Vaccination as social interaction: Experiments on intra- and inter-group processes in the vaccination decision

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Impfen als soziale Interaktion: Experimente zu intra- und intergruppalen Prozessen in der Impfentscheidung – Zusammenfassung

Einleitung

Die vorliegende Dissertation beschäftigt sich mit der Impfentscheidung und deren Konsequenzen in einer komplexen Umwelt. Die Impfentscheidung wurde im wissenschaftlichen Kontext über einen langen Zeitraum als isolierte, individuelle Entscheidung aufgefasst, bei denen Individuen Risiken der Impfung und Nicht-Impfung abwägen (Weinstein, 2000). Diese Sichtweise vernachlässigt jedoch einen wichtigen Aspekt: Viele Impfungen schützen nicht nur den Geimpften selbst, sondern tragen auch dazu bei, die Übertragung von Krankheiten zu unterbinden und folglich andere, ungeimpfte Personen mitzuschützen (Gemeinschaftsschutz bzw. Herdenimmunität, Fine, Eames, & Heymann, 2011). Damit wird die Impfentscheidung zu einer sozialen Entscheidung.

Die Berücksichtigung des Gemeinschaftsschutzes führt zudem zu der Erkenntnis, dass Impfungen das Opfer ihres eigenen Erfolges werden können (Böhm, Betsch, & Korn, 2016; Böhm, Meier, Korn, & Betsch, 2017; Korn, Holtmann, Betsch, & Böhm, 2015). Während die Risiken der Impfnebenwirkungen unabhängig von der Impfrate in der Gesellschaft sind, ergeben sich die Risiken einer impfpräventablen Erkrankung hingegen unter anderem aus der Höhe der Impfrate in der Bevölkerung. Die Wahrscheinlichkeit an einer bestimmten Infektion zu erkranken sinkt, je mehr Menschen gegen diese Krankheit geimpft sind. Das führt dazu, dass ab einer gewissen Impfrate die Risiken der Impfung die Risiken der Erkrankung überschreiten. Folglich ist es in dieser Situation aus einer egoistisch-rationalen Perspektive irrational, sich impfen zu lassen. Aus der kollektiven Perspektive hingegen bleibt die Impfung die beste Strategie. Eine Krankheit kann ab einer gewissen Impfrate eliminiert werden, was die soziale Wohlfahrt maximiert. Dieses Spannungsfeld zwischen individuellen und kollektiven Interessen definiert ein soziales Dilemma.

Globale Herausforderungen, wie die Eindämmung und Eliminierung von Infektionskrankheiten, erfordern Kooperation zwischen einzelnen Akteuren und ebenso eine globale Perspektive, denn Infektionskrankheiten kennen keine Ländergrenzen. Zudem befindet sich die Weltgemeinschaft permanent im Umbruch. Die wachsende Vernetzung zwischen Gesellschaften und vermehrte Migrationsbewegungen führen zu fundamentalen demographischen Transformationen und einst homogene Gesellschaften werden stetig heterogener (Danchev & Porter, 2018; Putnam, 2007). Das bedeutet, dass unterschiedliche Gruppen, wie beispielsweise eine Mehrheitsgesellschaft und Gruppen von Migranten, miteinander kooperieren müssen, um gesellschaftliche Ziele zu erreichen.

Daher stehen in der vorliegenden Dissertation die Fragen im Fokus, wie die Impfbereitschaft in einer komplexen Umwelt gefördert werden kann, wie Menschen den Impfstatus von anderen Personen, die einer Außengruppe angehören, in ihre eigene Impfentscheidung einfließen lassen und wie Personen auf den Impfstatus anderer Personen reagieren.

Maßgebend für meine Dissertation ist das I-Vax game (Böhm et al., 2016). Dabei handelt es sich um eine Untersuchungsmethode, die auf Grundlage ökonomischer und epidemiologischer Überlegungen sowohl die direkten als auch indirekten Effekte von Impfungen monetär modelliert. Damit ermöglicht das I-Vax game Impfentscheidungen in einem anreizbasierten Setting zu untersuchen. Das bedeutet, dass eine Impfentscheidung im I-Vax game geldwerte Konsequenzen für den Entscheider hat und damit eher in der Lage ist, tatsächliche Präferenzen hinsichtlich des Impfens zu messen als eine bloße Erhebung von Impfabsichten (Böhm et al., 2016).

Nachfolgend werden die drei Artikel präsentiert, die die Dissertation bilden. Der erste Artikel befasst sich mit der Effektivität von Interventionen zur Erhöhung von Impfraten. Der zweite Artikel untersucht den Einfluss von Gesundheitsinformationen über eine migrierende

Außengruppe auf die Impfbereitschaft in der Gastgeberpopulation. Der dritte Artikel schließlich untersucht, inwiefern sich die Prosozialität eines Individuums in Abhängigkeit von Informationen zum Impfstatus und der Gruppenzugehörigkeit einer anderen Person verändern kann. Diese Änderungen in der Prosozialität geben Aufschluss, ob Individuen Impfen als sozialen Kontrakt verstehen, den jedes Mitglied einer Gesellschaft folgen sollte.

Artikel 1: Der Einfluss von intra- und intergruppalen Feedbackinterventionen auf die Impfentscheidung; veröffentlicht in *Health Psychology*

Der erste Artikel bezieht sich auf die übergeordnete Forschungsfrage, wie im Bereich Impfen die Kooperation, also Entscheidungen für das Impfen, gefördert werden kann.

Dabei fokussierte sich das Papier auf zwei Strategien. Zum einen wurde auf Grundlage der Goal-Setting Theorie (Locke & Latham, 2002) angenommen, dass Ziele, und insbesondere Gruppenziele (Epton, Currie, & Armitage, 2017), Aufmerksamkeit lenken, Persistenz schaffen und damit die Transformation von Motivation in Volition erleichtern. Zudem kann die Erreichung von Gruppenzielen non-monetär belohnt werden, das zu einer höheren Wahrscheinlichkeit führt, dass Individuen das belohnte Verhalten wiederholt zeigen (law of effect; Thorndike, 1911). Zum anderen weist die Intergruppenvergleichs-Intragruppenkooperations-Hypothese von Böhm & Rockenbach (2013) darauf hin, dass Vergleiche mit einer strukturell unabhängigen Außengruppe die Impfbereitschaft innerhalb der eigenen Gruppe erhöhen. Hintergrund ist, dass die bloße Existenz einer Außengruppe einen komparativen Fokus aktiviert, der die Kooperation innerhalb einer Gruppe anstößt.

In zwölf Sessions nahmen 288 Teilnehmer am Experiment teil. Die Probanden spielten das I-Vax game in jeweils zwei Gruppen bestehend aus zwölf Personen über 20 Runden. Am Ende jeder Runde erhielten die Teilnehmer in Abhängigkeit der experimentellen Bedingung zusätzliche Informationen. In der Bedingung „non-monetäre Belohnung der Gruppenzielerreichung“ erhielten die Spieler Badges als zusätzliche symbolische Belohnung für die Eliminierung der Krankheit. Als Badges wurden farbige Sterne verwendet. Die Farbe des

Sterns hing von der Gruppenzugehörigkeit des Spielers ab – Mitglieder der gelben Gruppe erhielten gelbe Sterne, Mitglieder der blauen Gruppe blaue Sterne. Wenn die Gruppe die Krankheit in einer Runde nicht ausgelöscht hat, erhielten sie einen grauen Stern. Die andere Hälfte der Teilnehmer (keine Belohnung) erhielten nur schriftliche Informationen zum Eliminationsstatus der Krankheit.

Die Teilnehmer der Intergruppenvergleichsbedingung erhielten zusätzliche Informationen über das Impfverhalten der anderen Gruppe, während die anderen Personen diese Informationen nicht erhielten. Je nach Bedingung wurde die Information zur Gruppenzielerreichung als einfacher Text (keine Belohnung) oder zusätzlich über Stern-Badges für die andere Gruppe dargestellt (non-monetäre Belohnung der Gruppenzielerreichung).

Die Analysen zeigten den erwarteten positiven Effekt von non-monetären Belohnungen der Gruppenzielerreichung auf die Impfentscheidung. Dieser Effekt war zu Beginn des Experimentes besonders stark und schwächte im Laufe wiederholter Entscheidungen ab. Der Effekt von Intergruppenvergleichen genügte nicht den üblichen Kriterien statistischer Signifikanz. Außerdem zeigte sich, dass sowohl die soziale Wertorientierung als auch die Impfeinstellung Vorhersagekraft in Bezug auf die Impfentscheidung im I-Vax game besitzen.

Das berichtete Experiment zielte darauf ab, die Effektivität von intra- und intergruppenprozess-basierenden Nudging-Interventionen zu testen. Es konnte zeigen, dass die symbolische Belohnung der Gruppenzielerreichung die Impfbereitschaft erhöht. Allerdings sollte zum einen auf eine extensive Nutzung der Intervention verzichtet werden, da die Daten darauf hindeuten, dass die Effektivität über die Zeit abnimmt. Zum anderen sollte zukünftige Forschung untersuchen, ob eine alternative, intermittierende Variante der Gruppenzielbelohnung eine Möglichkeit darstellt, Impfverhalten ohne „Abnutzungseffekt“ positiv zu beeinflussen.

Die auf Intergruppenvergleiche basierende Intervention zeigte keinen positiven Effekt auf die Impfbereitschaft im I-Vax game. Eine mögliche Erklärung ist, dass die mit dem Minimalgruppenparadigma erzeugte Gruppenidentität nicht stark genug ausgeprägt war.

Zukünftige Forschung sollte die soziale Identität (minimale Gruppe vs. natürliche Gruppe, siehe Chowdhury, Jeon, & Ramalingam, 2016) als Moderator innerhalb der Intergruppenvergleichsintervention im Kontext von Impfentscheidung untersuchen.

Die Effekte der sozialen Wertorientierung und der Impfeinstellung auf die Impfentscheidung im I-Vax game weisen darauf hin, dass es sich um eine valide Untersuchungsmethode von Impfentscheidungen handelt.

Zusammenfassend konnte das Experiment zeigen, dass es möglich ist, Menschen in einer komplexen Umwelt zum Impfen zu bewegen. Insbesondere geht aus dem Experiment hervor, dass man Mitglieder einer Gruppe (bspw. eines Landes) zum Impfen bewegen kann, indem man innerhalb eines definierten Zeitraumes, wie beispielsweise eines Jahres, Rückmeldung zum Eliminierungsstatus gibt und diesen non-monetär belohnt. Das bedeutet, dass die Kommunikation und Belohnung von „kleinen Gewinnen“ die Bereitschaft des Einzelnen erhöhen kann, im Interesse der Gruppe zu handeln. Weiterhin zeigte das Experiment, dass Informationen über die Impfrate einer Außengruppe, die unabhängig von der eigenen Gruppe war, nicht zu einer Veränderung des Impfverhaltens führte. Allerdings verdienen Intergruppenprozesse weitere Aufmerksamkeit als psychologische Grundlage für mögliche Strategien zur Kommunikation von Impfungen. So befinden sich Gruppen, im Gegensatz zu diesem Experiment, oftmals in Wechselbeziehungen. Sie bilden gemeinsam Populationen eines Landes oder es bestehen Wanderungsbeziehungen zwischen Gruppen. Die Perspektive der Wechselbeziehung zwischen Gruppen wird in den folgenden beiden Artikeln näher beleuchtet.

Artikel 2: Die Kommunikation von Impfquoten über Flüchtlinge und dessen detrimentaler Effekt auf die Impfbereitschaft in der Gastgeberpopulation; veröffentlicht in *Lancet Infectious Diseases*

Der vorliegende Artikel geht der Forschungsfrage nach, inwiefern Informationen über den Gesundheitszustand von Mitgliedern einer migrierenden Außengruppe in die Impfentscheidung unter Mitgliedern der Mehrheitsgesellschaft einfließt. Hintergrund ist, dass beispielsweise Flüchtlinge und Migranten gesundheitsbezogenen Vorurteilen ausgesetzt sind (Khan et al., 2016). Dieser Bevölkerungsgruppe wird – oft fälschlicherweise – ein schlechter Gesundheitszustand vorgeworfen. Daher wurde von Khan und Kollegen (2016) argumentiert, dass eine Aufklärung der Gastgeberpopulation über den guten Gesundheitszustand von Migranten und Flüchtlingen notwendig ist, um Vorurteile abzubauen. Allerdings kann diese Vorurteilskorrektur aus gesundheitspsychologischer Sicht negative Folgen haben. Dies liegt in den indirekten Effekten von Impfungen begründet (Fine et al., 2011). Jede Erhöhung der Impfrate, wie beispielsweise durch den Zustrom durchgeimpfter Individuen, kann, wie eingangs ausgeführt, dazu führen, dass der Nutzen der Impfung sinkt und Nicht-Impfen attraktiver wird. Folglich kann die Kommunikation des guten Gesundheitszustandes von Migranten und Flüchtlingen nachteilige Auswirkungen auf das Impfverhalten in der Population der Gastgeberbevölkerung haben.

In 4 Sessions nahmen 96 Teilnehmer am Experiment teil. Der Versuchsaufbau variierte in einem 3 (historische Impfrate der Gastgeberpopulation: 0 vs. 3 vs. 4, quasi-experimentell, between) × 6 (historische Impfrate der Flüchtlingspopulation: 0 vs. 5 vs. 10 vs. 15 vs. 20 vs. keine Informationen, within) quasi-experimentellem, mixed Design. Die Probanden spielten das I-Vax game in jeweils zwei Gruppen bestehend aus 12 Personen über 20 Runden. Am Ende jeder Runde erhielten die Teilnehmer Informationen über den Eliminierungsstatus der Krankheit in ihrer eigenen (dieser diente aggregiert als quasi-experimenteller Faktor) und in der anderen Gruppe. Nachdem die Teilnehmer das I-Vax game gespielt hatten, wurden sie mit fiktiven Szenarien konfrontiert. Ihnen wurde mitgeteilt sich vorzustellen, dass eine migrierende Gruppe zur eigenen Gruppe hinzustößt, die in Abhängigkeit der Bedingung einen definierten Gesundheitsstatus besitzt. In einer Bedingung wurde keine Information über den Gesundheitsstatus der migrierenden Gruppe bereitgestellt.

Wie angenommen sank die Impfbereitschaft in der Gastgeberpopulation mit zunehmender Impfrate innerhalb der Flüchtlingspopulation. Dieser Effekt war zudem bei den Gastgeberpopulationen mit einer historisch höheren Impfbereitschaft stärker ausgeprägt. Es kann angenommen werden, dass sich dieser Effekt mit höherem Flüchtlingszustrom verstärkt (Khan et al., 2016), da sich mit zunehmender Migration die Gruppengröße der migrierenden Gruppe erhöht und sich das Größenverhältnis zwischen Gastgeberpopulation und migrierender Gruppe zu Gunsten letzterer verändert.

Damit zeigt sich, dass Informationen, die zum Abbau von Vorurteilen genutzt werden sollen, einen negativen Einfluss auf Gesundheitsentscheidungen haben können. Darauf folgt, dass von Khan et al. (2016) vorgeschlagene Strategie zur Vorurteilsreduktion aus gesundheitspsychologscher Sicht detrimentale Folgen auf die Impfbereitschaft der Mehrheitsgesellschaft haben kann. Zudem zeigt frühere Forschung, dass simple Informationspräsentation (für einen Überblick siehe Stangor, 2016) nicht zwangsläufig zu Vorurteilsreduktion führt.

Im Bezug zur übergeordneten Forschungsfrage der Dissertation, wie Informationen über den Impfstatus von anderen Personen wahrgenommen werden, zeigte das Experiment, dass Information über die Impfrate einer Außengruppe in die eigene Entscheidung einfließt, wenn Innen- und Außengruppe in einer Wechselbeziehung stehen.

Staatliche Institutionen und die Gesellschaft als Ganzes müssen zweifellos Vorurteile und Diskriminierungen von Flüchtlingen bekämpfen. Zukünftige sozial- und gesundheitspsychologische Forschung sollte sich mit innovativen Strategien auseinandersetzen, die beide Ziele gleichzeitig verfolgen: die Bekämpfung von Diskriminierung und Infektionskrankheiten.

Artikel 3: Der Einfluss kontextueller Informationen auf Änderungen in der Prosozialität; eingereicht bei *Proceedings of the National Academy of Sciences of the United States of America*

Der dritte Artikel der Dissertation beschäftigt sich mit der sozialen Präferenz (unter anderem auch soziale Wertorientierung oder Prosozialität genannt McClintock, 1972; Murphy, Ackermann, & Handgraaf, 2011; Van Lange, Joireman, Parks, & Van Dijk, 2013) im Kontext von Impfentscheidungen. Die Prosozialität gibt an, wie Personen die Konsequenzen von Entscheidungen für sich und andere gewichten, wobei diese Gewichtung dann in nachfolgende, interdependente Entscheidungen selbst einfließt (Fehr, Fischbacher, & Gächter, 2002). Der vorliegende Artikel geht der Frage nach, wie Personen auf Impfentscheidungen anderer Personen, die einer Innengruppe oder Außengruppe angehören, reagieren und ihre Prosozialität anpassen.

Hintergrund ist die Diskussion um und den Kabinettsbeschluss von einer zielgruppenspezifischen, partiellen Impfpflicht gegen Masern in Deutschland (Bundesministerium für Gesundheit, 2019). Laut Beschluss müssen spezifische Personengruppen, unter anderem Migranten und Asylbewerber, den Nachweis erbringen, gegen Masern geimpft zu sein und gegebenenfalls diese Impfung nachholen. Der Deutsche Ethikrat (Deutscher Ethikrat, 2019) hat sich zu dieser Maßnahme positioniert und schlägt anstelle einer Impfpflicht vor, Impfen gesellschaftlich als sozialen Kontrakt zu konzipieren. Diesen Vertrag kann man als moralische Verpflichtung verstehen, dem jeder Bürger nachkommen sollte. Zwar stehen moralische Werte und Impfakzeptanz in Zusammenhang (Amin et al., 2017; Betsch & Böhm, 2018), jedoch ist unklar, wie Individuen reagieren, wenn andere diesen sozialen Kontrakt verletzen.

Die Morality-as-Cooperation Theorie (Curry, 2016) postuliert, dass Moralität eine Sammlung von Verhaltensweisen darstellt, um Kooperationsprobleme im menschlichen Zusammenleben zu lösen. So spielt nach dieser Theorie Reziprozität (“Wie du mir, so ich dir”, Fehr et al., 2002; Fischbacher & Gächter, 2010) im Kontext von Verteilungsproblemen, wie sozialen Dilemmata, eine wichtige Rolle. Kooperation wird als moralisch gut betrachtet und geachtet. Trittbrettfahren hingegen wird als moralisch schlecht aufgefasst und verachtet. Im Impfkontext bedeutet dies, dass Personen, die sich impfen lassen (und damit den sozialen Kontrakt einhalten), positiv auf andere reagieren, die ebenfalls geimpft sind. Im Gegensatz dazu sollten sie sich gegenüber anderen, die nicht geimpft sind (und damit den sozialen Kontrakt verletzen), negativ verhalten. Zu beachten ist, dass Personen, die nicht selbst geimpft sind, keine (oder in geringerem Maße) reziprokes Verhalten an den Tag legen sollten.

Wie eingangs erwähnt, sind durch die fortschreitende Heterogenisierung von Gesellschaften (Danchev & Porter, 2018; Putnam, 2007) Personen verschiedenster Gruppenzugehörigkeiten, wie der Mehrheitsgesellschaft und Migranten, mit der Herausforderung konfrontiert, Infektionskrankheiten gemeinsam einzudämmen und auszulöschen. Damit stellt sich im Zusammenhang des Impfens als sozialen Kontrakt die Frage, ob dieser über Gruppengrenzen hinweg gültig ist.

Wenn Impfen ein sozialer Vertrag darstellt, sollte dieser für alle Personen gelten, unabhängig von ihrer Gruppenzugehörigkeit, da moralische Normen als universelle Prinzipien menschlicher Interaktion betrachtet werden (Curry, 2016; Graham et al., 2013). Jedoch zeigen Untersuchungen, dass Personen Innengruppenmitglieder positiver behandeln als Außengruppenmitglieder (Balliet, Wu, & De Dreu, 2014; Tajfel & Turner, 1986; Yamagishi & Kiyonari, 2000). Folglich wurde ebenso getestet, ob Individuen stärkere negative Reziprozität und weniger positive Reziprozität gegenüber Außengruppenmitgliedern zeigen als gegenüber Innengruppenmitgliedern (Yamagishi & Kiyonari, 2000).

Dieses reziproke Verhalten wurde in dem vorliegenden Artikel als Veränderung der Prosozialität (auch soziale Wertorientierung genannt, Murphy et al., 2011) konzeptualisiert. Negative Änderungen der Prosozialität deuten auf negative Reziprozität hin, positive Veränderungen hingegen auf positive Reziprozität. Auf Basis dieses reziproken Verhaltens ist es möglich festzustellen, ob Individuen Impfen als sozialen Vertrag wahrnehmen. Als zusätzliche Variable wurde in zwei der drei Experimenten wahrgenommene Wärme gegenüber anderen als zusätzliche abhängige Variable erhoben und analysiert. Wahrgenommene Wärme wird als moralische Bewertung von anderen aufgefasst (Ellemers, van der Toorn, Paunov, & van Leeuwen, 2019) und steht in Zusammenhang mit prosozialem Verhalten und Hilfeverhalten (Cuddy, Fiske, & Glick, 2008; Pletzer et al., 2018).

Um die Forschungsfragen zu beantworten, wurden drei präregistrierte, quasiexperimentelle, incentivierte Onlinestudien mit $N = 1032$ Teilnehmern durchgeführt. Die Teilnehmer gaben zunächst ihre allgemeine soziale Präferenz an und spielten einmalig das I-Vax game. Danach gaben die Probanden ihre subgruppen-spezifische soziale Präferenz an. Das heißt, der Versuchsaufbau variierte in einem 2 (Impfentscheidung des Teilnehmers: nicht geimpft vs. geimpft; quasi-experimentell between-subjects) × 2 (Impfentscheidung des Anderen: nicht geimpft vs. geimpft; within-subjects) × 2 (Gruppenmitgliedschaft des Anderen: Innengruppe vs. Außengruppe; within-subjects) design.

Über alle drei Experimente konnte die Reziprozitätshypothese bestätigt werden: Insbesondere Geimpfte reduzieren ihre Prosozialität gegenüber ungeimpften Anderen. Ungeimpfte Personen reduzieren ihre Prosozialität gegenüber ungeimpften Personen im Vergleich zu geimpften Personen ebenfalls, jedoch in einem geringeren Ausmaß als geimpfte Versuchsteilnehmer. Das bedeutet, dass Impfen als sozialer Kontrakt gilt, sowohl unter nicht-geimpften als auch unter geimpften Personen. Weiterhin konnte der Intergruppenbias nachgewiesen werden – Teilnehmer zeigen mehr Prosozialität gegenüber Innengruppenmitgliedern im Vergleich zu Außengruppenmitgliedern. Allerdings konnte festgestellt werden, dass der Reziprozitätseffekt unter geimpften Teilnehmern und der Innengruppenbias zwei unabhängige Effekte sind. Der soziale Vertrag gilt somit auch für Außengruppenmitglieder: Auch wenn sie nicht zur Innengruppe gehören, werden sie als Teil des sozialen Systems wahrgenommen, in dem Impfen als moralische Pflicht gilt. Diese Ergebnisse konnten ebenfalls im Bezug zur wahrgenommen Wärme gegenüber anderen repliziert werden.

Damit stützen die Ergebnisse den Ethikrat und das Konzept des Impfens als sozialer Kontrakt könnte hierbei eine vielversprechende Erweiterung der Kommunikation des sozialen Nutzens von Impfungen sein um Impfraten nachhaltig zu erhöhen (Betsch, Böhm, Korn, & Holtmann, 2017). So wäre es denkbar zu mitzuteilen, dass jedes Individuum, das in der Lage ist, sich impfen zu lassen, dies voraussichtlich tun wird. Dieser Appell könnte auf moralischen Gründen beruhen (Fairness oder Fürsorge). Ebenso wäre eine Kommunikation des sozialen Kontraktes mittels deskriptiver Normen möglich (Brewer, Chapman, Rothman, Leask, & Kempe, 2017). Die Impfraten in der Gesellschaft sind hoch und signalisieren damit starke gesellschaftliche Akzeptanz des sozialen Vertrages. Jedoch sollte hierbei das Phänomen des Trittbrettfahrens berücksichtigt werden (Böhm et al., 2016).

Die Ergebnisse der drei Experimente zeigen jedoch auch auf, dass der soziale Kontrakt gefährdet ist. Sozialverträge werden akzeptiert, wenn andere diesen ebenfalls akzeptieren (Rachels & Rachels, 2015). In Medien werden gern Narrative kommuniziert, die darauf hindeuten, dass es mehr und mehr Menschen gibt, die sich nicht impfen lassen wollen (McBain, 2019). Eine solche Berichterstattung kann, basierend auf den Ergebnissen der Experimente, demnach negative Konsequenzen auf die Prosozialität und wahrgenommene Wärme haben, was wiederum Impfverhalten negativ beeinflussen könnte. Dies bedeutet, dass eine übermäßige Kommunikation der Existenz von nicht geimpften Personen die Impfbereitschaft reduziert, da der Sozialvertrag das Vertrauen in die Vertragserfüllung anderer voraussetzt.

Weiterhin geht aus den Ergebnissen hervor, dass zwei moralische Domänen, Reziprozität und Gruppenloyalität, unabhängig voneinander wirksam sind, wenn die andere Person ein Außengruppenmitglied ist. Unter der Annahme, dass die Zugehörigkeit zu einer Minderheit und Gesundheitsentscheidungen nicht unabhängig voneinander sind (Ledoux, Pilot, Diaz, & Krafft, 2018), können unfreiwillige Gesundheitsentscheidungen (wie beispielsweise unzureichende Immunisierung) zu weiterer Marginalisierung von bereits marginalisierten Gruppen führen. Deshalb ist es von äußerster Wichtigkeit, Parität im Gesundheitssystem zu schaffen, um a) die Gesundheit von Minoritäten zu verbessern b) Minoritäten die Möglichkeit zu geben den sozialen Kontrakt zu erfüllen und c) damit Diskriminierung vorzubeugen.

Konklusion

Die Konzeption des Impfens als soziale Interaktion trägt dazu bei, intra- und intergruppale Dynamiken des Impfens aufzudecken. Es zeigte sich, dass es möglich ist, die Impfbereitschaft in einer komplexen Umwelt zu fördern. Insbesondere können soziale Ziele die Impfbereitschaft in einer homogenen Population verbessern. So setzt die Weltgesundheitsorganisation die Ergebnisse des ersten Artikels bereits um, indem sie die Zertifizierung der Elimination von Krankheiten nach Ländern durchführt und nicht über ganze Regionen hinweg. Zukünftige Forschung sollte die Effektivität dieser Intervention allerdings auch im Kontext von Diversität untersuchen. Denn es wurde auch deutlich, dass es darauf ankommt, ob und inwiefern Gruppen in einer Wechselbeziehung zueinanderstehen.

Während Informationen über die Impfbereitschaft einer strukturell unabhängigen Außengruppe die Impfbereitschaft in der Innengruppe nicht beeinflusst, ändert sich diese Beobachtung, wenn Gruppen in einer Wechselbeziehung stehen. Individuen tendieren zum Trittbrettfahren, wenn sie Informationen über den guten Gesundheitsstatus einer migrierenden Außengruppe erhalten. Schließlich legt die Ergebnisse der Dissertation dar, dass Impfen ein universeller sozialer Vertrag ist: Insbesondere geimpfte Individuen, die sich mit einer höheren Wahrscheinlichkeit in Zukunft impfen lassen als ungeimpfte Personen, reduzieren ihre Prosozialität gegenüber Nicht-Impfern. Dabei spielen Gruppenzugehörigkeiten keine Rolle – jedes Individuum des sozialen Systems, sei es nun ein Innen- oder Außengruppenmitglied, ist dazu moralisch verpflichtet, sich impfen zu lassen.

Die Ergebnisse des dritten Artikels deuten also darauf hin, dass man Impfen als sozialen Kontrakt der Gesellschaft breit kommunizieren sollte. Diese Kommunikationsstrategie könnte dazu beitragen, dass Impfen als moralische Pflicht wahrgenommen wird und damit die Impfraten erhöht werden können. Zukünftige Forschung sollte sich daher mit der Konzeption einer dezidierten moralischen Intervention widmen und diese sowohl im Labor als auch im Feld testen.

Es ist anzumerken, dass zwar incentivierte Experimente für die Beantwortung der Forschungsfragen verwendet wurden, die Entscheidungen innerhalb der Experimente jedoch nur Annäherungen an echte Impfentscheidungen sind. Zukünftige Forschung sollte daher die Ergebnisse der Dissertation im Feld replizieren.

Impfen ist ein komplexes Themenfeld und die Impfentscheidung beinhaltet sowohl eine individuelle als auch eine soziale Komponente. Letztere kann beispielsweise durch die Kommunikation und Belohnung von Gruppenzielen aktiviert werden und für Interventionen zur Erhöhung von Impfbereitschaft genutzt werden. Allerdings zeigt die Dissertation auch, dass die Nutzung der sozialen Komponente auch Fallstricke beinhaltet, weshalb mögliche Backfire-Effekte weiter erforscht und bei der Kommunikation berücksichtigt werden sollten.

Schließlich veranschaulicht die Dissertation, dass Personen Impfen als einen universellen sozialen Vertrag wahrnehmen. Diese Erkenntnis sollte in zukünftige Forschungen einfließen, die Strategien zur Kommunikation von Impfungen entwickeln, testen und umsetzen. Damit könnte ein Beitrag geleistet werden, um Infektionskrankheiten zurückzudrängen und letztlich auszulöschen.

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Contents

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Preface

Since the end of my master's degree, I have been concerned with the psychological aspects of vaccination decisions. This complex topic is of great interest to governmental and non-governmental institutions. The Psychology and Infectious Diseases Lab (PIDI Lab), the research group around Prof. Dr. Cornelia Betsch, therefore, pursues a multi-perspective approach, of which I was part.

My dissertation was written in the interdisciplinary, DFG-funded research project, "Ein interdisziplinärer Ansatz zur Erklärung und Überwindung von Impfmüdigkeit" (grant no.: BE 3970/8-1). In this context, my work is situated at the intersection of economics and psychology, and my research group and I have used both behavioral and psychological insights to better understand and change vaccination behavior. Thus, the research included in this dissertation ranges from intervention studies to social-psychological experiments on the variability of prosociality in the context of vaccination decisions. All experiments were financed through the DFG. The third article was also co-financed by ProUni — the research and graduate services of the University of Erfurt.

Apart from my work in the DFG-funded research project, I was also involved in other research projects concerning vaccination behavior (see full list of publications). For example, I co-authored a guideline for the WHO Europe on how to deal with vaccine side effects in a communication context.

This dissertation is divided into different chapters (see contents). Importantly, please note that the numbering of the tables and figures in each chapter begins anew. Moreover, vaccine decision-making is an interdisciplinary field of research and the articles and supplements included in this dissertation are attached as they are. This means that the layout of the articles and supplements vary depending on the respective journal and do not necessarily match APA style.

Overview

In the following section, the three publications included my dissertations are listed first. Subsequently, a complete list of my contributions to the field of research on vaccine decision-making is presented. After this, I give a brief overview of the implemented research methods, questions, and designs and briefly present the results of the experiments. Next, the author contributions are given for all included papers of the dissertation. I conclude with my position on open science and its importance in my dissertation.

Publications included in my dissertation

Table 1 shows the articles included in my dissertation. The table contains the title of the publication and its order of appearance in the dissertation. The impact factors of the individual journals in which the articles are published are also listed in order to highlight the value of the research. Since the third article is "submitted" at the time of submission of the dissertation, the impact factor of the journal *Proceedings of the National Academy of Sciences of the United States of America* is set in parentheses.

Article / Position in the dissertation	References and overview of contributions	Impact factor of the journal
1	Korn, L., Betsch, C., Böhm, R., & Meier, N. W. (2018). Social Nudging: The Effect of Social Feedback Interventions on Vaccine Uptake. *Health Psychology*, *37*(11), 1045–1054.	3.530
2	Korn, L., Betsch, C., Böhm, R., & Meier, N. W. (2017). Drawbacks of communicating refugee vaccination rates. *The Lancet Infectious Diseases*, *17*(4), 364–365.	27.516
3	Korn, L., Böhm, R., Meier, N. W., & Betsch, C. (submitted). Vaccination as a social contract. *Submitted: Proceedings of the National Academy of Sciences of the United States of America*	(9.580)

Table 1. Articles included in the dissertation, distributions of author contributions, and the journal's impact. *Note*. Impact factors refers to the journal's impact in 2018. Information on journals' impact factor was retrieved from Clarivate Analytics (2019). Note that Article 3 is in submission status. An extended version of Article 2 was included into the dissertation as well.

Additional publications in peer-reviewed journals, book chapters, and guidelines

The following list shows my contributions to the field of research of vaccination decision-making.

Peer-reviewed journal articles:

Meier, N., Böhm, R., **Korn, L.**, & Betsch, C. (2019). Individual Preferences for Voluntary vs. Mandatory Vaccination Policies: An Experimental Analysis. *European Journal of Public Health*, ckz181

Böhm, R., Meier, N., Groß, M, **Korn, L.**, & Betsch, C. (2019). The willingness to vaccinate increases when vaccination protects others who have low responsibility for not being vaccinated. *Journal of Behavioral Medicine*, *42*(3), 381–391.

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Book chapters:

Betsch, C., Schmid, P., Holtmann, C., Heinemeier, D., & **Korn, L.** (2018). Erklärung und Veränderung von Präventionsverhalten. In: Kohlmann, C.-W., Salewski, C., Wirtz, M. A. (Hrsg.) (2018). *Psychologie in der Gesundheitsförderung*. Bern: Hogrefe.

Guidelines:

World Health Organization, Regional Office for Europe (2017). *Vaccination and Trust - How Concerns Arise and the Role of Communication in Mitigating Crises*. Authored by Cornelia Betsch, Constanze Rossmann, Katrine Bach-Habersaat, Philipp Schmid, Cindy Holtmann, **Lars Korn**, Jascha Wiehn, & Linda Mummer.

Scope

The following section gives a brief overview of the applied research methods. I focus especially on the relationship between the research questions of the articles and the resulting research methods. Afterwards, short research highlights are presented, which impart the gist of the individual articles. Finally, I present a) how much I contributed to the individual articles in relation to my research group and b) how my research group and I relate to open sciences practices.

Research methods, research questions, and experimental designs. This dissertation is concerned with the vaccination decision in a complex social and interconnected environment. More specifically, the dissertation considers vaccination as a social dilemma and focuses on a) promoting vaccination behavior in a complex environment, b) the incorporation of others' vaccination decisions (e.g., health status of migrants) in one's own decision to vaccinate, and c) whether vaccination is a social contract, conceptualized as the reaction to others' vaccination behavior, wherein others are either (non-)vaccinated members of an in-group or an out-group. The research presented in this dissertation used different approaches and methods to answer the research questions (see Table 2). The research in Article 1 focused on the effectiveness of feedback interventions at the intra- and inter-group level to increase vaccine uptake. In contrast to the Article 1 research, in which the groups were structurally independent, the second article research examined whether health information about a migrating outgroup with simultaneous structural interdependence between the two groups was incorporated into the vaccination decision of the participants. Finally, the third article examines the boundary conditions of prosociality in the three studies in order to answer the research question of whether and to what extent vaccination is a social contract. Since the first two articles address feedback information and historical vaccination rates, the experiments required a laboratory setting. The third article research, on the other hand, used the Amazon Mechanical Turk online service to recruit respondents. The decision for online studies in Article 3 was based on two central considerations. First, the data quality of online studies using samples from Mechanical Turk is considered high (Bartneck, Duenser, Moltchanova, & Zawieska, 2015; Kees, Berry, Burton, & Sheehan, 2017; Ramsey, Thompson, McKenzie, & Rosenbaum, 2016). Second, in Germany, individuals with higher education and students have a generally positive attitude toward migrants and refugees (Helbling et al., 2017). This contrasts with Western countries, such as Germany and the U.S., in which the overall attitude toward migrants is rather negative (Poutvaara & Steinhardt, 2018; Verkuyten, Mepham, & Kros, 2018). Since Article 3 focuses on migration and refugees, online recruitment was preferred in order to map a more general picture regarding the attitudes toward migrants.

Article	Study	Data collection method	Experimental design	N
1	1	Lab	2 (rewarding goal attainment: absent vs. present) × 2 (inter-group comparison: absent vs. present) between-subjects design.	288
2	2	Lab	3 (host population's previous vaccine uptake: 0 vs. 3 vs. 4, between) × 6 (refugee population's vaccine uptake: 0 vs. 5 vs. 10 vs. 15 vs. 20 vs. no information, within) quasi-experimental mixed design.	96
3	3	Online	2 (participant's vaccination decision: non-vaccination vs. vaccination, between) × 2 (other's vaccination decision: non-vaccination vs. vaccination, within) × 2 (other's group membership: in-group vs. out-group, within) × 2 (interdependence of out-group members: absent vs. present, between) nested quasi-experimental mixed design.	216
	4	Online	2 (participant's vaccination decision: non-vaccination vs. vaccination, between) × 2 (other's vaccination decision: non-vaccination vs. vaccination, within) × 2 (other's group membership: in-group [A - host population] vs. out-group [B - migrating group], within) quasi-experimental mixed design.	372
	5	Online	2 (participant's vaccination decision: non-vaccination vs. vaccination, between) × 2 (other's vaccination decision: non-vaccination vs. vaccination, within) × 2 (other's group membership: in-group [host population] vs. out-group [migrating group], within) quasi-experimental mixed design.	444
Total				1416

Table 2. Presentation of data collection method, experimental design and sample sizes by article and study. *Note*. Article 1: Korn, L., Betsch, C., Böhm, R., & Meier, N. W. (2018). Social Nudging: The Effect of Social Feedback Interventions on Vaccine Uptake. *Health Psychology*, *37*(11), 1045–1054; Article 2: Korn, L., Betsch, C., Böhm, R., & Meier, N. W. (2017). Drawbacks of Communicating Refugee Vaccination Rates. *The Lancet Infectious Diseases*, *17*(4), 364–365; Article 3: Korn, L., Böhm, R., Meier, N. W., & Betsch, C. (submitted). Vaccination as a social contract. *Proceedings of the National Academy of Sciences of the United States of America*.

Research highlights. A short overview of the research questions and findings of the individual articles of my dissertation are presented below.

Article 1: This study was concerned with the effectiveness of social nudging interventions aimed at intra- and inter-group processes to increase vaccination uptake in homogeneous populations. The results were:

- Rewarding goal attainment (social goal of eliminating infectious diseases) increased vaccine uptake, making it a possible candidate for further field research.
- Inter-group comparisons did not increase vaccine uptake, but note that groups were structurally independent.
- Vaccination attitudes as well as social value orientation play a significant role in vaccine decision-making, indicating external validity of the experimental paradigm.

Article 2: This study examined whether individuals incorporate others' vaccination decisions (e.g., health status of migrants) in their own decision to vaccinate. The results were:

- When groups are structurally interdependent, individuals take information on a migrating minority into account when making a vaccination decision, i.e., they reduce their probability of vaccination the higher the vaccine uptake among the migrating minority.
- When information about the migrating minority is not available, individuals make vaccination decisions as if the vaccine uptake among the migrating minority is low.

- Communicating the good-to-excellent health status of migrants should be done cautiously, as it may have detrimental effects on the vaccine uptake among the host population.

Article 3: This study examined whether and how individuals react to others' vaccination behavior, wherein others are either (non-vaccinated) members of an in-group or an out-group. These behavioral reactions eventually serve to assess whether vaccination is a social contract and thus a moral obligation. The results were:

- Vaccinated participants, especially, react sensitively toward others' vaccination decisions — mainly showing negative reciprocity.
- Vaccinated participants show less prosociality toward non-vaccinated others compared to vaccinated others.
- Non-vaccinated participants differentiate less between vaccinated and non-vaccinated others.
- Individuals show less prosociality toward out-group members compared to in-group members.
- Reciprocity and the intergroup bias are two independent effects, indicating that vaccination as a social contract applies to all individuals — independent of group membership.
- Emphasizing that vaccination is a social contract seems to be a promising extension of communicating the social benefit of vaccination.

Author's contributions. For all included papers, the following applies:

- All authors conceived and designed the experiments.
- All authors approved the final draft.
- I performed the experiments and the analyses of the data.
- I wrote the manuscripts.

Note that two of the three articles were published in highly ranked, peer-reviewed academic journals. The third paper is currently under review. Also, the article "Drawbacks of communicating refugee vaccination rates" was first published as a comment in the journal *The Lancet Infectious Diseases.* This dissertation additionally includes an extended version of this article with an expanded introduction, results, and discussion.

Implementation of open science recommendations. Psychology is a science in a state of crisis. Since the publication of the research results regarding reproducibility in social and cognitive psychology (Open Science Collaboration, 2015), measures to overcome this crisis have been intensively discussed. In particular, pre-registration, open data, and open materials play an important role in making psychological research more transparent and sustainable (Renkewitz, 2018). At the end of 2016, I and the PIDI Lab also committed to open science practices. However, at that time, the studies of Article 1 and Article 2 had already been conducted without pre-registration. Nevertheless, I still followed open science principles (except pre-registration) in the research and publication process of these two articles. The hypotheses for Articles 1 and 2 were derived from theory, and the experiments were later developed on the basis of these hypotheses. Moreover, the data and analyses scripts are available online (Article 1: osf.io/5pjk6, Article 2: osf.io/q82q5). All the studies of Article 3 are pre-registered. In addition, the data, the analysis script, and all instructions are available online (osf.io/bn56v).

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General Introduction

Introduction

Life is filled with decisions, which are simple at first glance. For example, you wake up: Do you stay in bed or do you get up?

Would the decision change if it were a regular working day? What happens if you remember that your colleagues have to compensate for your absence when you are not there?

This example shows that seemingly trivial decisions can become complex if additional context and considerations are taken into account. Long-term consequences then emerge, and it becomes apparent that many decisions can also have consequences for other people. This is also the case with vaccinations. At first, the vaccination decision appears simple. One may decide on the basis of one's attitude toward vaccination or in considering the risks of vaccination and disease. But what about the consequences for other people? If you decide against vaccination, you could potentially become a carrier of the disease and put other people at risk. Conversely, you can protect susceptible individuals by opting for vaccination as you then help prevent the disease from spreading in the population.

This demonstrates that context information, which better reflects reality, may contribute to a different evaluation of the individual vaccination decision and to a better understanding of vaccination decisions from a scientific perspective.

Thus, this dissertation is concerned with the vaccination decision in a complex environment. The following section emphasizes why examining the vaccination decision is an important field of research. Subsequently, a brief overview of previous psychological research in the field of vaccination is given, and the gaps in research and methodological approach of the dissertation are presented. Finally, the focus of the dissertation and the central research questions are highlighted.

In order to improve the readability and clarity of the text, boxes are used to define key terms.

The importance of vaccinations

According to the WHO, a total of 56.9 million people died in 2016, of whom about 10% had previously suffered from infectious or parasitic diseases (WHO, 2019a). There are also historical examples illustrating the vulnerability of humanity to infectious diseases, such as the Spanish flu or the plague during the Middle Ages (Dean et al., 2018; Morens, Folkers, & Fauci, 2004).

Measures to contain and prevent infectious diseases are needed to reduce this vulnerability. Besides improving the health system, water supply, and living conditions in general, vaccination is one of the most successful measures for disease prevention (Andre et al., 2008; Kistemann & Exner, 2000). In the U.S., the incidence rate of major vaccine-preventable diseases, such as measles, rubella, and polio, were reduced by more than 99% in 2016 compared to the incidence rates of these diseases in the 20th century (Orenstein & Ahmed, 2017).

One of the most famous examples of the success of vaccinations is the smallpox eradication. Smallpox was a highly contagious disease with a mortality rate of about 30% (Variola major, depending on the cycling of the disease; Ferguson et al., 2003), which caused between 300 million and 500 million deaths in the 20th century (Thèves, Biagini, & Crubézy, 2014). With the development of a vaccine and the united efforts of many nations, by introducing coordinated vaccination campaigns (including mass vaccination campaigns and mandatory vaccination policies), the incidence rate of smallpox declined significantly (Ferguson et al., 2003). Smallpox was eliminated in 1978 and declared eradicated by the WHO in 1980 (Vutuc & Flamm, 2010).

Mortality rate: … is defined as "an approximate measure of the probability of death during a [given event and] period of time in members of a [specific] group" (Boslaugh, 2008, p. 690).

Incidence rate: … is defined as the rate of occurrence of an event, such as an infection, in a defined population during a given period of time (Porta, 2014).

Box 1. Definitions of mortality rate and incidence rate

These are examples of humanity's ability to contain infectious diseases when we work together in a coordinated manner. However, recurring outbreaks of infectious diseases are still a threat. Measles are currently striking with full force; in the first half of 2019, 364,808 measles cases have been recorded in 182 countries, the highest number since 2006 (WHO, 2019b). According to Rieck et al. (2019), the missing vaccinations among adults especially contributed to the outbreaks in Germany.

Vaccine hesitancy is a main driver for vaccination gaps and thus plays a major role with regard to the recurrence of vaccine-preventable diseases such as measles, as it undermines national as well as international health goals (Betsch et al., 2018). The WHO termed vaccine hesitancy as one of the ten global health threats of 2019 (WHO, 2019c).

Vaccine hesitancy: "… refers to delay in acceptance or refusal of vaccination despite availability of vaccination services." (MacDonald & the SAGE Working Group on Vaccine Hesitancy, 2015, p. 4161)

Box 2. Definition of vaccine hesitancy

These recent high rates of measles sparked emotionalized debates about the introduction of subgroup-specific mandatory vaccination, for example, in Germany (Bundesministerium für Gesundheit, 2019). Other countries also have introduced mandatory vaccinations (Signorelli, Iannazzo, & Odone, 2018; Yang & Rubinstein Reiss, 2018). According to this measure in Germany, specific populations, including migrants and asylum seekers, are required to provide proof that they have been vaccinated against measles and, if necessary, that they catch up. However, these mandates might have negative drawbacks on subsequent, voluntary vaccination decisions (Betsch & Böhm, 2016). In order to achieve a sustainable vaccination behavior change, it is thus crucial to understand how and why people make vaccination decisions.

In the following section, a brief overview of the psychological perspective on vaccination decision-making and vaccine hesitancy will be presented.

Behavioral insights on vaccinations

Identifying the determinants of vaccine acceptance is the subject of intensive interdisciplinary research, and one of the most elaborated approaches is the 5C model of vaccine acceptance (Betsch et al., 2018).

> **Behavioral insights**: … is defined as an approach for evidence-based policy making, which incorporates knowledge from behavioral and social sciences as well as from economic sciences (Kuehnhanss, 2019).

Box 3. Definition of behavioral insights

The 5C model describes five constructs that were identified as the central antecedents of the vaccination decision: confidence, complacency, constraints, calculation, and collective responsibility. Confidence mainly refers to trust in vaccines (regarding their effectiveness and safety) and the health care system but also includes attitudes toward vaccination and vaccine-related risk perceptions.

Risk: … can be understood as the "possibility of a negative future outcome" (WHO Europe, 2017, p. 11) and is defined in this dissertation as the product of the probability and the severity of a negative event (Betsch, Böhm, & Korn, 2013).

Box 4. Definition of risk

In contrast to confidence, complacency relates to disease-specific risk perceptions. Complacent individuals perceive low disease risks and therefore conceive vaccination as not necessary. They generally exhibit low involvement in the topic of vaccination and lack knowledge and awareness around it. Constraints refer to structural barriers, such as the missing cost absorption of vaccinations from health insurance plans or difficult geographical access. Thus, individuals confronted with constraints have lower perceived behavioral control regarding their vaccination decision (Ajzen, 1991; Betsch et al., 2018). Calculation refers to the need for information regarding the vaccination decision. Individuals who calculate show a high engagement in information search, and this is associated with risk perceptions and a weighing process regarding the disease and the vaccine. Lastly, collective responsibility refers to the social processes around the vaccination decision (see the section "Vaccination as social interaction" below). Individuals who show collective responsibility are willing to be vaccinated in order to protect those who are not able to get a vaccination (such as babies or immunocompromised individuals).

In a comprehensive narrative review, Brewer et al. (2017) illustrated behavioral insights into the vaccination decision. They conclude their review with three statements. First, they stated that deliberation as well as emotions or feelings affect the motivation to be vaccinated. In this context, especially risk perceptions of the disease and the vaccine, as well as anticipated regret, influence the intention to be vaccinated. Second, Brewer and colleagues (2017) argued that the interventions aimed at behavior rather than motivation are the most effective. In reference to the 5C model, this means that the interventions aimed at the construct constraints and at reducing barriers are likely to be most effective, such as implementing reminders (Jacobson Vann, Jacobson, Coyne-Beasley, Asafu-Adjei, & Szilagyi, 2018) or opt-out policies (Böhm, Betsch, Korn, & Holtmann, 2016; Chapman, Li, Colby, & Yoon, 2010). Lastly, they stated that social processes, such as descriptive and injunctive norms, play a key role in vaccination decision-making but are not extensively investigated.

In sum, the research groups around Betsch and Brewer emphasize the importance of risk perception and the influence of social processes on the vaccination decision. These aspects also play an important role in this dissertation and are discussed in the following sections.

Risk perception and vaccination

From a normative perspective, that is, assuming that individuals are egoistic-rational agents, individuals should weigh the costs and benefits of the available alternatives and choose the option that maximizes their outcomes (Edwards, 1954). Translated to a vaccination decision, this means that the individual makes a deliberate choice between vaccination and non-vaccination and selects the option with the highest individual utility (van der Pligt, 1996). A key component in this regard is risk perception (Brewer et al., 2007; van der Pligt, 1996; Weinstein, 1993).

A decision based on risk perception would be as follows (examples based on Korn, Holtmann, Betsch, & Böhm, 2015): Since vaccination is a preventive measure that, on the one hand, serves to avoid negative future events and, on the other hand, can itself have negative effects (vaccination side effects), the vaccination decision can be understood as a cost calculation (Betsch, Böhm, et al., 2013). Costs refer to the negative consequences of the decision. In the case of disease, for example, these consequences would be the symptoms of the illness and the associated absence from work, or even social isolation. The costs of the vaccination, on the other hand, result from the vaccine's side effects, the time required to get a vaccination or, possibly, the fear of injections. These costs are then integrated with the probability of the occurrence of the negative events.

Empirical evidence supports the link described above between risk perception and vaccination behavior. A meta-analysis (Brewer et al., 2007) showed that especially the perceived probability and severity of the disease is associated with a higher inclination to choose vaccination.

Why do people decide against vaccination, then, when the disease risks are generally high vis-à-vis the risks of vaccination? One reason is that individual risk perception is subjective rather than objective, and can be affected by cognitive biases (Betsch, Haase, Renkewitz, & Schmid, 2015; van der Pligt, 1996) and altered by emotions (Loewenstein, Weber, Hsee, & Welch, 2001; Schmid, Rauber, Betsch, Lidolt, & Denker, 2017; Slovic & Peters, 2006).

One example of a cognitive bias in the context of risk perception of vaccinations is the narrative bias. Narratives play a major role in human experience as they help to create bonds between individuals and to construct reality (Sukalla, 2018). When individuals search for information about vaccination, for example, they typically use the Internet (Ward, Peretti-Watel, & Vergera, 2016). On the Internet, however, individuals are likely to encounter exemplars or narratives on the side effects of vaccines. This information disproportionately increases the perceived risk of adverse events and thus decreases the intention to be vaccinated (Betsch et al., 2015; Betsch, Renkewitz, & Haase, 2013).

Narrative bias: … is defined as the “excessive influence of narrative information, exemplars, and testimonies” (Betsch et al., 2015, p. 241) on risk perceptions.

Box 5. Definition of narrative bias

In addition, the infection probability is not fixed, but varies with the vaccination rate in the population. This interaction between the vaccination behavior of others, the probability of the disease, and one's own vaccination behavior translates the vaccination decision into a social interaction. This aspect is elucidated in the following section.

Vaccination as social interaction

Brewer et al. (2017) argued that social processes play a role in the vaccination decision. However, they primarily refer to informational (descriptive) and normative (injunctive) social influence (Cialdini, Kallgren, & Reno, 1991; Deutsch & Gerard, 1955).

Social norm: … is defined as a social standard that indicates which behaviors are considered typical (descriptive) and/or proper (injunctive) in a given context (American Psychological Association, 2018c).

Descriptive norm: … is defined as a social standard that indicates typical behavior in a given context (American Psychological Association, 2018a).

Injunctive norm: … is defined as a social standard that indicates socially accepted behavior in a given context (American Psychological Association, 2018b).

Bandwagoning: … is defined as "an accelerating diffusion through a group or population of a pattern of behavior, the probability of any individual adopting it increasing with the proportion who have already done so" (Colman, 2015, p. 77).

Free riding: … "occurs when individuals or organizations enjoy the benefits of a good without contributing to its provision" (Rockart, 2016, p. 592).

Box 6. Definitions of social norm, descriptive norm, injunctive norm, bandwagoning, and free-riding.

In the field of persuasion research, descriptive (and injunctive) social norms are assumed to influence the behavior of individuals in a certain way (Cialdini et al., 1991).

Applying the concept of descriptive norms to the vaccination decision, this would mean that individuals are more likely to be vaccinated if they know or assume that a majority of other people are also vaccinated (see also bandwagoning, Hershey, Asch, Thumasathit, Meszaros, & Waters, 1994).

A systematic review (Schmid et al., 2017) on the barriers to influenza vaccination, however, showed that there is inconclusive evidence on the relationship between descriptive norms and vaccination behavior. For example, Ibuka et al. (2014) found, in an experimental study, that individuals show free-riding behavior in the context of influenza vaccination — the higher the vaccine uptake, the lower the preference for vaccination.

How can this pattern be explained when descriptive social norms are generally positively related to health behavior (Rivis & Sheeran, 2003)? The fact that the descriptive social norm can also have a negative influence on the vaccination decision can be exemplified from an epidemiological and game theoretical point of view.

The spreading of an infection is related to how contagious the disease is. In epidemiological research, this is termed the basic reproduction number. The higher the basic reproduction number of a disease, the higher the transmission potential of the disease (Anderson & May, 1985).

Basic reproduction number: … is defined as the “number of secondary cases generated by a typical infectious individual when the rest of the population is susceptible (i.e., at the start of a novel outbreak)” (Fine, Eames, & Heymann, 2011, p. 913) and is denoted as R_0 in this dissertation.

Box 7. Definition of basic reproduction number of a disease

Figure 1 shows the relation between the vaccination rate and infection probability for diseases with different transmission potentials. The x-axis depicts the vaccination rate; the y-axis depicts the infection probability. The infection probability for measles, for example, is almost 93% (solid line) if the whole population is not immune. The infection probabilities for the Spanish flu and smallpox, on the other hand, are around 70% (dotted line) and 86% (two-dashed), respectively.

However, the infection probability is more than just a function of the transmission potential of a disease. The probability also varies with the immunization rate in the population. This relationship can also be seen in Figure 1.

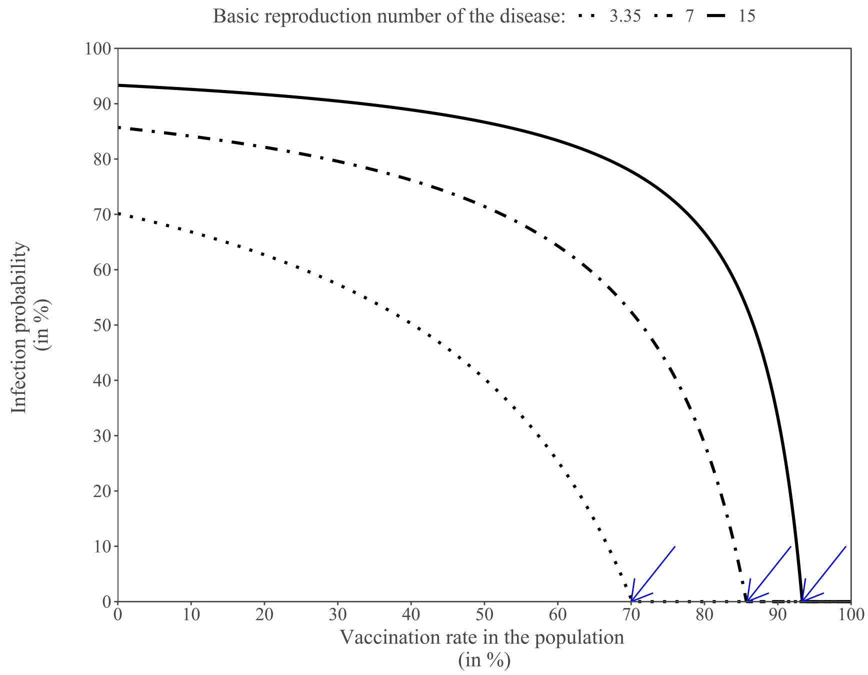

Figure 1. Infection probability as a function of the vaccination rate in the population and the basic reproduction number of the disease. *Note.* Line types represent different basic reproduction numbers and thus different diseases: solid line resembles measles (Ferguson et al., 2003), two-dashed line represents smallpox (Ferguson et al., 2003), and dotted line represents Spanish flu (Vynnycky, Trindall, & Mangtani, 2007). Vaccination rate ranges between 0 and 100, where 0 indicates a fully susceptible society and 100 indicates a fully immune society. Infection probability ranges between 0 and 100, where 100 indicates that infection will certainly occur and 0 indicates impossibility of infection. Blue arrows indicate the herd immunity threshold of the three diseases — at this theoretical point, the diseases would be eliminated (Fine et al., 2011).

Vaccinations provide not only individual protection, but also positive externalities by reducing the transmission of infectious diseases on the community level (Anderson & May, 1985; Böhm, Betsch, & Korn, 2016). Thus, the probability of infection decreases with an increasing vaccination rate in the society (see Figure 1). At the same time, the probability of vaccine side effects remains unaffected by the number of vaccinated individuals.

Externality: … is defined as the non-explicit influence of the behavior of an individual on the situation of another individual or group of individuals (Kollock, 1998).

Box 8. Definition of externality

Consequently, weighing the potential costs of vaccination and non-vaccination, the individual utility of vaccination decreases with higher vaccine uptake in a society. At a certain point, therefore, the costs of vaccination exceed the costs of non-vaccination. Then, from a selfish-rational point of view, vaccination may become irrational (Bauch & Earn, 2004; Böhm, Betsch, & Korn, 2016).

The positive externalities of the vaccination decision also have public health and social implications. It can be seen from Figure 1 (arrows) that, at a certain vaccine uptake, the infection probability becomes zero. This point is referred to as the herd immunity threshold (Fine et al., 2011); in other words, when the vaccine uptake is high enough, diseases can be eradicated or eliminated (Anderson & May, 1985).

Herd immunity: … is defined as "the effect that occurs when acquired immunity against a pathogen, generated through infection or vaccination, within a population (the "herd") has reached such a level that nonimmune individuals in this population are also protected, because the pathogen can no longer be transmitted" (Betsch, Böhm, et al., 2013, p. 980).

Box 9. Definition of herd immunity

Taken together, this conflict between the motivation of individuals to maximize the individual outcome and the collective goal of eliminating diseases defines a social dilemma (Bauch & Earn, 2004; Böhm, Betsch, & Korn, 2016; Kollock, 1998).

Social dilemma: … is defined as “a situation in which (a) each decision maker has a dominating strategy dictating non-cooperation (i.e., an option that produces the highest outcome, regardless of others’ choices), and (b) if all choose this dominating strategy, all end up worse off than if all had cooperated (i.e., a deficient equilibrium)” (Van Lange, Balliet, Parks, & Van Vugt, 2014, p. 5).

Box 10. Definition of social dilemma

The consideration of the vaccination decision as a social and strategic interaction therefore leads to two reflections:

1.) Studying vaccination decisions requires an adequate method that integrates the above-mentioned epidemiological and game theoretical mechanisms of the direct and indirect consequences of vaccination and non-vaccination (Bauch & Earn, 2004; Fine et al., 2011). For this purpose, this dissertation utilized the I-Vax game as a research paradigm (Böhm, Betsch, & Korn, 2016). Besides the opportunity to implement the epidemiological and economic interdependence between individuals, the vaccination decisions in the I-Vax game correspond to revealed preferences.

Revealed preferences: … is defined as “a person’s (usually marginal) willingness to pay for an entity as revealed by (for example) market transactions or a controlled experiment” (Culyer, 2005, p. 302). Individuals thus experience “real consequences for their choices or behaviors through aligned monetary and non-monetary incentives” (Galizzi & Wiesen, 2018, p. 2).

Box 11. Definition of revealed preferences

Therefore, participants find themselves in incentivized situations in which they experience the consequences of their decisions. This approach is less prone to socially desirable responses (Norwood & Lusk, 2011) and “cheap talk” (Galizzi & Wiesen, 2018) than the stated preferences approach and is thus more suitable for the research of vaccination decisions. In this sense, it is expected that incentivized behaviors in laboratory experiments are a better proxy for real-world vaccination behavior (see Böhm, Betsch, & Korn, 2016) than mere intentions (Sheeran, 2002).

Stated preferences: … is defined as the "willingness to pay for a non-marketed entity as derived from questionnaires or experiments. It is 'stated' verbally (orally or in writing) rather than revealed by actual [behavior] in experiments or in real life" (Culyer, 2005, p. 327). Individuals thus do not experience real consequences for their choices or behaviors (Galizzi & Wiesen, 2018).

Box 12. Definition of stated preferences

2.) As social dilemmas are defined as situations where self-interests are at odds with collective interests (Van Lange et al., 2014), the long-lasting question arises as to how cooperation can prevail (Nosenzo & Sefton, 2014; Van Lange, Joireman, Parks, & Van Dijk, 2013).

Moreover, as already stated, vaccination is embedded in a complex environment. Due to the world's interconnectedness and the migration of individuals, formerly homogeneous societies are being transformed into heterogeneous societies (Danchev & Porter, 2018). This means that individuals from different groups — for example, a majority community and migrant groups — need to cooperate to contain and eliminate infectious diseases. Vaccination is a social dilemma (Bauch & Earn, 2004; Betsch, Böhm, et al., 2013; Dawes, 1980) and requires collective action that, in the real world, touches the interplay of several groups within the society. This means that the long-lasting question is more complex than stated above, and is rather: How can cooperation prevail in a social environment comprised of several social groups?

The social aspects of decision-making around vaccines has recently gained increasing scientific attention (Attari, Krantz, & Weber, 2014; Bauch, D'Onofrio, & Manfredi, 2013; Bauch & Earn, 2004; Korn, Betsch, Böhm, & Meier, 2018). For example, previous research showed that communicating the social benefit of vaccinations can increase vaccination intentions (Betsch, Böhm, et al., 2013; Betsch, Böhm, Korn, & Holtmann, 2017). Also, social value orientations (Attari et al., 2014; Korn et al., 2018; Vietri, Li, Galvani, & Chapman, 2012) play a role in vaccine decision-making.

Social value orientation: … is defined as the way in which individuals weigh the consequences of options for themselves and others (Fehr, Fischbacher, & Gächter, 2002). The higher the social value orientation, the higher the concern for others (Murphy, Ackermann, & Handgraaf, 2011). Synonyms are social preferences, other-regarding preferences, social motives, welfare tradeoff ratios, altruism, and collective interest (Murphy & Ackermann, 2014).

Box 13. Definition of social value orientation

The following sections are based on the two above-mentioned implications. First, the research paradigm is presented — the I-Vax game — and then the research questions of the dissertation are introduced.

Research paradigm: The I-Vax game

The I-Vax game uses an interdisciplinary approach to capture the "psychological consequences of the risks from disease and from vaccination, and their effects on vaccination behavior in a realistic interaction setting" (Böhm, Betsch, & Korn, 2016, p. 184). First, it epidemiologically models disease transmission using a SIR model (see also Britton, 2003; Huppert & Katriel, 2013). As such, the game assumes that the population is stable over the course of the game (no deaths and births) and there is no clustering or networks; the population is mixed, and thus the contact probability for every individual is identical. Moreover, the modeling of infections is based on epidemiological considerations and rests on the vaccination rate of the population and the contagiousness of the disease (see section "The repeated I-Vax game"). Also, the vaccine is perfectly effective and therefore always provides immunity against the disease. Lastly, the I-Vax game does not model the epidemics of infectious diseases over a long period of time.

SIR model: … is defined as an epidemiological model, wherein an individual of a population is a member of one of three groups: susceptible, infected, or recovered. (Britton, 2003).

Box 14. Definition of an SIR model

Besides epidemiological insights, the I-Vax game incorporates game theoretical concepts to investigate the strategic component of vaccination, with revealed preferences as its core. This means that health, infection, and vaccine side effects are modeled monetarily. Decisions in favor or against vaccinations have pecuniary consequences for the respondents. Also, the occurrence of negative consequences is both a result of the decisions of the other respondents and chance.

Game theory: … is defined as the systematic (descriptively and normatively) study of behavior in strategic settings (Watson, 2013).

Game: … is defined as a situation with at least two players and a defined set of strategies, which lead to specific payoff-relevant outcomes for the players (Straffin, 1993).

Box 15. Definition of game theory and a game from a game theoretical perspective

A repeated as well as a one-shot version of the I-Vax game were used in the articles of this dissertation. Both versions share the same procedure, which is presented below.

As depicted in Figure 2, the I-Vax game consists of three phases. In the decision phase, participants are, in consideration of the basic SIR model, initially susceptible and simultaneously decide in favor of or against vaccination. In the incubation phase, respondents might experience vaccine side effects or get infected, depending on their own decision, the decisions of the other group members, and chance. The underlying calculations are presented in the following sections.

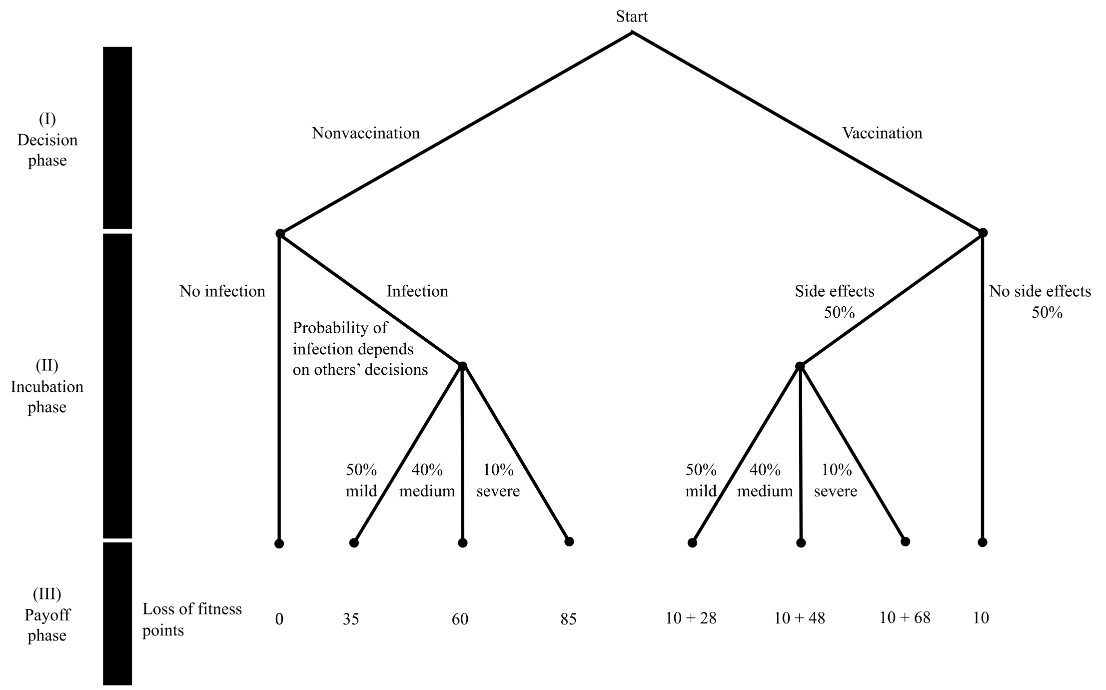

Figure 2. The three phases of the I-Vax game. *Note.* In the decision phase, individuals simultaneously decide either in favor or against vaccination. In the incubation phase, losses contingent to the decisions are calculated (see section below for exact calculations). In the payoff phase, individuals receive information on their losses and the remaining fitness points.

In the payoff phase, participants receive information about their own vaccination decision (health status in terms of monetary payoff). Depending on the experimental setup, they may receive more information (see Article 1).

Importantly, the I-Vax game does not model epidemics over time. This means that the rounds of the game are independent from each other. An elimination of a disease in a round has no influence on the infection probabilities in the following round, thus simulating infectious diseases such as influenza, which requires annual vaccination and cannot be eradicated.

The repeated I-Vax game

The I-Vax game resembles a volunteer's dilemma (Diekmann, 1985) and is played in groups of *n* players over *r* rounds (Böhm, Betsch, & Korn, 2016). In Article 1 and Article 2, there were $n = 12$ players who played the game over $r = 20$ rounds. In the current game form, group compositions remain stable for the course of the experiment.

Volunteer's dilemma: … is defined as a "conflict game simulating social traps in which a collective good can be provided by a volunteer" (Diekmann, 1985, p. 605).

Box 16. Definition of a volunteer's dilemma

The I-Vax game models the expected utility (EU) of vaccination and non-vaccination for an individual i as follows:

$$EU_i = e - c_{a_i}^{fix} - c_{a_i}^{var} \text{ [1]}$$

Players are endowed with $e = 100$ fitness points in each round. They can decide either in favor or against vaccination (a_i, 0 = non-vaccination, 1 = vaccination).

A decision in favor of vaccination yields a fixed loss of $\mathrm{c}_1^{\mathrm{fix}}$ fitness points, resembling costs such as the effort of visiting the GP's practice or the pain of the pinprick. Omission of vaccination yields no such fixed loss, $\mathrm{c}_0^{\mathrm{fix}} = 0$.

Both vaccination and non-vaccination entail variable costs:

$$c_{a_i}^{var} = p_{a_i}^{var} \times s_{a_i,j}. \text{ [2]}$$

In the case of vaccination, the probability of side effects is constant (p_1^{var} $with$ $0 \leq p_1^{var} \leq 1$). The amount of point loss due to side effects depends on their severity $s_{1,j}$ with $j \in \{mild, medium, severe\}$:

$$j \begin{cases} mild\ with\ s_{1,mild} & and\ probabilty\ p_{1,mild} \\ medium\ with\ s_{1,medium} & and\ probabilty\ p_{1,medium} \\ severe\ with\ s_{1,severe} & and\ probabilty\ p_{1,severe} \end{cases} [3]$$

In the case of non-vaccination, the probability of contracting the disease (p_0^{var} $with$ $0 \leq p_0^{var} \leq 1$) varies as a function of the basic reproduction number of the disease (R_0) and the vaccination rate (v, whereby $0 \leq v \leq 1$) in the respective round:

$$p_0^{var} \begin{cases} 1 - \frac{1}{R_0(1-v)}, & if\ R_0(1-v) \geq 1 \\ 0, & else \end{cases} \text{ [4]}$$

The probabilities $p_{0,j}$ of the different disease outcomes are equal to the probabilities of the different vaccine side effects $p_{1,j}$. The amount of point loss due to the disease depends on the severity $s_{0,j}$ with $j \in \{mild, medium, severe\}$:

$$j \begin{cases} mild\ with\ s_{0,mild} & and\ probability\ p_{0,mild} \\ medium\ with\ s_{0,medium} & and\ probability\ p_{0,medium} \\ severe\ with\ s_{0,severe} & and\ probability\ p_{0,severe} \end{cases} \text{ [5]}$$

Note that $p_{a_i,mild} \geq p_{a_i,medium} \geq p_{a_i,severe}$ and $p_{a_i,mild} + p_{a_i,medium} + p_{a_i,severe} = 1$.

In order to research vaccination as a social dilemma, it is crucial to find a parametrization so that a Nash equilibrium (Nash, 1951) in the I-Vax game exists.

Nash equilibrium: … is defined as "a set of strategies such that no player can benefit by changing their strategy while the other players keep theirs unchanged." (Culyer, 2005, p. 225).

Box 17. Definition of the Nash equilibrium

To determine whether a Nash equilibrium exists, Bauch and Earn (Bauch & Earn, 2004) suggest to interrelate (IR, formula [6]) the expected costs of vaccination with the expected severity of the disease as follows:

$$IR = \frac{c_1^{\mathrm{fix}} + c_1^{var}}{s_0} \quad [6]$$

Higher values indicate worse side effect to severity of the disease ratios. The authors note that a Nash equilibrium exists if $IR < p_0^{var}$ under the condition $v = 0$. This means that the expected costs of vaccination should be less than the expected severity of the disease, because then $IR < 1$, and since $0 \leq p_0^{var} \leq 1$, a Nash equilibrium is mathematically possible. However, the position of the Nash equilibrium also depends on the basic reproduction number of the disease, because the infection probability is a function of R_0 and v. The larger R_0 is, the larger IR may be. This means that, in the case of a highly contagious disease, the side effect to severity of the disease ratio may be worse than in the case of a disease that does not spread so quickly, and yet a Nash equilibrium still exists. The critical vaccination rate, v^N (Nash equilibrium, $0 \leq v^N \leq 1$), where no individual has an incentive to change his or her vaccination decision unilaterally, is calculated as follows (Bauch & Earn, 2004):

$$v^N = 1 - \frac{1}{R_0(1 - IR)} \quad [7]$$

The social optimum is reached when the aggregated costs of vaccination and non-vaccination in a population are minimized. This is the case when the vaccination rate corresponds to the herd immunity threshold. The herd immunity threshold, and therefore the critical vaccination for the social optimum, v^S ($0 \leq v^S \leq 1$), is solely determined by the basic reproduction number of the disease and is calculated as follows (Fine et al., 2011):

$$v^S = 1 - \frac{1}{R_0} \quad [8]$$

Social optimum: … is defined as the point where social welfare, i.e., the sum of payoffs of all players, is maximized (Black, Hashimzade, & Myles, 2017).

Box 18. Definition of a social optimum

Vaccinations beyond the herd immunity threshold would be not efficient from a collective perspective, because individuals would experience vaccination costs when there is no reason to vaccinate since the disease has already been eliminated.

To sum up, below the vaccination rate v^N, vaccination is the dominant strategy. Above the vaccination rate v^N, non-vaccination is dominant. Collective welfare, however, is maximized when the vaccination rate reaches v^S, because the infection probability reaches zero and the disease is eliminated. Thus, between the vaccination rates v^N and v^S (given $v^N < v^S$, this is always the case as long as vaccination is costly; see Bauch & Earn, 2004), the game constitutes a social dilemma wherein individual interests are in conflict with collective interests.

The one-shot I-Vax game

This variant differs from the original in the degree of complexity of the severity calculation of vaccination side effects in the case of vaccination and infection in the case of non-vaccination (apart from the fact that it is not played repeatedly [$r = 1$]).

Individuals play the game in groups of *n* persons (in Article 3: 95, 30, or 125). Players decide either in favor ($a_i = 1$) or against vaccination ($a_i = 0$). The calculation of the expected utility is the same as in the repeated I-Vax game (see formula [1]). Similar to the repeated I-Vax game, while vaccination entails fixed costs (c_1^{fix}), non-vaccination yields no fixed costs $c_0^{fix} = 0$. Moreover, vaccination and non-vaccination entail variable costs. In contrast to the repeated I-Vax game, there is no differentiation in the severity of the disease or vaccination side effects. This means that one value is assigned to the severity of the side effects, and another value is assigned to the severity of the disease:

$$c_{a_i}^{var} = p_{a_i}^{var} \times s_{a_i} \text{ [9]}$$

The one-shot I-Vax game also follows the repeated I-Vax game with regard to the probability of side effects and the infection probability (side effects are constant; infection probability is calculated from [4]). Also, the calculations of the Nash equilibrium and the social optimum correspond to the same considerations as in the repeated I-Vax game.

Exploring the I-Vax game

Figure 3 shows a screenshot and a QR code for an app programmed specifically for this dissertation.

Figure 3. Screenshot and QR code of the I-Vax app. *Note.* Redirection to the shinyapp "The one-shot I-Vax game." Web address: https://larskorn.shinyapps.io/ONE_SHOT_I_VAX/

The app is programmed in R (R Core Team, 2019) using the packages shiny (Chang, Cheng, Allaire, Xie, & McPherson, 2018) and tidyverse (Wickham, 2017). It graphically presents the relationship between the costs of vaccination and non-vaccination in a one-shot I-Vax game. It allows for defining the basic reproduction number of the disease, the probability of vaccine side effects, the fixed costs of vaccination, and the severity of the disease and side effects. For calculations of the costs of vaccination and non-vaccination, the above-mentioned formulas were utilized.

The app can be used to explore how the individual components of the I-Vax game interact with each other. Also, the app allows researchers to easily define parameters for the one-shot I-Vax game in experiments. This means that, with the application, one can ensure that the selected parameters also lead to a dilemma situation in the context of the vaccination decision. This is essential for the line of research that is being followed in this dissertation.

Contextualized games in health behavior research

The main goal of an experimental study is to deduce the causal effect of an independent variable on a dependent variable. For this reason, possible sources of errors are eliminated. One method is to formulate decision tasks as neutral as possible (Galizzi & Navarro-Martinez, 2018) in order to capture the treatment effects. However, this approach may not be suitable for experimental research in the domain of health (Galizzi & Wiesen, 2018).

For example, Harrison and List (2004) argued that context-free experiments are possibly not generalizable when context is relevant for the respondents. They even argued that in a context-free experiment, it is beyond the researcher's control which cognitions are activated during the experiment. These cognitions could alter the behavior systematically. In the original paper, which introduced the repeated I-Vax game (Böhm, Betsch, & Korn, 2016), the researchers tested behavioral differences between respondents in a context-free I-Vax game and contextualized I-Vax game. The results showed that vaccination attitude had a stronger impact on vaccination behavior in the contextualized condition than in the context-free condition. Since attitudes are a strong predictor of real-life vaccination behavior (Schmid et al., 2017), one can conclude that contextualized games in vaccination decision-making research are necessary in order to reach a certain level of external validity. Thus, this dissertation used contextualized versions of the I-Vax game to research vaccination decision-making.

Focus of the papers — Research questions of the dissertation

As noted above, the threat posed from infectious diseases requires collective action. Collective action, however, is hampered, because the challenge posed from infectious diseases constitutes a social dilemma. Thus, overcoming individual self-interest (free riding given high vaccination rates) and cooperation are required.

Moreover, due to the world's interconnectedness and the migration of individuals, once homogeneous societies are being transformed into heterogeneous societies (Danchev & Porter, 2018). This means that individuals from different groups need to cooperate with each other in order to achieve societal goals, such as the elimination of infectious diseases.

Therefore, in consideration of the implications of conceptualizing vaccination as a social dilemma, this dissertation focuses on a) promoting vaccination behavior in a complex environment, b) the incorporation of others' vaccination decisions, that is, out-group members' (i.e., migrants) decisions, in one's own decision to be vaccinated, and c) whether vaccination is a social contract, conceptualized as the reactions to others' vaccination behavior, wherein others are either (non-)vaccinated members of an in-group or an out-group.

Promoting vaccination behavior using social goals and inter-group comparisons

The first question concerns the effectiveness of social nudging interventions (Thaler & Sunstein, 2008) aimed at intra- and inter-group processes to increase the vaccination uptake in a homogeneous population.

Nudging: … is defined as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid" (Thaler & Sunstein, 2008, p. 6).

Box 19. Definition of nudging

Specifically, it was tested whether social goals (Epton, Currie, & Armitage, 2017) and inter-group comparisons (Böhm & Rockenbach, 2013) are effective in increasing vaccination uptake.

First, goals direct attention and action, create persistence, increase effort toward related behavior, and thus facilitate the transformation from motivation into volition (Locke & Latham, 2002). A meta-analysis on the effect of goal-setting (Epton et al., 2017) showed that especially setting group goals is an effective strategy for behavior change. In addition, the attainment of group goals may be rewarded non-monetarily and could lead to a higher probability that individuals will show the rewarded behavior in the future (law of effect; Thorndike, 1911). Therefore, it is assumed that non-monetarily rewarding the collective goal attainment (elimination of the disease) leads to a higher vaccination probability.

Secondly, from a rational point of view, the presence of structurally independent out-groups should not affect an individual's vaccination decision, since these out-groups do not affect individual outcomes (e.g., infection probability). Thus, citizens of one country should ignore whether or not other countries have already eliminated a disease (given none or low migration between countries). The inter-group comparison – intra-group cooperation hypothesis, however, proposed by Böhm and Rockenbach (2013), posits that comparisons with a structurally independent other group (out-group) improve cooperation behavior with one's own group (in-group).

Applied to vaccination decision-making, comparisons with an out-group increase vaccination uptake in the in-group. The mere presence of an out-group activates a comparative focus, which instigates individuals to increase their cooperation within their own group. This reflects the tendency of individuals to form a positive social identity by positively changing the relative reputation of the in-group vis-à-vis the out-group (see also intergroup bias, Böhm & Rockenbach, 2013; Tajfel, Billig, Bundy, & Flament, 1971).

Social identity: … is defined as "the part of the self-concept that derives from group membership" (Colman, 2015, p. 707).

Intergroup bias: … is defined as "behavior that favors own group over other groups" (Hogg & Vaughan, 2011, p. 415). This bias is also referred to as in-group bias and in-group favoritism.

Box 20. Definition of social identity and intergroup bias

Information on an interdependent out-group's vaccination uptake

As noted above, while a selfish-rational decision-maker would not consider the vaccine uptake of an independent out-group, this should be the case when groups are interdependent. Previous research on social dilemmas suggests that higher diversity in a population leads to changes in cooperative behavior (Chakravarty & Fonseca, 2014).

Additionally, stereotypes and prejudices regarding an out-group may serve as anchors in the decision-making process (Fiske, 1998; Kite & Whitley, 2016) when group membership is the only present information.

This dissertation adopts these findings and transfers them to vaccination decisions in a context of migration. Refugees and migrants are exposed to the false prejudice of a generally poor health status (Khan et al., 2016), and debunking this misconception is of utmost importance. However, from a psychological health and behavioral economic perspective, communicating a good-to-excellent health and vaccination status of migrants and refugees can have detrimental effects on the host population's prevention behavior. This is because migrants and refugees contribute to the public good. A selfish-rational decision-maker would consider the vaccination status of refugees and migrants and update the infection probability of the disease according to the provided health information (i.e., vaccination rate).

Consequently, I examine the extent to which information about the health status of a migrating out-group may influence the vaccination decision of individuals in a host population and whether a prejudice correction about the health status of migrants may have detrimental effects on the vaccination behavior of members of the host populations.

Reactions to others' vaccination behavior — vaccination as a social contract?

As noted above, the re-emergence of measles cases in Germany sparked an emotionalized debate about a subgroup-specific mandatory vaccination policy. As an alternative to mandates, the German Ethics Committee (Deutscher Ethikrat, 2019) recently stated that vaccinations should be considered a moral, but not legal, obligation. Thus, vaccination is proposed as a social contract to which every individual shall contribute. While there is evidence that moral values are associated with vaccine acceptance (Amin et al., 2017; Betsch & Böhm, 2018), it is unclear whether individuals' behavior suggests that vaccination is indeed perceived as a social contract. If so, then one could assume that the communication of vaccination as a social contract would be a promising intervention to increase vaccine uptake.

According to the Morality-as-Cooperation Theory (Curry, 2016), morality emerges in social dilemmas as reciprocal behavior (Fehr et al., 2002; "You scratch my back, and I'll scratch yours" Nowak & Sigmund, 2005, p. 1291). Cooperation is considered as morally good and respected. Defection, on the other hand, is seen as morally bad and despised. Since vaccinations pose social dilemmas, individuals who are vaccinated (and therefore comply with the social contract) should, therefore, positively reciprocate to others who are vaccinated as well. In contrast, they should negatively reciprocate to others who are not vaccinated (and therefore violate the social contract). Moreover, individuals who are not vaccinated themselves should not (or to a smaller extent) show reciprocal prosociality.

Moreover, as already stated, societies are in a transformation process toward more diversity (Danchev & Porter, 2018), wherein members of different groups need to cooperate to contain and eliminate infectious diseases. If vaccination is a social contract, based on a universal principle, then it should apply to all individuals irrespective of their group membership (Curry, 2016; Graham et al., 2013). However, intergroup bias is an often observed phenomenon (Balliet, Wu, & De Dreu, 2014; Tajfel & Turner, 1986; Yamagishi & Kiyonari, 2000). Thus, alternatively, it could be assumed that individuals show more negative and less positive reciprocity toward out-group members than toward in-group members (Yamagishi & Kiyonari, 2000).

Therefore, this dissertation examines how individuals react toward others' vaccination behavior. These reactions are conceptualized as changes in social value orientation (also called prosociality, Murphy et al., 2011). Negative changes indicate negative reciprocity, while positive changes are a clear indicator of positive reciprocity. On the basis of reciprocal behavior, it is possible to identify whether vaccination is actually regarded as a social contract.

What comes next?

First, the three articles that constitute the dissertation are presented. The first article deals with the effectiveness of social nudging interventions to increase vaccination uptake. The second article examines the influence of health information about a migrating out-group on the vaccination decision of individuals in a host population. Note that because this article was published first as a comment in *The Lancet Infectious Diseases* journal, the original manuscript as well as an extended version of the paper are included in the dissertation. Then, the third article examines individuals' changes of prosociality as reactions to others' vaccination behaviors. Finally, the general discussion will briefly restate and discuss the results of the respective articles, elaborate on the limitations of the dissertation, and give concluding remarks.

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Article 1

Social nudging: The effect of social feed-back interventions on vaccine uptake

Social nudging: The effect of social feedback interventions on vaccine uptake

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Abstract

Objective. Most vaccines provide indirect community protection by preventing the transmission of the disease. Paradoxically, this effect can also motivate omission of vaccination because increasing vaccination rates reduce the risk of infection and, therefore, the individual benefit of vaccination. Consequently, vaccination becomes a social dilemma where individuals' interests conflict with group interests. The current study investigated two social nudge interventions aiming to increasing individuals' motivation to act in the group's interest. Rewarding the attainment of the goal (disease elimination) is hypothesized to increase goal-directed behavior (vaccination). Further, it is assumed that comparisons with another group increase cooperative vaccination within one's own group.

Methods. In a laboratory experiment, the interactive vaccination (I-Vax) game was used to model the direct and indirect effects of vaccinations. The game was played by 288 participants over 20 rounds. The experimental setup varied the feedback information after each round to implement a 2 (*rewarding goal-attainment*: present vs. absent) × 2 (*inter-group comparison*: present vs. absent) between-subjects design.

Results. Analyses revealed the expected positive effect of *rewarding goal-attainment*, which was particularly strong at the beginning and weakened over the course of repeated decisions. The effect of *inter-group comparisons* was also positive, but did not reach conventional criteria of statistical significance.

Conclusions. The current experiment shows that communicating and rewarding "small wins" may increase individuals' willingness to act in the group's interest. Inter-group processes deserve further attention and investigation as potential strategies for improving vaccine communication and advocacy.

Keywords: vaccine decision-making, game theory, goal-setting, inter-group comparison, intra-group cooperation

Social nudging: The effect of social feedback interventions on vaccine uptake

Vaccines save approximately 2.5 million human lives per year (WHO, 2012). For instance, global polio cases were reduced by more than 99% from yearly 350,000 reported cases in 1988 to 37 cases in 2016 (WHO, 2017). Diseases can even be eliminated due to herd immunity, i.e., the phenomenon that most vaccines provide additional social benefit (protecting those who are not vaccinated) by reducing transmission of pathogens (Dubé et al., 2013). Unfortunately, vaccine hesitancy becomes a growing issue and severely undermines global goals of disease elimination, as in the case of measles and rubella (Larson et al., 2015; WHO, 2013).

The individual vaccination decision and its consequences

Vaccination decisions are typically seen as individual decision-making tasks, where individuals weigh costs (e.g., financial costs for obtaining the vaccine; potential vaccine adverse events) and benefits of vaccination (reduced infection probability) (Weinstein, 2000). From a rational choice perspective, vaccination is more likely when subjective risks of the disease outweigh risks of the vaccination (Betsch, Böhm, & Korn, 2013; Böhm, Betsch, & Korn, 2016).

Besides individual protection, most vaccinations also provide positive externalities by reducing the transmission of infectious diseases on a societal level (Anderson & May, 1985; Böhm, Betsch, & Korn, 2016). Hence, the risk of infection decreases with an increasing vaccination rate in society. In contrast, the risk of vaccine adverse events remains unaffected by the number of vaccinated individuals. Consequently, weighing the potential costs and benefits of vaccination, the utility of vaccination decreases with higher vaccine uptake in society. From a selfish-rational point of view, therefore, vaccination may become irrational when the vaccination rate increases (Bauch & Earn, 2004; Böhm, Betsch, & Korn, 2016). However, from a collective perspective, vaccination is also required when uptake is already high to allow eradication or elimination of diseases (Anderson & May, 1985). This conflict between individuals' motivation to maximize the personal outcome and the collective aim of eliminating diseases constitutes a social dilemma (Bauch & Earn, 2004; Böhm, Betsch, & Korn, 2016; Kollock, 1998). According to this perspective, vaccination can be interpreted as cooperative behavior to reach a group goal.

The present research: Social nudges toward vaccination

Innovative behavioral interventions are needed to overcome this dilemma situation. Social aspects regarding vaccination decisions have only recently gained increasing scientific attention, such as emphasizing the social benefit of vaccinations (Betsch, Böhm, Korn, & Holtmann, 2017) as well as the explanatory power of other-regarding preferences (e.g., Attari, Krantz, & Weber, 2014; Böhm, Betsch, Korn, & Holtmann, 2016; Vietri, Li, Galvani, & Chapman, 2012. However, merely knowing about the indirect societal benefit of vaccination also creates incentives to free-ride on the protection provided by the community (Betsch et al., 2013, 2017; Böhm, Betsch, & Korn, 2016).

Therefore, the present paper aims to identify novel interventions to increase an individual's concern for society's welfare, and thus, to increase prosocial vaccination. In particular, we examined whether intra- and inter-group processes and the salience of positive societal consequences of high (vs. low) vaccination rates could be harnessed to increase vaccination behavior. The current study proposes that even in the absence of additional economic incentives, the mere feedback about societal consequences may increase the willingness to get vaccinated. As such, the proposed interventions constitute "social nudges" (Thaler & Sunstein, 2008) to increase individuals' benevolence regarding the maximization of social welfare. Other types of nudging have been shown to increase vaccination intentions and behavior, for instance, changing the default option (e.g., Chapman, Li, Colby, & Yoon, 2010; Lehmann, Chapman, Franssen, Kok, & Ruiter, 2016) and fostering implementation intentions (Milkman, Beshears, Choi, Laibson, & Madrian, 2011). The following sections describe the psychological underpinnings of the two interventions in more detail and derive hypotheses.

Intra-group feedback as a symbolic reward

Goals direct attention and action, create persistence, increase effort toward related behavior, and thus facilitate the transformation from motivation into volition (Locke & Latham, 2002). As a consequence of the vaccination's indirect effect and the resulting social dilemma outlined above, there are two partly conflicting goals: maximizing the personal outcome vs. maximizing the group's outcome. That is, whereas personal interests reduce vaccination incentives with increasing vaccination rates, reaching high vaccination rates to eventually eliminate diseases represent the optimal goal from the collective perspective (Böhm, Betsch, & Korn, 2016; Fine, Eames, & Heymann, 2011). Hence, interventions that increase the salience of the collective goal might increase vaccine uptake.

A recent meta-analysis on the effect of goal-setting (Epton, Currie, & Armitage, 2017) indicates that setting group goals is an effective strategy for behavior change. Goal-setting strategies such as social framing and strategy labeling, which underline the collective instead of the individual's interest, can enhance coordination (Ellingsen, Johannesson, Mollerstrom, & Munkhammar, 2012) and cooperation (Dufwenberg, Gächter, & Hennig-Schmidt, 2011; Zhong, Loewenstein, & Murnighan, 2007). Furthermore, goal-progress monitoring is deemed to be one of the key determinants regarding goal attainment (Harkin et al., 2016). It can be understood as a feedback-loop, where an individual evaluates his or her actual state in reference to the target state, which encourages discrepancy detection and, consequentially, the adaptation of behavior (Baumeister & Heatherton, 1996; Harkin et al., 2016).

The visual feedback that goals have been reached serves as a symbolic reward. This pertains to groups and individuals alike. Rewards can be monetary or symbolic and direct behavior by increasing the future probability of the rewarded behavior (see law of effect; Thorndike, 1911). Symbolic, non-monetary rewards have been shown to improve performance toward goal-attainment in the context of work performance (Kube, Maréchal, & Puppe, 2012). A large-scale field experiment (Gallus, 2016) indicates that non-monetary rewards induce cooperative behavior in a public goods context and that those behaviors persist over time. Therefore, the present experiment used group-based non-monetary rewards to potentially improve cooperative vaccination behavior.

Moreover, rewards using gamification elements (e.g., pictures as symbols of goal-attainment) have been proven to be particularly effective (see Frey & Gallus, 2017; Oprescu, Jones, & Katsikitis, 2014). Thus, the first hypothesis posits:

H1: Rewarding the collective goal-attainment, i.e., a collectively optimal vaccination rate, with symbolic rewards leads to more cooperation, i.e., a higher vaccination rate.

Inter-group feedback to stimulate social competition

From a rational point of view, the presence of structurally independent other groups (e.g., countries) should not affect an individual's vaccination decision, since these outgroups do not affect individual outcomes (e.g., infection likelihood). Thus, citizens of one country should ignore whether or not other countries have already eliminated a disease (given none or low migration between countries). Yet, building on social identity theory (Tajfel & Turner, 1979) and self-categorization theory (Turner, Hogg, Oakes, Reicher, & Wetherell, 1987), the *inter-group comparison – intra-group cooperation hypothesis* assumes that an outgroup's performance *does* impact individual cooperation behavior regarding the ingroup (Böhm & Rockenbach, 2013). In essence, it has been argued that the mere presence of an outgroup activates a comparative focus, which instigates individuals to increase their cooperation within their own group. This is motivated by increasing the relative reputation of the own group vis-à-vis the other group (Böhm & Rockenbach, 2013). Indeed, previous studies have shown that intra-group cooperation increases when inter-group comparisons are possible (also known as pseudo-competition; Burton-Chellew & West, 2012; Böhm & Rockenbach, 2013; Tan & Bolle, 2007). Thus, it is expected that:

H2: Inter-group comparison (i.e., information about vaccination rates of another group) leads to more cooperation within the groups, i.e., a higher vaccination rate.

Inter-individual determinants of vaccine uptake

Previous studies on social dilemmas have shown that other-regarding preferences are determinants of cooperation decisions (for a meta-analysis see Balliet, Parks, & Joireman, 2009). Individuals who are more pro-socially-oriented are more inclined to cooperate whereas individuals who are more pro-self-oriented are willing to free-ride to a greater degree. It has been shown that such inter-individual differences are also important to prosocial vaccination decisions (e.g., Böhm, Betsch, & Korn, 2016). Therefore, the third hypothesis is as follows:

H3: The more pro-social an individual is, the higher is the probability to vaccinate.

Moreover, vaccination attitudes are a strong predictor of vaccination behavior (Böhm, Betsch, & Korn, 2016; Böhm, Meier, Korn, & Betsch, 2017; Schmid, Rauber, Betsch, Lidolt, & Denker, 2017) and should therefore also be positively associated with the vaccination decision in an experimental setting with sufficient external validity. Thus, it is expected that:

H4: The more positive the vaccination attitude, the higher the probability to vaccinate.

Methods

In order to adequately represent the mechanisms of individual (direct) and collective (indirect) consequences of vaccination, valid and reliable experimental approaches are required, which mirror the dynamic incentive structure of vaccination decisions. Game-theoretical approaches meet these requirements and have been proven fruitful in examining vaccination decisions and in piloting interventions aiming to increasing vaccine uptake (e.g., Attari et al., 2014; Betsch & Böhm, 2015; Böhm, et al., 2016; Böhm et al., 2017; Chapman et al., 2012). Therefore, this study uses a game-theoretical approach to model vaccination decisions. That is, the laboratory experiment used an adapted version of the interactive vaccination game (I-Vax game; Böhm, Betsch, & Korn, 2016; for details see below). It was conducted at the Laboratory for Experimental Economics (*eLab*) of the University of Erfurt using z-Tree (Fischbacher, 2007).

Ethics statement

The study included human subjects and was conducted in accordance with the guidelines of the Helsinki Declaration and the German Psychological Association. All participants gave their written informed consent to use and share their data for scientific purposes without disclosure of their identity. The experiment was conducted at a German university, where institutional review boards or committees are not mandatory.

Participants and Design

The experiment involved students from pedagogy (33.3 %), psychology (11.8%), political sciences / economics (10.8%) and other majors. The sample (N = 288; M_{age} = 22.11, SD = 2.91; 66.66 % female) was recruited via the online registration software ORSEE (Greiner, 2004) and personal recruitment on campus. The experiment implemented a 2 (*rewarding goal-attainment*: absent vs. present) × 2 (*inter-group comparison*: absent vs. present) between-subjects design. The sample size was determined based on prior experiments using repeated I-Vax games (Böhm, Betsch, & Korn, 2016; Böhm et al., 2017). Accordingly, there were 12 sessions with 24 participants each, distributed to one of two equal-sized groups, which were named blue group and yellow group. The sessions were randomly assigned to the four conditions. Eight sessions were assigned to the *inter-group comparison* condition (n = 192). The *no inter-group comparison* condition was implemented in four sessions (n = 96). The unequal distribution of the factor level implementation results from considerations concerning statistically independent observations. That is, each session in the *no inter-group comparison* condition provided two independent observations, because of the absence of informational interactions between the two groups. In the *inter-group comparison* condition, however, each session composed one independent observation resulting from the feedback intertwinement of both groups. Thus, eight independent observations were conducted in both conditions. In half of the sessions, goal-attainment was rewarded vs. not rewarded.

The I-Vax Game

The I-Vax game models vaccination behavior and its individual and collective consequences in an interactive, repeated decision setting. As depicted in Figure 1, each round in the I-Vax Game subdivides into three phases. In the decision phase, players decide in favor of or against vaccination, followed by the incubation phase, where players might experience vaccine side effects or get infected, depending on their own decision and the decisions of the other 11 group members (see below). In the payoff phase, players receive information about their own vaccination decision, the number of vaccinated members in their own group, the resulting infection probability, point loss (if any; due to side effects after vaccination or due to infection after non-vaccination), whether their group eliminated the disease in the past round, their resulting payoff in the respective round, and additional condition-dependent information detailed below. Having eliminated the disease in the past round has no influence on infection probabilities in the following round, resembling influenza, which requires an annual vaccination.

In the present experiment, the game was played over 20 rounds in groups of 12 players. In each round, players were endowed with 100 fitness points and had to decide either in favor of or against vaccination (see note below Figure 1 for details). A decision in favor of vaccination yields fixed costs of 10 fitness points, resembling costs such as the effort of obtaining the vaccine or fear of the pinprick. Additionally, vaccination side effects occur with a fixed probability of 50%. If side effects occur, they vary in their severity and probability: in 5 of 10 cases mild side effects (loss of 28 fitness points), in 4 of 10 cases medium side effects (loss of 48 fitness points), and in 1 of 10 cases severe side effects (loss of 68 fitness points) occur. In total, vaccination leads to an expected loss of 30 fitness points (including fixed costs).

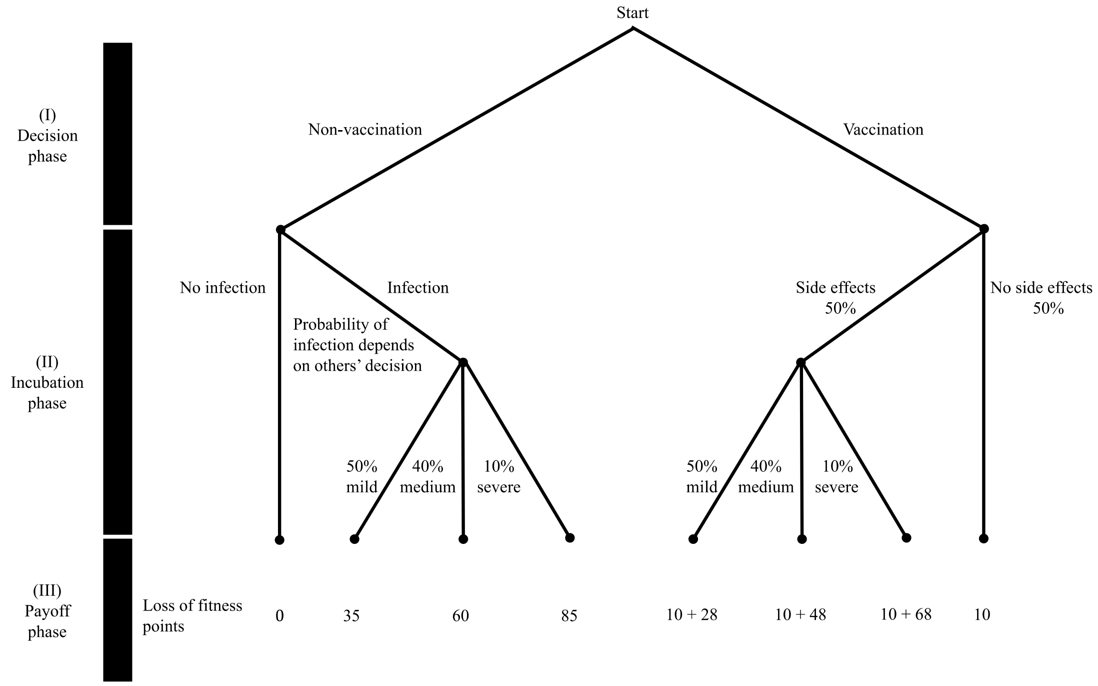

Figure 1. The I-Vax game. *Note*. The infection probability (resembles lifetime incidence; Betsch et al., 2017) results from $1 - \frac{1}{R_0(1-v)}$, where v refers to the vaccination rate in the group (ranging from 0 to 1) and R_0 denotes the basic reproduction number (in this study $R_0 = 4$) of the disease, which is a proxy for the contagiousness of the disease. If the denominator of the equation surpasses one, the infection probability is set to zero because of the non-negativity assumption of the infection probability's codomain. For a detailed mathematical formalization, see Böhm et al. (2016).

Non-vaccination yields no fixed costs. The probability of point loss due to infection varies as a function of the contagiousness of the disease and the vaccination rate within the participant's own group (see Figure 1 for epidemiologic underpinnings). In case of infection, players can experience a mild course of disease (in 5 of 10 cases, loss of 35 fitness points), medium course of disease (in 4 of 10 cases, loss of 60 fitness points), or severe course of disease (1 of 10 cases, loss of 85 fitness points). Thus, the expected average point loss in case of infection is 50 fitness points.

Consequently, the parametrization of the game implies a Nash equilibrium (Nash, 1951) at a fraction of 5 of 12 vaccinated players. Thus, when 5 of 12 players are vaccinated, no player would receive a higher personal payoff by changing the own decision unilaterally. Below this threshold, vaccination is the dominant choice. Likewise, non-vaccination is the dominant strategy when more than 5 of the 12 players are (expected to be) vaccinated. Importantly, however, the aggregated payoffs of all players are maximized when 9 players decide in favor of vaccination and the probability of infection becomes zero. This constitutes the social welfare optimum. Therefore, between 5/12 and 9/12 vaccinated players the I-Vax game resembles a social dilemma where individual incentives are at odds with the collective optimum.

Independent variables

Rewarding goal-attainment. This manipulation was realized in the payoff phase of the game. While all participants received information about whether their group had eliminated the disease in the past round, only players in the *rewarding goal-attainment* condition obtained badges as an additional symbolic reward of the elimination history of the disease (see Figure 2-A). Colored stars were used as badges to reward infection elimination. The color of the star depended on the group membership of the player – yellow-group players received yellow stars, blue-group players received blue ones. When the group failed to eliminate the disease, a gray star was presented. Participants in the *no reward* condition received only verbal information (e.g., in the case of disease elimination: "In the current round, the disease was eliminated in your group.").

Figure 2. Rewarding goal-attainment. *Note.* Panel A depicts the yellow group's reward for eliminating the disease in the first round of the game. Panel B depicts the perspective of a member of group "yellow" after playing two rounds. While both groups eliminated the disease in the first round of the game, only group "yellow" received a reward for reaching the social optimum and eliminating the disease in the second round.

Inter-group comparison. Participants in the inter-group comparison condition received additional information about the other group's vaccination behavior while the other individuals did not receive this information. In the *inter-group comparison* condition, participants learned about the number of vaccinated individuals in the other group, the resulting infection probability, and whether or not the other group had eliminated the disease in the past round. Depending on condition, the latter information was either presented as simple text in the *no reward* condition or additionally displayed by means of the star-badges for the other group (see Figure 2-B) in the *rewarding goal-attainment* condition.

Measures

Dependent variable. The vaccination decision in each round of the I-Vax game serves as the main dependent variable (0 = non-vaccination, 1 = vaccination).

Social value orientation. Social Value Orientation measures an individual's preferences for another individual's outcome in relation to her own outcome (Murphy, Ackermann, & Handgraaf, 2011). Hence, it provides a measure for an individual's basic level of pro-sociality. The measure contains six decision tasks, where a participant has to allocate points from the perspective of the sender between him- or herself and an unknown participant (receiver). The responses to the six items yield a single index of a participant's social value orientation, with higher values indicating higher pro-sociality. In this experiment, the social value orientation measurement was realized with the z-Tree implementation by Crosetto, Weisel, & Winter (2012) of the paper-based SVO slider measure (Murphy et al., 2011).

Vaccination attitude. The attitude toward vaccination was measured with 3 items (α_{Cron} = .87, e.g., "It is a good idea to get vaccinated", Askelson et al., 2010) on a 7-point Likert-type scale ranging from 1= *I totally disagree* to 7= *I totally agree.*

Procedure

At first, participants were randomly assigned to one of 24 cubicles and received printed instructions on general information regarding laboratory experiments, including the conversion rate in the experiment (100 points = 0.75 Euro). Additionally, participants received the instructions of the social value orientation slider measure. All instructions were read aloud by the same instructor and participants could ask questions before they started working on the tasks. After completing the social value orientation slider measure, the I-Vax game instructions were read aloud to the participants. They had to pass a comprehension test prior to playing the game. Those who did not answer the questions correctly were instructed again by the experimenter to ensure task-comprehension. After playing the I-Vax game, participants answered the post-experimental questionnaire assessing vaccination attitude, age, and gender. Finally, participants were informed about their individual payoff, and privately disbursed. On average, participants earned 12.13 Euro (*SD* = 0.20 Euro) for a mean duration of approximately 70 minutes, which also included another unrelated experimental task documented elsewhere (Korn, Betsch, Böhm, & Meier, 2017).[1]

Data analysis procedure

Data and analysis script are available via the Open Science Framework (osf.io/5pjk6). Mixed effects regression analyses with logit link and BOBYQA optimization (Powell, 2009) were applied to estimate the fixed effects on individual vaccination behavior in the I-Vax game. Since the feedback after each round was provided to all group members and the treatments were allotted session-wise, random effects of the subject, group, and session were considered. Additionally, round number was included as a fixed factor to capture changes in vaccine uptake in the I-Vax game over time. For estimation of the generalized linear mixed models, the R-environment and the lme4 package (Bates, Maechler, Bolker, & Walker, 2016; R Development Core Team, 2008) were used. In order to obtain the average effects of the independent variables, the factors of the interventions were effect-coded (-.5 and .5), and vaccination attitude as well as social value orientation were centered at the mean. The variable round indicates the time of measurement and was centered to the value of two in order to estimate the effects of the interventions at the round when the intervention feedback was shown first.[2] An alpha level of .05 for all analyses was applied.

[1] The additional task was conducted at the end of the experiment and did therefore not affect measures in the present experiment.

[2] Note that the reported results represent the effect at the beginning of the interventions, i.e., after round one. When centering round at its mean to determine the effects of the interventions at the hypothetical round 10.5 of the game, the interaction effect between round and rewarding goal-attainment remains statistically significant (b = -.03, p = .026). However, there is no effect of rewarding goal attainment (b = .25, p = .202) as well as no effect of inter-group comparison (b = .09, p = .648). This provides further evidence that the rewarding goal attainment condition had its strongest impact on vaccine uptake in the I-Vax game at the beginning of the intervention.

Results

Vaccination rates

The vaccination rate in the I-Vax game (percentage of all vaccinated individuals, aggregated over all 20 rounds at the respective level of independent observations; see above) was Mdn_{reward} = .52 (M_{reward} = .53 [SD = .04]) in the rewarding goal-attainment condition and Mdn_{no_reward} = .48 ($M_{no\ reward}$ = .49 [SD = .06]) in the condition without reward. Information about the outgroup's performance resulted in a vaccination rate in the I-Vax game of $Mdn_{comparison}$ = .51 ($M_{comparison}$ = .52 [SD = .05]), no information about the out-group's performance led to a vaccination rate of $Mdn_{no\_comparison}$ = .50 ($M_{no\_comparison}$ = .50 [SD = .05]).

The number of disease eradications in the I-Vax game during the experiment was Mdn_{reward} = 1.75 (M_{reward} = 1.62 [SD = 1.27]) in the rewarding goal-attainment and Mdn_{no_reward} = 1.00 (M_{no_reward} = 1.12 [SD = 1.13]) in the condition without reward. Information about the out-group's performance led to $Mdn_{comparison}$ = 1.75 ($M_{comparison}$ = 1.50 [SD = 1.16]) disease eradications in the I-Vax game, no information about the out-group's performance led to $Mdn_{no\_comparison}$ = 1.00 ($M_{no\_comparison}$ = 1.25 [SD = 1.28]) disease eradications.

Analysis of individual vaccination behavior

Figure 3 visualizes the results; Table 1 shows the regression coefficients of the treatments, round number, and their interaction terms, as well as the control variables.[3]

[3] Omitting the interaction between the manipulated factors from the analysis leads to similar results. Rewarding goal attainment tend to increase vaccination probability in the I-VAX game (qualified by an interaction with round), even when controlling for vaccination attitude and social value orientation.

Predictor	Model 1				Model 2			
	B	*SE*	*p*	*OR*	*B*	*SE*	*p*	*OR*
Intercept	.22	.11	.048	1.25	.20	.10	.034	1.22
Round (A)	-.02	.01	.001	.98	-.02	.01	.001	.98
Rewarding goal-attainment (B)	.46	.22	.034	1.58	.39	.19	.040	1.48
Inter-group comparison (C)	.16	.22	.471	1.17	.21	.19	.273	1.23
A*B	-.03	.01	.026	.97	-.03	.01	.026	.97
A*C	-.01	.01	.480	.99	-.01	.01	.497	.99
B*C	-.46	.44	.290	.63	-.27	.38	.486	.76
A*B*C	.02	.02	.488	1.02	.02	.02	.474	1.02
Social value orientation					.02	.01	.004	1.02
Vaccination attitude					.55	.05	<.001	1.73
ML model fit: AIC / BIC	6855.3 / 6928.6				6759.0 / 6845.5			

Table 1. Mixed effects models predicting decision in favor of vaccination by the interventions and round, its interactions and the control variables. *Note.* N = 288. Mixed effects model (prediction of vaccination decisions [0,1]): Subjects, groups, and session treated as random effect. Since both experimental factors are feedback manipulations, round = 2 was set as the reference level to estimate the effects at the beginning of the experiment. Effect coding was used for both interventions. Inter-group comparison: -.5 = absent, .5 = present. Rewarding goal-attainment: -.5 = absent, .5 = present. Vaccination attitude and social value orientation were centered at their mean (M_{attitude}= 4.83, M_{SVO} = 28.74).

Model 1 shows a significant effect of *rewarding goal-attainment* on vaccine uptake in the I-Vax game and therefore provides support for H1. Round affected vaccination behavior negatively, indicating a decrease of vaccination behavior as the game progresses. Furthermore, the effect of *rewarding goal-attainment* was qualified by a significant interaction effect of reward and round (A*B). This indicates that *rewarding goal-attainment* indeed increased vaccine uptake in the I-Vax game, but that this effect declined over the course of the game. The *inter-group comparison* intervention has no significant effect on vaccine uptake, rejecting H2.

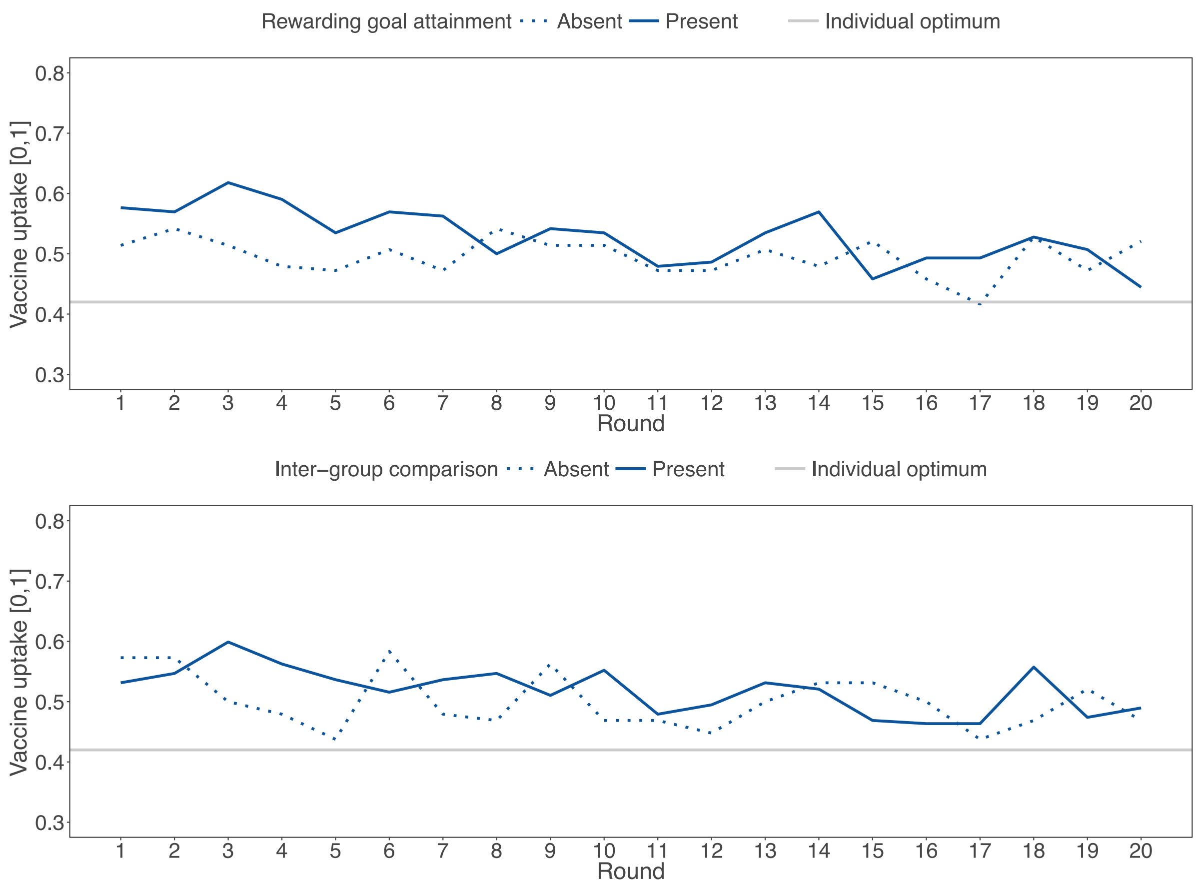

Figure 3. Development of the vaccination rates over the 20 rounds of the game, separately for the two interventions. *Note*. Panel A shows vaccine uptake as a function of rewarding goal-attainment and illustrates that the effect declines over the rounds. Panel B depicts mean vaccine uptake as a function of inter-group comparison.

In order to test H3 and H4, Model 2 additionally controlled for social value orientation and attitude toward vaccination. The individual SVO scores varied between -11.84° and 52.79° (M_{SVO} = 28.74°, *SD* = 12.18). Thus, according to Murphy and colleagues' (2011) taxonomy, 216 participants (75 %) were classified as pro-social and 72 participants (25 %) were classified as pro-self. The mean attitude toward vaccination was 4.83 (*SD* = 1.49).

Model 2 shows that the main effect of *rewarding goal-attainment* weakens but remains significant. Again, round had a negative effect on vaccination behavior in the I-Vax game. Also, the interaction effect of *rewarding goal-attainment* and round remains stable in Model 2. As in Model 1, there was no significant effect of *inter-group comparison*.[4] Furthermore, there were significant positive effects for social value orientation and vaccination

[4] The additional information on the outgroup's vaccination rate in the *inter-group comparison* condition can be considered as descriptive norm. Usually, descriptive norms are positively correlated with intentions and behavior (Rivis & Sheeran, 2003). Therefore, it is useful to examine whether individuals are more inclined to vaccinate when their in-group outperforms the outgroup (see Böhm & Rockenbach, 2013). However, regressing vaccination behavior on the relative performance of the in-group compared to the out-group (dummy coded 0 = in-group's vaccination rate is lower, 1 = in-group's vaccination rate is higher) on vaccination behavior revealed that this was no significant predictor. This provides further support that inter-group comparisons were not a major determinant of individuals' vaccine uptake.

attitude. The higher the pro-sociality and the more positive the vaccination attitude, the higher the probability of vaccination in the I-Vax game, providing evidence for both H3 and H4 and replicating results from previous experiments (Böhm, Betsch, & Korn, 2016; Böhm et al., 2017).

Discussion

The present data show that social nudges aiming to activate intra- and inter-group processes can be fruitful and effective methods of promoting vaccine uptake, as suggested by individual vaccination behavior in an interactive vaccination game (I-Vax game; Böhm, Betsch, & Korn, 2016). In particular, the experiment provides evidence that symbolically rewarding the attainment of the social goal of disease elimination is an effective strategy to increase vaccine uptake in the I-Vax game. This intervention puts insights from (group) goal-setting theory and goal-progress monitoring into practice. As this intervention loses its impact over time, an overuse of this strategy should probably be avoided. Future work should therefore test whether time lags or intermittent rewards boost the effectiveness of this strategy. Yet, having seen the visualizations in a very short period of time could lead to a greater decline in effectiveness as it would occur when feedback is available only once a year (e.g., in the case of influenza vaccination). Moreover, groups which eliminated the disease in a particular round of the game were confronted with a similar disease in the following rounds in order to ensure repeated measurements. This circumstance is quite artificial and could lead to an overestimation of the interaction between time and rewarding the attainment of goals.

The current study used a group goal (disease elimination) to increase vaccine uptake in the I-Vax game. One could argue that an individual goal of infection avoidance could be an equally effective intervention to boost vaccine uptake. However, groups goals have been shown to be more effective than individual goals in some contexts (Epton et al., 2017). Moreover, rewarding the individual goal of avoiding infection could also create an incentive to free-ride, which contrasts with the collective goal of disease elimination. Thus, both vaccination (direct self-protection) and non-vaccination (free-riding on others' indirect protection due to herd immunity) can be means to achieve the individual goal of avoiding infections. Therefore, we argue that rewarding the collective goal of disease elimination is likely to be a more effective intervention to increase vaccination rates. Nevertheless, future research should compare both kinds of goal reward.

The results regarding rewarding goal-attainment provide insights for revising existing communication strategies. WHO's Regional office for Europe (2016), for example, published an infographic about the current status of measles and rubella elimination in Europe. It displays information about countries that are already measles/rubella-free, that interrupted its circulation, or where the disease is still endemic. This information is displayed in an aggregated way, showing the total number of European countries in the different categories. While this may work in a comparison between different WHO regions (as this involves comparison), feedback to the countries *within* the WHO European region would probably benefit from a revision of the graph. Given the results of this experiment, naming the countries may be more effective.

Although provision of *inter-group comparison* in vaccination rates did increase the likelihood of vaccination in the I-Vax game (odds ratio around 1.2), the effect was too small to reach conventional criteria of statistical significance. Several reasons for this finding are possible. For example, higher rates of cooperation in inter-group contexts result from striving for positive distinctiveness and group identity (Böhm & Rockenbach, 2013). Previous research suggests that group identity has a positive effect on cooperation in social dilemma situations (Jackson, 2011). The present experiment used the minimal group paradigm, i.e., allocation of individuals to the groups based on chance. Chowdhury, Jeon, and Ramalingam (2016) showed that cooperation increases when a natural group identity is salient compared to when a minimal group identity is salient. Future research should therefore assess the possible moderating effect of nature of group identity, and include procedures to investigate the effect of pseudo-competitive public goods among natural groups. Moreover, information that an outgroup is well vaccinated could also lead to the opposite effect when individuals assume that there is exchange between the two respective groups. In this case, high vaccination rates of an outgroup can lead to lower willingness to vaccinate (Korn et al., 2017) because they contribute to herd immunity of one's own group and lower the personal infection probability. Therefore, migration between groups (such as extensive traveling or refugee migration) threatens the success of an intervention relying on inter-group competition, which would be an interesting avenue for future research.

The issue of vaccine hesitancy has recently led to debates about mandatory vaccinations and cumulated in the broadening of laws for compulsory vaccinations, for example in Italy (Signorelli, Iannazzo, & Odone, 2018) and France (Yang & Rubinstein Reiss, 2018). These regulations may work for the vaccines that are made compulsory; however, they can also threaten vaccination programs by reducing the willingness to receive vaccines that are not included in the compulsory schedule. Betsch and Böhm (2016) demonstrated that restricting the freedom of choice by partial compulsory vaccinations invokes reactance and increases the inclination to regain this freedom by refusing subsequent non-compulsory vaccinations. The present work suggests that strategies that use social nudges may be suitable to increase vaccine uptake without restricting the freedom of choice or using additional financial incentives.

Limitations and Outlook

This study has some limitations. First, study participants did not receive real vaccinations but the study examined vaccination decisions in a controlled, incentivized laboratory experiment. Considering that hypothetical vaccination intentions correspond only moderately with behavior (Sheeran, 2002), we argue that incentivized behavior in laboratory experiments is a better proxy for real-world vaccination behavior than mere intentions (see Böhm, Betsch, & Korn, 2016). Consequently, the I-Vax game can serve as an instrument to pilot interventions in a controlled setting and in a cost-effective way. Thus, interventions that have been shown to be successful in the context of the I-Vax game should be tested in future (field) studies. In a similar vein, real-world vaccinations are affected by numerous other influences that were excluded or controlled for in the present experiment. Therefore, it is important to adapt and replicate the present study in the context of real-world vaccinations.

Second, the current experiment recruited a student sample. Due to their homogeneity regarding certain aspects (e.g., education), student samples may be criticized for endangering the generalization to non-student populations (Gallander Wintre, North, & Sugar, 2001). However, the theories applied and tested in the present experiment, i.e., Social Identity Theory and Goal-Setting Theory, do not rely on specific sub-populations. Instead, they are assumed to describe basic psychological processes. Therefore, we argue that a student sample does not pose a serious threat to the study's external validity (Peterson & Merunka, 2014). Nevertheless, testing the validity of the findings in non-student populations is an important step for future research.

Third, participants' attitude toward vaccination was measured at the end of the experiment. Therefore, it is possible that experiences during the experimental game altered these attitudes. However, a regression analysis with vaccination attitude as dependent variable and the two experimental factors and their interaction as independent variables revealed that rewarding goal-attainment as well as inter-group comparison had no significant effect on vaccination attitudes.

Fourth, both interventions do not change economic incentives of the game and are therefore considered as social nudges. However, in reality, symbolic rewards can directly or indirectly affect economic incentives. In this way, symbolic rewards could have an impact on, for example, the reputation of the individual within a group. This can result in, for instance, social exclusion of the individual if the symbolic reward was not obtained by the individual, or in subsequent material benefits if the reward was obtained. These externalities were explicitly excluded in the present experiment. Consequently, it could be argued that the effects of the two interventions are rather underestimated in the experiment.

Lastly, in our experiment, rewarding goal-attainment increased an individual's likelihood to get vaccinated by 48% (Table 1; OR = 1.48), which can be considered a small effect.

It can be argued that interventions that base on this result may lead only to small behavioral change. However, it should be noted that in the medical field also small effects are of major importance (Rosenthal, 1991) as the events that may be prevented (disease, death) are serious and therefore a change in its probability of occurrence matters. In this regard, even small effects should inform interventions to increase the protection against severe infectious diseases and their spreading in the population. Interventions should further build on several concepts and use several angles and levers to increase prevention behavior. Thus, even interventions that, taken by themselves, have small effects, can contribute to change behavior when combined to a complex intervention (Petticrew, 2011). Behavioral insights therefore deliver building blocks for interventions rather than silver bullets.

Conclusion

Controlling and eliminating diseases are global goals of utmost importance. In order to achieve these goals, effective and evidence-based communication strategies are necessary. The current experiment shows that in infection control, “small wins” in the process of goal-attainment should also be rewarded. Thus, the results provide evidence for the potential – and some challenges – of social nudges in promoting vaccine uptake.

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Article 2 – original version

Drawbacks of communicating refugee vaccination rates

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Drawbacks of communicating refugee vaccination rates

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Drawbacks of communicating refugee vaccination rates

In their topical perspective, Kahn et al.[1] point out that the influx of migrants is often perceived as a health threat by host countries leading to discrimination against refugees. To prevent discrimination, the authors recommend debunking misconceptions about disease risks. While we agree that measures to decrease discrimination are crucial, we argue that communicating refugees' high vaccination uptake can have detrimental effects on the host population's prevention behaviour.

Most vaccinations provide, beyond individual protection of the vaccinated individual, a social benefit by reducing the transmission of pathogens and the risk of infection.[2,3] From an individual perspective, the utility of vaccination thus decreases the higher the vaccination uptake in society. Eventually, vaccination can even turn out to be irrational from a selfish-rational viewpoint, when subjectively perceived vaccination risks surpass the perceived disease risks.[3] However, from a societal perspective, vaccination is required also when uptake is already high to allow elimination of diseases.[2]

This conjecture leads to the hypothesis that knowledge about high vaccine uptake in the refugee population can have detrimental effects on the host population's vaccination behaviour. This was tested using an interactive vaccination game[3] detailed in the supplement. Participants (representing the host population) received information about a hypothetical influx of refugees and their vaccination uptake (clustered as low, medium, high, and no information in Figure 1). Participants subsequently indicated their vaccination decision for each situation.

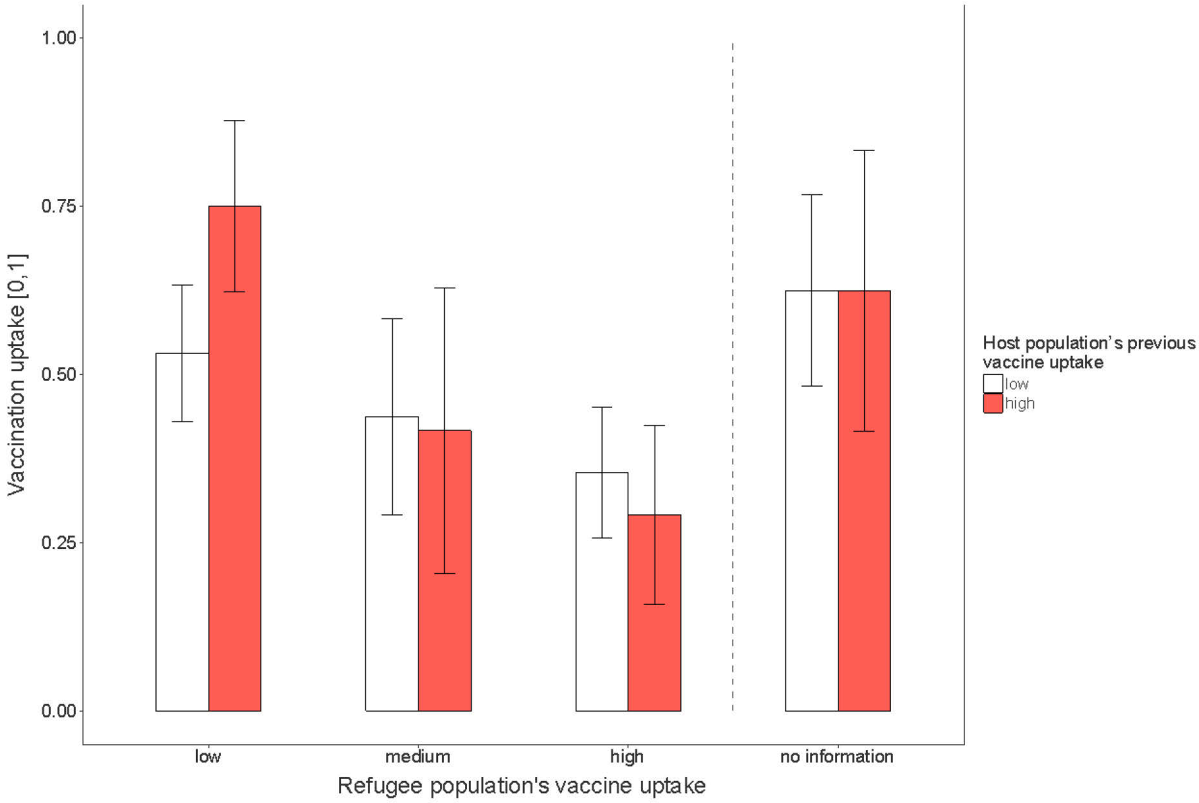

Figure 4. N= 96. Mean vaccination uptake in an interactive vaccination game as a function of the host population's previous vaccine uptake (low, high) and the refugee population's vaccine uptake (low, medium, high). Error bars represent 95% CIs. See online supplement for statistical analysis. Data available at [4]

Figure 1 shows that vaccination behaviour in the host population declined with increasing refugee vaccine uptake (for statistics, see supplement). In host populations with high (vs. low) uptake in the previous rounds of the game, vaccination willingness decreased more strongly. In uncertainty (no information), vaccination behaviour was similar compared to the high-risk situation. In general, the host population was significantly less willing to vaccinate when information about the refugee population's vaccine uptake was available (vs. absent).

The experiment shows that communicating refugees' vaccination status can have detrimental effects, especially when both the vaccine uptake of refugees and the host population's vaccine rate are high. This effect may increase with higher refugee influx.[1] Health officials and society as a whole must undoubtedly combat prejudice and discrimination against refugees by debunking misinformation. Regarding vaccine uptake, however, debunking should be complemented with communication measures aimed at preventing free-riding behaviour.

Communicating the social benefit of vaccinations is a potential remedy.[5] Only then will it be possible to pursue both goals at once: fighting discrimination *and* infectious diseases.

Declaration of interests

The authors declare no competing interests.

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Article 2 – extended version

Drawbacks of communicating refugee vaccination rates

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Drawbacks of communicating refugee vaccination rates

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Abstract

Objective. Refugees and migrants are subject to health-related prejudice as they are assumed to have a poor health status. The evidence, however, contradicts this perception and shows that migrants and refugees are often in good health. Therefore, it was argued that the communication of the good-to-excellent health status of this population could be useful to reduce prejudice toward them. However, there may be exceptions to this notion. Most vaccines provide indirect community protection by preventing transmission of the disease. Therefore, communicating the good health status of migrants and refugees could actually have detrimental effects on the vaccination behavior of members of the host population in terms of its free riding when assuming protection by others' vaccination behavior. The current experiment investigated whether the communication of the refugee's health status hampers vaccination behavior among members of the host population.

Methods. In a laboratory experiment, the interactive vaccination (I-Vax) game was used to model the direct and indirect effects of vaccinations. The game was played by 96 participants over 20 rounds. The experimental setup varied the feedback information after each round to implement a 3 (*host population's previous vaccine uptake*: 0 vs. 3 vs. 4, between) × 6 (*refugee population's vaccine uptake*: 0 vs. 5 vs. 10 vs. 15 vs. 20 vs. no information, within) quasi-experimental mixed design.

Results. As hypothesized, the communication of the refugee's health status hampers vaccination behavior among members of the host population. More specifically, vaccination behavior in the host population declined with increasing refugee vaccine uptake. Moreover, this effect was more pronounced among host populations with higher previous vaccination uptake. When no information about the refugees' vaccine uptake was present, the respondents acted as if this uptake was low, providing evidence that health-related prejudice exists toward refugees.

Conclusions. Health officials and society as a whole must undoubtedly combat prejudice and discrimination against refugees by debunking misinformation around their health. Regarding vaccine uptake, however, this debunking should be complemented with communication measures aimed at preventing free-riding behavior. Only then it will be possible to pursue both goals at once: fighting discrimination *and* infectious diseases.

Keywords: vaccine decision-making, game theory, migration, prejudice

Drawbacks of communicating refugee vaccination rates

Modern Western societies are undergoing a process of transformation toward more diversity, with migration playing a significant role in this process. Globally, it is estimated that around 244–258 million individuals are currently migrating within or between nations, seeking physical as well as economic safety (Aldridge et al., 2018; Juang et al., 2018).

Despite the countermeasures host communities implement, migrants continue to experience implicit as well as explicit discrimination (Fozdar & Torezani, 2008; Lynott et al., 2019), especially in the contexts of the workplace and the legal, health care, and education systems (Grimm & Klimm, 2018; Wood & Miller, 2016).

Stereotypes and prejudices play a major role in social processes and discrimination. Stereotypes reduce the complexity of a social situation (Fiske, 1998) — for example, if a person or group is unknown, stereotypes serve as an orientation to that "other" (Kite & Whitley, 2016). However, these generalizing, socially shared characterizations of other people based on their group membership are often non-neutral and function as prejudice (Kessler & Fritsche, 2018; Kite & Whitley, 2016). Since prejudices can influence group-related behavioral intentions (Wagner, Christ, & Pettigrew, 2008) and behavior (Bodenhausen & Richeson, 2010; Dovidio, Kawakami, & Gaertner, 2002), reducing them is of the utmost importance.

In their topical perspective, Kahn et al. (2016) pointed out that host countries often perceive the influx of migrants and refugees as a health threat and therefore tend to discriminate against these groups. However, evidence suggests that the perception of a health threat posed by this population is not correct. For example, on average, migrants have a lower mortality rate than individuals of the host community (Aldridge et al., 2018; Shai & Rosenwaike, 1987) and do not pose a health threat for the host population in terms of infectious diseases (Abbas et al., 2018).

To prevent discrimination and health-based prejudice toward refugees and migrants, Khan et al. (2016) recommended debunking these misconceptions. They argued that "[the small] risk level needs to be effectively communicated to both host communities and the in-coming refugees" (p. 3). However, a corrective intervention based on information of the health status of refugees is questionable from two perspectives.

First, there is inconclusive evidence whether providing facts and evidence can reduce prejudices. On the one hand, previous research has shown that corrective information can lead to lower levels of prejudice (Mansouri & Vergani, 2018; Moritz et al., 2017; Pettigrew & Tropp, 2008). On the other hand, however, there is evidence that corrective information about a group is likely to be ignored and devalued, and therefore does not lead to the desired reduction of prejudice (for an overview see, Stangor, 2016).

Secondly, from a health psychological and behavioral economic perspective, communicating the good-to-excellent health and vaccination status of migrants and refugees can have detrimental effects on the host population's prevention behavior in terms of their vaccine uptake.

The following section provides a more detailed examination of this argumentation and states the hypothesis.

Vaccination as strategic interaction

Vaccination decisions are typically conceptualized as individual decision-making tasks in which an individual weighs the risks of the disease against the risks of the vaccine (Weinstein, 2000). In this context, risk is understood as a conglomerate of the severity of the negative consequences (such as contracting the disease or experiencing adverse events) and the probability of them occurring (Brewer et al., 2007). If the risks of the disease exceed those of the vaccination, a rational decision-maker should opt for vaccination. In the opposite case, from a normative perspective, a decision should be made against vaccination. However, the risks of the disease are subject to collective dynamics. Besides the individual protection of the vaccinated individual, most vaccinations provide a social benefit by reducing the transmission of pathogens and the risk of infection (Anderson & May, 1985; Böhm, Betsch, & Korn, 2016). From an individual perspective, the value of vaccination thus decreases the higher the vaccination uptake in society and vice versa. At the same time, the risk of vaccine adverse events remains constant; in other words, the vaccination rate in the community does not affect the probability of adverse events.

This mechanism may result in the case where vaccination is seen as irrational from a selfish-rational viewpoint, when the subjectively perceived vaccination risks surpass the perceived disease risks (Böhm et al., 2016). However, from a societal perspective, vaccination is still required even when the vaccine uptake is already high in order to eliminate diseases (Anderson & May, 1985). Thus, vaccination can pose a social dilemma in which individual and collective interests are in conflict.

Assuming that the social interaction or strategic aspects of vaccination are known and salient by the decision-maker, communicating the good-to-excellent health status of refugees can actually have a diametrical impact on the vaccination rate in the population. From a rational perspective, a decision-maker should consider the vaccination status of refugees. That is, this individual should update the infection probability of the disease according to the health information provided (i.e., vaccination rate) and, if necessary, decide against or in favor of vaccination.

Accordingly, it can be hypothesized: *Information about high vaccine uptake in the refugee population has a negative effect on the host population's vaccination behavior. The higher the vaccine uptake in the refugee population, the lower the probability of individuals in the host community being vaccinated.*

Moreover, previous research in the field of health communication showed that individuals hold default beliefs regarding non-vaccinated others (Böhm, Meier, Groß, Korn, & Betsch, 2019). To be specific, when no additional information is provided, individuals tend to assume that the non-vaccination status of another individual is a result of a deliberate decision and are consequently less willing to protect those non-vaccinated others, compared to when information is provided that non-vaccinators are not responsible for their health status.

Likewise, as mentioned earlier, there are prejudices against migrants and refugees. Assuming that these prejudices also relate to health status and vaccine uptake, in particular, individuals who are confronted with an influx of migrants and do not receive health information about this population should decide as if they received information about the poor vaccine uptake among the refugees. Thus, it will be explored whether individuals' vaccination decisions differ when no information about the vaccination rate in the refugee group is provided vs. when the vaccination rate in the refugee group is low.

In order to adequately represent the mechanisms of the individual (direct) and collective (indirect) consequences of vaccination, valid and reliable experimental approaches that mirror the dynamic incentive structure of vaccination decision are required. Game-theoretical approaches meet these requirements and have been proven fruitful in examining vaccination decisions and in piloting interventions aimed at increasing vaccine uptake (e.g., Attari et al., 2014; Betsch & Böhm, 2015; Böhm, et al., 2016; Böhm et al., 2017; Chapman et al., 2012). Therefore, this study uses a game-theoretical approach, the I-Vax game (Böhm, Betsch, & Korn, 2016; for details see below), to model vaccination decisions and test the above hypotheses.

Methods

Ethics statement

The studies included human subjects and were conducted in accordance with the guidelines of the German Psychological Association. The studies did not involve deception. All participants gave written informed consent to use and share their data for scientific purposes without disclosure of their identity. The experiment was conducted at a German university, where institutional review boards or committees are not mandatory. The research contained negligible risks as there is no more foreseeable risk of harm or discomfort than potential inconvenience during participation; all participants were free to quit the study at any time without any consequences.

Participants

The experiment was conducted at the Erfurt Laboratory for Experimental Economics (eLab), University of Erfurt in Germany. There were four sessions, each with two groups ($N = 96$). The participants were 30 male and 66 female students from the University of Erfurt ($M = 22.02$ years, $SD = 2.91$).

The I-Vax game

The I-Vax game considers the epidemiological principles of disease transmission and models the direct and indirect effects of vaccinations. The game was played over 20 rounds in groups of 12 players. In each round, the players were endowed with fitness points, which were converted into money after the experiment. Moreover, they also decided if they wanted to be vaccinated. The exact parametrization of the game is documented elsewhere (see Supplement of original article, see also Korn, Betsch, Böhm, & Meier, 2018). The game implied a Nash equilibrium (Nash, 1951) at a vaccination rate of 41.7%, where no player has an incentive to change his or her decision unilaterally. Collective payoffs are maximized (social welfare optimum) when 75% of the players decide in favor of vaccination, because then the disease is eliminated. Therefore, between 41.7% and 75% vaccinated players in the I-Vax game resembles a social dilemma in which individual incentives are at odds with the collective optimum.

Manipulation

The study implemented a two-factorial, quasi-experimental mixed design. First, the participants played the I-Vax game over 20 rounds. The number of rounds in which the participants were able to eradicate the disease serves as a (between-subjects, quasi-experimental) proxy for the host population's previous vaccine uptake. Second, the participants received vignettes explaining that three players from a third, fictitious other group (named the "purple group"– in the manuscript described as refugees) replaced three players of the participant's group. Within the six vignettes, participants also received information regarding the other group's performance in eradicating the disease, which served as a proxy for refugees' vaccine uptake (within-subjects; 0, 5, 10, 15, 20, no information). Finally, they had to decide in favor of or against vaccination (0 = non-vaccination, 1 = vaccination) for each of the vignettes, given the respective refugees' vaccine uptake. These decisions were not relevant for participants' payoffs.

Procedure

The experiment was conducted in the lab, implemented with the software z-Tree (Fischbacher, 2007). Recruitment of the participants was realized via the online registration software ORSEE (Greiner, 2004) and additional individual recruiting. Upon arrival in the lab, participants were randomly assigned to one of 24 cubicles. All payoffs of the experiment were determined in health points and converted into euros at the end of the experiment (conversion rate: 100 points = 0.75 euros). On average, participants earned 11 euros for participating in the I-Vax Game (*SD* = 0.84 euros). The whole session took about 75 minutes.

First, the participants were randomly allocated to one of two structurally-independent, equal-sized groups (named as yellow and blue). Then they received printed instructions on general information regarding laboratory experiments; the rules of the I-Vax game, complemented by two examples; and instructions regarding the focal vaccination decisions given varying refugees' vaccine uptake. The instructions were read aloud, and the participants were allowed to ask questions. The participants had to pass a comprehension test prior to playing the I-Vax game. Each round of the game consisted of three phases: the *decision phase*, in which players decided in favor of or against vaccination; the *outbreak phase*, in which players might get infected depending on their own decision and the decisions of the other 11 group members; and the *feedback phase*, in which players learned, inter alia, about the status of the disease eradication in their own group, which served as a proxy for the host population's previous vaccine uptake in this experiment.

After completion of the I-Vax game, the participants were presented with the focal refugee scenario and indicated their six decisions contingent on the varying histories of disease eradication in the refugee population.

Finally, they answered questions regarding demographics, were informed about their individual payoffs, and privately received their earnings.

Data analysis procedure

The data are available via the Open Science Framework (OSF, osf.io/q82q5). Logistic regression analyses with logit link were applied to estimate the fixed effects. Furthermore, in order to adequately consider refugees' vaccine uptake as a six-step within-subjects factor, the random effects of the subject were taken into account. Thus, the generalized linear mixed models in Table 1 had the following form:

$$L(a = 1) \sim fixed\ effects + (1|subject) + \varepsilon$$

The R-environment (R Core Team, 2019) was used as statistical environment. Analyses were conducted with the lme4 package (Bates, Maechler, Bolker, & Walker, 2016). The visualization was created with the ggplot2 package (Wickham, 2016). Although the hypothesis proposed was directional, conservative two-sided tests were used and an alpha level of .05 for the analysis was applied.

Results

Main analysis

Table 1 and Figure 1 show the results. The first model predicted vaccination decisions with historical vaccine uptake of the host population (in-group), refugees' previous vaccine uptake, and their interaction as predictors. Note that the control group (no information) was excluded in Model 1 in order to be able to treat the refugees' vaccine uptake as a metric predictor. In accordance with Hypothesis 1, Model 1 demonstrates that participants actually consider the health status of the refugees when making a vaccination decision. That is, the vaccination behavior in the host population declined with increasing refugee vaccine uptake as indicated by the main effect of the refugees' vaccine uptake (A). This effect provides evidence for the first hypothesis.

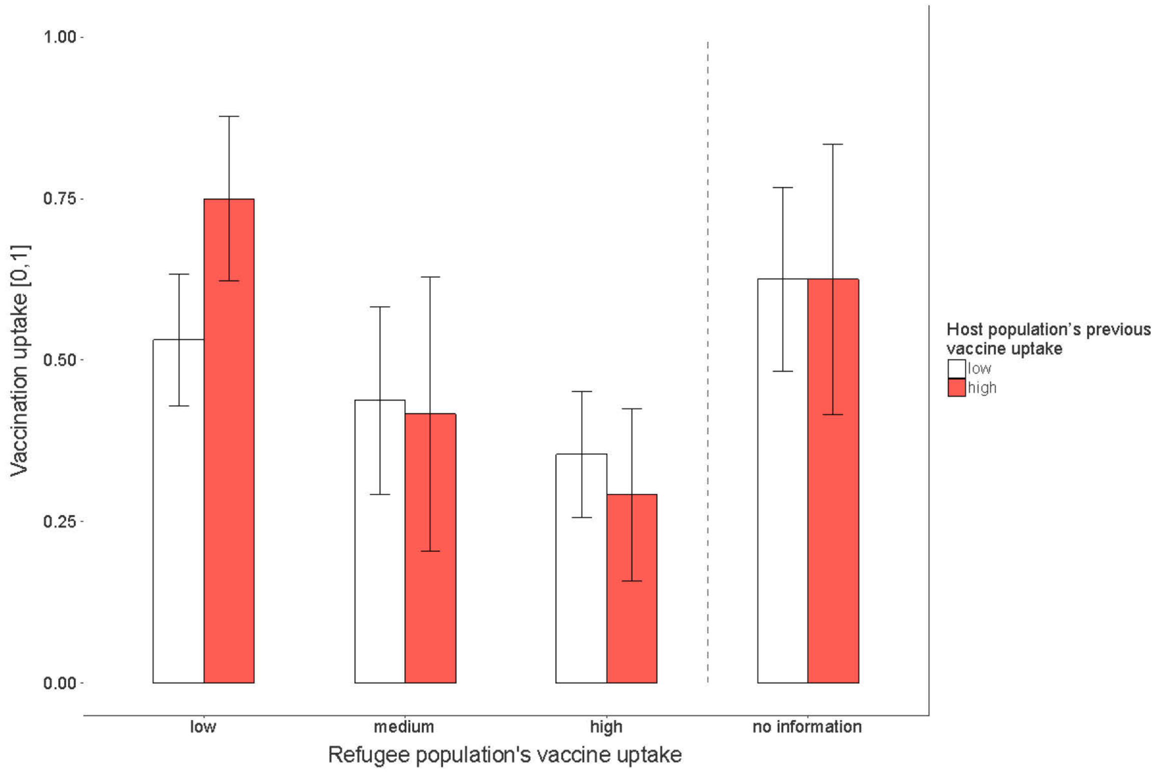

Figure 5. Mean vaccination uptake in an interactive vaccination game as a function of the host population's previous vaccine uptake (low, high) and the refugee population's vaccine uptake (low, medium, high). Error bars represent 95% CIs.

Moreover, individuals from populations with historically high vaccination rates tend to be more inclined to be vaccinated (B). However, this effect did not reach the conventional criteria of statistical significance.

The effect of the refugees' vaccine uptake (A) on an individual's vaccination behavior was qualified by a significant interaction with the historical vaccination rate in the host community (A*B). In host populations with high (vs. low) uptake in the previous rounds of the game, vaccination willingness decreased more strongly with increasing vaccination rates in the refugee group.

Predictor	Model 1				Model 2			
	B	*SE*	*p*	*OR*	*B*	*SE*	*p*	*OR*
Intercept	0.40	.40	.314	1.50	0.82	.42	.051	2.26
Refugees' vaccine uptake (A)	-0.08	.03	.002	0.92				
Historical vaccine uptake host population (B)	0.30	.16	.064	1.35	0.03	.16	.867	1.03
A*B	-0.02	.01	.049	0.98				
Information about refugees' vaccine uptake (C)					-1.16	.39	.003	0.31
B*C					0.06	.15	.697	1.06
ML model fit: AIC/BIC	558.9 / 579.7				719.3 / 741.0			

Table 1. Mixed effects models predicting decision in favor of vaccination as a function of the experimental factors and their interactions. *Note*. $N = 96$. Mixed effects model (prediction of vaccination decisions): subjects treated as random effect. Historical vaccine uptake in the host population: number of disease eradications that the group reached over 20 rounds, resulting in (0, 3, 4) eradications; treated as metric predictor in the analysis. Refugees' vaccine uptake: communicated number of disease eradications in the refugee population over 20 rounds (0, 5, 10, 15, 20); treated as metric predictor in the analysis. Information about refugees' vaccine uptake: 0 = absent, 1 = present.

In order to cross-validate the results, the logistic regression from Model 1 on vaccination behavior was repeated, and the predictor number of eliminations in the host community was replaced with the vaccination rate in the host population (range of vaccination rate: 25.00% to 66.66 %) in the last round of the I-Vax game. Similar to Model 1, the results of the regression show that information about refugees' high vaccine uptake tends to decrease the vaccine uptake in the host community ($B = -0.11$, $p = .073$, $OR = 0.90$). The interaction between the vaccination rate in round 20 and the refugees' vaccine uptake did not reach statistical significance ($B = -0.02$, $p = .877$, $OR = 0.98$). Furthermore, there was no independent effect of vaccine uptake in round 20 on the decision to be vaccinated (B = -0.07, p = .972, *OR* = 0.93).

Additional analyses

Additional analyses were conducted to explore whether individuals inherit default beliefs about the vaccine uptake among refugees. As a first step, therefore, a logistic regression (Model 2) on vaccination behavior with historical vaccine uptake of the host population, information about the refugees' vaccine uptake, and their interaction was conducted. Note that the dichotomous predictor information about the refugees' vaccine uptake was calculated from the variable refugees' vaccine uptake, where the factor level absent served as the reference in the regression. The results show that, in general, the host population was significantly less willing to be vaccinated when information about the refugee population's vaccine uptake was available (vs. absent; C). This result gives initial indications that when information about refugees' vaccine uptake is not available, individuals hold beliefs that refugees have a rather poor health status. Moreover, neither historical vaccine uptake host population (B) nor its interaction with information about refugees' vaccine uptake (B*C) was significant.

In order to further explore the above-mentioned effect that individuals hold default beliefs regarding refugees when information on the refugees' vaccine uptake was absent (vs. present), the distribution of vaccinated vs. non-vaccinated participants in the conditions no information vs. low refugees' vaccine uptake was examined using a Wilcoxon signed rank test with continuity correction. The results indicate that individuals show similar vaccination behavior under uncertainty (no information) and in the high-risk situation (i.e., low refugee vaccine uptake; $V = 195$, $p = .325$).

Discussion

The present experiment examined how the communication of refugees' vaccination rates affects the willingness of the host community to be vaccinated. The experiment showed that communicating refugees' vaccination status can have detrimental effects, especially when both the vaccine uptake of refugees and the host population's vaccine rate are high. This effect may increase with higher refugee influx (Khan et al., 2016). It was shown that information provided to the host population about the health status of refugees and migrants, which is supposed to be used for prejudice reduction, has a negative influence on health decisions, namely in the form of free riding. For this reason, the results of the experiment should be taken into account when communicating the health status of this population in order to reduce prejudice.

Beliefs and assumptions about the environment play a significant role in decisions under conditions of uncertainty (Kahneman, Slovic, & Tversky, 1982). The current experiment suggests that individuals in the host population fall back on the assumption that refugees' vaccine uptake is low when no information about the vaccination uptake is available. This result is in line with the finding of Böhm et al. (2019), who examined whether the willingness to be vaccinated is influenced by the non-vaccinators' level of responsibility for not being vaccinated. The results of the experiment showed a similar willingness to be vaccinated when no information about an unvaccinated other is given vs. when non-vaccination of the other person was a result of deliberate decision. Since the additional information was about group memberships, the default assumption about refugees' vaccine uptake is likely to be influenced by stereotypes and prejudices. This could indicate that individuals have a default belief that refugees have a rather poor health status. Future research should therefore focus on how to counter prejudice without providing health-related information, specifically around vaccine uptake, which can have detrimental effects on health decisions. One possibility would be to make use of empathic perspective-taking (Batson & Ahmad, 2009; Batson & Moran, 1999), which has been shown to improve inter-group attitudes.

Limitations

The participants were placed in a scenario in which they indicated their behavioral intentions. Thus, it could be argued that participants in such a situation are less inclined to reveal their true vaccination preferences, because indicating an intention does not result in consequences. The statistical results, therefore, could be prone to socially desirable response behavior, which could lead to an underestimation of the effects. Also, behavioral intention does not necessarily correspond to behavior (Sheeran, 2002). Thus, it is not clear whether the findings would translate into the actual behavior of obtaining vaccinations. Therefore, future research should implement a game structure that allows for the assessment of revealed vaccination preferences also in the context of migrating groups.

In the experiment, the participants were confronted with a scenario in which three persons from their own group were replaced by three persons from a refugee group. This replacement procedure may seem unrealistic, yet it was necessary from a game theoretical point of view due to the fixed group constellation of 12 players. Increasing the total population from 12 to 15 seemed less advantageous than replacing group members, as the effects could not be clearly attributed to the influence of refugees but could also be explained by general population growth and the associated lower influence of an individual on the vaccination rate. Future research should nevertheless replicate the findings in a more realistic scenario.

Finally, the sample consisted solely of students, a group that has a generally positive attitude toward refugees and migrants (Helbling et al., 2017). Therefore, one could assume that the current study somewhat underestimates the effects of refugee stigmatization. Future research should investigate the effects in various population groups in order to generalize the effects on the whole population.

Conclusions

Health officials and society as a whole must undoubtedly combat prejudice and discrimination against refugees by debunking misinformation. Regarding vaccine uptake, however, debunking misconceptions regarding the health status of refugees should be done cautiously and be complemented with communication measures aimed at preventing free-riding behavior. One possibility is to complement the corrective intervention with a herd immunity communication campaign (Betsch, Böhm, & Korn, 2013) and empathic perspective-taking in order to prevent free riding and improve inter-group attitudes. Only then will it be possible to pursue both goals at once: fighting discrimination *and* infectious diseases.

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Article 3

Vaccination as a social contract

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Vaccination as a social contract

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Abstract

Most vaccines protect both the vaccinated individual and the society at large by reducing the transmission of infectious diseases. In order to eliminate infectious diseases, individuals need to consider social welfare beyond mere self-interest — regardless of ethnic, religious, or national group borders. It has therefore been proposed that vaccination poses a social contract in which individuals are morally obliged to get vaccinated. However, little is known about whether individuals indeed act upon this social contract. If so, vaccinated individuals should show positive reciprocity toward other vaccinated individuals and negative reciprocity toward non-vaccinated individuals. Moreover, a social contract should be universally valid, i.e., reciprocity should occur irrespective of context factors, such as others' group membership. The present studies investigated reciprocal prosociality toward vaccinated and non-vaccinated others as a behavioral indicator for seeing vaccination as a social contract. Three pre-registered experiments tested the reciprocity hypothesis and its universality, investigating how a person's own vaccination behavior, others' vaccination behavior, and others' group membership influenced a person's prosociality toward the respective others. The pattern of results revealed by an internal meta-analysis ($N = 1{,}032$) suggests that especially those who get vaccinated, and therefore comply with the social contract, show negative reciprocity toward non-vaccinated individuals. Moreover, reciprocal prosociality was independent of others' group membership, suggesting a universal moral principle. Emphasizing that vaccination constitutes a social contract could be a promising intervention to increase vaccine uptake, prevent free riding, and, eventually, eliminate infectious diseases.

Significance Statement

Controlling and eliminating infectious diseases is of utmost importance. As most vaccines protect both vaccinated individuals and the society, vaccination is a prosocial act. Its success relies on a large number of contributing individuals. We study whether vaccination is a social contract where individuals show positive reciprocity toward vaccinated others and negative reciprocity toward non-vaccinated others. Three pre-registered experiments demonstrate that vaccinated individuals are less prosocial toward non-vaccinated individuals who violate the social contract. This effect is independent of whether the individuals are members of the same or different social groups. Thus, individuals' vaccination behavior follows the rules of a social contract, which provides a valuable basis for future interventions aiming at increasing vaccine uptake by emphasizing this social contract.

Measles has re-emerged with full force: in the first half of 2019, 364,808 measles cases were recorded in 182 countries — the highest number since 2006 (1). The insufficient uptake of the measles-containing vaccine is a major threat to individual and global health, such that the World Health Organization (WHO) termed vaccine hesitancy as one of the ten major threats to public health in 2019 (2). As a consequence, mandatory vaccination policies have been discussed and introduced in several countries (e.g., Italy, France, Germany, 3–5, see 6 for an overview). In Germany, for example, specific population groups, such as pre-school children, migrants, and asylum seekers, will soon be required to prove that they have been vaccinated against measles.

Mandates often elicit emotional public debates that weigh freedom of choice against social welfare concerns. The German Ethics Committee has made a strong case against mandates (7). At the same time, the committee has stressed that getting vaccinated is a *moral* obligation in the sense that vaccination constitutes a social contract that every individual is morally obliged to obey (7). This stance is justified due to the social benefit of vaccines. As most vaccines also reduce the transmission of a disease, they indirectly protect the community and individuals who are too young to get vaccinated or immunocompromised (8) ("herd immunity" or "community immunity"). Hence, the social contract results from the moral obligation to protect vulnerable others.

However, the interplay of such indirect effects of vaccination and the costs associated with vaccination (e.g., time, effort, risk of vaccine-adverse events) constitutes a social dilemma, in which collective and individual interests are at odds (9, 10, for an interactive simulation, see 11). Therefore, individuals have incentives to refrain from vaccination and to free-ride by profiting from others' indirect protection, and thus to selfishly break the social contract.

In this study, we therefore investigate whether individuals' behavior suggests that vaccination is indeed perceived as a social contract. The hypotheses are directly derived from the social-contract perspective, which we put to a critical empirical test.

Theoretical background and hypotheses

The Morality-as-Cooperation Theory (12) postulates that morality is a container of behaviors to solve cooperation problems. More specifically, cooperation is considered as morally good and respected, whereas defection is seen as morally bad and despised. Accordingly, individuals who are vaccinated (and therefore comply with the social contract) should positively reciprocate to others who are vaccinated as well. Reciprocity can be thus stated as "you scratch my back, and I'll scratch yours" (13). In contrast, individuals should negatively reciprocate to others who are not vaccinated (and therefore violate the social contract). Importantly, individuals who are not vaccinated themselves should not (or to a smaller extent) show reciprocal behavior. We refer to this as the *reciprocity hypothesis* (Figure 1 A illustrates this for a vaccinated individual).

Moral norms are considered universal principles of human interaction (12, 14). Thus, vaccination as a social contract should apply to all individuals irrespective of their group membership (Figure 1 A). For example, a (non-)vaccinated migrant from another country (i.e., an out-group member) and a (non-)vaccinated member from the same country (i.e., an in-group member) should induce equal reciprocal behavior. However, previous research showed that individuals treat in-group members more positively than out-group members (intergroup bias, 15–17). Therefore, we test whether individuals show more negative and less positive reciprocity toward out-group members than toward in-group members (17). We refer to this as the *conditional reciprocity hypothesis* (Figure 1 B). The hypothesis thus challenges the idea of vaccination as a social contract as it contrasts the idea of universal norms with group- and context-specific reactions toward non-vaccination. In addition to its theoretical importance, the question of whether vaccination-based reciprocity is conditional on others' group membership has practical relevance, as societies are growing more and more diverse through global migration movements (18).

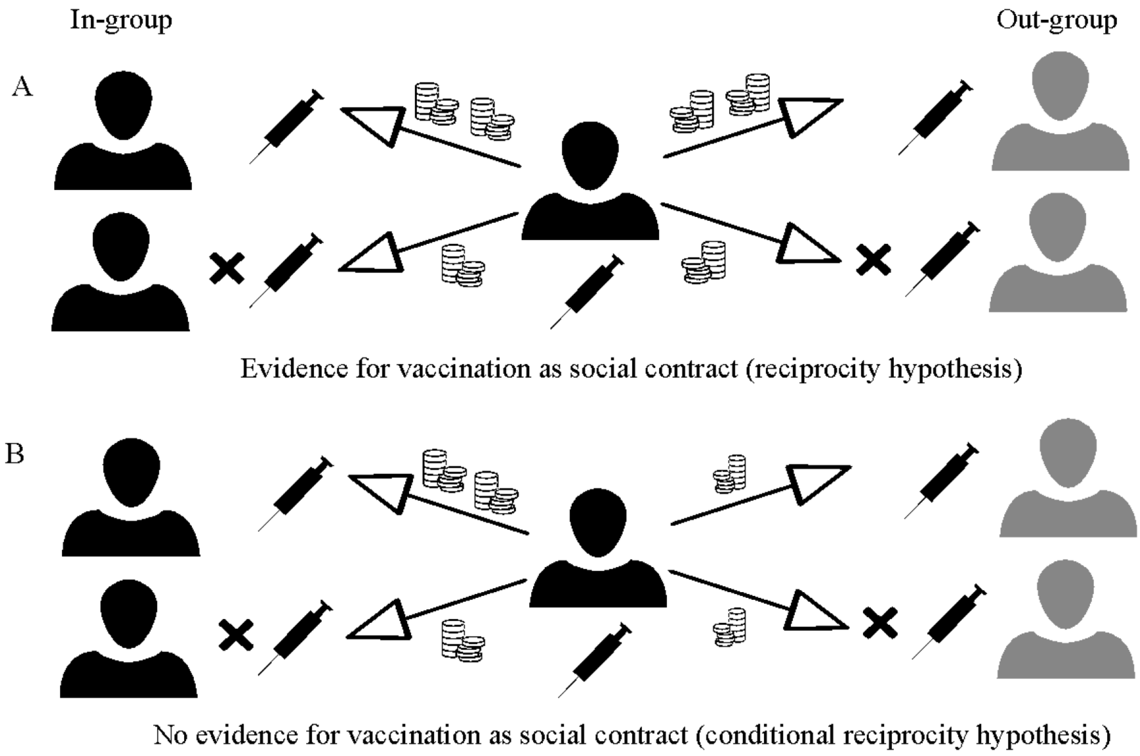

Figure 1. Illustration of the experimental setting used to test whether vaccination is a social contract. After learning whether the other person vaccinated or did not vaccinate in the experimental game, the participants (center) allocated money between oneself and four other people, respectively, who were either vaccinated or not and belonged to the ingroup (black) or an outgroup (grey). Changes to a baseline measure indicated reciprocal prosociality. Panel A describes the situation in which vaccination is a universal social contract: vaccinated individuals allocate more money to vaccinated others and less money to non-vaccinated others (*reciprocity hypothesis*). In A, reciprocal prosociality applies to all others alike, i.e. it is independent from the others' group memberships. Panel B, however, describes a case where the decision maker reciprocates only behavior by ingroup but not from outgroup members (*conditional reciprocity hypothesis*). This would indicate that vaccination is not a social contract.

Assessing reciprocity toward (non-)vaccinated individuals

Individuals condition their own vaccination decision on the (expected) vaccination decisions of others (10, 19–21). When a great number of others are vaccinated, reciprocity suggests vaccination. However, one may also decide not to be vaccinated and instead free-ride when the protection by the "herd" is sufficient (10). The incentives for vaccination are low, for example, when the vaccination uptake is already high and there are some costs associated with vaccination. A growing body of evidence shows that vaccination behavior is a result of strategic considerations responding to the changes in incentives, given different levels of vaccine uptake (10, 22). Thus, due to these strategic considerations, the vaccination intention or behavior, given a certain level of uptake, will not be a meaningful indicator for reciprocity.

We therefore measured reciprocity in an unrelated domain with an established and incentivized measure of social preferences (23). In this task, participants allocate monetary tokens between themselves and others (Figure 1) where more money distributed to others relative to oneself indicates higher prosociality. Higher levels of prosociality (relative to an unconditional baseline level of individual prosociality) are a clear indicator of positive reciprocity, whereas lower levels of prosociality indicate negative reciprocity.

Overview of the experiments and internal meta-analysis

In three incentivized and pre-registered online experiments, we collected data from $N = 1{,}032$ participants to test whether individuals act according to vaccination as a social contract. First, the participants indicated their unconditional prosociality by distributing monetary tokens between themselves and an unknown other participant. Afterward, they were informed that two groups existed during the experiment and that they were assigned to one of them. As framing may alter behavior (24), Experiments 2 and 3 varied the framing of the decision situation by using a migration context for the intergroup setting (e.g., instead of being a member of group A or B, participants were informed they were citizens of a country vs. immigrants from another country). The participants then made a vaccination decision in an incentivized vaccination game (one-shot I-Vax game, 10, 25), which models vaccinations based on epidemiologically-derived incentives capturing both the direct and indirect benefits, as well as the costs, of vaccination. Each decision in the game has real monetary consequences: becoming sick means a loss of money, and the less people are vaccinated, the higher is one’s likelihood to get sick; however, vaccination also leads to small fixed costs and can result in an additional loss of money when side effects occur. After the vaccination game, the participants again indicated their prosociality, but this time they received additional information about the other person (vaccination behavior and group membership). Main dependent variable are the changes in prosociality. Hence, the experiments used a 2 (participant's vaccination decision: non-vaccination vs. vaccination; quasi-experimental between-subjects) × 2 (other's vaccination decision: non-vaccination vs. vaccination; within-subjects) × 2 (other's group membership: in-group vs. out-group; within-subjects) design.

As stated above, positive and negative changes in prosociality (relative to unconditional baseline prosociality) indicate positive and negative reciprocity, respectively. If such reciprocal prosociality occurs, we interpret this as evidence for vaccination being a social contract. Moreover, assessing whether such reciprocity depends on the group membership of the other person challenges the idea of vaccination being a universal moral social contract. Experiments 2 and 3 also assessed how warm or cold one feels toward others ("perceived warmth"), as this fundamental evaluation of others corresponds to a moral judgment of others' behavior (26). An internal meta-analysis tested the hypotheses across all three experiments.

Results

Figure 2 and Figure S1 in the supplement show the results of the random effects meta-analysis. The results support the reciprocity hypothesis: across all three experiments, vaccinated participants reacted sensitively toward others' vaccination decisions and reduced their prosociality toward non-vaccinated others as compared to vaccinated others. Non-vaccinated participants differentiated less between vaccinated and non-vaccinated others (overall interaction effect $\beta = 0.18$, see Figure 2). As indicated by the mean level changes in prosociality displayed in Figure 3, negative reciprocity toward non-vaccinated others was stronger than positive reciprocity toward vaccinated others; the latter was only shown by vaccinated individuals. Thus, vaccinated individuals reciprocate others' vaccination behavior, thus revealing evidence for vaccination being a social contract.

In order to test whether the social contract is universal or dependent on group memberships, it first had to be confirmed that the groups were indeed perceived as distinct groups (and thus the manipulation was successful). Indeed, supporting previous research, there was a significant intergroup bias (15–17), which was indicated by greater prosociality toward in-group members than out-group members ($\beta = -0.04$). Further, and more importantly, the analysis provided no evidence for the conditional reciprocity hypothesis: the reduction of prosociality among vaccinated participants was not more pronounced toward non-vaccinated out-group members than toward non-vaccinated in-group members ($\beta = -0.01$). This supports the idea of vaccination being a universal social contract.

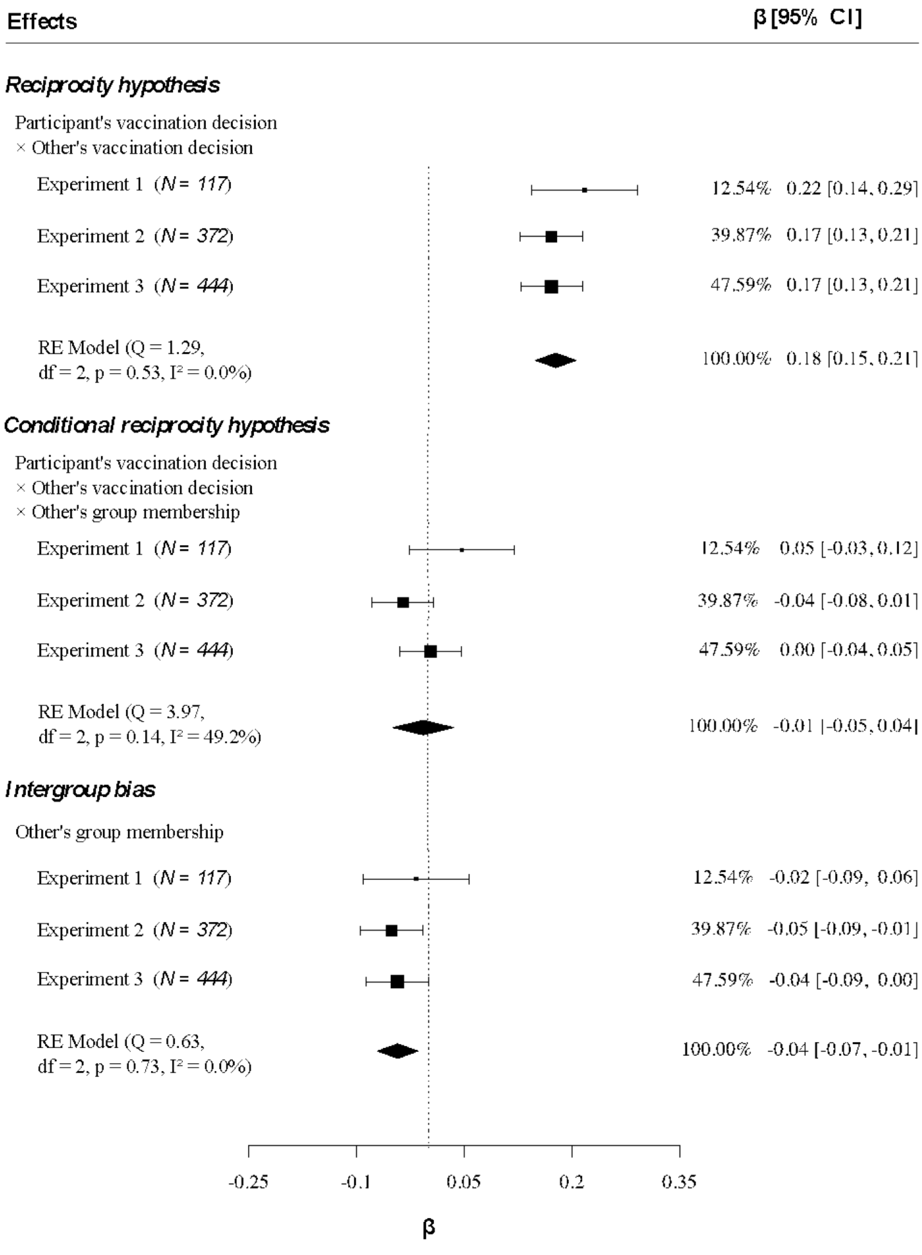

Figure 2. Forest plot displaying tests of the reciprocity and conditional reciprocity hypotheses. *Note:* Figure S1 in the supplement displays all remaining main effects and interaction effects of the analysis. The effects display betas, calculated from mixed effects regressions, and overall effects using a random effects model for meta-analysis. Q and I^2 were used for heterogeneity assessment.

Experiments 2 and 3 additionally assessed the perceived warmth conditional on the others' characteristics as measured after playing the I-Vax game but before assessing conditional prosociality. Supplementary Table S2 shows the results of a mixed effects regression with participants' vaccination decisions, others' vaccination decision, and group membership as experimental factors. The regression also included the experiment as a factor to account for the variation in materials between the experiments. Overall, the analysis of perceived warmth replicated the above pattern of results obtained with conditional reciprocity.

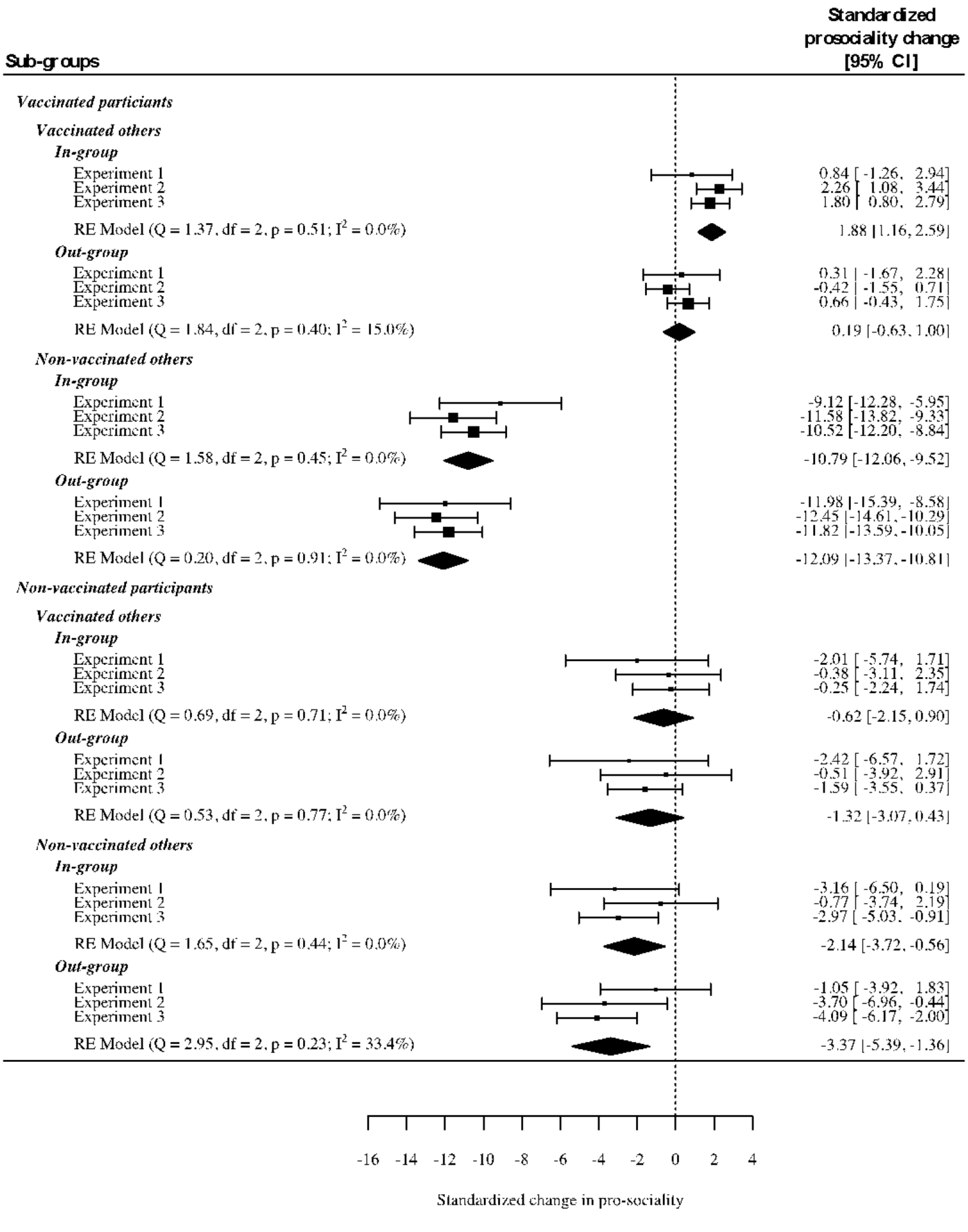

Figure 3. Forest plot of conditional prosociality relative to the unconditional baseline prosociality. Positive values indicate positive reciprocity, whereas negative values indicate negative reciprocity. The pattern of results shows that the interaction effect between participants' vaccination decisions and others' vaccination decisions (reciprocity hypothesis) was mainly driven by negative reciprocity from vaccinated participants toward non-vaccinated others. Non-vaccinated participants also showed negative reciprocity toward non-vaccinated others, but this effect was smaller than among vaccinated participants. Positive reciprocity was less pronounced and was only shown from vaccinated participants toward vaccinated in-group members. Note: Changes in prosociality refer to standardized changes. The overall effects were calculated using a random effects model for meta-analysis. Q and I^2 were used for heterogeneity assessment among the studies. CIs refer to 95% confidence intervals.

The vaccinated participants especially showed less warmth toward non-vaccinated others as compared to vaccinated others. Non-vaccinated participants again differentiated less between vaccinated and non-vaccinated others (interaction effect: $\beta = 0.22$, $p < .001$). Also, there was a significant intergroup bias: participants felt less warmth toward out-group members compared to in-group members ($\beta = -0.08$, $p < .001$). Again, whether vaccinated participants felt more or less warm toward vaccinated and non-vaccinated others was independent from the others' group membership ($\beta = -0.03$, $p = .078$).

Discussion

The social dilemma of vaccination sometimes puts individual interests at odds with the societal goal of eliminating infectious diseases. The present research supports the notion that vaccination is a social contract wherein getting vaccinated is the morally right behavior. Three pre-registered experiments investigated whether individuals' reciprocal behavior suggests that vaccination is a social contract based on a moral obligation. As an indicator of vaccination as a social contract, we assessed a person's prosociality toward others who either followed or violated the social contract. There was consistent evidence that vaccinated participants (more so than non-vaccinated participants) showed negative reciprocity toward non-vaccinated others, representing the behavioral foundation of a social contract. Furthermore, vaccinated individuals showed negative reciprocity toward non-vaccinated others regardless of their group membership. We interpret this finding as an indicator of a universal moral principle. This is backed up by the finding that the effects also replicated for perceived warmth as a dependent variable, as warmth corresponds to a moral judgment of others' behavior (26). Thus, we conclude that individuals indeed perceive vaccination as a universal social contract, in which cooperation is the morally-right choice.

Practical implications

Emphasizing that vaccination is a social contract seems to be a promising extension of communicating the social benefit of vaccination (20). Accordingly, stressing that everyone who is able to get vaccinated is expected to do so could have additional benefits in communicating the principle of herd immunity. The appeal could be based on moral grounds, either stressing fairness or care (e.g., stating that violating the social contract has a negative impact on vulnerable demographic groups and thus on the health of society). Overall, making the social contract explicit may help to increase vaccine uptake rates without relying on mandates, which seems to reflect the preferences of individuals (27) and would prevent countries from introducing selective mandates that could potentially decrease uptake for other voluntary vaccines (28).

However, there is also a potential downside to vaccination as a social contract. Individuals tend to accept social contracts if others do so as well (29). However, the media often reports that non-vaccination is becoming more and more common (e.g. 30). The results of the present study suggest that this narrative could negatively affect prosociality and warmth, especially in vaccinated individuals. Both variables are related to prosocial and helping behavior (31, 32). As vaccination is a prosocial act (10), low levels of prosociality and warmth can limit future willingness to be vaccinated. This means that over-communicating the prevalence of non-vaccinated individuals could jeopardize high vaccine uptake, as the social contract requires trust in others' compliance. We did not test this implication, but it is an important starting point for future research.

The results of the experiments also showed that people privilege those who obey the social contract irrespective of their group membership. In real life, belonging to a specific group may often be confounded with a specific health status — migrants, for example, may have limited access to health care and thus be unwillingly forced to violate the social contract. This can then fuel existing stereotypes (33), lead to further marginalization and less positive behaviors from those who obey the contract. Thus, equitable access to health care and vaccinations is of utmost importance (34, 35) to allow everyone to fulfill the social contract and also to avoid further discrimination based on health status.

Limitations

Our research has some limitations. First, the data collection was conducted online, an environment in which participants are more prone to distraction from tasks and written instructions. However, previous research showed that the Amazon Mechanical Turk samples are superior to student and panel samples regarding their data quality and replicability of effects (36), as well as with regard to participants' attentiveness (37).

Second, the experiment used a minimal group paradigm to allocate individuals to groups, which may imply reduced external validity of the results. A recent meta-analysis, however, showed no evidence for different in-group favoritism comparing natural versus minimal groups (16). Additionally, there was an intergroup bias in all three experiments, indicating that the group manipulation was successful. Future research could vary group types (natural vs. minimal) and examine actual previous vaccination behavior when researching changes of prosociality in the vaccination context in order to further increase the external validity of the research.

Third, Experiments 2 and 3 examined changes of prosociality in the context of migration. Migration is a sensitive topic (38), and, thus, it could be argued that socially desirable responses are especially prevalent in these experiments. However, to mitigate the influence of social desirability on prosociality change, the experiments incentivized behavioral responses, which are less prone to socially desirable responses and "cheap talk" (24).

Conclusion

The present research supports the notion that vaccination is a social contract wherein getting vaccinated is the morally right behavior. Future interventions should harness this finding to increase vaccine uptake. Moreover, the results also underline that equitable access to health systems and service delivery is of utmost importance to avoid further marginalization of already marginalized groups.

Materials and Methods

Ethics Statement

The studies included human subjects and were conducted in accordance with the guidelines of the German Psychological Association. The studies did not involve deception. All participants gave written informed consent to use and share their data for scientific purposes without disclosure of their identity. The experiment was conducted at a German university where institutional review boards or committees are not mandatory. The research contained negligible risks as there was no more foreseeable risk of harm or discomfort other than the potential inconvenience during participation. The participants were free to quit the study at any time without any consequences.

Experiments

Participants and design

All experiments used a 2 × 2 × 2 quasi-experimental mixed design with participant's vaccination decision (non-vaccination vs. vaccination, quasi-experimental, between), others' vaccination decisions (non-vaccination vs. vaccination, within), and others' group membership (in-group vs. out-group, within) as factors. Experiment 1 additionally varied the outcome interdependence of both groups (independent vs. interdependent, between), and participants were randomly allocated to the two conditions. Amazon Mechanical Turk users from the U.S. and Great Britain with an approval rate of 97% or higher were eligible for participation. The experiments were programmed with EFS survey and were pre-registered (Experiment 1:

https://aspredicted.org/5dp4n.pdf, Experiment 2: http://aspredicted.org/blind.php?x=mk5yd9, Experiment 3: http://aspredicted.org/blind.php?x=n9kp69).

For Experiment 1, an a priori power analysis, with an assumed small-to-medium effect size of the 4-way interaction with $f = 0.175$ and a statistical test power of $1-\beta = .90$ in a mixed effects ANOVA, revealed a target set of $N = 168$ participants. Due to the exclusion criteria (see below) and equally allocating participants to the conditions, we aimed to recruit 190 participants. The explorative analysis in Experiment 1 uncovered an accidental and unexpected confound of vaccination attitude and the interdependence factor (there were significantly more participants with a negative attitude in the interdependence condition). We decided to proceed with recruitment until this confound was resolved, and this resulted in a total sample size of $N = 242$ individuals. For the mixed effects ANOVA in Experiments 2 and 3, an a priori power analyses with $f = .182$ (derived from Experiment 1, 3-way interactions) and $1-\beta = .95$ suggested a required sample size of $N = 132$ participants. Moreover, Experiment 1 showed that the majority of the participants decided to get vaccinated. As one's own vaccination status was a quasi-experimental factor, we aimed to reach at least n = 66 participants also in the non-vaccination condition. Considering the potential exclusions, we recruited $N = 146$ (i.e., 78 participants in each of the conditions of the quasi-experimental factor) and continued to recruit participants until this number was reached.

The following exclusion criteria were pre-registered for the experiments: incomplete participation, inappropriate participation time (upper and lower 5% quantile), and incorrect answers to attention check questions (see online materials for exact wording: osf.io/bn56v).

Overall, $N = 1{,}275$ participants completed the experiments. According to the pre-registered exclusion criteria, we excluded from further analyses: $n = 26$ in Experiment 1, $n = 107$ in Experiment 2, and $n = 110$ in Experiment 3. Thus, the final sample consisted of $N = 1{,}032$ (Experiment 1: $n = 216$; Experiment 2: $n = 372$; Experiment 3: $n = 444$). For descriptive data on demographics and psychological characteristics, see Table S6 in the supplement.

The one-shot I-Vax game

In the one-shot I-Vax game, the participants were endowed with 100 fitness points (converting to $0.20) representing their health status (10). The participants were informed that 125 respondents were taking part in the study and that each of them would be allocated to group A (group size = 95) or group B (group size = 30). All participants were then assigned to group A. Members of group B (the out-group) were not part of the main study but were collected after the main study using Mechanical Turk. Participants of group B were paid based on their own vaccination decision and the group A members' prosocial choice. This procedure was done to ensure decision-compatible payment of the participants.

In Experiment 1, depending on the interdependence condition, the participants learned that either both groups' vaccination decisions or only group A's vaccination decision affected the respondent's payoff. The participants were confronted with a fictitious disease and had the opportunity to be vaccinated against this disease. A decision in favor of vaccination yielded fixed costs of 10 fitness points, resembling costs such as waiting time. Vaccine-adverse events occurred with a probability of 45%, leading to a loss of 15 points. The expected costs of vaccination were thus 16.75 fitness points. A decision against vaccination yielded no fixed costs. However, non-vaccinated individuals were at risk of contracting the disease. The probability of infection was calculated based on the variable vaccination rate in the population and the fixed contagiousness of the disease (basic reproduction number R_0). When infected, participants lost 50 fitness points. All this was known to the participants (see instruction materials on OSF: osf.io/bn56v).

In summary, the parametrization of the game implies a Nash equilibrium (39) at a vaccination rate of 50%, meaning that no participant has an incentive to change his or her strategy unilaterally at this vaccination rate (for visualization see, 11). Below a vaccination rate of 50%, vaccination is the dominant strategy; above a 50% vaccination rate, non-vaccination is the dominant strategy. However, collective welfare is maximized when 67% of the population decides in favor of vaccination. This yields the social optimum because, at this percentage, the infection probability reaches zero and the disease is eliminated. Thus, between the range of a 50% and 67% vaccination rate, the game constitutes a social dilemma in which individual interests are in conflict with collective interests. The participants' vaccination decision in the one-shot I-Vax game (coded as 0 = non-vaccination, 1 = vaccination) served as a quasi-experimental factor in the analysis.

Experimental factors

Before assessing conditional prosociality, participants were reminded of their group membership by a figure presented to them. They were informed about the other's group membership (coded 0 = in-group, 1 = out-group) and the other's vaccination decision (0 = non-vaccination, 1 = vaccination) when the dependent variable was assessed. This procedure is described below.

In Experiment 1, the participants were additionally informed whether the other group will influence their payment or not. In the independence condition (coded as 0), members of group A and group B constitute two separate, independent populations: "your payment will be affected by your decision, and the decisions of the members of your group A. Group B is irrelevant for your additional payment." In contrast, in the interdependence condition (coded as 1), members of group A and group B were outcome-interdependent: "your payment will be affected by your decision, the decisions of the members of your group A, and the decisions of the members of the other group B." The analysis of Experiment 1 (see Figure S2 and Table S3) also confirmed the reciprocity hypothesis. Furthermore, the analysis showed that vaccinated individuals in the independence condition showed reciprocal behavior but to a lesser degree than individuals in the interdependence condition. In Experiments 2 and 3, the groups were always interdependent.

Migration framing

The framing of the decision situation varied across the experiments. In Experiments 1 and 2, neutral group names A and B (in-group and out-group, respectively) were used. In Experiment 3, group A was framed as the "host population," and group B was framed as the "migrating group." In Experiments 2 and 3, participants received an animated figure (see online materials: osf.io/bn56v), indicating that the out-group was migrating into the in-group, visualizing the outcome interdependence between the groups.

Dependent variable

Reciprocal prosociality served as the main dependent variable. Prosociality was assessed via the social value orientation slider measure (23), consisting of a sequence of six decision tasks. Each respondent allocated points (100 points = US$0.20) between himself or herself and another participant (receiver). All decisions were made from the perspective of the sender (strategy method, 54). At the end of the experiment, one of the six allocation decisions in each block was payoff-relevant for the sender and the matched recipients. The role was chosen randomly. The responses were transformed into a single index of a participant's social value orientation, with lower values indicating a proself motivation, such as competitiveness and selfishness, and higher values indicating a prosocial motivation, e.g., equality and social welfare concerns.

Reciprocal prosociality was assessed by measuring participants' prosociality twice. The baseline measurement at the beginning of the experiment was the unconditional social value orientation, where participants had no information about the receiver. After the one-shot I-Vax game, conditional prosociality was measured such that participants received additional information about the receiver's vaccination decision and group membership. All four combinations were assessed within subjects, i.e., vaccinated in-group member, non-vaccinated in-group member, vaccinated out-group member, and non-vaccinated out-group member. For the analyses, the baseline measurement was subtracted from the conditional measurements.

Perceived warmth

In Experiments 2 and 3, perceived warmth regarding the in-group and the out-group, and individuals of the four specific subgroups was measured. This was done using the feeling thermometer (41), by which participants indicated their perceived warmth on a scale ranging from 0°F (very cold) to 100°F (very warm).

Additional variables

In all experiments, the following variables were assessed for explorative purposes, but were not part of the analysis: attitude toward vaccination (three items, e.g., “It is a good idea to get vaccinated,” adapted from (45) on a 7-point Likert-type scale ranging from 1= *fully disagree* to 7= *fully agree*; identification with the in-group (four items, e.g., “I am glad to be part of group A,” adapted from (57) on a 7-point Likert-type scale ranging from 1= *not at all* to 7 = *very much*. In addition, beliefs about vaccine uptake in both groups were assessed in an open, numeric answer format (value between 0 and 100; e.g., “I think that [insert number]% of the other group B will choose to get vaccinated.”).

Attention checks and comprehension questions

In Experiment 1, the attention check question was presented after the first assessment of prosociality and resembled an item of SVO measure (44). Incorrect answers led to immediate exclusion from the experiment (n = 140 participants were screened out). Experiments 2 and 3 included two attention check questions based on (45) (see instructions on OSF for exact wording: osf.io/bn56v). In contrast to Experiment 1, in Experiments 2 and 3, incorrect answers led to pre-registered exclusion from the analysis but not from participating and being paid (Experiment 2: n = 70, Experiment 3: n = 59).

After the participants received the instructions of the one-shot I-Vax game, they were asked to answer comprehension questions regarding the game. If, and only if, these responses were correct, could participants proceed with the study. However, wrong answers could be corrected, and the participants had the opportunity to download a pdf file containing the instructions of the one-shot I-Vax game.

Procedure

Instructions for all experiments are available via the Open Science Framework (osf.io/bn56v).

Payment

The participants received a fixed ($2) payment and a bonus payment via Mechanical Turk. The bonus payment was: $0.77 (*SD* = 0.09) in Experiment 1, $0.90 (*SD* = 0.11) in Experiment 2, and $0.91 (*SD* = 0.10) in Experiment 3. Bonus payments varied and were contingent on the decisions made in the game and the answers in the five blocks that assessed the social value orientation (one of the six allocation decisions in each block was payoff-relevant).

The members of the out-group (group B) also participated in the social value orientation measure and played the I-Vax game. They received a fixed remuneration of $0.67 and a decision-contingent bonus payment, based on the outcomes of the social value orientation measure and the one-shot I-Vax game. Their average bonus payment was: $0.34 (*SD* = 0.04) in Experiment 1, $0.31 (*SD* = 0.05) in Experiment 2, and $0.33 (*SD* = 0.05) in Experiment 3.

Data analysis

The R-environment (46) and the R-packages *lme4* (47) and *metafor* (48) were utilized for the meta-analysis. Although the hypotheses proposed were directional, conservative two-sided tests were used. An alpha level of .05 for all analyses was applied.

The meta-analysis was based on mixed effects regressions with the predictors being the participant's vaccination decision, other's vaccination decision, group membership, and their interactions on reciprocal prosociality for each experiment (see Table S1). The estimated effects of the mixed effects regressions and their standard errors were standardized. For each effect, 95% confidence intervals were computed. To account for the differences in the materials between the experiments, a random effects model for the meta-analysis was used. Across the effects, the Q statistics were not significant, indicating sufficient homogeneity. With regard to the 3-way interaction, however, the proportion of observed variance across the studies, reflected by I^2, was moderate. Omission of Experiment 2 led to the strongest reduction of I^2 but to qualitatively identical results. Thus, Experiment 2 was not removed from the analysis.

Acknowledgments

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Data access

The materials, data, and syntax of all three experiments are available online from the Open Science Framework (osf.io/bn56v).

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General Discussion

This dissertation is concerned with the vaccination decision in a complex social and interconnected environment. More specifically, it considers vaccination as a social dilemma and focuses on a) promoting vaccination behavior in a complex environment, b) the incorporation of others' vaccination decisions (e.g., health status of migrants) in one's own decision to be vaccinated, and c) whether vaccination is a social contract, conceptualized as the reactions to others' vaccination behaviors, wherein others are either (non-)vaccinated members of an in-group or an out-group.

In the following sections, the results of the articles are summarized and discussed in brief. Possible approaches for future research and practical implications are presented in each of the sections reflecting on the results of the articles. I then discuss the methodical limitations, touching particularly on the characteristics of the sample and the external validity.

Promoting vaccination behavior in a complex environment

Answering the research question

Article 1 examined the research question of how to promote vaccination behavior in a complex social environment. The article revealed that activating intra- and inter-group processes can be fruitful and effective methods of promoting vaccine uptake in the I-Vax game (Böhm, Betsch, & Korn, 2016). In particular, symbolically rewarding the attainment of the social goal of disease elimination can improve vaccination behavior. Even though the effect of rewarding goal attainment can be considered small ($OR = 1.48$, $p = .040$), it should be noted that, in the medical field, small effects are of major importance (Rosenthal, 1991). The events that may be prevented (disease, death) are serious, and therefore a change in their probability of occurrence matters. The experiment also showed that the effectiveness of the intervention decreased over the course of the experiment. Therefore, extensive use of the strategy is not advisable.

The provision of inter-group comparison in vaccination rates increased the likelihood of vaccination in the I-Vax game ($OR = 1.23$, $p = .273$), but the effect was too small to meet the conventional criteria of statistical significance. However, the result of the experiment does not imply that inter-group comparisons are ineffective per se. Rather, replications are necessary that provide sufficient power to evaluate the effectiveness of the intervention (Zwaan, Etz, Lucas, & Donnellan, 2018).

In the following sections, the possible directions of future research and the practical implications regarding the interventions are discussed.

Future research

As noted above, the effect of symbolically rewarding the attainment of the social goal is small and declined over the course of the experiment. These observations have two implications for future research.

First, it should be examined how the effectiveness of symbolically rewarding the attainment of the social goal can be amplified. Locke and Latham (2006), for example, emphasize that personal goals conflicting with collective goals may undermine the effectiveness of the social goals. In the context of vaccination, infection avoidance can be considered as personal goal. However, this personal goal creates an incentive to free-ride, which means benefiting from herd immunity without contributing to the public good. This contrasts with the collective goal of disease elimination. Therefore, it is important to communicate vaccination in a way that the personal and the social goal are concordant. In this sense, the effectiveness of communicating vaccination as a social goal could be increased when this intervention is complemented with the communication of the social benefit of vaccination. That way, social concerns for others are activated (Betsch, Böhm, & Korn, 2013), which could lead to an incorporation of the social goal into the personal goal and therefore could increase prosocial vaccination. Moreover, previous research showed that self-efficacy is a key moderator for goal setting and goal striving (Locke & Latham, 2006). In the context of vaccination, one could assume that individuals will be more likely to strive for the social goal of disease elimination when they think it is achievable. Therefore, future research should investigate whether perceived self-efficacy also moderates the effect of symbolically rewarding the attainment of the social goal and, if so, how self-efficacy can be strengthened.

Second, future research should also focus on the decreasing effect of symbolically rewarding the attainment of the social goal. First of all, it should be investigated whether the wear-out effect also occurs outside the laboratory and has practical relevance. In the experiment, the time intervals of the feedback were very short. This means that the decrease in the effectiveness of the intervention may be overestimated. In reality, feedback on the vaccination rates, such as in the case of influenza, would only be possible on an annual basis. This means that the interval of feedback is much larger in reality. However, when the wear-out effect has practical relevance, then countermeasures need to be implemented, such as time lags or intermittent rewards.

As noted above, the effect of inter-group comparison did not reach the conventional criteria of significance. Therefore, possible moderators should be considered in relation to inter-group processes. For example, the higher rates of cooperation in inter-group contexts result from striving for positive distinctiveness and group identity (Böhm & Rockenbach, 2013). Previous research suggests that group identity has a positive effect on cooperation within groups in social dilemma situations (Jackson, 2011). Thus, future research should also fathom whether identity-enhancing procedures may influence the effectiveness of the inter-group comparison intervention. Moreover, previous research (Chowdhury, Jeon, & Ramalingam, 2016) showed that cooperation within groups increases when a natural group identity is salient compared to when a minimal group identity is salient. Since the current dissertation used a minimal group approach to allocate individuals to groups (see also the limitations section), future research should vary group types (natural vs. minimal) to examine the effect of inter-group comparisons.

In Article 1, the populations were homogeneous. This means that each population was formed of one group. As mentioned in the introduction, this does not correspond to reality.

Societies consist of multiple social groups (Böhm, Rusch, & Baron, 2018) and are currently transitioning toward even more diversity (Danchev & Porter, 2018). Thus, collective action from different groups — for example, a majority community and migrant groups — are needed to overcome the burden of infectious diseases. However, previous research has shown that diversity negatively influences cooperative behavior in the context of social dilemmas, especially among members of a majority (Chakravarty & Fonseca, 2014; Smith, 2011). Therefore, when conceptualizing and communicating vaccination as a social goal, it is necessary to take this insight into account and examine to what extent the diversity of populations influences the effectiveness of symbolically rewarding the attainment of the social goal. In consideration of Sherif's (1961) realistic group conflict theory, communicating the social goal of disease eradication as a superordinate goal that requires cooperation between groups seems an interesting starting point.

Moreover, using inter-group comparisons as an intervention to increase vaccine uptake could have the opposite effect when populations are diverse. This is because the information that an out-group is well-vaccinated could also lead to a decrease in the willingness to be vaccinated when individuals assume that there is exchange between the two respective groups. This issue will be discussed in the section "Incorporation of others' vaccination behavior in one's own vaccination decision" below. Therefore, migration between groups (such as extensive traveling or refugee migration) could threaten the success of an intervention relying on inter-group comparisons, which would be an interesting avenue for future research.

Practical implications

As the inter-group comparison intervention needs further research to determine its effectiveness in increasing the likelihood of getting vaccinated, this section focuses exclusively on the practical implications of rewarding goal attainment as a possible intervention to increase vaccine uptake in the general population.

The results regarding rewarding goal attainment provide insights for revising existing communication strategies. WHO's Regional Office for Europe (see Figure 1, WHO Europe, 2016), for example, published an infographic about the current status of measles and rubella elimination in Europe.

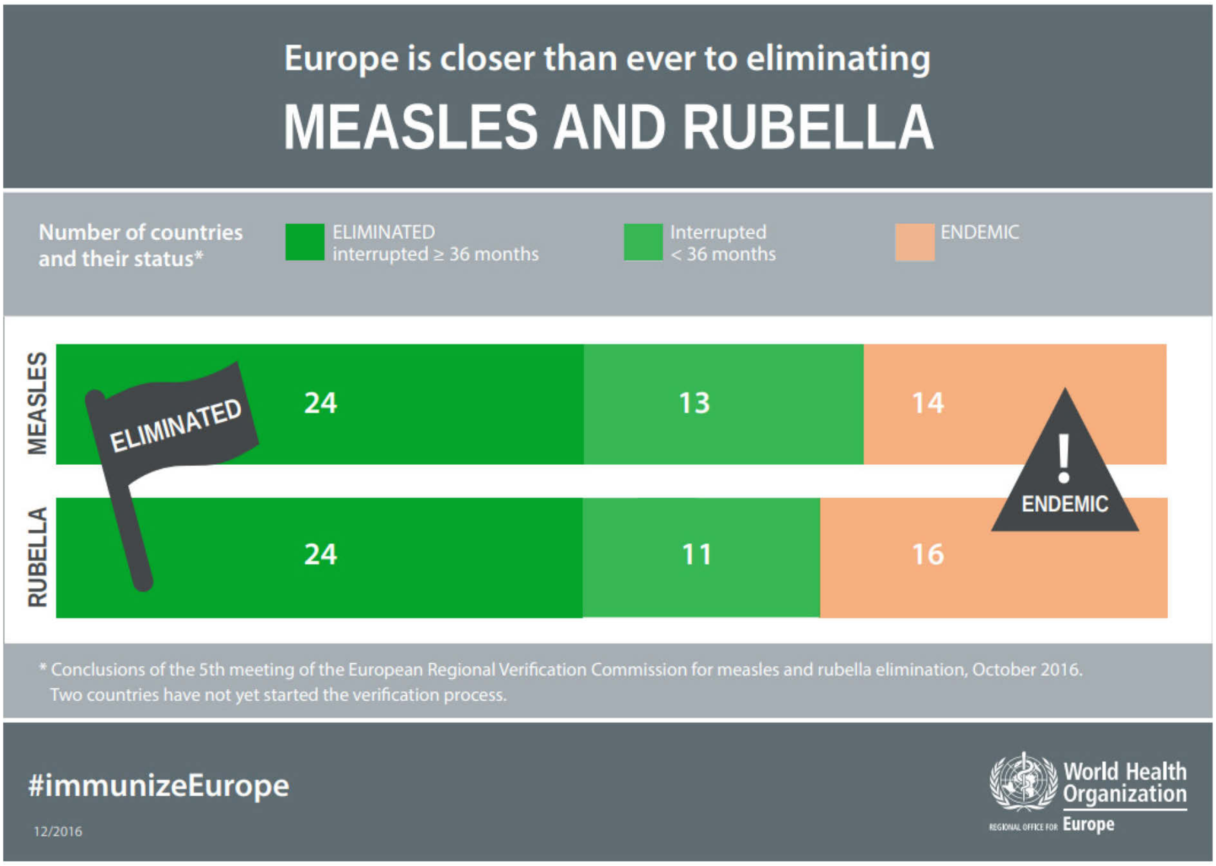

Figure 1. Infographic about the current status of measles and rubella elimination in Europe. *Note.* Taken from WHO Europe (2016).

Figure 1 displays information about countries that are already measles/rubella-free, that have interrupted the circulation of the disease, or where the diseases are still endemic. This information is displayed in an aggregated way, showing the total number of European countries in the different categories. While this may work in a comparison between different WHO regions (as this involves comparison), feedback to the countries within the WHO European region would probably benefit from a revision of the graph. Given the results of Article 1, naming the countries may be more effective, since it would provide a clear indication for individuals of a respective country to monitor the social goal, and it is also possible to symbolically reward goal attainment through the colorings.

Implementing the intervention of the social goal on a smaller scale, such as in hospitals or kindergartens, rather than at the state level, may also be conceivable. Low vaccination rates in hospitals represent a significant obstacle in the health care system (Ahmed, Lindley, Allred, Weinbaum, & Grohskopf, 2014; Böhm, Betsch, Korn, & Holtmann, 2016). To address this issue, setting social goals and rewarding goal attainment as an intervention could be a fruitful avenue for future research to increase the willingness of health care workers to be vaccinated against influenza.

Incorporation of others' vaccination behavior in one's own vaccination decision

Answering the research question

Article 2 (and the extended version) addressed the research question of whether the vaccination decisions of out-group members (i.e., health status of migrants) influence one's own vaccination decision.

From a rational point of view, consideration of an out-group's health status depends on outcome interdependence between groups (Korn, Betsch, Böhm, & Meier, 2018). Thus, while health decisions from a structurally independent out-group (e.g., another country) should be ignored, health decisions from an interdependent out-group (e.g., migrating group) should indeed matter.

The results of the experiments in this dissertation, i.e., Article 1 (Korn et al., 2018) and 2 (Korn, Betsch, Böhm, & Meier, 2017), support this assumption. Article 1 revealed that information on the vaccine uptake of an independent out-group has no impact on one's own vaccination behavior. The results of Article 2, however, showed that communicating the vaccination status of an interdependent and migrating out-group can have detrimental effects, especially when both the vaccine uptake of the migrants and the host population's vaccination rate are high. This also means that Article 2 showed that information, which is supposed to be used for prejudice reduction (i.e., good-to-excellent health status of refugees, Khan et al., 2016), entails a negative influence on health decisions, namely free riding. This insight has practical relevance and is explained below.

Moreover, Article 2 examined the default assumption of individuals on a migrating out-group's health status. The results suggested that individuals of the host population fall back on the assumption that migrants' vaccine uptake is low when no information about the vaccination uptake is available. Since the additional information was on group memberships, the default assumption about refugees' vaccine uptake is likely to be influenced by stereotypes and prejudices. This could indicate that individuals have a default belief that refugees have a rather poor health status.

Future research

Article 2 explicitly investigated whether information on the health status of members of a migrating out-group is incorporated into the vaccination decision among members of the host population. For this purpose, participants were confronted with hypothetical scenarios and asked to imagine that three members from their own group were replaced by three members from a refugee group. Although this scenario was necessary from a game theoretical point of view (see discussion section of Article 2, extended version, and limitations section "stable population"), it is unrealistic, as migration implies an influx of individuals from a migrating population into the host population. Therefore, future research should implement a procedure where the I-Vax game allows varying population sizes. Nevertheless, population size itself influences cooperation — the larger the population, the lower the rate of cooperation (Dawes, 1980; De Cremer & Leonardelli, 2003). Thus, future research will have to deal with the conceptual separation of this population size effect and a population composition effect in the context of migration and vaccination decisions.

Furthermore, individuals were informed about the extent of the influx of migrants beforehand. However, in reality, the numbers of migrating individuals might be unknown beforehand and are, rather, prognoses. Therefore, future research should also vary the presence of information on and the extent of the influx of migrants in the I-Vax game. This could address the question as to whether the number of migrants is a moderator for the vaccination decision or whether the mere fact that there is an influx results in individuals adapting their health decision (i.e., vaccination decision).

As noted in the introduction, experimental settings that include behavioral consequences (revealed preferences approach) are considered less prone to socially desirable responses (Norwood & Lusk, 2011) and "cheap talk" (Galizzi & Wiesen, 2018) than experimental settings that assess behavioral intentions. In Article 2, however, participants were asked to indicate their behavioral intentions. Intention corresponds only moderately with actual behavior (Sheeran, 2002). Therefore, future research should adapt the approach of investigating the influence of information on the vaccine uptake of an independent out-group to an incentivized setting.

Practical implications

In their topical perspective, Kahn et al. (2016) pointed out that the influx of migrants is often perceived as a health threat by host countries. This can lead to discrimination against migrants and refugees. As a consequence, the authors argue to debunk these misconceptions by effectively communicating the good-to-excellent health status of refugees.

The results of this dissertation, however, showed that the mere communication of the refugees' vaccination status can have detrimental effects, especially when both the vaccine uptake of refugees and the host population's vaccine rate are high. Moreover, previous research showed that there is inconclusive evidence as to whether providing facts and evidence can reduce prejudices (Mansouri & Vergani, 2018; Moritz et al., 2017; Pettigrew & Tropp, 2008; Stangor, 2016).

Based on the results of the dissertation and previous research on discrimination reduction, an intervention to reduce prejudice should not be based exclusively on communicating that the health status of migrants is very good. Considering the results and the discussion on the effectiveness of social goals (see discussion on the first research question above; Article 1), a possible intervention may be to communicate disease elimination as a superordinate goal. This could increase the willingness to be vaccinated and, at the same time, reduce intergroup conflicts (see, for example, Sherif, 1961). This approach might help to achieve two major goals simultaneously: fighting discrimination *and* infectious diseases.

Vaccination as social contract - the reactions to other's vaccination behavior

Answering the research question

The third article used incentivized experiments to investigate the boundary conditions of prosociality. More specifically, it was examined whether and how individuals react to others' vaccination behavior, wherein others are either (non-vaccinated) members of an in-group or and out-group. These behavioral reactions eventually serve to assess whether vaccination is a social contract and thus a moral obligation. According to the morality-as-cooperation theory (Curry, 2016), this would be the case when vaccinated individuals a) positively reciprocate vaccinated others, b) negatively reciprocate non-vaccinated others, and c) when reciprocal behavior occurs independently from the other's group membership.

The series of experiments in Article 3 showed that vaccinated participants, especially, react sensitively toward others' vaccination decisions — they reciprocate on the others' vaccination behaviors (also known as tit for tat; Fehr, Fischbacher, & Gächter, 2002). That is, vaccinated participants show less prosociality toward non-vaccinated others compared to vaccinated others. Non-vaccinated participants, however, differentiated less between vaccinated and non-vaccinated others. These results indicate that vaccination is indeed a social contract.

Moreover, when examining the absolute changes of prosociality, it becomes apparent that the effects of one's own and the other's vaccination behavior on changes in prosociality is mainly driven by negative reciprocity.

Importantly, this reciprocal behavior among vaccinated as well as non-vaccinated participants emerged independently from the group membership of the other individual. This means that participants show the same reciprocal behavior toward both in- and out-group members. This implies that vaccination as a social contract applies to all individuals, independent from the others' group membership. This serves as evidence for a universal principle.

Lastly, note that two out of three experiments in Article 3 additionally assessed warmth as a self-reported, evaluative measurement of interpersonal closeness. Warmth refers to interpersonal judgments of other individuals and indicates whether participants perceive other individuals positively or negatively, which is considered as a moral judgment of others' behavior (Ellemers, van der Toorn, Paunov, & van Leeuwen, 2019). Furthermore, previous research showed that warmth is fundamental in the evaluation of others and influences emotions and behavior toward others, such as helping behavior (Cuddy, Fiske, & Glick, 2008; Fiske, Cuddy, & Glick, 2007). The results regarding warmth showed the same pattern as the results regarding changes in prosociality. Taken together, this means that Article 3 showed, by reference to two qualitatively different measures, namely changes in prosociality and warmth, that individuals indeed perceive vaccination as a universal social contract, wherein cooperation is the morally right choice.

Based on these findings, the implications for future research and their practical relevance will be discussed.

Future research

Participants' changes in prosociality toward (un-)vaccinated others was assessed using an established measure of social preferences, namely the Murphy and colleagues' (2011) social value orientation. In the process, social preference was measured in terms of how individuals allocate money between themselves and others. The responses were transformed into a single angle index of a participant's social value orientation, with lower values indicating more proself motivations, such as competitiveness, and higher values indicating higher prosocial motivations, e.g., maximization concerns. Following from this, reciprocal behavior, it is in question whether a reduction in prosociality (negative reciprocity) can be interpreted as punishment behavior. Murphy's measurement method does not allow statements about the extent to which punishment occurs. This is due to the fact that the reduction in prosociality (less money for the other person) is confounded with self-interest. Allocating less money for the other person also means keeping more money for oneself. Therefore, in order to research punishment behavior in the context of vaccination decisions, procedures are needed that differentiate between self-interest and punishment. In economic research, punishment poses a second order public good (Ozono, Jin, Watabe, & Shimizu, 2016). This means that punishment is costly for the punisher, and therefore self-interest and punishment can be disentangled. Future research should address this issue and implement the possibility to punish as a second order public good into the I-Vax game. When punishing and rewarding is costly for an individual when evaluating others' vaccination decisions, then it is possible to research the phenomenon of strong reciprocity (Fehr et al., 2002) in the context of the vaccination decision.

Lastly, the analyses revealed that intergroup bias is a persistent and independent effect also in the domain of vaccination. Members of a minority are likely to experience disadvantages in terms of prosociality from members of the majority. Cooperative behavior (i.e., vaccination) cannot compensate for this effect. Future research should address this issue and replicate the current experiments in combination with potential interventions, such as imagined inter-group interaction (e.g., Vezzali, Stathi, Crisp, Giovannini, & Gaertner, 2015), to eliminate the intergroup bias.

Practical implications

In evaluating the appropriateness of vaccination mandates, the German Ethics Committee (Deutscher Ethikrat, 2019) recently stated that vaccinations should be considered a moral, but not legal, obligation. Thus, vaccination is proposed as a social contract to which every individual shall contribute. Article 3 showed that reciprocity (Fehr et al., 2002) plays a role when evaluating others' vaccination behavior, indicating that vaccination is indeed a social contract (on morality and its behavioral implications, see Curry, 2016). Individuals negatively reciprocate non-compliance with the social contract. Since ingroup bias and reciprocity emerged independently from each other, one could assume that people perceive this social contract as applicable to all individuals, regardless of group membership. However, since the experiments were carried out in Western, educated, industrialized, rich, and democratic (WEIRD) countries (see limitations section), cultural comparisons are needed to add more evidence in order to make universalistic propositions on the applicability of the social contract assumption. Nevertheless, communicating vaccination as a social contract could be a promising extension of communicating the social benefit of vaccination (Betsch, Böhm, Korn, & Holtmann, 2017) in order to increase vaccine uptake without relying on mandates. In this vein, stressing that everyone who is able to get vaccinated is expected to do so could have additional benefits to communicating the principle of herd immunity. This appeal could be based on moral grounds, either stressing fairness or care (e.g., stating that violating the social contract has a negative impact on vulnerable demographic groups and thus the health of society). It could also be based on providing descriptive norms (Brewer, Chapman, Rothman, Leask, & Kempe, 2017), given that the vaccine uptake is already high. As communicating high levels of vaccine uptake can also result in a lower willingness to be vaccinated due to free riding (Böhm, Betsch, & Korn, 2016), it will be important to assess whether stressing the social contract may attenuate or reverse this negative effect.

Moreover, the media often reports that non-vaccination is becoming more widespread (McBain, 2019). The results of Article 3 suggest that this narrative, the existence of non-vaccinators, can negatively affect prosociality and subjective closeness toward the other individual. Both variables are related to helping behavior (Cuddy et al., 2008; Pletzer et al., 2018). This means that over-communication of the prevalence of non-vaccinated individuals can also jeopardize the willingness to contribute to the social contract, as it may imply that the concept of vaccination as a social contract has failed. However, as this deduction was not tested explicitly, it is an interesting starting point for future research.

Limitations

In the following section, the methodological limitations of the dissertation are discussed. The subsequent section focuses on restrictions with regard to the sample and the method of research. Furthermore, the external validity of the results is discussed.

The samples

This dissertation used mainly convenience samples. This method is considered as a non-probability sample because the recruitment of respondents is based on accessibility and not on representativeness regarding a population (Colman, 2015). One major criticism of this approach is that it is unclear to what extent the results are generalizable (Bryman, 2016). I will discuss this point of criticism below.

Articles 1 and 2 recruited a student sample, and Article 3 conducted data collection online via Amazon Mechanical Turk. This was based on pragmatic considerations:

First, since the first two articles addressed feedback information and historical vaccination rates, the experiments required a laboratory setting. The Erfurt Laboratory for Empirical Research (ErfurtLab) is situated at the University of Erfurt and utilized the online registration software ORSEE (Greiner, 2004) for the recruitment of students. Due to their homogeneity regarding certain aspects (e.g., education), student samples may be criticized for endangering the generalization to non-student populations (Gallander Wintre, North, & Sugar, 2001). However, social identity theory, goal-setting theory, stereotypes, and prejudice do not rely on specific sub-populations. Instead, they are assumed to describe basic psychological processes. Therefore, it can be argued that a student sample does not pose a serious threat to the study's external validity (Peterson & Merunka, 2014).

Second, in Article 3, Mechanical Turk users from the UK and the U.S. were recruited. Even though online samples are prone to distraction from tasks and written instructions, previous research showed that Mechanical Turk samples were superior to student and panel samples regarding their data quality and replicability of effects (Bartneck, Duenser, Moltchanova, & Zawieska, 2015; Kees, Berry, Burton, & Sheehan, 2017), as well as in the context of participants' attentiveness (Ramsey, Thompson, McKenzie, & Rosenbaum, 2016). Moreover, since Article 3 focuses on migration and refugees, and migration, in turn, is a sensitive topic (Oberski, Weber, & Révilla, 2012), recruiting students was ineligible. In Germany, individuals with higher education and students generally have positive attitudes toward migrants and refugees (Helbling et al., 2017). This contrasts with Western countries, such as Germany and the U.S., in which the overall attitude toward migrants is rather negative (Poutvaara & Steinhardt, 2018; Verkuyten, Mepham, & Kros, 2018). Thus, online recruitment was preferred in order to map a more general picture regarding the attitudes toward migrants. Nevertheless, testing the validity of the findings of both studies using a probability sampling is an important step for future research.

Moreover, all studies included in the dissertation have in common that they recruited participants from WEIRD societies. Henrich and colleagues (2010) argued that participants from WEIRD countries are the least representative populations for generalizing findings in psychology. This means that the results of the studies should be replicated in different cultural settings to draw global conclusions on, for example, the effectiveness of symbolically rewarding the attainment of the social goal of disease elimination or the concept of vaccination as social contract. This reflection becomes more important when one considers that health communication should be conceived in a culturally sensitive way to increase its effectiveness (Betsch et al., 2016). Therefore, it is important that future research varies the type of sampling (probability sampling) and examines the results of the studies from a cultural and psychological perspective.

The research method

This dissertation used the I-Vax game as a research paradigm. As with any research method, the I-Vax game has limitations. Therefore, the upsides and downsides of the I-Vax game are discussed below.

As described in the introduction, the I-Vax game represents a method to model the interdependence of individuals in the context of vaccinations. Moreover, it “opens up the possibility of studying vaccination behavior under controlled conditions by means of an incentivized behavioral game” (Böhm, Betsch, & Korn, 2016, p. 11) and is proposed as an experimental tool that provides researchers the opportunity to test interventions in a controlled lab setting before implementing novel interventions in the real world. The method thus enables an economically efficient evaluation of new interventions to increase vaccination rates.

Incentives. In behavioral economics, financial incentives are considered a strength in an experimental setting (Hertwig & Ortmann, 2001). This is because incentives are assumed to enhance attentiveness and focus, and thus reduce response variability (Lonati, Quiroga, Zehnder, & Antonakis, 2018). Moreover, incentivized experiments are less prone to socially desirable responses (Norwood & Lusk, 2011) and “cheap talk” (Galizzi & Wiesen, 2018) than experiments using a stated preferences approach.

Hertwig and Ortmann (2001), as well as Lonati and colleagues (2018), conclude from their discussions about the conception of experimental studies in the field of behavioral sciences that incentives, as far as they can be implemented, should be used to obtain results that are reliable in the scientific field.

However, one could argue that health and monetary incentives do not match. As mentioned in the introduction, the vaccination decision can be conceptualized as a cost calculation because vaccination is a preventive measure which yields costs (in both cases: vaccination and non-vaccination). This consideration was included in the I-Vax game, as the I-Vax game is loss-framed. This means that participants were given a certain amount of endowment representing full health. The decision in favor or against vaccination yields monetary consequences. In both cases, monetary incentives and health, I argue that individuals show a minimization aspiration; in other words, an individual wants to reduce monetary losses and to preserve health. Therefore, I assume that monetary incentives can be used in the I-Vax game as a proxy for health.

Nevertheless, creating consequential settings in behavioral experiments is not restricted to monetary incentives (Lonati et al., 2018). With regard to the external validity of the I-Vax game, it would be interesting to replace monetary consequences with physical consequences. For example, as noises can induce subjective discomfort (Huang & Griffin, 2014), one could think of an uncomfortable noise representing a symptom of a disease and side effect of the vaccine. The severity of the disease and the side effect could be varied via the duration of the aversive stimulus. Any other aspect, such as determining the probability of infection, will be adopted from the original I-Vax game. The duration of the unpleasant noise is quantifiable, and it is thus possible, as in the original I-vax game, to make prescriptive assumptions about an individual's behavior, i.e., determining the Nash equilibria.

Assumptions of the I-Vax game. As stated in the beginning, the I-Vax game contains certain assumptions and procedures, which have to be discussed. The following discussion focuses on the assumption of stable populations and clustering.

Stable population. As the I-Vax game maps a SIR model to incorporate the epidemiological processes of infection and vaccination, it assumes stable populations (see also General Introduction). This means that neither birth nor death is involved. This is, of course, an unrealistic assumption. Suffering from measles or influenza, for example, not only leads to hospitalization, but both diseases can be fatal (CDC, 2019a, 2019b). Death, as the ultimate consequence of behavior, should influence decision-making. Thus, it would be an interesting avenue of future research to include the possibility of, for example, financial death in the I-Vax game.

In the dissertation, the migration of individuals was designed in such a way that the population remained stable and the participants knew in advance how the population was constituted and whether and how many migrants would join their own group. In Article 2 ("Information on an interdependent out-group's vaccination uptake"), for example, three individuals of a fictitious out-group replaced three individuals of the in-group. This replacement procedure may seem unrealistic, yet it was necessary from a game theoretical point of view due to the fixed group constellation of 12 players. Increasing the total population from 12 to 15 seemed less advantageous as the effects could not be clearly attributed to the influence on refugees but could also be explained by a general population growth and the associated lower influence of an individual on the vaccination rate. In Article 3, the participants received prior information on population size and composition (defined number of in-group and out-group members) after migration. The population was therefore determined a priori and thus stable.

A modified version of the repeated I-vax game in which participants are exposed to one or more migration waves in the course of the experiment would be of interest. For example, an avenue for future research would be to replicate the results of the second article with a revealed preferences approach. This would allow reliable statements on the influence of information on an interdependent out-group's vaccination uptake on individuals' vaccination behavior.

Mixed population. Another assumption of the I-Vax game is that the population is well-mixed. This means that the contact probability for every individual is identical. This assumption is, of course, quite artificial. Individuals favor interactions with friends and neighbors and have living preferences, which leads to segregation (Omidvar & Franceschetti, 2018). Consequently, the contact probabilities of individuals differ depending on where they live and their preferences. This means that individuals live in contact networks. Thus, in reference to the current dissertation, it would be interesting to model the I-Vax game into a system of networks of individuals in which proximity is a factor in disease transmission.

From the lab to the field

The present dissertation adopted an (quasi-) experimental approach to answer the research questions. The advantage of a lab experiment is its internal validity. This means that a hypothesized effect of an independent variable on a dependent variable can be investigated causally while, at the same time, controlling for undesirable, external influencing factors (Bhattacherjee, 2012). However, this upside is also its downside. Controlling for external influencing factors contributes to the artificiality of a lab experiment and therefore endangers external validity (i.e., generalizability). Online experiments have been shown as more ecologically valid than lab experiments (Finley & Penningroth, 2015) because of the possibility to recruit large and diverse samples (Radford et al., 2016; Reips, 2000). Moreover, Bhattacherjee (2012) argued that field experiments should be implemented to achieve high internal as well as external valid results. However, experiments in the field are expensive and difficult to implement. Nevertheless, future research could use a mixed methods approach, i.e., complementing lab and online experiments with quantitative studies or field experiments to investigate the effects observed in the current dissertation.

Minimal and real groups

The studies in this dissertation used the minimal group paradigm to investigate intra- and inter-group processes in the context of vaccination. As noted above, Chowdhury, Jeon, and Ramalingam (2016), for example, showed that cooperation increases when a natural group identity is salient compared to when a minimal group identity is salient. This means that future research should examine the results of the first article with regard to natural groups. Moreover, Balliet, Wu, and De Dreu (2014) showed in a meta-analysis that there is no difference in in-group favoritism between natural versus minimal groups. However, in regard to Articles 2 and 3, future research could vary the group types (natural vs. minimal) and examine actual vaccination behavior when researching a) the influence of information on an interdependent out-group's vaccination uptake on individuals' vaccination behavior and b) the changes of prosociality in the vaccination context.

Non-strategical considerations of vaccination

As outlined in the introduction of this dissertation, context information, such as the interdependence between individuals, may contribute to a different evaluation of the individual vaccination decision and add to a better understanding of vaccination decisions from a scientific perspective. However, focusing on the strategic aspects of the vaccination decision and its implications may neglect other perspectives, which are also important to understand the vaccination decision. For example, the interpersonal relationship between physician and patient is important in the vaccine decision-making process (Brewer et al., 2017). This cannot be modeled in the I-Vax game. However, the I-Vax game can be utilized to construct realistic, incentivized scenarios to inform interpersonal communication research. In this way, the influence of different variables, such as the severity of the disease and vaccination, the probability of occurrence of the disease, and vaccination side effects, on the doctor-patient dyad can be investigated, thus offering possible starting points for the effective communication of vaccinations.

In sum, it is important to follow different approaches and use different research methods to understand the decision-making processes from a scientific perspective and to ultimately increase the vaccine acceptance in the general population.

Conclusions

In conclusion, the conceptualization of vaccination as a social interaction facilitates the identification of the intra- and inter-group dynamics of vaccination. The dissertation showed that it is possible to promote vaccination behavior in a complex environment when communicating vaccination as a social goal using non-monetary rewards. Moreover, interdependence between groups plays a major role when examining the incorporation of others' vaccination behavior into one's own vaccination decision. This means that the social component of vaccination also involves pitfalls, and therefore possible backfire effects should be investigated and taken into account in health communication.

Finally, the dissertation showed, by examining individuals' reactions toward others' vaccination behavior, that individuals indeed perceive vaccination as a universal social contract. This insight provides a valuable basis for future interventions aiming to increase vaccine uptake by emphasizing this social contract. Therefore, future research should develop, test, and implement strategies for communicating vaccination as a social contract to help increase vaccine uptake and, ultimately, overcome the burden of diseases.

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Supplement

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Supplement

to

Drawbacks of communicating refugee vaccination rates

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Data

The raw data and a data legend can be downloaded here:

Korn L, Betsch C, Böhm R, Meier N. Data of Communicating high vaccine rates of refugees. 2016; published online Nov 23. osf.io/q82q5

Methods

Participants

The experiment was conducted between May and July 2016 at the Erfurt Laboratory for Experimental Economics (eLab), University of Erfurt in Germany. There were four sessions, each with two groups (*N* = 96). Participants were 30 male and 66 female students from the University of Erfurt (*M* = 22.02 years, *SD* = 2.91).

The I-Vax Game

Participants were randomly assigned to one of two structurally independent groups per session, consisting of 12 players each. Groups were named either as yellow or blue group, and represented the host countries. The group remained stable for the course of the experiment. The game consisted of 20 rounds.

The I-Vax Game models the expected utility (EU) of vaccination for an individual i as follows:

$$EU_i = e - c_{a_i}^{fix} - c_{a_i}^{var} \; [1]$$

Players are endowed with $e = 100$ health points in each round. The main dependent variable in the I-Vax Game is the vaccination decision (a_i, 0 = non-vaccination, 1 = vaccination).

A decision in favour of vaccination yields a fixed loss of $\mathrm{c}_1^{\mathrm{fix}} = 10$ health points, resembling costs such as the effort of visiting the GP's practice or the pain of the pinprick. Omission of vaccination yields no such fixed loss, $\mathrm{c}_0^{\mathrm{fix}} = 0$.

Both vaccination and non-vaccination entail variable costs:

$$c_{a_i}^{var} = p_{a_i}^{var} \times s_{a_i,j}. \text{ [2]}$$

In the case of vaccination, the probability of side effects is constant with $\mathrm{p}_1^{\mathrm{var}} = 0 \cdot 5$. The number of points lost due to side effects depends on their severity $s_{1,j}$ with $j \in \{mild, medium, severe\}$:

$$j \begin{cases} mild\ with\ s_{1,mild} = 28\ and\ probabilty\ p_{1,mild} = 0 \cdot 5 \\ medium\ with\ s_{1,medium} = 48\ and\ probabilty\ p_{1,medium} = 0 \cdot 4 \\ severe\ with\ s_{1,severe} = 68\ and\ probabilty\ p_{1,severe} = 0 \cdot 1 \end{cases} \text{[3]}$$

The mean severity of side effects is $s_1 = 40$.

Therefore, given [1], the expected utility of vaccination is:

$$EU = 100 - 10 - 0 \cdot 5 \times 40 = 70 \text{ health points.}$$

In the case of non-vaccination, the probability of contracting the disease varies as a function of the basic reproduction number of the disease (R_0, in this study, $R_0 = 4$) and the vaccination rate (v, whereby $0 \leq v \leq 1$) in the respective round:

$$\mathrm{p}_0^{\mathrm{var}} \begin{cases} 1 - \frac{1}{R_0(1-v)}, & \text{if } R_0(1-v) \geq 1 \\ 0, & \text{else} \end{cases} \text{[4]}$$

The probabilities $p_{1,j}$ of the different disease outcomes are equal to the probabilities of the vaccine side effects $p_{0,j}$. However, the mean severity of the disease ($s_1 = 50$, calculated from [5]) is higher than the mean severity of vaccine side effects ($s_0 = 40$, calculated from [3]):

$$j \begin{cases} mild\ with\ s_{0,mild} = 35\ and\ probabilty\ p_{0,mild} = 0 \cdot 5 \\ medium\ with\ s_{0,medium} = 60\ and\ probabilty\ p_{0,medium} = 0 \cdot 4 \\ severe\ with\ s_{0,severe} = 85\ and\ probabilty\ p_{0,severe} = 0 \cdot 1 \end{cases} \text{[5]}$$

Given the experiment's parameterisation, a fraction of 5 vaccinated players out of 12 ($v = 0 \cdot 42$) constitutes a Nash equilibrium (i.e., a player has no incentive to change her decision unilaterally). However, a selfish-rational player i has an incentive to switch from non-vaccination to vaccination if 4 players (or less) have been vaccinated ($EU_i = 68 \cdot 75, if\ a_i = 0$ and $EU_i = 70, if\ a_i = 1$, respectively), and to switch from vaccination to non-vaccination if 6 players (or more) have been vaccinated ($EU_i = 75, if\ a_i = 0$ and $EU_i = 70, if\ a_i = 1$, respectively).

In contrast, social welfare is maximised if 9 players decide in favour of vaccination ($v = 0 \cdot 75$), because the probability of infection for non-vaccinated individuals is zero and the aggregated payoffs reach their maximum (8 players vaccinated: $\sum_{i=1}^{12} EU_i = 910$, 9 players vaccinated: $\sum_{i=1}^{12} EU_i = 930$, 10 players vaccinated: $\sum_{i=1}^{12} EU_i = 900$).

Manipulation

The study implemented a two-factorial mixed design. First, the participants played the I-Vax Game over 20 rounds. The number of rounds in which the participants were able to eradicate the disease serves as a (between-subjects, quasi-experimental) proxy for the host population's previous vaccine uptake. Second, the refugee population's vaccine uptake varied as a six-step within-subjects factor (number of disease eradications in the refugee population over 20 rounds: 0, 5, 10, 15, 20, no information - control condition). Participants received vignettes of six scenarios. The scenarios described that 3 players from a third, fictitious other group (named as "purple group"), replaced 3 players of the participant's group. As such, participants received information regarding the other group's performance in eradicating the disease, which served as a proxy for refugees' vaccine uptake. Finally, they had to decide in favour of or against vaccination (0 = non-vaccination, 1 = vaccination) for each of the vignettes, given the refugees' vaccine uptake. These decisions were not payoff relevant.

Procedure

The experiment was conducted as a laboratory trial, implemented with the software z-Tree.[1] Recruitment of the participants was realised via the online registration software ORSEE[2] and individual recruiting. Upon arrival, participants were randomly assigned to one of 24 cubicles. All payoffs of the experiment were determined in health points and converted into Euros at the end of the experiment (conversion rate: 100 points = 0·75 Euros). Participants earned on average 11 Euros for participating in the I-Vax Game (*SD* = 0·84 Euros). The whole session took about 75 minutes and included another unrelated experimental task.

Participants received printed instructions on general information regarding laboratory experiments, the rules of the I-Vax Game, complemented with two examples, and instructions regarding the focal vaccination decisions given varying refugee influx. The instructions were read aloud and participants could ask questions. Participants had to demonstrate their understanding of the rules in a comprehension test prior to playing the I-Vax Game. Each round of the I-Vax Game subdivides into three phases. In the decision phase, players decide in favour of or against vaccination, followed by the outbreak phase, where players might get infected depending on their own decision and the decisions of the other 11 group members. In the feedback phase, players receive the following information: own vaccination decision, the number of vaccinated members in their own group (host population), the resulting infection probability, the accumulated number of disease eradications in their own group (from round one to current round), point loss (if any; due to side effects after vaccination or due to infection after non-vaccination), the resulting pay-off in the respective round (endowment minus point loss), the number of vaccinated members of the other group, the resulting infection probability in the other group, and the accumulated number of disease eradications in the other group (from round one to current round).

After completion of the I-Vax Game, participants were presented with the scenario and indicated their decisions contingent on the varying histories of disease eradication in the refugees' population. Finally, they answered questions regarding demographics, were informed about their individual payoff, and privately received their earnings.

Results

Logistic regression analyses with logit link were applied to estimate fixed effects. Furthermore, in order to adequately consider refugees' vaccine uptake as a six-step within-subjects factor, random effects of the subject were taken into account. Thus, the generalized linear mixed models in Table 1 had following form:

$$L(a = 1) \sim fixed\ effects + (1|subject) + \varepsilon$$

For model estimation, the R-environment[3] and the lme4 package[4] was used. Estimation results are shown in Table 1.

Predictor	Model 1		Model 2	
	B	SE	B	SE
Intercept	0·402	0·402	0·817†	0·418
Host population's previous vaccine uptake (A)	0·300†	0·162	0·028	0·164
Refugee population's vaccine uptake (B)	-0·079**	0·025		
A*B	-0·020*	0·010		
Information about refugees' vaccine uptake available (C)			-1·160**	0·392
A*C			0·059	0·152
ML model fit: AIC / BIC	558·9 / 579·7		719·3 / 741·0	

Table 1. N=96, M_{age} = 22·02 [SD = 2·91]. Mixed effects model (prediction of vaccination decisions): Subjects treated as random effect. Host population's previous vaccine uptake: number of disease eradications that the group reached over 20 rounds, resulting in (0, 3, 4) eradications. Refugee population's vaccine uptake: communicated number of disease eradications in the refugee population over 20 rounds (0, 1, 2, 3, 4). Information about refugees' vaccine uptake available: 0 = no, 1 = yes. Significance levels: † p <0·1, * p < 0·05, ** p < 0·01. Note. For detailed game description see [5].

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Supplement

to

Article 3

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Supplement

to

Vaccination as a social contract

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Results of the individual experiments

Experiment 1

The first experiment examined changes in prosociality towards others based on the participant's vaccination behavior, vaccination behavior of the other, group membership, and a situation where two groups were either outcome independent from each other or outcome interdependent. Table S3 shows the results from the pre-registered repeated-measures ANOVA with the changes in prosociality as a dependent variable. Figures 1 and S2 visualize the results across all experiments (Figure 1 provides the hypothesis tests and manipulation check; Figure S1 visualizes the remaining effects; and Figure S2 shows the results of Experiment 1 only). Figure S2 shows that, in accordance with the reciprocity hypothesis, vaccinated individuals especially reduced their prosociality toward others who did not get vaccinated in the I-Vax game (M_{no_vacc} = -8.04, SD_{no_vacc} = 14.52) as compared to others who did get vaccinated (M_{vacc} = 0.97, SD_{vacc} = 9.75). Non-vaccinated participants, in contrast, did not differentiate between vaccinated and non-vaccinated others (M_{vacc} = -2.20, SD_{vacc} = 11.80, M_{novacc} = -2.95, SD_{novacc} = 11.17; interaction B*D in Table S3).

Moreover, the results revealed an intergroup bias. Individuals showed more prosociality towards in-group members (*M* = -2.78, *SD* = 12.25) compared to out-group members (*M* = -3.83, *SD* = 13.26). We found, however, that this effect was moderated by interdependence, participant's vaccination decision, and other's vaccination decision.

The analysis further revealed a 4-way interaction (A*B*C*D in Table S3) on changes in prosociality. Individuals take other's previous vaccination behavior into account, and do so to a stronger degree when the other's group matters for the own outcome. Figure S2 shows that non-vaccinated participants (grey diamonds) do not condition their prosociality toward others on the other's vaccination decision, the other's group membership, or the interdependence condition. Moreover, all 95% CIs cross the zero-line, indicating no change from baseline to the conditional assessments of prosociality. In contrast, vaccinated participants (black diamonds) show reciprocal prosociality.

In order to explore the pattern among vaccinated participants, simple main effects for other's vaccination decision were calculated separately for each of the four quadrants in Figure S2 (combinations from the other's group membership and interdependence). When outcomes are independent (upper two quadrants), reciprocal prosociality towards in-group members (left, $M_{vacc} = 1.88$, $SD_{vacc} = 10.27$, $M_{novacc} = -5.43$, $SD_{novacc} = 13.09$; $F[1,83] = 22.29$, $p < .001$, $\eta^2_g = .09$) is quite similar to prosociality towards out-group members (right, $M_{vacc} = 0.82$, $SD_{vacc} = 10.13$, $M_{novacc} = -5.89$, $SD_{novacc} = 14.22$; $F[1,83] = 25.41$, $p < .001$, $\eta^2_g = .07$). When both groups are interdependent (lower two quadrants), reciprocal prosociality is less pronounced with members of the in-group (left, $M_{vacc} = 0.84$, $SD_{vacc} = 9.58$, $M_{novacc} = -9.12$, $SD_{novacc} = 14.46$; $F[1,79] = 33.51$, $p < .001$, $\eta^2_g = .14$) as compared to the out-group (right, $M_{vacc} = 0.31$, $SD_{vacc} = 9.03$, $M_{novacc} = -11.98$, $SD_{novacc} = 15.55$; $F[1,79] = 43.71$, $p < .001$, $\eta^2_g = .19$).

These results indicate that reciprocal prosociality occurs especially toward out-group members when the groups are outcome interdependent. Nevertheless, reciprocity also occurred in the independence condition, which indicates that vaccination as a social contract also applies to individuals from an independent out-group.

Experiment 2

The second experiment aimed at replicating the results and tested the hypotheses in a migration framing, where groups were always outcome interdependent. Figure S3 visualizes the results; Table S4 shows the results from the pre-registered repeated-measures ANOVA with changes in prosociality as the dependent variable. Similar to Experiment 1, there was evidence for the reciprocity hypothesis. Vaccinated individuals showed less prosociality toward others who did not get vaccinated ($M_{no\_vacc} = -12.01$, $SD_{no\_vacc} = 19.22$) compared to others who got vaccinated (M_{vacc} = 0.92, SD_{vacc} = 10.15). Non-vaccinated participants, in contrast, did not differentiate between vaccinated and non-vaccinated others (M_{vacc} = -0.44, SD_{vacc} = 13.97, M_{novacc} = -2.24, SD_{novacc} = 14.15; see Table S6, interaction A*C).

Again, the results revealed an intergroup bias. Individuals showed more prosociality towards in-group members (*M* = -3.79, *SD* = 16.37) compared to out-group members (*M* = -5.52, *SD* = 16.07). This effect was qualified by an interaction with participant's vaccination decision (A*C) and other's vaccination decision (B*C).

Moreover, the analysis revealed a 3-way interaction (A*B*C in Table S4). Reciprocal prosociality was moderated by group membership. Reciprocal prosociality among vaccinated participants was more pronounced towards in-group members (left panel) than towards out-group members (right panel). Moreover, the 95% CI (see Figure S3) regarding prosociality change from vaccinated participants toward vaccinated in-group members did not cross the zero-line, indicating a positive change from baseline to the conditional assessment of prosociality. This pattern indicated rewarding behavior.

Experiment 3

The third experiment aimed to replicate the finding from Experiment 2 with a more pronounced migration framing. Similar to Experiments 1 and 2, the data supported the reciprocity hypothesis (see Table S5 and Figure S4). The results showed that vaccinated individuals reduced their prosociality toward others who did not get vaccinated in the I-Vax game ($\text{M}_{\text{no\_vacc}}$ = -11.17, $\text{SD}_{\text{no\_vacc}}$ = 16.69) compared to others who got vaccinated (M_{vacc} = 1.23, SD_{vacc} = 10.10). Non-vaccinated participants, in contrast, did not differentiate between vaccinated and non-vaccinated others (M_{vacc} = -0.92, SD_{vacc} = 9.28, M_{novacc} = -3.53, SD_{novacc} = 9.73; see Table S7, interaction A*C).

Again, the results revealed an intergroup bias. Individuals showed more prosociality towards in-group members (*M* = -3.83, *SD* = 13.91) compared to out-group members (*M* = -

5.06, *SD* = 14.59). In contrast to Experiment 2, the effect of reciprocal prosociality was not moderated by group membership. This means that the intergroup bias and reciprocal prosociality are two independent effects.

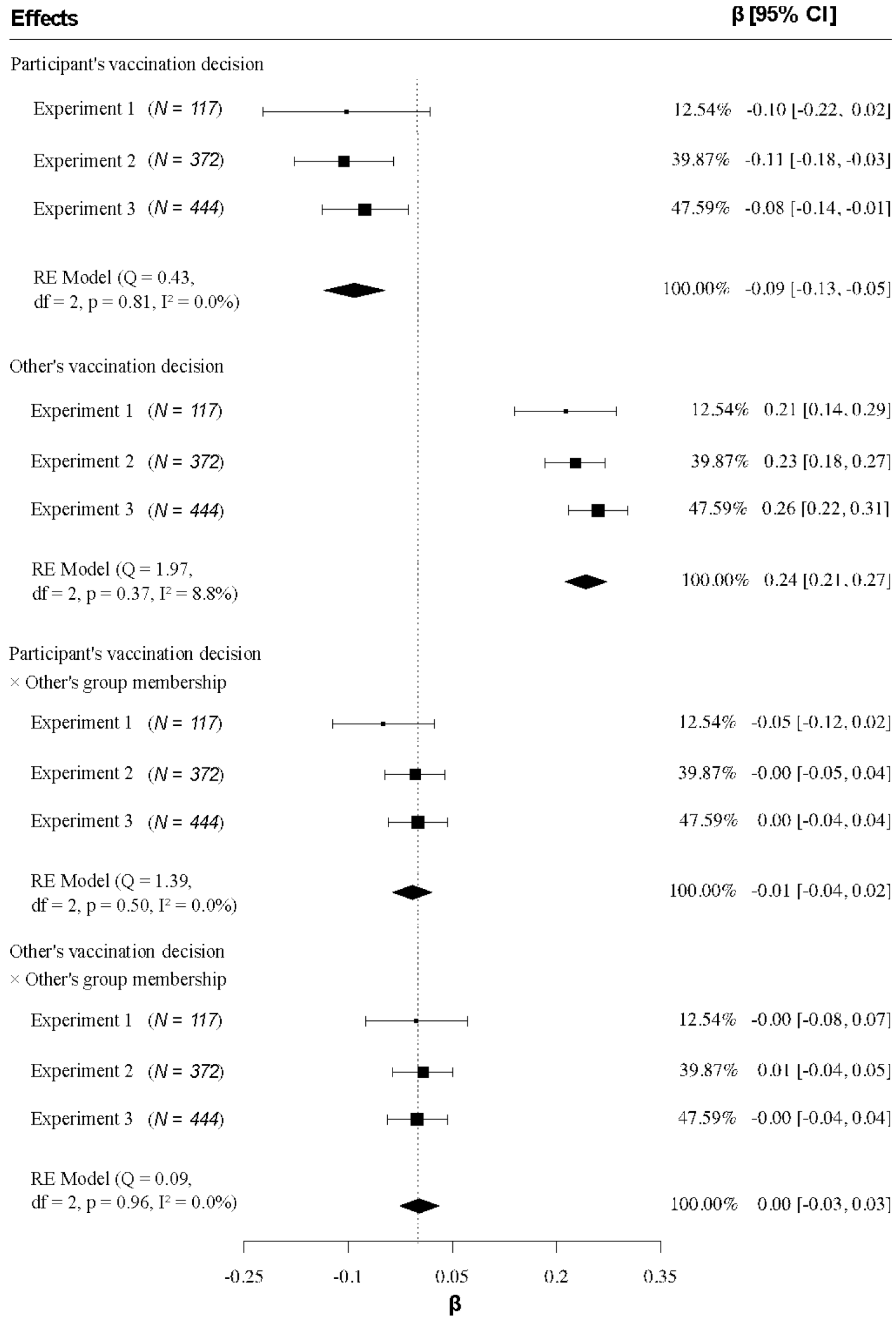

Figure S1. Forest plot of the effects of participant's vaccination decision, other's vaccination decision, interaction between participant's vaccination decision and other's group membership, and interaction between other's vaccination decision and other's group membership on prosociality change. Effects displaying betas, calculated from mixed effects regressions, and overall effects using a random effects model for meta-analysis. CIs refer to 95% confidence intervals. Q and I^2 were used for a heterogeneity assessment among studies.

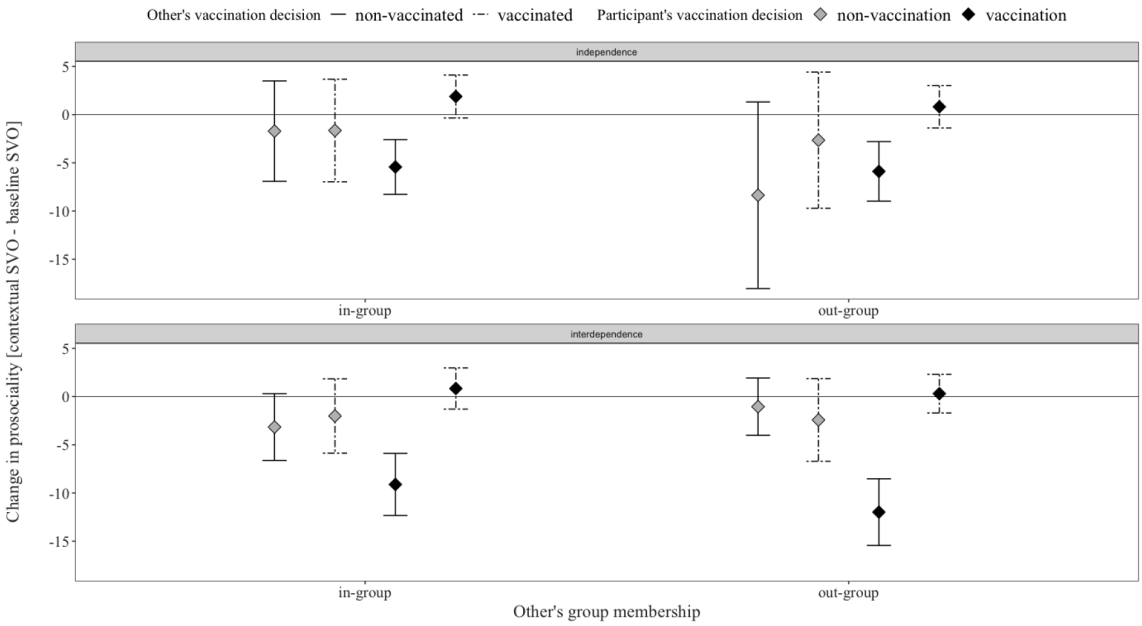

Figure S2. Changes in prosociality as a function of interdependence, other's group membership, other's vaccination decision, and participant's vaccination decision in Experiment 1. The factor of interdependence was used to split the errorbar plot. Diamonds show the mean change of prosociality; errorbars represent 95% CIs. Note: Non-vaccinated participants (grey errorbars) do not change their prosociality based on the other's vaccination behavior, group membership, and interdependence. Vaccinated participants (black errorbars) condition their prosociality on the other's vaccination behavior. Vaccinated participants reduce their prosociality toward non-vaccinated others (solid errorbars) compared to vaccinated others (dashed errorbars). This effect is more pronounced toward out-group members (right side of the plot) when both groups were outcome interdependent.

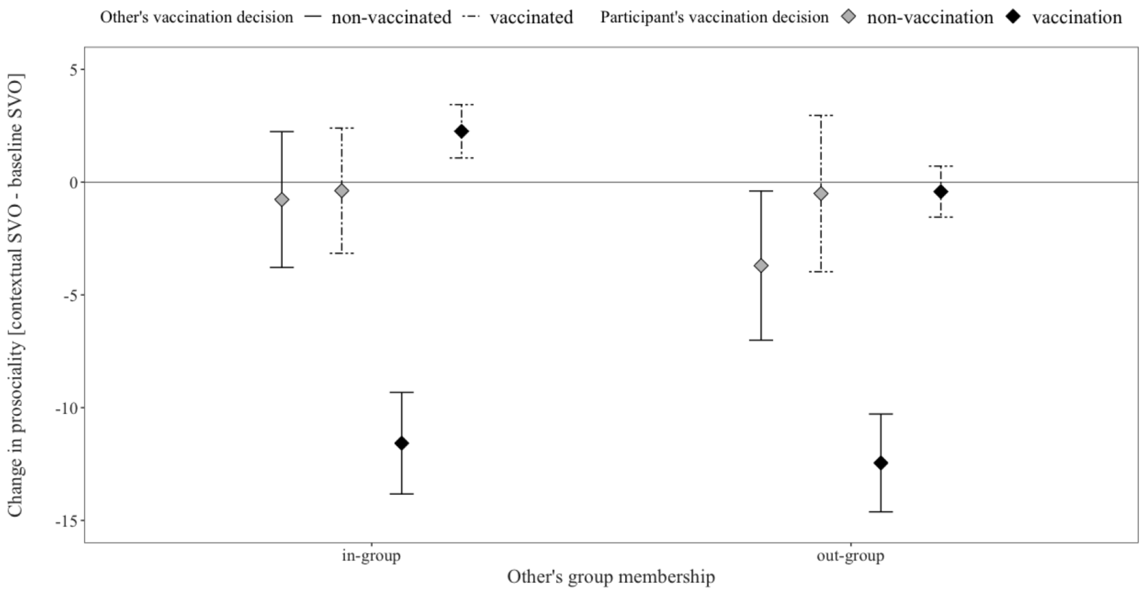

Figure S3. Changes in prosociality as a function of interdependence, other's group membership, other's vaccination decision, and participant's vaccination decision in Experiment 2. Diamonds show the mean change of prosociality; errorbars represent 95% CIs. Note: Non-vaccinated participants (grey errorbars) do not adapt their prosociality based on the other's vaccination behavior and group membership. Vaccinated participants (black errorbars) show reciprocal behavior and condition their prosociality on the other's vaccination behavior.

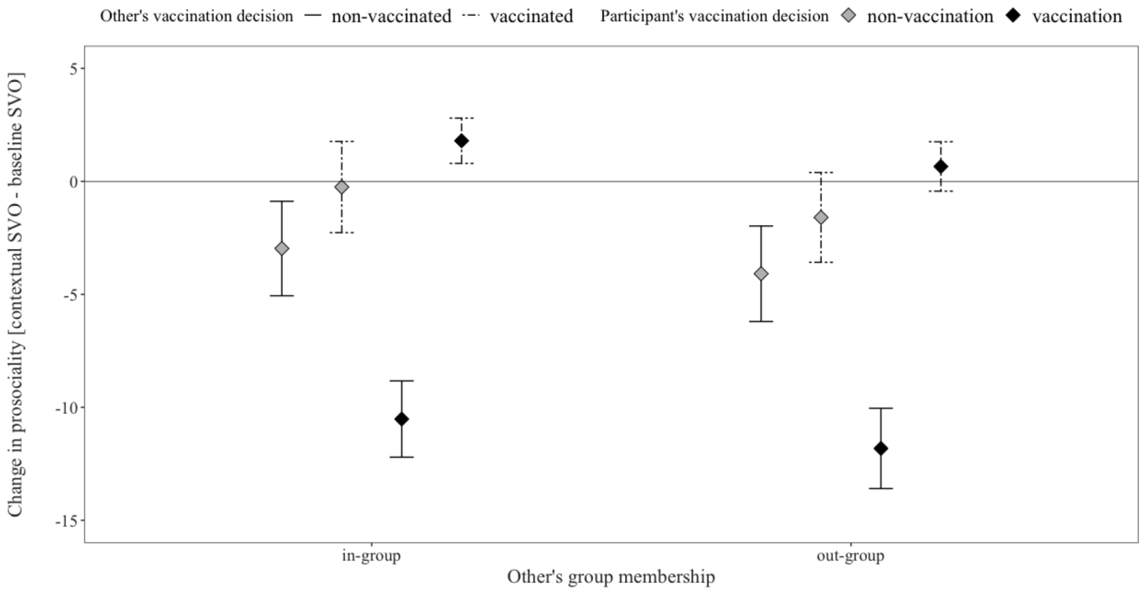

*Figure S4***.** Changes in prosociality as a function of interdependence, other's group membership, other's vaccination decision, and participant's vaccination decision in Experiment 3. Diamonds show the mean change of prosociality; errorbars represent 95% CIs. Note: Reciprocity was more pronounced among vaccinated participants (black errorbars). They condition their prosociality on the other's vaccination behavior, but not on the other's group membership.

	Experiment 1			Experiment 2			Experiment 3		
Predictors	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	-3.57	0.86	<.001	-3.44	0.73	<.001	-3.60	0.57	<.001
Participant's vaccination decision (A)	-2.83	1.71	.101	-4.21	1.46	.004	-2.75	1.15	.017
Other's vaccination decision (B)	5.50	0.97	<.001	7.36	0.72	<.001	7.50	0.63	<.001
Other's group membership (C)	-0.42	0.97	.662	-1.65	0.72	.021	-1.22	0.63	.051
A*B	11.24	1.94	<.001	11.14	1.43	<.001	9.79	1.25	<.001
A*C	-2.55	1.94	.189	-0.25	1.43	.863	0.01	1.25	.993
B*C	-0.09	1.94	.962	0.50	1.43	.727	-0.03	1.25	.978
A*B*C	4.87	3.87	.210	-4.60	2.86	.108	0.39	2.50	.876
Observations / N	468 / 117			1488 / 372			1776 / 444		
Marginal R^2 / Conditional R^2	.141 / .439			.140 / .519			.161 / .472		

Table S1. Mixed effects models predicting change in prosociality as a function of participant's vaccination decision, other's vaccination decision, other's group-membership, and their interactions, separate for each experiment. Note. Mixed effects model (prediction of prosociality change): Participants treated as random effect. Effect coding was used for all predictors. Participant's vaccination decision: -.5 = non-vaccination, +.5 = vaccination. Other's vaccination decision: -.5 = non-vaccination, +.5 vaccination. Group membership: -.5 = in-group, +.5 = out-group. ICC refers to intraclass correlation coefficient. Marginal R^2 refers to the proportion of variance explained by the fixed factors. Conditional R^2 refers to the proportion of variance explained by the fixed factors and the random factor.

	Warmth		
Predictors	β	*SE*	*p*
Participant's vaccination decision (A)	-0.05	0.02	<.001
Other's vaccination decision (B)	0.48	0.02	<.001
Other's group membership (C)	-0.08	0.02	<.001
Experiment (D)	-0.01	0.02	.438
A*B	0.22	0.02	<.001
A*C	0.02	0.02	.326
B*C	0.01	0.02	.751
A*B*C	-0.03	0.02	.078
Observations / N		3264 / 816	
Marginal R^2 / Conditional R^2		.418 / .482	

Table S2. Mixed effects model predicting warmth toward others as a function of the factors of participant's vaccination decision, other's vaccination decision, other's group membership, and their interactions in Experiments 2 and 3. *Note.* Mixed effects model (warmth): Participants treated as random effect. Effect coding was used for all predictors. Participant's vaccination decision: -.5 = non-vaccination, +.5 vaccination. Other's vaccination decision: -.5 = non-vaccination, +.5 vaccination. Group membership: -.5 = in-group, +.5 out-group. Experiment: -.5 = Experiment 2, +.5 = Experiment 3. Marginal R^2 refers to the proportion of variance explained by the fixed factors. Conditional R^2 refers to the proportion of variance explained by the fixed factors and the random factor.

Predictors	*df*	*MSE*	*F*	*p*	η^2_g
Participant's vaccination decision (A)	1,212	331.64	0.20	.657	<.001
Other's vaccination decision (B)	1,212	174.66	21.18	<.001	.030
Other's group membership (C)	1,212	44.00	5.69	.018	.002
Interdependence (D)	1,212	331.64	0.20	.654	<.001
A*B	1,212	174.66	11.43	.001	.020
A*C	1,212	44.00	0.05	.821	<.001
A*D	1,212	331.64	1.86	.174	.005
B*C	1,212	35.44	1.40	.238	<.001
B*D	1,212	174.66	0.06	.807	<.001
C*D	1,212	44.00	2.69	.102	.001
A*B*C	1,212	35.44	0.11	.735	<.001
A*B*D	1,212	174.66	2.46	.119	.003
A*C*D	1,212	44.00	6.08	.015	.002
B*C*D	1,212	35.44	1.62	.204	<.001
A*B*C*D	1,212	35.44	7.38	.007	.002

Table S3. Results from Univariate Type III Repeated-Measures ANOVA with assumed sphericity in Experiment 1: Changes in prosociality as a function of the factors of participant's vaccination decision, other's vaccination decision, other's group membership, and interdependence. *Note.* $N = 216$. *df* indicates numerator and denominator degrees of freedom. η^2_g indicates generalized eta-squared.

Predictors	*df*	*MSE*	*F*	*p*	η^2_g
Participant's vaccination decision (A)	1,370	528.75	8.34	.004	.010
Other's vaccination decision (B)	1,370	277.34	48.65	<.001	.040
Other's group membership (C)	1,370	58.24	11.67	.001	.002
A*B	1,370	277.34	27.83	<.001	.020
A*C	1,370	58.24	0.07	.798	<.001
B*C	1,370	46.33	0.34	.563	<.001
A*B*C	1,370	46.33	7.12	.008	<.001

Table S4. Results from Univariate Type III Repeated-Measures ANOVA with assumed sphericity in Experiment 2: Changes in prosociality as a function of the factors of participant's vaccination decision, other's vaccination decision, and other's group membership. Note. N = 372. df indicates numerator and denominator degrees of freedom. η^2_g indicates generalized eta-squared.

Predictors	*df*	*MSE*	*F*	*p*	η^2_g
Participant's vaccination decision (A)	1,442	361.66	5.73	.017	.007
Other's vaccination decision (B)	1,442	241.37	64.09	<.001	.050
Other's group membership (C)	1,442	45.53	9.05	.003	.001
A*B	1,442	241.37	27.29	<.001	.020
A*C	1,442	45.53	<0.01	.989	<.001
B*C	1,442	36.37	<0.01	.963	<.001
A*B*C	1,442	36.37	0.07	.789	<.001

Table S5. Results from Univariate Type III Repeated-Measures ANOVA with assumed sphericity in Experiment 3: Changes in prosociality as a function of the factors of participant's vaccination decision, other's vaccination decision, and other's group membership. *Note.* $N = 444$. *df* indicates numerator and denominator degrees of freedom. η^2_g indicates generalized eta-squared.

	Experiment 1		Experiment 2		Experiment 3	
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age in years	35.70	10.02	34.56	9.58	36.25	10.89
Gender (% female)	42.1		42.7		43.0	
Participation time in minutes	12.74	4.13	14.82	5.58	16.61	5.75
Baseline SVO	22.38	13.67	20.85	14.45	23.73	14.30
Vaccination attitude	5.95	1.49	6.14	1.35	6.10	1.40
Group identity	4.34	1.62	4.66	1.57	4.73	1.46
Behavioral beliefs in-group	63.61	18.90	67.51	20.38	66.31	18.18
Behavioral beliefs out-group	61.69	19.74	62.45	23.38	55.69	22.58
Warmth toward in-group, pre			70.29	18.43	71.54	18.77
Warmth toward in-group, post			69.54	17.80	71.48	17.49
Warmth toward out-group, pre			59.29	17.93	58.39	18.04
Warmth toward out-group, post			59.49	18.02	58.43	19.44

Table S6. Demographics and psychological characteristics of the participants of the individual experiments. Note. Missing values regarding gender: Experiment 1 = 5, Experiment 2 = 8, Experiment 3 = 9.

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