Warnung der Bevölkerung: Untersuchung von Risikowahrnehmung vor dem Hintergrund des Protective Action Decision Model

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Abkürzungen

BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe
EPPM	Extended Parallel Process Model
PADM	Protective Action Decision Model
PMT	Protection Motivation Theory

Inhalt

Abstract

Hazards such as severe storms, terrorist attacks, or the COVID-19 pandemic are present and future perils to our society. In case of these and other threats, warnings can prevent damage and save lives by informing the recipients and communicating protective measures. The Protective Action Decision Model (PADM) (Lindell & Perry, 2012) provides a theoretical framework that maps the processing of warnings and the emergence of protective behavior. Among others, the PADM includes the perception of risk as a pivotal factor. However, in terms of the model and existing literature, risk perception is often represented exclusively cognitive. Moreover, studies predominantly examine single types of hazards or singular events.

The Ph.D. thesis investigates the processing of warnings with one experimental and three observational studies. The studies examined the impact of warning messages on cognitive and affective aspects of risk perception and their subsequent role in determining information seeking and compliance intentions. Via online surveys, participants received warning messages addressing various threats (severe weather, major fire, acts of violence, breakdown of emergency number, discovery of a World War II bomb, COVID-19 pandemic, thunderstorm), which comprised information about the threat and recommendations for action. Risk perception was assessed before and after receiving the warning, as well as the intention to follow the protective measures given in the warning or to seek information. In addition, characteristics of the warning recipients were assessed.

The results support the role of affective risk perception in the processing of warnings, the emergence of protective behavior, and information seeking. However, this does not apply equally to all hazards, emphasizing the role of hazard characteristics, such as frequency of occurrence or severity. Likewise, no consistent pattern emerged regarding the characteristics of the warning recipients. Based on the results, an extension of the PADM to include affective risk perception is proposed.

Further research on warnings should aim at a multifaceted view of risk perception. Hazards should be comparatively investigated. Moreover, hazard and warning characteristics should be systematically varied.

Zusammenfassung

Gefahrenlagen, wie schwere Unwetter, Terroranschläge oder die COVID-19-Pandemie, stellen aktuell und zukünftig eine Bedrohung unserer Gesellschaft dar. Im Fall dieser und weiterer Gefahren können Warnungen helfen, Schäden zu verhindern und Menschenleben zu retten, indem sie die Empfänger*innen informieren und Schutzmaßnahmen vermitteln. Das Protective Action Decision Model (PADM) (Lindell & Perry, 2012) bietet einen theoretischen Rahmen, der Verarbeitungsprozesse von Warnungen und die Entstehung von Schutzverhalten abbildet. Neben zahlreichen weiteren Elementen beinhaltet das PADM die Wahrnehmung von Risiko als zentralen Faktor. Im Sinne des Modells sowie bereits existierender Literatur wird Risikowahrnehmung jedoch häufig ausschließlich kognitiv abgebildet. Zudem untersuchen Studien vorwiegend einzelne Gefahrenlagentypen oder singuläre Ereignisse.

Die vorliegende Arbeit bildet mit drei Beobachtungsstudien sowie einer experimentellen Studie Verarbeitungsprozesse von Warnungen vor verschiedenen Gefahrenlagen ab. Untersucht wurde der Einfluss der Warnungen auf kognitive und affektive Facetten der Risikowahrnehmung und ihre Rolle bei der Suche nach Informationen sowie der Intention, Schutzverhalten auszuführen. Über Online-Befragungen erhielten die Teilnehmenden Warnungen zu verschiedenen Gefahrenlagen (schweres Unwetter, Großbrand, extreme Gewalttat, Ausfall der Notrufnummer, Fund einer Weltkriegsbombe, COVID-19-Pandemie, Gewitter), die Informationen zur Gefahr sowie Handlungsempfehlungen enthielten. Befragt wurden sie unter anderem hinsichtlich ihrer Risikowahrnehmung vor und nach Warnerhalt sowie ihrer Intention, die angegebenen Schutzmaßnahmen zu befolgen oder sich Informationen zu suchen. Zudem wurden Eigenschaften der Warnungsempfänger*innen erhoben.

Die Ergebnisse stärken die Rolle affektiver Risikowahrnehmung für die Verarbeitung von Warnungen sowie die Entstehung von Schutzverhalten und Informationssuche. Dies gilt jedoch nicht für alle Gefahrenlagen gleichermaßen, sodass der Einfluss von Eigenschaften der Gefahr, wie Häufigkeit oder Schweregrad, deutlich wird. Bezüglich der Eigenschaften der Empfänger*innen ergab sich ebenfalls kein einheitliches Bild. Basierend auf den Ergebnissen wird eine Erweiterung des PADM um ein Modellelement der affektiven Risikowahrnehmung vorgeschlagen.

Fortführende Forschung zu Warnungen sollte eine multifacettierte Sichtweise von Risikowahrnehmung anstreben. Darüber hinaus sollten Gefahrenlagen vergleichend untersucht und ihre Eigenschaften sowie Eigenschaften der Warnungen systematisch variiert werden.

Übersicht der Dissertationsstudien

Studie 1: Einfluss von Warnerhalt, Gefahrenlagentyp und Eigenschaften der Warnungsempfänger*innen auf Risikowahrnehmung

Rahn, M., Tomczyk, S. & Schmidt, S. (2021). Storms, Fires, and Bombs: Analyzing the Impact of Warning Message and Receiver Characteristics on Risk Perception in Different Hazards. *Risk Analysis*, *41*(9), 1630–1642. https://doi.org/10.1111/risa.13636

Studie 2: Einfluss von Risikowahrnehmung, Gefahrenlagentyp und Eigenschaften der Warnungsempfänger*innen auf Schutzverhalten

Rahn, M.*, Tomczyk, S.*, Schopp, N. & Schmidt, S. (2021). Warning Messages in Crisis Communication: Risk Appraisal and Warning Compliance in Severe Weather, Violent Acts, and the COVID-19 Pandemic. *Frontiers in Psychology*, *12.* [* shared first authorship] https://doi.org/10.3389/fpsyg.2021.557178

Studie 3: Einfluss von Risikowahrnehmung und Eigenschaften von Warnungsempfänger*innen auf Schutzverhalten im Fall der COVID-19-Pandemie

Tomczyk, S., Rahn, M. & Schmidt, S. (2020). Social Distancing and Stigma: Association Between Compliance With Behavioral Recommendations, Risk Perception, and Stigmatizing Attitudes During the COVID-19 Outbreak. *Frontiers in Psychology*, *11*, 1821. https://doi.org/10.3389/fpsyg.2020.01821

Studie 4: Einfluss von Warnerhalt, Konfrontation mit der Gefahrenlage und Präsentationsformat auf Risikowahrnehmung sowie Informationssuche im Fall eines Gewitters

Tomczyk, S.*, Rahn, M.*, Markwart, H. & Schmidt, S. (2021). A Walk in the Park? Examining the Impact of App-Based Weather Warnings on Affective Reactions and the Search for Information in a Virtual City. *International Journal of Environmental Research and Public Health*, *18*(16). [* shared first authorship] https://doi.org/10.3390/ijerph18168353

1 Einleitung

Terroranschläge, Flutkatastrophen, oder die COVID-19-Pandemie – dies sind nur einige Gefahrenlagen, die seit dem Jahrtausendwechsel zunehmend in das Bewusstsein der Bevölkerung gelangt sind. Somit steigen seit einigen Jahren die Bedarfe nach zeitgerechter und effektiver Warnung der betroffenen Bevölkerung vor ebensolchen Gefahrenlagen, um Schäden vorzubeugen oder zu reduzieren und Handlungsfähigkeit zu erhalten. Es eröffnet sich das im internationalen Vergleich in Deutschland bislang wenig erforschte Feld der Bevölkerungswarnung. Aus aktuellen Beispielen wird die Bedeutung und Tragweite des Feldes für die Gesundheit und Sicherheit der Bevölkerung deutlich:

Durch menschliches Versagen wurde im Januar 2018 während einer Übung der Katastrophenschutzbehörde EMA im US-Bundesstaat Hawaii eine Warnung über Mobilfunk an die Bevölkerung adressiert, die vor einem kurz bevorstehenden Raketenangriff warnte und sie aufforderte, umgehend Schutz zu suchen (Murthy et al., 2019). Dies hatte auch Tage später noch Auswirkungen auf das psychische Wohlbefinden der betroffenen Bevölkerung (Jones & Silver, 2020).

Ebenfalls im Jahr 2018 versendete das Land Schweden eine zwanzigseitige Broschüre („*If Crisis or War Comes*“) an alle schwedischen Haushalte, mit dem Ziel, diese über mögliche Gefahren zu informieren (Petridou et al., 2019; Swedish Civil Contingencies Agency, 2018). Inhalt der Broschüre waren Erläuterungen zu Vorsorge- und Schutzmaßnahmen, wie sie im Fall von Kriegen, Terroranschlägen oder Hackerangriffen notwendig werden.

Nicht zuletzt stellt die COVID-19-Pandemie spätestens seit 2020 eine potentielle Bedrohung für den europäischen Raum dar, welche die Aktualität und Notwendigkeit von Warnungen beweist (Schilling et al., 2021). Aus dieser Pandemie, die bereits am 18. März 2020 in einer Fernsehansprache der damaligen Bundeskanzlerin Angela Merkel als eine der größten Herausforderungen seit dem Zweiten Weltkrieg bezeichnet wurde, resultierte unter anderem die Entwicklung der Corona-Warn-App (Bundesregierung, 2021a, 2021b) sowie eine verstärkte Diskussion über Stand, Chancen und Risiken der Digitalisierung in Deutschland.

Inhaltlich mögen die hier aufgeführten Beispiele divergieren, doch haben sie eines gemeinsam: Sie zeigen auf, dass die Warnung der Bevölkerung in verschiedenen Kontexten zunehmend an Relevanz gewinnt. Dementsprechend wichtig ist es, zu verstehen, wie Warnungen von ihren Empfänger*innen wahrgenommen und verarbeitet werden, um sie in Zukunft effektiv

gestalten zu können. Die vorliegende Arbeit befasst sich deswegen mit der Warnung der Bevölkerung vor verschiedenen Gefahrenlagen und im Speziellen mit Verarbeitungsprozessen auf der Seite der Warnungsempfänger*innen. Vor dem Hintergrund empirisch und theoretisch fundierter Modelle und Ansätze der Warnung, insbesondere des *Protective Action Decision Model* (PADM) (Lindell & Perry, 2003, 2012), umfasst die Dissertation vier empirische Studien, die die Bedeutung der Warnung für individuelles Erleben und Verhalten experimentell sowie observational untersuchen.

2 Warnung vor Gefahrenlagen: Definition und Relevanz

Das Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) beschreibt die Warnung der Bevölkerung als die „Information der Bevölkerung über drohende Gefahren und/oder akute Schadensereignisse inklusive Handlungsempfehlungen“ (BBK, 2019, S. 57). Zu Gefahren zählen all diejenigen Zustände, Umstände oder Vorgänge, die Schäden verursachen können (BBK, 2019, S. 22) und die während einer Gefahrenlage auf „einen bestimmten Raum zu einer bestimmten Zeit einwirken“ (BBK, 2019, S. 24). Die Herausgabe von Warnungen vor Gefahrenlagen erfolgt dabei durch öffentliche Behörden und Organisationen, wie etwa die Polizei, Feuerwehr, Leitstellen oder den Deutschen Wetterdienst (Hofinger et al., 2020).

Aus der Definition des BBK geht ein mindestens zweigeteilter Aufbau von Warnungen hervor, der sich so auch in der internationalen Warnungsliteratur wiederfindet (Mayhorn & McLaughlin, 2014; Mileti & Peek, 2000). Warnungen bestehen demnach zum einen aus Informationen zur Gefahrenlage und zum anderen aus Hinweisen, Empfehlungen oder Anweisungen zu möglichem Schutzverhalten, das Schäden abwenden oder minimieren kann. Weitere inhaltliche Elemente, welche zur Beschreibung einer Gefahrenlage hinzugezogen werden können, sind beispielsweise die Angabe eines Herausgebers beziehungsweise der Quelle der Information, Ort und zeitlicher Rahmen der Gefahr, Angaben zum betroffenen Personenkreis sowie Begründungen, warum empfohlene Maßnahmen ausgeführt werden sollten (Kuligowski, 2011; Kuligowski & Dootson, 2019; Mayhorn & McLaughlin, 2014; Mileti & Sorensen, 1990).

Die inhaltlichen Elemente einer Warnung müssen entsprechend der jeweiligen Gefahr angepasst werden (Drabek, 1999; Sorensen, 2000). Dabei lässt die Betrachtung einzelner Gefahrenlagen schnell klarwerden, dass dem Begriff eine extreme Variation inhärent ist. Diese ergibt sich unter anderem aus verschiedenen Charakteristika wie der Schwere, der Häufigkeit oder der Vorhersehbarkeit des Auftretens (Quarantelli, 2000). Zu Gefahrenlagen gezählt werden unter anderem Naturkatastrophen (z. B. Unwetter, Dürren) sowie menschengemachte (z. B. Terroranschläge, Verteidigungsfälle), technologische (z. B. Nuklearfälle) oder biologische (z. B. Pandemien) Ereignisse und Katastrophen (Kuipers & Welsh, 2017; Mileti, 1999).

Die Relevanz und Aktualität der Thematik wird deutlich, blickt man auf die Schäden, die mit Gefahrenlagen assoziiert sind. Im Jahr 2018 verursachten Naturereignisse, wie Überflutungen, Wildbrände und Stürme, weltweit monetäre Schäden in Höhe von über 132 Milliarden US-Dollar und kosteten darüber fast 12.000 Menschen das Leben (Centre for Research on the Epidemiology of Disasters, 2019). Durch über 8.300 offiziell erfasste terroristische Anschläge starben 2019 mehr als 28.000 Menschen weltweit (Statista, 2021). Die seit dem Jahr

2019 fortwährende COVID-19-Pandemie übersteigt diese Zahl an Todesopfern um ein Vielfaches. Bis Anfang Mai 2021 erkrankten weltweit über 154.000.000 Personen nachgewiesen an COVID-19, von denen mehr als 3.200.000 verstarben (World Health Organization, 2021, Stand 06.05.2021). Im Juli 2021 verstarben mindestens 180 Menschen bei dem Jahrhunderthochwasser in Rheinland-Pfalz und Nordrhein-Westfalen, das neben den Todesopfern Versicherungsschäden von 4,5 bis 5,5 Milliarden Euro verursachte (Bundeszentrale für politische Bildung, 2021). Im Nachgang dieser Katastrophe entstand ein wissenschaftlicher und medialer Diskurs über die zeitgerechte und effektive Warnung der Bevölkerung (Fekete & Sandholz, 2021; tagesschau, 2021; Wolf, 2021).

Sei es im Fall von Pandemien oder Flutkatastrophen – zur Rettung von Menschenleben, der Vermeidung oder Minimierung menschlichen Leids sowie materieller und finanzieller Schäden leisten Warnungen vor Gefahrenlagen einen maßgeblichen Beitrag (Mayhorn & McLaughlin, 2014). Nicht zuletzt deswegen gelangte die Thematik in den vergangenen Jahrzehnten zunehmend in den Fokus der internationalen empirischen Forschung. Beforscht werden beispielsweise die Entwicklung und Evaluation von (Früh-)Warnsystemen (Garcia & Fearnley, 2012; Lowe et al., 2011; Pursiainen & Francke, 2008; Sorensen, 2000) oder Aspekte der Gestaltung effektiver Warnungen (Bean et al., 2015; Mayhorn & McLaughlin, 2014; Omori et al., 2017; Potter et al., 2018; Weyrich et al., 2018). Die Untersuchung menschlichen Erlebens und Verhaltens im Zusammenhang mit Gefahrenlagen und Warnungen inklusive ablaufender Prozesse gewinnt dadurch ebenfalls an Bedeutung (Drabek, 1999; Mileti & Peek, 2000; Omori et al., 2017). Die Verarbeitungsprozesse auf der Seite der Warnungsempfänger*innen lassen sich anhand verschiedener Theorien schematisieren.

3 Informationsverarbeitung von Warnungen

Im folgenden Abschnitt soll zunächst das *Protective Action Decision Model* (PADM) (Lindell & Perry, 2003, 2012) als spezifisch für den Warnungskontext entwickeltes Prozessmodell beschrieben und hinsichtlich seiner Stärken und Schwächen diskutiert werden.

3.1 Protective Action Decision Model

Das PADM wurde für Warnungskontexte entwickelt und unter anderem im Zusammenhang mit Naturkatastrophen, technologischen Bedrohungen und Evakuierungen untersucht (Apatu et al., 2012; Heath et al., 2018; K. Strahan & Watson, 2019; Terpstra & Lindell, 2013). Es beschreibt mehrstufige Prozesse der Informationsverarbeitung im Fall von kurz- oder langfristigen Bedrohungen und Gefahren bis hin zur Ausführung von Schutzhandlungen (Abb. 1, adaptiert nach Lindell und Perry (2012)). Damit besitzt das PADM Bezüge zu allgemein- und gesundheitspsychologischen Modellen der Informationsverarbeitung und Handlungskontrolle, wie der Theorie der Schutzmotivation (*Protection Motivation Theory*, PMT) (Prentice-Dunn & Rogers, 1986), dem Erweiterten Modell der Parallelen Prozesse (*Extended Parallel Process Model*, EPPM) (Popova, 2012, 2020; Witte, 1994) oder der Affektheuristik (Finucane et al., 2000; Slovic et al., 2007). Ebenjene Modelle werden in Kapitel 3.2.1 genauer beschrieben.

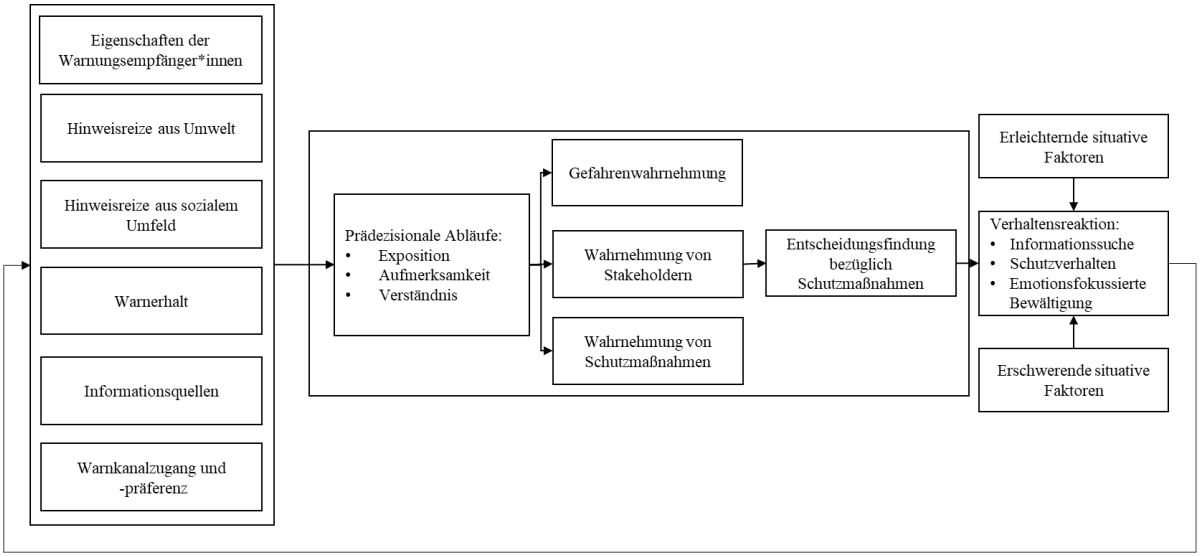

Abb. 1: Protective Action Decision Model, adaptiert nach Lindell und Perry (2012)

Im PADM werden zunächst kontextabhängige Faktoren betrachtet, zu denen auch der Erhalt von Warnungen gezählt wird. Es werden Hinweisreize aus der Umwelt und dem sozialen Umfeld sowie Eigenschaften der Warnungsempfänger*innen, Informationsquellen, Warnkanalzugang und Warnkanalpräferenzen in das Modell inkludiert. Einzeln genommen oder in der

Summe können der Erhalt von Warnungen, Informationen aus dem sozialen Umfeld und Hinweisreize aus der Umwelt psychologische Prozesse in Gang setzen. Zu diesen zählen wiederum prädezisionale Abläufe, dezisionale Kernwahrnehmungen sowie die Entscheidungsfindung bezüglich Schutzmaßnahmen. Zu den prädezisionalen Abläufen gehören Exposition, Aufmerksamkeit und Verständnis bezogen auf die Hinweisreize oder die Warnung. Erhält eine Person also eine Warnung vor einer Gefahrenlage, versteht diese und nimmt die Gefahr auch als solche wahr, wird sie in der Folge einschätzen, inwiefern sie selbst von der Gefahr betroffen ist (Gefahrenwahrnehmung), welche Stakeholder (etwa soziale Kontakte oder warnende Institutionen) beteiligt sind und welche Schutzmaßnahmen ihr zur Verfügung stehen. Dies wiederum mündet in die Entscheidungsfindung für oder gegen die Ausführung von Schutzverhaltensweisen. Zu den möglichen Verhaltensreaktionen zählen die Suche nach weiteren Informationen, die Ausführung schützender Handlungen (problemfokussierte Bewältigung) oder emotionsfokussierte Bewältigung. Situative Faktoren können die Ausführung erschweren, aber auch erleichtern. Zudem können Feedbackschleifen die im Modell beschriebenen, mehrstufigen Abläufe erneut in Gang setzen.

Das Modell liefert mit dieser komplexen Betrachtung verschiedener Komponenten Erklärungs- und Anwendungsmöglichkeiten für effektive Risikokommunikation im Fall von Gefahrenlagen. Die Wahrnehmung von Gefahren und die Planung beziehungsweise Ausführung von Schutzverhalten sind dementsprechend zentrale Elemente des Modells. Risikowahrnehmung findet sich in der Komponente der Gefahrenwahrnehmung wieder und setzt sich aus der Einschätzung der Auftretenswahrscheinlichkeit und den persönlichen Konsequenzen für die betroffene Person zusammen. Entsprechend des PADM müssen Warnungsempfänger*innen also zunächst abwägen, ob es sich um eine reale Bedrohung handelt und, ob sie hiervon auch betroffen sind, bevor Schutzmaßnahmen geplant und ausgeführt werden (Lindell & Perry, 2012).

In der Risiko- und Warnungsforschung existieren zahlreiche Befunde, die sich auf einzelne Aspekte des PADM im Zusammenhang mit Risikowahrnehmung und Schutzverhalten beziehen. Dem Aufbau des Modells folgend, werden einige dieser Befunde zu den Komponenten, die im empirischen Teil der Arbeit untersucht werden, vorgestellt. Hierzu zählen Eigenschaften von Warnungsempfänger*innen, Hinweisreize aus der Umwelt, der Erhalt von Warnungen selbst, Gefahrenwahrnehmung sowie mögliche Verhaltensreaktionen.

3.1.1 Eigenschaften der Warnungsempfänger*innen

Das PADM betrachtet die Eigenschaften derjenigen Personen, die von einer Gefahr beziehungsweise Warnung betroffen sind, als kontextuelle Faktoren. Hierzu zählen physiologische, psychomotorische, ökonomische, soziale, aber auch kognitive Aspekte, die Einfluss darauf nehmen, ob und wie eine Person auf eine Warnung oder Gefahr reagiert (Lindell & Perry, 2012). Neben zahlreichen weiteren Faktoren sind Geschlecht, Alter und Vorerfahrung häufig Bestandteil empirischer Untersuchungen.

In einer Untersuchung zum PADM zeigte sich beispielsweise, dass Frauen die Gefahr von Fluten als höher und Schutzmaßnahmen hiervor als effektiver einstuften als Männer (Terpstra & Lindell, 2013). Dass Männer Risiken als geringer wahrnehmen, erbrachten auch allgemein- und gesundheitspsychologische Studien sowie Untersuchungen zu verschiedenen Gefahrenlagen wie Pandemien oder Stürmen (Bateman & Edwards, 2002; Bish & Michie, 2010; Figner & Weber, 2011; Flynn et al., 1994; Ho et al., 2008; Kellens et al., 2011; Kwok et al., 2020; Savage, 1993; Zwart et al., 2009). Demgegenüber stehen Untersuchungen, die keinen Zusammenhang mit dem Geschlecht finden konnten, sodass die Befundlage als diskutabel zu betrachten ist (Greenberg & Schneider, 1995; Olofsson & Rashid, 2011). Bezüglich der Ausführung von Schutzverhalten zeigten Untersuchungen zu respiratorischen Erkrankungen, dass Frauen tendenziell häufiger Maßnahmen planten und ergriffen (Bish & Michie, 2010; Leung et al., 2003; Tang & Wong, 2003).

Auch das Alter einer Person hat maßgeblichen Einfluss auf beinahe alle im PADM beschriebenen Modellkomponenten (Mayhorn, 2005). Ein höheres Alter ist dabei häufig assoziiert mit gesteigerter Risikowahrnehmung (Kellens et al., 2011), der Ausführung von Schutzverhalten (Bish & Michie, 2010) sowie dem Befolgen von Warnungen (Perry & Lindell, 1997; Potter et al., 2018).

Die bereits bestehende Vorerfahrungen mit Gefahren findet als Eigenschaft der Warnungsempfänger*innen ebenfalls im PADM Beachtung (Lindell & Perry, 2012). Hierbei kann es sich um eigene Erfahrungen mit einer Gefahrenlage sowie erlittene Schäden handeln, aber auch um Erfahrungen, die Angehörige, Freunde oder Bekannte gemacht haben (Ge et al., 2011; Lindell & Hwang, 2008; Weinstein, 1989). Die Zusammenhänge von Vorerfahrung mit wahrgenommenen Risiken und der Ausführung von Schutzverhalten scheinen ambivalent: So wurde beispielsweise in Studien zu verschiedenen Gefahrenlagen, wie Naturkatastrophen und menschengemachten Gefahren, ein positiver Zusammenhang zwischen Vorerfahrung, erlittenen Schäden und Risikowahrnehmung sowie der Ausführung von Schutzhandlungen gefunden

(Armstrong & Towery, 2021; Frondel et al., 2017; Ho et al., 2008; Hong et al., 2019; Kox & Thieken, 2017; Lujala et al., 2015; Olofsson & Rashid, 2011; Sattler et al., 2000; Scolobig et al., 2012). Wachinger et al. (2013) zeigten in ihrer Übersichtsarbeit zu Naturkatastrophen jedoch, dass auch gegenläufige Assoziationen möglich sind. Hiernach kann die entsprechende Vorerfahrung zwar mit höherer Risikowahrnehmung assoziiert sein. Dieser Zusammenhang muss aber nicht zwangsläufig zur Ausführung von Schutzverhalten führen und kann im Sinne des Risikoparadoxes (*risk perception paradox*), also der fehlenden Ausführung entsprechender Handlungen bei gleichzeitig hoher Risikowahrnehmung, interpretiert werden. Die Autoren weisen auf die Rolle weiterer, intervenierender Variablen wie Motivation, Vertrauen, Verantwortung und individuelle Fähigkeiten der betroffenen Personen hin, welche der Ausführung von Schutzhandlungen entgegenwirken können.

3.1.2 Hinweisreize aus der Umwelt

Das PADM beschreibt Eigenschaften von Gefahrenlagen, die zum Beispiel auf technologischen, meteorologischen oder geophysikalischen (Entstehungs-)Prozessen basieren. Aus diesen Prozessen resultieren Merkmale der jeweiligen Gefahr, wie ihre Häufigkeit, Geschwindigkeit und Dauer ihres Auftretens oder der Umfang ihrer Auswirkungen (Lindell & Perry, 2012; Tierney et al., 2001). Auch die Art und Weise, wie eine Gefahrenlage für die betroffenen Personen erkennbar wird, fällt hierunter. So kann neben dem Erhalt einer Warnung oder sozialer Hinweisreize die Wahrnehmung von Hinweisreizen aus der Umwelt die beschriebenen Prozesse initiieren (Kuligowski, 2013; Lindell & Perry, 2012). Zu Hinweisreizen aus der Umwelt gehören visuelle, olfaktorische und auditive Reize – etwa das Sehen und Riechen von Rauch oder das Hören von Sirenen im Fall eines Brandes. Im Fall bestimmter Gefahren können diese Reize eindeutig erkenn- und interpretierbar sein (z. B. bei Blitzeinschlag und Donner bei Gewittern), während andere Reize mehrdeutig sind und fehlinterpretiert werden können (z. B. laute Knallgeräusche bei Explosionen, Schüssen oder Unfällen) (Lindell & Perry, 2012).

Nehmen die betroffenen Personen entsprechende Hinweisreize wahr, werden diese interpretiert und mit bereits bestehenden Überzeugungen und Kenntnissen abgeglichen. Die Wahrnehmung von Reizen aus der Umwelt nimmt so Einfluss auf die Risikowahrnehmung, ebenso wie die Ausführung von Schutzverhalten. Dies zeigte sich unter anderem für Evakuierungsverhalten im Fall von Wildfeuern, Hurrikans und Überflutungen (Dash & Gladwin, 2007; Fujimi & Fujimura, 2020; Huang et al., 2017; Lindell et al., 2005; McCaffrey et al., 2018). Der Zusammenhang muss dennoch mit Bedacht betrachtet werden, da die Wahrnehmung eines Rei-

zes (z. B. von Rauch und Flammen bei Bränden) auch dazu führen kann, dass betroffene Personen vorerst abwartend reagieren, um beispielsweise Eigentum zu schützen oder das Ausmaß der Gefahr abzuschätzen, bevor sie Evakuierungsmaßnahmen ausführen (McCaffrey et al., 2018; McLennan et al., 2012; Whittaker et al., 2013).

3.1.3 Warnerhalt

Wie auch die Wahrnehmung sozialer oder umweltbezogener Hinweisreize, wird der Erhalt einer Warnung im PADM als kontextabhängiger Faktor betrachtet, der Informationsverarbeitungsprozesse initiieren kann und idealerweise die adäquate Ausführung von Schutzverhalten bewirkt. Dafür müssen Warnungen, die im Regelfall aus Informationen zur Gefahrenlage sowie Handlungsempfehlungen bestehen, zunächst im Sinne der prädezisionalen Abläufe von den betroffenen Personen empfangen, wahrgenommen und verstanden werden (Lindell & Perry, 2012; Omori et al., 2017; Sutton & Kuligowski, 2019). Hierauf folgend finden die im Modell beschriebenen Kernwahrnehmungen sowie Prozesse bezüglich der Entscheidungsfindung statt. Nach dem Erhalt einer Warnung wird eine Person also einschätzen, ob und inwiefern sie von der Gefahrenlage betroffen ist, ob und welche Schutzhandlungen existieren und welche Stakeholder beteiligt sind, bevor eine Schutzhandlung intendiert und ausgeführt wird. All diese Prozesse geschehen wiederum in Abhängigkeit von den Eigenschaften und Fähigkeiten der Warnungsempfänger*innen (Lindell & Perry, 2012; Mayhorn, 2005).

Insgesamt kann der Erhalt einer Warnung dazu führen, dass Gefahrenlagen schneller erkannt, die Risikowahrnehmung erhöht und Schutzverhaltensweisen dementsprechend früher geplant sowie umgesetzt werden. Dies konnte für zahlreiche Gefahrenlagen wie Gewitter, Wildbrände, Hitzewellen oder Tsunamis gezeigt werden (Kalkstein & Sheridan, 2007; Markwart et al., 2019; K. W. Strahan et al., 2019; Sutton & Woods, 2016). Somit tragen Warnungen direkt dazu bei, dass Schäden verschiedenster Art verhindert oder minimiert werden können.

3.1.4 Gefahrenwahrnehmung

Die Gefahrenwahrnehmung entspricht im PADM einer der drei dezisionalen Kernwahrnehmungen. Sie setzt sich zusammen aus der Wahrscheinlichkeit des Eintretens der Gefahr sowie den daraus resultierenden Konsequenzen. Warnungsempfänger*innen müssen also zunächst eruieren, ob ein Risiko für sie relevant ist und ob dieses Auswirkungen für sie persönlich hat. Letztere können – je nach Bedrohung – in ihrem Ausmaß variieren (z. B. Unterbrechung alltäglicher Aktivitäten bis hin zu materiellen Schäden, Verletzung oder Tod) (Lindell & Perry, 2012; Sutton & Kuligowski, 2019). Faktoren wie die Unmittelbarkeit des Ereignisses, aber auch

die Bekanntheit, das Ausmaß an Intrusion oder die räumliche Nähe können darüber hinaus relevant für die Gefahrenwahrnehmung sein (Lindell & Hwang, 2008; Lindell & Perry, 2012).

Wenngleich sich auch Unterschiede in der Operationalisierung von Gefahrenwahrnehmung finden, wird dieser Begriff im PADM sowie in Studien häufig mit der Bezeichnung Risikowahrnehmung (*risk perception*) gleichgesetzt (Lindell & Perry, 2012; Wang et al., 2018). Für zahlreiche Gefahrenlagen, wie Überflutungen, Stürme oder respiratorische Erkrankungen, konnte ein Zusammenhang zwischen einer erhöhten Gefahren- beziehungsweise Risikowahrnehmung und der Ausführung von Schutzverhalten festgestellt werden (Lindell, 2013; Lindell & Hwang, 2008; Terpstra & Lindell, 2013; Wang et al., 2018). Aber auch hier existieren Befunde, die vielmehr die Rolle der verbleibenden zwei beiden Kernwahrnehmungen (Wahrnehmung von Stakeholdern sowie Schutzmaßnahmen) und soziodemographischer Faktoren betonen, oder auch keinen Zusammenhang von Gefahrenwahrnehmung und der Ausführung von Schutzmaßnahmen fanden (Heath et al., 2018; Lindell, 2013; Perry & Lindell, 2008; Scovell et al., 2021).

3.1.5 Entscheidungsfindung und Verhaltensreaktionen

Neben der Abbildung psychologischer Prozesse innerhalb von Warnungsempfänger*innen ist das Ziel des PADM die Erklärung und Vorhersage von Verhaltensreaktionen. Auf die prädezisionalen Prozesse sowie die drei Kernwahrnehmungen folgen im PADM eine Reihe kognitiver Verarbeitungsschritte, bevor es zu der tatsächlichen Umsetzung eines Verhaltens kommt. Die betroffenen Personen setzen sich – aufbauend auf der Gefahrenwahrnehmung – mit ihrem persönlichen Risiko auseinander (*risk identification* und *risk assessment*), indem sie eruieren, ob sie von der Gefahr betroffen sind und ob diese eine Handlung erfordert (Lindell & Perry, 2012). Danach beginnt die Suche und Bewertung möglicher Verhaltensreaktionen, zu denen im Idealfall Schutzverhalten zählt. Wurden eine oder mehrere Verhaltensreaktionen in Erfahrung gebracht und als sinnvoll bewertet, findet die Planung des entsprechenden Verhaltens statt, wobei Ausmaß und Spezifität der Planung variieren können. Nach erfolgreichem Abschluss dieser komplexen Prozesse folgt die Umsetzung der geplanten Verhaltensreaktionen. Zu ebensolchen Reaktionen zählen neben der emotionsfokussierten Bewältigung vor allem die Suche nach weiteren Informationen sowie Ausführung von Schutzverhalten. Letzteres kann beispielsweise erinnert (z. B. durch bereits bestehende Erfahrung), über Warnungen vermittelt oder durch den Austausch mit anderen Personen in Erfahrung gebracht werden. Liegen mehrere Schutzhandlungen vor, so kann abgewogen werden, ob und welche Maßnahmen (zuerst) ausgeführt werden (Lindell & Perry, 2012).

Informationssuche als Verhaltensreaktion kann innerhalb jeder Phase des PADM auftreten, insbesondere aber in jenen Situationen, die für betroffene Personen nicht eindeutig interpretierbar sind (Lindell & Perry, 2012; Sutton & Kuligowski, 2019). Dies ist möglicherweise der Fall, wenn lediglich ein Hinweisreiz aus der Umwelt wahrgenommen wurde (z. B. ein lauter Knall), aber keine weiteren Informationen zur Ursache oder dem erforderlichen Verhalten vorliegen. Ebenso kann Informationssuche dem Erhalt einer Warnung folgen, wenn die Empfänger*innen die Warnung verifizieren wollen, indem sie nach weiteren Warnungen und Informationsquellen suchen oder sich mit ihrem sozialen Umfeld austauschen (Mileti & Peek, 2000). Bestehende Unsicherheit (z. B. Unklarheiten bezüglich der Gefahrenursache) und negative Emotionen (z. B. Angst) können durch Informationssuche reduziert und Bewältigungsmöglichkeiten (z. B. über die Suche nach zusätzlichen Schutzmaßnahmen) gefördert werden (Sutton & Kuligowski, 2019; Sutton & Woods, 2016; Vihalemm et al., 2012). Dennoch kann die Suche nach Informationen in einem Phänomen münden, das im englischsprachigen Raum als *milling* bezeichnet wird. Milling beschreibt ebenjene auf Informationssuche oder soziale Austauschprozesse bezogenen Reaktionen, die letztlich das Ausführen der eigentlich erforderlichen Schutzhandlungen hinauszögern (Drabek, 1986; Wood et al., 2012; Wood et al., 2018).

3.1.6 Stärken und Schwächen des Protective Action Decision Model

Das PADM wurde unter Einbezug verschiedener Modellkomponenten und bezogen auf diverse Gefahrenlagen und Schutzhandlungen untersucht (Apatu et al., 2012; Heath et al., 2018; K. Strahan & Watson, 2019; Terpstra & Lindell, 2013). Die mitunter widersprüchlichen Befunde geben jedoch Hinweise auf mögliche Schwächen.

So bildet das Modell komplexe Prozesse der Informationsverarbeitung im Zusammenhang mit Gefahrenlagen ab. Das Rahmenmodell umfasst dabei eine Vielzahl an Komponenten und Aspekten, die in der Forschung und Anwendung bislang in unterschiedlichem, aber zunehmendem Ausmaß belegt wurden. Der Gehalt an empirischer Forschung zu den einzelnen Komponenten des PADM variiert jedoch stark, sodass sich – je nach Komponente – eine teilweise widersprüchlich oder weiter ausbaufähige Befundlage ergibt. Somit steht die weitere Prüfung der angenommenen, teilweise komplexen Zusammenhänge einzelner Modellkomponenten sowie eine metaanalytische Untersuchung des Modells noch aus (Heidenreich et al., 2020; Lindell & Perry, 2012).

Darüber hinaus betrachtet das PADM zwar Prozesse der Entscheidungsfindung und Umsetzung von Schutzverhalten, befasst sich aber nicht mit der dazwischenliegenden Ausbildung von Verhaltensintention als eigenständiger Modellkomponente. Die Intention gibt jedoch

Hinweise darauf, inwieweit Personen beabsichtigen, ebenjenes Verhalten auch tatsächlich auszuführen, und wird deshalb als zentraler Faktor beziehungsweise Prädiktor tatsächlich umgesetzten Verhaltens angesehen (z. B. Ajzen, 1991; Sheeran & Webb, 2016).

Weiterhin bietet das Modell eine eher kognitive Sicht auf warnassoziierte Prozesse, indem es Abläufe auf der Seite der Warnungsempfänger*innen im Sinne sukzessiv ablaufender, prädezisionaler und dezisionaler Phasen begreift. Risikowahrnehmung als eine zentrale Modellkomponente findet sich im PADM unter anderem im Rahmen der Gefahrenwahrnehmung sowie der Entscheidungsfindung (i. S. von *risk identification* und *risk assessment*) wieder. In jedem Fall wird Risikowahrnehmung kognitiv definiert – nämlich als Wahrscheinlichkeit des Eintretens und der persönlichen Auswirkungen der Bedrohung. Vereinzelte Befunde zu Gefahrenlagen sowie gesundheitspsychologische Studien geben jedoch Hinweise, dass diese vorwiegend kognitive Sichtweise gewinnbringend erweitert werden kann, in dem die Rolle von Affekt und Emotionen innerhalb der Informationsverarbeitungsprozesse mitbedacht wird (Noar et al., 2020; Terpstra, 2011; Yang & Yoon, 2021).

3.2 Informationsverarbeitung und Risikowahrnehmung

Risikowahrnehmung ist zentral für zahlreiche Theorien und Modelle sowie empirische Studien zur Informationsverarbeitung von Warnungen oder Gefahrenlagen (z. B. Potter et al., 2018; Shreve et al., 2016; Wachinger et al., 2013; Xue et al., 2014). Gleichwohl zeigt sich eine oft ambigue, teilweise widersprüchliche Befundlage zu Risikowahrnehmung und Schutzverhalten (z. B. Wachinger et al., 2013). Ein möglicher Grund hierfür könnte die unterschiedliche Operationalisierung des Konstrukts und die damit einhergehende variierende methodische Umsetzung sein: Die Operationalisierung von Risikowahrnehmung erfolgt häufig eher einseitig kognitiv – zum Beispiel über die Wahrscheinlichkeit des Eintretens einer Gefahr, die eigene Verletzlichkeit sowie den Schweregrad der Folgen (Brewer et al., 2007; Shreve et al., 2016).

Hingegen wird Affekt im Kontext von Risikowahrnehmung zum Beispiel von Slovic et al. (2007, S. 1333) als spezifischer Gefühlszustand gegenüber einem bestimmten Stimulus (z. B. einer Gefahr oder einer Warnung) betrachtet, der bewusst oder unbewusst erlebt, und als „gut“ oder „schlecht“ beschrieben werden kann. Affektive Risikowahrnehmung findet im Zusammenhang mit Gefahrenlagen häufig keine oder nur wenig Beachtung (Leppin & Aro, 2009; Wilson et al., 2019), besitzt in der psychologischen Forschung zur Handlungsmotivation im Kontext von Bedrohungen aber lange Tradition.

3.2.1 Affekt als Facette von Risikowahrnehmung – Theorien und Modelle

Die Theorie der Schutzmotivation (*Protection Motivation Theory*, PMT) (Prentice-Dunn & Rogers, 1986) hat ihren Ursprung in der Forschung zu Furchtappellen. Die PMT beschreibt zunächst kognitive Bewertungsprozesse: Informationen zu möglichen Gefahren (z. B. Warnungen) können Gefahreneinschätzungen (zusammengesetzt aus dem wahrgenommenen Schweregrad und der wahrgenommenen Verwundbarkeit) sowie Einschätzungen der eigenen Bewältigungsmöglichkeiten (zusammengesetzt aus Selbstwirksamkeit sowie Wirksamkeit schützender Handlungen) bewirken. Diese Einschätzungen führen zur Ausbildung einer Schutzmotivation und letztlich zur Ausführung adaptiver oder nicht-adaptiver Handlungen. Negative affektive Reaktionen – insbesondere Furcht – können indirekt über die Bedrohungseinschätzung auf die Ausbildung von Schutzmotivation einwirken, indem sie diese beispielsweise erhöhen (Gelbrich & Schröder, 2008; Heidenreich et al., 2020; Prentice-Dunn & Rogers, 1986).

Ein Modell, welches auf der PMT aufbaut und dabei die Rolle von Emotionen und Affekt weiter stärkt, ist das Erweiterte Modell der Parallelen Prozesse (*Extended Parallel Process Model*, EPPM) (Popova, 2012, 2020; Witte, 1994). Das EPPM differenziert ebenfalls zwischen kognitiven und affektiven Prozessen, die durch äußere Reize (z. B. Warnungen) initiiert werden. Bewusst ablaufende, kognitive Prozesse der Gefahreneinschätzung (i. S. wahrgenommenen Schweregrads und eigener Verwundbarkeit) und Wirksamkeitseinschätzungen (i. S. Selbstwirksamkeit und Wirksamkeit von Schutzhandlungen) beeinflussen die Wahrscheinlichkeit, dass Schutzmotivation ausgebildet und Schutzhandlungen ausgeführt werden. Nimmt eine Person eine Gefahr als relevant war, kann es im Sinne affektiver, automatisierter Prozesse zur Entstehung von Furcht kommen. Furcht wiederum kann die Gefahreneinschätzung bidirektional erhöhen und sich damit positiv auf die Ausbildung einer Schutzmotivation auswirken. Dennoch kann Furcht auch dazu führen, dass Schutzhandlungen unterlassen oder nicht-adaptive Handlungen ausgeführt werden. Dies ist beispielsweise Fall, wenn eine starke Furchtreaktion in Kombination mit niedrig eingeschätzter eigener Handlungsmöglichkeit besteht. Damit bietet das EPPM einen möglichen Erklärungsansatz, warum Furcht die Ausführung entsprechender Handlungen nicht nur fördern, sondern auch hindern kann (Gelbrich & Schröder, 2008; Popova, 2012, 2020; Witte, 1994).

Die Rolle affektiver Reaktionen im Zusammenhang mit Risikowahrnehmung sowie assoziiertem Verhalten wird weiterhin im Rahmen der Affektheuristik nach Slovic (Finucane et al., 2000; Slovic et al., 2004, 2007; Slovic & Peters, 2006) betrachtet. Die Affektheuristik ist eine Urteilsheuristik, welche zwei Systeme der Informationsverarbeitung unterscheidet: das

analytische und das intuitive System. Eine Information (z. B. Warnung) kann beispielsweise über das analytische System verarbeitet werden. Dabei laufen Prozesse der Bewertung und Entscheidungsfindung kognitiv, logisch und reflektiert ab, wodurch sie insgesamt mehr Zeit in Anspruch nehmen. Somit können weitere Informationen gesucht sowie Vor- und Nachteile (z. B. eines Schutzverhaltens) gegeneinander abgewogen werden. Eine Verarbeitung über das intuitive System hingegen ist affektgeleitet, damit automatisiert und insgesamt schneller. Die Aktivierung des intuitiven Systems und somit die Rolle von negativem Affekt in der Verarbeitung von Warnungen ist demnach vor allem dann relevant, wenn akute Bedrohungen bestehen und Entscheidungen unter Zeitdruck getroffen werden müssen.

3.2.2 Affekt als Facette von Risikowahrnehmung – empirische Befunde

Nicht nur aufgrund der eben genannten Theorien und Modelle lassen sich Hinweise für die wichtige Rolle des Affekts bei der Verarbeitung von Informationen zu Gefahren finden. Auch Untersuchungen aus dem gesundheitspsychologischen Kontext unterstützen die theoretisch angenommenen Zusammenhänge. Dies zeigte unter anderem eine Meta-Analyse von Sheeran et al. (2014) zu Risikowahrnehmung im Zusammenhang mit der Intention und Umsetzung von insgesamt 15 gesundheitsrelevanten Verhaltensweisen, wie sie zum Beispiel bei Alkohol- und Nikotinkonsum relevant sind. Die Autoren differenzierten vier Facetten beziehungsweise Komponenten der Risikowahrnehmung: wahrgenommene Wahrscheinlichkeit und wahrgenommener Schweregrad sowie antizipierte und antizipatorische Emotionen. Neben der Erhöhung einzelner Facetten durch spezifische Interventionen nahm vor allem eine kombinierte Erhöhung der Facetten einen positiven Einfluss auf die Intention und die tatsächliche Umsetzung gesundheitsförderlicher Verhaltensweisen. Keine der insgesamt 208 eingeschlossenen Studien untersuchte dabei alle angenommenen Facetten der Risikowahrnehmung, sodass die Anzahl und Operationalisierung der Facetten stark variierte.

Im Kontext verschiedener Gefahrenlagen zeichnet sich eine eher einseitige Konzeptualisierung von Risikowahrnehmung ab: In einer Übersichtsarbeit mit 28 Studien zu respiratorischen Erkrankungen konnten Leppin und Aro (2009) zeigen, dass bei 61 % der Studien Risikowahrnehmung eindimensional und dabei (mit einer Ausnahme) ausschließlich kognitiv erfasst wurde (z. B. über wahrgenommene Wahrscheinlichkeit und/oder wahrgenommenen Schweregrad einer Ansteckung). Die verbleibenden 39 % konzeptualisierten Risikowahrnehmung mit kognitiven und affektiven Dimensionen (z. B. Angst vor einer Ansteckung). Auch für weitere Gefahrenlagen, wie schwere Unwetter oder Trinkwasserverunreinigung, verdeutlicht eine Übersichtsarbeit von Wilson et al. (2019), dass Risikowahrnehmung häufig nur eindimensional

erfasst wird – obwohl sich diese Art der Betrachtung nachteilig auf die Vorhersage von Schutzhandlungen und gesundheitsbezogenem Verhalten auswirken kann (Ferrer et al., 2016; Wilson et al., 2019). Gestützt wird diese Annahme unter anderem durch eine Meta-Analyse zu Verhaltensänderungen im Zusammenhang mit klimaassoziierten Gefahrenlagen (van Valkengoed & Steg, 2019): Neben weiteren Faktoren spielte negativer Affekt eine wichtige Rolle in der Vorhersage entsprechender Verhaltensweisen zur Vorbeugung von Hitzewellen, Feuern, Überflutungen und weiteren Gefahrenlagen.

4 Zielstellungen

Die Betrachtung des PADM sowie der bereits existierenden empirischen Befunde zur Informationsverarbeitung von Warnungen und Gefahrenlagen – insbesondere zu Risikowahrnehmung – zeigt Forschungsdesiderata auf. Diese werden mit Hilfe von vier Studien im empirischen Teil der Dissertation adressiert.

Zentrales Element jeder Studie ist dabei der Erhalt einer Warnung vor einer Gefahrenlage. Es wurden Warnungen verwendet, die in Deutschland bereits im Bereich des Bevölkerungsschutzes genutzt wurden oder weiterhin in Verwendung sind. Ebendiese Warnungen bestehen aus Informationen zu einer Gefahrenlage sowie Handlungsempfehlungen im Sinne der empfohlenen oder notwendigen Schutzverhaltensweisen.

Entsprechend des PADM finden Eigenschaften der Warnungsempfänger*innen Beachtung. In vorangegangenen Arbeiten wurden Alter, Geschlecht sowie Vorerfahrung mit einer Gefahrenlage häufig in die Überlegungen und statistischen Auswertungen einbezogen (z. B. Bish & Michie, 2010; Lindell & Hwang, 2008; Mayhorn, 2005; Mayhorn & McLaughlin, 2014; Terpstra & Lindell, 2013; van Valkengoed & Steg, 2019). Deshalb werden diese drei Aspekte in jeder der vier Studien hinsichtlich ihres Einflusses auf Risikowahrnehmung oder Schutzverhalten überprüft. Darüber hinaus werden weitere Eigenschaften, wie Trait-Ängstlichkeit, in die Fragestellungen einzelner Arbeiten eingebunden.

Ziel der Dissertation ist weiterhin der Vergleich mehrerer Gefahrenlagen. Wenngleich es eine Reihe empirischer Arbeiten gibt, die sich mit den Eigenschaften einzelner Gefahren befassen, so existieren bislang nur wenige Studien, die mehrere Gefahrenlagen (z. B. vor dem Hintergrund des PADM) vergleichend untersuchten (z. B. Lindell & Hwang, 2008). Der Großteil der empirischen Forschung fokussierte bislang auf ein spezifisches Ereignis oder einen Gefahrenlagentyp, wie Brände, Stürme oder Fluten (Huang et al., 2017; Mousavi et al., 2019; Terpstra & Lindell, 2013). Unter anderem aufgrund fehlender Taxonomien von Gefahrenlagen und der Variation der methodischen Umsetzung innerhalb der Fachliteratur sind diese alleinstehenden Befunde nur schwer miteinander vergleich- oder gar generalisierbar (Drabek, 1999). Dennoch existieren vereinzelt Arbeiten, die Hinweise darauf geben, dass der Gefahrenlagentyp sowohl Einfluss auf die Wahrnehmung von Risiko als auch auf Schutzverhalten nimmt (Heilbrun et al., 2010; Ho et al., 2008). Aufgrund dessen werden in einem Teil der vorgestellten Studien die Ergebnisse zu mehreren Gefahrenlagen durch eine einheitliche methodische Umsetzung miteinander vergleichbar gemacht.

Eine mehrdimensionale Abbildung von Risikowahrnehmung, die sowohl kognitive als auch affektive Facetten einschließt, ist außerdem Ziel der vorliegenden Arbeit. Die Betrachtung affektiver Reaktionen als Teil von Risikowahrnehmung ist unter anderem theoretisch begründet im EPPM, in der PMT oder in der Affektheuristik (Prentice-Dunn & Rogers, 1986; Slovic et al., 2007; Witte, 1994), aber auch bewährt im gesundheitspsychologischen Kontext (Noar et al., 2020; Sheeran et al., 2014). Dennoch wurde Risikowahrnehmung als mehrdimensionales Konstrukt im Bereich von Warnungen vor Gefahrenlagen bislang nur vereinzelt untersucht, gleichwohl dies für die Erklärung von Informationsverarbeitungsprozessen und Schutzverhalten von Vorteil wäre (Leppin & Aro, 2009; van Valkengoed & Steg, 2019; Wilson et al., 2019). Die Dissertation zielt deswegen darauf ab, Risikowahrnehmung als facettiertes Konstrukt abzubilden, um die Bedeutung einzelner Facetten für die Verarbeitung von Warnungen vor Gefahrenlagen untersuchen zu können. In diesem Zusammenhang wird geprüft, ob der Erhalt einer Warnung Veränderungen der einzelnen Facetten herbeiführt. Darüber hinaus wird untersucht, ob die Facetten Einfluss auf verschiedene Verhaltensreaktionen, wie Schutzverhalten oder die Suche nach weiteren Informationen, nehmen.

5 Empirischer Teil

5.1 Studie 1

Einfluss von Warnerhalt, Gefahrenlagentyp und Eigenschaften der Warnungsempfänger*innen auf Risikowahrnehmung (Rahn, Tomczyk & Schmidt, 2021)

Mit der ersten Studie wurde ein multidimensionaler Ansatz von Risikowahrnehmung im Zusammenhang mit dem Erhalt einer Warnung vor einer von insgesamt fünf Gefahrenlagen angewendet. Neben der Rolle von Warnerhalt und Gefahrenlagentyp wurde der Einfluss von Eigenschaften der Warnungsempfänger*innen – insbesondere Trait-Ängstlichkeit – auf Risikowahrnehmung untersucht.

Es wurden vier Facetten der Risikowahrnehmung erhoben, davon zwei kognitive (wahrgenommene Wahrscheinlichkeit und wahrgenommener Schweregrad) und zwei affektive (antizipierte negative Emotionen (Angst, Anspannung, Traurigkeit) und antizipatorische Sorge) (vgl. Sheeran et al., 2014). 614 Teilnehmende im Alter von 18 bis 96 Jahren (M = 31,64 Jahre, 63 % weiblich) wurden im Rahmen einer Online-Befragung zufällig einer von insgesamt fünf Gefahrenlagen zugeordnet (schweres Unwetter, Großbrand, extreme Gewalttat, Ausfall der Notrufnummer, Fund einer Weltkriegsbombe), zu der sie eine kurze Erläuterung erhielten. Die Teilnehmenden wurden zudem zu ihrem Alter und Geschlecht befragt sowie zu ihrer Vorerfahrung mit der jeweiligen Gefahrenlage. Angst als überdauerndes Persönlichkeitsmerkmal (Trait-Ängstlichkeit) wurde mittels der Trait-Version des State-Trait-Angstinventars (Laux, Glanzmann, Schaffner, Spielberger, 1981) erhoben und die Teilnehmenden wurden hierüber in die Gruppen hoch- sowie niedrigängstlich eingeteilt. Risikowahrnehmung wurde im Sinne eines Prä-/Post-Vergleiches vor sowie nach dem Erhalt der Warnung zu einer der fünf Gefahrenlagen erhoben. Für die statistische Auswertung wurden unter anderem Varianzanalysen (u. a. mit Messwiederholung) herangezogen, die Alter, Geschlecht und Vorerfahrung jeweils als Kovariaten einbezogen.

Die statistischen Analysen ergaben signifikante Haupteffekte von Gefahrenlagentyp sowie Trait-Ängstlichkeit vor Erhalt der Warnung. Dies zeigte sich für drei Facetten der Risikowahrnehmung, mit Ausnahme der wahrgenommenen Wahrscheinlichkeit: Für Gefahrenlagen mit höherem anzunehmendem Schweregrad (z. B. Großbrand) oder seltenerem Auftreten (z. B. extreme Gewalttat) zeigte sich für die drei verbleibenden Facetten eine höhere Risikowahrnehmung. Für hochängstliche Teilnehmende ergab sich – mit Ausnahme der wahrgenommenen

Wahrscheinlichkeit – ebenfalls eine höhere Risikowahrnehmung. Weibliche Teilnehmende gaben für alle vier Facetten eine höhere Risikowahrnehmung an. Für die Vorerfahrung mit einer Gefahrenlage zeigten sich zwar signifikante, jedoch inkonsistente Zusammenhänge mit einigen Facetten der Risikowahrnehmung. Für das Alter ergaben sich keine signifikanten Zusammenhänge. Im Prä-/Post-Vergleich führte der Erhalt einer Warnung zu einer signifikanten Abnahme der antizipierten negativen Emotionen in der Gesamtstichprobe. Bei Betrachtung der Verläufe der Facetten allein sowie über die Gefahrenlagen hinweg fanden sich variierende – wenn auch nicht signifikante – Verläufe. So nahmen beispielsweise die antizipatorische Sorge sowie die wahrgenommene Wahrscheinlichkeit mit dem Erhalt einer Warnung im Trend eher zu, während antizipierte negative Emotionen und der wahrgenommene Schweregrad tendenziell abnahmen. Darüber hinaus zeigten sich drei Interaktionseffekte (wahrgenommener Schweregrad x Gefahrenlagentyp, wahrgenommener Schweregrad x Trait-Ängstlichkeit sowie antizipierte negative Emotionen x Gefahrenlagentyp).

Die Ergebnisse unterstützen den mehrdimensionalen Ansatz von Risikowahrnehmung. Die variierenden Verläufe im Zusammenhang mit dem Erhalt einer Warnung deuten auf unterschiedliche Verarbeitungsprozesse hin. Darüber hinaus betonen die Haupt- sowie Interaktionseffekte die Rolle von Gefahrenlagentyp und Eigenschaften der Empfänger*innen im Zusammenhang mit Risikowahrnehmung: Besonders häufig auftretende Gefahrenlagen (z. B. Unwetter) scheinen anders verarbeitet zu werden als seltenere Gefahrenlagen (z. B. schwere Gewalttat). Weiterhin sollten neben soziodemographischen Eigenschaften auch Persönlichkeitsmerkmale der Empfänger*innen (z. B. Trait-Ängstlichkeit) Beachtung finden.

5.2 Studie 2

Einfluss von Risikowahrnehmung, Gefahrenlagentyp und Eigenschaften der Warnungsempfänger*innen auf Schutzverhalten (Rahn, Tomczyk, Schopp & Schmidt, 2021)

In der zweiten Studie wurde der Einfluss von vier Facetten der Risikowahrnehmung sowie des Gefahrenlagentyps auf die Intention von Schutzverhalten nach Erhalt einer Warnung untersucht. Eigenschaften der Warnungsempfänger*innen wurden ebenso in die Analysen einbezogen.

Für die Erhebung der Daten wurden 403 Teilnehmende im Alter von 18 bis 89 Jahren (M = 29,24 Jahre, 72 % weiblich) im Rahmen einer Online-Befragung zufällig einer von insgesamt drei Gefahrenlagen zugeordnet (schweres Unwetter, extreme Gewalttat, COVID-19-Pandemie). Neben der Abfrage soziodemographischer Daten (Alter, Geschlecht, Vorerfahrung

mit der jeweiligen Gefahr) erhielten die Teilnehmenden eine kurze Beschreibung zur jeweiligen Gefahrenlage. Risikowahrnehmung wurde mit zwei kognitiven (wahrgenommene Wahrscheinlichkeit und wahrgenommener Schweregrad) sowie zwei affektiven Facetten (antizipierte negative Emotionen (Angst, Anspannung, Traurigkeit) und antizipatorische Sorge) (vgl. Sheeran et al., 2014) vor und nach dem Erhalt einer Warnung erhoben. Zudem wurden die Teilnehmenden hinsichtlich ihrer Intention befragt, die in der Warnung angegebenen Handlungsempfehlungen (im Sinne von Schutzverhalten) auszuführen. Zur Vorhersage von Schutzverhalten wurden für jede Gefahrenlage Pfadanalysen durchgeführt, die Alter, Geschlecht sowie Vorerfahrung als Kovariaten beinhalteten.

Für schwere Unwetter ergaben die statistischen Analysen den wahrgenommenen Schweregrad, zunehmendes Alter sowie weibliches Geschlecht als signifikante Prädiktoren für die Intention, die (Unwetter-)Warnung zu befolgen. Für die COVID-19-Pandemie war lediglich ein höheres Alter signifikant. Antizipierte negative Emotionen prädizierten Schutzhandlungen im Fall schwerer Gewalttaten. Die Verläufe der Facetten der Risikowahrnehmung zeigten im Prä-/Post-Vergleich kein einheitliches Bild, da einige Facetten in der Gesamtstichprobe sowie für die einzelnen Gefahrenlagen nach dem Erhalt einer Warnung anstiegen (z. B. wahrgenommene Wahrscheinlichkeit für schweres Unwetter und extreme Gewalttat), während wieder andere abnahmen (z. B. antizipierte negative Emotionen für alle drei Gefahrenlagen).

Für schwere Unwetter sagte eine kognitive Facette (wahrgenommener Schweregrad) und für extreme Gewalttaten eine affektive Facette (antizipierte negative Emotionen) der Risikowahrnehmung die Ausführung von Schutzverhalten vorher. Dies stützt den multidimensionalen Ansatz von Risikowahrnehmung sowie die differentielle Betrachtung einzelner Gefahrenlagen. Der Einfluss soziodemographischer Aspekte variierte für die einzelnen Gefahrenlagen. Gerade für neuartige Gefahrenlagen, wie die COVID-19-Pandemie, können hieraus Ansatzpunkte für folgende Studien gezogen werden.

5.3 Studie 3

Einfluss von Risikowahrnehmung und Eigenschaften von Warnungsempfänger*innen auf Schutzverhalten im Fall der COVID-19-Pandemie (Tomczyk et al., 2020)

Studie 3 befasste sich ebenso wie Studie 2 mit der Intention, Schutzmaßnahmen auszuführen, die als Handlungsempfehlungen über eine Warnung vermittelt wurden. Sie bezog sich jedoch nur auf eine Gefahrenlage (COVID-19 Pandemie). Neben soziodemographischen Aspekten und

Risikowahrnehmung wurden Vorwissen sowie stigmatisierende Einstellungen als Prädiktoren für Schutzverhalten untersucht.

157 Teilnehmende im Alter von 18 bis 77 Jahren (M = 27,87 Jahre, 80 % weiblich) wurden nach dem Erhalt einer Warnung vor COVID-19 hinsichtlich ihrer Intention, die in der Warnung dargebotenen Handlungsempfehlungen zu befolgen, befragt. Als soziodemographische Daten wurden Alter, Geschlecht, Herkunftsland, Wohnregion, Bildungsstatus sowie die Anzahl der im Haushalt lebenden Personen erhoben. Darüber hinaus wurden Vorwissen über Schutzhandlungen und stigmatisierende Einstellungen erfasst. Risikowahrnehmung wurde mit einer kognitiven (wahrgenommene Wahrscheinlichkeit einer Erkrankung) sowie einer affektiven Facette (antizipierte negative Emotion (Angst)) erhoben. Um Muster hinsichtlich der Verhaltensintention aufzudecken, wurden eine latente Klassenanalyse sowie darauf aufbauend multinomiale logistische Regressionen berechnet.

Für die Intention, die dargebotenen Handlungsempfehlungen zu befolgen, ergaben sich drei Gruppen: Teilnehmende, die angaben, die meisten Empfehlungen befolgen zu wollen (25 %, Klasse 1), Teilnehmende, die hauptsächlich öffentliche Maßnahmen befolgen wollten (z. B. Abstand halten, 51 %, Klasse 2) sowie Teilnehmende, die die meisten Empfehlungen nicht befolgen wollten (24 %, Klasse 3). Männliches Geschlecht sowie jüngeres Alter zeichnete vor allem die Gruppe der Teilnehmenden aus, die keine der Empfehlungen befolgen wollten (Klasse 3). Hinsichtlich ihrer Risikowahrnehmung unterschieden sich die Gruppen nicht signifikant voneinander, wenngleich Teilnehmende aus Klasse 3 im Vergleich zu Klasse 2 im Trend über eine geringere Angst (im Sinne affektiver Risikowahrnehmung) vor einer Infektion berichteten.

In der Untersuchung der COVID-19-Pandemie als neuartiger Gefahrenlage zeichnet sich die Bedeutung der soziodemographischen Eigenschaften von Warnungsempfänger*innen, wie beispielsweise Geschlecht und Alter, für die Befolgung von Schutzmaßnahmen ab. Dies eröffnet Bedarfe für die Erforschung sowie Entwicklung zielgerichteter Interventionen, welche sich an bestimmte Gruppen in der Bevölkerung richten, die der Ausführung von Schutzverhalten eher ablehnend gegenüberstehen.

5.4 Studie 4

Einfluss von Warnerhalt, Konfrontation mit der Gefahrenlage und Präsentationsformat auf Risikowahrnehmung sowie Informationssuche im Fall eines Gewitters (Tomczyk et al., 2021)

Studie 4 befasste sich mit Gewittern als Gefahrenlagetyp. Es wurde untersucht, welchen Einfluss der Erhalt einer Warnung, die Konfrontation mit einem Gewitter ebenso wie das Präsentationsformat auf momentane Ängstlichkeit nahmen. Weiterhin wurde der Zusammenhang all jener Faktoren mit der Suche nach weiteren Informationen zur Gefahrenlage beleuchtet.

Im Rahmen eines quasi-experimentellen Studiendesigns wurden 276 Teilnehmende im Alter von 17 bis 83 Jahren (M = 41,07, 62 % weiblich) online mittels einer App durch eine virtuelle Stadt geführt. Dabei wurden die Teilnehmenden zufällig einer von acht Bedingungen zugeordnet: Präsentationsformat (Vignette versus Video), Erhalt einer Warnung (keine Warnung erhalten versus Warnung erhalten), Konfrontation mit einem Gewitter (keine Konfrontation versus Konfrontation). Momentane Ängstlichkeit wurde als affektive Facette der Risikowahrnehmung zu drei Messzeitpunkten (t1 bis t3) erfasst, nämlich zu Beginn der Erhebung (t1), bei Erhalt beziehungsweise Nicht-Erhalt der Warnung (t2) und bei Konfrontation beziehungsweise ausbleibender Konfrontation mit dem Gewitter (t3). Zusätzlich wurde am Ende der Erhebung erfragt, wie wahrscheinlich sich die Teilnehmenden weitere Informationen zur Situation suchen würden. Um die Veränderung der momentanen Ängstlichkeit im Verlauf der drei Messzeitpunkte abzubilden, wurden Varianzanalysen berechnet, die Alter, Geschlecht, Vorerfahrung mit Gewittern ebenso wie Sturmangst und Warn-App-Nutzung als Kovariaten einbezogen. Der Einfluss momentaner Ängstlichkeit auf die Intention, sich weitere Informationen zu suchen, wurde mittels hierarchischer Regressionen untersucht.

Teilnehmende, die eine Warnung erhielten (t2) und mit einem Gewitter konfrontiert wurden (t3), gaben jeweils eine höhere momentane Ängstlichkeit an als Teilnehmende ohne Warnerhalt beziehungsweise ohne Gewitterkonfrontation. Das Präsentationsformat hingegen nahm keinen Einfluss auf momentane Ängstlichkeit. Unter den Kovariaten fand sich lediglich für (höheres) Alter ein signifikanter Effekt für (höhere) momentane Ängstlichkeit zu Beginn der Erhebung (t1). Eine höhere momentane Ängstlichkeit zu t3 war zudem positiv assoziiert mit der Suche nach weiteren Informationen. Für Teilnehmende, die mit einem Gewitter konfrontiert wurden, fanden sich keine Interaktionseffekte von Warnerhalt und Präsentationsformat mit der Suche nach weiteren Informationen.

Der Erhalt einer Warnung ebenso wie die Konfrontation mit einem Gewitter hatten Einfluss auf die berichtete momentane Ängstlichkeit. Dies spricht für die Aktivierung intuitiver Systeme, wie zum Beispiel der Affektheuristik (Slovic et al., 2007), und wiederum für die Rolle affektiver Facetten der Risikowahrnehmung im Kontext von Warnungen vor Gefahrenlagen. Die Assoziation von momentaner Ängstlichkeit und Informationssuche weist darauf hin, dass

affektive Reaktionen (die Suche nach weiteren) Schutzverhaltensweisen beeinflussen können. Gleichzeitig sprechen die Ergebnisse gegen das Phänomen des Milling (Wood et al., 2018), da Teilnehmende zwar bei Warnerhalt (t2) eine höhere momentane Ängstlichkeit angaben, diese aber wieder abnahm, wenn sie in der Folge nicht mit einem Gewitter konfrontiert wurden (t3).

6 Zusammenfassung und wissenschaftlicher Mehrwert

Die vorliegende Arbeit hat das Ziel, die Relevanz einer multidimensionalen Betrachtung von Risikowahrnehmung für die Verarbeitung von Warnungen zu untersuchen und dabei verschiedene Gefahrenlagen vergleichend zu betrachten. Beginnend mit Beispielen zu neuartigen sowie bekannten Gefahrenlagen wurde zunächst die Aktualität der Thematik unterstrichen. Dem folgend wurden empirische Befunde vor dem Hintergrund des PADM dargestellt und einsortiert. Mit Hilfe des Modells sowie weiterer Ansätze und empirischer Befunde wurde im Anschluss auf die Bedeutung kognitiver sowie affektiver Facetten der Risikowahrnehmung hingewiesen. Diese wurde durch vier Studien im empirischen Teil der Arbeit untermauert. Der sich ergebende wissenschaftliche Mehrwert ebenso wie ein Vorschlag einer Erweiterung des PADM nach Lindell und Perry (2012) sollen im folgenden Abschnitt erläutert werden. Schließlich leiten die Limitationen der vier Studien einen Ausblick für weitere Forschungsfragen ein.

6.1 Eigenschaften der Warnungsempfänger*innen

Eigenschaften von Warnungsempfänger*innen und ihr Einfluss auf Risikowahrnehmung und Schutzverhalten wurden in jeder der vier Studien mindestens über das Alter, Geschlecht und die Vorerfahrung mit der jeweiligen Gefahrenlage erfasst.

Für das Geschlecht einer Person zeigte sich – ähnlich wie in bereits existierenden Befunden – ein eher ambivalentes Bild (z. B. Bish & Michie, 2010; Olofsson & Rashid, 2011; Terpstra & Lindell, 2013). So gaben in Studie 1 weibliche Teilnehmende insgesamt eine höhere Risikowahrnehmung für die fünf verschiedenen Gefahrenlagen an. Studie 4 wiederum ergab keinen Zusammenhang von Geschlecht und Risikowahrnehmung im Fall von Gewittern. Für die Intention, Schutzverhalten auszuführen, zeigte Studie 2, dass weibliches Geschlecht nur im Fall von schweren Unwettern mit der entsprechenden Verhaltensintention assoziiert war. Studie 3 ergab für die COVID-19-Pandemie, dass vor allem junge Männer zu ebenjener Gruppe von Teilnehmenden gehörten, die angaben, pandemieassoziiertes Schutzverhalten nicht ausführen zu wollen. In Studie 4 ergab sich schließlich kein Zusammenhang zwischen dem Geschlecht und der Intention, weitere Informationen zu suchen.

Für das Alter der Teilnehmenden ergab sich ebenfalls kein einheitliches Bild: In den Studien 1 und 4 ließ sich kein Zusammenhang von Alter und Risikowahrnehmung beziehungsweise Schutzverhalten abbilden. Für schwere Unwetter und die COVID-19-Pandemie fanden sich in Studie 2 und 3 jedoch signifikante Zusammenhänge von (höherem) Alter sowie der

Ausführung von Schutzverhalten, was an bereits bestehenden Befunde anknüpft (Perry & Lindell, 1997; Potter et al., 2018).

Während in Studie 1 die bereits bestehende Vorerfahrung mit einer Gefahrenlage nur teilweise mit Risikowahrnehmung assoziiert war, fanden die Studien 2, 3 und 4 keine signifikanten Zusammenhänge mit der Ausführung von Schutzverhalten. Dieser fehlende Zusammenhang entspricht der bisherigen Studienlage (z. B. Frondel et al., 2017; Lujala et al., 2015) und könnte im Sinne des Risikoparadoxes – also der fehlenden Umsetzung von Schutzverhalten bei gleichzeitig erhöhter Risikowahrnehmung – interpretiert werden (Lujala et al., 2015; Wachinger et al., 2013).

Darüber hinaus zeigte Studie 1, dass auch weitere Eigenschaften der Warnungsempfänger*innen Einfluss auf die Risikowahrnehmung haben können. Ein positiver Zusammenhang zwischen Trait-Ängstlichkeit und Risikowahrnehmung ist bereits aus verschiedenen Kontexten bekannt (Butler & Mathews, 1987; Chauvin et al., 2007; Maner & Schmidt, 2006). Gleichzeitig belegen vorangegangene Studien einen eher hinderlichen Effekt von hoher Ängstlichkeit und der Ausführung von Schutzverhalten (McNeill et al., 2016; Mishra & Suar, 2012; Notebaert et al., 2016; Wirtz et al., 2019). Dies kann mit der Nutzung dysfunktionaler Bewältigungsmechanismen, wie emotions- oder vermeidungsorientiertem Coping beziehungsweise der Vermeidung von Informationen zu möglichen Schutzverhaltensweisen, begründet werden, die mit hoher Trait-Ängstlichkeit einhergehen (Mishra & Suar, 2012; Paton, 2003). Bislang existierten keine Befunde, die Trait-Ängstlichkeit im Rahmen verschiedener Gefahrenlagen und des Erhalts von Warnungen hiervor untersuchen. Studie 1 schließt diese Lücke erstmalig: Es konnte gezeigt werden, dass hochängstliche Personen den wahrgenommenen Schweregrad sowie antizipierte negative Emotionen und antizipatorische Sorgen unabhängig von der Art der Gefahr als insgesamt höher einschätzten als niedrigängstliche Personen. Der Erhalt einer Warnung bewirkte bei niedrigängstlichen Personen zudem einen Abfall hinsichtlich des wahrgenommenen Schweregrades, während sich keine Veränderung für Hochängstliche ergab. Trait-Ängstlichkeit könnte also dazu führen, dass Gefahrenlagen auch nach dem Erhalt einer Warnung als schwerwiegender wahrgenommen werden, obwohl Schutzverhaltensweisen vermittelt wurden. Hieraus ergeben sich neue Anknüpfungspunkte, etwa bezogen auf die Rolle des wahrgenommenen Schweregrades für die tatsächliche Ausführung von Schutzverhalten bei hochängstlichen Personen.

Die Ergebnisse zu Trait-Ängstlichkeit im Zusammenhang mit Warnungen liefern erste Erkenntnisse bezüglich möglicher Besonderheiten bei der Warnungsverarbeitung. Die insgesamt inkonsistenten Befunde zu Alter, Geschlecht und Vorerfahrung zeigen, dass Eigenschaften der Warnungsempfänger*innen weiterhin Teil jeder empirischen Untersuchung von Warnungen im Bevölkerungsschutz sein müssen.

6.2 Gefahrenlagenvergleich

Die inkonsistente Befundlage zu Eigenschaften der Warnungsempfänger*innen deutet bereits die Notwendigkeit einer differenzierten Betrachtung verschiedener Gefahrenlagen an. Dies zeigte sich auch im Rahmen der wenigen bislang existierender Studien, die mehrere Gefahrenlagen gleichzeitig untersuchten: So verglichen Ho et al. (2008) Erdrutsche und Fluten hinsichtlich ihrer Risikowahrnehmung und konnten zeigen, dass Fluten mit höherem (finanziellen) Schaden, Erdrutsche aber mit höherer Lebensbedrohung assoziiert waren. In einem systematischen Vergleich von Umweltgefahren, terroristischen Anschlägen und Gewaltverbrechen zeigten Heilbrun et al. (2010) zudem, dass unter Hochrisikobedingungen der Gefahrenlagentyp ebenso wie die Risikowahrnehmung Einfluss auf intendierte Schutzverhaltensweisen nahmen. Keine der beiden Studien untersuchte jedoch besagte Gefahrenlagen im Zusammenhang mit dem Erhalt einer Warnung.

Zwei Studien des empirischen Teils schlossen ebenjene Lücke, indem sie fünf (Studie 1) beziehungsweise drei (Studie 2) Gefahrenlagen durch eine jeweils einheitliche methodische Umsetzung miteinander vergleichbar machten. Studie 1 zeigte, dass der Gefahrenlagentyp Einfluss auf verschiedene Facetten der Risikowahrnehmung nahm. So wurden Gefahrenlagen, die sich durch schnelles Einsetzen, seltenes Auftreten oder hohe potentielle Schäden auszeichneten (z. B. extreme Gewalttaten und Großbrände) vor dem Erhalt einer Warnung hinsichtlich ihrer antizipierten negativen Emotionen sowie ihres Schweregrades als höher eingeschätzt als beispielsweise Unwetter. Im Sinne der Affektheuristik (Finucane et al., 2000; Slovic et al., 2007) könnte dies für die Aktivierung des intuitiven Systems sprechen. Das intuitive System kann bei Bedarf eine schnelle, von Affekt und Emotionen geleitete Risikowahrnehmung leisten. Für schwere Unwetter hingegen gaben Teilnehmende eine höhere wahrgenommene Wahrscheinlichkeit sowie niedrigere antizipierte negative Emotionen an. Ebenjener Zusammenhang könnte durch das häufigere Auftreten von Unwettern im deutschsprachigen Raum im Vergleich zu eher selteneren Gefahrenlagen (z. B. extreme Gewalttaten) erklärt werden (Frondel et al., 2017; Keul et al., 2018).

Nach dem Erhalt einer Warnung nahm die Risikowahrnehmung für die meisten Gefahrenlagen ab, jedoch mit einer Ausnahme: Für den Fund einer Weltkriegsbombe wurde nach Warnerhalt von höheren antizipierten negativen Emotionen und einem höheren wahrgenommenen Schweregrad berichtet. Da Schutzmaßnahmen im Rahmen eines Bombenfundes häufig wenig Handlungsspielraum für die betroffenen Personen bereithalten (z. B. bei Evakuierungen), könnte sich dieser Befund mit fehlender Selbst- beziehungsweise Handlungswirksamkeit im Sinne des EPPM (Popova, 2012, 2020; Witte, 1994) oder der PMT (Prentice-Dunn & Rogers, 1986) erklären lassen.

Studie 2 erweiterte Studie 1, indem sie sich mit Risikowahrnehmung und der intendierten Umsetzung von Schutzverhalten befasste. Auch hier zeigten sich – je nach Gefahrenlage – heterogene Einflussfaktoren: Für die COVID-19-Pandemie nahm lediglich ein höheres Alter Einfluss auf die Verhaltensintention. Für extreme Gewalttaten fanden sich antizipierte negative Emotionen und weibliches Geschlecht sowie höheres Alter und der wahrgenommene Schweregrad für schwere Unwetter als Prädiktoren. Für schwere Unwetter lassen sich die Ergebnisse im Sinne des PADM interpretieren, da ein höherer wahrgenommener Schweregrad laut Modell eher zur Suche und Umsetzung von Schutzverhalten führt (Lindell & Perry, 2012). Aber auch die Aktivierung des analytischen Systems im Sinne der Affektheuristik (Finucane et al., 2000; Slovic et al., 2007) ist an dieser Stelle denkbar. So haben Unwetter im mitteleuropäischen Raum in der Regel eine längere Vorlaufzeit und lassen den betroffenen Personen damit mehr Zeit für die Abwägung für oder gegen ein Schutzverhalten. Gleichbedeutend könnte die Aktivierung des intuitiven Systems die Assoziation von antizipierten negativen Emotionen und Schutzverhalten im Fall einer schweren Gewalttat erklären. Ebenjene Gefahrenlage erfordert – im Gegensatz zu den meisten Unwettern – ein schnelles Handeln bei gleichzeitig erhöhter Unsicherheit und seltenem Auftreten.

Insgesamt deuten die Ergebnisse der Studien 1 und 2 darauf hin, dass der Gefahrenlagentyp Einfluss auf Verarbeitungsprozesse innerhalb der Warnungsempfänger*innen nimmt. Es lässt sich schlussfolgern, dass Gefahrenlagen nicht nur singulär, sondern auch vergleichend untersucht werden müssen. Hierfür hilfreich wären standardisierte Taxonomien, die es erlauben, bestehende und folgende Befunde einzusortieren und so einander gegenüberstellen zu können (Drabek, 1999). Somit könnten auch weitere Eigenschaften der Gefahrenlagen, wie ihre räumliche und zeitliche Nähe, systematisch in zukünftige Untersuchungen einbezogen werden

(Lindell & Perry, 2012; Zhang et al., 2010). Weiterhin könnten bislang kaum untersuchte Gefahrenlagen, wie Bombenfunde oder Ausfälle von Notrufnummern, die nötige Beachtung finden.

6.3 Risikowahrnehmung mit kognitiven und affektiven Facetten

Für gesundheitsbezogene Verhaltensweisen konnten Sheeran et al. (2014) in ihrer Meta-Analyse bereits darlegen, dass die Kombination kognitiver und affektiver Facetten der Risikowahrnehmung für die Vorhersage und Ausführung gesundheitsförderlichen Handelns zielführend ist. Im Kontext verschiedener Gefahrenlagen wurde Risikowahrnehmung bislang häufig nur einseitig kognitiv operationalisiert (Ferrer et al., 2016; Leppin & Aro, 2009; van Valkengoed & Steg, 2019; Wilson et al., 2019). Ein dritter Mehrwert der Dissertation ergibt sich demnach aus der multidimensionalen Betrachtung von Risikowahrnehmung der Studien 1, 2 und 3 im Zusammenhang mit dem Erhalt von Warnungen vor Gefahrenlagen.

Studie 1 zeigte dabei nicht nur, dass Eigenschaften der Warnungsempfänger*innen sowie der Gefahrenlagentyp Einfluss auf kognitive und affektive Facetten nahmen. Es ließ sich zudem abbilden, dass der Erhalt einer Warnung unterschiedliche Trends in den Verläufen der vier untersuchten Facetten bewirkte. So nahmen beispielsweise die antizipierten negativen Emotionen mit Warnerhalt signifikant ab. Die Teilnehmenden empfanden nach dem Erhalt also weniger Angst, Anspannung oder Traurigkeit. Für die wahrgenommene Wahrscheinlichkeit sowie die antizipatorische Sorge hingegen zeigte sich im Trend eine, wenn auch nicht signifikante, Zunahme. Studie 2 erweiterte diese Ergebnisse, in dem sie den Zusammenhang der vier Facetten nach Warnerhalt auf intendierte Schutzverhaltensweisen untersuchte. Ähnlich wie in Studie 1 fand sich in Studie 2 für antizipierte negative Emotionen als affektive Facette ein signifikanter Zusammenhang für die Intention, Schutzverhaltensweisen auszuführen – jedoch nur für schwere Gewalttaten. Je mehr Angst, Anspannung oder Traurigkeit die Teilnehmenden nach Erhalt einer Warnung vor einer schweren Gewalttat berichteten, desto wahrscheinlicher war es für sie, die in der Warnung vermittelten Schutzmaßnahmen zu intendieren. Für Studie 3 ergab sich speziell für die COVID-19-Pandemie, dass Teilnehmende, die insgesamt kaum Schutzverhalten ausführen wollten, im Trend insgesamt von einer geringeren Angst vor einer Infektion mit COVID-19 berichteten.

Aus den Ergebnissen der Studien 1, 2 und 3 lässt sich die besondere Rolle affektiver Risikowahrnehmung im Kontext des Warnerhalts ableiten. Studie 4 hatte dementsprechend die Zielsetzung, momentane Ängstlichkeit als eine affektive Facette der Risikowahrnehmung im Rahmen eines quasi-experimentellen Designs und bezogen auf Gewitter zu untersuchen. Dabei

konnte gezeigt werden, dass der Erhalt einer Warnung, ebenso wie die Konfrontation mit einer Gefahrenlage, mit einer höheren affektiven Risikowahrnehmung einherging. Ebenso konnte der Einfluss affektiver Risikowahrnehmung nach der Konfrontation mit einem Gewitter und der Suche nach weiteren Informationen beobachtet werden: Berichteten Teilnehmende von einer höheren momentanen Ängstlichkeit, so gaben sie auch eine höhere Intention an, sich weitere Informationen zur aktuellen Situation zu suchen.

Affektive Risikowahrnehmung und die Ausführung von Schutzverhalten nach dem Erhalt einer Warnung können im Licht bereits existierender Theorien und Modelle betrachtet werden, die Affekt als Modellkomponente beinhalten. In der vorliegenden Arbeit exemplarisch genannt wurden die Theorie der Schutzmotivation (PMT, Prentice-Dunn & Rogers, 1986), das Erweiterte Modell der Parallelen Prozesse (EPPM, Witte, 1994) sowie die Affektheuristik (Finucane et al., 2000; Slovic et al., 2004, 2007; Slovic & Peters, 2006). So nahm in Studie 1 affektive Risikowahrnehmung (i. S. antizipierter negativer Emotionen) im Prä-/Post-Vergleich nach dem Erhalt einer Warnung ab, was entsprechend der Affektheuristik für eine Aktivierung des intuitiven Systems vor dem Warnerhalt spricht: Die Teilnehmenden erhielten zu Beginn der Untersuchung lediglich eine kurze Beschreibung der jeweiligen Gefahrenlage und hatten weder zusätzliche Informationen noch zeitliche Ressourcen, um sich mit der Gefahr auseinanderzusetzen. Mit der Warnung erhielten sie ebenjene Informationen sowie eine Aufzählung möglicher Schutzmaßnahmen. Dies könnte durch die Aktivierung des analytischen Systems mit einer Abnahme der negativen Emotionen, jedoch auch der Zunahme der kognitiven Risikowahrnehmung (i. S. der wahrgenommenen Wahrscheinlichkeit) einhergehen.

Studie 2 wiederum zeigte, dass affektive Risikowahrnehmung vor allem dann von Bedeutung für die Ausbildung von Schutzverhalten ist, wenn Gefahrenlagen (hier schwere Gewalttaten) selten auftreten oder sich durch ein besonderes Maß an Unsicherheit auszeichneten. Die Aktivierung des intuitiven Systems, also einer Heuristik basierend auf affektiven Reaktionen gegenüber der Gefahr, könnte im Fall ebenjener Gefahrenlagen dazu führen, dass die affektive Risikowahrnehmung nach dem Erhalt einer Warnung Schutzverhalten prädiziert. Im Sinne der PMT und des EPPM könnten affektive Reaktionen der Warnungsempfänger*innen hier auch über die Erhöhung der Bedrohungseinschätzung auf die Ausbildung der Schutzmotivation einwirken.

Mit Studie 4 konnte abschließend gezeigt werden, dass der Erhalt einer Warnung sowie die Konfrontation mit einem Gewitter auch im quasi-experimentellen Studiendesign zu einer

Zunahme affektiver Risikowahrnehmung führten. Neben der Affektheuristik lassen sich in diesem Zusammenhang die PMT sowie das EPPM heranziehen, in deren Sinne die Entstehung von Angst oder Furcht einen (unter anderem verstärkenden) Einfluss auf die Ausführung von Schutzverhalten – hier abgebildet als Informationssuche – haben kann.

6.4 Modellerweiterung des Protective Action Decision Model

Nach Betrachtung der vier empirischen Studien kann geschlussfolgert werden, dass die affektive Risikowahrnehmung für Prozesse der Verarbeitung von Warnungen vor Gefahrenlagen eine bedeutsame Rolle spielt. Das PADM (Lindell & Perry, 2012) bildet Abläufe der Informationsverarbeitung bereits sukzessive über diverse Aspekte ab. Dennoch liefert das Modell eine kognitive Sicht auf ebenjene Prozesse, die die Ausführung von Schutzverhalten erklären sollen. Und auch Risikowahrnehmung wird im Sinne des PADM als kognitive Komponente betrachtet – sei es über die Gefahrenwahrnehmung oder im Rahmen der Entscheidungsfindung.

Basierend auf der bestehenden Literatur sowie den Studien der vorliegenden Dissertation wird deshalb eine Modellerweiterung des PADM vorgeschlagen. Zusätzlich zu kognitiver Risikowahrnehmung kann affektive Risikowahrnehmung die dezisionalen Prozessabläufe im Modell gewinnbringend erweitern. Aufbauend auf Theorien und Modellen wie der PMT (Prentice-Dunn & Rogers, 1986), dem EPPM (Popova, 2012, 2020; Witte, 1994) oder der Affektheuristik (z. B. Slovic et al., 2007), könnte so der Einfluss affektiver Reaktionen auf die im PADM beschriebenen Abläufe abgebildet werden.

Aus der vorgeschlagenen Erweiterung ergeben sich neue Fragestellungen. So können anschließende Forschungsarbeiten etwaige Zusammenhänge zwischen affektiver Risikowahrnehmung und den im PADM enthaltenen dezisionalen Modellkomponenten (z. B. Gefahrenwahrnehmung, Wahrnehmung von Schutzmaßnahmen, Abläufe der Entscheidungsfindung), der Verhaltensintention sowie der tatsächlichen Ausführung von Schutzverhalten untersuchen. Zu überprüfen ist beispielsweise, in welchem Zusammenhang affektive und kognitive Risikowahrnehmung stehen und ob und inwiefern die affektive Risikowahrnehmung die im PADM abgebildeten Prozesse beeinflusst. Es könnte untersucht werden, ob ebenjene neue Komponente die Ausführung von Schutzverhalten hindert (i. S. des EPPM), fördert oder gar verkürzt (i. S. der PMT oder der Affektheuristik).

6.5 Limitationen

Den theoretischen Hintergrund der Dissertation liefert das PADM (Lindell & Perry, 2012) als zunehmend etabliertes Prozessmodell zur Erklärung menschlichen Verhaltens in Krisensituationen. Das Modell beinhaltet bereits eine Vielfalt an Komponenten. Die Intention, eine Schutzhandlung auszuführen, ist jedoch nicht explizit Teil des PADM. Vielmehr muss die Verhaltensintention als Teil der Entscheidungsfindung verstanden werden, im Rahmen derer verschiedene Handlungsmöglichkeiten gegeneinander abgewogen werden (Heidenreich et al., 2020; Lindell & Perry, 2012). Zudem prädiziert die Intention zwar, inwieweit eine Person beabsichtigt, ein Schutzverhalten auszuführen, jedoch ist eine Diskrepanz zwischen der Ausbildung der Intention und der tatsächlichen Ausführung des jeweiligen Verhaltens bekannt (Ajzen, 1991; Sheeran & Webb, 2016; Terpstra, 2010). Zukünftige Studien sollten eine umfassendere Operationalisierung der Intention anstreben, wie sie beispielsweise in der Theorie des geplanten Verhaltens (Ajzen, 1991) zu finden ist, um diesen Zwischenschritt zu tatsächlich ausgeführtem Verhalten besser abbilden zu können. Die Studien 2, 3 und 4 haben sich weiterhin zwar mit der Intention, Schutzhandlungen auszuführen, befasst, nicht aber mit der tatsächlichen Ausführung des Verhaltens. Weiterführende Forschung sollte es sich demnach zum Ziel machen, Warnungen und Schutzverhalten auch in realen Bedingungen zu untersuchen. Studien zu vereinzelten Gefahrenlagen konnten bereits zeigen, dass sich die Ergebnisse von Felduntersuchungen nicht maßgeblich von Vignettenstudien unterschieden (Weyrich et al., 2020a). Dennoch könnte die Umsetzung von Studiendesigns mit Hilfe virtueller Realität oder ambulantem Assessment neue Erkenntnisse für die Vorhersage menschlichen Verhaltens liefern (Markwart et al., 2019; Weyrich et al., 2020b).

Im Zusammenhang mit der Untersuchung tatsächlich ausgeführten Verhaltens sollten darüber hinaus weitere Prozessvariablen in die Überlegungen einbezogen werden. Beispielhaft zu nennen sind hier Selbstwirksamkeit, Handlungswirksamkeit oder auch soziale Normen. Diese sind unter anderem Teil verschiedener Modelle wie der PMT (Prentice-Dunn & Rogers, 1986) oder dem EPPM (Popova, 2012, 2020; Witte, 1994), gleichzeitig aber auch im Zusammenhang mit der multidimensionalen Abbildung von Risikowahrnehmung als maßgebliche Einflussfaktoren auf Verhalten bekannt (Sheeran et al., 2014; van Valkengoed & Steg, 2019).

In der Dissertation wurden mehrere Gefahrenlagen vergleichend dargestellt. Dies führte dazu, dass die einzelnen Gefahren in den Studien 1 und 2 nicht vertieft untersucht werden konnten. Es ergaben sich dennoch Ansätze für zukünftige Studien, zum Beispiel für die Untersuchung bislang kaum beforschter Gefahrenlagen, wie dem Ausfall von Notrufnummern oder

Funden von Weltkriegsbomben. Weiterhin konnten die Studien 1 bis 4 die jeweiligen Gefahrenlagen nicht hinsichtlich bestimmter Eigenschaften, wie ihrem Schweregrad oder der räumlichen und zeitlichen Distanz, variieren (Marris et al., 1997; Slovic et al., 1986; Zhang et al., 2010). Gleiches gilt für die in den Untersuchungen verwendeten Warnungen, da diese bereits im Kontext des Bevölkerungsschutzes verwendet wurden und somit keine systematische inhaltliche oder gestalterische Variation zuließen. Zwar ist bekannt, dass ebenjene Variation einen Einfluss auf affektive Risikowahrnehmung der Empfänger*innen nehmen kann, dennoch zeichnen sich alle vier Studien somit durch eine hohe ökologische Validität aus (Sutton & Woods, 2016). Zukünftige Studien sollten sich die systematische Variation von Gefahrenlagen und Warnungen zum Ziel machen und sich dennoch die Möglichkeit des Gefahrenlagenvergleichs beibehalten, beispielsweise durch eine konstante methodische Umsetzung der Studiendesigns.

Nicht zuletzt lieferte keine der empirischen Arbeiten repräsentative Studienergebnisse, da sich die Untersuchungen auf nicht-repräsentative Online-Stichproben bezogen. Weiterführende Arbeiten sollten auf repräsentative Stichproben Wert legen, um die Übertragung der Ergebnisse auf die Bevölkerung oder einzelne Bevölkerungsgruppen zu erleichtern. Weiterhin könnten so auch zusätzliche, im PADM vorgeschlagene Personenmerkmale – wie physische, ökonomische oder kognitive Voraussetzungen der Warnungsempfänger*innen – untersucht werden.

6.6 Fazit und Ausblick

Die vorliegende Dissertation befasst sich mit Risikowahrnehmung im Kontext von Warnungen vor verschiedenen Gefahrenlagen. Als theoretischer Rahmen diente das Protective Action Decision Model (Lindell & Perry, 2012), das kognitive Verarbeitungsprozesse von Gefahrenlagen und Warnungen sowie die Entstehung von Schutzverhaltensweisen abbildet. Zentrales Element der vier empirischen Studien war der Erhalt einer Warnung vor einer Gefahr, wie einem schweren Unwetter oder der COVID-19-Pandemie. Um bestehende Lücken in der Forschungsliteratur zu schließen, wurden mehrere Gefahrenlagen vergleichend untersucht und die Risikowahrnehmung mit kognitiven, aber auch affektiven Facetten abgebildet. Darüber hinaus wurde der Einfluss der Eigenschaften der Warnungsempfänger*innen in alle Analysen einbezogen.

Entsprechend bereits existierender Studien ergab sich bezüglich der Eigenschaften der Warnungsempfänger*innen ein inkonsistentes Bild. Fortführende Studien sollten deswegen Eigenschaften wie Alter, Geschlecht oder Vorerfahrung mit der Gefahrenlage bei der Untersuchung von Verarbeitungsprozessen bedenken. Weiterhin bieten bislang kaum untersuchte Persönlichkeitsmerkmale wie Trait-Ängstlichkeit neue Anknüpfungspunkte. Die Bedeutung der

affektiven Risikowahrnehmung für die Verarbeitung von Warnungen konnte gestärkt werden. Dies ließ sich über differierende Ausprägungen beziehungsweise Verläufe von affektiver und kognitiver Risikowahrnehmung vor und nach Warnerhalt sowie den Einfluss auf Schutzverhalten und Informationssuche zeigen. Zudem wurde deutlich, dass ebenjener Einfluss der Facetten nicht für alle Gefahrenlagen gleich zu sein scheint. Somit sollten Erkenntnisse zu einem Gefahrenlagentyp nicht ohne Weiteres auf andere oder neuartige Gefahrenlagen, wie die COVID-19-Pandemie, übertragen werden. Fortführende Studien aus dem Bereich der Warnungsforschung sollten die Risikowahrnehmung als multiples Konstrukt mit affektiven und kognitiven Dimensionen untersuchen und dabei verschiedene Gefahren möglichst vergleichend betrachten. Zusätzlich sollten Gefahrenlagen und Warnungen systematisch variiert werden. Abschließend wurde eine Erweiterung des PADM um eine Modellkomponente vorgeschlagen, die affektive Risikowahrnehmung in das bislang kognitive Modell inkludiert.

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8 Abbildungsverzeichnis

9 Appendix A. Publikationen

Bei allen im Folgenden aufgeführten Publikationen handelt es sich um Vorab-Publikationen. Die veröffentlichten Artikel und alle zusätzlichen Materialien sind unter den jeweils angegebenen Quellen zu finden. Aus Urheberrechtsgründen wurden in der vorliegenden Arbeit keine originalen Warnungen abgedruckt. Diese sind ebenfalls über die veröffentlichten Artikel abrufbar.

9.1 A1. Studie 1

Rahn, M., Tomczyk, S. & Schmidt, S. (2021). Storms, Fires, and Bombs: Analyzing the Impact of Warning Message and Receiver Characteristics on Risk Perception in Different Hazards. *Risk Analysis*, *41*(9), 1630–1642. https://doi.org/10.1111/risa.13636

TITLE

Storms, Fires, and Bombs: Analyzing the Impact of Warning Message and Receiver Characteristics on Risk Perception in Different Hazards

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ABSTRACT

In crisis communication, warning messages are key to prevent or mitigate damage by informing the public about impending risks and hazards. The present study explored the influence of hazard type, trait anxiety, and warning message on different components of risk perception. A survey examined 614 German participants (18-96 years, M=31.64, 63.0% female) using a pre-post comparison. Participants were randomly allocated to one of five hazards (severe weather, act of violence, breakdown of emergency number, discovery of a World War II bomb, or major fire) for which they received a warning message. Four components of risk perception (perceived severity, anticipatory worry, anticipated emotions, and perceived likelihood) were measured before and after the receipt. Also, trait anxiety was assessed. ANCOVAs of risk perception were calculated, examining the effect of warning message, trait anxiety, and hazard type while controlling for age, gender, and previous hazard experience. Results showed main effects of hazard type and trait anxiety on every component of risk perception, except for perceived likelihood. The receipt of a warning message led to a significant decrease in anticipated negative emotions. However, changes across components of risk perception, as well as hazards, were inconsistent, as perceived severity decreased while perceived likelihood and anticipatory worry increased. In addition, three interactional effects were found (perceived severity x hazard type, perceived severity x trait anxiety, anticipated emotions x hazard type). The findings point toward differences in the processing of warning messages yet underline the importance of hazard type, as well as characteristics of the recipient.

KEYWORDS: warning message, crisis communication, risk perception, hazard type, trait anxiety

SUMMARY: Warning research needs to consider the differential impact of hazard, warning message, and receiver characteristics: Warnings may reduce emotional impact and perceived severity of certain hazards but not in highly anxious persons.

1. INTRODUCTION

Hazards, crises, and disasters are and will be part of our lives, either in the form of man-made or natural incidents. In 2018, natural disasters alone – such as floods, storms, or wildfires – caused over 131 billion dollars of economic losses and more than 11.800 deaths globally (Centre for Research on the Epidemiology of Disasters, 2019). In the occurrence of such hazards, warning messages can help prevent or mitigate various forms of damages by communicating risks, giving information, and recommending protective actions. Due to advancing technological development, they can be received quickly and by a growing audience, e. g. via cellular broadcast-based warning systems (Gutteling et al., 2018) or smartphone apps (Rahn et al., 2020a; Reuter, Kaufhold, Spielhofer & Hahne, 2017). This makes it all the more important to understand which processes and changes warning messages initiate in their recipients.

There are seminal theoretical frameworks linking warning messages to processes within the receiver. Two well-established models are the Protective Action Decision Model (PADM) (Lindell & Perry, 2003, 2012), and the Communication-Human Information Processing Model (C-HIP) (Conzola & Wogalter, 2001; Wogalter, 2006). The PADM is focusing on human responses towards impending hazards. Within a multi-stage model, pre-decisional processes, core perceptions, decision-making processes, and behavioral responses of those at risk are integrated. The pre-decisional processes are initiated by several cues and factors, such as environmental cues, warnings, and characteristics of the receiver. Considering the PADM, warning messages depict one possible way to start multi-stage processes, with risk perception playing a central role in the adoption of protective behavior (Lindell et al., 2019; Strahan et al., 2019). The C-HIP rather refers to the processing of warning information, as the model includes aspects of warning source and channel, and describes several sub-stages of information processing within the receiver of a warning message, such as attention switch and maintenance, comprehension, beliefs and attitudes, and motivation to comply. Regarding the C-HIP, warning messages are a means to inform about risk, thus making risk perception an important part of in-

formation processing. Mayhorn und McLaughlin (2014) use parts of both models to explain how people react to warning messages, namely attributes of the hazard, the warning message, and the receiver. The present study aims to investigate the impact of these three areas on risk perception.

1.1 Components of Risk Perception

Risk perception is an extensively researched construct in safety science, resulting in a large body of research that addresses perceived risk by the public in connection with specific hazards and behaviors (Wachinger et al., 2013). In its original sense, risk perception is defined as the subjective judgment a person makes by characterizing and evaluating a hazard (Knuth et al., 2014; Slovic, 1987). It is commonly operationalized as the perceived likelihood of a potential outcome or being affected by a threat. Contrary to this rather cognitive conceptualization of risk perception, affective components, as well, can be considered part of this construct. These include, for instance, feelings towards a hazard or disaster, such as fear, anger, or sadness (Sheeran et al., 2014).

There are several theoretical frameworks that focus on cognitive and affective components of perceived risk and related (protective) behaviors or attitudes: The extended parallel process model (EPPM) (Popova, 2012; Witte, 1994) covers cognitive appraisals of threat and efficacy appraisals as influential factors on the likelihood of protective action. Affective appraisals, such as fear towards a threat, can lead to fear control, which in turn can result in maladaptive behaviors. The affect heuristic (Finucane et al., 2000; Slovic et al., 2007; Slovic & Peters, 2006) describes an affect driven experiential system. Especially in high-pressure situations, an automatic, intuitive information processing is initiated by feelings or affective perceptions towards a threat, enabling a fast adoption of protective behaviors. In contrary to the experiential system, the analytic system is based on a slower way of processing information, for example by weighing different aspects of a threat and required protective measures.

Cognitive *and* affective components of risk perception are relevant to the adoption of protective behaviors, as evidenced by a meta-analysis regarding health behaviors (Sheeran et al., 2014):

Heightening and combining cognitive and affective components of perceived risk (called risk appraisals) increase the intention to act and health-related behaviors itself. Similar associations have been reported in crises and warning associated research, however, risk perception is often operationalized via single components rather than as a multidimensional construct (Leppin & Aro, 2009; Sheeran et al., 2014; Wilson et al., 2019), making a multi-faceted approach a research desideratum. Therefore, as with Sheeran et al. (2014), perceived risk is measured in the present study with different components, namely risk perception and perceived severity as cognitive components and anticipated emotions and anticipatory worry as affective components.

1.2 Warning Message

Warning messages provide information to the public about threats and hazards, as well as recommendations for actions (Mayhorn & McLaughlin, 2014; Mileti & Peek, 2000). Their main objective is to galvanize the public, ideally towards protective behavior. In the case of a hazard, warning messages can help those at risk to take action faster (Markwart et al., 2019), which in turn can prevent or minimize damage. Important attributes to understand warning messages are their source, channel, style, timelines, and content (Kuligowski & Dootson, 2019; Mayhorn & McLaughlin, 2014). Looking at the content, Kuligowski und Dootson (2019) summarize the five W`s of a warning message: Who provides the message? When are they recommended or needed? Where does the hazard take place? Why do people need to take action? And what actions are recommended? To use this information properly when issuing warning messages, it must be adapted to the type of impending hazard (Drabek, 1999; Sorensen, 2000).

1.3 Hazard Type

Various taxonomies classify hazards and disasters, for example by making a distinction between natural (e.g., floods, storms, droughts), biological (e.g., crop fungal diseases), man-made (e.g., terroristic attacks, war) or technological hazards (e.g., nuclear accidents) (Kuipers & Welsh, 2017; Mileti, 1999; Perry, 2007; Tierney, 2001). Yet, the majority of empirical research in this field focuses on a specific hazard or event type and does not target a taxonomic or even comparative approach. This single-

sided view on different hazard types impedes a comparative examination of overlapping factors like risk perception. Thus, only a few studies exist which contrast hazards in terms of risk perception: Ho et al. (2008) investigated risk perception in connection with two different disaster types, namely landslides and floods. They found that, next to gender and previous experience, the type of disaster has an influence on risk perception. Landslides were associated with a higher life threat than floods, while floods had a higher impact on the associated financial loss. The authors conclude that characteristics of the hazard itself must also be taken into account when risk needs to be communicated. Heilbrun et al. (2010) compared three different kinds of hazards (natural disaster, violent crime, and terrorism) via vignettes and systematically varied threat imminence, risk level, and hazard type. Under the high-risk level condition, they found differences in risk perception and the intention to act between the three hazards. For example, in the event of a natural disaster participants were more likely to change their daily activities, relocate, or secure their homes. Based on these preliminary findings, a comparison of different hazard types seems reasonable to understand the role of hazard type in the process of risk and crisis communication.

1.4 Receiver

Characteristics and prior experiences of a person influence the perception of their environment, and thus the perception of warning messages and risk. Likewise, how people respond to a warning message is not always the same. Among others, reactions depend on several individual factors (Drabek, 1999; Figner & Weber, 2011; Mayhorn & McLaughlin, 2014). In terms of sociodemographic variables, the role of age and gender on risk perception is often examined. With regard to gender, some studies show that men perceive lower risks than women (Figner & Weber, 2011; Flynn et al., 1994; Ho et al., 2008; Savage, 1993), while women are more likely to believe in disaster warning messages (Turner et al., 1986). Other authors found no gender differences for people living in rather hazardous neighborhoods (Greenberg & Schneider, 1995), nonwhite men and women (Flynn et al., 1994), or inhabitants of gender-equal countries (Olofsson & Rashid, 2011). Higher age was found to be associated with an increased perception of risk in terms of natural disasters, but this relationship was inconsistent when

other types of hazards were considered (Kellens et al., 2011; Savage, 1993). Overall, the body of research regarding sociodemographic variables is rich but inconsistent.

Next to sociodemographic variables, personality traits, such as trait anxiety, may influence the perception of risk (Butler & Mathews, 1987; Chauvin et al., 2007). High trait-anxiety is often associated with a higher perception or even overestimation of risk (Maner & Schmidt, 2006). But in terms of preparatory behavior, anxious individuals may be less likely to prepare themselves (McNeill et al., 2016; Mishra & Suar, 2012; Notebaert et al., 2016). Possible reasons for this could be that anxious individuals tend to accept risk less, avoid information about possible protective actions (Paton, 2003), or use avoidance- and emotion-oriented coping strategies (Mishra & Suar, 2012). Wirtz et al. (2019) specifically focused on the relationship between trait-anxiety and preparedness behavior concerning terror threat. They found one direct and two indirect pathways between these two constructs: The effect of anxiety on preparedness was positively mediated through vulnerability and negatively mediated through self-efficacy. Also, there was a negative independent effect of anxiety on preparedness. Thus, the relationship between these two constructs is a rather complex one, involving multiple pathways.

In addition to individual characteristics, another considerable factor is whether a person has had previous experience with a hazard. Studies examining previous experience found that earlier experience leads to a higher risk perception (Ho et al., 2008; Olofsson & Rashid, 2011). But here, too, the findings are inconsistent, as other studies found opposite trends (Scolobig et al., 2012; Wachinger et al., 2013). And again, the majority of studies focuses on singular or specific hazards, for instance, risk perception and previous experience regarding earthquakes only (Kung & Chen, 2012).

1.5 Research Aims

As already implied by Mayhorn und McLaughlin (2014) and previous research (Lindell & Perry, 2012; Wogalter, 2006), there are a several of factors that play a role in warning associated processes. These include characteristics of the hazard itself, the warning message, but also characteristics and processes on the receiver's side. Looking at risk perception, to our knowledge, there are few studies that

examine cognitive *and* affective components of risk perception over time in connection with warning messages for different hazard types. Given these research gaps, the present study aims to compare five different types of hazards in terms of risk perception before and after the receipt of a warning message. In contrast to previous comparisons of hazards (e.g., Heilbrun et al., 2010), the study has higher ecological validity by using official previously issued warning messages as study materials. Also, individual factors and characteristics will be taken into account. Based on the existing findings, this study aims to answer the following research questions (RQ):

- RQ1: Do cognitive and affective components of risk perception differ between different hazard types?
- RQ2: Do receiver characteristics, such as trait anxiety, influence different components of risk perception?
- RQ3: Does the receipt of a warning message cause changes in different components risk perception? And how do interactions between trait anxiety and hazard type affect changes in risk perception?

2. METHOD

The present study was approved by the Ethics Committee of the University Medicine Greifswald (BB 169/18).

2.1 Sample

The sample was collected during a period of eight months from May to December 2019. The survey ended before the COVID-19 pandemic reached Germany at the end of 2019, thereby preventing any effects on the collected data. Participants were recruited via flyer advertising and internet forum posts. They were asked to take part in a survey about hazard warning messages. As compensation of expense, participants were offered 5 Euros or a voucher of the same value. Data collection occurred to be online (questionnaire via hyperlink) or offline (via paper-pencil-questionnaire) and took on average 20.51 minutes (*M*) (*SD*=56.90).

2.2 Materials

Participants were presented warning messages which had already been used to warn the public in Germany. This means that wording, content, and sender of the messages were already defined. The warning messages were anonymized and staged into the format of a warning application for smartphones, called NINA (BBK, 2020a). The app NINA is provided by the Federal Office of Civil Protection and Disaster Assistance. It is free of charge for the public and used by the German government, federal states and local communities to provide location-based warning messages via push notifications. Hazards to which the app refers include threatening weather situations, as well as large-scale emergencies and national or local threats (Petridou et al., 2019). All warning messages are attached in the supplementary information (supplementary figures S1 to S5).

2.3 Design and Study Procedure

The structure of the survey is shown in figure 1. Participants had to state their informed consent before starting the survey. In the beginning, age and gender were assessed. Trait anxiety was measured with the State-Trait-Anxiety Inventory (STAI-T) (Laux, Glanzmann, Schaffner, Spielberger, 1981) by assessing affective states related to trait anxiety in the past two weeks. STAI-T consists of 20 items with 4-point Likert scales from 1 (*almost never*) to 4 (*almost always*) and shows satisfying internal consistency (Cronbach`s α=.92). After that, participants were randomly allocated to one of five hazard types: 1) severe weather, 2) act of violence, 3) breakdown of emergency number, 4) discovery of a WWII bomb or, 5) major fire, for which they received a short explanation. All the following questions were related to this event. Participants were asked whether they or a person close to them (e.g. family or friends) had ever experienced the respective hazard. Personal experience was given when one of these conditions was answered with “yes”. Then, risk perception was assessed via the following four components: perceived likelihood (likelihood of being affected by the hazard in the future in %), anticipated emotions (mean score of three items for future feelings of anxiety, tension, sadness at the occurrence of the hazard; α=.81), anticipatory worry (concern of being affected by the hazard in the future) and perceived severity (severity of the consequences at the occurrence of the

hazard). Except for perceived likelihood (measured from 0 to 100 in % on a visual analogue scale), all components were assessed via 5-point Likert scales from 1 (*not at all*) to 5 (*very much*). After the assessment of risk perception, participants were presented with a warning message. The four components were then assessed again.

Please insert figure 1 here.

2.4 Statistics

A total of 621 participants took part in the survey. For the evaluation of the STAI-T, up to two missing values were replaced by the mean values (Laux, Glanzmann, Schaffner, Spielberger, 1981). Two participants were removed due to three or more missing STAI-T values. Finally, five participants were excluded that did not report male or female gender, leaving a total sample of 614. STAI-T items (partly reversed) were added up to obtain a STAI-T score. Participants were divided into high and low trait-anxiety by performing a median split. For anticipated emotions, mean values of the three items were calculated. Complete cases were used for all further calculations. Different tests were performed to examine the relationship between hazard type and age (univariate ANOVA), trait anxiety, gender, and previous experience (Chi-square tests). Pearson correlations and univariate ANCOVAs were used to investigate links between the components of risk perception before the warning message receipt and trait anxiety, age, gender, and previous experience. For each hazard type, Pearson correlations were performed for previous experience with age and gender.

After that, for each component of risk perception one repeated measure ANCOVA was conducted with risk perception component as within factor and trait anxiety and hazard type as in between factors. Partial eta squared (η_p^2) was applied as measure of effect size. For all ANCOVAs described below, age, gender, and previous experience were included as covariates.

3. RESULTS

3.1 Descriptive Statistics

In the remaining sample of 614 participants, nearly 1% (0.74%) of the data was missing with missing values ranging from 0 (e.g. age) to 27 (perceived likelihood after warning message receipt) at item

level. 32.1% (N=197) filled out paper-pencil questionnaires, while the remaining 67.9% (N=417) participated in the online survey. To examine potential bias, we included sampling method as a covariate in our analysis, but we did not find any significant associations (results available upon request from the first author), therefore we do not report them in this text. The sample included 63.0% (N=387) females and 37.0% (N=227) males. Age ranged from 18 to 96 years (*M*=31.64, *SD*=17.36).

Due to randomization, 117 to 138 participants were surveyed per hazard type. 35.8% (N=220) of the overall sample had previous experience with the particular hazard (severe weather 77.2%, act of violence 22.6%, breakdown of emergency number 14.3%, discovery of a WWII bomb 33.3%, major fire 29.9%). In the overall sample, mean value for STAI-T was 41.10 (*SD*=10.59, range=20-73) with a median of 39 (low anxiety: N=302, *M*=32.46, *SD*=4.27, high anxiety: N=312, *M*=49.51, *SD*=7.81).

The participants randomized to the different hazard types did not differ by age ($F(4, 614) = 1.85$, $p=.177$), trait anxiety ($\chi^2(4)=1.53$, $p=.821$) and gender ($\chi^2(4)=4.04$, $p=.400$). Yet, they differed by previous experience ($\chi^2(4)=125.95$, $p<.001$). The latter seems reasonable, as severe weather, for example, is experienced far more often than other hazards. For the particular hazard types, no significant correlations were found for previous experience with age and gender.

Please insert table I here.

3.2 Research Questions

RQ1: Do cognitive and affective components of risk perception differ between different hazard types?

At the first point of measurement, all four components of risk perception differed significantly between hazard types, namely perceived severity ($F(4,611)=44.83$, $p<.001$, $\eta_p^2=.23$), anticipatory worry ($F(4,610)=4.00$, $p<.01$, $\eta_p^2=.03$, anticipated emotions ($F(4,612)=69.42$, $p<.001$, $\eta_p^2=.32$), and perceived likelihood ($F(4,595)=5.22$, $p<.001$, $\eta_p^2=.03$). Perceived likelihood was rated higher for severe weather than for all other hazard types. Regarding perceived severity and anticipated emotions, act of violence and major fire were rated higher. For anticipatory worry, severe weather, act of violence, and

breakdown of the emergency number were rated higher. Descriptive statistics are summarized in table I.

RQ2: Do receiver characteristics, such as trait anxiety, influence the components of risk perception?

Regarding sociodemographic characteristics associated with risk perception, female participants reported generally higher risk perception. Moreover, previous hazard experience showed significant associations with different components of risk perception, but without a consistent trend. In contrast to that, no significant relationship between age and risk perception was found. Pearson`s correlation coefficients are shown in supplementary table TI.

Looking at trait anxiety, participants with low and high trait anxiety differed in their risk perception at the first point of measurement: While controlling for age, gender, and previous experience, participants with high anxiety reported higher perceived severity ($F(1,611)=4.73$, $p<.05$, $\eta_p^2=.01$), higher anticipatory worry ($F(1,609)=16.32$, $p<.001$, $\eta_p^2=.03$), and more negative anticipated emotions ($F(1,612)=14.80$, $p<.001$, $\eta_p^2=.02$). For perceived likelihood, no significant differences were found ($F(1,595)=0.83$, $p=.362$, $\eta_p^2=.00$).

Concerning the pre-post analysis, the associations between hazard type, trait anxiety, and risk perception were observed at both time points.

RQ3: Does the receipt of a warning message cause changes in risk perception? And how do interactions between trait anxiety and hazard type affect changes in risk perception?

In addition to the main effects reported above, pre-post analysis revealed changes in risk perception for some components. Anticipated emotions significantly decreased between the two times of measurement in the overall sample, when controlling for age, gender, and previous hazard experience ($F(1,599)=11.38$, $p<.01$, $\eta_p^2=0.02$). There were no main effects for warning message receipt for the remaining three components (see figure 2).

In addition, anticipated emotions interacted with hazard type ($F(4,599)=6.28$, $p<.001$, $\eta_p^2=0.04$) in that anticipated emotions decreased for all hazard types, except for discovery of a WWII bomb. For the latter, negative anticipated emotions increased after the receipt of a warning message.

For perceived severity, interactional effects were found for trait anxiety ($F(1,599)=5.11$, $p<.05$, $\eta_p^2=0.01$) and hazard type ($F(4,599)=4.54$, $p<.01$, $\eta_p^2=0.03$). Perceived severity decreased in participants with low trait anxiety while it remained high in individuals with high trait anxiety. Moreover, perceived severity increased for discovery of a WWII bomb while decreasing for the remaining hazard types.

Regarding anticipatory worry and perceived likelihood, no interactional effects for trait anxiety and hazard type were found.

Please insert figure 2 here.

Please insert figure 3 here.

4. DISCUSSION AND IMPLICATIONS

The present study examined the influence of hazard type, receiver characteristics, and the receipt of a warning message on different components of risk perception. Findings provided information regarding RQ1 by revealing an impact of hazard type on all four components of risk perception, including cognitive and affective appraisals of the five hazard types. Anticipated negative emotions and perceived severity were rated higher for major fire and violent act, which are characterized by a potentially high extent of damage, high uncertainty, or rapidly required adoption of protective actions (Ho et al., 2008; Sheppard, 2011). Severe weather depicts a hazard that occurs more frequently, resulting in higher ratings of perceived likelihood (i.e. probability of occurrence) and lower ratings of anticipated negative emotions (Frondel et al., 2017; Keul et al., 2018).

Concerning trait anxiety (RQ2), several significant associations with risk perception were found as well, albeit not for every component of risk perception. Individuals with high trait anxiety

showed higher anticipatory worry, anticipated negative emotions, and perceived severity after reading a short explanation of one out of five hazards. Regarding these components of risk perception, high anxious individuals seem to feel more threatened overall when confronted with a hazard. This is in line with earlier research (Maner & Schmidt, 2006). However, when it comes to estimating the likelihood of a hazard, the two groups did not differ from each other. This could be since the short explanations given during the data assessment only contained brief descriptions of the hazards and no further information on probabilities. Therefore, the participants did not have any frame of reference for their ratings of perceived likelihood, except for their previous experience. Yet, the question remains open as to what impact trait anxiety has on the adoption protective measures. For the latter, prior research showed associations between trait anxiety and decreased heat-wave and flood preparedness as well as decreased preparedness behaviors for terrorist attacks, but emphasized the importance of other determinants, such as given resources and disaster education, or cognitive factors, such as self-efficacy and perceived threat (Mishra & Suar, 2012; Wirtz et al., 2019). Other findings indicate no influence of trait anxiety on health related-behavior (Witte & Morrison, 2000). Thus, the effect of trait anxiety on protective behavior remains of interest – be it hindering or fostering.

Regarding RQ3, an influence of warning message receipt on anticipated negative emotions was observed in the overall sample, in that participants reported significantly less negative emotions after the receipt of a warning message. Interestingly, for the remaining components, no consistent trends were found for cognitive (perceived likelihood, perceived severity) and affective components (anticipated emotions, anticipatory worry): Some components increased (anticipatory worry, perceived likelihood), while others decreased (anticipated emotions, perceived severity) in the overall sample. This is contrary to general expectations, as warning messages are intended to raise awareness of risk (Mayhorn & McLaughlin, 2014), but may point toward differences in the processing of hazard-related information and warning messages: At the first point of risk perception measurement, participants reported higher negative emotions and perceived severity towards the majority of haz-

ard types. As they only received a short explanation of the particular hazards prior to their initial assessment, it can be presumed that they used their experiential system as proposed by the affect heuristic to make their ratings, which can result in higher ratings of negative emotions (Slovic et al., 2007). When confronted with a warning message and the included recommendations of protective measures, participants may be able to make more rational ratings of risk perception, since they now have more information about the situation (cf. analytical system according to affect heuristic). This, in turn, could lead to an increased perceived likelihood and anticipatory worry towards the hazard, but also a decrease in negative emotions and perceived severity, as the impending threat and protective actions become more salient. Thus, the decrease in some components could be explained if one considers that a warning message can provide a feeling of safety by giving orientation and recommendations on how to be prepared and avoid harm (Slagle et al., 2013; Vihalemm et al., 2012).

Moreover, interactional effects were found for warning message receipt and hazard type: Anticipated negative emotions and perceived severity decreased for all hazard types, except for discovery of a WWII bomb. For this hazard, all components of risk perception increased after the receipt of a warning message, making it a special case that demands further investigation. Discoveries of WWII bombs are somewhat frequent, but not commonplace, events in Germany and central Europe. They can, in some cases, influence public life without giving much scope of action (e.g., when evacuation is ordered by the authorities). The warning message used for this study announces evacuation measures and thereby leaves the receiver with few options to act otherwise than to follow the measures. Thus, the receipt of the message could make this hazard more salient, while leading to an increase in some components of risk perception caused by limited choices for action. In the sense of the EPPM (Popova, 2012; Witte, 1994), it is of interest whether the increase of risk perception is caused by a lack of efficacy appraisals and whether the observed changes could influence the adoption of evacuation behavior. Since, to the best of our knowledge, there are hardly any studies on this hazard type, further research in this field is essential, as failure to comply with warning messages regarding the discoveries of WWII bombs can cause various forms of harm, as well.

Lastly, one interactional effect was found for trait anxiety and perceived severity, as perceived severity decreased after the receipt of a warning message for low trait anxiety individuals, while no changes in high trait anxiety participants became apparent. This could point to high vigilance among high anxious participants. Similarly, a study on bushfires found that high trait anxiety is associated with an attentional bias, in that high anxious individuals tend to show higher vigilance towards bushfire-related threat (Notebaert et al., 2016). In our study, we also found increased levels of perceived severity in participants with high trait anxiety. Future research should investigate the association of perceived severity as against other aspects of risk perception regarding attention bias and information processing in warning messages. Since this effect was not influenced by hazard type, it might indicate a more general aspect of information processing (Wogalter, 2006). This could be an explanatory approach for the findings, assuming these participants rated the hazards as more severe or feel more threatened. Once again, further research on trait anxiety could contribute to a better understanding of warning associated processes.

4.1 Implications

The given results provide empirical evidence of the integrative view of hazard type, warning message, and receiver characteristics as described by Mayhorn und McLaughlin (2014), moreover offer several implications for research and practice. First, implications for future research support the application of a comparable methodology in the assessment of risk perception, as recently underlined by Wilson et al. (2019). The different trends in the components as shown in this study support the facetted or multidimensional approach of risk perception (Sheeran et al., 2014; Sjoberg, 1998; Wilson et al., 2019). In this regard, subsequent studies should also assess the relationship between components of risk perception, warning message induced changes, and the intention to act or protective behavior, since prior findings indicate varying associations (Wachinger et al., 2013). By assessing risk perception and following behaviors, different models, such as the affect heuristic or the EPPM, could be tested in the context of risk communication in the event of hazards and crises to improve the un-

derstanding of the processes within the warning message recipient. This could also permit the investigation of what components (i.e., cognition or affect) may have a greater impact on the adoption of protective measures (Gutteling et al., 2018).

Additionally, as this study has shown again, receiver characteristics should always be borne in mind when it comes to the assessment of risk perception. For instance, trait anxiety influenced three components of risk perception, and additionally one component when receiving a warning message. Yet, it is not clear whether trait anxiety has a promoting or hindering impact on the adoption of protective measures as given in hazard warning messages (Mishra & Suar, 2012; Wirtz et al., 2019).

Moreover, a comparative view on different hazard types proves beneficial, as the warning messages in this study caused different reactions within the warning message receivers. In this context, the proximity in time or space to the hazard could also be examined, since proximity to the hazard source is also associated with risk perception (Zhang et al., 2010). Studies on risk perception and infrequent occurring hazards or hazards with low severity depict a research desideratum. For example, as shown for discovery of a WWII bomb or breakdown of the emergency number, there is a lack of studies on these hazards types, which deal with the components of risk perception in association with protective measures.

Although often neglected in scientific research, further investigation of these hazard types can help to improve crisis communication and thus protect the public, as well. Standardized disaster or hazard taxonomies could be helpful here to systematically classify findings (Drabek, 1999).

The realization of further research and the transfer into practice may take place via virtual reality, as this approach allows to observe human behavior during various kinds of hazards and crises, and at the same time to modify aspects of the situation and the warning message (Duarte et al., 2010; Markwart et al., 2019).

Second, implications for practice point towards the idea that the type of hazard should always be considered when communicating risk, as there is no “one warning fits all”. Different types of

hazards can cause different reactions within those at risk, which should be borne in mind by stakeholders who issue warning messages. Besides the type of hazard, evidence from the present study implies that warning messages should be individualized (Wogalter et al., 1994). These findings may be helpful, for example, when messages are tailored to groups of people who have already experienced a hazard several times or never before.

Finally, while considering receiver characteristics and hazard type, thoughtful risk and crisis communication can help to take good preventive action, cope with fears or uncertainties and prevent or mitigate harm to life and property (Gray & Ropeik, 2002; Veil et al., 2008).

5. LIMITATIONS

The present study clearly has some limitations, which are typical for survey designs. Although the collection of data was prospective, no context factors from the participants' surroundings were assessed. Therefore, it was not possible to control (especially when participating online) under which circumstances participants completed the survey. Nevertheless, analyses of covariance showed that the sampling method did not influence the four components of risk perception.

Also, German convenience sample was collected, which impedes representative results for the German population, as well as a transcultural comparison of risk perception (Keul et al., 2018).

Previous hazard experience was assessed as a covariate, but not differentiated into direct or indirect experience with the particular hazards. As prior research implies the importance of hazard experience on risk perception (Wachinger et al., 2013), future studies should assess hazard experience more detailed. Furthermore, no intermediary variables, such as self-efficacy or response efficacy, were surveyed (Sheeran et al., 2014). This applies as well for the intention to act and protective behavior itself. Thus, the results cannot clarify whether the examined factors or changes influence the adoption of protective measures.

The five hazard types examined in this study varied in terms of frequency and extent of damage. Yet, as we used original but anonymized warning messages, we could neither systematically vary the content and design of the warning messages nor characteristics of the hazards. Nevertheless,

empirical research shows that a variation of different aspects of the hazards impacts risk perception. For example, proximity to hazard sources is positively associated with perceived personal risk regarding floods, hurricanes, and chemical hazards (Zhang et al., 2010). This can be interpreted according to the psychometric paradigm, which states that risk perception is rather driven by common qualitative risk characteristics (e.g., controllability, knowledge, dread) of hazards and less by the hazard type itself (Marris et al., 1997; Slovic et al., 1986). On the other hand, the naturalistic approach used in the present study results in a higher ecological validity of the given results. Future studies should try to merge the variation of risk characteristics and hazard types with the use of authentic warning messages to derive conclusions for science and practice. Despite these limitations, this study has gone some way towards enhancing the understanding of risk perception, hazard type, and receiver characteristics in crisis communication.

DECLARATION OF INTEREST

None.

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APPENDIX

Fig. 1. Study procedure.

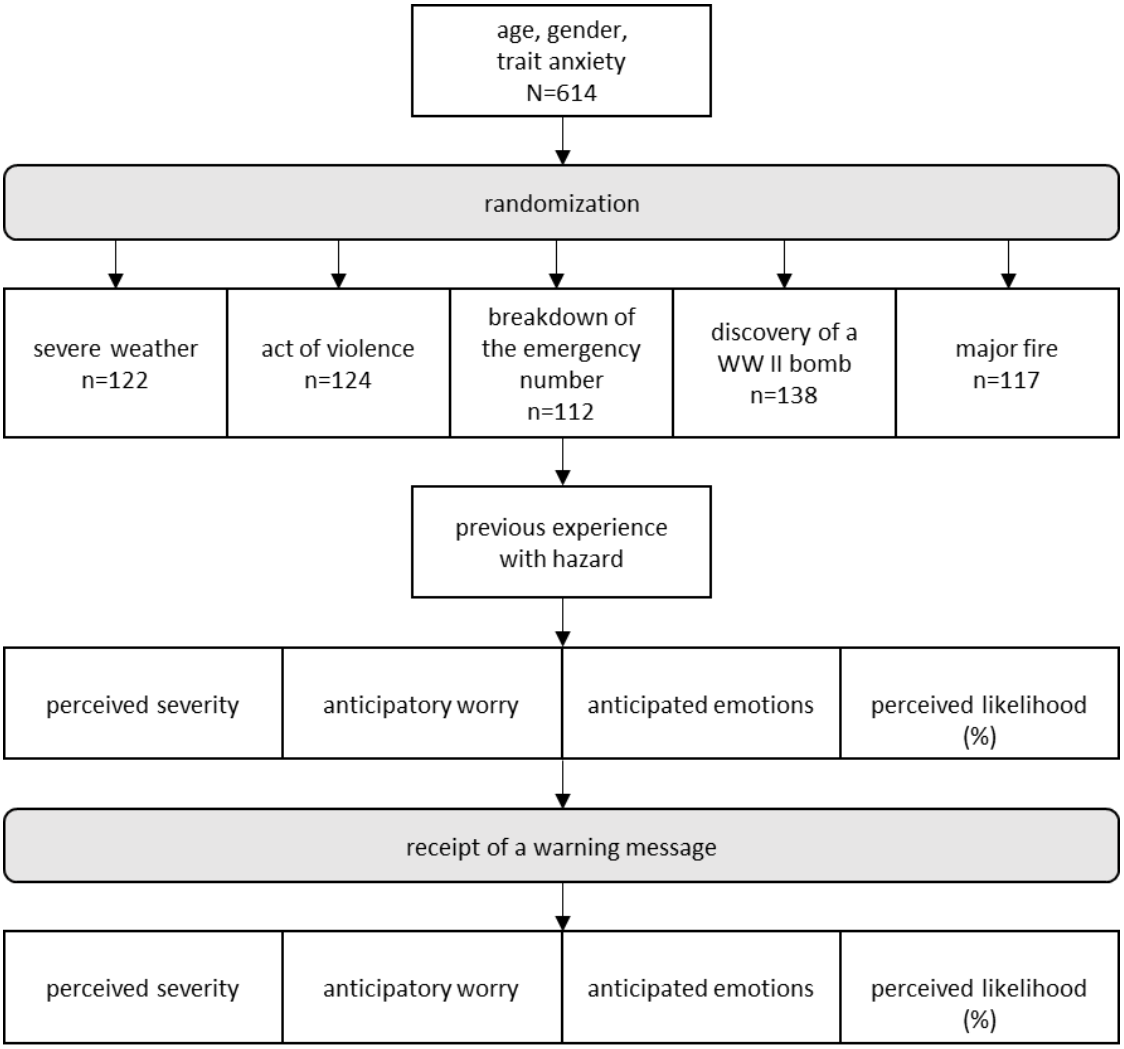
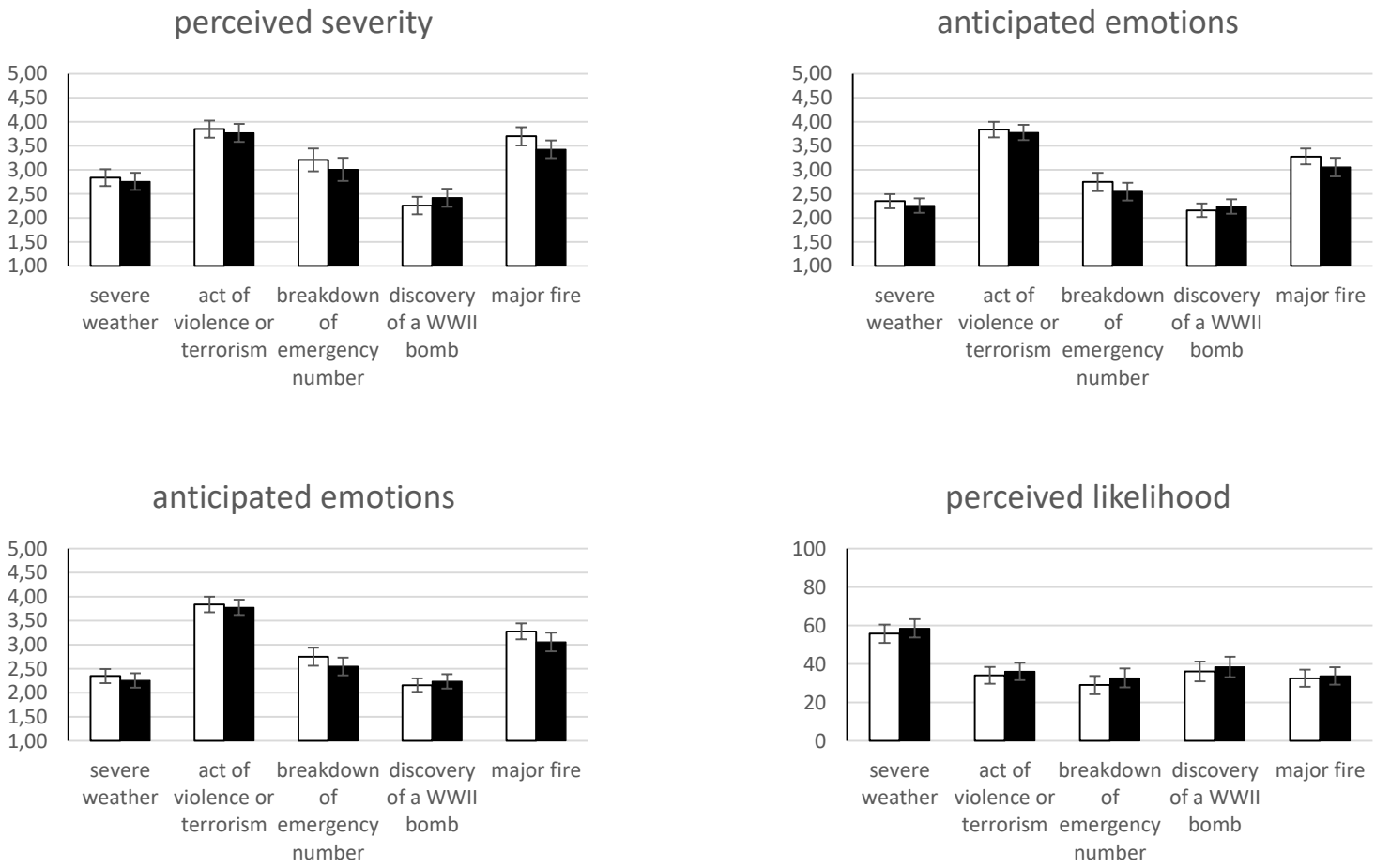


Table I. Unadjusted means of all components of risk perception (complete sample and separated by hazard type) before and after the receipt of a warning message.

Risk perception	Hazard type											
	Total sample		Severe weather[a]		Act of violence[b]		Breakdown of emergency number[c]		Discovery of a WWII bomb[d]		Major fire[e]	
	N=614		n=123		n=124		n=112		n=138		n=117	
Before warning message												
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Perceived severity	3.14	1.24	2.84 ^{bde}	1.00	3.85 ^{acd}	1.00	3.21 ^{bde}	1.30	2.26 ^{abce}	1.09	3.70 ^{acd}	1.06
Anticipatory worry	2.16	1.06	2.40 ^{de}	1.03	2.25	1.10	2.28	1.06	1.92 ^{a}	1.06	1.96 ^{a}	0.97
Anticipated emotions	2.86	1.09	2.35 ^{bce}	0.83	3.84 ^{acde}	0.91	2.75 ^{abde}	1.02	2.16 ^{bce}	0.84	3.28 ^{abcd}	0.92
Perceived likelihood (%)	37.77	28.03	55.78 ^{bcde}	27.02	34.09 ^{a}	24.88	29.10 ^{a}	25.01	36.15 ^{a}	30.08	32.61 ^{a}	24.40
After warning message												
Perceived severity	3.06	1.20	2.76 ^{be}	1.01	3.77 ^{abc}	1.07	3.01 ^{bd}	1.30	2.42 ^{bce}	1.12	3.43 ^{acd}	1.00
Anticipatory worry	2.34	1.11	2.55 ^{d}	0.98	2.44	1.15	2.40	1.11	2.12 ^{a}	1.18	2.22	1.06
Anticipated emotions	2.77	1.10	2.26 ^{be}	0.84	3.78 ^{acde}	0.90	2.55 ^{be}	1.01	2.24 ^{be}	0.91	3.06 ^{abcd}	1.00
Perceived likelihood (%)	40.24	28.39	58.51 ^{bcde}	26.9	36.15 ^{a}	24.60	32.75 ^{a}	26.41	38.50 ^{a}	30.58	33.83 ^{a}	24.55

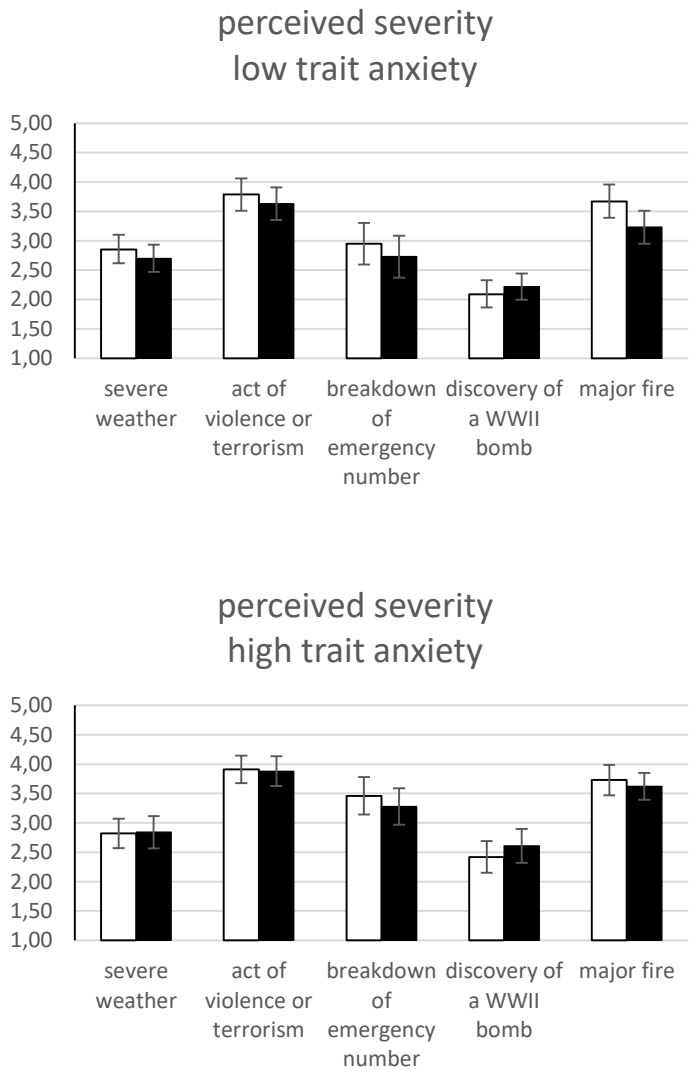
Notes. M: Unadjusted mean. SD: Standard deviation. Superscripts a, b, c, d, e indicate statistically significant differences between the hazard types (Bonferroni-adjusted post-hoc analysis ($p<.05$)) at each point of measurement.

Fig. 2. Unadjusted means of the components of risk perception before and after the receipt of a warning message, separated by hazard type.



Notes. Components of risk perception before (white bars) and after (black bars) the receipt of a warning message. Perceived severity, anticipatory worry, anticipated emotions measured via 5-point Likert scales from 1 (not at all) to 5 (very much). Perceived likelihood measured in %.

Fig. 3. Unadjusted means of the component perceived severity for the different hazard types before and after the receipt of a warning message, separated by low and high trait anxiety.



Notes. Perceived severity before (white bars) and after (black bars) the receipt of a warning message. Perceived likelihood measured via 5-point Likert scales from 1 (not at all) to 5 (very much).

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SUPPLEMENTARY

Supplementary figures S1 to S5. Warning messages staged into the format of the German smartphone application NINA and translated into English. S1 severe weather, S2 act of violence, S3 breakdown of emergency number, S4 discovery of a WW II bomb, S5 major fire.

S1 severe weather

Warning
Severe weather
There is a risk of severe thunderstorms (level 3 of 4).

Recommendations for action:
ATTENTION! Note on possible threats: There is a threat to life in case of lightning strikes! Among other things, there is widespread risk of serious damage to buildings. Trees can be uprooted and roof tiles, branches, and objects can fall. Flooding of cellars and streets, as well as local flooding of brooks and small rivers, is possible (details: www.hochwasserzentrale.de). For example, landslides can occur. Close all windows and doors! Secure objects outside! In particular, keep away from buildings, trees, scaffolding, and high-voltage lines! Avoid staying outside if possible!

Published by:
The Deutscher Wetterdienst

Further information:
Detailed warning information is available at http://www.wettergefahren.de

S2 act of violence

Warning

Act of violence

Your city reports: Amok situation in your city. For your safety, avoid squares and streets; offenders are fleeing; train and bus traffic stopped; turn on radio and television;

Recommendations for action:
Stay at home. Share the warning.

Published by:
Your City

S3 breakdown of emergency number

Warning

Breakdown of emergency number

Currently, emergency call 112 is not available in your city. Landline and mobile networks are not available.

Recommendations for action:
In an emergency, you can reach the fire department and police at their locations. Or call the police on 110! Inform your neighbors and assist if necessary!

Published by:
Your local control center

S4 discovery of a WW II bomb

Warning

Discovery of a WW II bomb

This is followed by information published by the city: Due to a discovery of a bomb, there will be evacuation measures in the area of the city center starting at 2.30 pm. Considerable traffic obstructions are to be expected. The affected population will be addressed directly by the local emergency services. Inform your neighbors if necessary. Do not block the emergency call of the fire department and police.

Recommendations for action:

Switch on radio and television. Inform yourself about all available media. Pay attention to loudspeaker announcements.

Published by:
Your City

S5) major fire

Warning

Major Fire

Due to a major fire, there is heavy smoke development in the area of the city center.

Recommendations for action:

Switch on radio and television. Inform yourself about all available media. Please close the windows and doors immediately. Switch off ventilation and air conditioning systems.

Published by:
Your Fire Department

Supplementary table TI. Pairwise Pearson correlation coefficients of age, gender previous experience, trait anxiety group and all for components of risk perception before and after the receipt of a warning message, N=580-619.

		1	2	3	4	5	6	7	8	9	10	11	12
1	Age	1											
2	Gender	-.11**	1										
3	Previous experience	-.03	-.03	1									
4	Trait anxiety low/high	-.12**	.14**	-.01	1								
5	Perceived severity (before)	.08	.11**	-.11**	.09*	1							
6	Perceived severity (after)	.08*	.06	-.09*	.15**	.74**	1						
7	Anticipatory worry (before)	.06	.11**	.09*	.16**	.34**	.39**	1					
8	Anticipatory worry (after)	.08*	-17**	.07	.19**	.40**	.53**	.68**	1				
9	Anticipated emotions (before)	-.03	.17**	-.18**	.17**	.61**	.58**	.30**	.34**	1			
10	Anticipated emotions (after)	-.03	.21**	-.15**	.21**	.58**	.61**	.28**	.40**	.88**	1		
11	Perceived likelihood (before)	-.06	.13**	.39**	.05	.01	.04	.39**	.31**	-.05	-.01	1	
12	Perceived likelihood (after)	-.05	.15**	.39**	.06	.03	.03	.38**	.35**	-.04	.01	.91**	1

Notes. Gender (1=male, 2=female), Previous experience (0=no, 1=yes); trait anxiety high/low (0=low trait anxiety, 1=high trait anxiety,); * $p<.05$, ** $p<.01$.

9.2 A2. Studie 2

Rahn, M.*, Tomczyk, S.*, Schopp, N. & Schmidt, S. (2021). Warning Messages in Crisis Communication: Risk Appraisal and Warning Compliance in Severe Weather, Violent Acts, and the COVID-19 Pandemic. *Frontiers in Psychology*, *12*. [* shared first authorship] https://doi.org/10.3389/fpsyg.2021.557178

Title:
Warning Messages in Crisis Communication: Risk Appraisal and Warning Compliance in Severe Weather, Violent Acts, and the COVID-19 Pandemic

Running head:
Warning Message Compliance and Risk Appraisal

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Words: 5231 (excluding abstract (266 words), references, 3 tables and 1 figure)

Abstract

Background: In crisis communication, warning messages are key to informing and galvanizing the public to prevent or mitigate damage. Therefore, this study examines how risk appraisal and individual characteristics influence the intention to comply with behavioral recommendations of a warning message regarding three hazard types: COVID-19 pandemic, violent acts, and severe weather.

Method: A cross-sectional survey examined 403 German participants from 18 to 89 years (M = 29.24; 72% female). Participants were allocated to one of three hazard types (COVID-19 pandemic, violent acts, severe weather) and presented with warning messages that were previously issued via an official warning app. Four components of risk appraisal (perceived severity (PS), anticipated negative emotions (AE), anticipatory worry (AW), and risk perception (RP)) were assessed before and after presenting the warning message. Path models were calculated to predict the intention to comply with the warning message, controlling for age, gender, and previous hazard experience.

Results: For the COVID-19 pandemic, higher age ($\beta = .18$) predicted warning compliance ($R^2 = .05$). AE ($\beta = .20$) predicted compliance in case of violent acts ($R^2 = .09$). For severe weather, PS ($\beta = .28$), age ($\beta = .29$), and female gender ($\beta = .34$) lead to higher compliance ($R^2 = .27$). Changes across risk appraisal components were not consistent, as some facets decreased after the receipt of a warning message.

Discussion: Risk appraisal has shown a marginal yet differential influence on warning message compliance in different types of hazards. Regarding the COVID-19 pandemic, the impact of sociodemographic factors on compliance should be studied more intensively. Moreover, integrating intermediary variables, such as self-efficacy, is necessary.

1. Introduction

Crisis communication aims to inform the public about various kinds of impending threats and hazards. Warning messages are a means of communicating risks and giving advice on how to act correctly in case of such hazards (Mayhorn & McLaughlin, 2014; Mileti & Peek, 2000). This is as important for everyday perils as it is for new or still unknown threats and crises.

The outbreak of the novel coronavirus COVID-19 in 2019 and the ongoing pandemic pose new challenges in this respect: At the end of April 2020, more than 2.5 million people have become infected with this respiratory disease, and over 180.000 thousand died (World Health Organization, 2020b). At this point in time, further development seemed yet unclear, as various factors were still unknown. Challenges arose, for example, from an uncertain case fatality rate, duration of infectiousness, pre-symptomatic infectiousness as well of asymptomatic courses (Anderson et al., 2020; Peeri et al., 2020).

To flatten the pandemic curve, a quick adaption to this new threat is necessary. This means inter alia that the public at large must be provided with information and recommendations for protective measures, as effective vaccination is not yet available. Therefore, the World Health Organization (2020a) gives a series of advice for the public to control the further spread of COVID-19. Among others, recommendations include maintaining social distance, respiratory hygiene, washing hands, and not touching eyes, nose, and mouth as well as following advice given by healthcare providers and public health services. For these measures to be effective, they must be shared with as many people as possible. Moreover, they must also be implemented and complied with by the public. Warning messages, again, are essential for this purpose.

To construct effective warning messages, several factors must be considered. In addition to characteristics of the warning message itself, these include contextual factors, such as the communication channel, as well as characteristics and processes on the receiver`s side (Bean et al., 2015; Mayhorn & McLaughlin, 2014; Mileti & Sorensen, 1990). Among other theoretical frameworks addressing such processes, the Protective Action Decision Model (PADM) focuses on human responses towards threats (Lindell & Perry, 2012). According to the PADM, warning messages, as well as contextual cues, can initiate pre-decisional processes (exposure, attention, and comprehension of the cue or warning message) that, in turn, influence three core perceptions, namely perceptions of risk or threat, possible protective actions, and stakeholder perceptions. These pre-decisional processes and core perceptions are key to decision-making for those at risk. Characteristics of the warning message receiver, his or her channel access, and channel preference, as well as the source of the incoming information, are also considered in the PADM. In light of this theoretical background, warning messages can start multi-stage processes by communicating risk and giving recommendations on protective actions, with the appraisal of risk being pivotal.

Risk Appraisal and Information Processing

Risk perception can be defined as a person`s beliefs about the vulnerability towards experiencing a potential threat. It is often operationalized as a subjective judgment of likelihood and thus conceived as a cognitive appraisal. Though, beyond this cognitive conceptualization, risk appraisal as well includes affective components that address feelings associated with a threat, for example, fear, sadness, or anger (Sheeran et al., 2014; Slovic, 1987). Previous research on risk appraisal towards threats and hazards, for instance, SARS or the avian flu (Leppin & Aro, 2009; Sheeran et al., 2014), points to a broad variation in conceptualization and assessment. This applies as well for natural hazards (Wachinger et al., 2013) or health-related behaviors (Sheeran et al., 2014), making it difficult to derive consistent conclusions and compare findings across scenarios, situations, and settings.

Seminal theoretical frameworks have focused either on the role of cognitions or affect towards risk and related attitudes and behaviors, such as the extended parallel process model (Popova, 2012; Witte, 1994), and the affect heuristic (Finucane et al., 2000; Slovic et al., 2007; Slovic & Peters, 2006). According to the extended parallel process model, cognitive threat appraisal as well as efficacy appraisal influence the likelihood of considering protective action, whereas affective appraisal (i.e., dread) can also lead to maladaptive behaviors, namely fear control, if efficacy is perceived as low. The affect heuristic focuses on the impact of affect and illustrates decision-making in high pressure situations. Consequently, under threat, negative affect activates the experiential system (i.e., automatic, intuitive information processing) that fosters swift action towards survival. The analytic system, on the other hand, represents a slower and more effortful way of processing information that is connected to information seeking, actively weighing pros and cons before performing behaviors. Regarding disaster scenarios, analytic processing is likely if one has enough lead time to seek and process further information, prior experience, and knowledge of the disaster and protective behaviors. If information and lead time are scarce, experiential processing is more likely. Thus, depending on the situation, both, cognitive and affective risk appraisals are important to compliance. This reasoning is echoed by research on health behaviors: A meta-analysis found that heightening and combining cognitive and affective appraisals of risk appraisal increases the intention to act and behavior itself (Sheeran et al., 2014).

For the ongoing COVID-19 pandemic, findings on risk appraisal and the adoption of protective measures are still preliminary. In a Hong Kong population at the beginning of the outbreak, participants of a survey reported high perceived susceptibility and high perceived severity towards COVID-19. In contrast, the willingness to distance oneself socially in the sample varied, with 39% to 88% intending to take this action (Kwok et al., 2020). In another study with a US American sample, risk perception (assessed as infection likelihood and severity for oneself and others) increased during the first week of the pandemic in Northern America, while participants' risk perception was higher for others than for themselves. In this sample, the adoption of protective measures, such as social distancing and hand-washing, increased as well during this first week, with protective measures being predicted by the perceived likelihood of becoming infected (Wise et al., 2020). Moreover, the role on individual characteristics on the appraisal of risk and the adoption of protective measures becomes apparent: In a German population, younger age was associated with a higher perceived likelihood of becoming infected by COVID-19 (for self, others, and in general), while females and the elderly worried more about becoming infected (Gerhold, 2020). Also, female gender and higher subjective knowledge of COVID-19 made it more likely for Hong Kong inhabitants to socially distance (Kwok et al., 2020). Findings on prior pandemics show a similar picture: For several infectious diseases, such as avian influenza, SARS, or swine influenza, older age, female gender, higher education, being non-white, as well as perceived susceptibility and severity of the respective disease predicted the adoption of protective measures (Bish & Michie, 2010).

To provide context for the analysis of warning communication in the COVID-19 pandemic, the present study aims to compare the ongoing pandemic to two additional hazard types, namely severe weather and violent acts, with varying degrees of severity and familiarity. On the one hand, severe weather, such as thunderstorms or heavy rainfalls, is a very familiar event in Germany and mostly characterized by moderate severity, with yet increasing economic damages (Coronese et al., 2019). Violent acts, on the other hand, are comparatively rare but of tremendous impact (Sheppard, 2011). That a comparative approach might be useful is shown by a broad body of research that focuses on specific hazards or singular events only while assessing risk appraisal inconsistently. Also, to our knowledge, only a few studies aim to compare different hazards in terms of risk appraisal. Their findings show that various hazard types are perceived differently in terms of risk appraisal (Rahn et al., 2020b) and vary

in how likely protective measures are intended, for example, due to a variation in threat imminence or risk level (Heilbrun et al., 2010; Ho et al., 2008). The type of hazard as well influences cognitive and affective components of risk appraisal when receiving warning messages, including interactional effects of hazard type and characteristics of the message receiver (Rahn et al., 2020b). Consequently, it is of interest whether the different components of risk appraisal influence the compliance of the protective measures and whether the hazard types differ in this respect.

Severe weather (e.g., thunderstorms, lightning, heavy rain- or snowfall) is experienced frequently by the public. This hazard type can be subsumed as a natural hazard, for which previous experience is a factor that is associated with the perception of risk (Frondel et al., 2017; Ho et al., 2008; Olofsson & Rashid, 2011; Wachinger et al., 2013). Despite a broad body of research, the relationship between risk appraisal, previous experience, and the adoption of protective measures is inconclusive, as findings are inconsistent and additional factors, as well as complex pathways, were found (Wachinger et al., 2013). Yet, warning messages regarding severe weather can lead to faster adoption of protective measures, for example, in the event of a thunderstorm (Markwart et al., 2019). In the present study, we used a warning message addressing a thunderstorm with chances of lightning and storm.

In contrast to severe weather, violent acts are experienced less likely, while being fairly severe, and therefore serving as an upper limit when comparing risk appraisal. In this study, violent acts are defined as directed, mostly planned acts of violence against people, which usually occur unexpectedly and cause deaths or injuries. In the early onset of a violent act, it is often unclear whether it is a rampage, terrorist threat, or any other kind of assault. For terror threats, risk perceptions towards terror as well as sociodemographic factors are associated with the anticipated emergency response (Gibson et al., 2015). Individual characteristics, such as trait anxiety, as well as perceptions of vulnerability and self-efficacy, were found to be associated with preparedness behavior in terror threats, too (Wirtz et al., 2019). Again, in the case of violent acts of all kinds, warning messages are a key to providing the public with information in near real-time (Reuter, Kaufhold, Leopold & Knipp, 2017). The warning message used in this study addressed a rampage in a city center, with a still unknown number of active shooters on the run. In this case, a violent incident had already occurred, so that a warning was indispensable. However, the exact outcome (number of deaths or injuries, unclear number of suspects) and the background of the violent act were still unknown at the time when the public received the warning message.

The influence of risk appraisal on warning message compliance regarding different types of hazards seems unclear. This applies especially to the new COVID-19 pandemic. Moreover, individual characteristics of those at risk, such as previous experience with a hazard or socio-demographic factors, play an important role in risk appraisal and the adoption of protective measures. While controlling for characteristics on the receiver`s side, the present study aims to explore the links between cognitive and affective components of risk appraisal on the intention to comply with protective measures given in a warning message. Moreover, these interrelations are examined for three different types of hazards, namely severe weather, violent acts, and the COVID-19 pandemic.

2. Materials and Methods

The present study was approved by the ethical committee of the University Medicine of Greifswald (BB 169/18) and included informed consent in alignment with the Declaration of Helsinki.

2.1. Sample

Participants were recruited via internet forum posts and flyer advertising. As incentives, they were offered 5 € or a voucher of the same value as compensation of expense. Data was collected online (questionnaire via hyperlink) and offline (via paper-pencil-questionnaire) for severe weather and violent acts. For COVID-19, data collection took place online only.

For severe weather and violent acts, a subsample was collected during a period of eight months from May to December 2019. Data collection regarding the COVID-19 pandemic took part between March 13 and March 27, 2020. The latter period covers the beginning of the COVID-19 outbreak in Germany and the start of large-scale measures by the German government, such as social distancing and closing of public institutions.

2.2. Materials

Participants were presented warning messages which had been previously used to warn the German public of severe weather, a violent act, and the COVID-19 pandemic. Because of that, wording, content, and sender of the warning message were already fixed. The warning messages were staged into the format of a warning application for smartphones, called NINA (BBK, 2020b). NINA is free of charge for the public and provided by the Federal Office of Civil Protection and Disaster Assistance. It is used by the German government, federal states, and local communities to provide location-based warning messages via push notifications. Hazards to which the app refers include threatening weather situations, as well as large-scale emergencies, and national or local threats (Petridou et al., 2019).

Before receiving the warning messages, participants received a short description of the hazard, which was presented in German:

- Severe weather: Severe weather is an umbrella term referring to different weather-related events. Severe weather can have immense consequences and threaten public safety. Among others, severe weather comprises heavy rain, severe storms, thunderstorms, or extreme snow.
- Violent acts: Violent acts are targeted, mostly planned acts of violence against people, which usually occur unexpectedly. Often people are injured or killed.
- COVID-19 pandemic: Coronaviruses cause a variety of diseases in humans, ranging from common colds to dangerous or even potentially fatal diseases. The novel coronavirus (COVID-19) is transmissible from person to person. The main mode of transmission is droplet infection.

All warning messages included information about the particular hazard, as well as recommendations for action. The warning message regarding severe weather referred to a heavy thunderstorm with possible lightning and storms. The message on the violent act warns about a yet unknown violent incident in the center of a city, with suspects still on the run. The message regarding COVID-19 as well consisted of information on COVID-19 (e.g., number of cases confirmed to date and action taken by the authorities) and recommendations for action to prevent an infection. The latter warning message was used in March 2020 in a district of Northern Germany.

For severe weather and violent act, warning messages (including English translations) can be found elsewhere (Rahn et al., 2020b). The English translation of the warning on COVID-19 is provided in the supplementary.

2.3. Measures

Sociodemographic data included age, gender (1 (female), 2 (male)), and previous experience with severe weather, violent acts, or pandemics. For previous hazard experience, participants were asked whether they or a person close to them (e.g., family, friends) had ever experienced

the hazard. Experience was given, when one of these questions was answered with “yes” (0 (no previous experience), 1 (previous experience)).

For the assessment of risk appraisal, a facetted approach was chosen in this study, measuring risk with four components: 1) perceived severity (PS), 2) anticipated negative emotions (AE), 3) anticipatory worry (AW), and 4) risk perception (RP) (Sheeran et al., 2014). PS and RP are considered cognitive facets, while AE and AW are considered affective components of risk appraisal (Leppin & Aro, 2009; Sheeran et al., 2014). Risk appraisal was assessed at two points in time, before (1) and after (2) the receipt of a warning message regarding one out of three hazards. For PS (“How serious would the consequences be for you if _____ happened?”), AE (“How would you feel if _____ happened?” (anxious, tense, sad)), and AW (“How worried are you that you might be affected by _____?”), 5-point Likert scales were used ranging from 1 (not at all) to 5 (very much). For AE, mean values of the three negative emotions were calculated, showing good internal consistency (Cronbach`s α = .82 - .84). RP (“How likely is it that you could be affected in the future by _____?”) was assessed via visual a analogue scale ranging from 0 to 100%.

To assess the intention to act, the participants were asked how likely they would follow with the particular recommendations given in the warning message using 5-point Likert scales (1 (not at all) to 5 (very much)). For each participant, a mean value was calculated for the intention to act. Protective measures for the three hazard types included:

- Severe weather (4 recommendations): close windows and doors; secure objects outdoors; keep away from buildings, trees, scaffolding, and power lines; avoid staying outside
- Violent acts (4 recommendations): avoid streets and public places; turn on radio and television; stay at home; share the warning message
- COVID-19 (9 recommendations): cover mouth and nose with elbow or tissue when coughing; not shaking hands; avoid touching eyes, nose, and mouth; use and safe disposal of used tissues; intensive room ventilation; maintain hand hygiene; stay at home in case of illness/symptomatic; avoid contact with possibly ill persons; avoid mass events

2.3. Design and study procedure

A cross-sectional survey design was conducted. All participants received study information and stated their informed consent before starting the survey. For severe weather and violent acts, participants were randomly allocated to one of the two disaster types. To avoid ambiguity, participants received a short explanation of their hazard type. After that, previous experience and the four components of risk appraisal were assessed. Participants then received a warning message with the instruction to imagine that they were affected by the hazard described therein. Lastly, risk appraisal was assessed again, as well as the intention to comply with the specific recommendations given in the presented warning message.

2.4. Statistics

IBM SPSS 25 and IBM Amos 25 were used for the statistical analyses. First, tests were conducted to investigate the links between hazard type and age (univariate ANOVA), previous experience, and gender (Chi-square tests). Bivariate (Pearson) correlations were then used to explore associations between all examined variables. To examine the influence of all four components of risk appraisal combined on warning message compliance, path models were calculated for each hazard type, controlling for age, gender, and previous hazard experience. Path models were estimated using the Full Information Maximum Likelihood method in consideration of missing data (Enders, 2001) and calculated without and with the control variables. A simplified path model for all three hazards is shown in figure 1.

Please insert figure 1 here.

2.4.1. Results

Descriptive statistics can be found in table 1, pairwise correlations in table 2. A total of 403 adults ($M\ (SD)_{age} = 29.24\ (13.99)$, 72.2% female) took part in the survey. 33.5% of the participants had previous hazard experience, ranging from 7.7% (pandemics) to 77.2% (severe weather). Participants allocated to the three hazard types did not differ by age ($F(2, 402) = 2.23$, $p = .109$). Thus, they did differ by gender ($\chi^2(2) = 7.68$, $p = .021$), and previous experience ($\chi^2(2) = 158.69$, $p = .001$). The latter seems reasonable, as severe weather is experienced far more often than violent acts or pandemics.

Bivariate correlations showed significant positive associations of all variables with the intention to comply with the warning message, except for previous experience ($r = -.14$, $p < .01$), RP1, and RP2 ($r = .06$ - $.08$, $p > .05$). Also, positive correlations were found for age, PS1, and PS2 ($r = .16$ - $.17$, $p < .01$), as well as age and RP2 ($r = -.11$), $p < .05$). For gender, positive correlations were found for all components of risk appraisal, except for PS1 and PS2. For previous experience, significant positive (RP1, RP2) and negative (AE1, AE2) correlations were found.

Interestingly, there was no consistent trend in the change of risk appraisal after the receipt of a warning message. Some components decreased while others increased: For COVID-19, AW ($M_{AW1} = 2.93$; $M_{AW2} = 2.68$) and RP ($M_{RP1} = 61.40$; $M_{RP2} = 59.97$) decreased, while severe weather and violent acts showed an increase after the receipt. In contrast to that, AE decreased in all hazard types.

Please insert table 1 and table 2 here.

Path models for severe weather, violent acts, and the COVID-19 pandemic can be found in table 3. For the three types of hazards, path models including all covariates (model 2) revealed different factors that had a direct influence on the intention to comply with the warning message, while showing good to moderate model fits.

For severe weather, the path model showed a significant influence of PS ($\beta = .28$), higher age ($\beta = .29$), and female gender ($\beta = .34$) on the intention to comply with the recommendations given in the warning message ($R^2 = .27$; CFI = .999; TLI = .984; RMSEA = .033).

For violent acts, AE ($\beta = .20$) predicted the intention to comply ($R^2 = .09$; CFI = .994; TLI = .922; RMSEA = .078).

For the COVID-19 pandemic, higher age ($\beta = .18$) predicted warning compliance ($R^2 = .05$; CFI = .999; TLI = .990; RMSEA = .028).

Please insert table 3 here.

3. Discussion

The present study examined warning message receipt, risk appraisal, and the intention to comply with a warning message while applying a consistent methodology in assessing risk appraisal with two cognitive and two affective components. Additionally, three types of hazards were compared: severe weather, violent act, and the COVID-19 pandemic. Sociodemographic factors were taken into account, as well. As seen in preceding research (Heilbrun et al., 2010; Ho et al., 2008; Rahn et al., 2020b), heterogeneous results between the hazard types were found.

For severe weather, perceived severity (PS) led to a higher intention to comply with the warning message. The more severe the hazard is perceived, the more likely it is to carry out the recommendations. This finding is consistent with the theoretical assumption of the PADM, as the perception of the impending threat and its severity play an important role in the

adoption of protective measures (Lindell & Perry, 2012). Besides, in the event of a thunderstorm, in most cases, it is possible to prepare for the hazard for a certain period. The pros and cons of implementing protective measures can be considered. This time lead could result in an analytical processing and, in turn, the cognitive component of risk appraisal influencing the intention to act. Also, higher age and female gender were associated with warning message compliance. This goes with prior research that found an association between age and female gender regarding warning message response, and the likelihood of seeking shelter in the case of severe weather or tornados (Ryherd, 2016). Other findings show that persons over 35 years show a better understanding of warning messages regarding weather events, report a better understanding of possible outcomes, and a higher concern towards the event, as well as higher intention to adopt protective measures (Potter et al., 2018).

Looking at violent acts, an influence of anticipated negative emotions (AE) on warning message compliance was found: The more anxious, tense, or sad participants felt about becoming involved in a violent act, the more likely it was for them to comply with the warning message. The occurrence of violent acts is associated with high potential threat and to some point unknown consequences for the ones involved. This may have an influence on which processes they cause in individuals when becoming confronted with a warning message regarding a violent act. Media coverage of terror threats, for example, has shown to induce fear (Slone, 2000). According to the affect heuristic, affective reactions towards stimuli (e.g., a feeling state of badness towards violent acts) influence judgments, decisions, and behavior. These so-called affect-based evaluations appear to happen quickly and are therefore mostly applied under time pressure, as they are processed through the experiential system (Finucane et al., 2000; Slovic et al., 2007). The warning message used for this study was issued during a violent act in a German city. It comprised a short text about a somewhat unknown and rare threat and was not able to determine full information of the exact nature of the hazard (rampage, terror threat, or else) at the same time. Additionally, the protective measures given in the message required a prompt reaction. In line with the affect heuristic, this could promote an experiential processing of the warning message, which, in turn, could be a possible explanation of the identified link between an affective component of risk appraisal, namely anticipated negative emotions, and the intention to comply in case of violent acts (Lerner et al., 2003). In contrast to severe weather and violent acts, no relationship between risk appraisal and the intention to comply with the warning message was found for COVID-19. These results seem to be in line with other research that also found little or no impact of risk perception on compliance regarding COVID-19 (Clark et al., 2020). Pandemics could be perceived as more controllable than violent acts, for instance, as there is a variety of protective measures for this hazard that can be consciously integrated into everyday life. In this context, the usage of protective measures can lead to risk appraisal being nullified or reduced, as if someone already carries them out, perhaps he or she will appraise the risk of becoming infected lower (Brewer et al., 2004; Leppin & Aro, 2009). Thus, this could turn pandemics into special cases. Ongoing investigations should address whether this also applies to the COVID-19 pandemic as well, as changes in risk appraisal seem to be possible in the further development of this pandemic. Yet, when looking at the covariates, a higher age was a significant predictor for the intention to comply. The latter finding is consistent with prior results regarding the beginning of the COVID-19 pandemic (Tomczyk et al., 2020), as well as other infectious diseases (Bish & Michie, 2010). In the COVID-19 pandemic, persons with a higher age were considered a high-risk group from the very beginning, for example, due to more severe disease progression and higher mortality (Bhopal & Bhopal, 2020; Kang & Jung, 2020). This might result in a higher appraisal of risk, particularly perceived susceptibility, among older persons, which in turn could lead to the adoption of protective measures (Barr et al., 2008).

In the comparison of the three hazard types, no consistent influence of age, gender, and previous experience on the intention to comply with a warning message were found. This

applies as well for risk appraisal and the intention to comply: While a cognitive component of risk appraisal showed an influence on warning message compliance in case of severe weather, affective appraisal seemed to predict the intention to comply in case of violent acts. Besides, no trend in the changes of risk appraisal after the receipt of a warning message was found, as for some hazard types components increased while others decreased. For violent acts and severe weather, the trend after receiving the warning is a slight decrease in perceived severity and anticipated negative emotions. Despite these being marginal changes, participants seemed to rate these hazards as less severe and have less negative emotions towards it when receiving a warning message. On the other hand, risk perception and anticipatory worry increased. By issuing a warning message including protective measures, people at risk could develop a feeling of preparedness, which, in turn, could result in fewer negative emotions and the feeling of the hazard being less severe for oneself. Risk perception, here assessed as the probability of becoming affected by the hazard, and worry of becoming affected may increase due to the confrontation with a possible threat that requires a rather fast response. For COVID-19, a slightly different image becomes apparent: For almost every component, a decrease can be observed. Participants felt less negative emotions, less worry, and less susceptible after the receipt. As already mentioned above, pandemics could constitute an exception in this context since warning messages could deliver a feeling of security by giving sufficient information and enough time for the implementation of protective measures. Additionally, data collection took place at a very early stage of the pandemic in Germany. At this time, the COVID-19 pandemic had just reached Germany, and in some areas of the country, there were only a few or no cases. Besides, pandemics of this extent are rather rare in Central Europe, so that there was hardly any contact or previous experience with this topic before. The collection of data in the further course of this pandemic can bring exclusion here and is therefore desirable.

In summary, the given results lead to the point that risk appraisal should be assessed with both cognitive *and* affective components. Also, it becomes clear that findings in warning research regarding different hazard types cannot be transferred straightforwardly, as there are indications for varying processing. Especially concerning the COVID-19 pandemic, future research on risk appraisal and warning compliance should look at already existing research on other hazard types in a comparative rather than a separate way.

Limitations

The present study certainly has some limitations: Our research aimed to compare three different hazards that varied in terms of several characteristics (e.g., frequency, extent of damage, proximity). Original, but anonymized, warning messages were presented to the participants. These warning messages had already been used to warn the public in Germany and, therefore, the content and design of the messages were not varied. Yet, empirical research shows that a variation of hazard characteristics, such as proximity of the hazard source, influences perceived risk, for example, in hurricanes, chemical hazards, and floods (Zhang et al., 2010). The psychometric paradigm (Marris et al., 1997; Slovic et al., 1986), according to which risk perception is influenced by common risk characteristics, such as controllability, dread, and knowledge of different hazards, could provide an additional perspective. On the other hand, the usage of original warnings in this study leads to a higher ecological validity of the presented results. Yet, future research should proceed with the use of authentic warning messages and also aim towards a systematical variation of the messages. Regarding COVID-19 pandemic, the collected data only shows a small part of a complex and fast process. Like others, we aimed to capture this process at an early stage, namely at the beginning of the restrictions in Germany. Further research must continue to collect data repeatedly in order to be able to make statements in the long term. This way, for example, a change in cognitive and affective appraisals of risk over time, as well as a change in behavioral intention and the adoption of protective measures, can be unveiled (Leppin & Aro, 2009). By doing so, upcoming

studies should examine representative samples, as the presented findings are based on a convenience sample.

Also, further research should focus on additional variables that are included in the PADM, such as stakeholder perceptions or social norms, to improve the understanding of the link between risk appraisal and behavior. In the context of health-related behaviors, self-efficacy and response efficacy showed to play important roles in the association between risk appraisal and behavioral intention or behavior (Sheeran et al., 2014) and should thus be considered for civil protection as well. This applies as well on the assessment of protective measures carried out by the public, as this study was scenario-based and therefore only able to assess behavioral intention. Nevertheless, recent research shows that experimental studies (in the sense of scenario-based studies) and field studies are equally suitable for the investigation of warning message understanding and response (Weyrich et al., 2018b).

Conflict of interest

None.

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5. Abbreviations

RP	Risk perception
AW	Anticipatory worry
AE	Anticipated emotions
PS	Perceived severity

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7. Authors contributions statement

MR, ST, SiS: conception and design of the study; NSC: preparation of the warning messages for severe weather and violent acts; MR, ST: collection of data; MR: organized the database and wrote the first draft of the manuscript; ST: calculated path models. All authors contributed to manuscript revision, read and approved the submitted version.

8. Data availability statement

Datasets are available on request. The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Table 1

Descriptive statistics of age, gender, previous hazard experience, the components of risk appraisal before (1) and after (2) the receipt of a warning message, and the intention to comply with a warning message, displayed for the complete sample and separated by hazard type.

		Hazard type		
	Complete sample	Severe weather	Violent act	COVID-19
	N=403	n=123	n=125	n=155
Gender				
% male	27.8 (112)	33.3 (41)	32.0 (40)	20.0 (31)
% female	72.2 (291)	66.7 (82)	68.0 (85)	80.0 (124)
Previous experience (% yes)	33.5 (135)	77.2 (95)	22.4 (28)	7.7 (12)
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Age	29.24 (13.99)	31.28 (15.73)	29.10 (15.32)	27.73 (10.98)
Risk appraisal				
Perceived severity 1	3.05 (1.12)	2.84 (1.00)	3.86 (1.00)	2.59 (0.95)
Perceived severity 2	3.01 (1.14)	2.76 (1.01)	3.78 (1.07)	2.60 (0.98)
Anticipated emotions 1	2.95 (1.07)	2.35 (0.83)	3.85 (0.91)	2.71 (0.87)
Anticipated emotions 2	2.84 (1.10)	2.26 (0.84)	3.79 (0.90)	2.54 (0.93)
Anticipatory worry 1	2.56 (1.11)	2.40 (1.03)	2.26 (1.10)	2.93 (1.09)
Anticipatory worry 2	2.57 (1.05)	2.55 (0.98)	2.45 (1.15)	2.68 (1.01)
Risk perception 1	50.99 (27.01)	55.78 (27.02)	34.10 (24.78)	61.40 (21.52)
Risk perception 2	52.33 (26.76)	58.51 (26.96)	36.09 (24.51)	59.97 (22.60)
Intention to comply	4.33 (0.66)	4.13 (0.85)	4.33 (0.69)	4.49 (0.36)

Notes. M: mean. SD: standard deviation. Risk appraisal measured before (1) and after (2) the receipt of a warning message including the components perceived severity, anticipated emotions, anticipatory worry (5-point Likert scales from 1 (not at all) to 5 (very much), and risk perception (%)).

Table 2

Pairwise (Pearson) correlations of age, gender, previous experience, risk appraisal before (1) and after (2) the receipt of a warning message, and the intention to comply, N = 377-403.

		1	2	3	4	5	6	7	8	9	10	11	12
1	Age	1											
2	Gender	-.21***	1										
3	Previous experience	.05	-.06	1									
4	Perceived severity 1	.17**	.03	-.05	1								
5	Perceived severity 2	.16**	.02	-.05	.83***	1							
6	Anticipated emotions 1	.06	.14**	-.19***	.61***	.60***	1						
7	Anticipated emotions 2	.05	.15**	-.14**	.60***	.61***	.91***	1					
8	Anticipatory worry 1	.06	.12*	-.05	.24***	.32***	.28***	.25***	1				
9	Anticipatory worry 2	.10	.19***	.02	.37***	.48***	.34***	.36***	.69***	1			
10	Risk perception 1	-.07	.16**	.15**	-.24***	-.16**	-.28***	-.29***	.33***	.21***	1		
11	Risk perception 2	-.11*	.21***	.20***	-.20***	-.15**	-.25***	-.25***	.29***	.27***	.89**	1	
12	Compliance	.16**	.20***	-.14**	.17**	.13**	.17**	.15**	.17**	.15**	.08	.06	1

Notes. Gender ((1) male, (2) female); previous experience ((0) no previous experience, (1) previous experience given). Risk appraisal before (1) and after (2) the receipt of a warning message: Perceived severity, anticipated emotions, and anticipated worry were assessed on 5-point Likert scales from 1 (not at all) to 5 (very much); risk perception was assessed in %. * $p<.05$, ** $p<.01$, *** $p<.001$.

Table 3

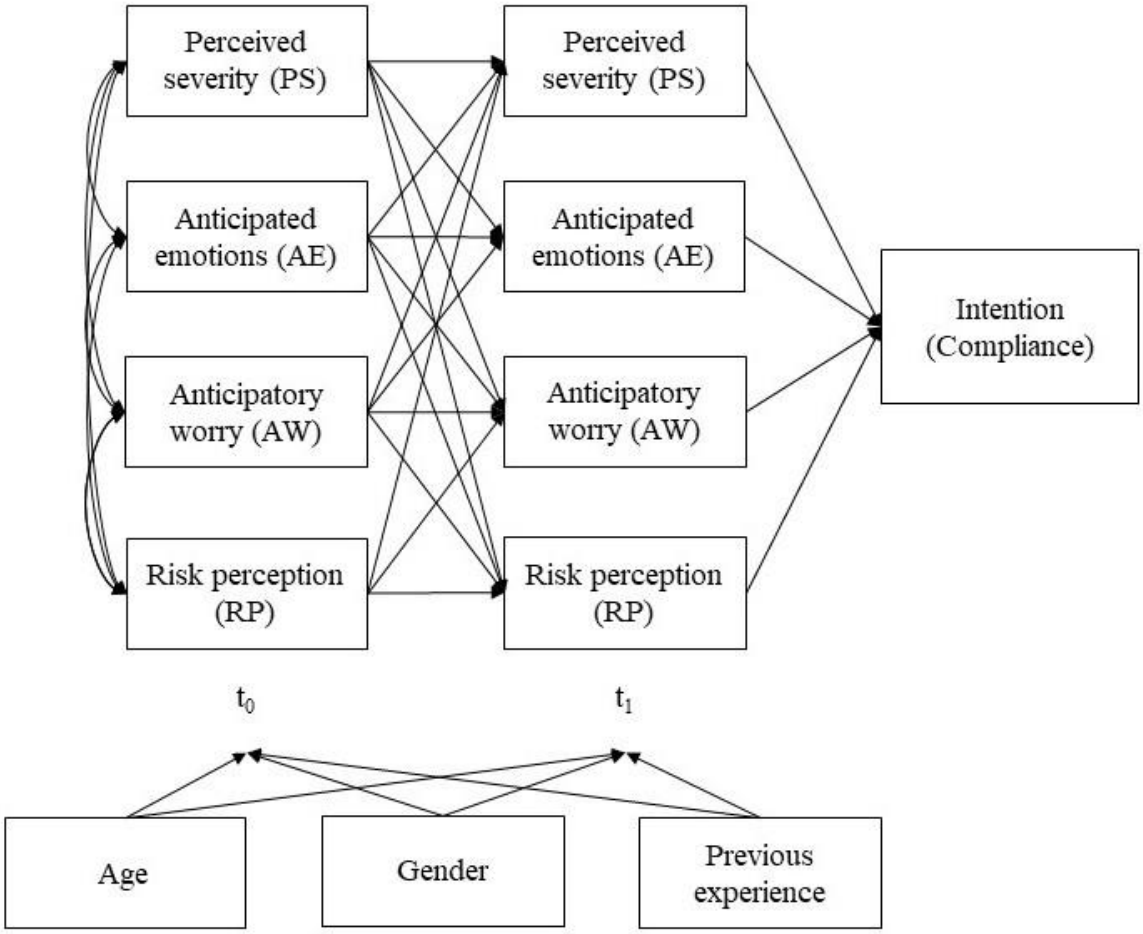
Path models for the hazard types severe weather, violent act, and COVID-19, with (model 2) and without age, gender, and previous experience (model 1) as covariates.

	Severe weather		Violent act		COVID-19	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Chi squared test (goodness-of-fit test)	3.203 (df = 6)	6.805 (df = 6)	11.533 (df = 6)	10.559 (df=6)	6.151 (df = 6)	6.735 (df = 6)
CFI	1.000	.999	.992	.994	1.000	.999
TLI	1.000	.984	.943	.922	.999	.990
RMSEA	.000 [.000; .078]	.033 [.000; .125]	.086 [.000; .160]	.078 [.000; .154]	.013 [.000; .105]	.028 [.000; .111]
Variables						
RP1 → RP2	0.883***	0.848***	0.908***	0.880***	0.814***	0.801***
AW1 → AW2	0.416***	0.421***	0.702***	0.709***	0.388***	0.384***
AE1 → AE2	0.709***	0.705***	0.879***	0.865***	0.916***	0.911***
PS1 → PS2	0.532***	0.513***	0.625***	0.642***	0.852***	0.828***
RP2 → Compliance	0.141	0.122	0.011	0.025	0.043	0.052
AW2 → Compliance	0.065	-0.068	-0.052	-0.058	0.090	0.083
AE2 → Compliance	0.013	0.016	0.253*	0.200*	0.106	0.097
PS2 → Compliance	0.249	0.279*	0.005	0.003	-0.102	-0.153
Age → Compliance	-	0.292***	-	0.160	-	0.176*
Gender → Compliance	-	0.338***	-	0.123	-	0.060
Previous experience → Compliance	-	0.004	-	-0.059	-	0.014
R^2 (compliance)	0.126	0.265	0.059	0.091	0.021	0.051

Notes. Standardized model results; * $p < .05$, ** $p < .01$, *** $p < .001$; brackets indicate 90% confidence interval. CFI comparative fit index; TLI Tucker-Lewis index; RMSEA root mean square error of approximation. Components of risk appraisal: RP risk perception; AW anticipatory worry; AE anticipated emotions; PS perceived severity. Risk appraisal was measured at two time points, before (1) and after (2) receiving a warning message.

Figure captions:

Figure 1. Simplified path model. Four components of risk appraisal (PS, AE, AW, RP) before (t_0) and after (t_1) the receipt of a warning message regarding one of three hazard types (severe weather, violent act, or the COVID-19 pandemic).



9.3 A3. Studie 3

Tomczyk, S., Rahn, M. & Schmidt, S. (2020). Social Distancing and Stigma: Association Between Compliance With Behavioral Recommendations, Risk Perception, and Stigmatizing Attitudes During the COVID-19 Outbreak. *Frontiers in Psychology*, *11*, 1821. https://doi.org/10.3389/fpsyg.2020.01821

Title:

Social distancing and stigma: Association between compliance with behavioral recommendations, risk perception, and stigmatizing attitudes during the COVID-19 outbreak

Running head:

Public compliance and stigmatizing attitudes

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Abstract

Introduction. Following behavioral recommendations is key to successful containment of the COVID-19 pandemic. Therefore, it is important to identify causes and patterns of noncompliance in the population to further optimize risk and health communication.

Methods. 157 participants (80% female; mean age= 27.82 (SD=11.01)) were surveyed regarding their intention to comply with behavioral recommendations issued by the German government. Latent class analysis examined patterns of compliance and subsequent multinomial logistic regression models tested sociodemographic (age, gender, country of origin, level of education, region, and number of persons per household), and psychosocial (knowledge about preventive behaviors, risk perception, stigmatizing attitudes) predictors.

Results. Three latent classes were identified: *high compliance* (25%) with all recommendations, *public compliance* (51%), with high compliance regarding public but not personal behaviors, and *low compliance* (24%) with most recommendations. Compared to high compliance, low compliance was associated with male gender (*RRR*=0.08; [0.01; 0.85]), younger age (*RRR*=0.72; [0.57; 0.93]), and lower public stigma (*RRR*=0.21; [0.05; 0.88]). Low compliers were also younger than public compliers (*RRR*=0.76; [0.59; 0.98]).

Discussion. With 25% of the sample reporting full compliance, and 51% differing in terms of public and personal compliance, these findings challenge the sustainability of strict regulatory measures. Moreover, young males were most likely to express low compliance, stressing the need for selective health promotion efforts. Finally, the positive association between public stigma and compliance points to potential othering effects of stigma during a pandemic, but further longitudinal research is required to examine its impact on health and social processes throughout the pandemic.

1 Introduction

The current outbreak of the coronavirus SARS-CoV-2 and the associated disease, COVID-19, are transfixing the world with over 2 million confirmed infections by April 16, 2020 (https://coronavirus.jhu.edu/). In addition to its physical threat, this outbreak also causes psychological distress, anxiety and depression (Wang et al., 2020). Moreover, research on the coronavirus-associated SARS pandemic in 2002/20003 points to potentially long-lasting adverse consequences, such as depression, stigmatization, diminished quality of life, and post-traumatic stress (Ko et al., 2006; Lee et al., 2006; Siu, 2008; Gardner and Moallef, 2015).

To contain infectious diseases like COVID-19, experts and government officials alike recommend a series of preventive behaviors, such as hand hygiene, and avoidance behaviors, such as social distancing or (voluntary) quarantine (e.g., Glass et al., 2006; Durham and Casman, 2012; Ding, 2014; Karimi et al., 2015; Weston et al., 2018; Lewnard and Lo, 2020). Previous simulations and current reports affirm that a combination of all strategies has the greatest success rates in containing the disease (Kelso et al., 2009; Kupferschmidt and Cohen, 2020). And yet, successful containment depends on adequate public compliance. While predictors of compliance can be explicated via behavior theory (e.g., the theory of planned behavior (Ajzen, 1991)), and they are well-documented for certain health behaviors (e.g., adherence in chronical illness (Rich et al., 2015)), far less is known about compliance in pandemics.

To date, several studies have identified perceived personal risk (i.e. susceptibility, anticipated severity, and anticipatory worry), and knowledge of adaptive behaviors as facilitators of compliance (c. Tang and Wong, 2003; 2005; Cheng and Ng, 2006; Leppin and Aro, 2009; Kwok et al., 2020), although an explicit theoretical framework is often missing (Bish and Michie, 2010). Moreover, barriers to adherence (i.e., noncompliance), have received less attention, presumably due to preventive and avoidance behaviors being very easy to carry out.

In a review of 26 studies on preventive behaviors in pandemics (Bish and Michie, 2010), however, compliance rates varied greatly, for example, between 4% for wearing a mask, 41.3% for "one or more specific actions" (Brug et al., 2004), and up to 95% for quarantine (Blendon et al., 2004). Despite the variety of illnesses, time frames, populations, and research methods in these studies, a general implication seems to be that a substantial proportion of the population does not adhere to the recommended behaviors. Composite measures of preventive behaviors revealed even lower compliance: 30.7% of a representative sample in Singapore practiced six or more out of eight (Quah and Hin-Peng, 2004), 48.7% in Hong Kong practiced five or more out of seven (Leung et al., 2003), and 37.8% in England practiced one or more out of three measures (Rubin et al., 2009).

In this respect, a qualitative study on (non)compliance with SARS quarantine identified ethical (e.g., civic duty), legal (e.g., monetary sanctions), and social (e.g., peer pressure) reasons to publicly comply with quarantine, whilst acceptance of quarantine differed markedly within households and private environments (Cava et al., 2005). Another study also identified practical issues (e.g., disposal of used tissues), selfishness and responsibility shift (Morrison and Yardley, 2009) as core barriers to compliance. Responsibility shift refers to the belief that infected persons are particularly responsible for (not) spreading the illness, thus protecting others, whereas healthy persons are responsible for protecting themselves from becoming infected, leading to a shift in personal priorities in protective behaviors depending on one's infection status.

Moreover, sociodemographic variables gender and age (i.e., male, younger age) consistently predicted noncompliance (Leung et al., 2003; Tang and Wong, 2003). This might be connected to a generally lower risk perception, particularly a lower perceived susceptibility, in

young males (de Zwart et al., 2009). Regarding educational attainment, higher levels of education have been discussed as barriers to as well as facilitators of behavioral compliance in different populations (Leung et al., 2003; Tang and Wong, 2005; de Zwart et al., 2009; Bish and Michie, 2010).

To capture the existing heterogeneity in (non)compliance, this study utilizes a latent class approach (Collins and Lanza, 2010). Latent classes are often used to analyze behavioral patterns in non-communicable diseases, such as substance use (e.g., Tomczyk et al., 2015; Tomczyk et al., 2016). However, to our knowledge, only one study applied latent class analysis to population behaviors following a novel virus outbreak (i.e., Influenza A(H7N9)) in Hong Kong (Liao et al., 2015), despite the method's statistical advantages in modelling behavioral patterns (e.g., flexibility, integration of measurement error). Liao et al. (2015) identified three latent classes of behavioral compliance, namely moderate hygiene compliance (moderate personal hygiene, low avoidance behaviors), good hygiene compliance (high personal hygiene, low avoidance), and vigilance (high hygiene and avoidance). Moderate hygiene compliance was the largest class (about 50% of the sample) and was significantly associated with male gender, lower age, poor education, and lower risk perception, thus stressing the need for selective prevention and health promotion.

Finally, the current study also focuses on stigmatizing attitudes in the context of compliance, due to the impact of stigma on fear, psychosocial stress, and social rejection during infectious diseases, such as SARS (Sim and Chua, 2004; Lee et al., 2005; Ko et al., 2006; Siu, 2008). Stigmatization can occur at different levels (e.g., individual, social, structural) and is connected to social identity processes (Tajfel and Turner, 1986; Bandura, 1998; Link and Phelan, 2001; Bandura, 2004), where in-groups (i.e. individuals or groups that a person identifies with) and out-groups (i.e. individuals or groups a person does not identify with) are constructed based on certain characteristics (e.g., profession, illness symptoms). Out-groups are subsequently devaluated, for instance, by being labeled irresponsible or dangerous. This devaluation can further lead to verbal discrimination or interpersonal violence (Parker and Aggleton, 2003; Corrigan et al., 2004). Moreover, public stigma comprises support for a restriction of public opportunities (e.g., vote, utilize health care) for the devaluated out-group, in this instance, symptomatic and/or infected persons. In fact, survivors of the SARS epidemic experienced blame and social rejection (Lee et al., 2005; Mak et al., 2006), while persons of Asian descent reported victimization, regardless of their personal infection status (Zheng et al., 2005). These experiences of being blamed and ostracized oftentimes outlasted the epidemic and were associated with continued psychosocial stress (Brug et al., 2004; Siu, 2008; Jiang et al., 2009). In addition, an increase in influenza infections also corresponded to an increase in stigmatizing attitudes (e.g., a lack of trust, increased hostility) in previous research (Williams and Gonzalez-Medina, 2011).

Furthermore, qualitative studies argue that anticipated stigma might even prohibit personal preventive behaviors during infectious diseases, such as wearing masks, to avoid future stigmatization (Siu, 2008; Jiang et al., 2009); this hypothesis is supported by cross-sectional, quantitative research (Leppin and Aro, 2009). Similarly, perceived differences in responsibility for personal (healthy persons) and public protection (infected persons) during a pandemic (Morrison and Yardley, 2009) might reinforce stigma-associated social identity processes and increase the salience of group differences.

In sum, stigmatization might differentially affect behavioral compliance: On the one hand, it might be beneficial from a prevention perspective by fostering social distancing towards and isolation of infected people, primarily by stigmatizing persons and defining them as a relevant

out-group (so-called *othering* (see Deacon, 2006)). On the other hand, it might reduce compliance with official recommendations among stigmatized and/or infected persons due to fear of social isolation, stress, or discrimination (Williams and Gonzalez-Medina, 2011; Smith and Hughes, 2014). Therefore, to investigate compliance and the role of stigmatization during pandemics, this exploratory study aims to:

1. Examine patterns of intentions to comply with behavioral recommendations to contain the COVID-19 pandemic in the German population via latent class analysis.

2. Inspect the role of stigma in noncompliance, while considering sociodemographic differences, risk perception, and knowledge of adaptive behaviors.

3. Explore intercultural similarities and differences of compliance by focusing on the German population, whereas previous research mostly focused on Asian populations.

2 Methods

2.1 Sample

Via an online survey, a community sample of 157 German adults (80% female; $M\ (SD)_{age} = 27.82\ (11.01)$) provided information about their knowledge of preventive measures, risk perception, intentions to comply with official behavioral recommendations and guidelines as well as their stigmatizing attitudes towards people suffering from COVID-19. Participants received gift vouchers (€5) as incentives. The survey was conducted via convenience sampling between March, 13 and March, 27 by placing online advertisements on social media, for instance, on Facebook. During this time, far-reaching social isolation measures were implemented in Germany, for instance, restricting public meetings to two people (except for households) and establishing guidelines for a safety distance of 1.5 to 2.0 meters in public spaces. In addition, behavioral recommendations on personal hygiene and avoidance behaviors were repeatedly and consistently issued by the government. The study procedure included informed consent in alignment with the Declaration of Helsinki and received ethical approval by a local Ethics Committee (BB 169/18).

2.2 Measures

Sociodemographic data comprised age, gender (1 (*female*), 2 (*male*)), country of origin (0 (*Germany*), 1 (*other*)), level of education (0 (*lower secondary education*), 1 (*higher secondary education, i.e. university entry level*), 2 (*tertiary education*, e.g., Bachelor's degree)), region (0 (rural, i.e. *up to 100,000 inhabitants*), 1 (urban, i.e. *more than 100,000 inhabitants*)), and number of persons in one's household (continuous; recoded as 1 (*1*), 2 (*2*), 3 (*3 or more*)). For analysis purposes, categorical variables were dummy-coded.

Measures of stigmatizing attitudes were adapted from previous research on mental health stigma, assessing support for discrimination (Schomerus et al., 2007; Schomerus et al., 2019) with three items ('Persons with COVID-19 should not be allowed to hold public office', 'Persons with COVID-19 should not be allowed to have a driver's license', 'If persons with COVID-19 do not consent to medical treatment, they should receive compulsory treatment'), and blame (Corrigan et al., 2006; Schomerus et al., 2019) with four items (e.g., 'Persons with COVID-19 are to blame for their problems') rated on a five-point scale each, from 1 (*don't agree at all*) to 5 (*agree completely*). Support for discrimination (Cronbach's $\alpha = .71$) and blame ($\alpha = .73$) showed satisfactory internal consistency.

Risk perception comprised two items representing cognitive and affective aspects of perceived risk, namely perceived susceptibility ('How likely will you become infected?'; 0 to 100%), and anticipated fear ('How afraid would you feel if you became infected?'; 1 (*not at all*) to 5 (*very*)).

Intentions to comply with official recommendations were assessed by asking participants how likely (1 (*not at all*) to 5 (*very*)) they would follow the following nine recommendations: (1) covering mouth and nose with flexed elbow or tissue when coughing or sneezing; (2) avoid handshakes; (3) avoid touching one's face (i.e., eyes, nose, and mouth) as much as possible; (4) dispose of used tissue immediately and securely; (5) frequent ventilation; (6) increased hand hygiene; (7) stay at home when sick/symptomatic; (8) avoid personal contact to symptomatic persons; (9) avoid mass events. Since strictly following these recommendations is the safest way to contain further spreading of the infection, we recoded items to reflect likelihood of compliance (1 (*very high likelihood*), 0 (*other*)). These nine indicators were then subjected to latent class analysis. In addition, a single item measuring subjective knowledge of adaptive behaviors was rated from 1 (*very low*) to 5 (*very high*). All measures are listed in supplementary table S1.

2.3 Statistical analysis

Following an inspection of missing data and descriptive data analysis, latent class models were computed to examine patterns of (non)compliance in the population. Subsequent multinomial logistic regression models inspected sociodemographic and psychosocial predictors of compliance patterns. Descriptive data analysis was performed with Stata 15.1 (StataCorp, 2017), latent class models and multinomial logistic regression models were computed with Mplus 7.4 (Muthén and Muthén, 1998-2015). All analyses were based on $\alpha = 0.05$.

We estimated latent class models of compliance via robust maximum likelihood estimation with 2000 sets of random start values. The estimation process started with two latent classes (indicating full compliance and noncompliance), the number of latent classes was subsequently increased up to five, whilst comparing model fit between models. Model selection considered overall model fit, parameter sparseness, classification quality, and theoretical tenability (Nylund et al., 2007; Tomczyk et al., 2016; Tomczyk et al., 2018). As an overall fit measure, the bootstrapped likelihood ratio test (BLRT) compared the estimated model to a model with one less class: a significant value indicated better fit of the current model. To achieve reliable estimates, we chose 50 random starts with 50 bootstrap draws for each comparison. The Akaike Information Criterion (AIC) and the sample-size adjusted Bayes Information Criterion (BIC) indicated sparseness of the model, a lower value meant a sparser model. Average latent class probabilities (ALCP) and entropy demonstrated classification quality that is the differentiation between latent classes. Values range between 0 and 1; the closer to 1 the better the fit; an entropy of at least .6 pointed to reliable estimates (Asparouhov and Muthén, 2014). Finally, latent classes needed to be interpreted based on the literature and theoretical background. Therefore, the best latent class solution was selected on statistical criteria as well as content validity.

Using the three-step approach (Asparouhov and Muthén, 2014), we calculated multinomial logistic regressions to predict compliance patterns by sociodemographic data and psychological variables (stigmatizing attitudes, risk perception, and subjective knowledge). For each regression model, Relative Risk Ratios (RRR) including 95% confidence intervals were reported as effect sizes.

3. Results

3.1 Descriptive statistics

Missing data was low (37 missing values; 0.01% overall) and equally distributed among variables, suggesting missing at random. Therefore, complete cases were analyzed for descriptive statistics (Schafer, 1999; Dong and Peng, 2013), while full information maximum likelihood was used for latent class estimation. The sample was predominantly female, most persons did not have a migration background, and about a fifth lived in single households. Due to the very high level of education, the variable 'education' was dichotomized for further analysis (1 (*tertiary*), 0 (*secondary*)). Intentions to comply were mixed but particularly low for immediate disposal of used tissues, frequent ventilation, and reduced hand-to-face contact (see table 1).

Please insert table 1 here.

3.2 Latent class models

Model fit criteria for latent class models are printed in table 2. While entropy and information criteria were in favor of a model with four classes, the difference to a three-class model was only marginal (ΔAIC = .04; ΔSSABIC = 1.14), and according to the BLRT, the latter was preferable. Moreover, a fourth class would have been very small (n = 6; 4.8%) with similar conditional response probabilities to class 1 of the three-class model. Since it also showed good entropy and latent class separation (ALCP>.8) compared to the remaining models, the three-class model was chosen. The following descriptions of latent class counts, and proportions are based on most likely latent class membership.

Please insert table 2 here.

The first class was labeled "low compliance" (n = 37; 24%), with low to moderate intentions to comply with most recommendations except for covering one's mouth and nose when sneezing or coughing. The second class was labeled "high compliance" (n = 40; 25%), with high probabilities of following most recommendations, and moderate compliance with reducing hand-to-face contact. Finally, the third class, "public compliance" (n = 80; 51%), had high intentions regarding compliance with public and avoidance behaviors (e.g., social distancing) but low intentions regarding personal behaviors (i.e., avoidance of face contact, tissue disposal, frequent ventilation). Conditional response probabilities for each class can be seen in figure 1.

Multinomial logistic regression compared sociodemographic data, stigmatizing attitudes, knowledge, and risk perception between latent classes (see table 3). To complement multinomial models, detailed descriptive comparisons of latent classes are provided in supplementary table S2. Compared to high compliance (class 2), low compliance (class 1) was associated with being male (*RRR* = 0.08 [0.01; 0.85]), younger (*RRR* = 0.72 [0.57; 0.93]) and expressing lower support for discrimination (*RRR* = 0.21 [0.05; 0.88]), whereas public compliance (class 3) and high compliance did not differ on sociodemographic data, stigmatizing attitudes or risk

perception, although support for discrimination was considerably lower in public compliers than in high compliers (*RRR* = 0.27 [0.06; 1.21]; $p = .09$). Furthermore, low compliers were significantly younger (RRR = 0.76 [0.59; 0.98]), than public compliers and, by trend, were less fearful of a possible infection (RRR = 0.46 [0.20; 1.06]; $p = .07$).

Please insert table 3 here.

4. Discussion

As one of the first studies examining patterns of (non)compliance with behavioral recommendations in the general population during the COVID-19 pandemic, this study revealed that only a quarter of the surveyed German population expressed intentions to fully comply with recommendations, while a majority (about 51%) intended to follow some public actions, but was less willing to enact personal hygiene behaviors (i.e., swift disposal of tissues, reduction of hand-to-face contact, ventilation). Young males were significantly less likely to comply with recommendations, and aspects of public stigma were also linked to compliance intentions.

In a virus outbreak, such as the COVID-19 pandemic, personal hygiene and social distancing in the general population are paramount to containment of the illness (Wu et al., 2006; Karimi et al., 2015; Weston et al., 2018). And yet, only a minority was ready to comply with the main recommendations, with 25% reaching high compliance in this sample, and similar, albeit slightly higher proportions of 30.7% (Quah and Hin-Peng, 2004), 37.8% (Williams and Gonzalez-Medina, 2011), and 48.7% (Lee et al., 2005) in previous studies. Since Germany was not affected by previous pandemics (e.g., H1N1, SARS) as strongly as Hong Kong, for instance, and measures like wearing face masks are not as common in Europe (e.g., Rubin et al., 2009), we assume the lack of familiarity with such strict preventive measures to be responsible for this lower level of compliance.

4.1 Patterns and Predictors of Noncompliance

To further explore cultural differences of compliance during a pandemic and connect our findings to previous research, we compare our findings (Germany) to Liao et al. (2015), who analyzed latent classes of behavior patterns in Hong Kong during a virus outbreak. They also identified three latent classes, with the class *moderate hygiene* being the largest group, followed by *good hygiene*, and *vigilance*. Moreover, younger males, persons with lower educational attainment, and lower risk perception were also more likely to belong to the moderate hygiene class (i.e., exhibit low compliance), similar to our findings. This trend of older persons, and females reporting higher risk perception and willingness to perform preventive behaviors was consistently found in a variety of health risks (Flynn et al., 1994), among them also pandemics (Bish and Michie, 2010; Kwok et al., 2020), presumably due to a higher perceived susceptibility in these groups. Since older people have a higher risk of manifesting COVID-19 symptoms (Davies et al., 2020), which was promulgated via mass media reports, this might have led to lower susceptibility perceptions among younger people. Across cultures and scenarios, young males tend to report lower risk perception and compliance intentions. By corroborating these associations in the context of COVID-19, our findings stress the need for selective prevention targeting young males to improve their compliance and thereby public health.

Despite these similarities, we observed differing intentions regarding personal hygiene behaviors but overall high intentions to comply with avoidance behaviors, in contrast to Liao et al. (2015). While studies in other Western countries, that is Canada (Toronto), and the United States (Blendon et al., 2004), also indicated high compliance with quarantine and social distancing strategies, it should be noted that avoidance measures are generally easier to implement than specific preventive behaviors that require personal action (Bish and Michie, 2010). Therefore, it is possible that in this early phase of the COVID-19 outbreak in Germany, personal responsibility was not as salient in the general population. This might be connected to the lack of familiarity with pandemics and appropriate preventive action in the German population. Nevertheless, personal preventive actions may yet increase over time, coinciding with an increase in vigilance, knowledge, and positive attitudes, if supported by concerted action, as suggested by previous SARS outbreak trajectories (Leung et al., 2003; Leung et al., 2005).

To concur, in their analysis of repeated cross-sectional surveys, Liao et al. (2015) observed fairly stable behavioral patterns (i.e., robust latent classes) across time, but an increase in public vigilance and perceived threat throughout the epidemic (i.e., an increase in latent class proportions in favor of vigilance). To foster vigilance, the media and governmental institutions are therefore urged to provide clear guidance, openly communicate and justify new measures to increase trust, and strengthen self-efficacy at early stages of a pandemic, as shown in previous health crises (e.g., Seeger, 2006; Bean et al., 2015; Jha et al., 2018).

4.2 Noncompliance and Stigmatizing Attitudes

In addition to compliance patterns, this study also examined the impact of stigmatizing attitudes on intentions to comply with behavioral recommendations. While Williams and Gonzalez-Medina (2011) connected an increase in influenza infections to an increase in stigmatizing attitudes, in this study, blame was low (mean = 1.42 on scale of 1-5) and did not predict compliance. Instead, support for discrimination was significantly associated with higher compliance intentions. Drawing on social psychiatric research, this type of discrimination might be described as *intentional structural discrimination*, where a worldview is actively supported that restricts patients' rights (by law), for example regarding their opportunities to vote, or to hold public office (Corrigan et al., 2004; Corrigan et al., 2006; Schomerus et al., 2007). In the context of COVID-19, a support for discrimination implies a desired restriction of access to socio-political resources for infected persons.

As a result, while high compliance represents law-abiding and theoretically desirable behavior, its connection to discrimination, particularly in this highly educated sample, is noteworthy. In line with the reasoning behind selfishness and responsibility shift in confronting the SARS pandemic (Morrison and Yardley, 2009), a support for discrimination might indicate a way to maximize differences between relevant in-groups (i.e., responsible, healthy) and out-groups (i.e., irresponsible, reckless) to affirm social identity status (Tajfel and Turner, 1986; Link and Phelan, 2001) and – at least symbolically – reduce the risk of infection. Since blame did not differ between latent classes and was generally low, we assume that in this sample, stigma facilitated othering but not discriminatory action (Deacon, 2006). Although this hypothesis requires further research in larger, longitudinal samples using more elaborate measures of stigmatizing attitudes, it is clearly in line with evidence-based demands of a more nuanced debate of the functional properties of stigmatization and its connection to discrimination in infectious diseases (Deacon, 2006).

4.3 Strengths and Limitations

Finally, this study is not without limitations, as the sample is a small convenience sample that is not representative of the German population. In fact, the sample was highly educated, predominantly female, and mostly without migration background. However, we still observed substantial heterogeneity in intentions, despite females and highly educated persons being generally more likely to report high compliance in previous studies. In addition, this study was cross-sectional, and exploratory, and used short but validated measures of core constructs, hence effects of risk perception, for example, were not fully explored. Components like anticipatory worry could also affect compliance intentions and should be studied in more detail (Leppin and Aro, 2009). Furthermore, items measuring stigmatizing attitudes were adapted to COVID-19 for this study, therefore a thorough psychometric validation is necessary. Moreover, we did not assess other important factors that might be connected to (non)compliance, such as ethnicity, interpersonal contact with infected persons, or trust in the government. Finally, we captured behavioral intentions but we did not assess actual behaviors, as the pandemic had just reached the German population, and official recommendations were first issued at the beginning of data collection. Therefore, future studies should also focus on behavioral performance. When investigating the connection between compliance intentions and behavioral performance, health behaviors models like the theory of planned behavior should be applied to incorporate relevant intermediary variables, such as self-efficacy (Ajzen, 1991; Bish and Michie, 2010). Overall, more comprehensive, longitudinal and experimental studies are necessary to validate our findings in the context of COVID-19 in diverse populations. Nevertheless, we think this study provides an important look at patterns of compliance at early stages of the COVID-19 outbreak and impactful sociodemographic and attitudinal factors, such as support for discrimination, that underline the need for selective preventive action.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

ST, MR, and SiS contributed to conception and design of the study. ST, and MR were responsible for data collection, and statistical analysis. ST wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Data Availability Statement

Datasets are available on request: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Tables

Table 1

Overview of mean values and relative frequencies of sociodemographic data, risk perception, knowledge, intentions to comply with recommendations, and stigmatizing attitudes in a German community sample (complete cases with listwise deletion; N = 154-157)

Variable	M (SD) or N (%)
Age (range: 18-77)	27.82 (11.01)
Gender	
Female	124 (80.0)
Male	31 (20.0)
Level of Education	
Lower secondary	4 (2.6)
Higher Secondary	91 (59.0)
Tertiary	59 (38.3)
Region	
Rural	105 (73.2)
Urban	42 (26.8)
Country of origin	
Germany	150 (95.5)
Other	7 (4.5)
Persons in one's household	
One	30 (19.5)
Two	63 (38.9)
Three or more	61 (39.6)
Support for discrimination (range: 1-5)	2.50 (0.82)
Blame (range: 1-5)	1.42 (0.54)
Risk perception	
Susceptibility (range: 1-100%)	62.17 (20.27)
Fear (range: 1-5)	3.11 (1.05)
Subjective knowledge about adaptive behaviors (range: 1-5)	3.80 (0.76)
Intentions to comply with behavioral recommendations (very high)	
(1) covering mouth and nose when coughing or sneezing	144 (91.7)
(2) avoid handshakes	121 (77.6)
(3) avoid touching one's face as much as possible	28 (17.8)
(4) dispose of used tissue immediately and securely	81 (52.3)
(5) frequent ventilation	55 (35.3)
(6) increased hand hygiene	113 (72.9)
(7) stay at home when sick	128 (81.5)
(8) avoid personal contact to symptomatic persons	124 (79.0)
(9) avoid mass events	128 (81.5)

Table 2

Model fit criteria for latent class models of intentions to comply with behavioral recommendations regarding infection prevention in a German community sample (N = 157)

	2 classes	3 classes	4 classes	5 classes
Free parameters	19	29	39	149
BLRT	77.28***	**29.01*** **	20.41	15.46
AIC	1423.81	1414.80	**1414.76**	1419.42
SSABIC	1421.74	1411.64	**1410.50**	1414.07
Entropy	0.60	0.70	**0.74**	0.74
ALCP	0.89	0.86	1.00	0.85
	0.88	0.81	0.82	0.77
		0.91	0.90	0.85
			0.80	1.00
				0.84

Note. BLRT bootstrapped likelihood ratio test; AIC Akaike Information Criterion; SSA-BIC sample-size-adjusted Bayes Information Criterion; ALCP average latent class probabilities; *** $p < .001$; fit criteria indicating the best model are printed **in bold**

Table 3

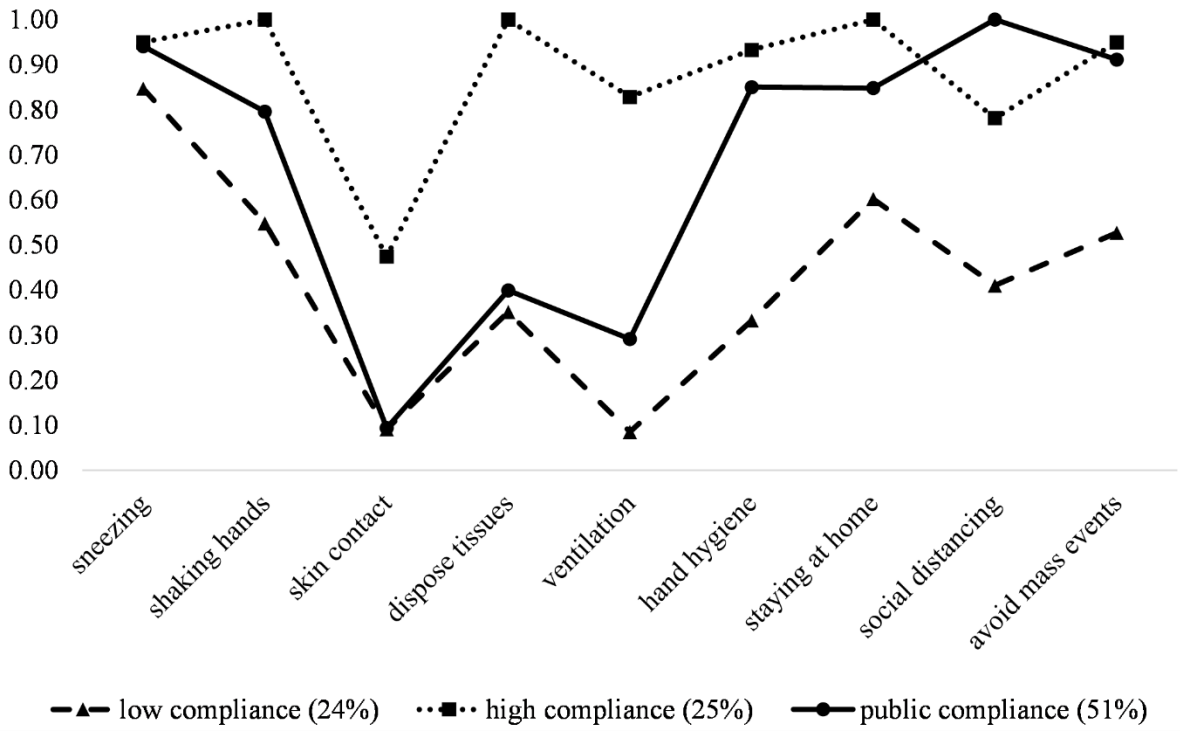
Multinomial logistic regression of latent classes of intentions to comply with behavioral recommendations regarding infection prevention in a German community sample (N = 157)

	Public compliance (class 3) vs. high compliance (class 2)			Low compliance (class 1) vs. high compliance (class 2)			Low compliance (class 1) vs. public compliance (class 3)		
Predictor	RRR	95% CI		RRR	95% CI		RRR	95% CI	
Age	0.95	0.87	1.04	**0.72***	0.57	0.93	**0.76***	0.59	0.98
Gender (ref. male)	0.38	0.05	3.16	**0.08***	0.01	0.85	0.22	0.02	1.90
Level of Education (ref. secondary)	1.20	0.12	11.68	2.82	0.41	19.58	0.44	0.03	6.60
Region (ref. rural)	3.00	0.36	24.95	3.39	0.37	30.75	0.37	0.02	5.67
Country of origin (ref. Germany)	0.54	0.08	3.67	0.25	0.03	1.76	5.19	0.53	50.83
Persons per household (ref. One)									
Two	3.40	0.68	17.13	0.52	0.07	4.16	1.00	0.18	5.49
Three or more	0.15	0.01	4.12	1.11	0.03	41.84	1.60	0.02	119.22
Support for discrimination	0.27	0.06	1.21	**0.21***	0.05	0.88	0.77	0.12	5.06
Blame	0.94	0.24	3.67	1.46	0.33	6.39	1.55	0.28	8.66
Risk perception									
Susceptibility	1.01	0.97	1.04	1.03	0.99	1.06	1.02	0.97	1.06
Fear	1.74	0.61	4.96	0.80	0.34	1.89	0.46	0.20	1.06
Subjective knowledge	0.46	0.13	1.67	0.25	0.05	1.26	0.55	0.08	3.84

Note. RRR Relative Risk Ratio; 95% CI 95% confidence interval; significant coefficients are printed **in bold**; * $p < .05$

Figure captions

Figure 1. Conditional response probabilities and latent class proportions of three latent classes of (non)compliance with behavioral recommendations regarding infection prevention in a German community sample (N=157). The probabilities correspond to the dichotomized likelihood of complying with recommendations (0 (*not at all likely* to *quite likely*); 1 (*very likely*)), thus a higher probability indicates higher compliance.



9.4 A4. Studie 4

Tomczyk, S.*, Rahn, M.*, Markwart, H. & Schmidt, S. (2021). A Walk in the Park? Examining the Impact of App-Based Weather Warnings on Affective Reactions and the Search for Information in a Virtual City. *International Journal of Environmental Research and Public Health*, *18*(16). [* shared first authorship] https://doi.org/10.3390/ijerph18168353

A walk in the park? Examining the impact of app-based weather warnings on affective reactions and the search for information in a virtual city

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Abstract:

Background: Warning apps can provide personalized public warnings, but research on their appraisal and impact on compliance is scarce. This study introduces a virtual city framework to examine affective reactions when receiving an app-based warning, and subsequent behavioral intentions. *Methods:* In an online experiment, 276 participants (M = 41.07, SD = 16.44, 62.0 % female) were randomly allocated to one of eight groups (warning vs. no warning, thunderstorm vs. no thunderstorm, video vs. vignette). Participants were guided through a virtual city by a mock-up touristic app (t1). Then, the app issued a warning about an impending thunderstorm (t2), followed by a virtual thunderstorm (t3). The virtual city tour was presented via vignettes or videos. ANCOVAs were used to investigate trajectories of momentary anxiety, hierarchical regressions analyzed the impact of momentary anxiety on information seeking. *Results:* Participants who received a warning message and were confronted with a thunderstorm showed the highest increase in momentary anxiety, which predicted information seeking intentions. *Conclusions:* The findings underscore the importance of affective appraisal in processing warning messages. The virtual city framework is able to differentiate the impact of warning versus event in an online context, and thus promising for future warning research in virtual settings.

Keywords: emergency alert; public warning systems; affect heuristic; weather; disaster; online experiment

1. Introduction

Severe weather comes in a variety of forms, such as droughts, floods, or thunderstorms, each of which may have massive societal and meteorological impacts (Doswell et al., 2006). The World Meteorological Organization has developed a definition of severe weather that acknowledges regional differences in types of (e.g., sand/snow storms, flash floods) as well as thresholds for severe weather events (e.g., intensity of wind or rain) but characterizes severe weather as "an extreme meteorological event or phenomenon, which represents a real hazard (to human life and property)" (World Meteorological Organization, 2004, S. 2). Although severe weather is less intense and occurs less frequently in the European region than in other parts of the world, it still poses an increasing threat in Europe (Allen & Allen, 2016; Doswell, 2003): for instance, thunderstorms, or so-called convective storms, can arise with heavy winds or even tornadoes, rainfall, hail, and lightning (Doswell, 2015; Groenemeijer et al., 2017; Kron et al., 2019; Rauhala & Schultz, 2009; Taszarek et al., 2020).

By alerting and providing information to populations that are potentially affected by thunderstorms and other large-scale weather events, warning messages are an effective means of preventing various forms of damage; including loss of life and property (Mayhorn & McLaughlin, 2014; Rauhala & Schultz, 2009). A large body of literature informs the construction of effective warning messages from an interdisciplinary perspective (Bean et al., 2015; Mayhorn & McLaughlin, 2014). For example, studies on weather warnings indicate that warning messages emphasizing potential consequences and providing guidance for protective measures are perceived as more threatening and are more likely to be followed than those, which describe the event alone (Potter et al., 2018; Weyrich et al., 2018a).

Traditionally, TV and radio news broadcast weather reports and weather warnings, but in recent years, new channels have been utilized to communicate warning messages. Mobile warning apps, such as FEMA in the U.S., or NINA and KATWARN in Germany, are able to promptly alert a broad range of the population regarding hazards and threats while simultaneously providing them with information on protective measures (Fischer et al., 2019; Petridou et al., 2019; Reuter, Kaufhold, Leopold & Knipp, 2017). While some apps inform about a range of hazards (e.g., FEMA and KATWARN), others specifically focus on weather forecasting and severe weather (e.g., WarnWetter, a weather app), with the latter being highly popular (DWD, 2021; Zabini, 2016). A survey conducted among university students found that around 80 % used weather warning apps at least once per day to get forecasts, thus indicating high use rates compared to traditional media, such as local television (6.8 %) (Phan et al., 2018). Yet, information processing of app-based warning messages has not been conclusively investigated, for instance, a range of new requirements needs to be considered (e.g., brevity of the warning message or format of the warning). As they play a seminal role in the future of civil protection regarding environmental hazards, it is important to comprehensively understand how mobile warning messages are processed by recipients.

Sutton and Kuligowski (2019) provide an overview of existing short messaging channels used to communicate warning messages and they outline a theoretical background referring to an adaption of the Protective Action Decision Model (PADM) (Lindell & Perry, 2003, 2012). The PADM describes information processing and human responses towards hazards and threats through several stages, such as pre-decisional processes and core perceptions, followed by decision-making processes. Social or environmental cues, as well as information provided by warning messages, and a recipient's characteristics, can elicit pre-decisional processes, which consist of the reception, attention, and comprehension of said cues or information. Consequently, an estimation of credibility and personal threat or risk can take place. If a cue is perceived as credible and one's own risk is perceived as high (including cognitive and affective appraisal of the threat), the individual will seek protective actions and implement them. This makes risk appraisal an important factor in the warning process.

1.1 Risk appraisal and warning compliance

However, several studies revealed complex relationships between risk appraisal and behavior, in that perceived risk is not necessarily accompanied by the implementation of protective measures (Keul et al., 2018; Wachinger et al., 2013; Williams & Noyes, 2007). One reason for this could be the varying – and partly one-sided – cognitive operationalization of risk appraisal (Leppin & Aro, 2009; Wilson et al., 2019). Beyond cognitive risk appraisal, research from the field of health behavior (Sheeran et al., 2014) and on different hazards and warnings (Gutteling et al., 2018; Rahn et al., 2020b; Villegas et al., 2013; Weyrich et al., 2020b) showed that affective responses are as important when examining hazard-related information processing and compliance. The Protection Motivation Theory (Prentice-Dunn & Rogers, 1986) and the Extended Parallel Process Model (Witte, 1992), for example, formalize this distinction in the context of fear appeals. They discern threat appraisals and efficacy appraisals as key determinants of compliance, with negative affective reactions (e.g., fear) leading to higher threat appraisal (i.e., affective risk appraisal), and positive evaluations of personal coping capabilities (e.g., self-efficacy) leading to more positive efficacy beliefs. Taken together, high threat perceptions and high efficacy beliefs predict behavioral compliance with a warning message. Conversely, a study on home fires showed that positive affective associations with wood heating (i.e. lower affective risk appraisal) attenuated the effects of cognitive risk appraisal on using alternative heating systems, thus weakening the association between risk perceptions and behavior (Hine et al., 2007).

Another theoretical model considering such affective reactions towards threats is the affect heuristic, which differentiates between an analytic and an experiential system when it comes to information processing (Finucane et al., 2000; Slovic et al., 2007; Slovic & Peters, 2006). The analytical system describes a slower way of processing information, which is activated when there is enough time to weigh all the facts and information about the situation. In contrast, the experiential system is driven by affective reactions and emotions towards the hazard. It is activated when there is an acute threat, so that judgments and decisions have to be made fast or under time pressure. In this sense, warning messages represent acute threats, as they point to imminent danger. This perspective aligns with neurobiological assumptions based on the BIS/BAS Model (Amodio et al., 2008; Carver & White, 1994;

Gray, 1990; Voigt et al., 2009), which postulates two motivational systems - the BIS (behavioral inhibition) and the BAS (behavioral approach) - that influence affect and behavior. While BAS is activated by cues of reward and may enhance approach tendencies, BIS is sensitive towards cues of punishment and threat, and therefore often associated with avoidance tendencies. When confronted with an unknown or threatening cue – for example after receiving a warning message for a thunderstorm or perceiving other thunderstorm-related stimuli, such as dark clouds or growling thunder – activation of the BIS can increase attention towards the cue, and enhance arousal and negative emotions such as anxiety. This in turn can lead to the inhibition or reduction of current behaviors, eventually followed by avoidance behavior. With the BIS activated, a person may interrupt their current activity, collect more information about the impending threat, and implement protective measures.

To date, applied warning research has produced ample evidence for these assumptions: For instance, a study on pop-up messages showed that negative affect impacts the perception and processing of relatively trivial threats (e.g., outdated software while surfing the internet) (Buck et al., 2018). Meta-analyses and studies of warning messages on tobacco products highlighted the advantages of pictorial warnings over text-based warnings by evoking more negative emotional responses (e.g., fear, sadness, or disgust), as well as higher intentions not to start or to quit smoking. Thus, it appears that warnings on tobacco products influence behavioral intentions by increasing negative affect (Hall et al., 2018; Noar et al., 2016; Noar et al., 2020). Similar affective response patterns also seem to play a role in weather-related hazards. For example, exposure-based research in a clinical sample found that the (virtual) exposure to a threatening stimulus can elicit affective, mainly fear-related reactions (Krause et al., 2018; Nelson et al., 2014; Westefeld et al., 2006). These effects are applied in exposure-based cognitive behavioral therapies for storm-related phobias (Lima et al., 2018). Previous research on other hazards like earthquakes (Feng et al., 2020), fires (Jansen et al., 2020), and floods (Fujimi & Fujimura, 2020b) has also used virtual reality to create a realistic scenario that can induce negative affect when confronted with an event. This allows researchers to study and modify subsequent affective, cognitive, and behavioral reactions.

Consequently, eliciting negative affect could also be a key factor of weather warning compliance in that increased fear will lead to increased compliance intentions or behaviors (Sutton et al., 2018; Villegas et al., 2013; Weyrich et al., 2020b). Nevertheless, receiving warning messages can also lead to a reduction in negative affect (Rahn et al., 2020b). A meta-analytic study of fear appeal theory offers a potential explanation for this countervailing trend, namely an interaction between threat and efficacy (Peters et al., 2013). The receipt of a warning message could increase salience of a threat, thereby evoking negative affect. But simultaneously communicating effective protective measures against the threat could lead to increased efficacy, which, in turn, might reduce negative affect.

1.2 Research questions and hypothesis

Despite recommendations to investigate mobile warning messages under conditions that are as realistic as possible (Bean et al., 2015; Hancock et al., 2020), few studies have investigated said processes under real-life conditions (Weyrich et al., 2020b) or in experimental settings (LeClerc & Joslyn, 2015) that dissect the warning process (i.e., perceiving, processing, and complying with app-based warnings). Therefore, the intuitive affective processing of weather warnings poses unanswered questions. To close this gap, the present study introduces the virtual city framework and aims to examine affective processing of a thunderstorm warning message via an experimental, repeated measures design. This virtual city framework is embedded in a browser-based online survey platform (Leiner, 2019) that provides easy access and ensures functionality across different browsers and devices. While this increases the reach and applicability of the virtual city framework, it also means lower realism than more complex and immersive virtual environments, such as virtual reality (Pan & Hamilton, Antonia F de C, 2018) that require additional equiment. In virtual reality, users can create photorealistic representations of real buildings and topographic structures [e.g.,Keil et al., 2021; Zhao et al., 2019] that can increase immersive effects and perceived realism of the virtual environment. Virtual reality is already widely implemented in (geo-)spatial sciences [60] and construction (Wang, P. et al., 2018) and it also holds promise for sociobehavioral spatial research, for instance, in evaluating warning compliance under realistic conditions [e.g.,Duarte et al., 2010; Markwart et al., 2019].

Highly immersive environments can lead to stronger emotional (e.g., negative affective appraisal) and cognitive reactions (e.g., perceived severity, self-efficacy) (Benvegnù et al., 2021; Buttussi &

Chittaro, 2018) and the evoked reactions might be closer to their real-life equivalent than in low immersive environments. So far, however, findings regarding the ecological validity of these methods (e.g., the congruency between virtual and real behavior) are mixed [e.g., Jensen & Konradsen, 2018; Morélot et al., 2021; Parsons, 2015; Williams-Bell et al., 2015]. Hence, more research is needed to examine biopsychosocial processes underlying decision-making in these situations to explore facilitators and barriers to compliance and implementing adaptive behavior when confronted with warnings or hazards.

Therefore, in this experiment, we choose a simpler, less immersive approach where warning message and thunderstorm are presented in two different formats, namely in videos or vignettes. Videos can elicit stronger negative affective appraisals than vignettes, have a higher criterion validity, and they are connected to stronger stimulation of cognitive learning processes (Balslev et al., 2005; Christian et al., 2010; Sleed et al., 2002; van Gelder et al., 2018). Presumably, videos are able to present a more accurate depiction of contextual cues that increase the perceived realism of a scenario and thus increases external validity (Christian et al., 2010; van Gelder et al., 2018). Due to their efficiency and high internal validity, however, experimental vignette studies are still popular in applied warning research (Aguinis & Bradley, 2014; Hahm et al., 2019; Rahn et al., 2020b). Therefore, both formats will be compared in the current study: Participants will receive a thunderstorm warning message via a mobile app during a virtual city tour, followed by an exposure (vs. non-exposure) toa thunderstorm. Based on previous research, we propose the following hypotheses:

- **H1:** The receipt of a warning message regarding a thunderstorm will lead to an increase in momentary anxiety.
- **H2:** The exposure to a thunderstorm will lead to an increase in momentary anxiety.
- **H3:** Presentation format will influence momentary anxiety, in that video footage will lead to greater momentary anxiety than vignettes.

To enhance the relevance of our research, the present study will additionally focus on the recipient's search for information in association with momentary anxiety. The search for further information can be part of every stage of the PADM, for example, by inquiring about effective protective measures or suitable locations to seek shelter (Sutton & Kuligowski, 2019). Also, individuals who have received a warning message often try to verify and confirm it by seeking out other sources (Mileti & Peek, 2000). Such behaviors are connected to negative affect and might be associated with risk and coping appraisals or uncertainty, for instance, regarding message content or behavioral recommendations (Sutton & Woods, 2016). Thus, searching for information following a warning message may reduce negative affect by leading to more positive coping appraisals or reducing perceived threat and uncertainty (Rahn et al., 2020b; Sutton & Woods, 2016; Vihalemm et al., 2012), but it could also be a sign of milling. Milling refers to information seeking behavior following a warning, for example, by searching on other channels and exchanging information with others, which lead to a time delay and further protective measures not being initiated immediately (Wood et al., 2018). Hence, information seeking depicts a protective behavior that cannot in itself be labeled as an adaptive or maladaptive response to a warning message, but we can assume that it is predicted by negative affect. Therefore, we will examine the following hypotheses:

- **H4:** Higher momentary anxiety will lead to an increased search for further information.
- **H5:** In participants who were confronted with a thunderstorm, the receipt of a warning message, and the presentation format will interact with momentary anxiety, which will lead to an increased search for further information.

Finally, as already outlined in the PADM, individual characteristics can impact the processing of weather warning messages. Prior experience with severe weather as well as experienced personal harm impacts the subsequent appraisal of risk and the implementation of preparedness behavior (Armstrong & Towery, 2021; Frondel et al., 2017; Hong et al., 2019; Kox & Thieken, 2017; Lujala et al.,

2015; Sattler et al., 2000).Sociodemographic variables, such as age or gender, play a role in risk appraisal in connection with weather warnings and protective measures: female gender and higher age are factors that are associated with higher compliance (Bateman & Edwards, 2002; Perry & Lindell, 1997; Potter et al., 2018). Therefore, age, gender, previous experience with thunderstorms, and storm fear are included as covariates. We will also include current the usage of warning apps as a covariate.

2. Materials and Methods

2.1 Sample

Data collection took place from February to June 2020. A German adult sample was recruited via various online services (e.g., internet forum posts via Facebook, and platforms for psychological online surveys). Participants were invited to participate in an online study evaluating a novel app as a cover story (see 2.4). Participants were included if they were at least 18 years of age and fluent in German. As an incentive, participants entered a raffle for six gift vouchers (15 Euros).

2.2 Materials

The videos used in this study took the viewer on a virtual city tour to Berlin. The virtual scenery was created with the game engine Unity (Team License) version 5.3.1. For the generation of the videos, Open Broadcaster Software (OBS) and OpenShot Video Editor were used. Vignettes consisted of screenshots of the videos and written descriptions. Videos and vignettes used in this study can be found in the supplementary material online (File S1 (vignettes) and File S2 (videos)). In both files, videos and vignettes are labelled according to their position in the experiment (1 baseline, 2 warning, 3 no warning, 4 thunderstorm, 5 no thunderstorm).

In this study, a thunderstorm warning message was sent via a simulated mobile phone app. The message was issued by the Deutscher Wetterdienst (DWD). The DWD operates as the German National Meteorological Service and is in charge of the forecast as well as the warning of weather hazards (DWD, 2021). The warning message contained a description of a pending thunderstorm, possible impact, recommended protective actions, and the affected region. The message was adapted from previously issued severe weather warnings, optimized for mobile warning systems based on current recommendations (Bean et al., 2016; Sutton et al., 2018; Sutton & Kuligowski, 2019). The thresholds for severe weather were based on DWD criteria for warnings of severe weather (so-called Level 3 events) (Deutscher Wetterdienst). The original message (in German) and its English translation can be found in figure 1. The text is available upon request from the first author.

Translation:

Official warning of severe weather

Validity: The warning is valid for today.

Warning: Thunderstorms with hurricane winds up to 120 km/h (33 m/s, 64 kn, Bft 12) as well as heavy rain with precipitation amounts around 35 l/m² will occur quickly.

Information about possible threats: ATTENTION! Threat to life in case of lightning strikes! Trees can be uprooted, and roof tiles, branches, or objects can fall.

Recommended action: Close all windows and doors! Secure objects outside! In particular, keep your distance from buildings, trees, scaffolding, and high-voltage lines! Avoid being outdoors if possible!

Affected regions: Berlin and surroundings

Published by: Deutscher Wetterdienst

Figure 1. Warning message used at second point of measurement (t2; in German), and English translation of the warning message.

2.3 Measures

Momentary anxiety was assessed with one item ("How anxious do you feel at the moment?") at three time points. A 5-point Likert scale was used, ranging from 1 (not at all) to 5 (extremely). The search for further information was assessed using one item ("How likely is it that you would search for more information about this situation?"). Again, a 5-point Likert scale was used, ranging from 1 (not at all) to 5 (very likely).

Seven items were used to measure previous thunderstorm experience with 7-point Likert scales (1 (never) to 7 (very often)). For example, participants were asked whether they or their friends and family had already experienced a thunderstorm, or whether they were in danger during a thunderstorm. To measure storm fear, the Storm Fear Questionnaire (SFQ) (Nelson et al., 2014) was used. The SFQ consists of 15 items that address weather- and storm-related phobia in adults. Current warning app use was assessed via one item ("Do you currently use one or more apps to be warned of weather events?"); a 'yes' indicated current app use. Gender (1=male, 2=female) and age (in years) were assessed using single items.

2.4 Study Design and Study Procedure

Participants were invited via Facebook posts, and online survey platforms (e.g., Psychology Today) to test and rate a touristic app that aims to provide multifaceted information about location, sights, traffic, and weather. A hyperlink directed participants to the experiment, which was implemented via SoSci Survey (Leiner, 2019) and took about 30 minutes to complete. Participants were welcomed to the study and received information about the study background and how their data would be collected and used. After they gave their informed consent, participants first reported sociodemographic data (e.g., age and gender). Then, they received a cover story asking them to take part in the evaluation of a new touristic city app called "Local App" during a virtual city tour.

Data collection took place using a quasi-experimental 2x2x2 factorial design. The study procedure can be found in figure 2. Due to randomization, a subset of participants received all further footage of the virtual city either via videos or vignettes (video/vignette). Following randomization by random draw, momentary anxiety was assessed for the first time (t1). Then, one group received a thunderstorm warning message while the other group received neutral information about the city (warning message/no warning message), followed by the second assessment of momentary anxiety (t2). Finally, either a thunderstorm or neutral information was presented (thunderstorm/no thunderstorm), and momentary anxiety was assessed for the last time point (t3).

Lastly, prior thunderstorm experience, storm fear, and current use of warning apps were assessed in a questionnaire. Upon completion, all participants were given information for psychosocial support services if they needed assistance due to the exposure to a thunderstorm. The required sample size for this study was estimated a priori using G*Power (Faul et al., 2007), based on an anticipated power of β=.80, an alpha error value of α=.05, a medium effect size of f=.25, eight groups, and three repeated measurements with an estimated non-correlation between repeated measures (due to experimental manipulation). An ANOVA with repeated measures, and within-between interactions was chosen as the statistical analysis, resulting in a required sample size of n=104.

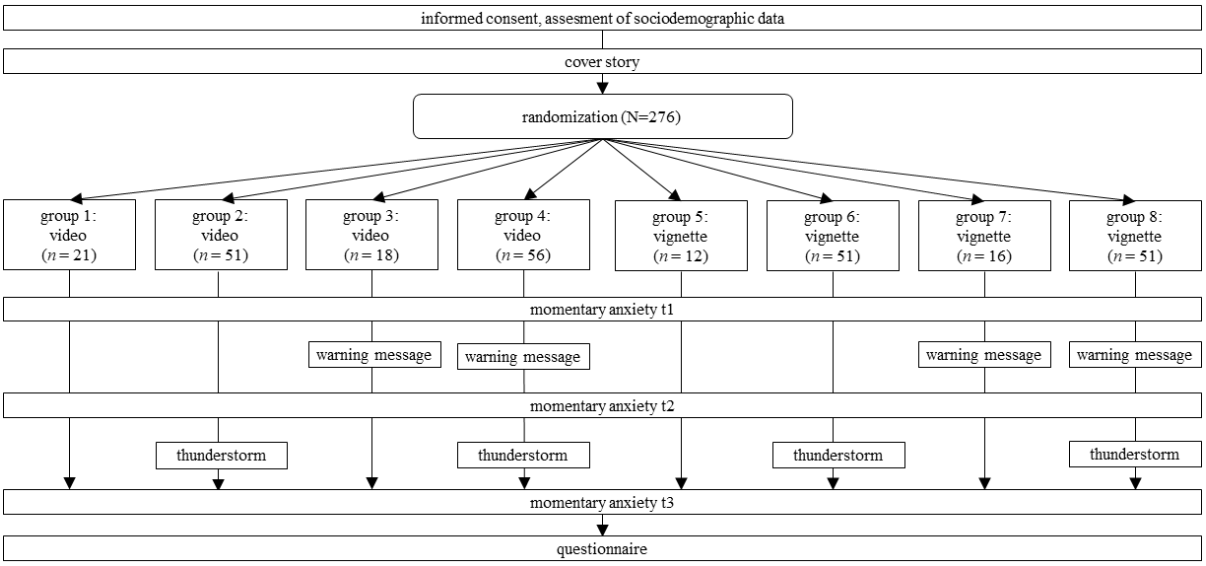


Figure 2. Study procedure: Participants were randomized into eight groups according to presentation format (video vs. vignette), warning receipt (no warning vs. warning), and thunderstorm exposure (no thunderstorm vs. thunderstorm). Momentary anxiety was assessed at three time points: t1 (beginning of the cover story), t2 (warning message receipt vs. no receipt), t3 (thunderstorm exposure vs. no exposure).

2.5 Statistical Analysis

All analyses were performed using IBM SPSS Statistics 27 and PROCESS macro (version 3). Means and standard deviations were calculated for the SFQ and prior thunderstorm experience. Chi-square tests and t tests were performed to analyze differences between experimental conditions. Pearson correlations were performed to investigate links between the examined constructs.

To answer hypotheses 1 to 3, a repeated measures ANOVA as well as ANCOVA were conducted with time (i.e., momentary anxiety at three time points) as a within-persons factor and warning, thunderstorm, and format (video/vignette) as a between-persons factors. As a measure of effect size, partial eta squared (η_p^2) was reported. To correct violations of sphericity, Greenhouse-Geisser adjustment was applied. To answer hypotheses 4 and 5, a moderation analysis was conducted via multiple linear regression. For the repeated measure ANCOVA and moderation analysis, age, gender, prior thunderstorm experience, storm fear, and app use were included as covariates. The moderation analysis was performed in the subsample of participants who were confronted with a thunderstorm during the experiment (n=209).

3. Results

3.1 Descriptive Statistics

A total of 276 participants completed the survey. Missing values on item level ranged from 0.0 % (e.g., momentary anxiety at t1) to 5.4 % (app use). Most participants had no or one missing value (89.3%), followed by multiple missing values in previous experience of thunderstorms (3.7%), and storm fear (3.7%). Complete cases analysis was performed.

The sample included 62.0 % females (n = 171) and 34.1 % males (n = 94), with no information received from 4.0 % (n = 11). Participants` age ranged from 17 to 83 years (M = 41.07, SD = 16.44). Mean score of previous thunderstorm experience was 2.90 (SD = 0.71, Range = 1.00 - 6.43) and mean score of storm fear was 1.50 (SD = 0.54, Range = 1 - 5). About 31.2 % (n = 86) of participants reported current use of a mobile warning app for weather events.

According to the randomization, 141 (48.9 %) participants received a warning message, 209 (75.7 %) participants were confronted with a thunderstorm, and 146 (52.9 %) received their information as videos. The thunderstorm condition was oversampled to account for potential dropout due to technical difficulties in playing the videos that were reported in a pilot test of the experiment. The sample size for each group (n = 12 - 56) as well as descriptive statistics for each group can be found in Appendix A (Table A1). The eight groups did not differ by age, gender, previous thunderstorm experience,

storm fear, and app use, pointing to a successful randomization procedure. The only difference was observed for format and gender ($\chi^2(1) = 8.15$, $p < 0.01$), in that more female participants received information via vignettes.

Bivariate correlations of study variables can be found in table 1. Significant positive correlations were found for momentary anxiety (t1-t3) and the search for further information (t3) ($r = .13$ - $.31$, $p <$ .05 - .001). In the warning message group, significant positive associations were found for momentary anxiety at t2 ($r = .34$, $p < .001$) and t3 ($r = .14$, $p < .05$), while exposure to a virtual thunderstormwas positively correlated with momentary anxiety at t3 ($r = .34$, $p < .001$). Thus, receiving a warning message and being exposed to a thunderstorm was associated with higher anxiety ratings. Negative correlations were found for presentation format and momentary anxiety at t2 ($r = -.12$, $p < .05$) and t3 ($r = -.14$, $p < .05$), meaning that vignettes caused less momentary anxiety than videos.

Table 1. Pairwise (Pearson) correlations of momentary anxiety (t1 - t3), search for further information, warning message receipt, thunderstorm confrontation, and presentation fomat, including covariates (age, gender, thunderstorm experience, storm fear, app use), n = 250 – 276.

		1	2	3	4	5	6	7	8	9	10	11	12
1	momentary anxiety t1	1											
2	momentary anxiety t2	.49***	1										
3	momentary anxiety t3	.39***	.53***	1									
4	search for further information	.13*	.25***	.31***	1								
5	warning message receipt	.02	.34***	.14*	.10	1							
6	thunderstorm exposure	.10	.02	.34***	.18**	.00	1						
7	format	-.01	-.12*	-.14*	.03	-.01	-.06	1					
8	age	-.12*	-.09	.02	.08	-.05	.13*	.02	1				
9	gender	.07	.11	.14*	.12*	.02	.05	-.18**	-.18**	1			
10	thunderstorm experience	.11	.01	-.02	.08	.02	-.03	-.07	.08	-.04	1		
11	storm fear	.20**	.23***	.19**	.12*	.01	-.02	-.01	-.02	.01	.23***	1	
12	app use	-.10	-.12*	-.05	.02	.11	.09	.01	.21**	-.09	.15*	.18**	1

Note. t1-t3: Points of measurement: t1 (beginning of the cover story), t2 (warning message receipt vs. no receipt), t3 (thunderstorm exposure vs. no exposure). Momentary anxiety was assessed using a 5-point Likert scale, ranging from 1 (not at all) to 5 (extremely). Warning message receipt (0 = no warning. 1 = warning); thunderstorm exposure (0 = no exposure. 1 = exposure); presentation format (1 = vignette. 2 = film); gender (0 = male, 1 = female); app use (0 = no current use. 1 = current use). *p < .05. **p < .01. ***p < .001.

3.2 Trajectory of momentary anxiety

The following section presents the results of the ANCOVA regarding momentary anxiety (H1 to H3), and the regression of information seeking intentions on momentary anxiety (H4 and H5). A repeated measures ANOVA without covariates showed three significant effects: a main effect of time, indicating an increase in momentary anxiety over time ($F(1.81, 482.64) = 34.148$, $p < 0.001$, $\eta_p^2 = 0.113$), an interaction of time x warning ($F(1.81, 482.64) = 8.19$, $p < 0.05$, $\eta_p^2 = 0.03$), and an interaction of time x thunderstorm ($F(1.82, 482.64) = 27.64$, $p < 0.001$, $\eta_p^2 = 0.09$), with participants receiving a warning or being exposed to a thunderstorm reporting higher anxiety scores. The remaining effects did not reach statistical significance.

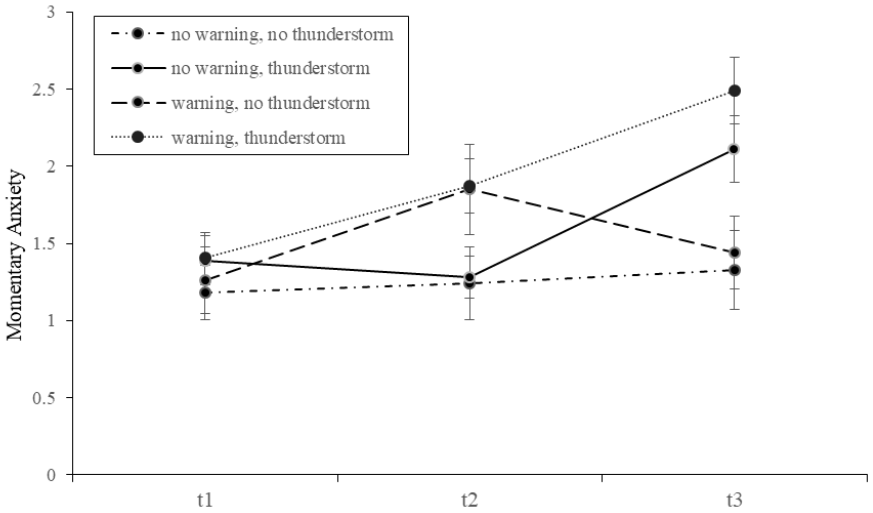
H1: The receipt of a warning message regarding a thunderstorm will lead to an increase in momentary anxiety.

Repeated measure ANCOVA revealed a significant interaction of time and receiving a warning message ($F(1.82, 412.01) = 7.84$, $p < 0.01$, $\eta_p^2 = 0.03$). Participants who received a warning message regarding

a thunderstorm reported higher momentary anxiety compared to participants who received no warning.

H2: The exposure to a thunderstorm will lead to an increase in momentary anxiety.
A significant interaction was found for time and exposure to a thunderstorm ($F(1.82, 412.01) = 21.70$, $p < 0.001$, $\eta_p^2 = 0.09$), in that participants who were confronted reported higher momentary anxiety. Trajectories of momentary anxiety divided for warning receipt and thunderstorm exposure can be found in figure 3.

Figure 3. Mean values of momentary anxiety over the course of the study.



Note. The lines represent four groups (warning/no warning x thunderstorm/no thunderstorm); presentation format was not included as an additional factor due to a lack of statistical significance in the ANOVA and ANCOVA. Points of measurement: t1 (beginning of the cover story), t2 (warning message receipt vs. no receipt), t3 (thunderstorm exposure vs. no exposure). Momentary anxiety was assessed using a 5-point Likert scale, ranging from 1 (not at all) to 5 (extremely). Error bars show the 95 % confidence interval.

H3: Presentation format will influence momentary anxiety, in that video footage will cause more momentary anxiety than vignettes.

No significant interaction was found for time and presentation format ($F(1.82, 412.01) = 0.59$, $p = 0.54$, $\eta_p^2 = 0.00$).

3.3 Association between momentary anxiety and information seeking

Hypotheses 4 and 5 examined the association between momentary anxiety (t3) and information seeking intentions via hierarchical regression models.

H4: Higher momentary anxiety will lead to an increased search for further information.

Multiple regression analysis for participants who were confronted with a thunderstorm revealed a significant overall model ($F(10.00, 171.00) = 2.83$, $p < 0.01$, $R^2 = 0.12$). Momentary anxiety (t3) predicted the search for further information (b = .30, $p < .001$, 95% CI = 0.14-0.47), while the other effects were non-significant.

H5: In participants who were exposed to a thunderstorm, the receipt of a warning message, and the presentation format will interact with momentary anxiety, which will lead to an increased search for further information.

The receipt of a warning message (b = 0.25, $p = .10$, 95% CI = -0.05-0.56, $\Delta R^2 = 0.01$, $F(1.00, 171.00) = 2.66$) and presentation format (b = -0.07, $p = .65$, 95% CI = -0.38-0.24, $\Delta R^2 = 0.00$, $F(1.00, 171.00) = 0.20$) did not significantly moderate the effect between momentary anxiety (t3) and search for further information.

Regarding the examined covariates, a significant interaction was found for momentary anxiety and age in the ANCOVA ($F(1.82, 412.01) = 3.20$, $p < 0.05$, $\eta_p^2 = 0.01$). Higher age was associated with

less momentary anxiety at the first point of measurement (t1). For the remaining covariates, no significant interactions were found.

4. Discussion

The present study investigated changes of momentary anxiety and intention to seek further information following the receipt of an app-based thunderstorm warning message, and the exposure to a thunderstorm in a virtual city. Results showed that receiving a warning message and being confronted with a virtual thunderstorm both significantly increased momentary anxiety compared to control conditions, which in turn predicted intentions to seek further information. However, neither format (video or vignette) nor the interaction between warning and thunderstorm had a significant impact on momentary anxiety.

4.1 The role of affective appraisal in app-based warning processes

Statistical analyses confirmed hypotheses 1 and 2, in that momentary anxiety increased after receiving a warning message, as well as after being confronted with a thunderstorm. These trajectories point to the activation of the experiential system as proposed by the affect heuristic (Finucane et al., 2000; Slovic et al., 2007; Slovic & Peters, 2006), and the behavioral inhibition system as defined by the BIS/BAS model (Amodio et al., 2008; Carver & White, 1994; Gray, 1990; Voigt et al., 2009). Facing an unexpected or potentially threatening stimulus (in the present case, a warning of an impending thunderstorm) appeared to activate appropriate systems and induce affective reactions. This observation corroborates previous research on the processing of severe weather hazards (Krause et al., 2018; Nelson et al., 2014; Westefeld et al., 2006). In line with fear appeal theory (Prentice-Dunn & Rogers, 1986; Witte, 1992), and the PADM (Lindell & Perry, 2012), this affective appraisal could indicate enhanced threat appraisal.

In contrast to the first two hypotheses, hypothesis 3 was not confirmed. This means that there was no difference in the reported level of momentary anxiety regarding the presentation format. Videos, as well as vignettes, seem to be equally suitable for the experimental investigation of thunderstorm warning messages. This contrast previous studies (Balslev et al., 2005; Christian et al., 2010; Sleed et al., 2002; van Gelder et al., 2018) that pointed to stronger affective reactions to videos. However, in said studies, affect was mediated by perceived realism of the scenario, which we did not assess in this study, therefore we could not compare the perceived realism of both formats. Since higher perceived realism is associated with stronger affective reactions (Benvegnù et al., 2021; Buttussi & Chittaro, 2018), this could be a limiting factor of our study, because neither videos nor vignettes are highly immersive, unlike modern virtual reality applications (Guna et al., 2019; Yeo et al., 2020).

However, the association between perceived realism and anxiety is more complex: research on the connection between perceived realism (as a part of the overall sense of presence in a virtual environement) and emotional arousal (e.g., anxiety) suggests that exteroception (i.e., immersive qualities of the environments) as well as interoception (i.e.,physiological arousal) influence assessments of realism and anxiety (Diemer et al., 2015). Since we observed a significant increase in anxiety ratings, we assume that it was not strongly affected by the immersiveness of the technology and thus exteroceptive cues but rather the interoceptive appraisal of the threat.

In future research, a direct comparison of high immersive technology (e.g., virtual reality) and low immersive technology (e.g., vignettes) implementing the virtual city framework can provide more information on the interplay of immersion, and perceived realism on affective and cognitive processing of warning messages throughout the warning process.

Furthermore, qualitative research methods can be integrated to identify relevant dimensions of perceived realism to enhance immersiveness and arousal. A qualitative analysis of a virtual reality fire extinguisher training, for example (Saghafian et al., 2020), revealed specific aspects of the virtual environment that were connected to perceived realism and could be addressed in future iterations of the training to improve training effects.

Finally, field studies promise higher validity and allow for in-situ assessments of physiological reactions in addition to cognitive and affective appraisals of warning messages (e.g., via ambulatory assessments) (Bean et al., 2015).A recent study on app-based weather warnings (Weyrich et al., 2020a) found that affective and cognitive but not behavioral responses to warning messages differed

betweenexperimental and field approaches. In the field experiment, participants reported better understanding of warning message, threat and how to respond but also less concern regarding one's safety. But since the research was cross-sectional and did not examine cognitive and affective appraisal of warning messages prospectively, further research is necessary to examine and compare trajectories of appraisal and subsequent behaviors in field studies as well as experiments. Combining field studies and the experimental approach of the virtual city framework could be a promising area for future warning research .

4.2 Information seeking versus milling

By examining the search for further information, the present study mapped another step of processing warning messages as described in the PADM, namely behavioral responses (Lindell & Perry, 2003, 2012; Sutton & Kuligowski, 2019). Hypothesis 4 was confirmed as higher momentary anxiety at the third point of measurement was associated with increased intention to search for more information. The results are in line with prior research, which found that emotional reactions, such as fear, towards real-time weather events could have a main impact on the implementation of behavioral responses (Weyrich et al., 2020b). Activated by the BIS (Amodio et al., 2008; Carver & White, 1994; Gray, 1990; Voigt et al., 2009), momentary anxiety could interrupt the current activity and promote seeking information for a better orientation. This interpretation was further supported by testing hypothesis 5, which revealed that warning message receipt did not affect the intention to seek further information, thus hypothesis 5 had to be rejected. This indicates that momentary affect is particularly important in the decision-making process following warning messages or weather events, which corroborates the affect heuristic (Slovic et al., 2007). Moreover, our findings contradict the phenomenon of milling. According to milling, the receipt of a warning message leads to an increased search for information as the individuals at risk do not feel sufficiently informed and want to exchange information with each other before taking protective measures (Wood et al., 2018). In this study, although momentary anxiety increased with warning message receipt, it also decreased when no threat occurred. Thus, the search for further information seems to be affected by the thunderstorm itself rather than by the warning message. This, as well, is depicted in the non-significant correlative relationship between message receipt and information search.

Nevertheless, the search for further information embodies only one (protective) behavior, which can be both beneficial and detrimental (Wood et al., 2018). Also, for most hazards as well as for thunderstorms, a combination of several measures needs to be implemented to protect oneself (e.g., closing doors and windows, search for shelter). Future studies should examine all protective measures conveyed in a warning message. In this context, the intention to act is suitable, as is the actual implementation of protective measures. Field studies could allow situational analyses by using ambulatory assessment (Weyrich et al., 2020a).

In an effort to include characteristics of the warning message recipients, statistical analyses were controlled for age, gender, previous thunderstorm experience, app use, and storm fear. With one exception (i.e., a negative association between age and anxiety at baseline), none of these variables affected momentary anxiety. However, the bivariate correlations (table 1) showed that the investigated covariates were associated with anxiety, and they may still become relevant in other stages of the warning process. For example, participants who were currently using a weather warning app showed less momentary anxiety at the second point of measurement (i.e., when they received a warning). This may indicate that the affective reaction was reduced due to existing experience with such warning messages, which may have implications for threat and efficacy appraisals within the compliance process (Witte, 1992), as previous research pointed to a connection between positive affect (i.e. less negative affect), and lower intentions regarding behavior change, for instance, towards pro-environmental behavior (Hine et al., 2007). This interplay of warning app use, affective and cognitive risk appraisal, and compliance warrants further research.

Positive correlations also emerged between app use and prior thunderstorm experience, as well as app use and storm fear. One can assume that individuals who had already experienced severe weather and were perhaps harmed were more likely to develop a fear regarding storms and, therefore, wanted to protect themselves through the use of weather warning apps (Armstrong & Towery, 2021; Frondel et al., 2017; Kox & Thieken, 2017; Sattler et al., 2000). Although these correlations do

not imply causality and require further investigation, it becomes apparent that the characteristics of the message receivers should not be neglected.

4.3 Limitations

The present study clearly has limitations that should be considered when interpreting the results. The results are based on a German convenience sample. Therefore, no representative statements can be made. Since weather-related fears are relatively low in Germany and European countries vary in their risk communication practice and policies (Keul et al., 2018; Rauhala & Schultz, 2009), an international comparison would be of interest.

Although this study was based on established and well-known definitions of severe weather (according to the DWD), and recommendations for designing mobile public warning messages (Bean et al., 2015; Bean et al., 2016; Sutton & Kuligowski, 2019), we did not examine the realism and perceived of each vignette or video. Prior research showed that the more severe or threatening a weather event is perceived, the more likely it is for those at risk to take protective actions and start to implement them at an earlier stage (Kox & Thieken, 2017). Because of this, future research should consider various levels of severity, and assess cognitive and affective appraisals of the hazard simultaneously. Similarly, effects of differing warning message content and style could also be tested, as we were not able to vary aspects, such as length and design, that may have an impact on affective reactions (Sutton & Woods, 2016).

Although the participants in the present study were presented with realistic footage of warning messages sent by an app and thunderstorms (e.g., video material), we were not able to collect data under real-life conditions (e.g., field studies). Recent research shows, however, that scenario-based surveys do not seem to differ from field assessments in their results (Weyrich et al., 2020b). Nevertheless, the virtual city framework could also be tested in more realistic conditions, for example, by using virtual reality (Markwart et al., 2019), and be extended by more fine-grained assessments, such as ambulatory assessments to further explore psychosocial mechanisms of warning compliance, and observe behavioral reactions.

5. Conclusions

Overall, the results of this study indicate that app-based warning messages regarding a severe weather event as well as the event itself differentially affect momentary anxiety (i.e., negative affect) throughout the warning process, when controlling for previous warning app use as well as experience with thunderstorms. While the study has methodological limitations, it provides support for a virtual city framework to test warning messages and subsequent appraisals, and potentially behaviors. The multi-step structure allows for a segmentation of the warning process that can be used to study psychophysiological, cognitive, and affective correlates of each step of the warning process more closely. With mobile warning apps increasing in popularity and reach, the digital stetting presented in this study can be useful to develop and test different types of warnings and conditions with presumably high internal validity, before implementing them in field studies, and testing their ecological validity. The set-up could also be used to implement warning-based trainings, for senders and receivers of warning messages. Therefore, we welcome future research to replicate and refine the virtual city framework in more diverse samples, using different measures and investigating different hazards, to improve our understanding of app-based warning processing, and strengthen preventive efforts and resiliency.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, File S1: Vignettes, File S2: Videos. The supplementary material is available online. It contains supplementary files S1 and S2 that were used as study materials.

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Appendix A

Table A1. Momentary anxiety in the overall sample, and divided by groups (warning message vs. no warning message; thunderstorm vs. no thunderstorm; video vs. vignette).

Momentary anxiety	Total sample		Group 1 No warning, no thunderstorm, video		Group 2 No warning, thunderstorm, video		Group 3 Warning, no thunderstorm, video		Group 4 Warning, thunderstorm, video		Group 5 No warning, no thunderstorm, vignette		Group 6 No warning, thunderstorm, vignette		Group 7 Warning, no thunderstorm, vignette		Group 8 Warning, thunderstorm, vignette	
	N = 276		*n* = 21		*n* = 51		*n* = 18		*n* = 56		*n* = 12		*n* = 51		*n* = 16		*n* = 51	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
t1	1.36	0.74	1.14	0.48	1.33	0.77	1.17	0.51	1.50	0.87	1.25	0.62	1.45	0.83	1.38	0.72	1.31	0.65
t2	1.57	0.87	1.05	0.22	1.22	0.61	1.78	0.88	1.78	0.92	1.58	1.00	1.35	0.74	1.94	0.85	1.96	1.02
t3	2.08	1.15	1.24	0.70	1.76	1.09	1.50	0.71	2.46	1.14	1.50	0.80	2.45	1.08	1.38	0.72	2.51	1.22

Note. Points of measurement: t1 (beginning of the cover story), t2 (warning message receipt vs. no receipt), t3 (thunderstorm vs. no thunderstorm). Momentary anxiety was assessed using a 5-point Likert scale, ranging from 1 (not at all) to 5 (extremely).

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10 Appendix B. Eigenständigkeitserklärung

Hiermit erkläre ich, dass die vorliegende Arbeit von mir bisher weder an der Mathematisch-Naturwissenschaftlichen Fakultät der Universität Greifswald noch einer anderen wissenschaftlichen Einrichtung zum Zwecke der Promotion eingereicht wurde.

Ferner erkläre ich, dass ich diese Arbeit selbstständig verfasst, keine anderen als die darin angegebenen Hilfsmittel und Hilfen benutzt und keine Textabschnitte eines Dritten ohne Kennzeichnung übernommen habe.

_____ _____

Greifswald, den Maxi Rahn

11 Appendix C. Eigenanteil aller Autor*innen an den eingebundenen Publikationen

Die Auflistung der Autor*innen erfolgt in alphabetischer Reihenfolge.

Studie 1: Rahn, M., Tomczyk, S. & Schmidt, S. (2021). Storms, Fires, and Bombs: Analyzing the Impact of Warning Message and Receiver Characteristics on Risk Perception in Different Hazards. *Risk Analysis*, 41(9), 1630–1642. https://doi.org/10.1111/risa.13636

Studienkonzeption/-design	Rahn, Schmidt, Tomczyk
Erarbeitung der Fragestellung	Rahn, Tomczyk
Datenerhebung	Rahn, Tomczyk
Datenanalysen	Rahn
Interpretation der Daten	Rahn
Erstellung des Manuskriptes	Rahn
Revision des Manuskriptes	Rahn, Schmidt, Tomczyk

Studie 2: Rahn, M.*, Tomczyk, S.*, Schopp, N. & Schmidt, S. (2021). Warning Messages in Crisis Communication: Risk Appraisal and Warning Compliance in Severe Weather, Violent Acts, and the COVID-19 Pandemic. *Frontiers in Psychology*, 12. [* shared first authorship] https://doi.org/10.3389/fpsyg.2021.557178

*geteilte Erstautor*innenschaft

Studienkonzeption/-design	Rahn, Schmidt, Tomczyk
Erarbeitung der Fragestellung	Rahn, Tomczyk
Datenerhebung	Rahn, Tomczyk
Datenanalysen	Rahn, Tomczyk
Interpretation der Daten	Rahn, Tomczyk
Erstellung des Manuskriptes	Rahn
Revision des Manuskriptes	Rahn, Schmidt, Tomczyk

Studie 3: Tomczyk, S., Rahn, M. & Schmidt, S. (2020). Social Distancing and Stigma: Association Between Compliance With Behavioral Recommendations, Risk Perception, and Stigmatizing Attitudes During the COVID-19 Outbreak. *Frontiers in Psychology*, *11*, 1821. https://doi.org/10.3389/fpsyg.2020.01821

Studienkonzeption/-design	Rahn, Schmidt, Tomczyk
Erarbeitung der Fragestellung	Tomczyk
Datenerhebung	Rahn, Tomczyk
Datenanalysen	Tomczyk
Interpretation der Daten	Tomczyk
Erstellung des Manuskriptes	Tomczyk
Revision des Manuskriptes	Rahn, Schmidt, Tomczyk

Studie 4: Tomczyk, S.*, Rahn, M.*, Markwart, H. & Schmidt, S. (2021). A Walk in the Park? Examining the Impact of App-Based Weather Warnings on Affective Reactions and the Search for Information in a Virtual City. *International Journal of Environmental Research and Public Health*, *18*(16). [* shared first authorship] https://doi.org/10.3390/ijerph18168353

*geteilte Erstautor*innenschaft

Studienkonzeption/-design	Markwart, Tomczyk
Erarbeitung der Fragestellung	Rahn, Tomczyk
Datenerhebung	Markwart, Tomczyk
Datenanalysen	Rahn
Interpretation der Daten	Rahn, Tomczyk
Erstellung des Manuskriptes	Rahn, Tomczyk
Revision des Manuskriptes	Markwart, Schmidt, Tomczyk

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Greifswald, den Maxi Rahn

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Greifswald, den Prof. Dr. Silke Schmidt