4
Optimistic bias in perceived risk.....	4
Perceiving the general level of health risks .....	5
Perceiving dynamics in risks .....	6
From Risk Perception to Protective Behaviors .....	8
Protective behaviors during infectious disease threats .....	8
Risk perception and protective behaviors during Covid-19 .....	9
The Importance of Personal Risk Perception for Adopting Protective Behaviors ..	11
Interplay Between Health Risk, Perceived Risk, and Protective Behaviors.....	12
Outline and Research Aims of the Present Dissertation.....	13
<b>Health Risk and Risk Perception.....</b>	<b>16</b>
Abstract .....	17
Introduction .....	18
The Present Study .....	22
Method .....	23
Procedure and Sample .....	23
Measures .....	27
<i>Personal risk perception (self)</i> .....	27
<i>Others' risk perception (others)</i> .....	27
Analytic Procedure .....	27
Results .....	28
Social Accuracy: Perceived Personal vs. Others' Risk.....	31
General Problem Level Accuracy: Rank Order in Risk Perceptions Across Diseases .....	32
Dynamic Problem Level Accuracy: Dynamic Response of Risk Perceptions to Epidemics/Seasons vs. Non-Epidemic/off-Season Times.....	32
Differential Effects in Dynamic Accuracy: Perceived Personal vs. Others' Risk Across Waves .....	34

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Personal risk perception .....	34
Others' risk perception .....	35
Discussion .....	36
Accuracy of Risk Perceptions: A Matter of the Comparison Standard .....	36
Social Inaccuracy of Risk Perceptions: For Others, it will be Worse .....	37
Dynamic Accuracy in Risk Perceptions: Commonalities and Differences Between Infectious Diseases .....	39
Limitations .....	41
Conclusion .....	43
Declarations .....	44
<b>Health Risk and Protective Behavior Intentions .....</b>	<b>45</b>
Abstract .....	46
Introduction .....	47
Method .....	48
Results .....	49
Discussion .....	53
Conclusion .....	56
Declarations .....	57
<b>Behavior, Risk Perception, and Health Risk .....</b>	<b>58</b>
Abstract .....	59
Introduction .....	60
The Present Study .....	61
Method .....	62
Procedure and Sample .....	62
Measures .....	63
Healthy eating .....	63
Risk perception .....	63
Health feedback .....	63
Analytic Procedure .....	64
Results .....	65
Relative Accuracy of Perceived Risk .....	65
Adaptive Accuracy of Perceived Risk .....	65
Discussion .....	68
Adaptive and Relative Accuracy in Healthy Eating .....	68
Underlying Mechanism of Adaptive Accuracy .....	69
Relations Between Health Behavior and Feedback on Risk Factors .....	69

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The Importance of Dynamic Risk Perceptions .....	70
Limitations and Future Research .....	71
Conclusion .....	72
<b>General Discussion .....</b>	<b>73</b>
Models of Risk Perception and Behavior.....	75
Including time .....	77
Including target .....	78
<i>Health risk</i> .....	78
<i>Perceived risk</i> .....	79
Optimistic Bias and Protective Behaviors.....	80
The Dynamic Nature of Perceived Risk.....	81
The Importance of Changes in Risk Perception for Maintaining Behavior.....	82
The Social Context of Risk Perception and Behavior .....	83
Limitations and Future Research.....	85
Conclusion .....	87
<b>List of Contributions .....</b>	<b>89</b>
<b>Danksagung .....</b>	<b>91</b>
<b>References .....</b>	<b>93</b>

## Summary

Life is fraught with hazards. However, the risk of many of these hazards can be reduced by performing protective behaviors. Acting appropriately to both stable and emerging or changing hazards requires humans to modify their protective behavior accordingly. It has been shown that risk perception is among the factors that are prerequisites for initiating protective behavior. Thus, when a new hazard emerges or the risk of a hazard changes, people presumably modify their risk perception accordingly, which in turn may promote the initiation of protective behaviors. This implies a dynamic interplay between risk, the perception of risk, and protective behaviors. The present dissertation aims at exploring aspects of this dynamic interplay for health risks.

The present dissertation first examined the association between health risk and risk perception. Three indicators of accuracy were examined for three infectious diseases, namely avian influenza, seasonal influenza, and the common cold. Specifically, conducting four cross-sectional surveys over a time period of 12 years showed that risk perceptions were concurrently accurate and inaccurate. While people held lower personal than general risk perceptions, indicating social inaccuracy (i.e., optimistic bias), the rank order between diseases was accurate at all four measurement points (i.e., general problem level accuracy), as people rated the risk for infection as highest for the common cold and lowest for avian influenza. Moreover, risk perceptions also accurately reflected the season and off-season times for seasonal influenza and common cold (i.e., dynamic problem level accuracy), although general risk perceptions reflected changes in the health risk to a greater extent. Thus, overall, people accurately modified their risk perceptions to changes in the general health risk.

The present dissertation then explored the relationship between health risk and protective behavior intentions. Specifically, it investigated whether increases in health

risk were accompanied by increases in protective behavior intentions during the emerging phase of the Covid-19 pandemic in Germany. The analyses of three cross-sectional surveys indicated that intentions for social distancing and increasing personal hygiene increased in line with increases in health risk (i.e., total confirmed cases of Covid-19), whereas intentions to seek medical care increased at first but then decreased after the imposition of the lockdown in Germany. Moreover, small associations of age and intentions for protective behavior were revealed, which varied in accordance with the health risk. Specifically, age was positively associated with intentions for social distancing and personal hygiene in the early emergence of Covid-19 in Germany, but this effect diminished after the imposition of the lockdown. However, a positive association of age and intention to visit a doctor only emerged after the imposition of the lockdown. Thus, people modified their protective behavior intentions as the health risk increased, and health risk moderated the small associations between age and protective behavior intentions.

Lastly, the interplay between protective behavior and risk perception in dependence of health risk was investigated. While the first two studies focused on infectious disease threats, the third study shifted the attention to noncommunicable diseases, specifically examining the interplay between self-reported healthy eating and diet-related risk perception in the context of providing personalized health feedback. Assessing the reciprocal relationship between self-reported healthy eating and diet-related risk perception for two groups of different feedback valence revealed relative and adaptive accuracy of perceived risk in both feedback groups. Specifically, people with higher perceived risk generally reported lower healthy eating (i.e., relative accuracy) and increases in self-reported healthy eating were followed by lower risk perception (i.e., adaptive accuracy). Thus, the same dynamic interplay between protective behavior and risk perception emerged for two degrees of health risk.

The findings of the present dissertation emphasize that people generally respond reasonably to changing health risks by modifying their risk perception and protective behavior intentions accordingly. Furthermore, the occurrence of changes in perceived risk after changes in self-reported protective behavior further highlights the dynamic nature of perceived risk. Overall, the findings of this dissertation provide an initial starting point for further research on the dynamic interplay between health risk, perceived risk, and protective behavior, to gain a more comprehensive understanding of the interactions between them. The further investigation of this interplay may contribute to a stronger focus on the reciprocal relationships between constructs and their dynamic interplay across time, which may foster the development of models and theories in health psychology that emphasize dynamics and reciprocal interrelations.

## Zusammenfassung

Das Leben ist voller Gefahren. Das Risiko, durch diese Gefahren Schaden zu nehmen, kann jedoch durch individuelles Schutzverhalten reduziert werden. Um sowohl auf stabile als auch auf neu auftretende oder sich verändernde Gefahren angemessen reagieren zu können, muss das Schutzverhalten jedoch entsprechend angepasst werden. Die Wahrnehmung des Risikos gilt, neben anderen Faktoren, als Voraussetzung für die Initiierung von Schutzverhalten. Wenn demnach eine neue Gefahr auftritt oder sich das Risiko einer Gefahr ändert, ändern Personen voraussichtlich ihre Risikowahrnehmung, was wiederum die Initiierung von Schutzverhalten begünstigen kann. Dies impliziert ein dynamisches Zusammenspiel zwischen Risiko, Risikowahrnehmung und Schutzverhalten. Die vorliegende Dissertation zielt darauf ab, Aspekte dieses dynamischen Zusammenspiels für Gesundheitsrisiken zu explorieren.

In der vorliegenden Dissertation wurde zunächst der Zusammenhang zwischen Gesundheitsrisiken und Risikowahrnehmung untersucht. Drei Maße für den Grad der Genauigkeit wurden für drei Infektionskrankheiten, konkret für die Vogelgrippe, die saisonale Influenza und die Erkältung, untersucht. Die Analyse von vier Querschnittsbefragungen über einen Zeitraum von 12 Jahren zeigte, dass die Risikowahrnehmung sowohl akkurat als auch verzerrt war. Während das persönliche Risiko als niedriger verglichen mit dem allgemeinen Risiko wahrgenommen wurde, was auf soziale Ungenauigkeit (d.h. optimistischer Fehlschluss) hinweist, wurde die Rangfolge der Krankheiten in Bezug auf ihr Infektionsrisiko zu allen vier Messzeitpunkten akkurat eingeschätzt (d.h. Genauigkeit auf allgemeiner Problemebene), da das Infektionsrisiko für die Erkältung jeweils am höchsten und für die Vogelgrippe jeweils am niedrigsten eingeschätzt wurde. Darüber hinaus wurden die Saison- und Nebensaisonzeiten von der Risikowahrnehmung für die saisonale

Grippe und die Erkältung akkurat wiedergespiegelt (d. h. Genauigkeit auf der dynamischen Problemebene), wobei die allgemeine Risikowahrnehmung die Veränderungen des Gesundheitsrisikos in höherem Maße widerspiegelte, als die persönliche Risikowahrnehmung. Insgesamt zeigte sich eine akkurate Anpassung der Risikowahrnehmung an Veränderungen des generellen Gesundheitsrisikos.

Die vorliegende Dissertation untersuchte anschließend den Zusammenhang zwischen Gesundheitsrisiken und Schutzverhaltensintentionen. Konkret wurde während der aufkommenden Covid-19-Pandemie in Deutschland untersucht, ob Anstiege des Gesundheitsrisikos mit Anstiegen der Schutzverhaltensintentionen einhergingen. Die Analyse von drei Querschnittserhebungen zeigte, dass mit einem Anstieg des Gesundheitsrisikos (d.h. der Gesamtzahl der bestätigten Covid-19-Fälle) auch die Intentionen, sich sozial zu distanzieren und die persönliche Hygiene zu steigern, zunahm, während die Intention, ärztliche Hilfe in Anspruch zu nehmen, zunächst zunahm, nach der Einführung des Lockdowns in Deutschland jedoch abnahm. Darüber hinaus zeigten sich kleine Zusammenhänge zwischen Alter und Schutzverhaltensintentionen, deren Größe in Abhängigkeit vom Ausmaß des Gesundheitsrisikos variierten. Insbesondere war das Alter während der anfänglichen Phase der Covid-19-Pandemie in Deutschland positiv mit den Intentionen „soziale Distanzierung“ und „persönliche Hygiene“ assoziiert, dieser Effekt verringerte sich jedoch nach der Einführung des Lockdowns. Ein positiver Zusammenhang zwischen Alter und der Intention, einen Arzt aufzusuchen, trat dagegen erst nach der Einführung des Lockdowns auf. Die Menschen änderten demnach ihre Schutzverhaltensintentionen mit zunehmendem Gesundheitsrisiko und das Ausmaß des Gesundheitsrisikos moderierte die geringen Zusammenhänge zwischen Alter und Schutzverhaltensintentionen.

Abschließend wurde das Zusammenspiel von Schutzverhalten und Risikowahrnehmung in Abhängigkeit vom Gesundheitsrisiko untersucht. Während sich die ersten beiden Studien auf Infektionskrankheiten konzentrierten, verlagerte sich der Fokus in der dritten Studie auf nicht-übertragbare Krankheiten. Konkret wurde hier im Zusammenhang mit personalisiertem Feedback zur Gesundheit das Zusammenspiel zwischen selbstberichteter gesunder Ernährung und ernährungsbezogener Risikowahrnehmung untersucht. Diese Untersuchung des Zusammenspiels für zwei Gruppen mit unterschiedlicher Feedback-Valenz ergab eine relative und adaptive Genauigkeit der Risikowahrnehmung in beiden Feedback-Gruppen. Personen mit einem höheren wahrgenommenen Risiko berichteten im Allgemeinen eine ungesündere Ernährung (d.h. relative Genauigkeit) und auf eine Steigerung der selbstberichteten gesunden Ernährung folgte eine geringere Risikowahrnehmung (d.h. adaptive Genauigkeit). Somit trat das gleiche dynamische Zusammenspiel zwischen Schutzverhalten und Risikowahrnehmung für zwei Ausprägungen des Gesundheitsrisikos auf.

Die Ergebnisse der vorliegenden Arbeit unterstreichen, dass Menschen im Allgemeinen auf sich verändernde Gesundheitsrisiken in angemessener Weise reagieren, indem sie ihre Risikowahrnehmung und Schutzverhaltensintentionen entsprechend anpassen. Weiterhin betonen die generellen Anpassungen der Risikowahrnehmung in Folge von Veränderungen im selbstberichteten Schutzverhalten die dynamische Natur der Risikowahrnehmung. Insgesamt bieten die Ergebnisse dieser Dissertation einen ersten Ansatzpunkt für die weitere Erforschung des dynamischen Zusammenspiels zwischen Gesundheitsrisiko, Risikowahrnehmung und Schutzverhalten, um ein umfassenderes Verständnis der Interaktionen zwischen den drei Konstrukten zu gewinnen. Die weitere Untersuchung des Zusammenspiels kann zu einer stärkeren Fokussierung auf die wechselseitigen Beziehungen zwischen

den Konstrukten und deren dynamisches Zusammenspiel im Zeitverlauf beitragen. Dies kann die Entwicklung von Modellen und Theorien in der Gesundheitspsychologie fördern, die die Dynamik und wechselseitige Interaktionen betonen.

# 1

## General Introduction

Life is full of hazards, which differ in their risk and thus in their potential to cause harm. Some of these risks are characterized as stable, while others are more dynamic. Furthermore, it is also possible for new hazards to emerge. People therefore need to be flexible to cope with changes in the risks posed by new and existing hazards, and to modify their behavior accordingly. Since, a person's behavioral response to a hazard is partly determined by their perception of the risk it poses, behavioral change depends to some degree on that perception changing. This reveals a dynamic interplay between risk, the perception of risk, and resultant behavior. The present dissertation aims at exploring this dynamic interplay by examining the reciprocal interrelations between health risk, perceived risk, and protective behavior.

### **Assessment of Health Risks**

There is a general agreement that risks consist of two components, i.e., likelihood and severity (Renner & Schwarzer, 2003). Likelihood assesses the probability of negative outcomes, while severity encompasses how serious these negative outcomes may be. While a hazard's risk is determined by multiplying likelihood and severity (Renner & Schupp, 2011; Slovic, 2000), this formal definition may produce different levels of risk for a single hazard due to varying operationalizations of the two components (Bostrom, 1997). For instance, in the field of health risks, likelihood can be operationalized by the number of cases of a disease with negative outcomes per year and severity can be indicated by either death or the degree of impairment that the disease causes (see also Renner & Schupp, 2011). These two ways of operationalizing severity can generate different risk levels that objectively describe the same situation. This emphasizes the complexity of the assessment of health risks and, since there is no generally applicable measure of the risk to health, shows that the magnitude of health risks varies in accordance with the applied operationalization (Renner & Schupp, 2011; see also Slovic, 2000). The

specific operationalization of risk should therefore be taken into account when interpreting and comparing results.

Expressing the health risk of a disease through, e.g., number of deaths or cases gives insights into the general health risk of a specific disease that applies to the average population. However, for diseases that belong within the domain of noncommunicable diseases (NCDs), a differentiation between general and personal health risk is possible. The majority of deaths worldwide are caused by NCDs, such as cardiovascular diseases (World Health Organization, 2020d), and thus they pose a serious threat to health. NCDs refer to long-lasting diseases and modifiable behavioral risk factors (e.g., unhealthy diet) contribute to their development (World Health Organization, 2018b). Along with the general health risk, personalized health feedback can be generated and provided to the individual. This feedback contains, for instance, information about the person's risk factors (e.g., blood parameter readings) and thus provides estimates of the person's personal health risk for developing an NCD. Hence, the assessment of a health risk may vary for different diseases and targets (general vs. personal).

### **Assessment of Perceived Risk**

In addition to the health risk there is also the perceived risk, and the two do not always coincide. Perceived risk (i.e., risk perception) describes the feelings and thoughts people have in regard to specific risks (Renner, Gamp, Schmäzle, & Schupp, 2015). It encompasses both a cognitive (e.g., logical, deliberate) and an affective component (e.g., fear, worry; Loewenstein, Weber, Hsee, & Welch, 2001; Renner & Reuter, 2012; Slovic & Peters, 2006). The first may be assessed by asking participants to rate their vulnerability to and the severity of a disease, while the latter may be assessed by ratings of threat and worry (Renner & Reuter, 2012). Furthermore, comparably to the health risk, perceived risk also includes a personal and a general

component (Renner et al., 2015; Renner & Schupp, 2011). General risk perception describes the extent to which individuals perceive that people in general are affected by certain risks, whereas personal risk perception encompasses the degree to which individuals perceive themselves to be at risk for certain hazards (Renner & Schupp, 2011). Thus, perceived risk includes cognitive, affective, personal, and general components. However, it should be noted that different conceptions of perceived risk exist (see e.g., ‘the psychometric paradigm’ by Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978). The disagreement on how to assess health risks therefore also applies to perceived risk, as there is still no general agreement on how to assess risk perception (Weinstein et al., 2007; Wilson, Zwickle, & Walpole, 2019).

### **Accuracy of Perceived Risk**

Despite the lack of standardized measures for assessing health risks and perceived risk, the general extent to which perceived risk matches the level a health risk, i.e., the accurate perception of health risks, has important implications for health (Ferrer & Klein, 2015), since biased perceptions may lead to resources being steered in unfavorable directions (Slovic, Fischhoff, & Lichtenstein, 1980, 1985b). The accuracy of perceived risk is therefore crucial, and can be based on different indicators.

**Optimistic bias in perceived risk.** For instance, general and personal risk perception often differ from each other in such a way that people tend to estimate their personal risk as lower than that generally faced by other people, i.e., social (in-)accuracy (Renner & Schwarzer, 2003). This robust finding has been termed “optimistic bias” or “unrealistic optimism” (Perloff & Fetzer, 1986; Weinstein, 1980). The optimistic bias has been demonstrated across a variety of diseases and negative outcomes (for an overview, see e.g., Renner & Schupp, 2011; Shepperd, Klein, Waters, & Weinstein, 2013), and is for instance determined by subtracting the general risk perception from the personal risk perception (i.e., ‘indirect method’, Perloff

& Fetzter, 1986; see Helweg-Larsen & Shepperd, 2001; Weinstein & Klein, 1996 for 'direct' vs. 'indirect method' to determine the optimistic bias). This implies that both personal and general risk perceptions are necessary to determine the magnitude of the optimistic bias, and thus the extent to which risk perceptions are socially accurate.

**Perceiving the general level of health risks.** In contrast, people generally rank the level of risk posed by different hazards accurately (i.e., general problem level accuracy), since they tend to be rather accurate at rating the risks which occur with a higher frequency as being more likely to happen (e.g., Slovic et al., 1980). People's tendency to perceive general risks accurately has also been shown within the context of H1N1 (i.e., 'swine flu'; Ibuka, Chapman, Meyers, Li, & Galvani, 2010). The authors reported that risk perception varied geographically in accordance with the cumulative number of infection cases, and thus the general health risk. Hence, the results provide some evidence for general problem level accuracy in the domain of infectious disease threats (i.e., communicable diseases).

Moreover, general problem level accuracy can also be observed in the domain of NCDs. People generally perceive their personal health risk accurately when they receive personalized health feedback. Since feedback of a negative valence implies that the individual concerned has an increased personal health risk, it poses a threat to the self (e.g., Renner & Schupp, 2011). A broad amount of literature has examined how people receive and respond to health relevant information (overviews: Croyle, Sun, & Hart, 1997; Renner & Schupp, 2011). Most studies have focused on analyzing the reception of feedback of different valence, and multiple studies have demonstrated that people are less likely to accept feedback when that feedback is of negative valence (overviews: Croyle et al., 1997; Renner et al., 2015; Renner & Schupp, 2011). However, some studies have shown that this association is not so straightforward and have demonstrated that other factors such as expectancy also play a critical role in

how readily feedback is accepted (Gamp & Renner, 2016; Renner, 2004). Furthermore, more recent research on the reception of health feedback suggests that people respond rather accurately to negative health feedback. Specifically, participants who were randomly told that they had a higher risk for (fictitious) diseases showed a subsequent increase in perceived risk (French, Sutton, Marteau, & Kinmonth, 2004; Gamp & Renner, 2016). This was replicated for the reception of actual personalized health feedback, after which the participants only reported an increase in the level of perceived risk for the specific elevated risk factor (Gamp, Schupp, & Renner, 2018). While there are instances in which people may not change their risk perception, on average health risk is positively related to perceived risk, with higher health risk leading to higher perceived risk. Hence, people seem to accurately modify their risk perceptions to the health risk.

**Perceiving dynamics in risks.** Since the risk of a hazard is not necessarily stable, the accuracy of perceived risk can also be assessed by investigating dynamics. As many hazards vary in their risk across time, risk perceptions may be accurate once they reflect changes in risk and thus vary accordingly (i.e., dynamic problem level accuracy; Loewenstein & Mather, 1990). A comprehensive study investigating dynamics in general risk and public concern over more than a decade for nine hazards ranging from infectious diseases (e.g., polio and AIDS) to accidents (e.g., crime and drunk driving) showed that, despite the different measures of assessing the various hazards, public concern generally corresponded to the risk across time, albeit to a different extent for the different hazards (Loewenstein & Mather, 1990). These results have two implications: First, the extent to which risk perception coincides with the risk may vary for different hazards. Second, the use of different measures of public concern might imply that different types of risk perception reflect variations in risk to different extents.

In a similar vein, general and personal risk perceptions may reflect dynamics in risk to varying degrees. Therefore, examining changes in these two components in accordance with changes in risk may reveal different patterns for general and personal risk perceptions. Lau, Yang, Tsui, and Kim (2003) assessed both personal and general risk perception (i.e., perceived risk for family members) of contracting severe acute respiratory syndrome (SARS) during an outbreak of this infectious disease in Hong Kong. The results revealed that while an initial increase in infection cases (i.e., general health risk) was not significantly mirrored by an increase in perceived risk, when the general health risk declined, risk perception also declined accurately. This pattern was found both for personal and general risk perception (Lau et al., 2003). A different study on the H1N1 influenza outbreak in China found increases in personal and general risk perceptions (i.e., perceived risk for immediate family members) from before the outbreak, to the emergence, and the peak of the outbreak (Xu & Peng, 2015). Thus, increases in the number of cases were accurately mirrored by risk perception. It should be noted that general risk perception during the H1N1 outbreak was equally high as personal risk perception, which is presumably a result of the fact that family members were chosen as the comparison target (i.e., specific people that the respondents knew). This is in line with the notion that the optimistic bias increases as the comparison target becomes less familiar (Perloff & Fetzer, 1986). This implies that the use of an unfamiliar comparison target, e.g., an average person of the same sex and age, may have produced different results. Specifically, different patterns of change for personal and general risk perception may have emerged when using an unfamiliar comparison target, and thus one may have mirrored the changes in the general health risk more accurately than the other.

## From Risk Perception to Protective Behaviors

The primary importance of perceiving health risks accurately is to enable people to act in accordance with the health risk and thus initiate effective protective behaviors (Hahn & Renner, 1998). There are many health behavior models that strive to predict and explain the formation of intentions and ultimately behavior change from a theoretical perspective (for an overview see e.g., Armitage & Conner, 2000). Many of these models include risk perception as an important motivator for health behavior change (Renner & Schwarzer, 2003; van der Pligt, 1998; see also 'behavior motivation hypothesis' by Brewer, Weinstein, Cuite, & Herrington, 2004), as people presumably adopt protective behaviors to reduce their personal health risk (Weinstein, Rothman, & Nicolich, 1998). A meta-analysis of experimental studies, which examined risk perception as a predictor for intention and behavior found evidence for the causal role of risk perception (Sheeran, Harris, & Epton, 2014). Specifically, when interventions succeeded in increasing risk perceptions, intentions and behavior also increased by small but reliable degrees ( $d_+ = .31$  and  $d_+ = .23$ , respectively; Sheeran et al., 2014). Similar effect sizes were obtained by a meta-analysis of risk perception and vaccination behavior (Brewer et al., 2007), leading to the conclusion that risk perception significantly predicted vaccination behavior. These reliable effects illustrate the importance of risk perception for the formation of behavioral intentions and the performance of protective behaviors.

**Protective behaviors during infectious disease threats.** Investigating when protective behaviors are performed is especially critical during infectious disease threats, as these demand high adoption rates of protective behavior. During the emergence of an infectious disease threat (epidemic or pandemic), implementing protective behaviors on a large scale is often the only way to contain the further spread of the disease (Brug, Aro, & Richardus, 2009). A previous review of the effectiveness

of protective behaviors at containing the spread of respiratory viruses found evidence that behaviors such as handwashing, wearing a mask, and isolating individuals that may be infected were effective in containing the spread of the viruses (Jefferson et al., 2008).

While some studies have investigated the adoption of protective behavior during infectious disease threats in relation to risk perception, their findings were mixed. For instance, a study on the H1N1 outbreak in the United States in 2009 found that while risk perception increased as the epidemic emerged, interest in performing protective behaviors, specifically preventive pharmaceutical interventions (e.g., vaccination intentions) and information seeking decreased (Ibuka et al., 2010). In contrast, a study on avian influenza found that protective behaviors were associated with risk perception (de Zwart, Veldhuijzen, Richardus, & Brug, 2010). However, analyses across time were not possible as risk perception remained low, so the required variance in perceived risk across time was lacking. Likewise, a study that was conducted during the escalating phase of a SARS outbreak in Hong Kong found associations between risk perception and protective behaviors (Lau et al., 2003). The general health risk (i.e., number of cases) increased and decreased over time. The increase was closely mirrored by protective behaviors, whereas the decline was mirrored by risk perception. Thus, while some studies revealed first evidence for an existing association between risk perception and protective behaviors for infectious disease threats, a consistent pattern did not emerge.

**Risk perception and protective behaviors during Covid-19.** The worldwide emergence of the current Covid-19 pandemic, which is caused by the spread of the new coronavirus SARS-CoV-2 (World Health Organization, 2020a), also emphasizes the high importance of performing protective behaviors. Until enough vaccines are available to the general public, the current pandemic can only be contained by

protective behaviors and physical distancing measures (Anderson, Heesterbeek, Klinkenberg, & Hollingsworth, 2020; van Bavel et al., 2020).

First results on protective behaviors during the early stages of the Covid-19 pandemic (from March 11<sup>th</sup> onwards) were obtained in the United States (Wise, Zbozinek, Michelini, Hagan, & Mobbs, 2020), where risk perception (i.e., the perceived likelihood of becoming infected) was positively associated with self-reported hand washing ( $\beta = .17, p < .001$ ) and social distancing ( $\beta = .20, p < .001$ ), thus people who perceived a higher risk of infection reported more protective behaviors. Furthermore, increases in risk perception and protective behaviors were even observed within the short time frame of five days amongst participants who took the survey twice (Wise et al., 2020). Less clear results were obtained in Norway during a 15-day assessment period beginning on March 12<sup>th</sup> in the initial phase of Covid-19 (Zickfeld, Schubert, Herting, Grahe, & Faasse, 2020). Physical distancing increased across time but hygiene behaviors remained stable, although it should be noted that high frequencies of hygiene behaviors were already reported at the start of data collection. Furthermore, the trend for risk perception was also ambiguous, as different patterns were identified for perceived likelihood, severity, and worry. Specifically, while perceived likelihood increased in the beginning of the assessment period, perceived severity and worry decreased. Subsequently, perceived likelihood decreased slightly, whereas severity and worry increased slightly (Zickfeld et al., 2020). Overall, since Covid-19 represents the largest respiratory virus threat to public health since the Spanish flu in 1918 (Ferguson et al., 2020), further research on health risk, perceived risk, and protective behaviors is needed to shed light on the associations between them for such large-scale infectious disease threats. Furthermore, the large fluctuations in the health risk posed (e.g., active cases) by the Covid-19 pandemic over a prolonged period of time enables a comprehensive examination of the dynamic interplay between health risk,

risk perception, and adoption rates of protective behaviors across time (Dong, Du, & Gardner, 2020).

### **The Importance of Personal Risk Perception for Adopting Protective Behaviors**

The current Covid-19 pandemic has seen large-scale public health campaigns to promote behavior change and increase the adoption rates of protective behaviors (World Health Organization, n.d.-a). Overall, while risk perception is an important predictor for protective behaviors (Sheeran et al., 2014), it may be advisable to distinguish between personal and general risk perception. Even in the face of an increasing general health risk (e.g., rising numbers of active cases during an infectious disease threat), perceiving the general risk of a hazard as high is usually not sufficiently motivating to initiate protective behaviors, and personal risk perception may be more likely to work as a motivator for behavior change (Renner et al., 2015; Renner & Schupp, 2011). In the case of the current Covid-19 pandemic, someone who is generally aware that many people will become infected with SARS-CoV-2 (i.e., general risk perception) but who perceives it as unlikely that he or she will become infected (i.e., personal risk perception) will presumably have a low likelihood of engaging in protective behaviors as their perceived personal risk is low. This underlines the notion that increasing personal and general risk perceptions will have different implications for adopting protective behaviors.

These associations apply to NCDs as well as infectious disease threats. In the domain of NCDs, it is possible to estimate any specific individual's personal health risk of developing a certain disease (e.g., cardiovascular disease), and to provide that person with personalized health feedback. Previous research which investigated the effects of personalized negative feedback on intentions has shown that negative feedback leads to higher subsequent risk perceptions and increased behavior change intentions than positive feedback (e.g., Kreuter & Strecher, 1996; Panzer & Renner,

2008; Renner, 2004). Addressing the nuanced interrelations between risk perception and protective behaviors suggests a dynamic interplay between these.

### **Interplay Between Health Risk, Perceived Risk, and Protective Behaviors**

Interrelations between risk perception and protective behavior appear complex (Gerrard, Gibbons, Benthin, & Hessling, 1996; Weinstein & Nicolich, 1993). Since people presumably adopt protective behaviors to reduce their personal health risk (Brewer et al., 2004; Gerrard, Gibbons, & Bushman, 1996; Weinstein et al., 1998), initiating this behavior should result in a subsequent decrease in personal risk perception (Brewer et al., 2004; Renner, Schüz, & Sniehotta, 2008). This has been called 'adaptive accuracy' of perceived risk (Renner et al., 2008; see also 'risk reappraisal' by Brewer et al., 2004).

Investigating adaptive accuracy requires longitudinal data, since adaptive accuracy describes changes that occur within individuals (Brewer et al., 2004; Hay et al., 2007; Renner et al., 2008). Early approaches towards investigating the relationship between risk perception and protective behaviors frequently used correlational data to predict behavior from risk perception, but this led to distorted conclusions being drawn (Weinstein & Nicolich, 1993). Specifically, cross-sectional data can only examine the level of relative accuracy of perceived risk, i.e., higher performance of risk behavior is associated with higher risk perception (Weinstein et al., 1998). This implies a negative relationship between risk perception and protective behavior (Renner et al., 2008; see also 'accuracy hypothesis' by Brewer et al., 2004). However, cross-sectional data cannot give insights into adaptive accuracy. Examining adaptive and relative accuracy emphasizes the dynamic interrelationship between risk perception and protective behavior.

The dynamic interplay between health risk, risk perception, and protective behavior is further extended by the notion that increasing appropriate protective

behavior is most likely to result in a subsequent decrease in personal health risk. For instance, adopting protective behaviors aimed at containing the spread of the Covid-19 pandemic protects oneself and close others from an infection, which reduces the personal risk of infection (World Health Organization, 2021) independently from the general risk which may continuously increase due to rising numbers of active cases.

To summarize, examining the literature shows that different steps are relevant for humans to be able to respond to changing health risks. Firstly, perceiving health risks accurately is crucial for reacting to risks in an appropriate way. However, there are different indicators of accuracy of perceived risk. In particular, risk perceptions can be both accurate and biased at the same time (Ferrer & Klein, 2015), as both general and dynamic problem level accuracy and social inaccuracy may be observed. Secondly, dynamic problem level accuracy seems particularly important when reacting towards changing health risks. Previous research has shown that people generally modify their risk perception to match changes in risk. However, so far it remains unclear whether personal and general risk perceptions correspond to changes in health risks to the same extent. Thirdly, personal risk perception is particularly relevant for adopting protective behaviors. Fourthly, initiating protective behaviors should lead to a reduction in subsequent personal risk perception and personal health risk. Thus, a dynamic interplay between health risk, risk perception, and protective behavior can be assumed.

### **Outline and Research Aims of the Present Dissertation**

The overall aim of the present dissertation is to gain a deeper understanding of how humans respond to changing health risks by examining the interplay between health risk, perceived risk, and protective behavior (intentions). Aspects of which are tested by the empirical research of this dissertation. The first aim of the present dissertation is, through two studies, to investigate the extent to which humans respond

to changes in health risk, especially the dynamics of risk perception and protective behavior intentions in relation to changes in health risk. Thus, Chapter 2 analyzes whether health risks are accurately reflected by perceived risks (personal and general), while Chapter 3 examines whether increases in health risk are accompanied by increases in protective behavior intentions. The second aim of this dissertation is to examine the interplay between protective behavior and risk perception in dependence of the level of health risk. Hence, Chapter 4 investigates the reciprocal interrelations between protective behavior and risk perception for two degrees of health risk.

In detail, Chapter 2 of the present dissertation focuses on the associations between general health risks and both general and personal risk perceptions by examining three indicators of accuracy (i.e., social accuracy, general problem level accuracy, and dynamic problem level accuracy) for three infectious diseases (i.e., avian influenza, seasonal influenza, and the common cold). Personal and general risk perceptions are investigated separately, which enables the examination of whether personal or general risk perceptions are more modified to fit changes in health risks.

Chapter 3 of the current dissertation examines whether increases in health risk are being accompanied by increases in protective behavior intentions during the current Covid-19 pandemic. Specifically, rates of behavioral intentions (i.e., increasing personal hygiene, adopting social distancing, and seeking medical care) when experiencing cold-like symptoms are compared for three assessment periods that, based on total confirmed SARS-CoV-2 cases in Germany, differ strongly in their general health risk. Furthermore, this chapter investigates whether age is associated with the intentions for protective behaviors. Since older people are particularly vulnerable to severe outcomes of Covid-19 (Oke & Heneghan, 2020), they may perceive an increased personal risk and may therefore report increased intentions for protective behaviors compared to younger individuals. Chapter 3 examines whether

this association can be found to the same extent for different levels of health risks as the pandemic emerged.

While research in Chapters 2 and 3 reports data on infectious disease threats, Chapter 4 looks more closely at NCDs as an additional field of application. Investigating NCDs permits the examination of interrelations in the context of providing personalized health feedback, which displays the estimated personal health risk. Research in the field of health feedback has so far focused on the reception of feedback and its implications for risk perception and behavior, while comparably neglecting the interplay between them. Thus, Chapter 4 examines this interplay between risk perception and behavior in the context of providing health feedback. In particular, the relative and adaptive accuracy of perceived risk are examined for two groups of people with different personal health risks using the example of self-reported healthy eating. Hence, the study explicitly explores the interplay between health risk, perceived risk, and self-reported protective behavior.

Finally, Chapter 5 discusses and integrates the findings on the dynamics of risk perception and protective behavior (intentions) related to changing health risks. Theoretical and practical implications are discussed.

# 2

## Health Risk and Risk Perception

Dynamic risk perceptions in times of avian and  
seasonal influenza epidemics: A repeated  
cross-sectional design

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### Abstract

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. non-epidemic/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 non-epidemic/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 to 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.

*Keywords:* Risk perception; infectious diseases; optimistic bias; dynamic; accuracy

## Introduction

The year 2018 marked the 100<sup>th</sup> 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 manuscript, the coronavirus (SARS-CoV-2 and the associated disease COVID-19) outbreak revealed the vulnerability 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, n.d.-d), with 5% to 10% of the world’s adults infected annually (World Health Organization, n.d.-e), and up to 10 million infections in Germany every year (Robert Koch Institute, 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 (World Health Organization, n.d.-c). 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 (World Health Organization, n.d.-c). Highly pathogenic avian influenza (HPAIV) also emerged in Germany (HPAIV/H5N1; Arbeitsgemeinschaft Influenza, 2012) in 2006, when the present study

was launched, and reemerged ten years later in 2016/17 (subtypes *HPAN/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 et al., 2019). A prominent approach in research on risk perception is the psychometric paradigm (e.g., Slovic, Fischhoff, & Lichtenstein, 1985a; 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 to 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 et al., 1980; Slovic, 2000; 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 et al. (2010) corroborated these findings with respect to infections related to influenza viruses, showing that participants felt more vulnerable towards 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 et al., 2015; Renner & Schupp, 2011). 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 et al., 2009; Renner & Reuter, 2012; Rubin, Potts, & Michie, 2010; World Health Organization, 2018a). Numerous studies have shown that personal risk perception is an essential motivational trigger for preventive behavior change (Gaube, Lerner, & 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  $r = .16$  for perceived severity to  $r = .26$  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 et al., 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 et al., 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 et al., 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 et al., 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.

### **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. non-epidemic/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; Robert Koch Institute, 2019, 2020b). 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.

## **Method**

### **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 (Robert Koch Institute, 2019), and the common cold, which is most prevalent during autumn and winter (Robert Koch Institute, 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 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 to 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 2.1 shows, participants across the four waves differed significantly in terms of age  $F(3, 1964) = 65.21, p < .001, \eta^2 = .09$ , gender  $\chi^2(3) = 11.68, p = .009, V = .08$ , and education  $\chi^2(3) = 53.28, p < .001, V = .17$ . Post-hoc tests (Bonferroni) indicated that participants in the 2009 wave were significantly older than the other three samples, all  $p$ 's  $\leq .010$ , and the participants from the 2016 wave were significantly younger than the remaining samples, all  $p$ 's  $< .001$ . 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  $\leq .05$ . Education levels were significantly higher in 2006 and 2016, compared to 2009 and 2018, all  $p$ 's  $\leq .05$ .

The study sample was significantly older than the drop-out sample ( $M_{study} = 33.86, SD = 12.37$  vs.  $M_{drop-out} = 29.41, SD = 11.52$ ),  $t(1353.73) = 8.67, p < .001, d = .37$  and differed in gender distribution  $\chi^2(1) = 4.95, p = .026, V = .04$ , with 56.5% females in the drop-out sample and 63.2% in the study sample. Education levels were equally high in both samples,  $\chi^2(1) = 0.20, p = .651$ . On average, participants in the study sample perceived their personal risk for seasonal influenza as significantly lower compared to the drop-out sample ( $M_{study} = 3.18, SD = 1.43$  vs.  $M_{drop-out} = 3.69, SD = 1.55$ ),  $t(2037) = -2.90, p = .004, d = .34$ . However, the study and drop-out sample did not differ significantly regarding the other five risk perception variables,  $t(218.39) \leq | -1.52 |$ , all  $p$ 's  $\geq .130$ .

Table 2.1

*Participants' Characteristics (N = 1,971)*

Measure	Wave 2006 ( <i>n</i> = 387)	Wave 2009 ( <i>n</i> = 792)	Wave 2016 ( <i>n</i> = 370)	Wave 2018 ( <i>n</i> = 422)	Statistics
Gender <i>n</i> (%)					$\chi^2(3) = 11.68,$ $p = .009,$ $V = .08$
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 <i>M</i> ( <i>SD</i> )	34.8 (11.9)	37.2 (13.6)	26.9 (10.3)	32.9 (9.2)	$F(3, 1964) =$ $65.21, p <$ $.001, \eta^2 = .09$
Education level <i>n</i> (%)					$\chi^2(3) = 53.28,$ $p < .001,$ $V = .17$
Full-time training finished $\leq$ 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.

**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).

**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).

**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.

### **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

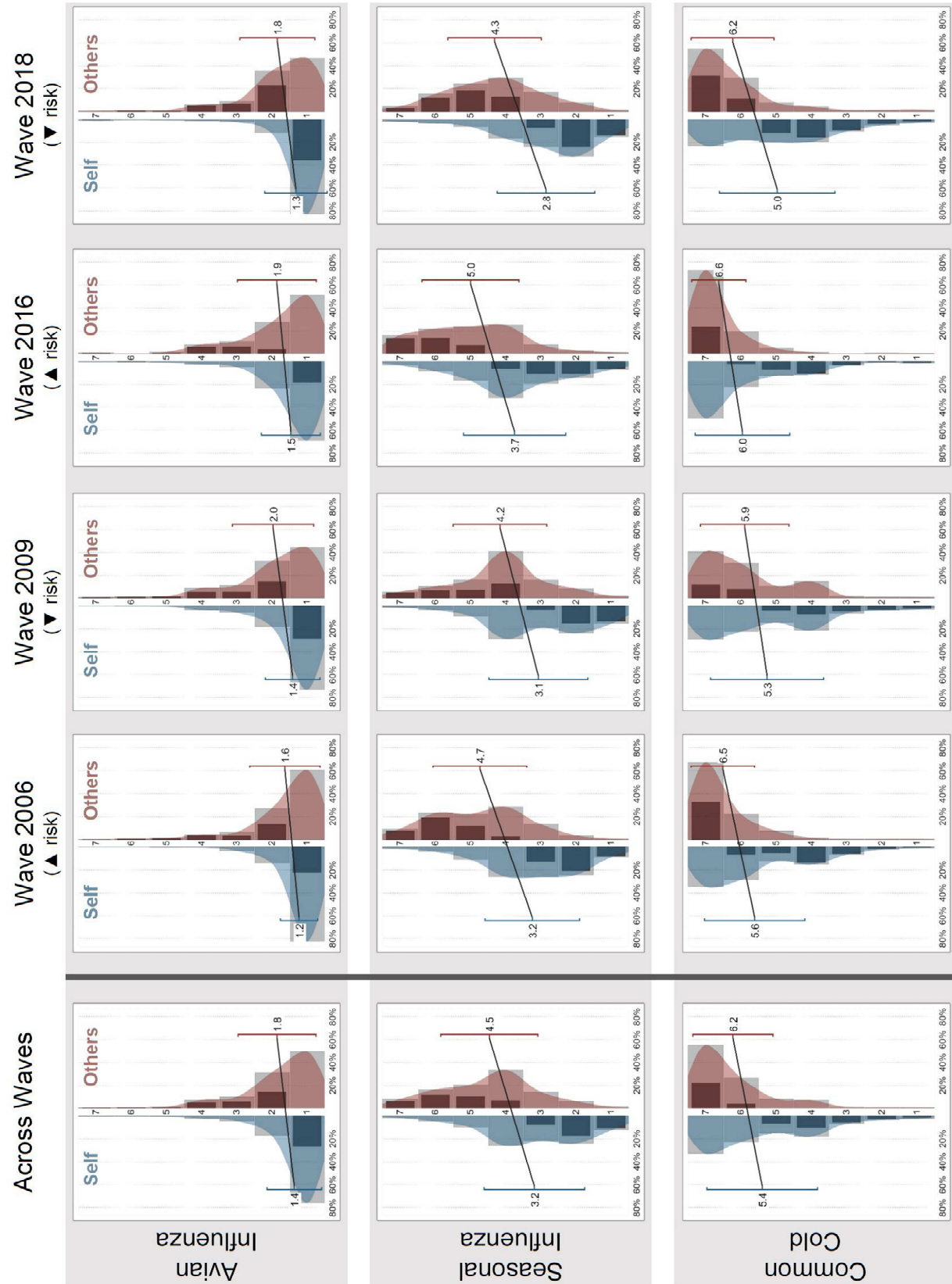
Blumenschein et al., 2020 for a detailed description). Figure 1 depicts 15 v-plots which show the similarities and differences between multiple distribution properties. Each v-plot displays a histogram in light gray which shows the relative frequency of each response category for the respective variable. 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 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>.

## Results

The v-plots in Figure 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 2.2). 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, 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 to the right side and, (ii) by the different smoothed density distributions as the blue compared to 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 to their peers.



*Figure 2.1.* Risk perception for three infectious diseases (avian influenza, seasonal influenza, and the common cold) at four waves split for self and others. Notes: 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” = non-epidemic/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.

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 to 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) × 3 “disease” (avian influenza vs. seasonal influenza vs. common cold) × 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.

Table 2.2

*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]	
<b>Self</b>								
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]	
<b>Others</b>								
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.

### **Social Accuracy: Perceived Personal vs. Others' Risk**

The 2 x 3 x 4 ANOVA yielded a significant main effect for the factor "target",  $F(1, 1967) = 1696.23$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , 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 Figure 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 x disease” interaction effect emerged,  $F(2, 3934) = 249.14, p < .001, \eta_p^2 = .11$ , indicating differences in the extent of the optimistic bias relating to the disease. As Figure 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,  $F(1, 1967) = 1486.92, 668.71, 405.26$ , respectively, all  $p$ 's  $< .001$ .

### **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”,  $F(2, 3934) = 9766.21, p < .001, \eta_p^2 = .83$ , indicating pronounced differences in risk perception for the three different infectious diseases (see also Figure 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. Figure 1 furthermore depicts that risk perceptions for seasonal influenza and the common cold varied more than for avian influenza.

### **Dynamic Problem Level Accuracy: Dynamic Response of Risk Perceptions to Epidemics/Seasons vs. Non-Epidemic/off-Season Times**

Furthermore, the  $2 \times 3 \times 4$  ANOVA yielded a significant main effect for “wave”,  $F(3, 1967) = 46.06, p < .001, \eta_p^2 = .07$ , and a significant “wave x disease” interaction effect,  $F(6, 3934) = 30.25, p < .001, \eta_p^2 = .04$ , 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 x 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,  $F(3, 1967) = 9.53, p < .001, \eta_p^2 = .01$ , seasonal influenza  $F(3, 1967) = 44.65, p < .001, \eta_p^2 = .06$ , and the common cold,  $F(3, 1967) = 45.42, p < .001, \eta_p^2 = .06$ .

For avian influenza, the participants showed a lower risk perception in 2006 ( $M = 1.42, SD = 0.66$ ) compared to the other three measurement points (all  $M$ 's  $\geq 1.57$ , all  $SD$ 's  $\geq 0.83$ ), all  $p$ 's  $\leq .050$ . No other significant differences between waves were observed, all  $p$ 's  $\geq .158$ . 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 to 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  $< .001$ . Moreover, seasonal influenza risk perceptions 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 to 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  $\leq .001$ . 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.

### **Differential Effects in Dynamic Accuracy: Perceived Personal vs. Others' Risk Across Waves**

The  $2 \times 3 \times 4$  ANOVA yielded a significant two-way interaction effect for “wave x target”,  $F(3, 1967) = 13.52, p < .001, \eta_p^2 = .02$ , and a significant three-way interaction for “wave x disease x target”,  $F(6, 3934) = 11.40, p < .001, \eta_p^2 = .02$ , 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 x disease x 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 x target” interaction, with  $F(3, 1967)$  for avian influenza = 3.40,  $p = .017, \eta_p^2 = .01$ , seasonal influenza = 9.34,  $p < .001, \eta_p^2 = .01$ , and common cold = 20.07,  $p < .001, \eta_p^2 = .03$ . Thus, the degree of optimistic bias or social accuracy varied across waves within diseases.

The three-way interaction was also analyzed by calculating “wave x 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 x disease” interaction,  $F(6, 3934) = 17.44, p < .001, \eta_p^2 = .03$ , and  $F(6, 3934) = 32.99, p < .001, \eta_p^2 = .05$ , 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.

**Personal risk perception.** Within personal risk perception, the main effect for “wave” reached statistical significance for avian influenza, seasonal influenza, and the common cold,  $F(3, 1967) = 7.38, 29.82, \text{ and } 32.19, \eta^2 = .01, .04, \text{ and } .05$ , respectively,

all  $p$ 's < .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 to 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  $\geq$  .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 < .001, except for risk perceptions in 2006 and 2009, which did not differ significantly,  $p = .277$ . 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 ( $M = 5.95$ ,  $SD = 1.35$ ) vs. 2009 ( $M = 5.25$ ,  $SD = 1.61$ ) and 2018 ( $M = 4.96$ ,  $SD = 1.64$ ), all  $p$ 's  $\leq$  .001.

**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:  $F(3, 1967) = 8.11, 40.01, 49.91$ ;  $\eta^2 = .01, .06, .07$ , respectively, all  $p$ 's < .001). Post-hoc tests revealed a lower others' risk perception for avian influenza in 2006 ( $M = 1.62$ ,  $SD = 1.0$ ) compared to 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  $\leq$  .036. No other effects were significant, all  $p$ 's  $\geq$  .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 ( $M = 4.99$ ,  $SD = 1.38$ ) vs. 2009 ( $M = 4.16$ ,  $SD = 1.33$ ) and 2018 ( $M = 4.31$ ,  $SD = 1.33$ ), all  $p$ 's < .001. Others' risk perceptions for common cold in 2006 ( $M = 6.51$ ,  $SD = 0.90$ ) and 2016 ( $M = 6.62$ ,  $SD = 0.77$ ) vs. 2009 ( $M = 5.89$ ,  $SD = 1.26$ ) and 2018 ( $M = 6.23$ ,  $SD = 1.18$ ), all  $p$ 's  $\leq$  .002.

## 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 vs. non-epidemic/off-season times.

### **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 (Robert Koch Institute, 2019). In contrast, there have never been any human avian influenza infections in Germany (Robert Koch Institute, 2020b). As shown in Figure 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 vs. non-epidemic/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 to 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 to 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).

### **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 Figure 1 show that while risk perceptions for avian influenza and the common cold were skewed towards 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 to 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).

### **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; World Health Organization, 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.

### **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 to 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 which 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 non-selective 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.

## 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 problem 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.

## **Declarations**

### **Competing interests**

The authors declare that they have no competing interests.

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# 3

## Health Risk and Protective Behavior Intentions

The relation of threat level and age with protective  
behavior intentions during Covid-19 in Germany

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### Abstract

To contain the spread of Covid-19, engagement in protective behaviors across the population is of great importance. The present study investigated protective behavior intentions during the early phases of Covid-19 in Germany (February 2 – April 3, 2020) as a function of threat level and age using data from 4,940 participants in the EUCLID project. Results indicated that the intention to engage in social distancing increased sharply with threat level. Intentions for personal hygiene also increased, although to a lesser extent. While age only had a small overall effect on behavioral intentions, differential patterns emerged. After the lockdown was introduced, the impact of age decreased for social distancing and hygiene behavior intentions but increased for seeing a doctor. Since containing the Covid-19 pandemic depends on high adoption rates of protective behaviors, future research should track sustained phases of the pandemic, including the easing of restrictions and possible new waves of infections.

*Keywords:* Health behavior; infectious disease; emergency, risk and crisis communication

## Introduction

Since the outbreak of Covid-19 in December 2019, the coronavirus has spread rapidly around the globe, appearing in Europe by the end of January 2020 and reaching the level of a global pandemic at the beginning of March (World Health Organization, 2020b). In the absence of an effective medical treatment or vaccine, massive global public health campaigns have been launched to contain the spread of the coronavirus by promoting social and behavioral strategies to increase protective behaviors in the population (Lunn et al., 2020; World Health Organization, n.d.-a, 2021).

Studies of previous infectious disease epidemics suggest that the adoption of protective behaviors varies with the objective threat level of the epidemiological situation, e.g., the temporal dynamics of infection rates (Ibuka et al., 2010; Lau et al., 2003). Early data during the emergence of Covid-19 in the United States provided initial evidence for increases in adoption of protective behaviors such as washing hands, social distancing, and staying at home (Wise et al., 2020).

Since the effectiveness of social and behavioral strategies relies on high adoption rates of protective behaviors across the entire population (van Bavel et al., 2020), it is important to identify variables that affect engagement in protective behaviors. Covid-19 is associated with higher mortality rates and health risks for elderly people (Oke & Heneghan, 2020), so the question arises as to whether they are more likely to adopt protective behaviors. While first evidence from the United States suggests that they were slightly more engaged in taking protective measures during the emergence of Covid-19 (Li, Feng, Liao, & Pan, 2020), a previous review of infectious disease pandemics reported mixed findings for age on the adoption of protective behaviors (Bish & Michie, 2010).

The present research therefore aimed to assess the dynamics of engagement in protective behaviors as a function of objective threat levels, with a particular focus

on age as a potential moderator. Specifically, using last winter as reference, we assessed the intentions to adopt protective behaviors regarding personal hygiene, social distancing, and seeking medical care (doctor and hospital visits) when experiencing cold symptoms. Data were assessed in a cross-sectional design, covering the emergence of Covid-19 in Germany from the initial stage of the outbreak to after the imposition of the first lockdown. We hypothesized that increasing threat levels would be associated with increased protective behavior intentions, particularly for older adults.

### Method

Data were collected in Germany between February 2 and April 3, 2020 as part of the “EUCLID” project (<https://euclid.dbvis.de>) via online surveys using google forms and the software Qualtrics. The University ethics committee approved the study in March 2020 (ID number 07/2020) and it adhered to the declaration of Helsinki. All participants gave informed consent prior to participation.

Participants were recruited via advertising in social media (Facebook, Twitter), Prolific Academic, and email lists using a snowball system. As compensation, participants could take part in a raffle (25€ Amazon vouchers) or received financial reimbursement from Prolific Academic. In total, 5,443 participants were recruited. Of these,  $n = 503$  were excluded due to missing data on core variables or failed attention checks. The final study sample comprised  $N = 4,940$  participants (75.2% women) with a mean age of 33.33 years ( $SD = 13.20$ ; 18-90 years). Overall, 44.1% of the sample indicated being employed or self-employed, while 46.1% were in training or education. The sample included participants from all federal states with the majority from Baden-Wuerttemberg (36.1%), North Rhine-Westphalia (17.1%), and Bavaria (12.0%).

Intentions to engage in protective behavior were assessed by asking ‘if you have common cold symptoms during this coronavirus crisis, is it more or less likely that you

would behave in the following ways, compared to last winter?'. Participants rated the likelihood of (1) avoiding contact with other people more strongly, (2) paying more attention to their personal hygiene (e.g., frequent hand washing), (3) seeing a doctor, and (4) going straight to the hospital on a five-point Likert scale from (1) "very unlikely" to (5) "very likely".

Dynamics in protective behavior intentions were examined across three time periods, reflecting critical events related to Covid-19 in Germany and an increasing threat level. T1 (February 2 – March 7, 2020;  $n = 1,144$ ) represents the early emergence of SARS-CoV-2 with 795 confirmed cases in Germany. T2 (March 8 – March 21, 2020;  $n = 1,448$ ) is marked by the first Covid-19 deaths and an accelerating number of confirmed SARS-CoV-2 cases (16,662 confirmed cases in Germany). T3 (March 22 – April 3, 2020;  $n = 2,348$ ) started with the introduction of a lockdown and a further accelerating number of confirmed SARS-CoV-2 cases (79,696 confirmed cases in Germany).

A 3 x 4 mixed ANOVA was conducted, containing factors of Time (T1, T2, and T3) reflecting an increase in the objective Covid-19 threat level, and Protective Behavior (social distancing, personal hygiene, seeing a doctor, going to the hospital). Follow-up post-hoc analyses used Bonferroni corrections. Age effects on behavioral intentions were assessed by linear regressions, using bootstrapping with 1000 iterations and bias-corrected 95% confidence intervals to test for significance. Data was analyzed using IBM SPSS Statistics (Version 27).

## Results

Intentions varied between protective behaviors,  $F(3, 14655) = 8021.74$ ,  $p < .001$ ,  $\eta_p^2 = .62$ . Participants reported being most likely to engage in personal hygiene ( $M = 4.29$ ,  $SD = 0.97$ ) and social distancing behaviors ( $M = 4.00$ ,  $SD = 1.17$ ,  $p < .001$ ), followed by seeing a doctor ( $M = 2.91$ ,  $SD = 1.25$ ,  $p < .001$ ) and going straight to the

hospital ( $M = 1.69$ ,  $SD = 0.93$ ,  $p < .001$ ) when showing symptoms of a common cold (see Fig. 3.1). Furthermore, intentions for protective behaviors varied with threat level, i.e., Time,  $F(2, 4885) = 374.50$ ,  $p < .001$ ,  $\eta_p^2 = .13$ , which was further qualified by the interaction of protective behavior and time,  $F(6, 14655) = 303.46$ ,  $p < .001$ ,  $\eta_p^2 = .11$ . Follow-up analyses were therefore conducted for each of the protective behavior intentions.

As shown in Figure 3.1, the intention to engage in social distancing continuously increased with rising threat levels from T1 ( $M = 2.80$ ,  $SD = 1.24$ ) through T2 ( $M = 4.21$ ,  $SD = 0.96$ ,  $p < .001$ ) to after the imposition of the lockdown (T3:  $M = 4.45$ ,  $SD = 0.80$ ,  $p < .001$ ),  $F(2, 4927) = 1180.09$ ,  $p < .001$ ,  $\eta^2 = .32$ . Similarly, the intention for personal hygiene continuously increased from the very early emergence of Covid-19 (T1:  $M = 3.73$ ,  $SD = 1.21$ ), after the first deaths (T2:  $M = 4.37$ ,  $SD = 0.88$ ,  $p < .001$ ), to the imposition of the lockdown (T3:  $M = 4.51$ ,  $SD = 0.75$ ,  $p < .001$ ),  $F(2, 4914) = 282.89$ ,  $p < .001$ ,  $\eta^2 = .10$ .

A different pattern was seen for medical care seeking behaviors. Specifically, intentions to see a doctor increased from the early emergence (T1:  $M = 2.71$ ,  $SD = 1.20$ ) to after the first deaths (T2:  $M = 3.05$ ,  $SD = 1.25$ ,  $p < .001$ ) but decreased after the lockdown (T3:  $M = 2.93$ ,  $SD = 1.25$ ,  $p = .013$ ),  $F(2, 4930) = 24.44$ ,  $p < .001$ ,  $\eta^2 = .01$ . Similarly, while intentions for hospital visits increased from T1 ( $M = 1.61$ ,  $SD = 0.88$ ) to T2 ( $M = 1.90$ ,  $SD = 1.05$ ,  $p < .001$ ), it decreased from T2 to T3 ( $M = 1.61$ ,  $SD = 0.84$ ,  $p < .001$ ),  $F(2, 4921) = 52.24$ ,  $p < .001$ ,  $\eta^2 = .02$ , returning to the initial T1 level ( $p = 1.00$ ).

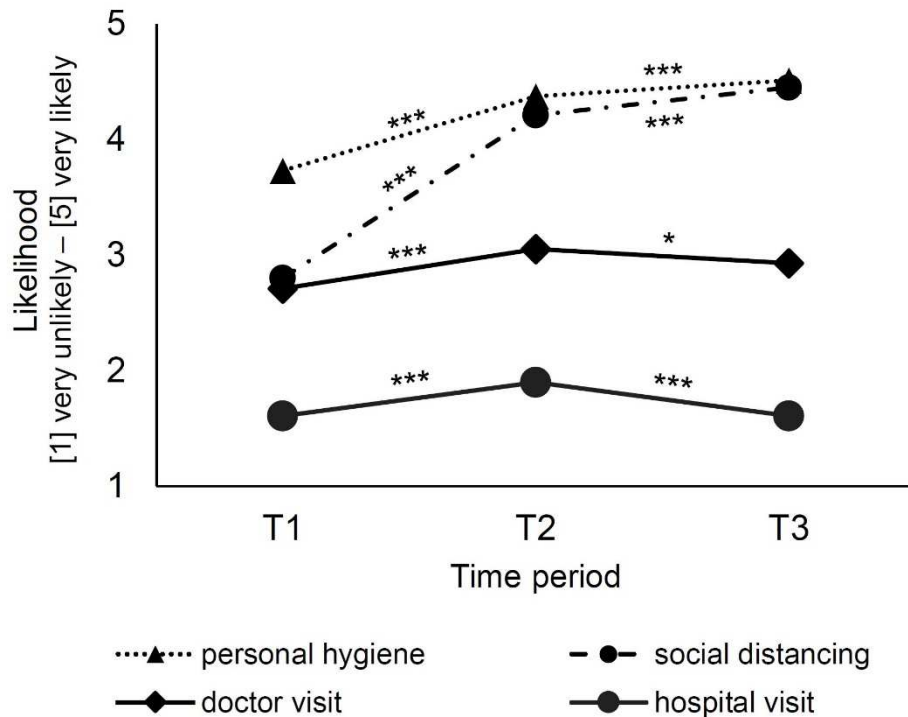
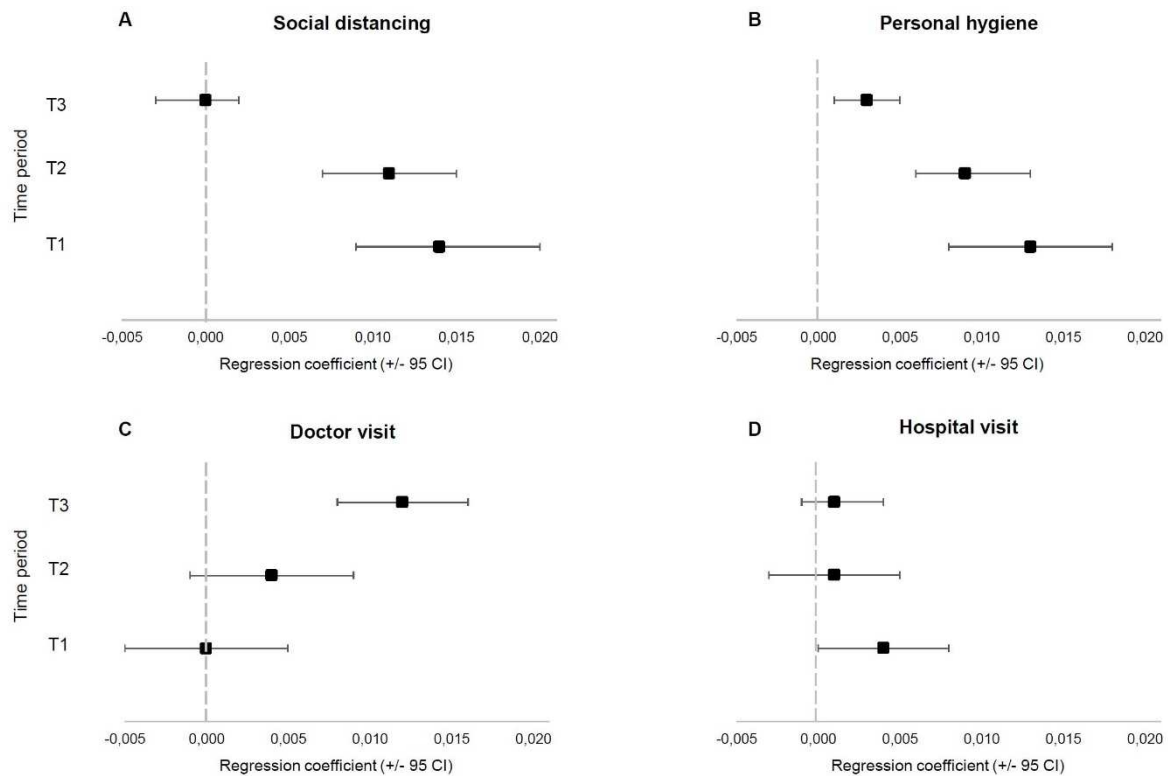


Figure 3.1. The likelihood of engaging in protective behaviors across the three time periods.

Overall, analyses revealed a small effect of age on intentions for protective behaviors. As shown in Figure 3.2A and B, the positive relationship of age and intentions for social distancing and personal hygiene decreased across time, indicating that age effects diminished with increasing Covid-19 threat (social distancing: T1  $F(1, 1139) = 28.00, p < .001, R^2 = .02, b = .014$ ; T2  $F(1, 1442) = 36.18, p < .001, R^2 = .02, b = .011$ ; personal hygiene: T1  $F(1, 1139) = 22.86, p < .001, R^2 = .02, b = .013$ ; T2  $F(1, 1440) = 30.30, p < .001, R^2 = .02, b = .009$ ). However, while a significant but small association of age remained for personal hygiene after the imposition of the lockdown (T3:  $F(1, 2332) = 6.43, p = .011, R^2 = .003, b = .003$ ), no age effect was revealed for social distancing (T3:  $F(1, 2343) = 0.01, p = .943$ ).

A different association emerged for age with medical care seeking behavior (see Fig. 3.2C and D). Specifically, while the intention to see a doctor was not significantly

associated with age at T1,  $F(1, 1140) = 0.02$ ,  $p = .903$ , or T2,  $F(1, 1445) = 2.48$ ,  $p = .115$ , a significant effect of age was revealed at T3, indicating an increased intention to see a doctor with increasing age,  $F(1, 2342) = 37.57$ ,  $p < .001$ ,  $R^2 = .02$ ,  $b = .012$ . In addition, intentions regarding hospital visits showed only a marginal positive relationship with age at T1,  $F(1, 1134) = 4.21$ ,  $p = .040$ ,  $R^2 = .004$ ,  $b = .004$ , and no significant effect at T2,  $F(1, 1445) = 0.36$ ,  $p = .550$ , or T3,  $F(1, 2339) = 1.14$ ,  $p = .285$ .



*Figure 3.2.* Regression coefficients are shown revealing the association of age and intentions regarding protective behaviors, separately for each behavior (A - D) and time period (T1, T2, and T3). Error bars are displayed indicating the 95% confidence interval. A confidence interval that does not contain zero is significant.

## Discussion

The present research examined intentions for protective behaviors across the early phases of Covid-19 in Germany, starting only a few days after the first cases were reported and ending after the lockdown was introduced. The findings indicate that the intentions to engage in social distancing and personal hygiene behaviors varied across threat levels, with a small differential effect of age on protective behavior intentions. The early assessment allows the investigation of psychobehavioral responses to the pandemic even before it posed an acute threat.

A main finding is that rising threat levels from the emergence of the first cases to the first deaths corresponded with a sharp increase in the intention to engage in social distancing. Notably, this increase was observed in reference to experiencing common cold symptoms during the last winter. The finding of an increased intention to engage in social distancing may be a consequence of activating a sensitized behavioral immune system (Schaller, 2006), since recognizing potential pathogen threat signals is associated with adopting protective behaviors to avoid diseases (Neuberg, Kenrick, & Schaller, 2011). Specifically, the emergence of a new infectious disease in concert with rising infection rates may sensitize the behavioral immune system. Thus, the increased intention to engage in social distancing may reflect an increased sensitivity to recognizing visible signals of a pathogen threat. However, relying on the behavioral immune system does not provide sufficient protection from Covid-19, which is characterized by high transmission rates even without showing symptoms (Bai et al., 2020). Public health campaigns have therefore promoted social and behavioral strategies to encourage protective behaviors even in the absence of symptoms to contain the spread of Covid-19 (World Health Organization, n.d.-a, 2021). Overall, the finding that the intention to engage in social distancing increased with rising threat levels may reflect both, the sensitization of the behavioral immune system

and the deliberate implementation of behavior rules which public health campaigns promote.

Interestingly, during the early emergence of the pandemic, there were similar increases in the likelihood of engaging in both personal hygiene, which is comparably easy to incorporate in daily life routines, and social distancing, which is more difficult to implement and associated with potential costs. Specifically, reducing social contacts could impair social relations, resulting in potentially adverse side-effects such as loneliness (Hawkley & Cacioppo, 2010). Thus, the benefit of protection through social distancing must be balanced against potential costs, which may reduce engagement rates and the maintenance of the behavior over prolonged periods of time. While this reasoning may explain different likelihoods of personal hygiene and social distancing behaviors during the early emergence of the pandemic, it is noteworthy that as threat levels increased people were presumably more willing to accept potential social costs to contain the spread of the virus.

An increased threat was not uniformly associated with increased protective behaviors as seeking medical care decreased after the imposition of the lockdown. This may also reflect official recommendations, as people experiencing symptoms were increasingly advised to self-isolate and seek medical advice over the telephone to also reduce the potential risk of infection when visiting a doctor or the hospital (World Health Organization, 2021).

A further aim was to determine whether intentions regarding protective behaviors across threat levels vary with age. While a previous review of infectious disease pandemics provided some evidence that older participants are more likely to engage in protective behaviors, the findings were inconclusive (Bish & Michie, 2010). This is relevant for Covid-19, as older participants are more likely to suffer serious health consequences from it (Oke & Heneghan, 2020). Our findings indicate rather

small positive associations between age and intentions to engage in social distancing and personal hygiene, these varied across objective threat levels. Specifically, during the early emergence of the new pandemic, a positive association of age was observed for both the intentions to engage in social distancing and personal hygiene. Specifically, younger adults increased intentions for protective behavior only at higher threat levels, leading to diminished age effects with increasing Covid-19 threat. Furthermore, while age and intentions for medical care seeking behaviors were significantly related, the observed effect sizes were rather small. Specifically, a positive association of age with the intention to see a doctor when experiencing common cold symptoms was only significant after the imposition of the lockdown (T3). Beyond age related differences in risk sensitivity, this finding may reflect emerging evidence that older people are particularly vulnerable to Covid-19 (Oke & Heneghan, 2020).

When interpreting the results, it should be considered that the present study focused on intentions for protective behaviors. Although the frequency of actual behavior was not assessed, intentions specifically related to Covid-19 allow the examination of motivational and behavioral dynamics in response to the pandemic. Future research could expand the current findings by assessing additional variables, i.e., risk perception and self-efficacy, affecting intentions and behavioral action as specified in current health behavior theories (Renner et al., 2015).

Furthermore, limitations of the present research need to be acknowledged. The present convenience sample is on average substantially younger than the German population (33.3 vs. 44.3 years of age, respectively) and includes more female participants (75% vs. 51%, respectively). While age was a continuous predictor in regression analyses, the observed relationship between age and intentions for protective behaviors awaits replication based on representative samples. Furthermore,

while not representative, the consistency of the findings regarding protective behavior intentions invites an examination across the full cycle of a pandemic.

### **Conclusion**

The present research provided insights into intentions regarding protective behaviors during a newly emerging infectious disease. Covering the initial phase of the Covid-19 pandemic, intentions for protective behaviors, namely social distancing and personal hygiene, increased with increasing threat levels. Furthermore, intentions regarding protective behaviors were found to vary little with age, even though Covid-19's mortality and health risk increases with age. Tracking intentions towards protective behaviors across continuing phases of the pandemic may inform the design of public health campaigns.

## **Declarations**

### **Conflicting Interests**

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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### **Supplementary Materials**

Any underlying research materials related to the present manuscript (e.g., data sets) are available from the corresponding author on reasonable request.

# 4

## Behavior, Risk Perception, and Health Risk

Risk perception after implementing  
behavior change:  
Adaptive and relative accuracy of perceived risk

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### Abstract

Harmful lifestyle behaviors pose a threat to health. One motivator to increase health behaviors may be a high personal risk perception, which can be elicited through negative feedback. The reception of feedback impacts on both risk perception and health behavior and may therefore change the strength of interrelations between them. The present study examined this for self-reported healthy eating in the context of personalized health feedback. Accordingly, relative and adaptive accuracy were examined in two groups of different feedback valence. In a longitudinal health study, participants were asked to rate how healthy their diet is and how worried they are regarding their diet on two occasions six months apart (T1, T2;  $N=775$ ). Approximately six weeks after T1, participants received personalized health feedback on the five risk factors for the metabolic syndrome. If one was elevated, participants were categorized into the at-risk group ( $n=473$ ). Analyses revealed higher risk perception in people reporting lower levels of healthy eating, i.e., relative accuracy. Furthermore, lowered risk perceptions followed increases in self-reported healthy eating, i.e., adaptive accuracy. Similar effects were found in both groups as feedback valence did not change the strength of interrelations. To summarize, relative and adaptive accuracy in risk perception were shown for self-reported healthy eating in both feedback groups. This may suggest the existence of underlying mechanisms on which people base their adjustments in risk perception. Overall, the results strengthen the notion to include time into models of health psychology to enable the modeling of dynamic interplays between cognitions and behavior.

*Keywords:* Accuracy; risk perception; eating behavior; health feedback

## Introduction

Harmful lifestyle behaviors like an unhealthy diet or physical inactivity are among key risk factors for non-communicable diseases, which are accountable for more than two thirds of all deaths worldwide (NCDs; World Health Organization, 2018b, 2020d). Therefore, the promotion of health behavior change with a view to reducing the global mortality from NCDs is a major aim of our time. However, initiating behavior change is challenging because one possible motivator may be that individuals perceive a high level of personal risk (Brewer et al., 2007; Renner et al., 2015; Renner & Schupp, 2011; Sheeran et al., 2014).

The perception of a high personal risk may be elicited through providing negative personalized health feedback. Even when the feedback includes different feedback on multiple risk indicators, people generally respond accurately to personalized feedback as they increase their personal risk perception only specifically for the elevated risk indicator (Gamp et al., 2018). However, accuracy of perceived risk can be assessed through different measures (e.g., Ferrer & Klein, 2015; Lages et al., in press; Renner et al., 2015; Renner & Schupp, 2011). Focusing on the association between risk perception and health behavior, accuracy can be operationalized both by relative and adaptive accuracy (Brewer et al., 2004; Gaube et al., 2019; Renner et al., 2008). While relative accuracy is implied by negative relationships between risk perception and health behavior, i.e., individuals engaging in higher levels of health behavior report lower risk perceptions as compared to individuals performing lower levels of health behavior (Brewer et al., 2004; Renner et al., 2008), adaptive accuracy is indicated by lowered risk perceptions following increases in health behaviors (Brewer et al., 2004; Renner et al., 2008; Weinstein et al., 1998).

To date, only a few studies have investigated both relative and adaptive accuracy in health behaviors (e.g., Brewer et al., 2004; Hay et al., 2007; Renner et al.,

2008). Data from Lyme disease vaccination revealed that vaccinated individuals reported both a lower risk perception (i.e., relative accuracy) and showed a greater decrease in risk perception as compared to unvaccinated individuals (i.e., adaptive accuracy; Brewer et al., 2004). Similarly, data collected during an outbreak of bovine spongiform encephalopathy (BSE) showed that people who reported a higher consumption of red meat perceived a higher risk (i.e., relative accuracy) and that increases in preventive nutrition (i.e., reduction of red meat consumption) were associated with decreases in BSE-related risk perceptions (i.e., adaptive accuracy; Renner et al., 2008).

So far, research has investigated relative and adaptive accuracy only for specific health behaviors (e.g., vaccination and red meat consumption). Thus, a valuable extension to the existing literature is the assessment of relative and adaptive accuracy in the context of providing personalized health feedback. Previous research has shown that health feedback of negative valence (i.e., elevated risk) is associated with higher intentions for behavior change due to increases in perceived risk (e.g., Bowen, Fries, & Hopp, 1994; Kreuter & Strecher, 1996; Panzer & Renner, 2008, 2009; Renner, 2004). As such, feedback generally impacts on both risk perception and health behavior and may therefore change the strength of the interrelations between them. This would indicate a moderating effect of feedback valence on the interrelations. Specifically, interrelations may be stronger in the at-risk group, which would result in varying degrees of relative and adaptive accuracy in dependence of feedback valence.

### **The Present Study**

The main aim of this study was to investigate the association between risk perception and health behavior in the context of providing personalized health feedback. Accordingly, we examined relative and adaptive accuracy in dependence of at-risk or not-at-risk feedback focusing on healthy eating and diet-related risk

perceptions. Healthy eating was chosen for the present study as it is of utmost importance with regard to reducing NCDs. While the occurrence of relative accuracy would be indicated by negative cross-sectional relationships between healthy eating and diet-related risk perceptions, a decrease in diet-related risk perceptions after changing towards healthier eating would indicate adaptive accuracy.

## **Method**

### **Procedure and Sample**

Data were collected as part of the Konstanz Life-Study, an ongoing longitudinal cohort study launched in spring 2012 (König, Sproesser, Schupp, & Renner, 2018; Konstanzer Life-Studie, n.d.; Renner, Sproesser, Klusmann, & Schupp, 2012; Sproesser, Klusmann, Schupp, & Renner, 2017). The overall goal of the Konstanz Life-Study is to investigate influences on health behaviors, such as physical activity and eating behavior, across time. Measurements include fasting blood samples, questionnaires, anthropometric measures, and cognitive and physical fitness tests. The study adhered to the guidelines of the German Psychological Society and the Declaration of Helsinki. The study protocol was approved by the University of Konstanz Ethics Committee. All participants gave written informed consent prior to participation. People aged 18 years and older without acute infectious diseases were eligible for participation in the Konstanz Life-Study. Participants were recruited via flyers, posters, and newspaper articles and participants of preceding waves were re-invited via email.

Data of the present study were collected in autumn 2012 (T1) and spring 2013 (T2) during the second and third waves of the Konstanz Life-Study, respectively. Approximately six weeks after T1, participants received personalized health feedback on their blood samples and risk factors indicating the metabolic syndrome. The feedback was provided via mail and included the actual blood values as well as

information on the presence of risk factors indicating the metabolic syndrome on the basis of displayed cut-off values.

A total sample of  $N = 883$  (T1) and  $N = 685$  (T2) participated in the study with 587 participants taking part at both assessment points. However, participants were included into the analyses if they had provided at least one of the core measures at T1. Thus, the final study sample comprised  $N = 775$  participants (58% female) with an age range between 19 and 87 years ( $M = 47.68$ ,  $SD = 17.43$ ). In general, the sample was well educated with on average 15.8 years of education ( $SD = 2.4$ , ranging from 8 to 20).

The study sample did not differ significantly from the drop-out sample ( $n = 108$ ) in age ( $M_{study} = 47.68$ ,  $SD = 17.43$  vs.  $M_{drop-out} = 52.00$ ,  $SD = 20.14$ ),  $t(103.83) = -1.94$ ,  $p = .055$ , gender,  $\chi^2(1) = 1.71$ ,  $p = .191$ , with 58% females in the study sample and 65% females in the drop-out sample, and years of education ( $M_{study} = 15.8$ ,  $SD = 2.4$  vs.  $M_{drop-out} = 15.8$ ,  $SD = 2.3$ ),  $t(780) = -0.05$ ,  $p = .958$ .

## Measures

**Healthy eating.** The participants were asked to estimate the healthiness of their own eating behavior at T1 and T2. The item stem 'Currently, my diet is...' was assessed on a Likert scale ranging from [1] '*unhealthy*' to [7] '*healthy and balanced*'.

**Risk perception.** Risk perception was assessed by asking participants at T1 and T2 to indicate how often they had worried about their diet during the past month on a Likert scale from [1] '*I have never worried about this during the past month*' to [7] '*I have worried about this during the past month all the time*' (adapted from Croyle & Hunt, 1991; see also Renner & Reuter, 2012).

**Health feedback.** As previous research had shown that the metabolic syndrome is related to eating behavior, the presence of risk factors for the metabolic syndrome was provided in the form of personalized health feedback (Malik et al.,

2010). Anthropometric measures were taken at T1 following standardized procedures by trained research staff. The presence or absence of risk factors for the metabolic syndrome was determined using criteria outlined by the World Health Organization (2000) and the International Diabetes Federation (2006). Risk factors for the metabolic syndrome are (1) abdominal obesity (waist circumference > 94 cm for men, > 80 cm for women); (2) systolic blood pressure  $\geq$  130 mm Hg or diastolic blood pressure  $\geq$  85 mm HG; (3) fasting serum glucose  $\geq$  100 mg/dl; (4) fasting serum triglycerides  $\geq$  150 mg/dL; and (5) low fasting serum HDL cholesterol (< 40 mg/dl in men, < 50 mg/dl in women; see also Sproesser et al., 2018). For the analysis of the present study, participants were categorized into the at-risk group if at least one of the five risk factors for the metabolic syndrome was prevalent.

### **Analytic Procedure**

Analyses were conducted in Mplus 8. In order to estimate missing values and account for longitudinal drop-out, full information maximum likelihood (FIML) estimates were applied (Muthén & Muthén, 2012). By applying FIML, missing values were estimated from the observed values in the model. An index of change in healthy eating was obtained by subtracting healthy eating at T1 from healthy eating at T2. Similarly, the index of change in diet-related risk perception was calculated using the same rationale.

Multigroup model analyses were conducted in order to investigate the moderating effect of feedback valence on adaptive accuracy. Starting with an unconstrained model, all paths were freely estimated for the two groups of different feedback valence. Thus, the model fitted the data perfectly,  $\chi^2(0) = 0.0$ ,  $p = 1.0$ , RMSEA = 0.0. Then, one by one, the three paths of the model between the independent variables and the dependent variable were set equal across feedback groups (i.e., constrained). Differences in model fit between the constrained and the unconstrained

model were then compared via  $\chi^2$ -difference tests (see Klusmann, Sproesser, Wolff, & Renner, 2019). If significant changes in model fit occurred, feedback valence moderated the respective relation.

## Results

### Relative Accuracy of Perceived Risk

Participants who rated their diet as rather unhealthy, reported on average higher worry about their diet during the past month with comparable effects at T1 ( $r = -.35$ ,  $p < .001$ ) and at T2 ( $r = -.39$ ,  $p < .001$ ). Similar results were obtained for the at-risk and the not-at-risk groups (see Table 4.1). The negative cross-sectional relationships indicate the presence of relative accuracy in both groups at both measurement points.

### Adaptive Accuracy of Perceived Risk

Investigating the relationships between risk perception and healthy eating longitudinally from T1 to T2 revealed similar patterns in both groups (see Fig. 4.1). At T1, higher diet-related risk perceptions were generally associated with lower ratings of healthy eating ( $\beta_{not-at-risk} = -.420$ ,  $p < .001$ ;  $\beta_{at-risk} = -.313$ ,  $p < .001$ ). Furthermore, participants who rated their eating behavior as comparably unhealthy at the first measurement point, tended to shift towards a healthier diet from T1 to T2 ( $\beta_{not-at-risk} = -.435$ ,  $p < .001$ ;  $\beta_{at-risk} = -.443$ ,  $p < .001$ ). Also, participants from the not-at-risk group who reported higher risk perceptions at T1 more likely changed towards a healthier diet from T1 to T2 ( $\beta = .243$ ,  $p = .001$ ). However, this association was not observed in the at-risk group.

In regard to the relationships between the three predictor variables and change in risk perception, the following patterns emerged in both groups (see Fig. 4.1): Higher diet-related risk perceptions at T1 were related to a significant decrease of perceived risk between measurement points ( $\beta_{not-at-risk} = -.476$ ,  $p < .001$ ;  $\beta_{at-risk} = -.656$ ,  $p < .001$ ).

Table 4.1

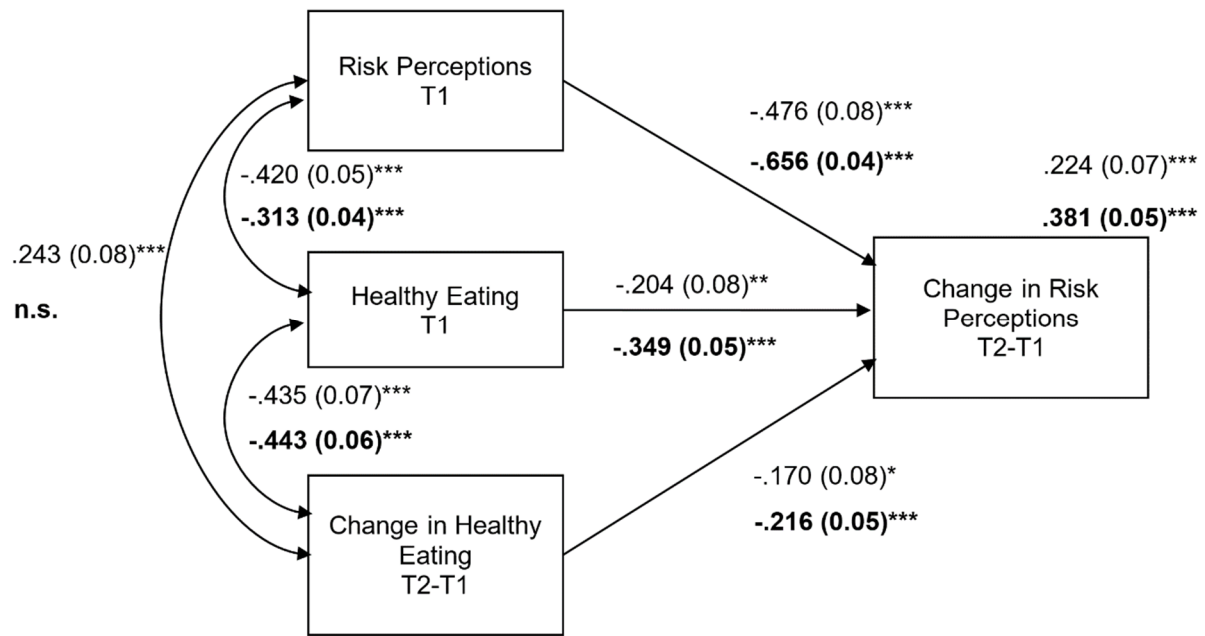
*Intercorrelations, means (M), and standard deviations (SD) between risk perception and healthy eating for the total sample, not-at-risk, and at-risk groups, respectively*

Variable	2	3	4	M	SD
<b>Total sample</b>					
1. Healthy eating T1	.63***	-.35***	-.37***	5.08	1.18
2. Healthy eating T2		-.30***	-.39***	5.13	1.16
3. Risk perception T1			.52***	2.45	1.56
4. Risk perception T2				2.56	1.52
<b>Not-at-risk group (n = 301)</b>					
1. Healthy eating T1	.57***	-.42***	-.35***	5.22	1.06
2. Healthy eating T2		-.22***	-.30***	5.24	1.10
3. Risk perception T1			.55***	2.29	1.47
4. Risk perception T2				2.50	1.55
<b>At-risk group (n = 473)</b>					
1. Healthy eating T1	.66***	-.31***	-.37***	4.99	1.24
2. Healthy eating T2		-.34***	-.45***	5.05	1.20
3. Risk perception T1			.51***	2.55	1.61
4. Risk perception T2				2.60	1.50

*Note.* \*\*\*  $p < .001$ .

Furthermore, participants who rated their diet as rather unhealthy at T1 were more likely to increase their diet-related perceived risk from T1 to T2 ( $\beta_{not-at-risk} = -.204$ ,  $p = .010$ ;  $\beta_{at-risk} = -.349$ ,  $p < .001$ ). In addition, changes in healthy eating predicted changes in perceived risk ( $\beta_{not-at-risk} = -.170$ ,  $p = .025$ ;  $\beta_{at-risk} = -.216$ ,  $p < .001$ ). This implies that

participants who increased their healthy eating ratings from T1 to T2, tended to decrease their diet-related risk perceptions during the same time frame which indicates adaptive accuracy for healthy eating and diet-related risk perceptions in both groups.



*Figure 4.1.* Path analysis (standardized solution) displays relations between self-reported healthy eating and diet-related risk perception between T1 and T2 for the at-risk group ( $n = 473$ ) in bold and for the not-at-risk group ( $n = 301$ ) in not-bold. Standard errors are displayed in brackets. Coefficients are significant at  $^{***} p \leq .001$ ,  $^{**} p \leq .01$ ,  $^* p \leq .05$ .

To test the moderating effect of feedback valence, multigroup model analysis was applied. The results revealed that feedback valence did not significantly moderate the relation between prior risk perception and subsequent change in risk perception,  $\Delta\chi^2(1) = 3.64$ ,  $p = .057$ . Also, feedback valence did not influence the strength of the relation between healthy eating at T1 and subsequent change in perceived risk,  $\Delta\chi^2(1) = 1.58$ ,  $p = .208$ . Likewise, the effect of change in healthy eating on change in risk perception was comparable across both feedback groups,  $\Delta\chi^2(1) = 0.45$ ,  $p = .503$ . This

implies that the magnitude of adaptive accuracy did not significantly vary in accordance with feedback valence. Overall, 38% and 22% of variance in change in risk perception were explained by the models for the at-risk and the not-at-risk groups, respectively.

### **Discussion**

The present study investigated the relations between self-reported healthy eating and risk perception in the context of providing feedback. The results indicate an interplay between diet-related perceived risk and self-reported healthy eating in groups of both negative and positive feedback valence, as relative and adaptive accuracy of perceived risk were shown despite the different feedback valence. Differential effects of relative and adaptive accuracy in dependence of feedback valence were not observed.

#### **Adaptive and Relative Accuracy in Healthy Eating**

Results of the present study demonstrated the occurrence of both relative and adaptive accuracy in self-reported healthy eating. Comparing the results to those obtained by Renner et al. (2008), who have assessed both relative and adaptive accuracy in a similar way albeit focusing on red meat consumption and BSE-related risk perceptions during an outbreak of BSE, interesting patterns can be observed.

While in the present study solely medium effects ( $r \leq -.35$ ) for relative accuracy were revealed, Renner et al. (2008) had obtained large effect sizes ( $r \leq -.52$ ; Cohen, 1992). This may be explained by the different questions used to assess the behavior in the two studies. While the present study assessed self-reported healthiness of eating via one overall rating that ranged from 'unhealthy' to 'healthy and balanced', Renner et al. (2008) investigated the frequency of red meat consumption ranging from 'never' to 'several times daily', which is comparably specific. The difference in these items may explain the obtained differences in relative accuracy, as people may find it easier to rate the frequency of red meat consumption than healthy eating in general, which may

in turn explain the larger effect sizes in the study on BSE. However, despite this difference between studies, the effect sizes for adaptive accuracy were remarkably similar comparing the two studies (present study:  $\beta \geq .17$ ; Renner et al., 2008:  $\beta = .21$ ). This may reflect a general underlying mechanism on which people base their changes in risk perceptions after changes in behavior.

### **Underlying Mechanism of Adaptive Accuracy**

The similar effect sizes suggest the existence of a general underlying mechanism modifying perceived risk, which is further underscored by the occurrence of adaptive accuracy independent of feedback valence. As people generally may initiate health behaviors to reduce their risk of a disease (Weinstein et al., 1998), a high motivation to reduce the perceived risk after changing towards healthier behavior could be assumed especially after receiving negative feedback, which could result in stronger effects of adaptive accuracy in the at-risk group.

Indeed, in comparing the  $\beta$ -coefficients of the path models for the at-risk and not-at-risk groups in the present study, consistently stronger associations were found in the at-risk group, albeit no significant differences were obtained. The lack of significant differences between  $\beta$ -coefficients of the two models indicates that the interplay between risk perception and health behavior was not moderated by feedback valence in the present study. Therefore, it could be assumed that regardless of the feedback people receive, the reciprocal adjustments between health behavior change and risk perception change seem to follow similar mechanisms.

### **Relations Between Health Behavior and Feedback on Risk Factors**

One may argue that the personalized feedback of the present study contained information on the risk factors for the metabolic syndrome and not on the healthiness of the diet. A vast amount of literature reveals the importance of specific risk perceptions matching specific behavior (Brewer et al., 2004; Grenen, Ferrer, Klein, &

Han, 2016; Hahn & Renner, 1998; Renner et al., 2008). In a similar vein, it remains unclear whether participants of the present study related their received feedback on the metabolic syndrome to their diet to such an extent as to obtain significant differences between the models. Thus, the question arises whether people generally relate feedback on risk factors for the metabolic syndrome to associated health behaviors such as eating behavior.

Analyzing the responses to personalized feedback on risk factors for the metabolic syndrome in a South Korean sample showed that the group classified as high-risk spontaneously responded more frequently with intentions for future lifestyle change (e.g., increasing physical activity and improving eating behavior) compared to the not-at-risk group. This pattern emerged for both blood pressure readings (38% vs. 13%, respectively) and cholesterol readings (49% vs. 21%, respectively; Panzer & Renner, 2008). The results of this study suggest that people are aware of the association between risk factors for the metabolic syndrome and specific related health behaviors such as eating behavior. Nevertheless, it would be interesting to examine relative and adaptive accuracy in people who have received personalized feedback on the target behavior and not only on related risk factors. This would allow to verify that adaptive accuracy emerges regardless of the feedback valence, which would further strengthen the notion of underlying mechanisms operating in the same manner.

### **The Importance of Dynamic Risk Perceptions**

The notion of underlying mechanisms suggests the existence of a specific dynamic interplay between risk perception and health behavior, which is emphasized by the emergence of the same pattern of results in both feedback groups. Investigating the dynamics of cognition and behavior is critical to gain a deeper understanding of the adoption and maintenance of health behaviors (Renner, Hankonen, Ghisletta, & Absetz, 2012). In particular, adaptive accuracy of perceived risk may be of crucial

importance for successful behavior change, as it may foster maintaining the behavior change (Hay et al., 2007; Renner et al., 2008). Following the experience of a reduction in risk perception due to a change in behavior, such behavior change will presumably be perceived as an effective risk reduction measure, which may then act as a motivator to maintain this behavior. The illustrated dynamic interplay emphasizes the importance of adaptive accuracy for the maintenance of behavior change. However, future research needs to further elaborate on the motivational effect of adaptive accuracy on maintenance (see also Hay et al., 2007; Renner et al., 2008).

To facilitate research that contributes to revealing the importance of dynamics in risk perception for, e.g., the maintenance of behavior, theories and models in health psychology should integrate time. Only by including time can the dynamic interplay between health behavior and related cognitions be fully assessed (see also Scholz, 2019). In this regard, the present study adds to the literature by giving evidence for behavior change and an associated change in risk perceptions over time.

### **Limitations and Future Research**

There are some limitations to the present study that should be noted as they possibly affect the interpretation of the results. In the present study, behavior change was assessed via self-reported healthy eating, without objective measures. However, the perception of healthy eating is of high relevance in regard to risk perception. If participants subjectively did not perceive a change, even though objectively the eating behavior had changed, it does not seem reasonable to expect any changes in risk perception. Recent research showed that people who perceive a change in their diet also show an actual shift towards a healthier dietary pattern (Szymczak et al., 2021). Hence, a perceived change is likely to be accompanied by an actual change.

Furthermore, in the real world (as in the Konstanz Life-Study), people are confronted with feedback on multiple risk factors at a time (Gamp et al., 2018). Thus,

one might argue that the threshold of a single elevated risk factor as a criterion for inclusion in the at-risk group might not be sufficient to obtain significant differences between the models (at-risk vs. not-at-risk). Future research may compare the strength of relations between risk perception and behavior between people with no and others with five elevated risk factors, and may thus investigate relative and adaptive accuracy in relation to personalized health feedback in a more fine-grained manner.

Finally, the predominantly white sample with high self-interest in health limits the generalizability of the results as participants in this study might be more ready to process health feedback compared to the general public. Therefore, these results require a replication with a more representative sample.

## **Conclusion**

Overall, the current study investigated the associations between risk perception and self-reported healthy eating in the context of providing personalized health feedback. The results show that: First, people generally perceive their current risk status quite accurately (i.e., relative accuracy). Second, people tend to accurately adjust their perceived risk after behavior change (i.e., adaptive accuracy), which is an adaptive response and may help to maintain these behavior changes. The similar patterns in both feedback groups indicate a general underlying mechanism that operates regardless of feedback valence. Furthermore, the results of this study emphasize the need to include the notion of time into health behavior models, in order to enable the modeling of the dynamic interplay between cognitions and health behaviors, which will enhance the understanding of such dynamics.

# 5

## General Discussion

Hazards are constantly emerging or changing, but often humans can reduce the risk that they pose by adopting protective behaviors. Among other factors, an important motivator for doing this is an increased perception of risk. Thus, if people's risk perception increases when a new hazard emerges, for instance through a public health campaign, this might increase the chances of them initiating the protective behavior to reduce the associated risk. This implies a dynamic interplay between risk, the perception of risk, and protective behaviors.

The overall aim of the present dissertation was to gain a deeper understanding of this dynamic interplay in the field of health risks. Humans responses to changes in health risks were first investigated. To this end, Chapter 2 revealed that risk perceptions in relation to health risks were both accurate and inaccurate at the same time during infectious disease threats, depending on the respective indicator of accuracy. For instance, risk perceptions were generally accurate as they mostly varied in accordance with changes in the health risk. Chapter 3 showed that while protective behavior intentions were associated with increases in the health risk during the Covid-19 pandemic, different patterns emerged for different protective behavior intentions. Furthermore, Chapter 3 revealed small associations between age and intentions for protective behavior, which also varied in accordance with the health risk.

In a second step, the interplay between protective behavior and risk perception in dependence of the health risk was investigated in the domain of NCDs. Chapter 4 demonstrated both relative (i.e., people with higher perceived risk generally reported lower protective behavior) and adaptive accuracy in perceived risk (i.e., people showed subsequent lower risk perceptions after reporting positive changes in protective behavior) in two groups with different degrees of health risk. These interrelations were examined using the example of self-reported healthy eating.

The combination of these findings allows a further elaboration on the interrelations between health risk, perceived risk, and protective behavior. This may serve as a starting point to focus more explicitly on the reciprocal relationships between all three constructs, which may in turn foster the development of models that include the dynamic interplay between them.

### **Models of Risk Perception and Behavior**

Health psychological models have not yet explicitly combined health risk, perceived risk, and protective behaviors into one comprehensive model to illustrate how they are interrelated. There are models that focus solely on explaining variance in risk perception (Fischhoff et al., 1978; Paek & Hove, 2017; Sjöberg, 2000; van der Linden, 2015), while the majority of theories and models in health psychology aim at describing, explaining, and predicting behavioral intentions and behavior change (Armitage & Conner, 2000; Gaube et al., 2019; Michie, West, Campbell, Brown, & Gainforth, 2014; Prentice-Dunn & Rogers, 1986; Renner, Hankonen et al., 2012; Renner & Schwarzer, 2003; Weinstein, 1988, 1993). Many of these models have emphasized risk perception as one of the key determinants to predict behavioral intentions (e.g., Renner & Schwarzer, 2003), which would suggest an integration of risk perception and behavior change models. However, the vast amount of models with varying foci so far lack a comprehensive integration, which provides leeway for further research in this field.

Since most of this vast number of theories and models were predominately developed through researching risk perception and behavior in the context of NCDs, it remains questionable whether they can be directly applied to infectious disease threats (Brug et al., 2009). The most striking difference between NCDs and infectious disease threats is the speed and manner by which infectious diseases, which can be transmitted directly from human to human (World Health Organization, n.d.-b), expand.

However, this difference should not affect the general associations between health risk, risk perception, and protective behavior, so the dynamic interplay, aspects of which have been examined by this dissertation, should be applicable to both domains of diseases. Most studies that research infectious disease threats are not based on either a model or a theory (Leppin & Aro, 2009). However, a thorough and theory-based understanding of the determinants of risk perception and their relation to protective behaviors during infectious disease threats is crucial for developing effective interventions that succeed in containing the spread of infectious diseases (Leppin & Aro, 2009). In a similar vein, a recent review of mathematical models, that try to predict the spread of infectious diseases, recommended the inclusion of protective behaviors, and specifically account for the heterogeneity of human behavior to accurately model the spread of the disease (Weston, Hauck, & Amlôt, 2018). This further emphasizes the importance of investigating human behavior during the spread of infectious diseases. Overall, while the lack of using models of risk perception and protective behavior when investigating emerging infectious disease threats may result from the necessity to respond rapidly to the risk (Leppin & Aro, 2009), it may also reflect a lack of an appropriate and easy-to-apply model as these threats emerge.

The findings of the present dissertation may serve as an initial approach towards meeting this need. Examining aspects of the interplay between three main constructs, namely health risk, perceived risk, and protective behaviors, the constructs and respective relations could be integrated into a single model. Moreover, the limited number of constructs involved suggests that it might be possible to operationalize them to fit the respective infectious disease threat and to assess them during an emerging disease threat. However, fully addressing the proposed interrelations would require the assessment of time and different targets. While the resulting model would be applicable

to NCDs, it would be particularly suitable for infectious disease threats. The two components, namely time and target (personal vs. general), will now be addressed.

**Including time.** Including time enables the modeling of dynamics which allows changes in constructs to be assessed (Renner, Hankonen et al., 2012). The inclusion of time in models and theories may also foster a stronger focus on the reciprocal relationships between constructs in future theories (Scholz, 2019), and may change both the relevance of the constructs that are included and the importance of the interrelations between them (George & Jones, 2000). The findings of the present dissertation (Chapter 4) strengthen this notion and extend previous research by revealing a dynamic interplay between risk perception and protective behaviors across time for two different levels of health risk. The occurrence of a dynamic interplay at different levels of health risk may suggest underlying mechanisms on which the reciprocal interrelations between risk perception and behavior may be based. While Chapter 4 investigated this in the context of NCDs, assessing time and dynamics may be particularly important for infectious disease threats as some viruses are highly contagious and spread rapidly (e.g., SARS-CoV-2; Sanche et al., 2020), which implies rapid increases in the general health risk (i.e., number of active cases) and similarly rapid modifications of perceived risk and protective behaviors would be needed to respond to these changes. A rapid dynamic interplay between the constructs assessed in this dissertation can therefore be assumed.

Given that current theories and models in health psychology largely neglect time and thus reciprocal relationships (Scholz, 2019), the present dissertation adds evidence to the importance of time and interactions. Presumably, health psychologists are about to increasingly recognize time as an important component in future models (Scholz, 2019). This does not generally apply to the second component, namely target.

**Including target.** Integrating targets by explicitly modeling personal and general components would allow important differentiations, which may be particularly suitable for models of infectious disease threats, to be made. In particular, the present dissertation suggests a differentiation between different targets in both health and perceived risk.

**Health risk.** The model of risk perception and risk behavior developed by Brewer et al. (2004) only includes health risk implicitly, and does not clearly differentiate it from changes in protective behavior. However, including health risk as a distinct construct within the model would allow for a differentiation between personal and general health risk, which may be particularly crucial for infectious disease threats. While the general risk of infection during an infectious disease threat is directly related to the number of active cases (Robert Koch Institute, 2020a), a discrete person's own risk of infection also depends on their individual protective behavior (World Health Organization, 2021). Specifically, the personal risk of infection of someone showing high rates of protective behavior (e.g., social distancing), might be low, despite a high general risk. However, the adoption of protective behaviors by a single person is only likely to have a marginal impact on the general health risk. Furthermore, the general health risk may fluctuate for infectious disease threats (i.e., changes in number of active cases), whereas overall it remains stable for NCDs, which hints towards an important difference between the two domains of diseases. Changes in the general health risk of infectious diseases encourage the investigation of whether people respond to these changes. The present dissertation's empirical results demonstrated changes in the general health risk and corresponding changes in both associated risk perceptions (Chapter 2) and protective behavior intentions (Chapter 3). Future research that explicitly differentiates between personal and general health risk may be able to explicitly assess the changes in both.

**Perceived risk.** Differentiating between the personal and general component is also important for risk perception. Personal risk perception is especially critical from a practical perspective, since it may serve as a prerequisite for initiating protective behaviors (Renner et al., 2015; Renner & Schupp, 2011). Despite the importance of personal risk perception in predicting behavior, the ratio between personal and general risk perception (i.e., optimistic bias; Weinstein, 1980; see also 'vulnerability difference score' by Perloff & Fetzer, 1986) may also be crucial for adopting protective behaviors. It has frequently been discussed that a high degree of unrealistic optimism or optimistic bias may inhibit people from adopting protective behaviors, since they may feel less need to act protectively when others are more at risk (Renner & Schwarzer, 2003; van der Pligt, 1998). This further emphasizes the need to assess both personal and general risk perception to be able to derive the extent of the optimistic bias.

Optimistic bias was observed during the earliest stages of the current Covid-19 pandemic in a comparably small sample of Polish students ( $N = 171$ ), who rated their own likelihood of infection with the coronavirus as lower compared with their peers (Dolinski, Dolinska, Zmaczynska-Witek, Banach, & Kulesza, 2020). The same pattern, also with a much larger sample, was observed in Germany throughout eight waves of data collection from February to May, 2020 (Renner, Koller, Lages, Villinger, & Schupp, 2020). Chapter 2 similarly confirmed the optimistic bias in three infectious diseases, namely avian influenza, seasonal influenza, and the common cold. However, results from the present dissertation (Chapter 2) add to previous research in that while both personal and general risk perception were modified to fit the changes in the health risks, increases in general risk perception were more pronounced during times of higher health risk compared to personal risk perception. Thus, differential extents of the optimistic bias were observed in a direction which may point towards defensive optimism. Defensive optimism proposes that while people acknowledge a higher health

risk and thus take reality into account, they maintain a favorable view of themselves by, e.g., creating extreme risk stereotypes (Hahn & Renner, 1998).

### **Optimistic Bias and Protective Behaviors**

Defensive optimism (i.e., favorable changes in optimistic bias during times of higher risk) may be particularly harmful during times of infectious disease threats, as it might inhibit people from adopting protective behaviors. Since these are the only measures that are effective in containing the spread of the Covid-19 pandemic until pharmaceutical interventions are sufficiently available (e.g., van Bavel et al., 2020), Dolinski et al. (2020) argue for the importance of investigating whether the optimistic bias is related to the adoption of protective behaviors.

Research on the relationship between optimistic bias and protective behaviors has so far been mixed, revealing both positive, negative, and non-significant relationships (Cho, Lee, & Lee, 2013; Ferrer & Klein, 2015). For instance, during the swine flu (H1N1) outbreak in 2009, a cross-sectional study conducted in Great Britain found no association between optimistic bias and intentions to vaccinate or avoidance behaviors (Rudisill, 2013). While most studies to date have used cross-sectional designs, the direction of a potential relationship can only be determined using longitudinal designs (see also Cho et al., 2013). A longitudinal study on H1N1 in South Korea with two measurement points, which were approximately seven weeks apart, revealed no association between optimistic bias and protective behaviors (Cho et al., 2013). However, since protective behaviors were only assessed at the second time point, this study only assessed the semi-dynamic perspective (see Renner, Hankonen et al., 2012). Further research is therefore needed to fully assess the impact of optimistic bias on protective behaviors.

Overall, previous literature and the results of the present dissertation further support the notion of including personal and general risk perceptions, as well as the

personal and general health risks and protective behavior, into a comprehensive model that depicts the reciprocal relationships.

### **The Dynamic Nature of Perceived Risk**

The present dissertation is mainly focused on the reciprocal interrelations between health risk, perceived risk, and protective behaviors. This approach is based on the assumption that risk perceptions are dynamic.

The presumably dynamic nature of perceived risk is in contrast to a recent approach that regards risk preference (defined as people's general responses to risks) as a trait (Frey, Pedroni, Mata, Rieskamp, & Hertwig, 2017). More precisely, in the study by Frey et al. (2017), participants were tested on 39 different measures of risk-taking that fell into one of three categories, i.e., propensity, behavioral, and frequency measures. A general factor of risk preference emerged across the categories. Moreover, the investigation of a subsample after six months revealed stability of risk preference across time (Frey et al., 2017), further pointing towards risk preference as a trait. Thus, risk preference seems to depict whether a person is, on average, more likely to be inclined or averse to risks. Despite these level differences between people, changes in risk perception should be similar for different levels of risk preference.

Natural fluctuations in risk perceptions have been investigated in a U.S. sample over the course of three years for multiple unexpected health risks (e.g., terrorist attacks, infectious diseases, accidents, natural disasters; Brady, 2012). The study revealed that the extent of change across time in perceived risk differed for specific risks. For instance, there were clear peaks in the general risk perception for terrorist attacks which coincided with terrorist attacks outside of the USA, and general risk perception for infectious diseases seemed to fluctuate in accordance with the seasons, as measurement points in January were significant predictors of perceived risk (Brady,

2012). These results hint towards the notion that risk perception primarily changes in accordance with changes in risk, and thus are modified accordingly.

The results of the present dissertation further support this notion. Chapter 2 revealed that risk perceptions for infectious disease threats increased during seasons associated with an increased general health risk for seasonal influenza and the common cold, compared with off-season times. This pattern was not found for avian influenza, the perceived risk of which remained comparably stable, which matches stable scores of avian influenza risk perception from the Netherlands (de Zwart et al., 2010). The Dutch authors concluded that it may need an acute threat of zoonotic influenza to increase associated risk perceptions. And indeed, massive changes in perceived risk can be observed during the current Covid-19 pandemic (e.g., Euclid, 2020). Thus, while risk perceptions generally correspond to changes in health risk, natural fluctuations of perceived risk seem to be less common. Investigating the dynamics of risk perception is crucial, since perceived risk plays a critical role for protective behaviors.

### **The Importance of Changes in Risk Perception for Maintaining Behavior**

The adoption of protective behaviors is of utmost importance for both reducing NCDs and containing infectious disease threats (e.g., van Bavel et al., 2020; World Health Organization, 2018b). However, the adoption and maintenance of these newly acquired behaviors are both crucial to effectively reducing the risks, and both need to be considered (Schwarzer, 2008).

While it is commonly known that successful reductions in the risk of NCDs are only achieved by performing protective behaviors over a long period of time (e.g., dietary changes to decrease the risk of cardiovascular disease), the current Covid-19 pandemic emphasizes that the importance of maintaining protective behaviors also holds true for infectious disease threats. Specifically, the pandemic lasted for over nine

months (World Health Organization, 2020c) before the first authorized vaccine became available in the European Union (European Medicines Agency, 2020). Therefore, people around the world are facing the challenge of performing protective behaviors over a very long time (Ferguson et al., 2020). Research on maintaining physical activity has revealed that maintenance was more prevalent at shorter time intervals (6 – 9 months,  $d = 0.28$ ) than longer time intervals (9 – 15 months,  $d = 0.20$ ; Murray et al., 2017), which suggests that maintaining behavioral changes after physical activity interventions becomes increasingly difficult over time and raises the question of what fosters the maintenance of behavior.

Previous research showed that changes in cognitions are essential for the maintenance of protective behaviors (Renner, Hankonen et al., 2012). Specifically, the decrease in personal risk perception that potentially follows an increase in protective behaviors may serve as an important motivator to maintain the behavior, since performing the behavior is then likely to be seen as effective (i.e., adaptive accuracy; Hay et al., 2007; Renner et al., 2008). However, for the maintenance of protective behaviors during infectious disease threats, it seems that people who do not maintain a high level of general risk perception no longer perceive protective behaviors as necessary and are presumably then more likely to discontinue the behavior. Hence, general risk perception should be continuously high to maintain the behavior during infectious disease threats, whereas personal risk perception should decrease when performing protective behaviors. This further emphasizes the need to assess changes in both personal and general risk perception.

### **The Social Context of Risk Perception and Behavior**

Elaborating on the general dimensions of both risk perception and health risk also points towards the notion that risk perception is not only limited to the individual but also embedded within a larger social context (e.g., social norms, culture, and

general environment). A conceptual framework of the social amplification of risk has previously been proposed (Kasperson et al., 1988; Renn, Burns, Kasperson, Kasperson, & Slovic, 1992; see also Joffe, 2003 for a review on the strong social component of risk perception), which strengthens the importance of the social context for risk perceptions.

The importance of the social context when eliciting risk perception and protective behaviors is particularly evident during infectious disease threats, as the risk of infection for the individual can be multiplied or reduced by the behavior of others (Leppin & Aro, 2009). Furthermore, as infectious diseases are communicable diseases, they spread along networks (van Bavel et al., 2020). Similarly, protective behaviors are also usually disseminated along the structure of a social network by the spread of social norms (van Bavel et al., 2020), which have been shown to be predictive of people's behavior (Cialdini & Goldstein, 2004), and risk perceptions (van der Linden, 2015). Socio-cultural factors were also shown to be predictive of the perception of risk during the current Covid-19 pandemic (Dryhurst et al., 2020). Thus, the spread of risk perception and protective behavior seems at least to some degree to be bound to the social context.

Despite the spread of protective behaviors, it should be emphasized that some of the protective behaviors that public authorities recommend for containing the spread of infectious diseases themselves contain a social dimension. The most striking example of this is social distancing, which is generally associated with increases in psychological distress (Hawryluck et al., 2004; overview: Venkatesh & Edirappuli, 2020) and thus contains high costs which are presumably weighed against the benefits. The results of the present dissertation (Chapter 3) emphasize this notion by showing that intentions to perform social distancing measures were increasingly reported only when a comparably high increase in health risk had occurred, whereas

intentions for personal hygiene were also rather frequent at lower levels of health risk. Thus, the social dimension is more substantial for infectious disease threats than other diseases, including NCDs (Leppin & Aro, 2009). This should be kept in mind when investigating risk perception and protective behaviors during emerging infectious disease threats.

### **Limitations and Future Research**

The present dissertation presents an initial approach towards assessing the interplay between the constructs of health risk, perceived risk, and protective behaviors across time, and thus fosters further investigations of the dynamics between them. However, some limitations should be addressed regarding its results. First, the current state of the art lacks a clear definition of what constitutes health risk and perceived risk (Ferrer et al., 2018; Loewenstein et al., 2001; Portnoy, Ferrer, Bergman, & Klein, 2014; Renner et al., 2015; Renner & Reuter, 2012; Wilson et al., 2019). In particular, risk perceptions during infectious disease threats have been revealed as a heterogeneous concept (Leppin & Aro, 2009; Renner & Reuter, 2012). This emphasizes the need to clearly define risk perception and to regard the different definitions when interpreting and comparing results from different studies. Despite the shortcomings of clear definitions, it remains essential to investigate the interrelationships and dynamic processes between health risk, perceived risk, and protective behaviors to gain a more comprehensive understanding of the constructs and their interplay, which may then inform public health campaigns. Thus, the findings of the current dissertation on aspects of this interplay add to a more comprehensive understanding, even if it has not been fully accounted for the complexity of the operationalization of both the health risk and the perceived risk.

Second, since Chapters 2 and 3 of the present dissertation made use of cross-sectional designs, the possibility that the results may have derived from differences in

sample composition cannot be completely ruled out. Specifically, the different cross-sectional samples may have diverged from each other in such a way that the pattern of results was based on differences between cross-sectional samples rather than differences in health risk. However, in Chapter 2, dynamics in accordance to health risk were only observed for seasonal influenza and the common cold, and not for avian influenza, which contradicts the assumption that coincidentally the cross-sectional samples at a higher health risk may have had higher overall levels of risk perception, regardless of the increased health risk, and that this may have produced the results. Nevertheless, a longitudinal design would have been preferable to completely rule out this option and fully capture the dynamics (Siegrist, 2014), although reaching a sufficient sample size to capture dynamics across multiple infectious disease epidemics as in Chapter 2 may be quite challenging when applying a longitudinal design.

Third, it should be noted that the present dissertation's research did not objectively assess protective behavior. Although Chapter 3 assessed protective behavior intentions, a vast amount of the research which elaborates on the intention-behavior gap implies that people's intentions do not necessarily translate into actual behavior ( $d_+ = .36$ , Webb & Sheeran, 2006; see also, e.g., Rhodes & Dickau, 2013; Sheeran & Webb, 2016). This emphasizes the importance of assessing actual behavior. However, in Chapter 3, assessing intentions enabled us to directly compare the three measurement points of different levels of health risk, as behavioral intentions may have remained stable, but actually seeking medical care may have increased throughout the emerging phase of the pandemic as it coincided with the flu season, thus natural increases in seeking medical care while the study was being conducted could have been assumed. Hence, changes in protective behavior intentions can be more directly attributed to the changes in health risk.

In a similar vein, Chapter 4 did not assess healthy eating objectively but rather assessed self-reported healthy eating with a single item, although eating behavior is very complex (Renner, Sproesser, Strohbach, & Schupp, 2012). Assessing eating behavior with a single item does not allow the complexity of the behavior to be captured. Likewise, by not capturing the complexity, the measure may presumably be rather insensitive to change. Future research should assess the complex behavior of healthy eating in a more detailed manner when investigating relative and adaptive accuracy, e.g., by applying the food frequency questionnaire (FFQ; Winkler & Döring, 1995). However, assessing healthy eating through self-reports is crucial for the study and thus should be maintained, as lower risk perceptions are assumed after a perceived change but not after an actual change that is not perceived (Brewer et al., 2004; Renner et al., 2008). Nevertheless, future research could also capture actual behavior to further elaborate on the dynamic interplay between health risk, perceived risk, and protective behaviors.

## **Conclusion**

In conclusion, the findings of the present dissertation emphasize that people generally respond reasonably to changing health risks by modifying their risk perception and protective behavior intentions accordingly. Furthermore, the occurrence of changes in perceived risk after changes in self-reported protective behavior further emphasizes the dynamic nature of perceived risk. Overall, the findings of this dissertation provide an initial starting point for further research, which could assess all the interrelations of the dynamic interplay between health risk, perceived risk, and protective behaviors to gain a more comprehensive understanding of them. The further investigation of this interplay may contribute to a stronger focus on reciprocal relationships and dynamics across time, which may in turn foster the

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development of models and theories in health psychology that emphasize dynamics and reciprocal interrelations.

## List of Contributions

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In the following, contributions are detailed based on the criteria suggested by the International Committee of Medical Journal Editors (ICMJE; <http://www.icmje.org/>).

For Chapter 2, BR designed the study. BR collected the data for waves 2006 and 2009; Nadine C. Lages (NCL), Luka J. Debbeler (LJD), Josianne Kollmann (JK), and BR for waves 2016 and 2018. NCL, BR, and HTS analyzed the data and drafted the manuscript with input from LJD, JK, Hermann Szymczak (HS), and Michael Blumenschein (MB). MB adapted the visualization tool for the data with input from NCL, LJD, Daniel A. Keim (DAK), HTS, and BR.

For Chapter 3, BR and Julia E. Koller (JEK) developed the questionnaire with critical input from Isabel Brünecke (IB), Kai D. Engel (KDE), Sofia Griebler (SG), Peer C. Homann (PCH), Robin Kaufmann (RK), Kim M. Koppe (KMK), Vanessa C. Radtke (VCR), Sarah Rogula (SR), and Johanna Stähler (JS). All authors carried out the data collection under supervision of BR, JEK, and HTS. NCL and Karoline Villinger (KV) conducted the data analyses with critical input from JEK, HTS, and BR. The manuscript draft was prepared by NCL, KV, JEK, and HTS and finalized with critical input from BR and comments from all authors.

For Chapter 4, HTS and BR designed the Konstanz Life-Study and developed the questionnaire. NCL conducted the data analyses with critical input from BR. The

manuscript draft was prepared by NCL with significant input from BR and comments from JK.

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*„Hinffllen. Aufstehen. Kroner. Weitergehen. [sic]“ P. B.*

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