Modelling adaptive behaviour to predict the effectiveness of contact-tracing apps integrated in risk mitigation strategies

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Faculty of Technology, Policy and Management

by

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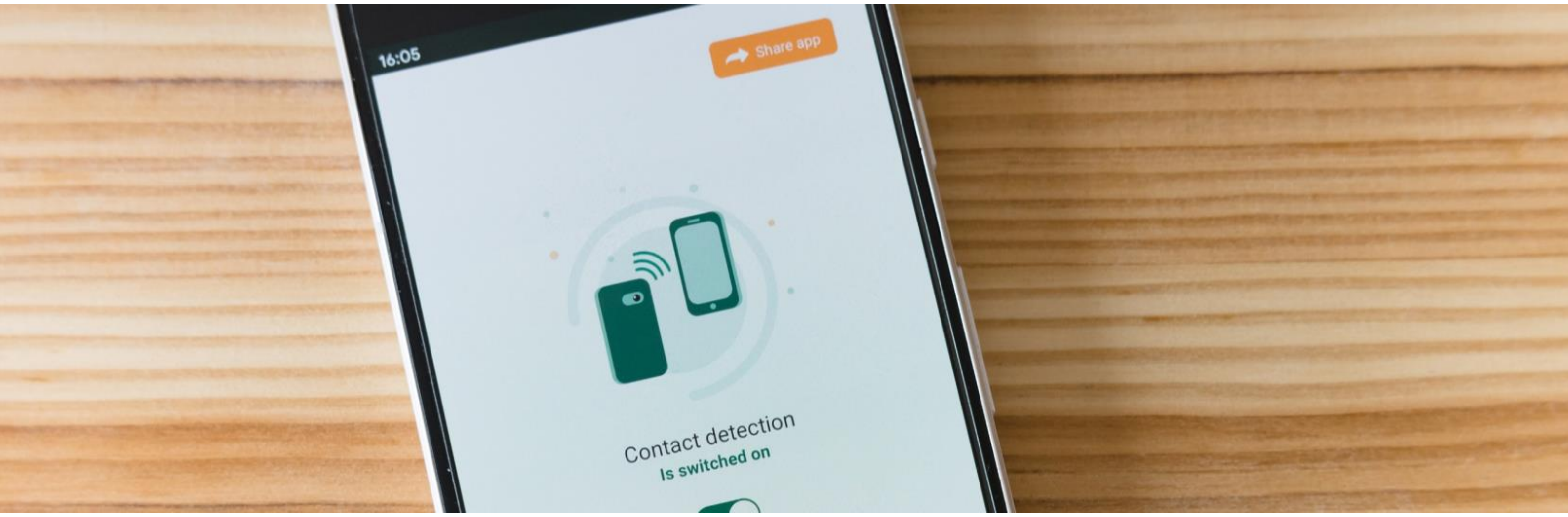
MSc Thesis in Complex Systems Engineering and Management

Modelling adaptive behaviour to predict the effectiveness of contact-tracing apps integrated in risk mitigation strategies

How the Dutch government can achieve positive compliance with the CoronaMelder during the Covid-19 pandemic

Ministerie van Volksgezondheid, Welzijn en Sport



July 21, 2021

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"You had to live – did live, from habit that became instinct – in the assumption that every sound you made was overheard, and, except in darkness, every moment scrutinized."

- George Orwell in 1984

With this thesis, my academic career comes to an end. I am grateful to have had the opportunity to accomplish studying at renown universities with the perseverance of my maternal side and the ambition of my paternal side. This chance has not only deepened my thirst for knowledge, but it has also enlarged my open-mindedness to the multitude of possibilities deriving from it. It is time to reap the benefits of these lessons-learnt, bearing in mind that with hard work, determination and kindness most doors will open.

Past year has forced us to stand still and evaluate life as we knew it, learning to value people including ourselves, discovering aspects that had been buried under our constant need to excel. In the midst of this period, my thesis subject became evident almost by chance: a previously written paper about the promises of contact-tracing apps made me passionate to contact the Ministry of Health about a possible collaboration; further reading about the subject illuminated me about whom to ask for supervision; and so, here we are.

I would like to thank my chair and first supervisor prof.dr.ir. Reniers for providing me with the confidence to independently finish this research. With his reassuring energy, he assisted me with the details of my research remembering that formulations are part of the problem but also of the answer. Hopefully, this will be his first supervisory role of numerous master theses to come.

In the same line, I would like to show my appreciation for dr.ir. Kroesen who acted as the second supervisor to my research. His strong reputation among the CoSEM students was confirmed when during a videocall he was able to cycle on a trainer and at the same time pinpoint specific aspects of my thesis that needed clarification. In times that I got lost in details, his fresh and constructive feedback helped me translating my results into meaningful outcomes.

Continuing with prof.dr. Ebbers, I would like to thank him to have guided me on behalf of the Ministry of Health. Despite being involved in so many (if not all) evaluations of the CoronaMelder, he took the time to help me to responsibly roll out my survey since such a practicality had not yet been part of my academic curriculum. His positive feedback soothed my unspoken worries, even during our early morning meetings.

Lastly, I would like to thank my mother for her unwavering trust in my abilities, now and in years that have passed. And I would also like to thank my father in memory of the last afternoons that he helped me with my homework.

Enjoy reading.

Marise Nelle Francesca Costanzo

Executive summary

Introduction

The Covid-19 pandemic has outlined the creativeness of each country in the definition of the most appropriate public health management strategies to curb the spread of the SARS-CoV-2 virus, ranging from total lockdowns to trusting in people's common sense to act properly. Several non-pharmaceutical health interventions have nationally been issued either on a voluntary bases or required by law. Maintaining 1.5 m distance and wearing protective face masks provide two respective examples. Proximity contact-tracing apps have furthermore been launched at a national scale to alleviate the pressure on the overburdened testing capabilities by means of automatic contact-tracing. Also the Dutch Ministry of Health launched its CoronaMelder on October 10, 2020. However, its efficacy is being questioned with the consideration of its instigated user behaviour.

Problem statement

The interaction between the technical artefact and the social entity has not yet been evaluated with the inclusion of risk compensatory behaviour. As such, its appraisal could overlook a possible negative consequence of its implementation. More specifically, it is being hypothesized that the CoronaMelder app instigates users to comply less with the issued non-pharmaceutical health interventions, thereby countering their expected beneficial effects in curbing the spread of the virus. The implicit severity of this unintended consequence therefore requires further investigation.

Research questions

The questions raised throughout this study are contained by the main research question formulated as follows: *What is the effect of the CoronaMelder app on people's conduct with respect to the mitigation measures issued by the Dutch Ministry of Health during the Covid-19 pandemic?* In all, four parts specified the various facets of the main question, specifically: the first part outlined how the utilization of the app can be modelled in existing behavioural models with the integration of the Risk Homeostatic Theory (RHT); the second part focused on the effect of the app on people's perception with particular focus on the change in perceived susceptibility and perceived severity as defined by the RHT; the third part presented the behavioural changes due to the CoronaMelder utilization to define whether the app indeed results in decreased adherence to the issued mitigation measures; whereas the last past elucidated which personal determinants defined a person's predisposition for adopting the CoronaMelder in an attempt to characterize the users of such a technology. These four parts then fuelled relevant recommendations for the Ministry of Health with regard to the implementation of the app as part of the national strategy.

Research methods

Literature research was the method employed to integrate the RHT with empirically validated theories. With the understanding of each variable involved in the identification of actual behaviour, a structured questionnaire with a length of 7.5 minutes was designed to identify how users and non-users scored on each item using a Likert-type scale. In total, N=828 participated to the survey of which N=776 resulted to be complete and valid. The sample population was representative for the Dutch population, with a male/female ration of 52/48. The answers were inserted in IBM® SPSS® AMOS™ 26 Graphics to study the fit of the data to the previously conceptualized model. By means of this software program, Structural Equation Modelling outlined the causalities among the identified (observed and latent) variables conducing to a given behaviour in order to test the formulated hypotheses and confirm the expected relationships. The conceptual model was studied twice per mitigation category to understand the changes in people's perceptions and behaviour in two coronavirus-specific contexts, namely the symptomatic and the asymptomatic context. The aim of this differentiation was to identify whether the conceptual model was able to capture the relevant variables of non-compliant behaviour without the consideration of contextual factors (e.g. showing coronavirus-specific symptoms). In total, N=261 responded to questions about the hygiene measures, N=252 answered the questions about the distancing measures, and N=263 responded to the questions about the mobility measures. The last part of the main question was answered by means of a Multinomial Logistic Regression performed in IBM® SPSS® Statistics ™ 25. This method was chosen based on its capability to deal with ordinary input variables and specifically with a binary outcome variable.

Results – First Part: Modelling of risk compensating behaviour

The modelling of risk compensating behaviour comprised a Basic Model, specifying the relationships among the behaviour variables, and an Extended Model, lacking any hypothesized relationship with the CoronaMelder utilization. The behavioural variables contained by the Basic Model were derived from the general description of safety and health behaviour in literature. These variables comprised perception, attitude and actual behaviour where behaviour is directly affected by attitude and perception, but also indirectly by attitude through perception. In line with previous RHT studies, a hazard-specific attitude towards behaviour was introduced succeeding perception. The inclusion of the Health Belief Model (HBM) resulted in the differentiation of five types of perceptions. Perceived susceptibility and perceived severity referred to an individual's perception of the hazard (in this case, the coronavirus), and these could then be utilized to derive the individual's perceived threat (perceived susceptibility *times* perceived severity). The person's behavioural evaluation of each the mitigation category - either hygiene, distancing or mobility measures - was provided by the inclusion of perceived benefits and perceived barriers (perceived benefits *minus* perceived barriers) together with their perceived self-efficacy. Subsequently, the variable expressing the CoronaMelder utilization was positioned to directly affect perception and indirectly affect behaviour according to the RHT's expectations: for at-risk behaviour to occur, the technology's adoption should have lowered the individual's perceived threat, thereby inducing less compliant behaviour. Consequently, the negative effect of the CoronaMelder utilization of perceived susceptibility and perceived severity presented the two most significant hypotheses of this study. Moreover, to rule out any influence of a person's inherent attitude to adopt the app, the relationship between these two variables was hypothesized to be inexistent to be able to independently pinpoint the effects of the app on actual behaviour. Finally, the Extended Model only defined which the demographic characteristics (age, gender, education level, household size) and coronavirus-health characteristics (being at risk, working with people in the risk group, having previously contracted the virus, and attitude towards the Covid-19 vaccination) to include as determinants for becoming a user.

Results – Second Part: Perceptive change due to CoronaMelder

The perceived threat resulted to significantly differ among users and non-users when asked about the hygiene measures and the mobility measures. Also the behavioural evaluation of the mobility measures was found to significantly differ between users and non-users. However, this could not be explained by the utilization of the CoronaMelder as this variable resulted not to be related to any of the perceptive variables nor with the attitudinal variables. As such, the only hypothesis to be confirmed was the hypothesized inexistence of a relationship with attitude. Attitude, on the contrary, resulted to be significantly related to the HBM perception variables, with the exception of perceived susceptibility for the mobility measures. Most correlations were weak, except for the direct path among attitude and perceived benefits which resulted to be consistently stronger in all models. Any perceptive change could therefore not be attributed to the utilization of the app but rather to alterations in the inherent attitude.

Results – Third Part: Behavioural change due to CoronaMelder

In general, users and non-users were found to comply with the hygiene measures, the distancing measures and the mobility measures without the occurrence of risky behaviour. Although non-users resulted to comply less with these rules than users of the CoronaMelder app, their behaviour can still be considered safe behaviour and as such, it does not provide room for worry. However, the results of the analysis provided a lacking significant indirect effect of the CoronaMelder utilization on behaviour and therefore, these consistent differences could not be ascribed to the app's adoption. The model presented a significant but weak relationship between self-efficacy and behaviour of the hygiene measures in the symptomatic context, as well as between self-efficacy and behaviour and between perceived severity and behaviour of the mobility measures in both contexts. Other relationships between the perceptive and the behavioural realm resulted to not be significant. Thus, it can be concluded that engaging in safe behaviour is independent of the CoronaMelder app's utilization but it can be partially defined by changes in perceived severity and self-efficacy. An additional finding is provided by the understanding that both users and non-users were found to increasingly comply with the issued measures when showing coronavirus-specific symptoms, suggesting that this health variable (thus, presenting symptoms or not) should explicitly be included in the conceptualization of at-risk behaviour to understand how it affects behaviour.

Results – Fourth Part: Determinants of CoronaMelder adoption

Continuing with the results of the Extended model, it was found that age and education level were determinants for the utilization of the CoronaMelder. More specifically, the older and higher educated the person, the more likely he or she was to having installed the app. With respect to the coronavirus-specific health characteristics, individuals at risk and those who had previously contracted the virus, characterized a greater portion of the user population. As such, these health characteristics were also found to be valuable determinants for adopting the CoronaMelder.

Conclusion

Although this exploration provided a misfit with the identified conceptual model, it could be concluded that the CoronaMelder was not altering user's perceived threat and consequently that it was not causing behavioural changes. So, the app cannot be found to be considered responsible for risky behaviour. In all, users and non-users were found adhere to the hygiene, distancing and mobility measures issued by the Ministry in both the symptomatic and the asymptomatic context.

Implications for Ministry of Health

The study of the instigated user behaviour resulted to favour the utilization of the app as a supplementary intervention in the Dutch public health management strategy. With this knowledge, the Ministry is advised on several actions to accommodate the introduction of the app with the appropriate temporal policy. Other recommendations ensure its widespread adoption by means of an effective targeted communication strategy, combining appropriate promotional channels with suitable informative messages.

Recommendations for further research

The CoronaMelder was not found to affect perception nor behaviour, but significant differences were found between users and non-users in their compliance with the rules. As such, further research should focus on improving the conceptualization of the RHT as initiated by this thesis. Emphasis should be put on the inclusion of hazard-specific determinants of behaviour. The influence of age, education, being at risk and having previously contracted the virus on each determinant of behaviour should additionally be studied to holistically comprehend their role in the observed behavioural differences. Moreover, several limitation of this thesis have outlined the possibility to study the mediating effect of personality traits and emotional responses in understanding how behavioural responses occur in the context of a health crisis. Lastly, the effect of external drivers (e.g. media attention, presenting symptoms) on behaviour should also be investigated.

Contents

1 Introduction

Current “Coronavirus Disease 2019”, or Covid-19 pandemic, has outlined the consequences of enhanced levels of globalisation, where the modern highly interconnected society has given rise to a worldwide humanitarian tragedy as well as the most serious economic crisis since World War II (Arthi & Parman, 2021). The epidemic outbreak started in November 2019 in Wuhan City, a national and international transport hub in the Hubei region in China (Peeri et al., 2020). Global travel further eased the worldwide spread, giving rise to a modern pandemic with Italy as the European epi-centre and Iran as the Middle-Eastern epi-centre (Jebril, 2020). Soon, countries were compared based on their death toll versus time, with increasing awareness about the combined impact of specific national strategies and cultural traits on the observed numbers.

1.1 Covid-19 mitigation strategies

Lessons learnt from the 2002-2003 SARS epidemic experience mitigated the spread in China and South Korea by the facilitated implementation of counter-measures such as high volume testing, wearing face masks, applying disinfection spray and providing information campaigns (Moes, 2020). Countries lacking this emergency preparedness, firstly opted for lockdowns to contain the death-toll and subsequently followed the example provided by the Asian hemisphere. Per February 2020, more than 160 countries had issued or recommended an additional set of *non-pharmaceutical health interventions* (NHIs) for healthy people including wearing face coverings, maintaining physical distance from others and appropriate hand hygiene (Mantzari et al., 2020). Isolation was, furthermore, the preferred action for infected people. On the whole, all nations introduced measures to reduce the transmission of the virus, although at varying degree.

The efficacy of the above mentioned interventions could, however, only be assured with an appropriate infrastructure for the identification of infected people. Setting up reliable “test and trace” capabilities proved to also be essential for the definition of an appropriate NHI combination by the governments, where the more stringent measures were installed in response to higher officially reported cases of infection (Anderson et al., 2020). Countries that were able to quickly install such infrastructures, benefitted in their fight against the spread of the virus. Other countries lagged the ability to adopt this essential control measure, partly due to logistical challenges, but also due to lacking competence to perform contact tracing at the required scale for such a highly infectious disease (Anderson et al., 2020; Herszenhorn & Wheaton, 2020). As previously stated, Asian countries were able to quickly set-up high-volume testing capabilities whereas Europe was only able to do so in the summer of 2020, specifically July 1st in The Netherlands.

This delay could be attributed to the missing previous experience with the activities of testing and tracing at a national scale. In the continuous search for new best practices to implement, a solution was presented in the form of contact-tracing apps to supplement the activity of manual contact-tracing. This activity consisted of asking public health institutions such as the Dutch Gemeentelijke Gezondheidsdiensten (GGDs) to create contact-lists of people with whom infected citizens had been in contact with such that they could be informed and asked to accordingly quarantine themselves. The promise of automating the time-consuming tracing activities formerly performed by health care personnel, provided the means to lower the burden on their work. In other words, the implementation of a contact-tracing technology could have permitted the overburdened personnel to focus on testing activities in times were time was scarce due to the pressure imposed by the threat of the coronavirus.

1.1.1 Supplementary contact-tracing apps

Location contact-tracing apps were introduced to support the existing infrastructure with activities of notification and localization of possibly infected individuals. These apps performed the three contact-tracing steps that were generally performed by hand: they automatically collected temporal and location data about social encounters (*contact identification*) to subsequently use this information to identify possibly infected individuals (*contact listing*) and to communicate the plausible contagion (*contact follow-up*) (WHO, 2017). This automatic method was based on either Bluetooth or GPS tracking and as such, it utilized the widespread smartphone adoption to enhance the tracing rate while employing a fast and cheap procedure.

However, when Bluetooth-based apps such as the Singaporean TraceTogether app appeared in March 2020, concerns were raised about the extent to which user privacy could be maintained. Several communication protocols have therefore followed to ensure that data would be handled safely, but also to prevent false notification from alarming its users. Nonetheless, the initial concerns about possible privacy breaches related to the deployed technology had been surmounted by March 2021 as citizens' were found not to particularly prioritize privacy under pandemic conditions (Horvath et al., 2020).

After the appearance of apps such as TraceTogether, Apple and Google joint forces to adapt their iOS and Android operating systems with enhanced Bluetooth capabilities through a decentralised Application Programming Interface (API) to be used for any publicly developed contact-tracing app. By then, 22 European countries had introduced their nationally-developed contact-tracing apps (European Commission, 2021). Specifically for The Netherlands, the Dutch Ministry of Health (MoH) launched its CoronaMelder app on October 10th 2020 (Rijksoverheid, 2020).

1.1.2 Citizens' responsibilities as prerequisite

Countries all over the world have introduced various Covid-19 proximity-tracing apps, not only varying based on their digital framework and their operational aspects, but also on the implied citizen's participation – either voluntary or mandatory. This ambivalence among countries lays in the intention with which the apps have been introduced as part of the national strategy towards pandemic response. Countries which have adopted a "*trace, test and treat strategy*", like South Korea, heavily relied on measures at the individual level. Hereby they enforced the nation-wide installation of contact-tracing apps to emphasize the citizen's responsibility in the battle against the SARS-CoV-2 spread (Park et al., 2017, p. 2129). Refusing to use the applications, therefore, resulted in penalties varying from one-year imprisonment to fines as established under their national Infectious Disease Control and Prevention Act (Lee, 2021). Contrarily, countries that opted for a strategy of "*aggressive measures including immigration control, lockdown or roadblocks*", like The Netherlands, preferred to introduce measures at a national level, attenuating their reliance on contact-tracing apps which were consequently considered as voluntary additional measures (Park et al., 2017, p. 2129). Not using the app was, thus, not penalised.

1.2 An overview of the Dutch organizational crisis strategy

Having outlined the overall governmental response to the Covid-19 pandemic, it is necessary to sketch the specific Dutch strategy in relation to the official number of cases and deaths starting from the onset in March 2020 till the moment of start of this study, namely February 2021. *Figure 1* provides the graphical representation of this timeline (WHO, 2021).

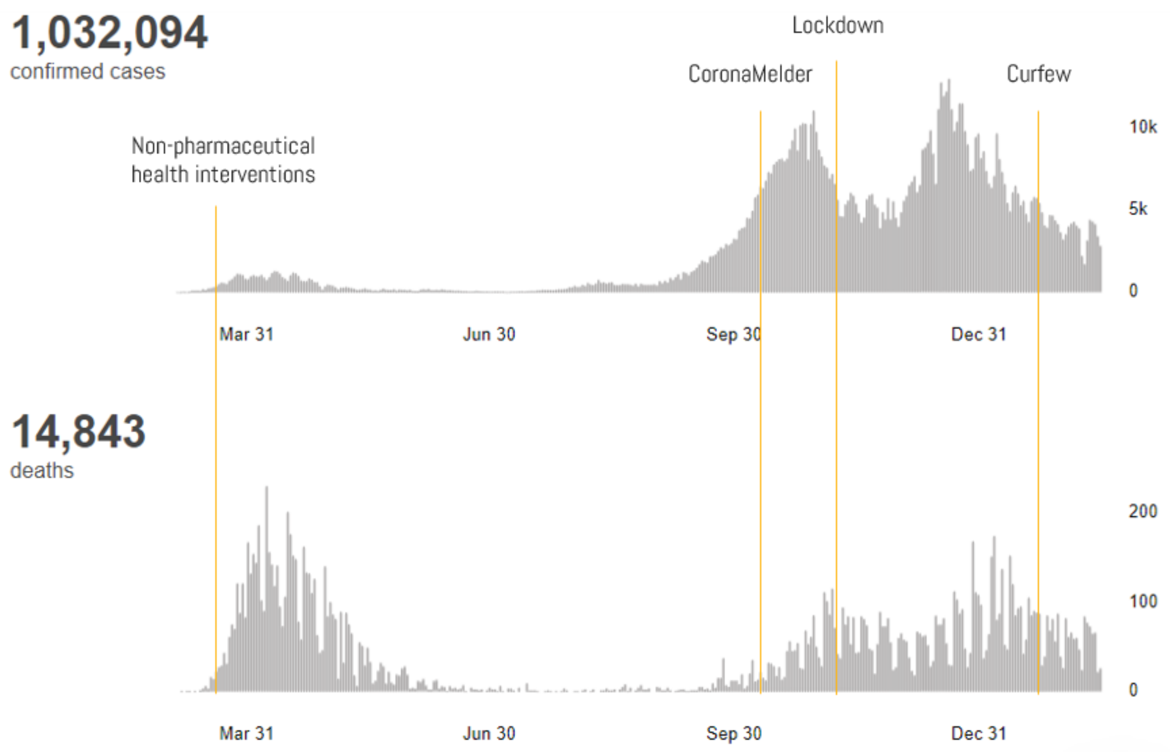


Figure 1: Covid-19 confirmed cases and deaths in The Netherlands (March 2020-February 2021).

At the onset of the Dutch epidemic in March 2020 the Dutch MoH issued a number of NHIs to instruct its citizens about the preferred code of conduct. The stringiness of these measures was adjusted to the development of the ongoing threat's gravity. The foremost goal of such a code of conduct was to preserve the individuality of each Dutch citizen as a person first, while making an appeal to the responsibility of the people as part of the Dutch citizenship second. The Dutch code of conduct included amongst others (RIVM, 2021):

1. Keeping 1.5 m distance from others;
2. Avoiding crowded spaces;
3. Inviting a maximum number of guests in your house;
4. Seeing a maximum number of different people a week;
5. Gathering in less than 2-3 people at once;
6. No shaking hands;
7. Coughing and sneezing in your inner elbow;
8. Using face masks covering nose and mouth;
9. Frequently and appropriately washing hands (>10/day);
10. Working from home if non-essential worker;
11. Using public transport only if strict necessary
12. Being home during the curfew.

Even though the initial numbers have to be adjusted to the absence of high-volume testing capabilities before July 1st, the numbers reflect an enhancement of the virus spread after September 2020, culminating in the re-introduction of the *intelligent lockdown* in November 2020 to which the graphically outlined contagion decrease can be attributed. This relaxation of the widely adopted form of lockdown, reflects the adopted proactive stance by the Dutch MoH to ensure that the safety of its citizens was guaranteed while preserving people's freedom of choice. However, with the emergence of new and more contagious variants of the SARS-CoV-2, the MoH has enforced stricter lockdown variances with an additional curfew following the example of other European countries such as France and Italy (Rijksoverheid, 2020).

Nevertheless, the numbers of confirmed cases had started to raise again in December 2020 after a period of improvement. All the while, the exogenous characteristics have remained stable: the rules of conduct and proper hygiene have not changed, the CoronaMelder app had been launched, and the more contagious SARS-CoV-2 variants present in the U.K., South-Afrika and Brazil, had not reached the Dutch boarders yet (RIVM, 2021). A disputed source for the increase in the virus spread could therefore be the people themselves as illustrated in the next section.

1.3 Problem definition

Despite the prevalence of numerous mitigation and control measures, their effectiveness is only ensured by design. Their interaction with the social entity is still under scrutiny as the uncertainty of the emergent situation has affected people's normal behaviour. The fear for the implications of the ongoing pandemic has startled citizens who are therefore deviating from their expected behaviour, for instance by massively stocking up toilet paper as a helpless defensive reaction act (Van Bavel et al., 2020). Moreover, the interconnection and possible competition among these measures has not yet been established, consequently affecting the certainty with which their efficacy can be optimized. To illustrate, speculation exists that users of the App exhibit compensatory behaviour or, in other words, whether having installed the App instigates them to engage less in other preventive measures, thereby countering their beneficial effects (Ebbers, 2020; Roozendaal, 2020). The implicit severity of this behaviour, therefore, defines the necessity to rule out any unintended consequences that thwart the success of the implemented mitigation strategies (Saurin, 2021).

The aimed beneficial effects of these strategies in curbing the spread of the virus can thus only be assured when citizens behave according to the expectations. The MoH's appropriate management commitment is of foremost importance as it is defined as the most influential predictor of citizen safety behaviour (Hu et al., 2021). The interdependence between the governmental as well as the citizen's responsibilities, thus defines the necessity to appropriately understand the observed citizen's behaviour to ensure the beneficial effect of the issued mitigation measures.

1.4 Research objective

This thesis intends to be a piece for the assemblage of the puzzle that involves understanding of the pandemic from a complexity thinking perspective. The investigation of the national's resilient performance to cope with the pandemic deserves particular investigation as near experience highlighted the lag in the government's response to appropriately tackle the crisis. Numerous mitigation measures have been introduced at a micro, meso and macro level, including proximity-tracing apps as tools providing visibility to the human-to-human propagation of the virus.

This research therefore focuses on the evaluation of the CoronaMelder to identify whether this individual level solution breached its promises form the perspective of the instigated user behaviour. "*Perceptions of risk play a prominent role in the decisions people make, in the sense that difference in risk perception lie at the heart of disagreements about the best course of action between technical experts and members of the general public*" (Slovic & Weber, 2002, p.2). As such, this thesis will explore people's perceptions of risk stemming from the utilization of the app and how these perceptions translate into preventive or maladaptive behaviour.

The goal of this study is therefore twofold. The first objective is to adopt a quantitative model in an attempt to explore the citizen's compliance process. More specifically, the focus will lay on the societal responses to the integration of the CoronaMelder as a viable NHI at micro-level. These responses will be evaluated in face of the collective benefit of the intervention, as Hagel and Meeuwisse (2004, p.195) pledged "*it may indeed be the case that introducing well-intentioned countermeasures is more harmful than doing nothing. Only through well planned and executed studies we can evaluate the net benefit of our interventions and minimize the side effects of injury prevention strategies*".

The second objective of this research, is to integrate the findings of the empirical research into the definition of the most appropriate management process for the MoH to include contact-tracing apps as part of their risk mitigation strategy. As such, behaviourally informed decision-making will be granted. The insights acquired will therefore be utilized to challenge the government's status quo during the current health crisis in an attempt to establish a more sustainable political environment based upon the interaction with the public.

1.5 Research structure

This thesis is structured as follows. Chapter 2 will outline the knowledge gap following from the conducted literature review on the definition of risk and the varying perceptions of risk that people hold. This information is then funnelled to the Risk Homeostatic Theory, introducing the concepts holding according to this theoretical background. After the research objective and the academic alignment have been provided, Chapter 3 will continue with the research formulation. This section will provide the main Research Question (RQ) as well as the sub-questions that are required to answer the RQ. The research approach will subsequently be provided together with their according methods and required data. Chapter 4 will then outline the conceptual model which is subsequently empirically validated in Chapter 5. The Chapter 6 that will follow, will present the results obtained from the cross-sectional study, to then be discussed in Chapter 7. Chapter 8 will then relate these findings to suggest how to reach the behaviourally-informed integration of the CoronaMelder in the Dutch organizational crisis strategy. The limitations of this research will be presented in Chapter 9, to conclude with Chapter 10 containing the conclusions and recommendations stemming from this study.

2 Literature review

The mechanisms by which individuals make choices under uncertain conditions are thoroughly described in literature and attributed to various determinants. The exploratory phase hereby presented, highlights the pertinence of Risk Homeostatic Theory in the analysis of risk compensating behaviour resulting from the application of the CoronaMelder app. In the end, the insights gained through literature review are combined to aid the definition of the knowledge gap to support the subsequent research on the appropriate Dutch risk management during the Covid-19 pandemic.

2.1 Definition of risk

Literature does not agree upon an encompassing definition of *risk*, varying from it being defined as a hazard, but also as a probability or as a consequence (Slovic & Weber, 2002). Although various domains of science differ in their notion of risk, consensus has been reached on the characterization of risk as the result of a lack of information or knowledge (Van Winsen et al., 2011). In this context, *risk* and *uncertainty* become synonyms. This concept is especially true for new risks. According to the definition of the realist perspective, risk is seen as the multiplication of the probability of the event happening and the negative or positive consequence of it: *risk = probability * consequence*. This calculation is usually based on past experience, therefore complicating the quantification of new risks. Next to this rational approach towards risk estimation, the definition of risk is still dependent on a personal interpretation of risk and the perception of it. This subjective bias complicates the systematic definition of risk (Van Winsen et al., 2011). Provided the newness of the risk imposed by the coronavirus and the magnitude of its individual and its collective consequences (including the physical – getting the illness, the economic and the social consequences), this topic acquires a growing attention as the inadequate assessment of risk, complicates the definition of appropriate risk management.

The consideration of risks always been essential in politics but recent crises have outlined growing degrees of risks that increasingly put pressure on the political debate (Van Winsen et al., 2011). Despite the unanimous agreement on the relevance of risk, political risk management often fails to meet expectations. Evidently success cannot be guaranteed by the mere existence of principles, processes and knowledge. Whenever risk management strategies are found to be inadequate, the problem is being linked to either the inability to calculate the objective risk or to a biased perception of objective risk (Van Winsen et al., 2011). Individual risk behaviour is not yet well understood and as such risk management tools are destined to fail (Van Winsen et al., 2011). Traditionally, the most prominent method in Dutch management practices is provided by the objective expected utility approach, where a preference is outlined towards the choice with the highest utility (Mouter, 2019). However, these calculations do not consider risk explicitly. As such, current practices are "*incomplete at best and misleading at worst*" (Slovic & Weber, 2002, p.4).

2.2 Risk Homeostatic Theory

A debated theory in the study of (mal)adaptive behaviour is provided by the risk compensation theory. This theory is related to the efficacy of safety measures designed to reduce the safety risk associated with a given field of interest. Bicycle helmets were, for example, introduced to protect its users from more serious medical injuries such as brain injuries. It was, however, argued that the engineered risk reduction was offset by cyclists' unforeseen behaviour of engaging in more risky behaviour than ever before, thereby nullifying the expected benefits. In Noland's (1991, p.504) words, this behaviour resulted in "*less than expected decline in fatalities based on pure* *engineering calculations"*. This compensating behaviour, therefore, declined the safety improvement's effectiveness contrary to the original expectations.

Reasons for this increased exposure to risk can be associated to either (a) overall decreased perceived risk of the mode, or (b) increased usage of the safer mode (Noland, 1995). This is illustrated by means of the same bicycle helmet example. With the promised benefits of the helmet, cyclists felt more protected while cycling than without helmet. This reduced their perception of the extent to which they were prone to serious injuries, therefore motivating them to cycle faster or to opt for the bumpy track. This behaviour, consequently, brought cyclists to be increasingly exposed to risks than otherwise without helmet. The enhanced exposure to risk could also be attributed to increased mode frequency. In other words, the perceived 'safer' mode could have motivated cyclists to cycle more often than normally without helmet, increasing their exposure to the associated risks. Either way, an alteration in the perceived risk of the activity resulted in offsetting results.

2.2.1 Theoretical background

In an attempt to evaluate the impact of risk-reduction measures, Evans (1985) suggested a plausible theoretical formulation following three general approaches, namely the:

(a) Engineering approach, where safety is assumed as non-interacting with risk;
(b) Economic approach, where safety is seen as a commodity, hence a substitute for risk;
(c) Homeostatic approach, where safety is compensated by increased exposure to risk.

The economist Sam Peltzman was the first to mention compensatory behaviour in transportation, stating that government regulation was useless and at worst counterproductive (Hedlund, 2000). He formulated his 1975 theory in response to the introduction of the seatbelt law in most U.S. states. According to his view, drivers would respond to the compulsory seatbelt by driving faster, resulting in decreased, rather than increased, driver-safety. So, the benefits of transportation regulation intended to improve driver-safety were offset by the driver's behaviour. He eventually extended the so-called Peltzman Effect to safety regulation in general, stating that individuals would act more carelessly following government regulation. Graham (1982) interpreted Peltzman's study by showing that it is more likely to occur for policies designed to reduce accident *frequency* rather than those designed to reduce accident *severity*. Chirinko and Harper (1993) followed a similar line of reasoning by distinguishing two effects for any regulation, namely the protective effect that reduces the level of vulnerability to an accident, and the substitution effect that results in an increase in accident frequencies. They found that vulnerability was significantly reduced by safety regulations, whereas the frequency of accidents remained unaffected (Noland, 1994).

Peltzman's economic-based theory, nonetheless, did not specify the underlying psychological mechanisms of this compensation behaviour. Those were proposed by Wilde's 1982 Risk Homeostasis Theory (RHT), complementing Peltzman's positions with a theoretical basis for predictions concerning compensatory behaviours. According to the RHT, people have a target level of risk at which their net benefits are maximized, or alternatively at which the injury likelihood is minimized. For any activity, people compare the perceived risk of the associated activity with their target level of risk, adjusting their behaviour to remove any variance between the two levels (Gerald J.S. Wilde, 1998). Hogben and Liddon (2008, p.1010) said that when "*balancing costs and benefits of risk and preventive behaviour, individuals adjust activities to maintain their set point. These adjustments become risk compensation if a prevention intervention reduces risk through the intervention"*. But this equilibrium changes according to dynamic situational factors and personal goals, hence adjusting their risk levels over time. It therefore explains an aggregate phenomenon, compared to Peltzman's approach on the individual level risk compensation behaviour (Stetzer & Hofmann, 1996).

2.2.2 Empirical evidence

Literature debates with much disagreement about the existence of risk compensating behaviour and the magnitude of its effect. The relative magnitude is dependent on how objective reductions in risk translate into perceived reductions in risk (Noland, 1994). Early publications revising driver-safety regulations surrounding devices such as helmet use, seatbelt use and alcohol prohibition, provide the empirical evidence that supports RHT (Evans & Graham, 1991; Hedlund, 2000; Hillman & Adams, 2002; Noland, 1995). However, the theory can also be disregarded based on another interpretation of the same empirical evidence (Thompson et al., 2001). Stetzer and Hoffman (1996, p.73) agree with the inconclusive nature of the empirical evidence, stating that the "*the added costs of being safe do not always outweigh the benefits accrued through the risky behaviour"*. Nonetheless, Adam and Hillman (2002, p.89) are strongly opposed to the evidence set by Thompson *et al.* (2001), stating that "*the evidence is overwhelming that some laws and regulations, as well as safety measures voluntary adopted, are counterbalanced by compensating behaviour*". They stress the importance of such behaviour emerging with both mandatory and voluntary measures, especially where risks are large (Hedlund, 2000).

A more recent field of application of the RHT is provided by the health sector which also presents controversial evidence. Brewer *et al.* (2007) concluded that Lyme disease vaccination presented some empirical evidence for risk compensation behaviour, mostly related to *regression* and partially to *disinhibition*. The first one related to engaging in more risky activities and fewer protective behaviours as a result of Lyme vaccination, which merely moved them towards the risk profile of people without it. The latter related to engaging in more risky activities and fewer protective behaviours as a result of Lyme vaccination, which led people to engage in more risky activities and fewer protective behaviours than the people without it. Vaccination against the human papilloma virus, on the other hand, failed at responding to the risk compensation profiles in its patients. They attribute this difference to conditions that allow risk compensation to occur, such as the severity of the perceived involved risk and the belief surrounding the effectiveness of the vaccine. Holt *et al.* (2017) agree with the relevance of the latter point, but in reference to HIV related safety activities, such as condom use and HIV treatment. A part of the examined population seemed to behave according to the RHT, whereas the other part did not.

Mantzari *et al.* (2020, p.2) reviewed the effects of wearing face masks on proper hand hygiene and maintaining distance. They stated that they did "*not rule out the possibility that for some people, engaging in one behaviour can influence other behaviours in ways that might attenuate their beneficial effects. But based on the evidence we review here, any attenuation is unlikely to be sufficient to counter or even reverse, these beneficial effects and lead to a worse outcome for a population"*. But they also considered the possibility that wearing face masks could alternatively have 'no effect'. It can occur if two or more behaviours – motivated by the same goal – become routine and are activated by different cues (*e.g.* face mask cued by sign at the entrance to a train station; washing hands cued by seeing a hand sanitiser). Moreover, the authors outlined that people who engage in one protective behaviour may become more likely to engage in related behaviours. This can occur if protective behaviours also serve as cues to initiate other protective behaviours (*e.g.* wearing face coverings acts as a cue to wearers or observers to maintain a safe physical distance). Hagel and Meeuwisse (2004) agree with the latter point, advocating that people using protective equipment are already risk-averting. Thus, risk-seeking behaviour is mostly defined by people's inherent risk-propensity rather than on reduced perceived risk due to any safety measurement.

2.3 Academic knowledge gap

Figure 2 embodies the graphical representation of the three plausible combined effects of the CoronaMelder following the line of reasoning provided by Mantzari *et al.* (2020). The first effect is defined as possibly not influencing behaviour, whereas the second and third effect result in behavioural adaptation with respect to user's compliance with the other preventive measures (either negative or positive). It is being hypothesized that individuals provided with the app act in a riskier manner because of the sense of increased protection, thereby nullifying the protection afforded by the app (Thompson *et al.,* 2008). The RHT attributes this phenomenon to the concept of *prevention optimism*, or in other words the reduced perceived risk for infection provided by an increased sense of protection provided by the app (Evans & Graham, 1991; Hogben & Liddon, 2008; Stetzer & Hofmann, 1996). The hypothesized decrease adherence to the NHIs would fit with the RHT, but it still needs to be empirically tested (Ebbers, 2020).

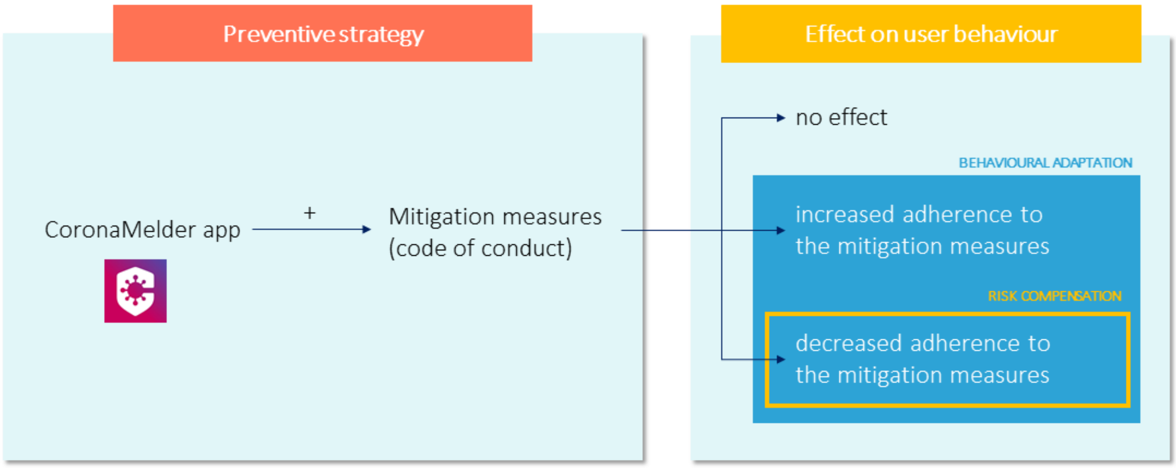


Figure 2: The three possible combined effects of the CoronaMelder app with the mitigation measures on user behaviour.

All things considered, the empirical evidence of the RHT is controversial either based on the varying interpretation of the empirical findings or based on the experimental setup. As such, academic literature is inconclusive about the contextual existence of risk compensation behaviour and, consequently, the relevance of RHT remains uncertain. However, the theory has not yet been applied in similar studies, therefore justifying the exploration of the RHT to the underlying case. Several reasons can be given to describe the lack of academic information of the topic, the most relevant being the newness of the technological application in the field of epidemic spread confinement and the novelty about the awareness of such conduct and its implications for public purposes. To this end, the post-hoc analysis of the app's user behaviour can be considered as an additional example to test the applicability of the RHT.

2.4 Relevance

Although the pandemic itself is not a traditional safety science problem, it has elements that are commonly a concern for safety practices: the hazard is provided by the virus, whereas the risk associated with the hazard depends on a number of contextual factors, such as demographic characteristics and the safety culture. It is a complex system which requires appropriate understanding of the interconnected elements for the definition of an appropriate risk mitigation strategy. These lessons learned could moreover anticipate the appropriate response for future events. It will certainly contribute to provide learning opportunities in the field of safety science and more specifically, how behaviourally-informed decisions stem from the implementation of a technology at a national level.

2.5 Academic alignment

The institutional significance and the multidisciplinary character of addressing the issue provide the prerequisites for its acceptance as a master thesis subject. Outlining the efficacy of the app with special regard to the instigated conduct in its users, provides the means to evaluate the positioning of such a technological advancement in society. It, consequently, fits the knowledge acquired through the courses of *Innovation in Transport and Logistics* and *Institutional Economics for Designing is Socio-technical Systems,* expanding on the application of an innovation for overall public benefit rather than for transportation only. Courses such as *Travel Behaviour Research* and *Statistical Analysis of Choice Behaviour* provided the necessary modelling experience to actuate the study and interpret the significance of its results*.* The further contextualisation of these results meets the course *Advanced Evaluation Methods for Transportation Policy Decision-Making* as it frames the relevance of the outcome based upon the involved social institutions rather than rational notions of good and bad practice. All in all, the subject also encompasses the knowledge acquired as part of the track *Transportation and Logistics*, albeit the initial focus on behavioural economics.

3 Research formulation

This chapter discusses the research questions guiding the thesis towards the completion of the knowledge gap. First, the main research question is presented subsequently followed by its respective sub-questions. Afterwards, the methodology is described per sub-question to finalize with the visualization of the Research Flow Diagram.

3.1 Main Research Question

While the focus of this research is based on the hypothesis that risk compensating behaviour is applicable to the study, it should be noted that its pertinence is not necessarily related to the effectiveness of the app (Ebbers, 2020). Instead, its pertinence relies on the widespread application of all measures to curb the infection spread, including the CoronaMelder app as well as all the issued NHIs (Thomson et al., 2008). The resulting research question is, therefore, defined as:

What is the effect of the CoronaMelder app on people's conduct with respect to the mitigation measures issued by the Dutch Ministry of Health during the Covid-19 pandemic?

3.2 Sub-questions and research methods

The following subset of questions have been formulated to answer the main research question. These sub-questions are named SQ1 till SQ4, where SQ2 and SQ3 have a separate set of underlying questions. Each of the sub-questions are presented with their corresponding methodology, together illustrating the overall research method employed.

SQ1: In which way can the CoronaMelder app's effect of the on user behaviour be modelled to also incorporate risk compensating behaviour?

This first sub-question attempts to model suitable behavioural theories in a comprehensive conceptual model including the predictors of interest for the evaluation of people's conduct with after the installation of the App. The initial literature review will, therefore, be supplemented by additional reviewed academic articles, journal articles and government documents retrieved through the TU Delft library and Google Scholar. The goal is to conceptually represent the effect of the CoronaMelder on determinants of behaviour such that the RHT is considered in combination with empirically validated theories. The answer to this sub-question can be found in Chapter 4. The relationship between the identified dependent and independent variables will then be validated through structured questionnaires. The given formalization of the conceptual model is presented in Chapter 5.

SQ2: In which way does the CoronaMelder app influence people's behavioural perception? *With the following subsets of questions:*

a. How does people's threat perception relate to the installation of the CoronaMelder app?
b. In which way does people's behavioural evaluation of each mitigation measure differ due to the installation of the CoronaMelder app?
c. To what extent does the CoronaMelder app affect people's perceived efficacy of the implemented NHIs?

The second sub-question is resolved through the analysis of the causal relationship among the determinants obtained by the questionnaire's answers. These answers will be studied by means of Structural Equation Modelling (SEM) in IBM® SPSS® Statistics™ 25 and IBM® SPSS® AMOS™ 26 Graphics. The obtained regression analysis results will, then, provide the relationship between using the CoronaMelder app (as the *independent* variable) and user's perceived risk of infection (as the *dependent* variable). As Van der Laan et al. (2021) stated that non-users are characterized by lower perceived susceptibility and severity of the coronavirus disease than users, it is hypothesized that the same holds for the given random sample. After having outlined people's susceptibility to the virus and severity of infection, the benefits and barriers of the NHIs have to be outlined for users and non-users. A concluding part should then focus on people's view about the efficacy of each NHI such that all together, conclusions can be drawn about the occurrence of *prevention optimism* as expected by the Risk Homeostatic Theory. The answer to this sub-question is contained in Chapter 6 and it is further discussed in Chapter 7.

SQ3: To what extent does the CoronaMelder app affect people's behaviour? *With the following subsets of questions:*

a. In which way do users and non-users differ in their compliance with the implemented NHIs?
b. Is the CoronaMelder app utilization a valid predictor for the occurrence of risky behaviour among the population?

The third sub-question is answered through the regression results outlining the causalities between using the CoronaMelder app (as the *independent* variable) and user's actual behaviour (as the *dependent* variable). To this end, it is necessary to outline people's compliance with the implemented measures and differentiate among users and non-users. Significant variances could for instance validate the role of the CoronaMelder app in the incidence of non-compliant behaviour or risky behaviour. Together with the previous sub-question, responding to those sub-parts will eventually provide a holistic understanding of the effect of the CoronaMelder app on perception and behaviour as the two dependent variables. The answer to this sub-question can be found in Chapter 6, whereas the discussed results are available in Chapter 7.

SQ4: In which way should contact-tracing apps such as CoronaMelder app become an integral part of behaviourally-informed health policy?

The final sub-question comprises the translation of the obtained results into recommendations for the Ministry, provides the concluding part of this study. The validated results, obtained from the surveyed population, will be generalized where possible in order to define the practical implications of these results. From this, the MoH will be provided with suggestions as how to integrate the CoronaMelder with knowledge about its behavioural implications. A positive outlook of the app's utilization will be followed by recommended measures to increase its effectiveness , whereas a negative outcome will motivate the recommendation of revising the overall utility of the app. The identified predictors' correlation through SEM will illuminate policy-makers on the relevant factors that influence the performance of the app, providing them with the necessary information on how to optimize it.

3.3 Research approach

The chosen methodology addressing possible behavioural adaptation resulting from the implementation of the app motivates the choice for an *explorative sequential design* as proposed by Creswell and Clarck (2011). The advantage of the selected research method is provided by the possibility to overcome the limited time available for the completion of this study while complementing existing research with additional empirical findings. With the mixture of both qualitative (e.g. literature review) and quantitative methods (e.g. SEM), the knowledge gap will be provided with substantiated findings.

Understanding adaptive behaviour has both a scientific and a practical perspective, since it requires the understanding of the underlying factors to be able to predict such behaviour and from this, to define appropriate policy. The underlying factors are unknown under the RHT, but they are contained in the realms of perception and attitude as outlined by Kroesen and Chorus (2020). Therefore, this study has to identify the underlying factors as well as their causal relationship in order to answer the question about the effect of the CoronaMelder app on the adherence to the implemented NHIs. The main research question will, thus, be answered through the evaluation of the utilisation of the app and its effect on perceived risk for infection and actual behaviour.

Given the post-hoc analysis of the impact of the CoronaMelder app on user behaviour, a retrospective cohort study will be performed through structured questionnaires. Respondents will be differentiated among people without the CoronaMelder app (also called *non-users*) those who are using the CoronaMelder app (also called *users*). These two groups will then be compared on the basis of their respective prevalence of risk compensating behaviour to determine the relative influence of the CoronaMelder app on maladaptive behaviour. By means of SEM, the direct and indirect paths between perception and attitude as well as perception and behaviour will be outlined, defining points of interest for the second part of this study. This advanced multivariate modelling technique provides the means to test causal theories while correcting for the implied measurement error (Molin, 2019). As such, this technique is preferred over simpler models such as regression analysis, path models and factor analysis.

This empirical study will, thus, identify the key factors predicting adaptive behaviour in the context of implemented technological health innovations. These insights will be used to fuel the debate about risk mitigation strategies in times of a health crisis. The associated implications for practice, policy and research will be analysed through a substantiated literature review. The latter method will also form the basis for the advised action plan for the MoH in an attempt to achieve valuable insights for the conclusion of this study.

3.3.1 Research Flow Diagram

The sub-questions should be answered in sequence, where the outputs of the one question become the inputs for the following. The specific methods and tools required to answer the identified sub-questions as well as their corresponding output, are presented in *Figure 3* on the next page.

3.4 Limitations of research methodology

This thesis starts from the premise that the relevance of RHT is still contested in the academic world. The limited comparation material for the obtained model, thus, delimits the objectivity of the results while increasing the confirmation bias of the resulting correlations. The three rules set out by Hedlund (2000), will therefore be reminded in the analysis of the observed correlations to restrict the possibility for bias. The rules can be summarizes as follows:

- Consider system effects.
- Do not over-predict benefits.
- Trading safety for performance is not necessarily bad.

Furthermore, the identified model and its corresponding correlations are dependent on the interviewed population. Hence, although the respondents should preferably be representative for the Dutch population, generalisations to the overall Dutch population are still speculative. Moreover, the surveys are 'one-moment-measurements', therefore limiting the applicability of the results to assumed causality (Molin, 2019).

Lastly, as Hagel and Meeuwisse (2004, p.193) stated: "*perhaps the greatest difficulty with the evidence for risk compensation is that much of it is ecological: that is, there are few comprehensive* *examinations of individual risk-taking behaviour before and after a safety measure is implemented*". This study is, therefore, constrained by the impossibility to examine such behaviour prior to the launch of the app.

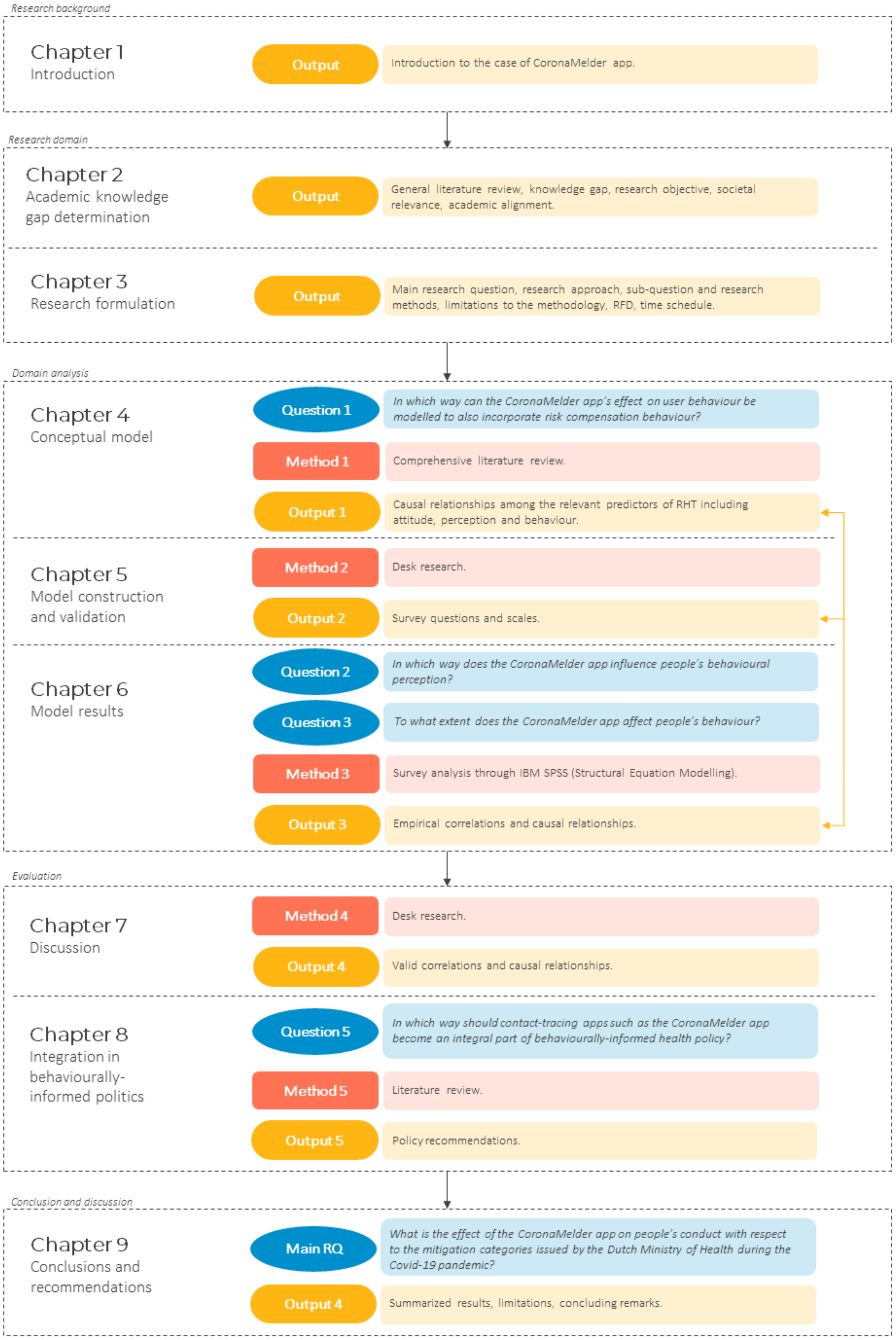


Figure 3: Research Flow Diagram.

3.5 Scope

For the continuation of this thesis, citizen behaviour should be differentiated between desired behaviour and undesired behaviour. The mitigation measures have been issued based on the expectation that people would interact in a given way with the artefacts by changing their behaviour. The behaviour has been considered in the definition of the measure's effectiveness is, therefore, defined as desired or *adaptive behaviour.* Undesired behaviour, on the other hand, has not been considered while designing the artefact and therefore it is defined as undesired behaviour. The latter can take a positive or a negative value, depending on the implications for the whole system. Previously outlined compensating behaviour has a negative connotation and therefore it is referred to as *maladaptive behaviour* as opposed to the positive undesired behaviour that can also fall under adaptive behaviour. The Risk Homeostatic Theory has been considered to be applicable for the given case (Ebbers, 2020). As empirical evidence about this theory is still controversial, the scope of this research is delimited to testing the viability of the theory in the context of behavioural adaptation due to the CoronaMelder. The exploratory goal of this thesis is therefore not intended to provide a conclusive argument for the feasibility of the theory.

4 Conceptualisation

In order to understand the impact of the CoronaMelder app on user's behaviour, it is necessary to investigate the "black box" of how the application influences user's perception (Champion et al., 2002). Given the lack of pre-established conceptualizations of the RHT, the full range of factors that might influence a given behaviour need to be measured to ensure validity. The starting point is provided by the definition of the antecedents and outcomes of the usage of contact-tracing technology, while presenting the overall underlying mechanisms. These mechanisms are presented as hypotheses to conclude each section. By means of this conceptualisation, the effect of the CoronaMelder will thus be modelled with the incorporation of risk compensating theory. This chapter will therefore enlighten the first sub-question: *In which way can the CoronaMelder app's effect on user behaviour be modelled to also incorporate risk compensating behaviour?*

4.1 Individual risk behaviour model

The behavioural variables included in this study comprise the concepts of perception, attitude and actual behaviour which are generally used to describe security and safety behaviours, including health behaviours (Ajzen, 2011; Godin & Kok, 1996; Lippke & Ziegelmann, 2008; O'Connor & Armitage, 2003; Sadiq et al., 2021). Before the theorization of their causal relation, their definition is provided.

4.1.1 Risk attitude

The first determinant to induce a specific risk behaviour is risk attitude. The former definition stems from the view that risk attitude is a stable personality trait. The classical division of risk attitude distinguishes risk-seeking and risk-averting as the two opposing extremes of a continuous scale. Risk tolerance resides along the scale between these two extremes, also defined as "*a person's standing on the continuum from risk aversion to risk seeking"* (Grable, 2008, p.3). The extremes are both characterized by a given degree of acceptance of a loss in face of a apparent gain, where the risk-seeking person is willing to accept any risk even for a marginal increase in return, whereas the risk-averting person is not willing to accept any risk no matter what the increase in return (Van Winsen et al., 2011). A more recent definition, however, describes risk attitude to be context specific (Penning & Garcia, 2001). To be more precise, risk attitude is influenced by risk perception. As such risk behaviour does not only reflect an individual's risk attitude, but also one's risk perception (Van Winsen et al., 2011).

Building on the latter perspective, Underwood and Ingram (2010) have defined four different risk attitude types: maximisers, conservators, managers and pragmatists. Maximisers are depicted as seeking for risks, thereby letting the negative consequence of any risk be outweighed by a possible gain; conservators are opposed to maximisers as they avoid risks at any cost; managers on the other hand choose for the risks that maximize the profit and minimize the losses; whereas the pragmatists decide to leave the most options open and in so doing, they become indifferent of the risks. Each of the described types flourishes in a specific risk environment: the maximisers attitude will be optimal during boom times where profits peak and risks are little; in a recession the conservator will be the preferred risk attitude; in time where risk and profits are moderate, the preferred attitude will be that of a managers; whereas in uncertain times a pragmatist attitude will benefit the most (Van Winsen et al., 2011).

4.1.2 Risk perception

Following from the previous section, risk perception constitutes the second determinant to induce a specific risk behaviour. Individual perceptions of risk differs from the objective 'real risk' as intended by the realist perspective since people do not have imperfect knowledge on the real risk and moreover, their interpretations of reality differs among people (Van Winsen et al., 2011). These perceptions also vary within the same person depending on the time and on the circumstances it is being perceived. As these perceptions are not real and reside in one's mind, they are all about beliefs and thoughts constructs (Sjöberg, 2000). People therefore tend to use heuristics or rules of thumb to estimate the magnitude of risk and translate it in both gains and losses.

The type of imperfect knowledge that is being transferred provides the basis for the typification of risk perception. Three streams can be distinguished, namely the axiomatic measurement paradigm, the socio-cultural paradigm and the psychometric paradigm (Slovic & Weber, 2002; Van Winsen et al., 2011). The first theory focuses on the subjective transformation of objective risk information or simply put, on the individual's interpretation of the impact of a particular risky choice on his life. The second theory, on the other hand, contends that the group which the individual is socially interacting with, defines the perception of risk related to a hazard. This knowledge is rather a collective worldview than an individual cognitive process. The third theory argues that perceptions can only be understood with insights in people's minds as their emotions affect their judgements to risky situations.

Another influential theory, namely the social amplification of risk, moreover outlines the relevance of communication tools in the amplification of amortization of the perceived risk, including both social or individual channels (Van Winsen et al., 2011).

4.1.3 Combining risk perception and risk attitude

Both risk attitude and risk perception, thus, determine risk behaviour and as such, they should be considered for appropriate risk management practices. In addition to that, risk perception is also a determinant of risk specific attitude. Therefore, for the purpose of this study it is essential to distinguish among perception and attitude. To provide a descriptive model explaining how and why a specific behaviour occurs, the subsequent conceptualization should consider both risk-seeking and risk-averting to appropriately consider how a potential loss and a potential gain from engaging in a specific mitigation measure relate to the context of the Covid-19 pandemic. Furthermore, the perception of risk as intended for this study should reflect the psychometric paradigm as the focus lies on the result of each individual behaviour. The descriptive model could then be utilized to define follow-up steps to eradicate risk behaviour as defined by Weber and Milliman (1997) :

1. If risk behaviour stems from non adapted risk attitude, then the users' emotional responses should be targeted.
2. If non-conforming behaviour is to be attributed to risk perception, then users should be informed about the real risk to influence the social and cultural factors that influence this perception.

4.2 Variables and hypotheses

Having established how risk attitude and risk perception are considered by this research, their causal relations with actual behaviour are presented.

4.2.1 Protective risk behaviour

The outcome variable behaviour can be either adaptive (increasing preventive behaviours) or maladaptive (decreasing adherence to preventive behaviours) (Nowak et al., 2020). These two behaviours are encompassed in the variable of *protective risk behaviour*, indicated as the two opposing extremes of the observed behaviour. In other words, this concept reflects whether an individual will act to prevent an illness through the implementation of the mitigation measure or not.

4.2.2 Risk perception

The evaluation of each mitigation measure reflects the individual's risk perception. These perceptions are derived from the Health Belief Model (HBM), an extensively applied model for the determination of community-based health interventions (Champion et al., 2002; Morowatisharifabad, 2009). This model has guided the design of numerous health behaviour interventions, thereby validating its usage for the evaluation of the app (Champion et al., 2002).

The key individual perceptions proposed by the HBM are: (1) perceived susceptibility to a disease or illness, (2) perceived severity of a particular condition, (3) perceived barriers, that may prevent action, (4) perceived benefits of the recommended behaviour (Morowatisharifabad, 2009). Most recently, the concept of (5) *self-efficacy* was added to the model to describe the extent of experienced individual power to effectuate a behaviour (Morowatisharifabad, 2009). These individual perceptions can be grouped among two main components, namely threat perception and behavioural evaluation. Each component is described in the following section.

4.2.2.1 Threat perception: Perceived susceptibility and perceived severity

Threat perception is the product of *perceived susceptibility* – referring to beliefs about the probability of getting the coronavirus disease - and *anticipated severity* – referring to the believed severity of the consequences of the same health condition at both the medical and the social level. As such, threat perception captures individual perceptions about the coronavirus. Recent studies found that the higher the perceived threat for infection is associated to more risk-averting behaviour, hence justifying a positive correlation between threat perception and protective risk behaviour (Ajzen, 2011; Godin & Kok, 1996; Man et al., 2021; O'Connor & Armitage, 2003).

The mentioned relationships are summarized as follows:

- **H1** Perceived susceptibility will be positively correlated with protective risk behaviour.
- **H2** Perceived severity will be positively correlated with protective risk behaviour.

4.2.2.2 Behavioural evaluation: Perceived benefits and perceived barriers

Behavioural adaptation is the difference between *perceived benefits* – referring to the benefits of engaging in a mitigation measure – and *perceived barriers* – referring to the barriers to engage in the same mitigation measure. Hence, the behavioural evaluation refers to perceived effectiveness of the mitigation measures. The same positive correlation as described in the previous section is defined between the perceived effectiveness of a measure with the protective risk behaviour.

The described relationships are therefore defined as follows:

- **H3** Perceived benefits will be positively correlated with protective risk behaviour.
- **H4** Perceived barriers will be negatively correlated with protective risk behaviour.

4.2.2.3 Self-efficacy

Similarly to perceived benefits, the perception of the ease of actualisation positively affects the actualisation of such a measures. This actualisation is known as *self-efficacy* and it represents the most recent theoretical addition to the HBM.

The following summarizes the hypothesized relationship:

- **H5** Self-efficacy will be positively correlated with protective risk behaviour.

4.2.3 Inherent attitude

Attitude refers to the individual orientation towards taking or avoiding risks in situations with uncertain outcomes. It encompasses people's intentions to evaluate a behaviour to be favourable or unfavourable and act accordingly (Rohrmann, 2008). A person's inherent inclination therefore affects the interpretation of risk according to a negative, positive and neutral perspective. Examples of such interpretations are provided by Rohrmann (2012, p.2):

- "*The possibility of physical or social or financial harm/detriment/loss due to a hazard"* (negative perspective)*;*
- *"The thrill, representing a danger-induced feeling of excitement"* (positive perspective)*;*
- "*The uncertainty about the outcomes (good and/or bad ones) of a decision"* (neutral perspective)*.*

Therefore, attitude enhances or reduces the likelihood that a risky behaviour occurs (Rohrmann, 2002, 2008). By analogy, the described relationship can be is defined to be as follows:

- **H6** Attitude is positively related with protective risk behaviour.

4.2.4 Modifying variables

The behavioural variables are accompanied by three classes of modifying factors, namely (1) demographic factors, (2) coronavirus-specific health factors, (3) the CoronaMelder app, and (4) Covid-19 risk attitude. These groups determine the magnitude of the perceived risks and as a result the likelihood of compliance with recommended preventive health behaviours through a direct or an indirect effect (Morowatisharifabad, 2009). The following sections describe each modifying variable according to the order of their mentioning.

4.2.4.1 Demographic variables

Demographic variables are exogenous variables which influence behaviour only indirectly (Champion et al., 2002). Previous evaluations of the app have outlined the effect of *age*, and *education* level on the adoption of the app (Van der Laan et al., 2020b, 2021). Extending this effect on the adoption of any preventive measure, these demographic variables are also included in the model as the modifying factors in the adoption of each mitigation category with the addition of *gender* and the size of the *household*. Provided the inconclusive empirical evidence about the relation among the demographic variables and a technological application, no hypotheses can be formulated about their correlation.

4.2.4.2 Coronavirus-specific health variables

Like the demographic variables, the *coronavirus-specific health variables* are exogenous variables which are thought to influence the adoption of the app. These variables include *being a person at risk* or *working with people* who are in the risk group but also having previously contracted the coronavirus the individual's attitude towards vaccination. Vaccination and previous infection provide a physical protection against the virus, whereas being at risk or working with people at risk enhances the susceptibility to the virus of one's self or of others. A such, it could be stated that these variables could affect a person's inclination to adopt protective measures. Nonetheless, empirical evidence lacks proof for these hypothesized relationships, and as such no hypothesis can be formulated.

4.2.4.3 CoronaMelder app utilisation

Continuing with the *CoronaMelder app*, its hypothesized effect on behaviour can be studied through its direct and indirect modifying effect on protective risk behaviour. The RHT states that an intervention instigates risk compensation behaviour through *prevention optimism*, thus by lowering the overall perceived risk for infection (Noland, 1995; G.J.S. Wilde, 2010; Gerald J.S. Wilde, 1998). It would, therefore, mean that the app lowers the perceived threat (direct effect) thereby influencing the outcome (indirect effect). For an encompassing analysis, all other relationships with risk perceptions are also included.

The usage of the CoronaMelder could however be the result of an inherent positive attitude towards preventive measures, therefore complicating the definition of the causality between the app's usage and the resulting behaviour. It is, therefore, necessary to identify the correlation between attitude and the app's usage to make solid conclusions concerning causality towards the instigated behaviour.

All the relationships are summarized as follows:

- **H7** CoronaMelder app is negatively correlated with perceived susceptibility.
- **H8** CoronaMelder app is negatively correlated with perceived severity.
- **H9** CoronaMelder app is not correlated with attitude.

4.2.4.4 Covid-19 risk attitude

The latter variable is provided by risk attitude as a separate entity from the inherent attitude described before. Literature suggests that people do not present a stable nor a homogeneous attitude towards risk types (Rohrmann, 2008). They can be considered to be risk tolerant. Nonetheless, at a given time an individual can have either one or the other propensity. As such, these factors also shape behaviour in the context of the current pandemic. People's motivation for accepting risks is dependent on their mind-set towards risk-taking, but it varies depending on the type of hazard. Hence, the underlying propensity to being risk-seeking or risk-averting in the context of the coronavirus requires a separate also variable named *specific risk attitude*.

Literature suggests that a risk-averting inclination is positively correlated with protective behavioural adaptation (Man et al., 2021; Rohrmann, 2008; Sadiq et al., 2021; Van Winsen et al., 2011). This means that an individual having a positive attitude towards preventive measures is expected to implement such measure. Risk perceptions are therefore mitigated by the inherent inclination on an individual to be risk-averting (or risk-seeking). The positive correlations among risk perceptions and protective behaviour are, subsequently, indirectly reinforced through risk-averting attitude. Thus, the following hypothesis is formulated:

- **H10** Specific risk-averting attitude is positively correlated with protective risk behaviour.
- **H11** Specific risk-seeking attitude is negatively correlated with protective risk behaviour/

4.3 Applicability of the Risk Homeostatic Theory

Conclusions about the applicability of the RHT will be provided through the simultaneous satisfaction of H7, H8 and H9. The satisfaction of H7 and H8 would affirm the applicability of the RHT and are therefore called the **Prevention Optimism Hypotheses**. The additional satisfaction of H9 would affirm the independence of the CoronaMelder app from inherent risk-averting attitude, thus representing the **Inherent Selection Hypothesis**. When these hypotheses do not hold simultaneously, the applicability of the RHT to the given case is rejected.

4.4 Resulting conceptual model

The graphical representation of all independent and dependent variables previously outlined, is provided by *Figure 4* on the next page. The figure differentiates among the Basic Model and the Extended Model, where the latter contains the lacking hypothesized correlations between the demographic variables and the health variables with the utilization of the app. The former model, on the other hand, visualizes the effect of people's perception and attitude as well as the possibly mitigating effect of the CoronaMelder adoption on the adherence to the mitigation rules. As risk and exposure assessment vary among mitigation measures, the model should be specifically studied for each mitigation rule (Bruinen de Bruin et al., 2020). Provided the temporal limitation for the termination of this thesis, it is decided to group the measures in three categories.

Bruinen de Bruin et al. (2020) have clustered the mitigation measures into six categories: (a) mobility restrictions, (b) socio-economic restrictions, (c) physical distancing, (d) hygiene measures, (e) communication, (f) international support mechanism. Whereas the first three categories limited or slowed the direct human-to-human propagation of the virus, the aim of the hygiene measures was to prevent the spread of infectious particles that would indirectly contaminate people. They comprised drastic measures that altering the way people interacted at a micro- and meso-level, such as closing the officed of non-essential jobs to consequently confine workers to their own house to complete their tasks. The latter two mitigation measures, on the other side, targeted the macro-level by establishing ways to coordinate knowledge exchange at a national and an international scale respectively. Examples of each category are provided by *Figure 5*.

Figure 5: Categorized risk mitigating measures *(adapted from Bruinen de Bruin et al., 2020)*

The categorization can also be applied to the Dutch code of conduct previously outlined. The resulting categorization is presented in *Table 1.* It is necessary to remind that this code of conduct has been designed to instruct citizens about the appropriate behaviour to curb the spread of the virus at a personal level. Other measures, such as closing of universities and prohibiting flight traffic, are not included in the table as these measures do not fall under the volitional control of the people and as such, they fall beyond the scope of this research. Therefore, only the micro- and the meso-level have been included in this analysis.

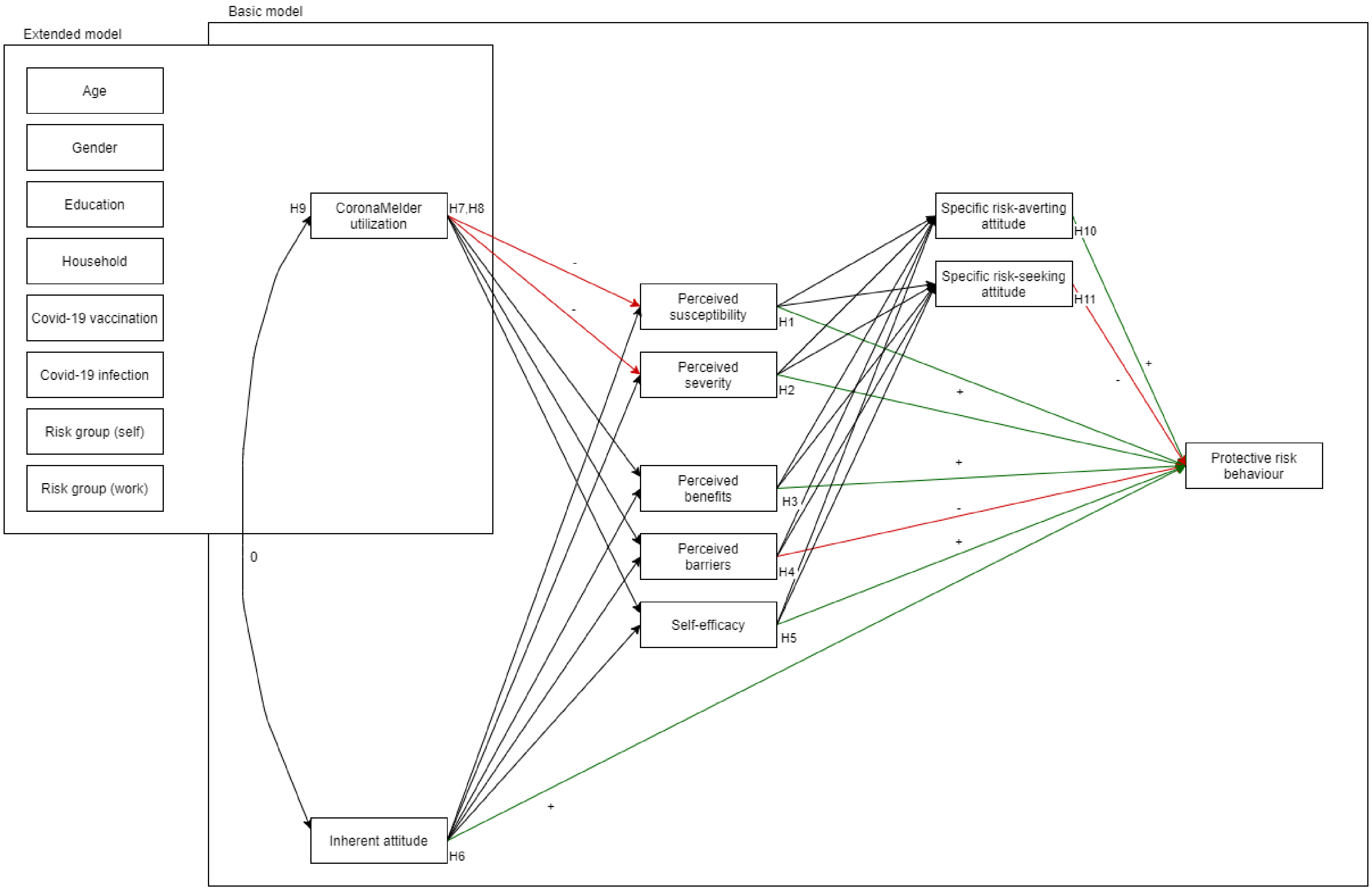


Figure 4: Conceptual model for behavioural adaptation due to the CoronaMelder app.

Table 1: Dutch mitigation rule categorization

Mitigating measure	Categorization	Level	Voluntary/mandatory
Keeping 1.5 m distance from others	Distancing	Micro	Voluntary
Avoiding crowded places	Distancing	Micro	Voluntary
Inviting a maximum number of guests in one's home	Distancing	Micro	Voluntary
Seeing a maximum number of different people in a week	Distancing	Micro	Voluntary
Gathering in less than 2-3 people at once	Distancing	Micro	Voluntary
No shaking hands	Hygiene	Micro	Voluntary
Coughing and sneezing in inner elbow	Hygiene	Micro	Voluntary
Frequently and appropriately washing of hands (>10/day)	Hygiene	Micro	Voluntary
Using a face mask covering nose and mouth	Hygiene	Micro	Mandatory*
Working from home if non-essential worker	Mobility	Meso	Voluntary
Using public transport only if strict necessary	Mobility	Meso	Voluntary
Being home during the curfew (22:00h-4:30h)	Mobility	Meso	Mandatory**

* Voluntary at first, but mandatory since Dec 1, 2020 until writing on Mar 12, 2021; ** Mandatory since Jan 23, 2021 until writing on Mar 12, 2021; after such date the curfew has been postponed to 22:00h.

According to this categorization, three groups of NHIs are of importance for this research, namely: (a) hygiene measures, (b) physical distancing, and (c) mobility restrictions. They have mostly been implemented on a voluntary basis, with the exception of wearing face masks and respecting the curfew which are subject to the Dutch corona-specific law such that their application is enforced, thereby maximizing their desired beneficial effect. Based on this categorization, three models will be analysed in the study of the combined effect of the app with either hygiene rules, distancing measures or mobility restrictions.

4.5 Model limitations

Several limitations have to be outlined as they affect the outcome of the model. The absence of theoretical relationships among the components, complicate testing for the construct validity. It could, for instance, be that one variable acts as a mediator in the relationship between other variables. Likewise, temporality of relationships provides another issue. That is, measuring beliefs and behaviours simultaneously might result in spurious apparent relationships (Champion et al., 2002). These deficiencies therefore constrain the identified model. However, this descriptive model is intended to be studied from an exploratory analysis' perspective. In other words, the aim of this research is not to provide a solid conceptual model for the integration of the RHT with existing behavioural models but rather to study the applicability of the theory to the introduction of the app. Moreover, like all models and schemes, it is a simplification of reality and it therefore does not pretend to be comprehensive. It omits many factors that indirectly control preventive behaviour (or risk behaviour), including the mediating effect of the demographic and health variables as their study is limited to the adoption of the app.

5 Model formalization

The conceptual model derived from the previous chapter is consequently formalized by means of a structured questionnaire. Each variable of the conceptual model is hereby translated into practical constructs and their according scales. This chapter therefore illustrates how these questionnaires have been structured.

5.1 Sample

The questionnaire was built on Qualtrics XM and it was distributed by the externally dedicated company PanelClix. In total, three batches were sent by PanelClix to all age, gender and education segments of their Dutch-speaking respondents' pool above 15 years of age, such that the demographical composition of the sample population matched that of the Dutch population. Although these demographic characteristics have been monitored, it should be reminded that the sample population could differ from the composition of the Dutch population in other demographic information like, for instance, income level and residential area. This bias should therefore be reminded to generalize the obtained findings. The resulting composition is shown in the next chapter.

Participation to the study was furthermore voluntary and subject to informal consent. Respondent were, thus, only allowed to continue with the survey after they had provided their consent. In the instructions to the questionnaire, the purpose of the study was explained to be a complementary part of the app's evaluation. Risk taking related to CoronaMelder app usage was not mention to not influence the respondent's answers. The survey was additionally subject to the approval of the TU Delft Human Research Ethics Committee and confidential handling of the responses was assured. The total time spent for the questionnaire completion was 7.5 minutes on average.

The survey was divided into two phases, namely data retrieval and data validation. In the first stage of the survey, all respondents were required to fill in the survey from which the data foundation for the subsequent analysis was retrieved. A second stage required a panel of 5 users and 5 non-users to assess the content validity of the collected data as to evaluate the pertinence and relevance of the items.

5.2 Measures

The structured questionnaire was developed by the graduate student in accordance with prof.dr. W. Ebbers to assess the appropriateness of the instruments. The survey was based on proven questions taken from existing empirical testing, the items of which were only altered to fit them in the context of risk perception and preventive behaviour. By adhering to the current body of research, it was attempted to enhance the validity of the constructs while paying attention to the contextual nature of risk perceptions. The content was nonetheless checked for validity by the dedicated supervisors.

The constructs, number of items, scales and reliability coefficients are listed in Table 2. Conceptual and operational definitions for each construct, along with examples for each measure, are presented in the following sections. All results were obtained with the application of a 5-point Likert-type scale, following the example of existing empirical findings (Costa, 2020; Grimmelikhuijsen & Knies, 2017). So, each variable was measured through statements describing mind-sets or behaviours with a 1-to-5 scale response format, meaning that respondents were asked for their level of agreement with each statement on a 5-point scale ranging from 1 (Strongly agree) to 5 (Strongly disagree).

To enhance the reliability of the psychological attributes, multi-item measures were inserted to control for the random measurement error and to capture a greater portion of the theoretical concept's complexity (Gillem & Gillem, 2003). For multi-item measures containing opposing statements, reverse scoring was applicable to assure that the mean construct would be valid. Reverse scoring is characterized by scores ranging from 1 (Strongly disagree) to 5 (Strongly agree). For each item, the type of scoring is outlined.

To limit the length of the survey, it was decided to randomly assign each respondent to a mitigation rule category, such that each category was presented to a third of the respondents. The higher the respondent scored (thus, the more they opposed to the statement), the lower was the evaluation of the measure. The specifications of each construct are then outlined in the following sections. The resulting questionnaire has been included in Appendix A.

Table 2: Questionnaire characteristics (N=776)

Construct (value ranges)	Measure	N of items	Scale
General attitude (range 4-20)	Competence	1	5-point Likert scale
	Benevolence	1	
	Integrity	1	
	General	1	
Perceived susceptibility (range 3-15)	Self	2	5-point Likert scale
	Other	1	
Perceived severity (range 3-15)	Self	2	5-point Likert scale
	Other	1	
Perceived benefits (range 2-10)	Hygiene rules*	2 (N=261)	5-point Likert scale
	Social rules*	2 (N=263)	
	Mobility rules*	2 (N=252)	
Perceived barriers (range 2-10)	Hygiene rules*	2 (N=261)	5-point Likert scale
	Social rules*	2 (N=263)	
	Mobility rules*	2 (N=252)	
Self-efficacy (range 2-10)	Hygiene rules*	2 (N=261)	5-point Likert scale
	Social rules*	2 (N=263)	
	Mobility rules*	2 (N=252)	
Specific attitude (range 2-10)	General	1	5-point Likert scale
	Importance**	1	
Protective risk behaviour (range 3-15)	**No symptoms:**		Never = 1
	Hygiene rules*	3 (N=261)	Sometimes = 2
	Social rules*	3 (N=263)	Regularly = 3
	Mobility rules*	3 (N=252)	Usually = 4
			Always = 5
	Symptoms:		Never = 1
	Hygiene rules*	3 (N=261)	Sometimes = 2
	Social rules*	3 (N=263)	Regularly = 3
	Mobility rules*	3 (N=252)	Usually = 4
			Always = 5
CoronaMelder utilization (range 0-99)	N/A	1	Currently using it = 2 Used in the past, not now = 1 Never used = 0 I did not know it before the survey = 99
Protective risk behaviour after CoronaMelder notification (range 2-10)	**No symptoms:**		5-point Likert scale
	Hygiene rules*	2 (N=261)	
	Social rules*	2 (N=263)	
	Mobility rules*	2 (N=252)	
	Symptoms:		5-point Likert scale
	Hygiene rules*	2 (N=261)	
	Social rules*	2 (N=263)	
	Mobility rules*	2 (N=252)	

*respondents were randomly assigned to either group a, b or c, **reverse scoring was applied.

5.2.1 Demographic variables and health variables

The exogenous variables included in this survey reflect the personal and the social sphere of the respondent, including both the demographic characteristics and the coronavirus-specific health characteristics. As these variables present straightforward questioning, the details of these questions are presented in Table 2.

Table 2: Demographic and health characteristics (N=776)

Construct	**Scale**
Gender	Man = 1 Woman = 2 Do not want to tell = 99
Age	15-35 years old = 1 36-55 years old = 2 56-75 years old = 3 76 years old or more = 4
Education	Elementary school = 1 VMBO, MBO1, AVO Onderbouw = 2 MBO2, MBO3, MBO4 = 3 HAVO, VWO = 4 HBO = 5 University or higher = 6
Household	Alone = 0 One roommate = 1 Two or more roommates = 2 Do not want to tell = 99
Risk group (self)	Yes = 1 No = 0
Risk group (work)	Never = 1 Sometimes = 2 Regularly = 3 Usually = 4 Always = 5
Coronavirus infection (self)	Yes, positive test = 1 Yes, but no test = 2 No, negative test = 3 No, but no test = 4 Do not want to tell = 99
Coronavirus infection (work)	Yes, partner = 1 Yes, one or more roommates = 2 Yes, one or more family members = 3 Yes, one or more friends = 4 Yes, one or more peers/colleagues = 5 Yes, one or more acquaintances = 6 Yes, other [*string*] = 7 No, nobody = 8 Do not know = 99
Vaccination	Yes = 1 Not yet, but planned = 2 Not yet, but want to as soon as I get an invite = 3 Not yet, because torn (do not know yet) = 4 No, because I do not want to = 5 Do not want to tell = 99

5.2.2 General attitude

Attitude scaling is generally performed through the presentation of statements expressing risk propensity or aversion to which people are asked to present their level of agreement. In this particular questionnaire followed the example set by Grimmelikhuisen and Knies (2017), where attitude was specified for the context of pubic administration. According to their research, citizen's trust in government organizations are determinants of the pursuit of any measure issued by the same government. So, the more people trust in it, the higher their propensity will be to adhere to the issued measures. As such, it resembles to the interpretation of attitude given in this study. Moreover, its applicability is validated by previous research in the same domain (Ebbers, 2021).

This scale measures the three dimensions central to most organizational trust studies, namely perceived competence, benevolence and integrity (Grimmelikhuijsen & Knies, 2017). Perceived *competence* is reflected by how citizens perceive the government to be capable and effective. Perceived *benevolence* is more concerned with the motivation of the government organization and whether citizens perceive it to be acting for the welfare of the public. Lastly, perceived *integrity* revolves around the citizen's perception with respect to the government's sincerity and about the fulfilment of its promises.

Following this reasoning, people were asked to provide their level of agreement with the statements presented in Table 3 (Ebbers, 2021). The higher the score (thus, the more the respondent disagrees with the statements), the lower is the trust in the government.

Table 3: General attitude

Statement (*During a crisis…*)	**Measure**	**Scale**
… I think the government is very competent.	Trust, Competence	Normal
… the government does its best to help citizens.	Trust, Benevolence	Normal
… the government is honest about the current of events.	Trust, Integrity	Normal
… I can trust the government.	Trust, General	Normal

5.2.3 Perceived susceptibility and perceived severity

Statements about perceived susceptibility to the coronavirus and its perceived severity were derived from previous empirical research (Van der Laan et al., 2020, 2021). Susceptibility statement were defined similarly to "Based on my overall well-being, my chance of catching the coronavirus disease is low", whereas statements about its severity were formulated similarly to "If I caught the coronavirus disease, my chance of getting excessively impaired to do my daily activities would be low".

Each questioned perception type focused on the personal threat (*self*) and on the threat to others (*other*) as outlined by Table 4 on the next page. The stronger the respondent agreed with the statements (thus, the lower the score), the higher was their perceived threat of the virus.

5.2.4 Perceived barriers, perceived benefits and self-efficacy

Specificity to the mitigation rules is introduced through this section. The statements presented to each respondent were derived from the questions already studied by the RIVM in their continuous investigation in people's adherence to the measures. According to the HBM, two statements per perception were presented to each respondent according to Table 5 on the next page. Hence, each respondent provided his or hers agreeableness with statements regarding the perceived benefits, perceived barriers and self-efficacy of each measure.

Table 4: Perceived susceptibility and perceived severity

Statement	Measure	Scale
In the coming two months, I take a chance of getting infected with the coronavirus.	Susceptibility, Self	Normal
The chances are high that I will get infected with the coronavirus within the coming two months.	Susceptibility, Self	Normal
If I get infected with the coronavirus, the chances are high that I will infect others.	Susceptibility, Others	Normal
I feel bad to get infected with the coronavirus.	Severity, Self	Normal
An infection with the coronavirus, has great physical, psychical and economic impact on me.	Severity, Self	Normal
I feel bad if I infect other people with the coronavirus.	Severity, Others	Normal

Table 5: Behavioural evaluation and self-efficacy per mitigation rule category

Statement	Measure	Scale
For me, following the hygiene/social/mobility rules results in personal benefits.	Benefits	Normal
The hygiene/social/mobility rules help preventing the spread of the coronavirus.	Benefits	Normal
I suffer from personal ill-effects to follow the hygiene/social/mobility rules.	Barriers	Reverse
The hygiene/social/mobility rules are useless in the battle against the spread of the coronavirus.	Barriers	Reverse
I am capable of following the hygiene/social/mobility rules.	Self-efficacy	Normal
The hygiene/social/mobility rules are easy to follow.	Self-efficacy	Normal

5.2.5 Specific attitude

As there is no generally accepted view on the number of dimensions of risk taking nor on how they are constituted, it was decided to differentiate among risk-averting and risk-seeking statements to measure this one-dimensional variable. Following the empirical examples, two statements were formulated regarding people's general conduct towards the adherence to the mitigation rules (*general*) and about the value they associate to these rules (*importance*). As these statements measure opposing attitudes, the scoring is adjusted to the type of question as outlined in Table 6. The stronger the people agreed with the statements, the more they presented a risk-averting mind-set and the weaker they scored on the statements, the less they were found to be risk-averting.

Table 6: Specific attitude

Statement	Measure	Scale
I do my best to prevent that I get infected with the coronavirus.	Risk-averting, General	Normal
I think that the mitigation rules are superfluous.	Risk-seeking, Importance	Reverse

5.2.6 Protective risk behaviour

Finally, respondents were presented with two vignettes per randomly assigned mitigation category in which two hypothetical situations were introduced. The situations were identical expect for the symptoms felt by the respondents (*no symptoms* and *symptoms*) after which they were asked to express their level of agreeableness with the statements presented by Table 7. These behavioural statements are based upon the continuous monitor survey conducted by the RIVM. The more the respondent agreed with the statements, the more their behaviour could be described to be preventive. The goal of this differentiation is to identify whether symptoms equally cue a specific behaviour among users and non-users.

Table 7: Behaviour per mitigation rule category

Statement	Measure	Scale
I wash my hands regularly, for example when I get home or when I am visiting.	Hygiene rules	Normal
I cough and sneeze in my elbow.	Hygiene rules	Normal
I wear a face cloth in public inner areas.	Hygiene rules	Normal
I keep 1.5 meter distance from friends, family and colleagues.	Social rules	Normal
I avoid crowded places at work, at parties or in the shopping street.	Social rules	Normal
I receive 1 person a day at maximum at my home.	Social rules	Normal
I do not use public transportation, unless necessary.	Mobility rules	Normal
I work from home, unless there is no other way.	Mobility rules	Normal
I stay inside from 22:00 h till 4:30 h (curfew).	Mobility rules	Normal

5.3 Model specification

A cross-sectional, correlational design was employed and the data were collected using the survey questions developed by the researcher. At the item level, the variables used to measure the constructs were treated as categorical data. At the scale level, the measures of the constructs were treated as continuous data. The Statistical Package for the Social Sciences (SPSS) was used for the purpose of data entry, manipulation and analysis. The level of significance was set a priori at 0.05.

5.3.1 Model identification

The goal of data validation was to test whether the generated items indeed measured the hypothesized dimension and to determine the reliability of the scale. Through confirmatory factor analyses (CFAs) the empirical model was examined. In general, the CFA models are identified when factors have at least three items each (Stevens, 2002). This questionnaire was built upon existing studies which a-priori did not meet this prerequisite. Resultingly, the analysis of the factors Benefits, Barriers and Self-Efficacy could result in under-identification. In other words, these factors could present factor loadings or correlations that greatly vary from the expected magnitude, that have the wrong sign, that present negative variances or have correlations bigger than 1.0 (Stevens, 2002). The reliability on the other hand, was provided through examination of the reliability coefficients Cronbach's α of the observed indicator relative to the selected latent variable. The closer the Cronbach's α coefficient is to 1.0, the greater the internal consistency of the items in the scale (Gillem & Gillem, 2003). The generally applied benchmark for reliable measures is 0.7, however, the reasoning behind this requirement is unspecified (Spiliotopoulou, 2009). Therefore, this study considers indicators with a Cronbach's α greater than 0.6 to be reasonable for this research's purpose.

5.3.2 Model fit

The model fit was assessed by means of fit statistics including the measurement of the overall fit of the model and the individual model parameters. Conclusions about a good model fit were based upon values of the comparative chi-square statistic (χ^2, checked for significance at α=0.05), the goodness-of-fit index (GFI>0.9), the normed fit index (NFI>0.9), and the root mean square error approximation (RMSEA<0.05 for good fit or RMSEA<0.08 for reasonable fit) (Bentler & Bonnel, 1980; Browne & Cudeck, 1993; Jöreskog & Sörbom, 1992; Stevens, 2002). Nonetheless, as MacCallum (1995) stated "*A critical principle in model specification and evaluation is the fact that all the models that we would be interested in specifying and evaluating are wrong to some degree*" and as such the obtained model "*at their best can be expected to provide only a close approximation to observed data, rather than an exact fit*" (p.17).

5.3.3 Model modification

A poor model fit is indicative of large discrepancies between the sample and the hypothesized model. However, modifications to the hypothesized model on theoretical considerations were not feasible given the ad hoc implementation of the best available theory. Post hoc modifications as suggested by the fit statistics must be validated through replication on a different sample. Given the explorative nature of this study, these modifications have thus not been considered. Furthermore, any proposed modifications were solely based on a better statistical fit of the empirical evidence. As such the improved model was not defensible from a theoretical point of view (Stevens, 2002). So, these proposed changes were not made and instead they were suggested for further research.

5.4 Model validity and reliability

The reliability and validity of the measures, as well as the impact and the applicability of the results is a key requirement for the appraisal of the model outcomes (Spiliotopoulou, 2009). With the introduction of multiple items per scale it is attempted to minimize the measurement errors and to maximize the probability of including all relative components per construct. By means of the Cronbach's alpha, the reliability of each measure was analysed. The reliability of the described relationships was furthermore analysed through CFA, confirming or refuting the hypothesized dimensionality of the model.

The internal and external validity of the outcomes was also checked. Internal validity was assured by the study of the specificity and sensitivity of the model outcomes, whereas the external validity was provided by replication of the results with another sample (Giancristofaro & Salmaso, 2003). The latter form of validity was employed by questioning random respondents from the original sample population to qualitatively confirm the outcomes.

Despite these considerations, the validity and reliability of the outcomes are constrained by several assumptions and limitations affecting their interpretability. These limitations are further discussed in Chapter 9.

6 Results

The underlying chapter present the survey results obtained through the distribution of the questionnaire in the period of 20 April 2021 and 28 April 2021. The subsequent model analyses are outlined along the way to answer the second and third sub-question: *In which way does the CoronaMelder app influence people's behavioural perception?* And: *To what extent does the CoronaMelder affect people's behaviour?*

6.1 Survey results

6.1.1 Representativeness of sample

The survey was started by 828 people of which 4% did not provide its consent or did not answer the consent question (N=35). People who completed the survey below the threshold of 120 seconds, were removed from the analysis (N=14). They have thus not been included in the analysis, nor in the representativeness analysis. Lastly, people with missing information were excluded from the analysis (N=1). As such, the analysis is completed for 776 respondents. Table 8 (left) provides the distribution of based on age, gender and education of the sample.

The man-woman distribution is almost equal, respectively 51% and 48% where 2 people preferred not to reveal their gender. For the analysis, the level of education has been subdivided among low, middle and high. The level of education coded as low, encompasses elementary school, VMBO, MBO1 and AVO Onderbouw (N=112, 14%). Middle-level education refers to secondary school (HAVO and VWO) as well as MBO2, MBO3 and MBO4 (N=409, 53%). The final group indicated by high education contains higher professional education (HBO) and university degree (N=256, 33%). This differentiation holds for the entire analysis.

Table 8: Gender, age and education level

Gender	Age	Education			Gender	Age	Education		
		Low	Middle	High			Low	Middle	High
Men	15-35 years	5%	2%	7%	Men	15-35 years	5%	6%	4%
	36-55 years	6%	3%	9%		36-55 years	3%	6%	6%
	56-75 years	6%	3%	9%		56-75 years	4%	6%	5%
	76+ years	0%	0%	1%		76+ years	2%	1%	1%
Women	15-35 years	5%	2%	9%	Women	15-35 years	4%	6%	5%
	36-55 years	7%	2%	9%		36-55 years	3%	6%	7%
	56-75 years	4%	2%	8%		56-75 years	6%	5%	4%
	76+ years	0%	0%	0%		76+ years	4%	1%	1%

Left: Representativeness of the sample (N=776). **Right:** Segmentation of the Dutch population (CBS, 2019). Due to rounding up and down, the 0% vary between de 0 and the 0.4%. The education columns of men and women together add up to 100%.

Despite the accuracy of the data collection, several differences can be found when the numbers are compared with the official reports about the Dutch population (CBS, 2019). These numbers are presented in Table 10 (right). Highly educated women (15-35 years and 55-75 years) are slightly overrepresented. The same holds for men and women with lower education (35-55 years) and highly educated men (55-75 years). At the other end of the spectrum, men and woman with a moderate education level are underrepresented (15-35 years and 36-55 years). Lastly, older lower educated women are also slightly underrepresented (76 or more years).

Considering the slight variations in the mentioned groups, it can nonetheless be concluded that the sample is representative for the Dutch population for gender, age and education.

6.1.2 CoronaMelder usage among respondents

To the question whether the respondents had installed the CoronaMelder, 30% (N=236) of the respondents was currently using the app. The biggest majority responded that they had not installed it (N=438, 56%) whereas 12% (N=89) responded that they had used it in the past but were not using it anymore. A small portion of the respondents had never heard of the app (N=14, 2%). In total, thus, 30% (N=236) of the respondents can be considered as current *users* compared to the remaining 70% (N=541) of *non-users*. The details are also represented in Figure 6.

The start of the surveys was taken as a reference for the CoronaMelder adoption. The amount of total downloads of the CoronaMelder app by the Dutch population was 4,788,158 at 20 April 2021 ("Appstore Statistics", 2021). Knowing that only 60% of these downloads are properly exchanging data with the sever, the actual adoption amounts to around 2,872,895 (Ebbers et al., 2021). With a population of 17,487,491, 16% of the population has downloaded the app (CBS, 2021). The 30% adoption resulting from the surveys is thus an indication of a overrepresentation of the CoronaMelder users. However it should be noted that no distinction was made between active utilization of the app and mere download of the app on the phone.

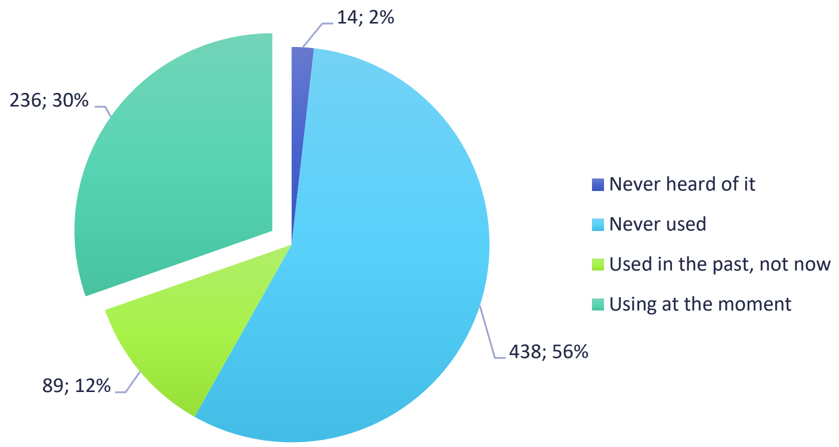


Figure 6: CoronaMelder usage among respondents.

Deepening the understanding of the demographic variation that characterizes the adoption of the CoronaMelder usage, next are presented the utilization rates per age group and education level. According to the following segmentation of age, groups till 35 years have been coded as *young*, the ages between 36 and 55 years have been coded as *middle*, whereas older than 56 years have been grouped as *old*. In all, older respondents have installed the app the most (N=106, 39%) compared to the middle aged group (N=70, 26%) and the younger respondents (N=59, 25%). The prevailing answer for each age group was, nonetheless, not having ever used the CoronaMelder as depicted in Figure 7 on the next page. Continuing with education level, this differentiation follows the previously described segmentation in *high*, *middle* and *low*. The highest educated respondents provided the greatest adoption (N=104, 41%) followed by middle-level educated people (N=107, 26%) and low-level educated respondents (N=25, 22%). Also here, there is no education level that prevails in adoption over non-adoption of the CoronaMelder such as can be seen in Figure 8 on the following page. The latter point needs reinterpretation when considering the combination of age and education, as it reveals the highest adoption for the portion of older and higher educated respondents (N=40, 51%). The lowest adoption is presented by the middle-age group with lower education (N=4, 12%) and the younger population with lower education (N=4, 13%). These results are presented in Figure 9 on the next page.

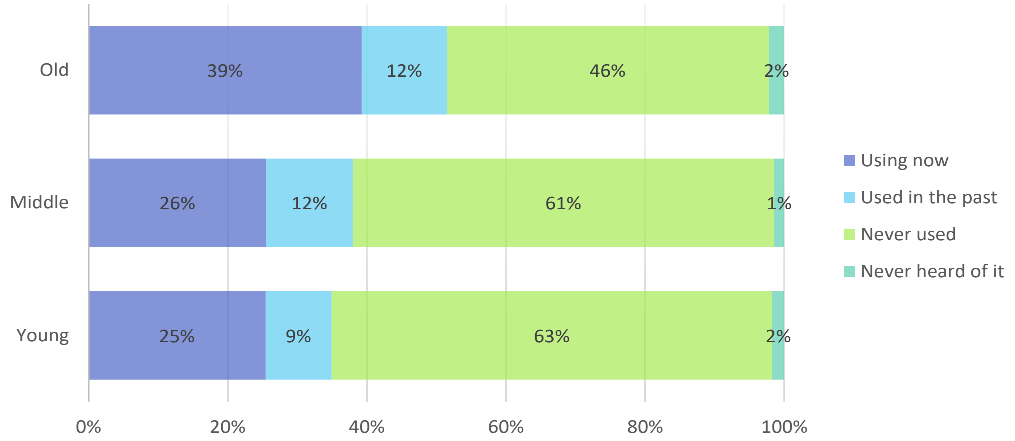


Figure 7: CoronaMelder usage among respondents segmented according to age group.

Figure 8: CoronaMelder usage among respondents segmented according to education level.

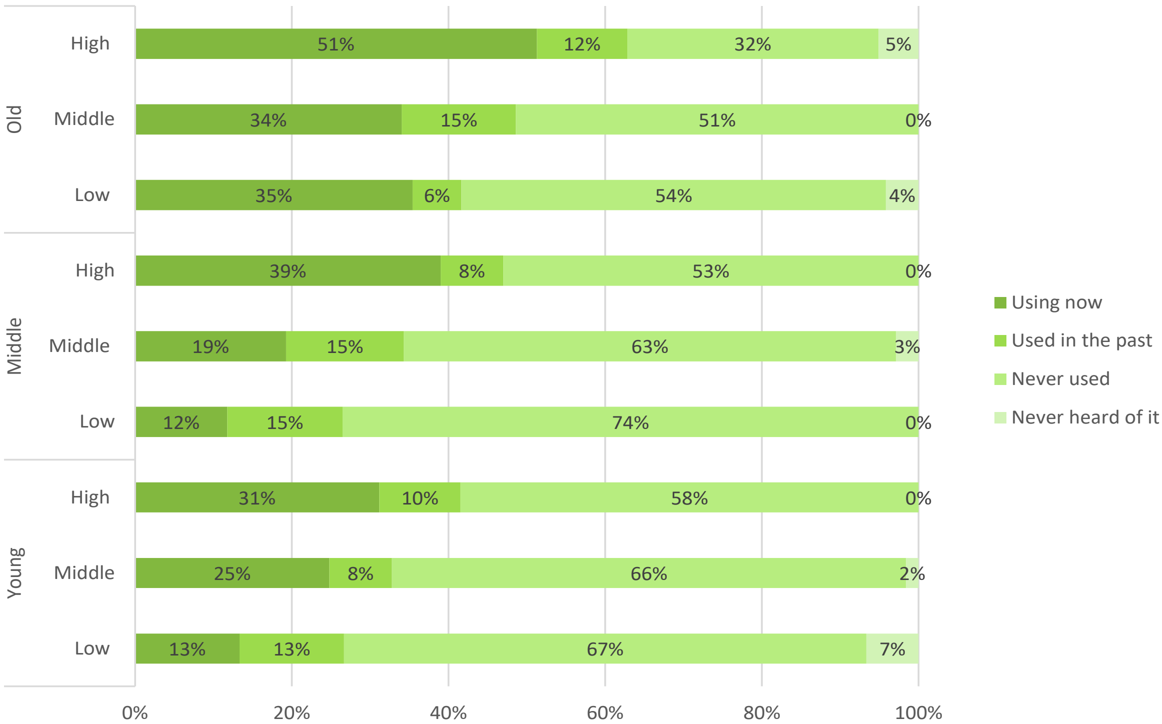


Figure 9: CoronaMelder usage among the respondents segmented according to age group and education level.

The next sections will outline the differences between user and non-users on a demographic basis and on a health basis specific for the Covid-19 pandemic. The former, illustrates the characterization of users and non-users based on age group, education level and size of household. The latter, on the other hand, defines the specification of users and non-users on the basis of being at risk for the infection (people older than 70 years old or people with a fragile health) or working with persons at risk, but also dependent on previous infection with the virus (officially confirmed by a test or not) and Covid-19 vaccination (intention also included).

6.1.2.1.1 CoronaMelder users and non-users: Age, education and household

Table 9 on the left provides the characterization of users and non-users according to gender, age group, education level and size of household. The gender composition of users and non-users is almost equal. Continuing with age, users are mostly characterized by older users (45%), then followed by middle-aged people (30%) and people younger than 35 years old (25%). The segmentation among old, middle-aged and younger of non-users, on the other hand, is almost equal (30%, 38% and 32% respectively). According to the differentiation based on education level, highly educated and the middle educated people almost uniformly adopted the CoronaMelder (44% and 45% respectively), whereas lower education is the minority (11%). Middle schooled people represent the majority of non-users (56%), followed by highly educated respondents (28%) and lower educated people (16%). Finally, users and non-users do not differ greatly on adoption based on the size of household. Most of the users and non-users live with one person (37% and 32% respectively) or two and more people (49% and 51% respectively), whereas the minority lives alone (14% and 16% respectively).

Table 9: Demographic and health characterization of users and non-users

Demographic variable	User	Non-user
Gender		
Do not want to tell	0%	0%
Man	52%	51%
Woman	48%	48%
Age		
Young	25%	32%
Middle	30%	38%
Old	45%	30%
Education		
Low	11%	16%
Middle	45%	56%
High	44%	28%
Household		
1 person	37%	32%
2 or more people	49%	51%
Alone	14%	16%
Do not want to tell	0%	0%

Health variable	User	Non-user
Risk group (self)		
No	63%	72%
Yes	37%	28%
Previous infection		
Do not want to tell	0%	1%
No, but never been tested	41%	50%
No, negative test	43%	35%
Yes, but I have never been tested	8%	7%
Yes, positive test	8%	7%
Vaccination attitude		
Do not want to tell	0%	1%
No, but planned	14%	6%
No, do not want to	1%	12%
No, torn	7%	21%
No, willing to plan	49%	44%
Yes	28%	17%

The column categories add up to 100%, where the 0% vary between the 0% and the 0.4%.

6.1.2.1.2 CoronaMelder users and non-users: Risk group, previous infection and vaccination

The segmentation of users and non-users according to their coronavirus-specific health characteristics is also provided by Table 9 on the right. To start with, only a third of the users as well as the non-users are considered members of the risk group (37% and 28% respectively), where the remaining two thirds are not considered people with a fragile health (63% and 72% respectively). When considering previous infection to the coronavirus, both users and non-users have not been previously infected (43% and 35% respectively) or believe they have not been infected before (41% and 50% respectively). Only a small portion of users and non-users has been infected with the coronavirus (8% and 7% respectively) or beliefs to have been infected (8% and 7% respectively). Closing with the Covid-19 vaccination, most of the users and non-users have already been vaccinated (28% and 17% respectively), have planned their vaccination date (14% and 6% respectively) or are willing to plan it (49% and 44% respectively). Only 7% of the users are torn by the decision compared to 21% of the non-users. Lastly, only 1% of the users stated that they did not desire the vaccination, as opposed to 12% of the non-users.

6.1.3 Mitigation categories characteristics

The respondents were randomly divided among the three mitigation categories: hygiene measures (N=261), distancing measures (N=263), mobility measures (N=252). As their categorization is based on random assignment, it is necessary to outline their demographic variables to assess the reliability of the outcomes. The measures are also specified according to the coronavirus-specific health characteristics. These results are contained by Table 10. The segmentation of age and education level, follows the same line of reasoning as outlined before.

Table 10: Demographic and health variables per mitigation category

Demographic variable	Hygiene	Distancing	Mobility	Health variable	Hygiene	Distancing	Mobility
Gender				*Risk group (self)*			
Do not want to tell	0%	0%	1%	No	71%	67%	69%
Man	52%	50%	53%	Yes	29%	33%	31%
Woman	48%	50%	46%	*Previous infection*			
Age				Do not want to tell	0%	0%	1%
Young	28%	33%	29%	No, but never been tested	46%	50%	47%
Middle	39%	35%	32%	No, negative test	36%	37%	40%
Old	34%	32%	39%	Yes, but I have never been tested	10%	6%	6%
Education				Yes, positive test	8%	7%	7%
Low	15%	14%	14%	*Vaccination attitude*			
Middle	49%	56%	53%	Do not want to tell	1%	0%	1%
High	36%	30%	32%	No, but planned	7%	6%	12%
Household				No, do not want to	8%	10%	9%
1 person	33%	32%	37%	No, torn	14%	21%	16%
2 or more people	53%	53%	45%	No, willing to plan	49%	44%	42%
Alone	13%	15%	18%	Yes	22%	18%	20%
Do not want to tell	0%	0%	0%				

The columns add up to 100% , where the 0% vary between the 0% and the 0.4%.

The mitigation categories presented similar demographic characteristics, with a maximum deviation of 7% contained in the education level segmentation. The same holds for the health variable, where the maximum deviation of 6% was captured in the vaccination attitude. In general, the respondents of each mitigation categories can be regarded as being representative.

Table 11 provides an overview of the resulting number of users and non-users per mitigation category. Of the total number of hygiene respondents, 31% said to be using the CoronaMelder, whereas the distancing measures contained 27% users and the mobility measures counted 33% users. As these numbers do not differ greatly, the outcomes can be considered reliable.

Table 11: Users and non-users per mitigation category

CoronaMelder usage	Hygiene		Distancing		Mobility	
	N	%	N	%	N	%
Users	82	31%	71	27%	83	33%
Non-users	175	67%	185	70%	166	66%

The columns add up to 100%.

6.1.4 Variable frequencies

Finally, the frequencies, means and variances of the observed variables are presented in Table 12. Six variables describing Specific Attitude (S.ATTpub1, S.ATThome1, S.ATTmot1, S.ATTpub2, S.ATThome2, S.ATTmot2) are consistently less numerous because of a deficient choice by the researcher during the programming of the survey. As the analysis cannot run with missing data, it was chosen to eliminate the lacking variables from the subsequent analyses and to continue with S.ATTgen and S.ATTimp only.

Table 12: Frequencies of the observed variables

Variables	Range	Hygiene				Distancing				Mobility			
		N	Mean	SE	Var	N	Mean	SE	Var	N	Mean	SE	Var
SUSself1	1-5	261	3.14	0.07	1.18	263	3.24	0.07	1.30	252	3.10	0.07	1.29
SUSself2	1-5	261	3.56	0.06	0.87	263	3.54	0.06	0.97	252	3.54	0.06	1.01
SUSother3	1-5	261	2.56	0.08	1.60	263	2.74	0.07	1.45	252	2.68	0.08	1.48
SEVself1	1-5	261	1.97	0.07	1.31	263	1.93	0.07	1.11	252	1.95	0.07	1.24
SEVself2	1-5	261	2.84	0.08	1.63	263	2.78	0.08	1.61	252	2.83	0.08	1.44
SEVother3	1-5	261	1.51	0.05	0.76	263	1.48	0.05	0.70	252	1.54	0.06	0.77
ATTcomp	1-5	261	3.01	0.08	1.54	263	3.05	0.07	1.20	252	3.00	0.07	1.37
ATTben	1-5	261	2.44	0.07	1.46	263	2.54	0.07	1.33	252	2.50	0.08	1.49
ATTint	1-5	261	2.90	0.08	1.57	263	2.92	0.07	1.39	252	2.88	0.08	1.54
ATTgen	1-5	261	2.87	0.08	1.53	263	2.97	0.07	1.33	252	2.91	0.08	1.46
S.ATTgen	1-5	261	1.72	0.06	0.96	263	1.70	0.06	0.93	252	1.64	0.06	0.89
S.ATTimp	1-5	261	2.16	0.08	1.63	263	2.20	0.07	1.46	252	2.10	0.08	1.60
S.ATTpub1	1-5	123	1.66	0.10	1.11	131	1.50	0.07	0.65	136	1.60	0.09	1.07
S.ATThome1	1-5	138	2.47	0.11	1.62	117	2.48	0.11	1.42	133	2.30	0.11	1.48
S.ATTmot1	1-5	132	2.70	0.12	1.83	133	2.44	0.10	1.34	126	2.54	0.10	1.35
S.ATTpub2	1-5	122	4.29	0.10	1.30	146	4.10	0.10	1.56	118	4.19	0.11	1.50
S.ATThome2	1-5	126	3.11	0.13	2.02	135	3.19	0.10	1.48	126	3.42	0.11	1.49
S.ATTmot2	1-5	142	4.30	0.09	1.11	127	4.20	0.10	1.35	117	4.41	0.08	0.78
BEN1	1-5	261	2.29	0.08	1.50	263	2.68	0.07	1.41	252	2.90	0.07	1.41
BEN2	1-5	261	1.80	0.07	1.14	263	2.05	0.06	1.02	252	2.12	0.07	1.38
BAR1	1-5	261	4.04	0.08	1.58	263	3.63	0.08	1.58	252	3.45	0.08	1.69
BAR2	1-5	261	4.00	0.08	1.57	263	3.99	0.07	1.24	252	3.90	0.07	1.41
SEE1	1-5	261	1.64	0.06	0.92	263	1.95	0.06	0.82	252	1.73	0.06	0.90
SEE2	1-5	261	1.78	0.06	1.01	263	2.51	0.07	1.22	252	2.05	0.07	1.12
BEH1_nosympt	1-5	261	2.19	0.08	1.54	263	2.44	0.07	1.34	252	2.59	0.11	2.82
BEH2_nosympt	1-5	261	1.95	0.07	1.38	263	2.01	0.07	1.27	252	2.67	0.11	2.93
BEH3_nosympt	1-5	261	1.33	0.05	0.71	263	2.65	0.08	1.79	252	1.43	0.06	0.86
BEH1_sympt	1-5	261	1.83	0.07	1.27	263	1.84	0.07	1.27	252	2.28	0.11	2.86
BEH2_sympt	1-5	261	1.72	0.07	1.25	263	1.70	0.07	1.15	252	2.10	0.10	2.59
BEH3_sympt	1-5	261	1.34	0.06	0.82	263	2.10	0.09	1.93	252	1.37	0.06	0.82
CM	0-99	261	2.28	0.75	146.96	263	3.26	0.98	252.35	252	1.95	0.67	114.75

SE = stardard error, Var = variance, CM = CoronaMelder utilization, ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, SEE = self-efficacy, S.ATT = specific attitude, BEH_nosympt = behaviour with asymptomatic context, BEH_sympt = behaviour with symptomatic context, new = new constructs from factorial analysis.

6.2 Analysis of the basic model

After having established the reliability of the samples and the characterization of the various groups, this section studies the basic model. The start of the analysis is provided by an investigation of the internal validity of each construct. As such, exploratory factors analyses (EFA) and CFA were conducted to determine and confirm the factor structure of generic attitude, perception and behaviour implied by previous research (Ebbers, 2021; Hooijmans, 2021; Van der Laan et al., 2020, 2021). The same was done for the specific attitude as defined for this context.

6.2.1 Internal validity

The internal validity of each construct was analysed by means of the Cronbach's α. Using a threshold of Cronbach's α =0.600, several constructs were identified having poor internal validity. These values are presented in Table 13. For each mitigation category, the two variables of Specific Attitude performed poorly under the same construct. Continuing with the distancing measures, the Barriers construct was also found to perform poorly (α =0.570). This construct also lacked validity for the mobility measures (α =0.459), as well as the construct of Behaviour in the asymptomatic context (α =0.578). The poor performance of these constructs, asked for a revision of the identified factors. Nonetheless, for comparative purposes, it was decided to revise the construct of Specific Attitude only, as this represented the only construct originated by the researcher and as such it lacked empirical validity. Any other alteration to the model would have lacked theoretical foundation. The other constructs were therefore left unchanged to mimic previous research, although this limitation should be considered for the interpretation of the overall models.

Table 13: Cronbach's alpha per construct

Indicator variable	<--	Latent variable	Cronbach's a		
			Hygiene	Distancing	Mobility
SUSself1	<---	SUSCEPTIBILITY	0.648	0.698	0.616
SUSself2	<---	SUSCEPTIBILITY			
SUSother3	<---	SUSCEPTIBILITY			
SEVself1	<---	SEVERITY	0.676	0.605	0.684
SEVself2	<---	SEVERITY			
SEVother3	<---	SEVERITY			
BEN1	<---	BENEFITS	0.728	0.611	0.523
BEN2	<---	BENEFITS			
BAR1	<---	BARRIERS	0.654	0.570	0.459
BAR2	<---	BARRIERS			
SEE1	<---	EFFICACY	0.801	0.684	0.685
SEE2	<---	EFFICACY			
ATTgen	<---	ATTITUDE	0.927	0.915	0.933
ATTint	<---	ATTITUDE			
ATTben	<---	ATTITUDE			
ATTcomp	<---	ATTITUDE			
S.ATTgen	<---	SPEC.ATTITUDE	0.585	0.534	0.486
S.ATTimp	<---	SPEC.ATTITUDE			
BEH_nosympt1	<---	BEHAVIOUR_nosympt	0.660	0.684	0.578
BEH_nosympt2	<---	BEHAVIOUR_nosympt			
BEH_nosympt3	<---	BEHAVIOUR_nosympt			
BEH_sympt1	<---	BEHAVIOUR_sympt	0.777	0.850	0.622
BEH_sympt2	<---	BEHAVIOUR_sympt			
BEH_sympt3	<---	BEHAVIOUR_sympt			

The revision of the Specific Attitude construct was performed by means of a dimension reduction analysis in SPSS with seven fixed factors. S.ATTimp and S.ATTgen were consequently re-ordered under Benefits and Behaviour respectively. Appendix B provides the results of the conducted dimension reduction analysis. After such a re-arrangement, the Cronbach's α was recalculated to assess the internal validity of the new constructs. The values were all above the validity threshold, therefore justifying the rearrangement for the continuation of the analyses. The new values are presented in Table 14.

Table 14: Cronbach's alpha per new construct

Indicator variable	<--	Latent variable	New Cronbach's a		
			Hygiene	Distancing	Mobility
BEN1	<---	BENEFITS			
BEN2	<---	BENEFITS	0.705	0.655	0.659
S.ATTimp	<--	BENEFITS			
BEH_nosympt1	<---	BEHAVIOUR_nosympt			
BEH_nosympt2	<---	BEHAVIOUR_nosympt	0.739	0.808	0.617
BEH_nosympt3	<---	BEHAVIOUR_nosympt			
S.ATTgen	<---	BEHAVIOUR_nosympt			
BEH_sympt1	<---	BEHAVIOUR_sympt			
BEH_sympt2	<---	BEHAVIOUR_sympt	0.789	0.817	0.659
BEH_sympt3	<---	BEHAVIOUR_sympt			
S.ATTgen	<---	BEHAVIOUR_sympt			

6.2.2 Construct means

The analysis was continued by the calculation of the basic means of each variable. These means represent the mean scores of the valid observed variables comprised in each construct. Table 18 outlines the mean values and standard error (SE) of the scores of each construct per mitigation category. Moreover, the overall mean has been provided as well as the difference between the mean specific for the mitigation category and the overall mean. It should be noted that the closer the variable is to 5, the least the respondent was found to agree with the statement. An exception is provided by Perceived Barriers, to which the inverse is true.

Table 15: Unobserved variable means per mitigation category

Variables	Range	Overall	Hygiene		Distancing		Mobility	
		Mean*	Mean (SD)	Δmean	Mean (SD)	Δmean	Mean (SD)	Δmean
CM	0-99	2.50	2.28 (12.1)	-0.22	3.26 (15.9)	0.76	1.95 (10.7)	-0.57
ATT_mean	1-5	2.96	2.80 (1.1)	-0.08	2.87 (1.0)	0.00	2.83 (1.1)	0.08
SUS_mean	1-5	3.14	3.09 (0.8)	-0.06	3.17 (0.9)	0.01	3.11 (0.8)	0.04
SEV_mean	1-5	2.13	2.11 (0.9)	-0.02	2.06 (0.8)	-0.07	2.11 (0.8)	0.08
BEN_mean_new	1-5	2.32	2.09 (0.9)	-0.24	2.31 (0.9)	0.01	2.37 (0.9)	0.24
BAR_mean	1-5	3.98	4.02 (1.1)	0.18	3.81 (1.0)	0.00	3.67 (1.0)	-0.19
SEE_mean	1-5	2.13	1.71 (0.9)	-0.29	2.23 (0.9)	0.28	1.89 (0.9)	0.02
BEH_nosympt_mean_new	1-5	1.96	1.80 (0.8)	-0.25	2.20 (0.9)	-0.10	2.08 (0.9)	0.36
BEH_sympt_mean_new	1-5	2.51	1.65 (0.8)	-0.23	1.83 (0.9)	0.75	1.85 (0.9)	-0.53

SD = standard deviation, CM = CoronaMelder utilization, ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, SEE = self-efficacy, S.ATT = specific attitude, BEH_nosympt = behaviour with asymptomatic context, BEH_sympt = behaviour with symptomatic context, new = new constructs from factorial analysis.

* the overall means have considered the sample size of each mitigation category.

Using the overall mean as a reference for each mitigation category, it can be seen that the difference of every mitigation category with respect to the CoronaMelder usage falls within the error margins. As such, no conclusions can be given about their relative difference.

Contrarily, the other construct means can be compared. In all, respondents of the hygiene measures scored relatively lower at Generic Attitude (Δ=-0.08), Perceived Benefits (Δ=-0.24), Self-Efficacy (Δ=-0.29) and Behaviour in the asymptomatic context (Δ=-0.25). They moreover scored relatively higher at Perceived Barriers (Δ=0.18). Respondents of the distancing measures, on the other hand, scored relatively lower at Perceived Severity (Δ=-0.07), whereas they scored relatively higher at Self-Efficacy (Δ=0.28) and Behaviour in the symptomatic context (Δ=0.75). Finalizing with the respondents of the mobility measures, they scored relatively higher at Perceived Severity (Δ=0.08), Perceived Benefits (Δ=0.24) and Behaviour in the asymptomatic context (0.36). On the contrary, they scored lower than the average at Perceived Barriers and Behaviour in the symptomatic context (Δ=-0.53).

6.2.2.1 Threat perception and behavioural evaluation

To finalize this section, a first glance on behaviour and CoronaMelder utilization outlined a difference in behaviour among users and non-users, where the latter group consistently stated to adhere less to the measures (indicated by the higher scores) than their counterparts. Both groups resulted to adhere more to the measures when showing symptoms similar to a coronavirus infection. These results are graphically represented by Figure 10. Further investigation towards the influence of the CoronaMelder on behaviour is however needed before conclusions can be drawn from these values.

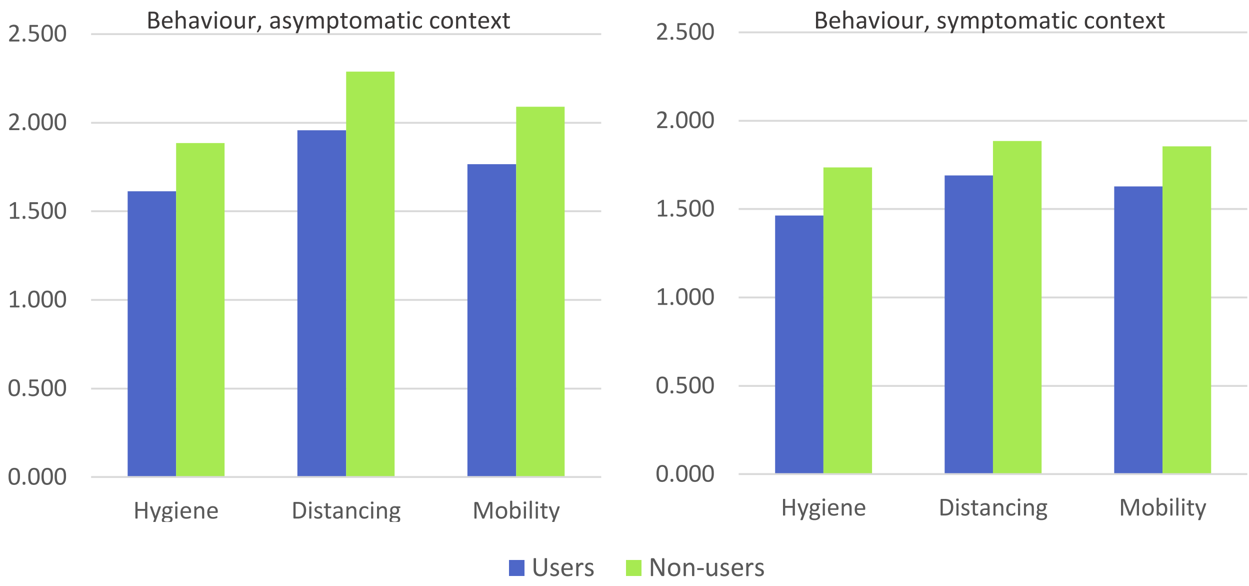


Figure 10: Behavioural differences between users and non-users, distinguishing among (**left**) the asymptomatic context and (**right**) the symptomatic context.

In the consideration of the combined effects typical of the HBM, respondents outlined a similar threat perception (*Perceived Susceptibility * Perceived Severity*) across all mitigation categories (mean=6.74), while their behavioural evaluation (*Perceived Benefits – Perceived Barriers*) resulted to be small and negative (mean=-0.33). The negative estimate can be interpreted as that the barriers excel the benefits perceived by the respondents. Recollecting the scoring of 5 (Strongly Disagree) to 1 (Strongly Agree), they can both be considered rather neutral or leaning towards compliant behaviour. These results are contained by Table 18 (upper).

Although the perceived threat and behaviour evaluation are similar across mitigation measures, users and non-users presented differences as shown by Table 16 (below). Users and non-users presented significant differences in perceived threat when confronted with hygiene measures ($p<0.001$) and with the mobility measures ($p<0.05$). Moreover, they outlined a significant difference in behavioural evaluation of the mobility measures ($p<0.05$). However, these results do not confirm nor reject the hypothesized relationships.

Table 16: Independence test of perceived threat and behavioural evaluation

HBM construct	Range	Overall	Hygiene		Distancing		Mobility	
		Mean*	Mean	SD	Mean	SD	Mean	SD
Perceived Threat	2-10	6.74	6.772	4.059	6.720	3.583	6.720	3.640
Behavioural Evaluation	(-4)-4	-0.33	-0.353	1.245	-0.186	1.272	-0.451	1.342

HBM construct		N	Mean	SD	F	P	Mean diff	95% CI diff	
Hygiene								Lower	Upper
Perceived Threat	User	178	7.343	4.141	1.486	0.000	1.812	0.818	2.807
	Non-user	82	5.531	3.595					
Behavioural Evaluation	User	179	-0.305	1.217	1.199	0.374	0.152	-0.185	0.489
	Non-user	82	-0.457	1.305					
Distancing									
Perceived Threat	User	192	6.764	3.485	0.484	0.753	0.165	-0.870	1.200
	Non-user	71	6.599	3.859					
Behavioural Evaluation	User	192	-0.150	1.250	1.755	0.472	0.132	-0.230	0.493
	Non-user	71	-0.282	1.335					
Mobility									
Perceived Threat	User	170	7.198	3.682	4.048	0.003	1.470	0.522	2.419
	Non-user	82	5.728	3.359					
Behavioural Evaluation	User	170	-0.327	1.339	0.439	0.035	0.380	0.027	0.733
	Non-user	82	-0.707	1.321					

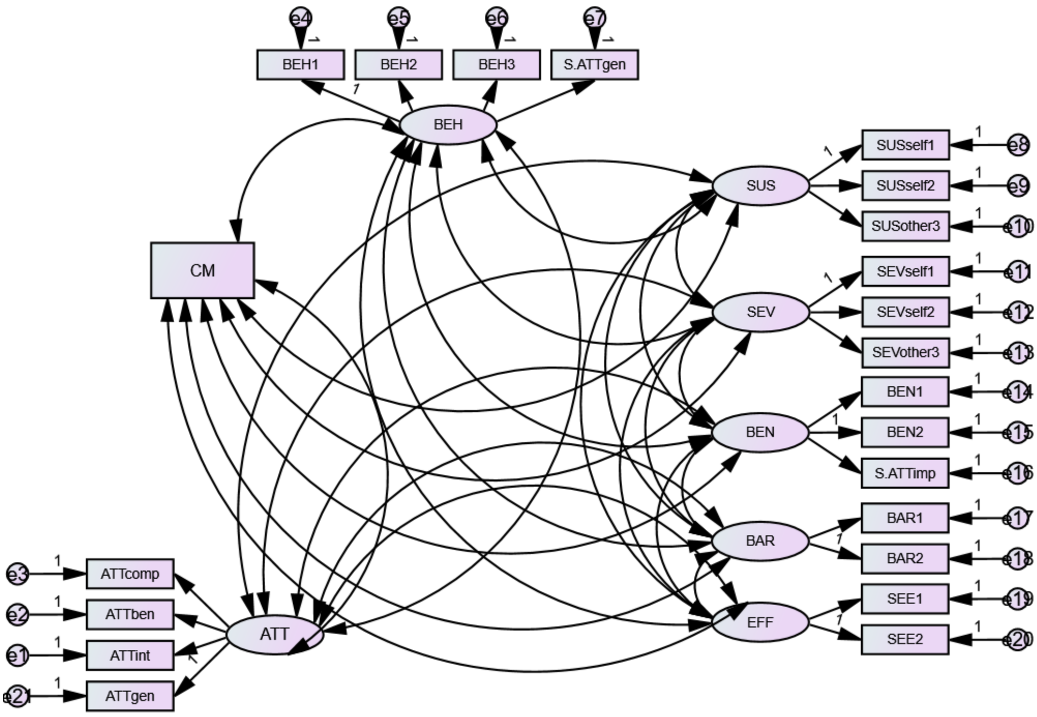
* the overall means have considered the sample size of each mitigation category. **reverse scoring was applied.

6.2.3 AMOS model analysis

This section outlines the results obtained by IBM AMOS using the formalized model. The first step is provided by the determination of valid factor loadings per construct. From that, the causal paths among the various constructs were studied to understand the influence of the CoronaMelder on each perception by means of a direct effect, and subsequently on protective behaviour through an indirect path.

6.2.3.1 Measurement model

The schematic representation of the measurement model is presented in Figure 11. Six models, named Model A to Model F, were specified: two models per mitigation category, each outlining the results specific for the studied behavioural context (e.g. without symptoms and with symptoms). The obtained constructs are confirmed by studying each factor loading. Valid constructs of the hygiene and distancing models had factor loadings above the threshold of |0.421|, whereas the mobility models should have shown factor loadings above the threshold of |0.425|. These thresholds differ from the generally applied value of |0.3| as they are more specifically identified for the sample size of each category. As the three models have sample sizes N<500, it was decided to use the interpretation by Stevens (2002) to not underestimate the actual amount of error in the factor loadings. The reasoning behind the values is contained in Appendix C.



ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, EFF = self-efficacy, BEH = behaviour, CM = CoronaMelder utilization.

Figure 11: Schematic representation of the measurement model.

6.2.3.1.1 Model fit

The results of the fit statistics are provided by Table 17. The model fit indices provided by the measurement models are the chi-square statistics, the GFI and the RMSEA. Moreover, the Chi-square ratio is statistically significant, meaning that the model fits the data poorly. However, this statistics is almost always significant, reducing its adequacy to test the fit of the model (Walrave et al., 2020). As such, the model fit is provided on the basis of the GFI and the RMSEA. All models provided a poor model fit, where the hygiene measures fit the model better than the other two groups of mitigation measures. Summarized, the model fits of each model are:

- *Hygiene measures*, asymptomatic (X^2_{182}/DF=1.846, p<0.01; GFI=0.889; RMSEA=0.057, 90% CI=0.047-0.067), symptomatic (X^2_{182}/DF=1.928, p<0.01; GFI=0.884; RMSEA=0.060, 90% CI=0.050-0.069).
- *Distancing measures*, asymptomatic (X^2_{182}/DF=2.299, p<0.01; GFI=0.879; RMSEA=0.070, 90% CI=0.062-0.079), symptomatic (X^2_{182}/DF=2.458, p<0.01; GFI=0.871; RMSEA=0.075, 90% CI=0.066-0.083).
- *Mobility measures*, asymptomatic (X^2_{182}/DF=2.306, p<0.01; GFI=0.877; RMSEA=0.072, 90% CI=0.063-0.081), symptomatic (X^2_{182}/DF=2.242, p<0.01; GFI=0.878; RMSEA=0.070, 90% CI=0.061-0.079).

Table 17: Model fit indices of the measurement model (Basic Model)

Model fit indices	Model A		Model B		Model C			
	Value	90% CI	Value	90% CI	Value	90% CI	acceptable	excellent
Chi-Square/Degrees Of Freedom Ratio (X^2/DF)	1.846*	-	1.928*	-	2.299*	-	3.00 - 5.00	1.00 - 3.00
Goodness-Of-Fit Index (GFI)	0.889	-	0.884	-	0.874	-	0.90 - 0.95	>0.95
Mean Square Error of Approximation (RMSEA)	0.057	0.047-0.067	0.060	0.050-0.069	0.070	0.062-0.079	0.06-0.08	<0.06

Model fit indices	Model D		Model E		Model F			
	Value	90% CI	Value	90% CI	Value	90% CI	acceptable	excellent
Chi-Square/Degrees Of Freedom Ratio (X^2/DF)	2.458*	-	2.306*	-	2.242*	-	3.00 - 5.00	1.00 - 3.00
Goodness-Of-Fit Index (GFI)	0.871	-	0.877	-	0.878	-	0.90 - 0.95	>0.95
Mean Square Error of Approximation (RMSEA)	0.075	0.066-0.083	0.072	0.063-0.081	0.070	0.061-0.079	0.06-0.08	<0.06

* Correlation is significant at the 0.01 level (2-tailed).

6.2.3.1.2 Correlations among constructs

As a result of the measurement model, the correlations among the constructs have become visible as well as their significance. Table 18 outlines the estimated values of these correlation according to the hypothesized model.

Starting with the correlation among the CoronaMelder utilization and the Generic Attitude, it can be seen that the estimates range between -0.081 and 0.088. These values are less than the threshold of 0.350 and therefore they are considered weak (Taylor, 1990). These mere correlations are, moreover, not significant and as such they cannot be defined as being relevant. Similarly, the correlations between the app and the constructs of perception and behaviour are weak and not significant. Therefore, the CoronaMelder is not considered to be related to any of the constructs.

Continuing with Generic Attitude, it resulted to have a significant correlations with all constructs of the HBM except for Perceived Susceptibility. The overall strongest positive and significant correlation was outlined with Perceived Benefits (hygiene: β=0.579-0.580, p<0.01; distancing: β=0.581-0.583, p<0.01; mobility: β=0.697-0.698, p<0.01). Perceived Barriers of the mobility measures resulted to be also moderate, negative and significant (β=-0.654-0.655, p<0.01) compared to the weak, negative and significant correlation measured in the other two mitigation categories (hygiene: β=-0.312-0.315, p<0.01; distancing: β=-0.320-0.329, p<0.01). Generic Attitude was moreover found to have a weak, positive and significant correlation with Self-Efficacy (hygiene: β=0.417, p<0.01; distancing: β=0.351-0.352, p<0.01; mobility: β=0.415-0.416, p<0.01) and Perceived Severity (hygiene: β=0.326-0.327, p<0.01; distancing: β=0.170, p<0.01; mobility: 0.382-0.385, p<0.01) where the weakest correlation was experienced with the distancing measures. With respect to the relationships with Behaviour, the correlation resulted to be weak, significant and positive for most measures and most weak in the symptomatic distancing measures (hygiene: β=0.400-0.403, p<0.01; distancing: β=0.167-0.381, p<0.01; mobility: β=0.383-0.438, p<0.01).

Furthermore, several HBM constructs were found to strongly and significantly correlate among each other. Especially Perceived Benefits had strong and positive correlations with Self Efficacy (hygiene: β=0.804-0.805, p<0.01; distancing: β=0.791-0.805, p<0.01; mobility: β=0.700-0.702, p<0.01), Perceived Severity (hygiene: β=0.809-0.812, p<0.01; distancing: β=0.586-0.595, p<0.01; mobility: β=0.682-0.684, p<0.01) and Perceived Barriers (hygiene: β=-0.678-0.681, p<0.01; distancing: β=-0.745-0.780, p<0.01; mobility: β=-1.107-1.108, p<0.01) where the correlation resulted to be problematic (β >|1.000|) for the mobility measures. Perceived Barriers was moreover moderately, significantly and negatively correlated with Self Efficacy (hygiene: β=-0.430-0.439, p<0.01; distancing: β=-0.384-0.386, p<0.01; mobility: β=-0.592-0.601, p<0.01) and

Perceived Severity (hygiene: β=-0.441-0.449, p<0.01; distancing: β=-0.385-0.409, p<0.01; mobility: β=-0.836-0.839, p<0.01). Self Efficacy was furthermore weakly to moderately, significantly and positively correlated with Perceived Severity (hygiene: β=0.624-0.625, p<0.01; mobility: β=0.483-0.488, p<0.01) with exception for the distancing measures. Lastly, Perceived Susceptibility presented very weak, positive and significant correlations with Perceived Severity (hygiene: β=0.325-0.328, p<0.01; distancing: β=0.227-0.227, p<0.01) except for the non-significant correlations for the mobility measures. It also had very weak, positive and significant correlations with Perceived Benefits (respectively β=0.309-0.310, p<0.01; distancing: β=0235-0.236, p<0.01) except for the mobility measures, and very weak, positive and significant correlations with Self-Efficacy for the hygiene measures only (β=0.260-0.261, p<0.01).

To finalize, the correlations among the HBM constructs and behaviour outlined to be moderate to strong and significant, being positive with Perceived Severity (hygiene: β=0.708-0.806, p<0.01; distancing: β=0.475-0.614, p<0.01; mobility: β=0585-0.698, p<0.01), Perceived Benefits (hygiene: β=0.782-0.855, p<0.01; distancing: β=0.626-0.683, p<0.01; mobility: β=0.683-0.797, p<0.01), Self-Efficacy (hygiene: β=0.737-0.761, p<0.01; distancing: β=0.497-0.663, p<0.01; mobility: β=0.657-0.738, p<0.01) and negative with Perceived Barriers (hygiene: β=-0.562-0.593, p<0.01; distancing: β=-0.431-0.588, p<0.01; mobility: β=-0.702-0.783, p<0.01).

Table 18: Correlations among the constructs and their significance

			Hygiene				Distancing				Hygiene			
			No symptoms, A		Symptoms, B		No symptoms, C		Symptoms, D		No symptoms, E		Symptoms, F	
			β	P	β	P	β	P	β	P	β	P	β	P
BEH_new	<-->	CM	-0.020	0.780	-0.026	0.708	0.049	0.465	0.073	0.266	-0.100	0.196	-0.101	0.204
ATT	<-->	CM	0.066	0.304	0.066	0.304	0.087	0.175	0.087	0.175	-0.081	0.215	-0.081	0.216
SUS	<-->	CM	0.117	0.102	0.117	0.101	0.060	0.396	0.061	0.390	0.074	0.299	0.077	0.273
SEV	<-->	CM	-0.086	0.236	-0.086	0.233	-0.040	0.579	-0.042	0.561	-0.034	0.638	-0.033	0.645
BEN_new	<-->	CM	0.044	0.541	0.045	0.531	0.042	0.570	0.045	0.532	-0.151	0.042	-0.151	0.042
BAR	<-->	CM	0.046	0.513	0.047	0.509	-0.031	0.635	-0.032	0.614	0.122	0.120	0.122	0.120
EFF	<-->	CM	-0.039	0.577	-0.039	0.578	-0.084	0.262	-0.095	0.199	-0.072	0.343	-0.072	0.343
SUS	<-->	BEH_new	0.204	0.016	0.206	0.012	0.134	0.086	0.251	0.001	0.130	0.146	0.065	0.444
SEV	<-->	BEH_new	0.806	***	0.708	***	0.614	***	0.475	***	0.585	***	0.698	***
BEN_new	<-->	BEH_new	0.855	***	0.782	***	0.791	***	0.626	***	0.683	***	0.797	***
BAR	<-->	BEH_new	-0.593	***	-0.562	***	-0.588	***	-0.431	***	-0.702	***	-0.783	***
EFF	<-->	BEH_new	0.761	***	0.737	***	0.663	***	0.497	***	0.657	***	0.738	***
ATT	<-->	BEH_new	0.400	***	0.403	***	0.381	***	0.167	0.015	0.383	***	0.438	***
SUS	<-->	ATT	0.151	0.043	0.151	0.043	0.202	0.008	0.202	0.007	0.048	0.510	0.048	0.506
SEV	<-->	ATT	0.327	***	0.326	***	0.170	0.026	0.170	0.026	0.382	***	0.385	***
BEN_new	<-->	ATT	0.580	***	0.578	***	0.583	***	0.581	***	0.698	***	0.697	***
BAR	<-->	ATT	-0.312	***	-0.315	***	-0.329	***	-0.320	***	-0.654	***	-0.655	***
EFF	<-->	ATT	0.417	***	0.417	***	0.354	***	0.351	***	0.416	***	0.415	***
SUS	<-->	SEV	0.328	***	0.325	***	0.229	0.007	0.227	0.008	0.135	0.106	0.117	0.155
SUS	<-->	BEN_new	0.309	***	0.310	***	0.235	0.006	0.236	0.006	0.110	0.190	0.100	0.224
SUS	<-->	BAR	-0.007	0.932	-0.006	0.937	-0.115	0.125	-0.122	0.091	-0.018	0.835	-0.006	0.942
SUS	<-->	EFF	0.260	0.002	0.261	0.002	0.102	0.232	0.095	0.258	-0.117	0.180	-0.127	0.140
SEV	<-->	BEN_new	0.812	***	0.809	***	0.595	***	0.586	***	0.682	***	0.684	***
SEV	<-->	BAR	-0.430	***	-0.439	***	-0.386	***	-0.384	***	-0.592	***	-0.601	***
SEV	<-->	EFF	0.624	***	0.625	***	0.202	0.023	0.206	0.019	0.483	***	0.488	***
BEN_new	<-->	BAR	-0.678	***	-0.681	***	-0.780	***	-0.745	***	-1.108	***	-1.107	***
BEN_new	<-->	EFF	0.805	***	0.804	***	0.805	***	0.791	***	0.702	***	0.700	***
BAR	<-->	EFF	-0.441	***	-0.449	***	-0.409	***	-0.385	***	-0.836	***	-0.839	***

CM = CoronaMelder utilization, ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, SEE = self-efficacy, S.ATT = specific attitude, BEH_nosympt = behaviour with asymptomatic context, BEH_sympt = behaviour with symptomatic context, new = new constructs from factorial analysis.

*** Correlation is significant at the 0.01 level (2-tailed).

6.2.3.1.3 Factor loadings

Table 19 provides the loadings among the observed variables and their latent variables. In the analysis of the constructs, the observed variables contained by Perceived Susceptibility were found to be significant in all models, but valid in only three models namely Model A, Model C and Model D. For the remaining models, the variable SUSother3 presented a factor loading inferior to the threshold with the lowest significant value of β=0.320. Perceived Severity, Perceived Benefits, Self-Efficacy and Generic Attitude, on the other hand, proved to be significant and valid in all models. As for Perceived Barriers, the observed variables were all significant and valid in Model A, Model B and Model C. In Model D, Model E and Model F, the observed variable BAR2 presented a lower factor loading than the threshold, with the lowest significant value of β=0.374. With respect to the Behaviour construct, Model A, Model B, Model C and Model D presented valid and significant factor loadings in either symptomatic context. Model E and Model F outlined the variable BEH1 to have a significant but lower factor loading than the described threshold, with the smallest value of β=0.387.

Table 19: Factor loadings and significance of the observed variables

	Hygiene				Distancing				Mobility			
	No symptoms, A		Symptoms, B		No symptoms, C		Symptoms, D		No symptoms, E		Symptoms, F	
	β	P	β	P	β	P	β	P	β	P	β	P
SUSself1 <--- SUS	0.785		0.786		0.784		0.793		0.641		0.665	
SUSself2 <--- SUS	0.788	***	0.787	***	0.772	***	0.764	***	0.907	***	0.875	***
SUSother3 <--- SUS	0.404	***	0.402	***	0.479	***	0.476	***	0.320	***	0.327	***
SEVself1 <--- SEV	0.799		0.800		0.800		0.804		0.820		0.834	
SEVself2 <--- SEV	0.543	***	0.529	***	0.464	***	0.422	***	0.567	***	0.568	***
SEVother3 <--- SEV	0.652	***	0.660	***	0.609	***	0.632	***	0.622	***	0.611	***
BEN1 <--- BEN	0.658	***	0.659	***	0.498	***	0.482	***	0.443	***	0.443	***
BEN2 <--- BEN_new	0.796		0.805		0.767		0.788		0.801		0.795	
S.ATTimp <--- BEN_new	0.594	***	0.589	***	0.640	***	0.636	***	0.657	***	0.663	***
BAR1 <--- BAR	0.568	***	0.575	***	0.423	***	0.406	***	0.374	***	0.374	***
BAR2 <--- BAR	0.857		0.847		0.949		0.989		0.792		0.797	
SEE1 <--- EFF	0.815	***	0.818	***	0.741	***	0.797	***	0.761	***	0.760	***
SEE2 <--- EFF	0.823		0.820		0.715		0.665		0.690		0.691	
ATTgen <--- ATT	0.911		0.911		0.918		0.919		0.916		0.916	
ATTint <--- ATT	0.868	***	0.868	***	0.799	***	0.799	***	0.883	***	0.883	***
ATTben <--- ATT	0.842	***	0.842	***	0.835	***	0.835	***	0.862	***	0.862	***
ATTcomp <--- ATT	0.874	***	0.874	***	0.876	***	0.875	***	0.864	***	0.864	***
BEH1 <--- BEH_new	0.605		0.708		0.808		0.859		0.387		0.400	
BEH2 <--- BEH_new	0.531	***	0.638	***	0.796	***	0.896	***	0.448	***	0.574	***
BEH3 <--- BEH_new	0.703	***	0.743	***	0.596	***	0.695	***	0.636	***	0.662	***
S.ATTgen <--- BEH_new	0.752	***	0.691	***	0.705	***	0.540	***	0.692	***	0.685	***

CM = CoronaMelder utilization, ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, SEE = self-efficacy, S.ATT = specific attitude, BEH_nosympt = behaviour with asymptomatic context, BEH_sympt = behaviour with symptomatic context, new = new constructs from factorial analysis.

*** Correlation is significant at the 0.01 level (2-tailed). Missing values stand for the regression weights that were fixed in AMOS.

6.2.3.2 Structural model

Having outlined the significance and validity of each construct individually, as well as their correlation in the whole, the paths among the variables are studied next to understand the causality among the variables. To this end, the measurement model was retained with the alteration of the paths among the latent variables.

6.2.3.2.1 Model fit

Besides the significance of each regression weight and correlation estimate provided by the analysis, the overall models have also been studied for the extent of properly fitting the data. The results of the fit statistics are provided by Table 20.

Table 20: Model fit for Model A to F

Model fit indices	Model A		Model B		Model C			
	Value	90% CI	Value	90% CI	Value	90% CI	acceptable	excellent
Chi-Square/Degrees Of Freedom Ratio (X^2/DF)	1.837*	-	1.918*	-	2.286*	-	3.00 - 5.00	1.00 - 3.00
Goodness-Of-Fit Index (GFI)	0.889	-	0.884	-	0.874	-	0.90 - 0.95	>0.95
Comparative Fit Index (CFI)	0.939	-	0.934	-	0.903	-	0.90 - 0.95	>0.95
Incremental Fit Index (IFI)	0.940	-	0.935	-	0.904	-	0.90 - 0.95	>0.95
Mean Square Error of Approximation (RMSEA)	0.057	0.047-0.066	0.059	0.050-0.069	0.070	0.061-0.079	0.06-0.08	<0.06

Model fit indices	Model D		Model E		Model F			
	Value	90% CI	Value	90% CI	Value	90% CI	acceptable	excellent
Chi-Square/Degrees Of Freedom Ratio (X^2/DF)	2.142*	-	2.295*	-	2.232*	-	3.00 - 5.00	1.00 - 3.00
Goodness-Of-Fit Index (GFI)	0.871	-	0.877	-	0.878	-	0.90 - 0.95	>0.95
Comparative Fit Index (CFI)	0.918	-	0.897	-	0.901	-	0.90 - 0.95	>0.95
Incremental Fit Index (IFI)	0.920	-	0.899	-	0.903	-	0.90 - 0.95	>0.95
Mean Square Error of Approximation (RMSEA)	0.066	0.066-0.083	0.072	0.063-0.081	0.070	0.061-0.079	0.06-0.08	<0.06

* Correlation is significant at the 0.01 level (2-tailed).

Considering the CFI, the IFI and the RMSEA, all models present an acceptable model fit. Nonetheless, the GFI of every model performs poorly, despite being close to the threshold of 0.90. Moreover, the chi-square statistics resulted to be significant. In all, thus, the models provide a poor model fit. Summarized, the model fits of each model are:

- *Hygiene measures*, asymptomatic (X^2_{182}/DF=1.837, p<0.01; GFI=0.889; CFI=0.934; RMSEA=0.057, 90% CI=0.047-0.066), symptomatic (X^2_{182}/DF=1.918, p<0.01; GFI=0.884; CFI=0.934; RMSEA=0.059, 90% CI=0.050-0.069).
- *Distancing measures*, asymptomatic (X^2_{182}/DF=2.286, p<0.01; GFI=0.874; CFI=0.903; RMSEA=0.070, 90% CI=0.061-0.079), symptomatic (X^2_{182}/DF=2.142, p<0.01; GFI=0.871; CFI=0.918; RMSEA=0.066, 90% CI=0.066-0.083).
- *Mobility measures*, asymptomatic (X^2_{182}/DF=2.295, p<0.01; GFI=0.877; CFI=0.897; RMSEA=0.072, 90% CI=0.063-0.081), symptomatic (X^2_{182}/DF=2.232, p<0.01; GFI=0.878; CFI=0.901; RMSEA=0.070, 90% CI=0.061-0.079).

6.2.3.2.2 Significant estimates

The significant regression results are provided by Table 21. The realm of the hygiene measures will be discussed first, followed by the distancing measures and finalizing with the mobility measures. The β coefficients are first valued on the basis of the thresholds used in medical and social sciences, where coefficients ≤|0.36| are considered weak, correlations between |0.36| and |0.67| are considered moderate, and coefficients ≥|0.68| are judged as strong (Taylor, 1990). In all, the CoronaMelder utilization does not present significant relationships with any of the HBM predictor variables nor with the behaviour variables.

6.2.3.2.2.1.1 Hygiene measures: Model A and Model B

To initiate with the hygiene measures first, several significant relationships were found. Generic attitude positively and significantly influenced Perceived Severity (β=0.144, p<0.05) and Perceived Susceptibility (β=0.332, p<0.01), both weak correlations and explaining only 3.40% and 11.7% of their respective variances. Generic Attitude moreover positively and significantly influenced Self-Efficacy (β=0.421, p<0.01). This moderate correlation had an R^2 of 17.8%. Model A and Model B start to show discrepancies for Perceived Benefits and Perceives Barriers and as such, they are explained by two separate sets of regressions. Generic Attitude positively and significantly affected Perceived Benefits in both Model A and Model B with a modest correlation strength (respectively β=0.582, p<0.01; β=0.578, p<0.01), therefore explaining 34.0% and 33.4% of their variances respectively. Generic Attitude moreover negatively and significantly influenced Perceived Barriers (β=-0.316, p<0.01) with an R^2 of 10.2%. This correlation was however weak.

Table 21: IBM AMOS regression results with significance and explained variance for Model A to F

Equation	Predictor variables	Dependent variable
1	CoronaMelder utilization Generic attitude	Perceived susceptibility
2	CoronaMelder utilization Generic attitude	Perceived severity
3	CoronaMelder utilization Generic attitude	Perceived benefits
4	CoronaMelder utilization Generic attitude	Perceived barriers
5	CoronaMelder utilization Generic attitude	Self-efficacy

Equation	Predictor variables	Dependent variable
6	CoronaMelder utilization Generic attitude Perceived susceptibility Perceived severity Perceived benefits Perceived barriers Self-efficacy	Behaviour, symptoms
7	CoronaMelder utilization Generic attitude Perceived susceptibility Perceived severity Perceived benefits Perceived barriers Self-efficacy	Behaviour, no symptoms

Model (df=183)		A			B			C			D			E			F		
		β	P	R^2	β	P	R^2	β	P	R^2	β	P	R^2	β	P	R^2	β	P	R^2
1	SUS <--- CM	0.107	0.128	0.034	0.107	0.126	0.034	0.043	0.540	0.042	0.043	0.533	0.043	0.081	0.249	0.009	0.077	0.277	0.008
	SUS <--- ATT	0.144	0.049		0.144	0.049		0.198	0.007		0.198	0.007		0.054	0.450		0.054	0.457	
2	SEV <--- CM	-0.104	0.129	0.117	-0.106	0.124	0.117	-0.056	0.441	0.032	-0.057	0.425	0.032	-0.006	0.929	0.148	-0.006	0.931	0.146
	SEV <--- ATT	0.332	***		0.332	***		0.175	0.020		0.175	0.020		0.384	***		0.382	***	
3	BEN_new <--- CM	0.009	0.888	0.340	0.008	0.904	0.334	-0.011	0.861	0.342	-0.005	0.933	0.337	-0.096	0.108	0.495	-0.098	0.104	0.497
	BEN_new <--- ATT	0.582	***		0.578	***		0.586	***		0.581	***		0.690	***		0.691	***	
4	BAR <--- CM	0.067	0.331	0.102	0.067	0.331	0.104	-0.002	0.976	0.109	-0.004	0.950	0.102	0.075	0.260	0.437	0.072	0.282	0.434
	BAR <--- ATT	-0.316	***		-0.319	***		-0.330	***		-0.319	***		-0.651	***		-0.649	***	
5	EFF <--- CM	-0.065	0.315	0.178	-0.064	0.319	0.178	-0.115	0.107	0.138	-0.126	0.074	0.139	-0.044	0.538	0.174	-0.045	0.521	0.174
	EFF <--- ATT	0.421	***		0.421	***		0.364	***		0.362	***		0.411	***		0.412	***	
6	BEH_new <--- ATT	-0.058	0.581	0.805	0.026	0.794	0.680	-0.262	0.349	0.658	-0.487	0.077	0.487	-0.058	0.563	0.725	-0.055	0.586	0.565
	BEH_new <--- SUS	-0.082	0.234		-0.033	0.637		-0.096	0.339		0.094	0.371		0.060	0.410		0.123	0.122	
	BEH_new <--- SEV	0.332	0.076		0.289	0.099		-0.034	0.925		-0.175	0.613		0.342	0.006		0.231	0.043	
	BEH_new <--- BEN	0.412	0.313		0.150	0.687		1.556	0.182		1.633	0.141		0.069	0.779		0.161	0.478	
	BEH_new <--- BAR	-0.087	0.547		-0.162	0.251		0.386	0.408		0.403	0.345		-0.273	0.195		-0.121	0.541	
	BEH_new <--- EFF	0.226	0.153		0.359	0.019		-0.326	0.579		-0.439	0.440		0.322	0.041		0.366	0.027	

A = Hygiene, no symptoms; B = Hygiene, symptoms; C = Distancing, no symptoms; D = Distancing, symptoms, E = Mobility, no symtpoms; Mobility = symptoms. CM = CoronaMelder utilization, ATT = generic attitude, SUS = perceived susceptibility, SEV = perceived severity, BEN = perceived benefits, BAR = perceived barriers, SEE = self-efficacy, S.ATT = specific attitude, BEH_nosympt = behaviour with asymptomatic context, BEH_sympt = behaviour with symptomatic context, new = new constructs from factorial analysis.

*** Correlation is significant at the 0.01 level (2-tailed).

Continuing with the influence of each HBM predictor on Behaviour, only Self-Efficacy was found to positively and significantly affect Behaviour but only in the symptomatic context (β=0.359, p<0.05). This weak correlation explained 68.0% of the variance.

6.2.3.2.2.1.2 Distancing measures: Model C and Model D

Next, the two models of the distancing measures are discussed. Generic Attitude significantly influences all the HBM predictors but does not influence behaviour. Perceived Susceptibility and Perceived Severity are both positively and significantly affected by Generic Attitude (respectively β=0.198, p<0.01; β=0.175, p<0.05). These weak correlations explained 4.3% and 3.2% of their respective variances. In the realm of the perceived effectiveness of the measures, discrepancies are shown among Model C and Model D. Perceived Benefits positively and significantly influenced by Generic Attitude in either Model C and Model D (respectively β=0.586, p<0.01; β=0.581, p<0.01). The observed moderate correlation presented an R^2 of 34.2% and 33.7% respectively. Following on the same line, Self-Efficacy is also positively and significantly influenced by Generic Attitude in both models (respectively β=0.364, p<0.01; β=0.362, p<0.01). Both estimates were, however, considered just modest explaining 13.8% and 13.9% of their respective variances. A negative and significant relationship was found among Generic Attitude and Perceived Barriers in both Model C and Model D (respectively β=-0.330, p<0.01; β=-0.319, p<0.01) explaining respectively 10.9% and 10.2% of their variance. The low explained variance is provided by the weak strength of this correlation. The described perceptions, however, do not present significant any significant relationship with Behaviour, not in the symptomatic nor in the symptomatic context.

6.2.3.2.2.1.3 Mobility measures: Model E and Model F

Finalizing with the last mitigation category, all variables present varying regression weights when comparing Model E with Model F. Perceived Susceptibility is not significantly influenced either by the CoronaMelder utilization or by Generic Attitude. The latter variable does positively and significantly influence Perceived Severity in either Models (respectively β=0.384, p<0.01; β=0.382, p<0.01). This moderate correlation explained 14.4% of its variance in the asymptomatic context and 14.6% of its variance in the symptomatic context. Also Perceived Benefits are positively and significantly influenced by Generic Attitude in Model E and Model F, both by a moderate correlation (respectively β=0.690, p<0.01; β=0.691, p<0.01) with an R^2 of 49.5% and 49.7% respectively. The latter predictor that is positively and significantly influenced by Generic Attitude is Self-Efficacy, in either Model E and Model F (respectively β=0.441, p<0.01; β=0.412, p<0.01). These correlations could be considered moderate in strength, providing an R^2 of 17.4% in both cases. On the contrary, Perceived Barriers are negatively and significantly affected by Generic Attitude for both models (respectively β=-0.651, p<0.01; β=-0.649, p<0.01), explaining 43.7% and 43.5% of either model. Moving towards Behaviour, both the asymptomatic and the symptomatic contexts, Perceived Severity positively and significantly, but weakly influenced the dependent variable (respectively β=0.342, p<0.01; β=0.231, p<0.05). Together with the positive and significant influence of Self-Efficacy in either Model E and Model F (respectively β=0.322, p<0.01; β=0.366, p<0.01). The former weak correlation and the latter moderate correlation explained 72.5% and 56.6% of the variability of Behaviour in both contexts.

The results of the significant correlations are visually represented by Figure 12 where only the significant paths are included. Two equations summarize the obtained results, namely Equation A and Equation B. Equation A focuses on the influence of the CoronaMelder (CM) and the Generic Attitude (ATT) on the constructs of the HBM indicated by the Y. Equation B, on the other hand, outlines the effect of these constructs on behaviour indicated by Z.

Equation A: $$Y = \beta_1 * CM + \beta_2 * ATT$$

Equation B: $$Z = \beta_1 * CM + \beta_2 * ATT + \beta_3 * SUS + \beta_4 * SEV + \beta_5 * BEN + \beta_6 * BAR + \beta_7 * SEE$$

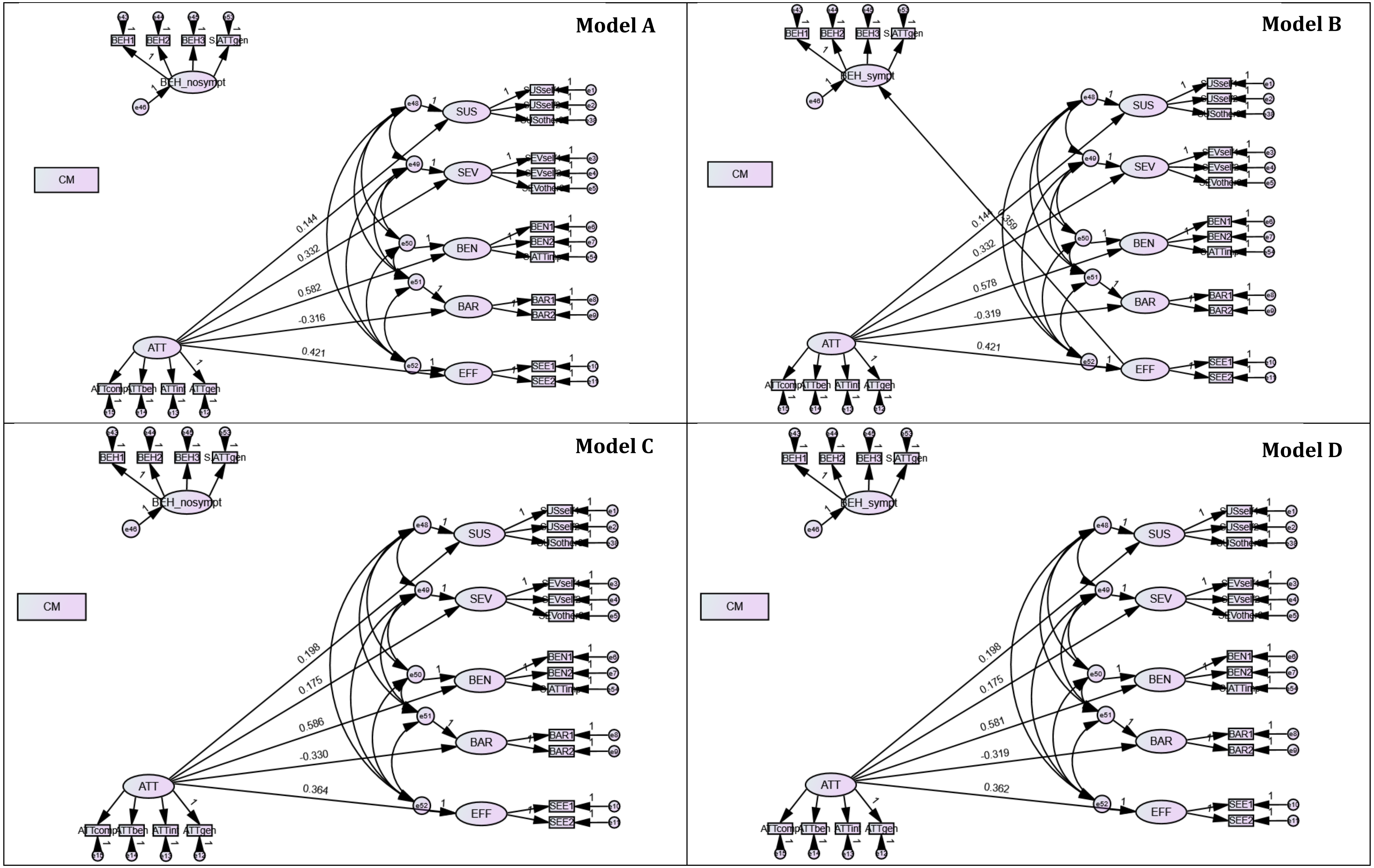


Figure 12: Structural models of Model A to Model F. Nonsignificant paths among the constructs are not included.

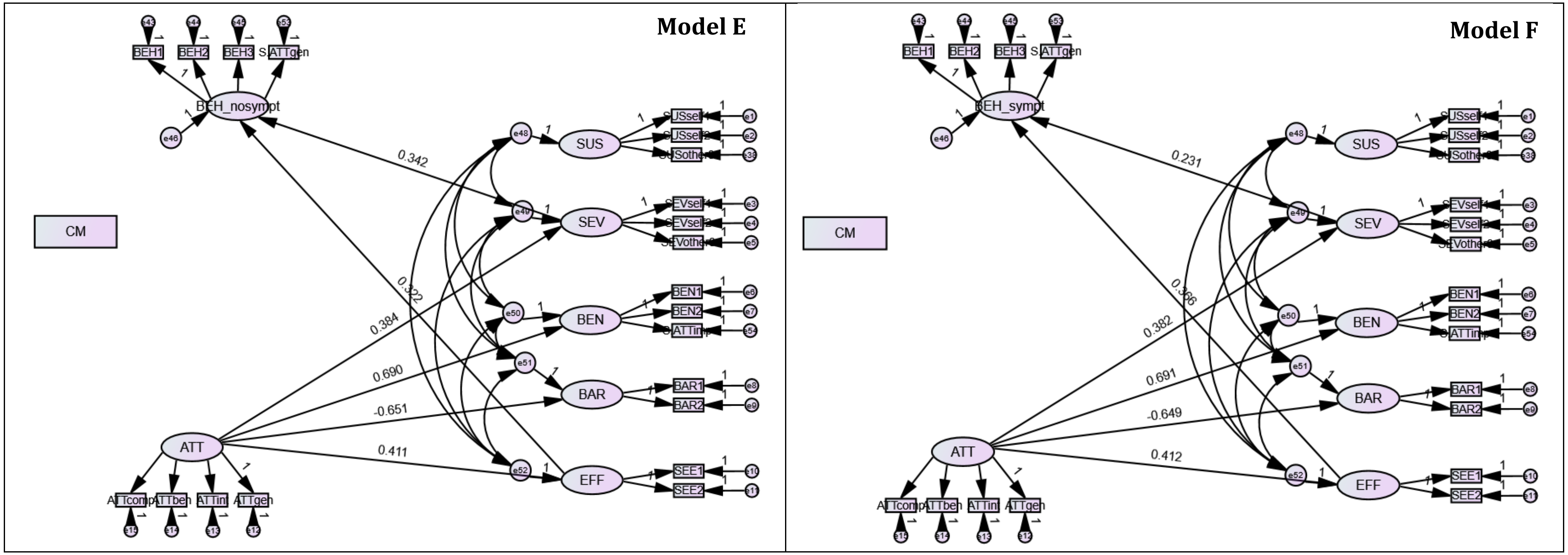


Figure 12 (continued): Structural models of Model A to Model F. Nonsignificant paths among the constructs are not included.

6.2.3.2.3 Direct effects, indirect effect and total effects

Finally, the standardized coefficient (sc) of the direct, indirect and total effects as presented in Table 22. Here, the columns represent the outgoing variable and the rows represent the dependent variable. The hypothesized relationships are validated by means of the sign of the *sc*. In other words, if the hypothesis assumed a positive correlation, the *sc* should be positive to affirm this expectation. Contrarily, if the hypothesis assumed a negative correlation, the *sc* should be negative to affirm it.

6.2.3.2.3.1.1 Hypothesis 1

Hypothesis 1 hypothesized that Perceived Susceptibility had a positive relation with preventive behaviour and hence, a positive *sc* would be expected. The direct effect of this variable on Behaviour was indeed positive in Model D (sc = 0.094), Model E (sc = 0.060) and Model F (sc = -0.110), but it was negative in Model A (sc = -0.082), Model B (sc = -0.033) and Model C (sc = -0.096). However, none of these relationships proved to be significant. So, no conclusions can be drawn from these coefficients regarding the first hypothesis.

6.2.3.2.3.1.2 Hypothesis 2

According to Hypothesis 2, Perceived Severity had a positive relation with preventive behaviour and, therefore, a positive *sc* would be projected. The direct effect of this variable on Behaviour was indeed positive in Model A (sc = 0.332), Model B (sc = 0.289), Model E (sc = 0.342, p<0.01) and Model F (sc = 0.231, p<0.05), whereas it was negative in Model C (sc = -0.034) and Model D (sc = -0.174). Only Model E and Model F provided weak, but significant relationships and from these values it can be derived that the higher the perceived severity of the coronavirus, the more respondents stated to adhere to the mobility measures (both symptomatic contexts).

6.2.3.2.3.1.3 Hypothesis 3

Hypothesis 3 stated that Perceived Benefits were positively related with preventive behaviour, and as such, a positive *sc* would be expected. The direct effect of this variable on Behaviour was indeed positive in Model A (sc = 0.226), Model B (sc = 0.359), Model E (sc = 0.332) and Model F (sc = 0.366) but it was negative in Model C (sc = -0.326) and Model D (sc = -0.439). Nonetheless, no coefficients proved to be significant and as such, no conclusions can be drawn regarding the effect of Perceived Benefits on Behaviour.

6.2.3.2.3.1.4 Hypothesis 4

Continuing with Hypothesis 4, it was hypothesized that Perceived Barriers had a negative relation with behaviour, and so a negative *sc* would be expected. The direct effect of this variable on Behaviour was indeed negative in Model A (sc = -0.087), Model B (sc = -0.162), Model E (sc = -0.273) and Model F (sc = -0.121) but it was positive in Model C (sc = 0.386) and Model D (sc = -0.403). However, these coefficients proved to be nonsignificant. Therefore, the influence of Perceived Barriers on Behaviour cannot be confirmed.

6.2.3.2.3.1.5 Hypothesis 5

Hypothesis 5 stated that Self-Efficacy had a positive relation with behaviour, making the expected *sc* positive. This hypothesis was affirmed by the negative direct effect of this variable on Behaviour in Model A (sc = 0.226), Model B (sc = 0.359, p<0.05), Model E (sc = 0.322, p<0.05) and Model F (sc = 0.366, p<0.05) but it was negative in Model C (sc = -0.326) and Model D (sc = -0.439). Only the coefficients of Model B, Model E and Model F resulted to be significant and from these values

Table 22: Standardized total, direct and indirect effects for Model A to Model F

Model A	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.065	-0.065	0.000	0.421**	0.421**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	0.067	0.067	0.000	-0.316**	-0.316**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	0.009	0.009	0.000	0.582**	0.582**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.104	-0.104	0.000	0.332**	0.332**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.107	0.107	0.000	0.144*	0.144*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, asympt (new)	-0.06	0.000	-0.06	0.403	-0.058	0.461	-0.082	-0.082	0.000	0.332	0.332	0.000	0.412	0.412	0.000	-0.087	-0.087	0.000	0.226	0.226	0.000
Model B	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.064	-0.064	0.000	0.421**	0.421**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	0.067	0.067	0.000	-0.319**	-0.319**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	0.008	0.008	0.000	0.578**	0.578**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.106	-0.106	0.000	0.332**	0.332**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.107	0.107	0.000	0.144*	0.144*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, sympt (new)	-0.067	0.000	-0.067	0.407	0.026	0.381	-0.033	-0.033	0.000	0.289	0.289	0.000	0.15	0.15	0.000	-0.162	-0.162	0.000	0.359*	0.359*	0.000
Model C	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.115	-0.115	0.000	0.364**	0.364**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	-0.002	-0.002	0.000	-0.330**	-0.330**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	-0.011	-0.011	0.000	0.586**	0.586**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.056	-0.056	0.000	0.175*	0.175*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.043	0.043	0.000	0.198**	0.198**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, asympt (new)	0.017	0.000	0.017	0.379	-0.262	0.641	-0.096	-0.096	0.000	-0.034	-0.034	0.000	1.556	1.556	0.000	0.386	0.386	0.000	-0.326	-0.326	0.000
Model D	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.126	-0.126	0.000	0.362**	0.362**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	-0.004	-0.004	0.000	-0.319**	-0.319**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	-0.005	-0.005	0.000	0.581**	0.581**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.057	-0.057	0.000	0.175**	0.175**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.043	0.043	0.000	0.198	0.198	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, sympt (new)	0.059	0.000	0.059	0.162	-0.487	0.649	0.094	0.094	0.000	-0.175	-0.175	0.000	1.633	1.633	0.000	0.403	0.403	0.000	-0.439	-0.439	0.000
Model E	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.044	-0.044	0.000	0.411**	0.411**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	0.075	0.075	0.000	-0.651**	-0.651**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	-0.096	-0.096	0.000	0.690**	0.690**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.006	-0.006	0.000	0.384**	0.384**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.081	0.081	0.000	0.054	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, asympt (new)	-0.038	0.000	-0.038	0.435	-0.058	0.493	0.06	0.06	0.000	0.342**	0.342**	0.000	0.069	0.069	0.000	-0.273	-0.273	0.000	0.322*	0.322*	0.000
Model F	CoronaMelder utilization			Generic Attitude			Perceived Susceptibility			Perceived Severity			Perceived Benefits (new)			Perceived Barriers			Self-Efficacy		
	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Self-Efficacy	-0.003	-0.045	0.000	0.412**	0.412**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Percieved Barriers	0.006	0.072	0.000	-0.649**	-0.649**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Benefits (new)	-0.009	-0.098	0.000	0.691**	0.691**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Severity	-0.001	-0.006	0.000	0.382**	0.382**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Perceived Susceptibility	0.005	0.077	0.000	0.054	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Behaviour, sympt (new)	-0.002	0.000	-0.033	0.232	-0.055	0.435	0.123	0.123	0.000	0.231*	0.231*	0.000	0.116	0.161	0.000	-0.121	-0.121	0.000	0.366*	0.366*	0.000

* Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

the hypothesis can be confirmed for the hygiene measures in the asymptomatic context and for both contexts of the mobility measures.

6.2.3.2.3.1.6 Hypothesis 6

Corresponding to Hypothesis 6, Generic Attitude had a positive relation with behaviour, and therefore, a positive *sc* would be expected. Only Model B indeed outlined a positive direct effect on Behaviour (sc = 0.026), whereas the other models presented a negative *sc* (Model A: sc = -0.058, Model C: sc = -0.262; Model D: sc = -0.487; Model E: sc = -0.058; Model F: sc = -0.055). Despite these findings, the coefficients were nonsignificant and thus, no conclusions can be drawn from these values.

6.2.3.2.3.1.7 Hypothesis 7 and Hypothesis 8

Continuing with the Prevention Optimism Hypotheses, also known as Hypothesis 7 and Hypothesis 8, the CoronaMelder was hypothesized to lower the Perceived Susceptibility and Perceived Severity of the coronavirus by its users. These constructs were scored on a 5-point Likert scale where 5 (Strongly disagree) and 1 (Strongly agree). A reduction in these perceptions therefore resulted in a higher score. Also the CoronaMelder utilization is reflected by a higher score for a higher adoption. As such, the hypothesized negative relation should be affirmed by a positive *sc*.. Despite the direct effects were being met for Perceived Susceptibility (Model A: sc = 0.107; Model B: sc = 0.107; Model C: sc = 0.043; Model D: sc = 0.043; Model E: sc = 0.081; Model F: sc = 0.077), these correlations were not significant. Perceived Severity presented a negative coefficient (Model A: sc = -0.104; Model B: sc = -0.106; Model C: sc = -0.056; Model D: sc = -0.057; Model E: sc = -0.006; Model F: sc = -0.001), but also these relationships were nonsignificant. As such, the Prevention Optimism Hypothesis cannot be considered fulfilled.

6.2.3.2.3.1.8 Hypothesis 9

The ninth hypothesis is also called the Inherent Selection Hypothesis, suggesting that no correlation exists among the CoronaMelder utilization and Generic Attitude. This hypothesis cannot be tested by means of the standardized direct, indirect and total effects. The non-significant correlations derived from Table 18, however, permit to affirm this hypothesis for all models. Weak correlations were found among these variables but these relations resulted not to be significant in any of the models. From these findings, it can be concluded that the variables are indeed not correlated.

6.2.3.2.3.1.9 Hypothesis 10

As Hypothesis 10 cannot be empirically tested for the re-organized observed variables, Hypothesis 9 represents the last hypothesis to be investigated.

6.3 Extended model

The second part of the analysis provided the investigation of the demographic characteristics and the coronavirus-specific health characteristics, more specifically on their effect on becoming a CoronaMelder user. As such, CoronaMelder utilization has been dummy coded into the dummy variable *CoronaMelder user* according to the distinction previously made in which 1 = user and 0 = non-user. For the analysis, the bivariate correlations among the characteristics and being a user will be outlined first to understand the strength and significance of each relationship. From there, causality among the variables is explored by means of a multinomial logit regression (MLR).

6.3.1 Frequencies

Before the analysis is started, the frequencies of the variables of interest are presented in Table 25. The frequency of the additional option coded as 99= do not want to tell, has also been provided to understand the percentile change in the mean caused by this option. This percentage varies among 0% and 1%, and as such it can be assumed that the means remain unchanged by this option.

Table 23: Frequencies of the observed covariates

Variables	Range	N	Mean	SE	SD	Var
RG_self	0-1	777	0.310	0.017	0.463	0.214
RG_other	1-5	777	2.069	0.037	1.044	1.091
CIS	1-99	777	3.624	0.216	6.007	36.088
VAC	1-99	777	3.481	0.279	7.782	60.564
GEN	1-99	777	1.735	0.178	4.969	24.695
AGE	1-4	776	2.070	0.030	0.840	0.705
EDU	1-6	777	3.757	0.045	1.255	1.576
HOU	0-99	777	1.475	0.128	3.579	12.812
CM_users	0-1	777	0.304	0.017	0.460	0.212

Variables	Score	N(99)	%N(99)/tot
CIS	99	3	0%
VAC	99	5	1%
GEN	99	2	0%
HOU	99	1	0%

N = sample size, SE = standard error, SD = standard deviation, Var = variance, RGself = risk group self, RGother = risk group other, CIS = coronavirus infection self, VAC = vaccination, GEN = gender, AGE = age, EDU = education level, HOU = household zise, CM_users = CoronaMelder users.

The demographic characteristics of the surveyed population have already been presented at the beginning of this chapter and as such, they are not repeated. Continuing with the coronavirus-specific health variables, the majority of the respondents were not in the risk group (RG_{self}, mean=0.310, SD=0.5) and they sometimes worked with people in the risk group (RG_{other}, mean=2.069, SD=1.0). No conclusions can be derived from the statistics on previous infection (CIS) and vaccination (VAC) as the magnitude of the standard deviation is greater than the value options. Additionally, the values of these variables are not equally spaced and only represent categories of options. Therefore, no value can be attached to the mean presented by the table for CIS and VAC.

Table 24: CoronaMelder users independence test

	Test		df	F	P
Gender	ANOVA	Between groups	2	0.454	0.636
		Within groups	774		
Age	ANOVA	Between groups	3	5.528	0.001
		Within groups	772		
Education	ANOVA	Between groups	5	4.447	0.001
		Within groups	771		
Household	ANOVA	Between groups	3	0.871	0.454
		Within groups	773		
Risk group (self)	T-test	Equal variances not assumed	775	20.579	0.013
Risk group (other)	ANOVA	Between groups	1	0.627	0.429
		Within groups	776		
Previous infection	ANOVA	Between groups	1	1.944	0.164
		Within groups	776		
Vaccination	ANOVA	Between groups	1	2.532	0.112
		Within groups	776		

Table 24 outlines the results of the one-way ANOVA and independence T-test. Considering the difference between users and non-users, it resulted that there were significant differences in age ($p<0.05$) and education level ($p<0.05$) among the respondents. Moreover, significant differences were also noticed among people being considered part of the risk group ($p<0.05$). These differences therefore justify the investigation on the influence of these characteristics on the utilization of the app.

6.3.2 Bivariate correlation between demographic characteristics, health characteristics and CoronaMelder utilization

The Spearman's *rho* was chosen over the Pearson's *rho* as the scrutinized data are not continuous but rather ordinal in nature. The means with the possible ranges of each variable have been outlined in Table 25 together with the resulting correlation coefficients. The significant bivariate correlation coefficients have been graphically presented in Figure 13. These relationships are described below.

Table 25: Spearman's coefficient results between the variables

All measures (N=777)

	Variable	Mean (SD)	Possible ranges	1	2	3	4	5	6	7	8	9
1	CM_users	0.30 (0.5)	0-1	1								
2	GEN	1.73 (5.0)	1-99	-0.010	1							
3	AGE	2.07 (0.8)	1-4	0.123**	-0.094**	1						
4	EDU	3.76 (1.3)	1-6	0.162**	0.001	-0.073*	1					
5	HOU	1.47 (3.6)	0-99	-0.003	-0.039	-0.305**	0.032	1				
6	RGself	0.31 (0.5)	0-1	0.090*	-0.057	0.278**	-0.072*	-0.095**	1			
7	RGother	2.07 (1.0)	1-5	0.038	0.020	-0.025	-0.042	0.074*	0.108**	1		
8	CIS	3.62 (6.0)	1-99	-0.084*	-0.035	0.216**	-0.045	-0.165**	0.026	-0.131**	1	
9	VAC	3.48 (7.8)	1-99	-0.270**	0.063	-0.493**	-0.020	0.174**	-0.283**	-,119**	-0.059	1

CM_user = CoronaMelder users, GEN = gender, AGE = age, EDU = education level, HOU = household size, RGself = risk group self, RGother = risk group work, CIS = coronavirus infection self, VAC = coronavirus vaccination.

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

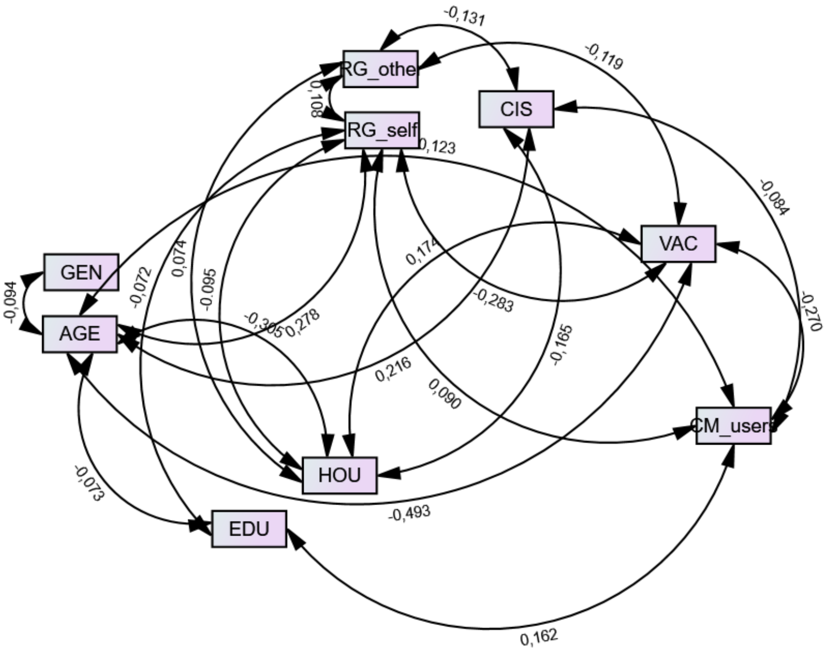


Figure 13: Graphical representation of the bivariate correlations

Starting with the demographic characteristics, the negative correlation with gender (GEN) and household size (HOU) resulted not to be significant. Age and education level, on the other hand, presented a significant positive but very weak coefficient (respectively r=0.123, p<0.01; r=0.162, p<0.01) with being a CoronaMelder user (CM_{users}). Continuing with the coronavirus-specific health characteristics, being a person at risk had a significant positive but very weak relationship (r=0.090, p<0.05), whereas working with people at risk did not present a significant coefficient. Both previous infection with the virus and vaccination attitude resulted to have a significant negative and very weak correlation (respectively r=-0.084, p<0.05; r=-0.270, p<0.01) with the CoronaMelder user.

6.3.3 Multinomial logistic regression for demographic characteristics and the CoronaMelder utilization

To estimate the potential or odds ratio of age, gender, household size and education level for a person to utilize the CoronaMelder, a multinomial logistic regression (MLR) was run on IBM SPSS. The choice for the MLR was validated by the dichotomous nature of the outcome variable coded as 0 = non-user, 1 = user. Users were programmed as the reference category for the analysis. The Demographic Model then contains the demographic characteristics AGE, GEN, EDU and HOU, whereas the Health Model, on the other hand, contains the coronavirus-specific health variables RG_{self}, RG_{other}, CIS and VAC. The general logit regression model is described by Equation C and Equation D.

Equation C: $$Logit\ (CM_{users}) = \beta_0 + \beta_1 * AGE + \beta_2 * GEN + \beta_3 * HOU + \beta_4 * EDU$$

Equation D: $$Logit\ (CM_{users}) = \beta_0 + \beta_1 * RGself + \beta_2 * RGother + \beta_3 * CIS + \beta_4 * VAC$$

Where AGE is coded as 1 = 15-35 years, 2 = 36-55 years, 3 = 56-75 years, 4 = 76 years or more; GEN is coded as 1 = man, 2 = woman; HOU is coded as 1 = alone , 2 = one roommate, 3 = two or more roommates, 99 = do not want to tell; EDU is coded as 1 = elementary school, 2 = VMBO, MBO1, AVO Onderbouw, 3 = MBO2, MBO3, MBO4, 4 = HAVO, VWO, 5 = HBO, 6 = University or more. RG_{self} is coded as 0 = not in the risk group, 1 = in the risk group; RG_{other} is coded as 1 = never, 2 = sometimes, 3 = regularly, 4 = usually, 5 = always; CIS is coded as 1 = yes, positive test, 2 = yes, believed but no test, 3 = no, negative test, 4 = no, believed but no negative test, 99 = do not want to tell; VAC is coded as 1 = yes, 2 = not yet, but planned, 3 = no yet, but waiting for the invite, 4 = torn, 5 = do not want to. The results obtained from the analysis are contained in detail in Appendix E. The next sections will outline the most relevant findings. The results are presented according to two models, namely Demographic and Health.

6.3.3.1 Overall test of relationship: Demographic and Health Model

The independent variables AGE, GEN, EDU, HOU, RG_{self}, RG_{other}, CIS and VAC were inserted as covariates in their corresponding models and the obtained Likelihood Ration Test results are presented in Table 26. The models showed a significant improvement in fit over the null model (Demographic: $\chi^2(4)=34.424$, $p<0.001$; Health: $\chi^2(4)=13.392$, $p<0.001$). As such, the null hypothesis that there is no difference between the model without the independent variables and the model with the independent variables, was rejected. The alternative hypothesis that a relationship exists between the independent variables and the dependent variable was therefore supported. In other words, AGE, GEN, EDU and HOU are related to CM_{users}. Similarly RG_{self}, RG_{other}, CIS and VAC are related to CM_{users} justifying the continuation of the analysis.

Table 26: Likelihood Ratio Test results

Model	**Likelihood Ratio Tests**		
	X^2	**df**	**P**
Demographic	34.424	4	0.000
Health	13.392	4	0.010

X^2 = Chi-squared, df = degrees of freedom, P = p-value.

6.3.3.2 Strength of the relationship, model fit and model accuracy: Demographic and Health Model

Having established the relationship, the strength of the regression was studied through the pseudo R-square measures. These results are contained in Table 29. Even though no definite interpretation of these measures exists, these measures were considered indicative for the amount of variation in the dependent variable (Bayaga, 2010). Focusing on the Demographic Model first, the values of the Cox and Snell R-square, the Nagelkerke R-square and the McFadden R-square range from 0.036 to 0.061, suggesting that between 3.6% and 6.1% of the variability of CM_{users} is explained by AGE, GEN, EDU and HOU. Continuing with the Health Model, these values range from 0.014 to 0.024, suggesting that between 1.4% and 2.4% of the variability of CM_{users} is explained by the variables RG_{self}, RG_{other}, CIS and VAC.

Table 27: Pseudo R-square and Goodness-Of-Fit indices

Model		X^2	df	P		Pseudo R^2
Demographic	**Pearson**	107.357	107	0.472	**Cox and Snell**	0.043
	Deviance	123.751	107	0.128	**Nagelkerke**	0.061
					McFadden	0.036
Health	**Pearson**	255.711	128	0.000	**Cox and Snell**	0.017
	Deviance	226.029	128	0.000	**Nagelkerke**	0.024
					McFadden	0.014

X^2 = Chi-squared, df = degrees of freedom, P = p-value, R^2 = explained variance.

Continuing with the model fit of the Demographic Model, the Pearson's chi-square test provided a non-significant result (X^2_{107}=107.357, p=0.472) as well as the Deviance chi-square (X^2_{107}=123.751, p=0.128). As non-significant test results are indicators that the model fits well, both Goodness-of-Fit indices provided a good fit of the Demographic Model. The usefulness of the model was moreover outlined by the classification statistics in Table 30, which provided insight in the particularly poor accuracy of the model to predict those people who used the CoronaMelder (at a rate of 3.0%) compared to the accuracy strength in predicting non-users, who on the other hand were correctly predicted 97.6% of the time. The overall accuracy rate of the Demographic Model was 68.9%.

On the contrary, both the Pearson's chi-square test and the Deviance chi-square test of the Health Model resulted to be significant (respectively X^2_{128}=255.711, p<0.001; X^2_{128}=226.029, p<0.001). Consequently, the Health Model cannot be considered a good model fit. The model, moreover, lacked in the prediction of the CoronaMelder users (at a rate of 0.0%) since it predicted all respondents to be non-users (at a rate of 100.0%). The overall accuracy rate of the Health Model was 69.6%.

Table 28: Classification results

Model	Observed	Predicted		Percent Correct
		Non-user	User	
Demographic	Non-user	528	13	97.6%
	User	228	7	3.0%
	Overall Percentage	*97.4%*	*2.6%*	*68.9%*
Health	Non-user	541	0	100.0%
	User	236	0	0.0%
	Overall Percentage	*100.0%*	*0.0%*	*69.6%*

6.3.3.3 Multinomial logit regression results

Once the Demographic Model has been justified and the Health Model has been discarded as not providing a good fit, the relationships between the independent and dependent variables were scrutinized. The contribution of each variable to the model was studied through the likelihood ratio test results outlined by Table 31. Using the conventional α=0.05 threshold, AGE and EDU were found to be significantly related to the CoronaMelder usage (respectively X_1^2=12.698, p<0.001; X_1^2= 22.365, p<0.001). The intercept also proved to be significant (X_1^2=37.819, p<0.001). GEN and HOU did not contribute significantly to the model (respectively χ2(1)= 0.964, p=0.326; X_1^2=0.113, p=0.737). In addition, RG_{self} and CIS were significantly related to being a CoronaMelder user (respectively X_1^2=4.910, p<0.05; X_1^2= 3.941, p<0.05). RG_{other} and VAC did not result to significantly impact its adoption (respectively X_1^2=0.068, p=0.794; X_1^2= 1.877, p=0.171) and neither did the intercept (X_1^2=0.845, p=0.358).

The results therefore showed that:

Equation C: $Logit\ (CM_{users}) = \ 2.660 - 0.344 * AGE - 0.304 * EDU$

Equation D: $Logit\ (CM_{users}) = \ -0.377 * RG_{self} + 0.160 * CIS$

Table 29: Parameter estimate results

Predictor variable		Parameter estimates					Likelihood Ratio Test		
		β	Exp(β)	P	$CI_{.95}$for Exp(β)		X^2	df	P
CM_users*					Upper	Lower			
,00	Intercept	2.660		0.000			37.819	1.000	0.000
	GEN	0.034	1.034	0.573	0.920	1.162	0.964	1.000	0.326
	AGE	-0.344	0.709	0.000	0.585	0.858	12.698	1.000	0.000
	EDU	-0.304	0.738	0.000	0.650	0.839	22.365	1.000	0.000
	HOU	0.009	1.009	0.763	0.949	1.073	0.113	1.000	0.737
,00	Intercept	0.369		0.345			0.845	1.000	0.358
	RG_self	-0.377	0.686	0.025	0.493	0.954	4.910	1.000	0.027
	RG_other	-0.020	0.980	0.794	0.844	1.139	0.068	1.000	0.794
	CIS	0.160	1.173	0.070	0.987	1.395	3.941	1.000	0.047
	VAC	0.035	1.035	0.399	0.955	1.122	1.877	1.000	0.171

P = p-value, CI = confidence interval, df = degrees of freedom, GEN = gender, AGE = age, EDU = education level, HOU = household size, RG_self = risk group (self), RG_other = risk group (others), CIS = coronavirus previous infection (self), VAC = vaccination.

* the reference category is CM_users = 1 (users).

Thus, when comparing non-users to the users as the reference category, age and education were found to be significant predictors of the CoronaMelder adoption in the Demographic Model (respectively β=-0.344, SE=0.097, p<0.001; β=-0.304, SE=0.065, p<0.001). The negative sign should be interpreted that non-users tended to score lower on these variables relative to users. Also, age's odds ratio of 0.709 indicated that for every unit increase in age, the odds of a person not being a user decreased by 29.1% (0.709 – 1.0). Thus, older survey respondents had a higher chance of being users than younger respondents. The same holds for education's odds ratio of 0.738. This implicates that for every unit increase in education, the odds of a person being a non-user decreased by 26.2% (0.738 – 1.0). This means that the higher educated respondents had a higher probability of being a user than lower educated respondents.

In addition, being a person at risk and having previously been infected with the virus were found to be significant predict the adoption of the app in the Health Model (respectively β=-0.377, SE=0.169, p<0.05; β=0.160, SE=0.088, p<0.05). The odds ratio of 0.686 should be interpreted that for the dichotomous choice of being at risk, the odds of the individual not being a user decreased by 31.4% (0.686 – 1.0). Hence, people at risk had a higher probability of being users than people who were not considered at risk. Finalizing with the previous infection's odds ratio of 1.173, the odds of an individual not being a user increased with not having been previously infected by 17.3% (1.173 - 1.0). Thus, previous infection resulted in a higher chance of installing the app than not being previously infected with the coronavirus. The probability outcomes of the logit regression functions are contained in Table 30.

Table 30: Probability outcome of CoronaMelder user and non-user

AGE	EDU	P	
		Non-user	User
15-35 years	Elementary	0.88	0.12
36-55 years	Elementary	0.84	0.16
56-75 years	Elementary	0.79	0.21
76+ years	Elementary	0.73	0.27
15-35 years	VMBO, MBO1, AVO	0.85	0.15
36-55 years	VMBO, MBO1, AVO	0.80	0.20
56-75 years	VMBO, MBO1, AVO	0.74	0.26
76+ years	VMBO, MBO1, AVO	0.66	0.34
15-35 years	MBO2, 3, 4	0.80	0.20
36-55 years	MBO2, 3, 4	0.74	0.26
56-75 years	MBO2, 3, 4	0.67	0.33
76+ years	MBO2, 3, 4	0.59	0.41
15-35 years	HAVO, VWO	0.75	0.25
36-55 years	HAVO, VWO	0.68	0.32
56-75 years	HAVO, VWO	0.60	0.40
76+ years	HAVO, VWO	0.52	0.48
15-35 years	HBO	0.69	0.31
36-55 years	HBO	0.61	0.39
56-75 years	HBO	0.53	0.47
76+ years	HBO	0.44	0.56
15-35 years	University +	0.62	0.38
36-55 years	University +	0.54	0.46
56-75 years	University +	0.45	0.55
76+ years	University +	0.37	0.63

RGself	CIS	P	
		Non-user	User
At risk	Yes, positive test	0.45	0.55
At risk	Yes, believed	0.49	0.51
At risk	No, negative test	0.53	0.47
At risk	No, believed	0.57	0.43
Not at risk	Yes, positive test	0.54	0.46
Not at risk	Yes, believed	0.58	0.42
Not at risk	No, negative test	0.62	0.38
Not at risk	No, believed	0.65	0.35

AGE = age, EDU = education level, RGself = risk group (self), CIS = coronavirus previous infection; 0 ≤ P ≤ 1.

6.4 Conclusion

In this chapter the outcomes of the survey analysis are presented in order to answer the second and third sub-question: *In which way does the CoronaMelder app influence people's behavioural perception?* And *To what extent does the CoronaMelder app affect people's behaviour?* Six basic models were studied to provide conclusions per mitigation category, differentiating among asymptomatic and symptomatic contexts. First of all, the CoronaMelder was found not to have a significant direct effect on perception and consequently, the app did not have a significant indirect effect on behaviour. As such, the app cannot be linked to the occurrence of any risky behaviour. Moreover, the utilization of the CoronaMelder resulted not to be correlated with Generic Attitude and as such, its utilization cannot be associated with an inherent risk-averting attitude. Although users presented a higher compliance with the rules compared to non-users, this consistent difference cannot be attributed to the app nor to inherent attitude. In general, symptoms cued safer behaviour in both users and non-users. Further analysis moreover outlined the adoption of the app to be dependent on age and education characteristics as well as being a person at risk and having previously contracted the virus. More specifically, older and higher educated people were found to be more likely to install the app as well as individuals at risk and those who had previously been infected.

7 Analysis of model results

In this chapter, the model results are validated and further discussed in an attempt to generalize the answers to the second and third sub-question: *In which way does the CoronaMelder app influence people's behavioural perception?* And *To what extent does the CoronaMelder app affect people's behaviour?* Contrary to the previous chapter, the details of each question are further discussed in an attempt to respond to every part of the sub-question. The chapter first validates the model results from the previous chapter, after which the results are discussed in further detail.

7.1 Model validation

Where verification led to confidence in the hypothesized model, validation is intended to spread the confidence throughout the model results (Sargent, 2010). This can be done by means of internal of external validation, where the latter is considered to provide the least biased validation (Giancristofaro & Salmaso, 2003). The validation was performed by combining internal with external validation as described below.

7.1.1 Validity of Basic Model: External sample validation

The validity of the Basic Model was ensured by means of a representative sample population and validated cause-and-effect relationships. Starting with the sample population (N=779), it resulted to be representative for the Dutch population based on the CBS's statistics (CBS, 2019). However, the study of each mitigation measure separately, limited the sample population per group (N<300). Therefore, it is recommended to replicate the study in a representative sample population with greater sample size to ensure the validity of the specific outcomes per mitigation category. Additionally, the sample's adoption rate resulted to be significantly higher than the actual utilization rate by the Dutch population. This overrepresentation should therefore be considered in the evaluation of the outcome.

In an attempt to verify the validity of the identified causalities - or lacks thereof – within the Models A to F, N=11 respondents were randomly selected from the original sample population to be asked about their level of agreeableness with statements connecting (1) attitude with perceptions and (2) perceptions with behaviour but also linking (3) the CoronaMelder to perceptions and to behaviour. In total, N=5 users and N=6 non-users were questioned. Users and non-users were presented with the statements shown in Table 31. The respondents had to provide their level of agreeableness with each statements by means of Disagree, Neutral and Agree.

According to the methodology identified by the researcher, each statement is provided with an expected response and an observed response. The expected response – either Agree or Disagree – reflects the outcome as expected under the obtained model results. The observed response, on the other hand, outlines the percentage of the respondents within the group – either users or non-users – agreeing with the expected response. To illustrate, 60% of the users (N=3/5) responded to agree with *statement i.2* ("I will experience less symptoms in case of infection with the coronavirus because of the mitigation measures"), whereas only 17% of the non-users (N=1/6) responded to agree with the same statement.

To validate the model outcomes, the results of users and non-users would have to be similar but preferably equal. Per design, the model outcomes were considered validated when at least 50% of the users and 50% of the non-users responded with the expected level of agreeableness concurrently. For instance, *statement i.2* was not validated as non-users did not meet the required threshold. *Statement i.1* ("The mitigation interventions define that in the coming two months, I am less prone to getting infected with the coronavirus") however, resulted to be validated by a 100% of the users (N=5/5) and 67% of the non-users (N=4/6).

Using the method explicated above, the validated statements resulted to be *i.1* and *i.5*, which supported the causal path identified between Generic Attitude and Susceptibility first, Generic Attitude and Self-Efficacy second. Moreover, *statements ii.2* and *ii.5* were validated and as such, the relationship between Perceived Severity and Behaviour as well as Self-Efficacy and Behaviour were proven. Finally, *statements iii.1*, *iii.2* and *iii.3* were validated by both users and non-users and by doing so, the uncorrelation of the CoronaMelder to perception and behaviour is proven.

Although the validation outcomes can be interpreted as supporting the uncorrelation of the CoronaMelder with the constructs of the HBM and behaviour, nothing much can be said about the validity of the model outcomes focusing on the causality between attitude and perception nor on the causality between perception and behaviour. Provided the focus of this research on the effects of the CoronaMelder, these results can however be utilized to define the validity of the conclusions.

Table 31: External validation N=11 respondents with N=5 users and N=6 non-users

Statements	**Expected**	**Observed**			
		User		**Non-user**	
i) Attitude to perceptions		**N**	**%**	**N**	**%**
1 The mitigation interventions define that in the coming two months, I am less prone to getting infected with the coronavirus.	Agree	5/5	100%	4/6	67%
2 I will experience less symptoms in case of infection with the coronavirus because of the mitigation measures.	Agree	3/5	60%	1/6	17%
3 For me, the mitigation measures have personal benefits.	Agree	3/5	60%	2/6	33%
4 For me, the mitigation measures do not contain personal ill-effects.	Agree	2/5	40%	4/6	67%
5 The mitigation rules are easy to follow.	Agree	5/5	100%	4/6	67%
ii) Perceptions to behaviour					
I follow the mitigation measures because…					
1 … then I am less prone to getting infected with the coronavirus in the coming two months.	Disagree	1/5	20%	1/6	17%
2 … I feel bad getting infected with the coronavirus.	Agree	4/5	80%	5/6	83%
3 … it results in personal benefits.	Disagree	0/5	0%	2/6	33%
4 … I do not experience ill-effects from doing so.	Disagree	0/5	0%	1/6	17%
5 … they are easy to implement.	Agree	5/5	100%	3/6	50%
iii) CoronaMelder					
1 I (do not) use the CoronaMelder, but in the coming two months I run the same risk of contracting the coronavirus.	Agree	4/5	80%	3/6	50%
2 I (do not) use the CoronaMelder, but I still feel bad for contracting the coronavirus.	Agree	4/5	80%	5/6	83%
3 I (do not) use the CoronaMelder, but I generally adhere to the measures.	Agree	5/5	100%	5/6	83%

7.1.2 Validity of Extended Model: ROC-curve

The validity of the Extended Model was tested by means of the specificity and the sensitivity of the regression results. To this end, the predictions of the identified logistic regression model for the CoronaMelder user classification were assessed through the threshold probability (PT). The PT represents the value that maximizes the sensitivity - portion of true positives - and the specificity - portion of true negatives - of the prediction. This threshold is visualized by the Receiver Operating Characteristics (ROC)-curve. The ROC-curve was obtained through the definition of CoronaMelder user = 1 to represent the positive outcome. The negative coefficients from Equation C and D provided larger test result with a positive test, whereas positive coefficients presented smaller values with a positive test. The curves of the Demographic model and the Health model are outlined by Figure 14. Two separate figures are provided for the Health model as CIS and RG_{self} presented opposing coefficients, thereby affecting the interpretation of the positive test. The Demographic model on the other hand could be fit in one figure, as AGE and EDU presented the same negative coefficients. Table 32 on the next page specifies the results also including the value of the area under the curve. An areas above the threshold of 0.600 was considered to provide a moderate test.

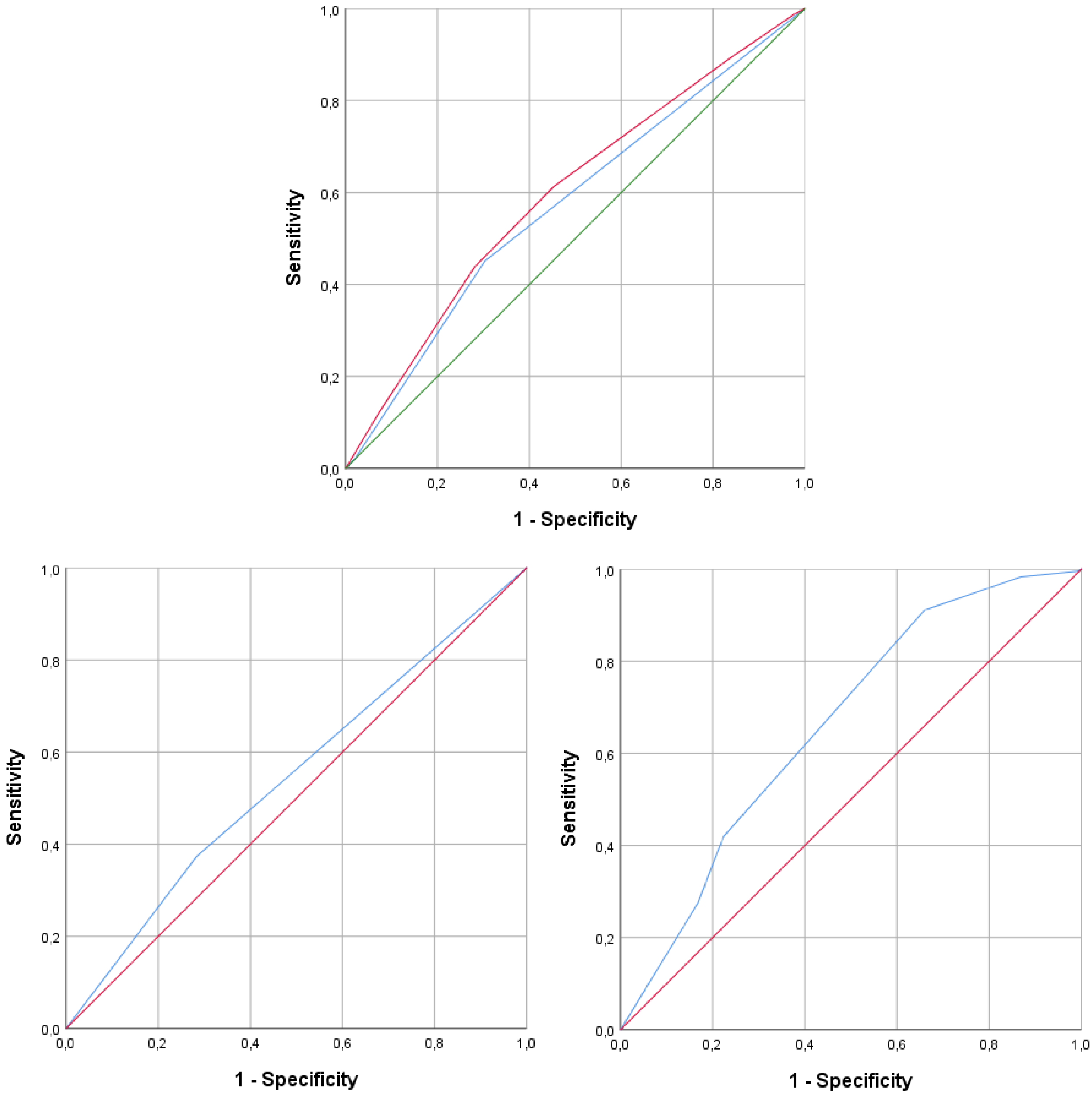


Figure 14: ROC curves of UPPER: age (**blue**) and education (**red**), including the reference line (**green**); BELOW, risk group self (left, **blue**), previous infection (right, **blue**), including the reference line (**red**).

Table 32: Area under the curve results per ROC curve

Test result variable(s)	Area	SE	Asymptotic P*	Asymptotic 95% CI	
				Lower Bound	Upper Bound
Age	0.573	0.023	0.001	0.529	0.617
Education level	0.597	0.022	0.000	0.553	0.640
Risk group (self)	0.545	0.023	0.046	0.501	0.590
Coronavirus Infection	0.660	0.020	0.000	0.621	0.700

* Null hypothesis is true area = 0.5

The curves are close to the reference line and the area under the curve provided a poor test for age (area=0.573, p<0.001, $CI_{.95}$ 0.529-0.617) and for education (area=0.597, p<0.001, $CI_{.95}$ 0.553-0.640). This is also reflected in the lacking performance of the model with a preferred $PT_{age} \geq 2.5$ resulting in 45.1% true positive predictions and 30.3% false positive predictions. For education the preferred $PT_{edu} \geq 3.5$ providing 61.3% true positives and 45.3% false positives. In short, the logistic regression model performs poorly in identifying CoronaMelder users.

With respect to the Health Model, the curves are also close to the reference line with a poor test for being a person at risk and a moderate test for previous infection (respectively area=0.545, p<0.05, $CI_{.95}$ 0.501-0.590; area=0.660, p<0.001, $CI_{.95}$ 0.621-0.700). The preferred $PT_{RGself} \geq 0.5$ resulting in 37.3% true positive predictions and 28.3% false positive predictions. These reflect the dichotomous nature of the variable with 0 (not at risk) and 1 (at risk). For previous infection, the preferred $PT_{age} \geq 2.5$ resulted in 41.9% true positive predictions and 22.4% false positive predictions. It can therefore be concluded that the Health logistic regression did not have a desirable prediction to individuate CoronaMelder users.

7.2 Discussion of model results

The definition of the model results involved an extensive surveyed population, careful attention to item content and rigorous statistical analyses. The dimensions covered by the questionnaire targeted internal drivers of behaviour, including attitude, perception and actual behaviour. The main conclusions drawn from the model analyses are that the CoronaMelder cannot be identified to directly influence people's perception and neither to indirectly affect people's protective behaviour. Moreover, the models did not present maladaptive behaviour and they also did not provide significant paths from the app towards behaviour. No plausible link can, therefore, be attributed between the utilization of the app and non-compliant behaviour.

An important remark behind these finding is provided by the poor internal consistency of certain measures. After the factor analyses the overall reported Cronbach's α estimates for the hygiene measures ranged between 0.654 and 0.927, whereas for the distancing measures it ranged between 0.570 and 0.915, and for the mobility measures it ranged between 0.459 and 0.933. This research considered 0.600 as the benchmark for an acceptable reliability and therefore, the distancing measures and the mobility measures contained inconsistent outcome measures. The below 0.600 was found in the (i) perceived barriers (Cronbach's α=0.570) of the distancing measures, the (ii) perceived barriers (Cronbach's α=0.459) as well as the (iii) perceived benefits (Cronbach's α=0.523) of the mobility measures.

Literature suggests two plausible causes, namely too few numbers of items per scale and uneven width of the scales (Spiliotopoulou, 2009). All the scales were measured on a 5-point Likert scale and as such, the latter possibility is not considered. The number of items per measure, on the other hand, is two numbers per item which is below the critical number of seven, suggesting a detriment in the interpretation of the reliability estimates (Spiliotopoulou, 2009). Spliliotopoulou (2009) furthermore suggests the calculation of a mean inter-item correlation (ρ) to acknowledge the sensitivity of the alpha to the scale length. The formula is as follows:

$$\rho = \frac{\alpha}{n - (n-1) * \alpha}$$

where ρ = the reliability coefficient independent of scale length, α = Cronbach's alpha, and *n* = the number of items in the scale. Values in the range 0.400 and 0.500 for narrow measures such as specific perceptions are considered valid, but the resulting values do not match this requirement (i = 0.339, ii = 0.298, iii = 0.354). The insufficient Cronbach's α and mean inter-item correlation, hence, outline the poor correlation between the items of the constructs. The random measurement error of the latent variable was therefore considerable, resulting in the lacking reliability (Gillem & Gillem, 2003).

Moving from insufficient internal consistency to poor model fit, the CFA displayed a GFI ranging from 0.87 to 0.89, a CFI between 0.90 and 0.94, a IFI ranging from 0.90 and 0.94, and a RMSEA between 0.06 and 0.07. Neither the asymptomatic not the symptomatic contexts provided a good fit. The poor model fit is the consequence of the misfit already indicated by the measurement model. The conceptual model is therefore not considered to be appropriate.

The root of such a misfit can be identified in the constructs. A principle component analysis was performed to extract seven components in total, to remedy the poor internal consistency of Specific Attitude. It was chosen to hold the original conceptual model to retain the theoretical understanding of each variable and their hypothesized relationships. However, the factor analysis outlined poor communalities with all the extracted components, except for Generic Attitude and Self-Efficacy. Thus, the identified factors did not fully explain the variance of the observed items therefore impacting the model fit of the measurement model first, and the structural model next.

7.2.1 Difference among mitigation categories

Recollecting the decision to study the CoronaMelder app's impact on people's adherence to a subdivision of the mitigation measures, a total of six models were obtained in which each mitigation category was presented in two situations, namely the asymptomatic and the symptomatic contexts. Although no difference was hypothesized among the models, the categorization was implemented to also understand people's behaviour according to the type of measure, having either repercussions at the micro-level (hygiene and distancing measures) or at the meso-level (mobility measures). The results could then be compared to a longitudinal study of the RIVM and GGD GHOR, which surveyed a representative population sample over 13 measurement moments since the onset of the Dutch epidemic to understand people's compliance with the rules and their support of such measures. The findings of the 11th round of surveys (24-28 march 2021) were taken one month prior to the start of the surveys for this thesis. As such, the official results can be compared to the obtained results.

Starting with the mean scores of each mitigation category, these results showed that the respondents tended to perceive the hygiene measures as having higher benefits than the distancing and the mobility measures. Moreover, they perceived them as easier to implement and effectuate than the other two measure categories. The distancing measures were found to be more difficult to actuate than the hygiene and the mobility measures, whereas respondents perceived the mobility measures to be less beneficial to counter the coronavirus that their counterparts. When considering behaviour, respondents consistently adhered more to the hygiene measures both in the asymptomatic and in the symptomatic context. A reason for this discrepancy can be provided by the limitation of the study in grouping the measures into one category. The public opinion about "frequently washing hands" and "wearing a face cloth in public inner areas" differs in perceived benefits and self-efficacy, whereas this study focused on the public opinion about their collective implementation.

Respondents of the distancing measures perceived the severity of the coronavirus to be higher than the other measures as opposed to the respondents that were asked about the mobility measures who perceived a low severity of the virus. According to the hypothesized model, this varying perception of severity should have been reflected in a varying adherence to the measures. In other words, it would have been expected that respondents adhered more to the proposed distancing measures and less to the mobility measures. This resulted to be the case in the asymptomatic context but in the case of showing coronavirus-symptoms, the outcomes were contradicting the expectations: respondents resulted to adhere less to the distancing measures and more to the mobility measures.

A possible cause for this contradiction could be provided by the *affect heuristic* proposed by Slovic and Peters (2006). The authors argue that affect guides perceptions of risk and benefit associated with certain measures and so, people's feelings rather than ratio are the determinant factor in judging a measure to be positive or negative. The relationship between risk and benefit is moreover inversed, thus a favourable measure is judged as having high benefits and low risks, whereas an unfavourable measure tends to be judged as having low benefits and high risks (Slovic & Peters, 2006). Following this line of reasoning, the respondent's feelings towards the involved benefits and risks could have differed in the asymptomatic and symptomatic context, explaining the discrepancy in behaviour. So, the distancing measures are considered to be less favourable than mobility measures when showing coronavirus-symptoms.

Despite the difference between expectation and the resulting scores, people in general showed to adhere to the measures in the asymptomatic context and they showed a higher adherence in the symptomatic context compared to the asymptomatic one. The biggest disparity among these values was encountered for the distancing measures, where people tended to comparatively adhere less to them when showing no symptoms. One plausible explanation could be provided by the perceived threat of the coronavirus and the behavioural evaluation of each measure. Thus, a careful understanding of perceived susceptibility, severity, benefits, barriers and self-efficacy is next in line.

7.2.2 People's perception of risk and the CoronaMelder

As far as the HBM constructs are concerned, it was found that Attitude significantly affected Perceived Susceptibility (β_{dist}=0.198, p<0.001; β_{hyg}=0.144, p<0.05) Perceived Severity (β_{mob}=0.384, p<0.001; β_{hyg}=0.332, p<0.001; β_{dist}=0.175, p<0.001), Perceived Benefits (β_{mob}=0.690-0.691, p<0.001; β_{dist}=0.581-0.586, p<0.05; β_{hyg}=0.578-0.582, p<0.001), Perceived Barriers (β_{mob}=(-)0.649-(-)0.651, p<0.001; β_{dist}=(-)0.319-(-)0.330, p<0.001; β_{hyg}=(-)0.316-(-)0.319, p<0.001) and Self-Efficacy (β_{mob}=0.411-0.412, p<0.001; β_{dist}=0.362-0.364, p<0.001; β_{hyg}=0.421, p<0.001). The Attitude of the mobility measures' respondents however did not significantly associate with Perceived Susceptibility. In general, the strongest relation was encountered between Attitude and Perceived Benefits as well as Perceived Barriers and no association was found with Behaviour, neither in the asymptomatic context nor in the symptomatic context.

The correlations among attitude and perception are consistent with literature whereas the missing association with behaviour is incongruent with most empirical findings (Chudry et al., 2011; Godin & Kok, 1996; Lippke & Ziegelmann, 2008; O'Connor & Armitage, 2003; Sale et al., 2017; Tomczyk et al., 2021). Van Winsen *et al.* (2011) provided a comprehensive model in which risk perception and risk attitude are considered to equally influence risk behaviour. In their evaluation, the constructs were specifically designed around the type of hazard excluding any generalization from the analysis. The main contradiction between the empirical findings and the observed relationships could therefore lay in the conceptualization of these constructs. More specifically, the definition of attitude could have interfered with the expected causality. Contrary to literature, the studied attitude was defined only as a general personality trait by asking the respondents about their level of agreeance with the governmental actions to overcome a crisis situation. Specific attitude as an independent construct was lost due to incomplete data. No reference was thus made to the coronavirus and as a result, the conceptual model lost all the attitude specificity to the type of hazard.

The identification of this lack is then consistent with literature. The empirically defined paths between perception and behaviour as well as attitude and behaviour generally belong to the same contextual realms, whereas generic constructs like personality traits are regarded as indirectly affecting behaviour (Godin & Kok, 1996; Ji et al., 2011; Van Winsen et al., 2011). As such, the hypothesized relations were formulated for a type of attitude that was wrongly interpreted as being context-specific rather than an inherent trait. From this it can thus be derived that the study of behavioural responses to a digital intervention require the appropriate scoping to the contextual characteristics in order to find support in previous empirical findings.

Contrary to attitude, the CoronaMelder app's utilization resulted not to be related with perception and neither with behaviour. To the knowledge of the researcher, no previous research has investigated the influence of an intervention on the constructs of the HBM constructs as the intervention itself is generally the focus of the analysis. As such, no material for comparison was found. The HBM is mostly used to study behaviour resulting from the implementation of an intervention (Champion et al., 2002; Costa, 2020; Walrave et al., 2020). The model as applied in this study, however, was conceptualized to capture people's beliefs surrounding the implemented mitigation measures – analogous to the hypothetical intervention as defined by the HBM - and subsequent behaviour, to identify the mitigating effect of the CoronaMelder app. The outcomes of this study should therefore be replicated by further research to rigorously confirm the lack of influence on perception and behaviour.

7.2.3 People's adaptive behaviour and the CoronaMelder

With respect to the observed causality between the constructs of perception and behaviour, significant associations were only found between Perceived Severity and Behaviour (β_{mob}=0.231-0.342, p<0.05), and from Self-Efficacy to Behaviour (β_{hyg}=0.359, p<0.05; β_{mob}=0.322-0.366, p<0.05). The hygiene measures and the distancing measures did not present significant correlations with Behaviour, the former not in the asymptomatic context and the latter not in any context. Based on these outcomes, an individual's belief of the gravity of the coronavirus can only be considered a weak predictor for the adherence to the mobility measures, whereas people's perceived ease to implement the hygiene and mobility measures poorly define their protective behaviour. These finding are not consistent with meta-analyses of studies that used the HBM in the context of protection motivation theory (Floyd et al., 2000; Milne et al., 2000; Walrave et al., 2020). According to their findings, Perceived Benefits and Self-Efficacy are moderately associated with behaviour, followed by Threat Perception, the joint product of Perceived Susceptibility and Perceived Severity.

Milne (2000) suggested that an overall average nonsignificant correlation between Perceived Susceptibility and Behaviour might be the result of both positive and negative relationships existing between the variables among the data. The correlations observed in this study are indeed positive and negative, therefore, it is likely that this influences the lacking relationship. Weinstein and Nicolich (1993), moreover, defined cross-sectional studies as being the determinants for poorly observed causal inference between the Threat Perception variables and Behaviour. Longitudinal studies would better serve the purpose as they permit to measure Perceived Susceptibility and Perceived Severity immediately after the threat communication has been presented to the participants (Weinstein & Nicolich, 1993). To support this, the investigation of these perceptions was performed 13 months after the onset of the Covid-19 epidemic in the Netherlands. This prolonged exposure to news about the consequences of the virus could therefore have affected the significance of the observed relationships.

Moving to the coping variables, the absence of significant associations between Perceived Benefits and Behaviour cannot be explained by literature, although it is considered second important after Self-Efficacy (Costa, 2020; Nowak et al., 2020; Walrave et al., 2020). A longitudinal study by the RIVM and GGD GHOR on people's compliance with the mitigation rules on the contrary outlined a positive effect among Perceived Benefit and Behaviour. The discrepancy might be provided by the scrutiny of people's compliance with specific mitigation measures instead of grouped measures. As people are not fully rational, their responses to the surveys might lack rationality when they predilect one measure over the other within the same group (Floyd et al., 2000). This is supported by the diverging compliance observed with specific hygiene rules, specifically with "frequently washing of hands" and "wearing a face cloth in public inner areas". The former is thought to be sufficient in curbing the spread of the virus and easy to implement, whereas the latter is considered to be ineffective and difficult to implement (Coronadashboard, 2021; Van der Laan et al., 2020b, 2021).

All considering, respondents were found to adhere to the mitigation measures, irrespective of them being users or non-users. The indirect effect on behaviour was not considered significant and therefore, digital interventions such as contact-tracing apps cannot be defined as causing any change in behaviour. This is in line with the recent study by Nowak *et al.* (2020) who pointed the relevance of personality traits in the occurrence of adaptive and maladaptive behaviour. Impulsive and self-centred people tended towards risk-taking behaviour, whereas collective-mindedness was linked to more preventive behaviour. Consequently, if this study would still have outlined maladaptive behaviour, it might have been caused by traits that we not considered by the basic model. Where Nowak *et al.* (2020) outlined a linking mechanisms from personality to behaviour through perception, others defined attitude as the mediator (Ji et al., 2011). As personality has not been included in the basic model, these paths are recommended for further research.

Even though no difference was found among user's and non-user's protective behaviour, they were found to have significantly different perceptions of threat when confronted with the hygiene measures and the mobility measures. The behavioural evaluation of the mobility measures also resulted to provide significant differences among users and non-users. In addition to this, users were also found to adhere more to the measures compared to the non-users. These results are counterintuitive as the CoronaMelder is not associated with any of the HBM constructs nor with behaviour, suggesting the inadequacy of the conceptual model to capture the variability. Three possible causes for this lack are provided by: (a) inadequate study of the CoronaMelder's effect on perceived threat and behavioural evaluation as separate constructs, (b) precluded app's causality in mediating the path from perception to behaviour, (c) inconsideration of other factors affecting the app's adoption. Whereas the former two points provide subjects for further research, the latter explication was studied in more detail by means of the Extended Model. The role of demographic characteristics and coronavirus-specific characteristics were explored in their role as covariates for the CoronaMelder use and these findings are discussed in the following section.

7.2.4 Modifying factors

This research studied the influence of gender, age, education and household size on the adoption of the app, concluding that age and education are weak predictors of the CoronaMelder adoption. More specifically, the probability of adoption resulted to increase with age and education level. Hence, older and higher educated people are more likely to install the app than younger and lower educated individuals. In addition, this study outlined how being a person at risk and having previously contracted the virus are also determinants for the utilization of the app, even though weak. The respondent's attitude towards vaccination also resulted to be correlated with the adoption of the CoronaMelder, but this bivariate relationship resulted to fade away in the concurrent analysis of the other covariates. Careful analysis of these correlations, outlined a greater correlation between being at risk and vaccination attitude than the one between vaccination attitude and the app's adoption. A hierarchical logistic regression could resolve the ambiguity of these relationships, outlining the preceding steps to the final adoption of the CoronaMelder.

Age and education were previously identified to be predictors of the app's adoption, where the highest adoption was encountered in older people (52% of the respondents) and higher educated people (49% of the respondents) (Ebbers, 2021). However, the official evaluation of the CoronaMelder defined the group of 40-64 year-olds to be the most abundant source of users whereas the 79 years old and older are represented the less (Ebbers et al., 2021). In their study about the age differences in technology adoption decisions, Morris and Venkatesh (2000) also provided solid proof for age to be a strong predictor of technology utilization, and in accordance to the research by Ebbers et al. (2021), they outlined younger people as being the greatest adopters of technology compared to their older colleagues. The evaluation of Ebbers et al. (2021) included the findings of various longitudinal and cross-sectional studies performed by RIVM, CentERdata, Center eHealth Research & Wellbeing, GGD GHOR of different representative sample populations. The hereby presented study results, on the other hand, are reliant on the surveyed sample population only. Although this population was considered to be representative, the sample size was mere in comparison. As such, another sample could still outline the dependency on age and education found, but the size and the dimensionality of the causality could differ.

Although the balance of evidence shows that increasing age is associated with a greater probability of carrying out adherent behaviour, the review of Bish and Michie (2010) nonetheless concluded that these findings lack consistency: where cross-sectional studies in Singapore and Hong Kong found that older people tended to adhere more to hand washing and mask wearing to protect against the SARS, whereas people aged 18-24 were indicated to be more likely to engage in these recommended behaviours in the context of the 2009 swine flu pandemic (Bish & Michie, 2010). Education level was moreover defined as being an important cofound associated with age, together with income and occupation (Morris & Venkatesh, 2000). Also in the context of the SARS and avian influenza, those with a higher education were identified as being more likely to adopt precautionary behaviours (Lau et al., 2007; Leung et al., 2003; Tang & Wong, 2004). But a careful review of these findings outlined an unclear pattern between education level and avoidant behaviour (Bish & Michie, 2010).

Moreover, there is strong evidence that the observed associations are mediated by differing attitudes (Bish & Michie, 2010). The decision of younger people to adopt a technology is defined by their attitude towards using technology, whereas older people are more strongly influenced by subjective norm and perceived behaviour control (Morris & Venkatesh, 2000). This would indicate that although age and education influence the utilization of the app, other variables might control or influence its outcome. However, these were not included in the underlying research. The theoretical basis of the analysis can, thus, have practical repercussions on the outcome. The

HBM as used in this research was used in addition to other theories of behaviour, including the Unified Theory of Acceptance and Use of Technology (UTAUT), the Theory of Planned Behaviour (TPB) and the Protective Motivation Theory (PMT) (Bish & Michie, 2010; Ebbers et al., 2021; Morris & Venkatesh, 2000). These explanatory models differ in their perspectives used to describe how people react to a threat to their health. Where the HBM focuses on the effects of changes in perception, the TPB also informs about the noticeable effect of subjective norm and attitude on behaviour intention. The PMT further enhances the role of the perceived threat of the virus and the behavioural evaluation of the intervention already introduced by the HBM. As such, a mixture of theoretical foundations could furthermore clarify the practicality of the identified relations.

Even though the inclusion of the above mentioned theories would result in a more careful understanding of the causalities present among behavioural predictors, these constructs provide the inclusion of cognitive and rational drivers of behaviour only, without adequately considering the emotional realm in decision-making. Literature suggests that in the context of protective behaviour, a prominent role is played by anxiety and trust (Bish & Michie, 2010; Slovic & Weber, 2002). Other aspects such as cultural traits are moreover relevant, as they could impact the outcome variable in consistent patterns of respect, authority and risk-taking propensity (Bish & Michie, 2010). Thus, in addition to controlling for demographic and health variables, reasoned and impulsive processes should be equally represented in models describing protective behavioural responses in order to provide a holistic model able to generalize the findings across geographical areas.

7.3 Conclusion

As part of the second sub-question, this chapter outlined the lack of change in people's threat perception, behavioural evaluation and perceived efficacy of the measures to be attributed to the utilization of the CoronaMelder. Nonetheless, the investigation of the hygiene measures and the mobility measures outlined a significant difference in threat perception among users and non-users and also their significantly different behavioural perception of the mobility measures. These variances however cannot be affected by the utilization of the CoronaMelder, suggesting that the cause for this disparity could be attributed to variables that were not included in this research. As age, education, being a person at risk and previous infection with the virus resulted to play a determinant role in the utilization of the CoronaMelder, it might be valuable to investigate their effect on the threat perception and behavioural evaluation of the mitigation measures. As the hygiene measures and the mobility measures presented causality from Self-Efficacy to Behaviour, it could be valuable to investigate this relationship in particular. Furthermore, in an attempt to fully understand the third sub-question, the respondents were found to adhere to all the measures without a significant detriment in compliance due to the utilization of the app. In all, thus, the CoronaMelder cannot be defined as being a valuable predictor of risky behaviour. The influence of the demographic variables and the coronavirus-specific health variables on the CoronaMelder utilization retains its relevance as this understanding can be used to inform communication strategies aimed at maximizing the app's adoption. This understanding is used to fuel the investigation on the appropriate implementation strategy of the CoronaMelder to then enhance the overall effectiveness of the intervention. The next chapter will therefore explicate how these lessons learnt can be translated into practical steps.

8 Integration in behaviourally-informed politics

The findings of the previous chapters can subsequently be utilized to provide unique and essential insights for the applicability of the CoronaMelder in the context of pandemic control. This chapter therefore tries to bridge the gap between theory and practice, by providing recommendations as how to properly integrate the CoronaMelder as part of the national crisis strategy. By means of information acquired through the three-weekly meetings with the internal department Realisatie Digitale Ondersteuning from February till June 2021, the final sub-question is answered: *In which way should contact-tracing apps such as the CoronaMelder app become an integral part of behaviourally-informed health policy?* The judicious reflections derived from such work are, however, strictly developed to inform and influence policy related to the application of contact-tracing apps during a pandemic. This final section thus contains nuanced messages limited by the specificity of the technical intervention and contained by the situational characteristics. These final suggestions are moreover intended to be formative or, in other words, to seed matters for further discussion.

8.1 A complex-systems approach to implement the CoronaMelder

Public health is centred around people, for which interventions are implemented subsequent to the clarification of their applicability by policy. To use the words of Rutter et al. (2017, p. 2603), "*people live, policies are made and interventions are implemented*" and in real-world circumstances they are interdependent. This system is highly dynamic in each of the three aspects. Firstly, people adapt their behaviour in response to the implemented interventions and secondly, interventions are modified to counter any dilution in the desired effect due to the observed learning path (Rutter et al., 2017). As a result of this, policymakers need to continuously change their strategies, preventing the definition of static and always-encompassing policies.

In terms of the CoronaMelder, this dynamic aspect has been incorporated by the current political framework by means of the specific temporary law named *Tijdelijke wet notificatieapplicatie Covid-19*. This law outlines the responsibilities of the public authorities and the limitations to the usage of the technology, including possible privacy breaches. The law was approved on October 6, 2020, and it has been subject to continuous political scrutiny to ensure that the intervention continues to pertain its value in the current situation. To provide an example, the law formerly recognized the value of the app in curbing the spread of the virus whilst the lockdown was effective but recent alterations have recognized the need of such an application especially during the relaxation of such stringent measures.

These alterations have been driven by various studies over the past year which have evaluated different aspects of the implemented contact-tracing solution. Analogous to clinical interventions, it has been evaluated by means of linearly modelling its causes and effects. However, it should preferably be evaluated in terms of its interdependence with other interventions, as together they reshape public health towards a more favourable state. Focusing on one single intervention will therefore not generate effective policy when faced with multicausal and context-driven problems such as the Covid-19 pandemic. A complex systems approach could hence surmount the problem of answering the wrong question and thereby improving population health. So, instead of asking whether the CoronaMelder corrected the problem, the focus should lay on the identification whether and how it contributed to reshape the system in a desirable way (Rutter et al., 2017). Following this line of reasoning, the next section will describe the derived added value of the CoronaMelder.

8.2 The adjusted national value of the CoronaMelder

From the previous chapters it emerged that the CoronaMelder app was not responsible for possible non-compliant behaviour resulting from maladaptation by its users. With this, a plausible pitfall of the technology was eradicated from the discussion. Thus, the contribution of the CoronaMelder can be positively defined as a means to curb the spread of the coronavirus during the current pandemic. Controlling the spread of the virus should, however, be differentiated into containing the formation of new infections and optimizing the treatment of those who are indeed infected. The recent epidemiological evaluation by the RIVM about the efficacy of the CoronaMelder outlined a mere reduction of the R value by 0.3% (Klinkenberg et al., 2021). With this, the original goal of the app can be adjusted to be foremost optimizing the existing infrastructure, ranging from automatically performing labour-intensive contact-tracing activities and providing assistance to infected people by means of recommendations (Ebbers et al., 2021).

The identified value of the app, can furthermore increase in face of the relaxation of the mitigation measures and the national vaccination strategy. With less stringent rules, the higher occurrence of social interactions will densify and this increase will be indulged by the enhanced probability that individuals will be within 1.5 meter of an infected person for longer than 15 minutes (Ebbers et al., 2021). In addition to this, 'normalization' of the health infrastructures from the current crisis modus to the pre-coronavirus strategy, provides another promising situational context for the app to flourish. The capacity of the current contact-tracing infrastructure will resultingly reduce as other types of care can no longer be postponed. As such, the need for automatic contact-tracing will increase.

These advantages are, nonetheless, still dependent on the behaviour of the citizens both as actors deciding to utilize the app and as responsible users in actively adhering to the recommendations provided by the technology. The app remains a supplementary intervention to an effective pandemic strategy destined at guiding people's behaviour to curb the spread of the virus. Therefore, the added value of the app is only probable when people act responsibly and compliantly to the issued measures. So, the next section will outline how behavioural compliance can be strived for specifically for the CoronaMelder in times of a pandemic.

8.3 Enhancing behavioural compliance through risk perception

Empirical studies have framed people's behaviour to be influenced by their perception of risk, although their relationship remains unclear (Williams & Noyes, 2007). This research was able to explain a weak, direct and positive relationship among the perceived self-efficacy of mobility and hygiene measures with behaviour as well as between the perceived severity of the virus and actual compliant behaviour. However, other relations seemed not to be significant. In spite of the undefined causalities, the review by Williams and Noyes (2007) stated that decision-making can usually be reliably manipulated by means of alterations to people's risk perception. As such, it is imperative to consider risk perception when positive behavioural changes are aspired.

Risk perception is closely related with the perceived consequences of a potential hazard. More specifically, the greater the perceived risk of a hazard, the greater the desire to avoid the negative consequences of it (Geller, 2001; Williams & Noyes, 2007). The prominent role of the hazard hence requires its effective management, generally including the following steps: (1) removal of the hazard, (2) control of the hazard, (3) control of people, (4) training of people, and (5) warning of people (Williams & Noyes, 2007). The first two actions are preferred in safety engineering, but in the specific context of pandemic control, it is impossible to remove or control the hazard (namely the coronavirus). As such, the latter three actions are of interest.

Starting with how to control people, proper risk communication has been indicated as an effective way to manipulate people's perception of risk (Bish & Michie, 2010; Williams & Noyes, 2007). Providing clear and honest information about the course of the outbreak can enhance people's levels of trust and satisfaction with the mitigation measures implemented by the authorities. As a result, they will be more willing to comply with the issued rules (Bish & Michie, 2010). Lack of trust can therefore have detrimental effects in terms of controlling people. Open and transparent communication therefore constitutes an essential priority throughout the development of the pandemic, such as recognized throughout the design of the CoronaMelder (Beukers, 2021).

Another important action is provided by training people in an attempt to equalize the perceived risk across individuals. This perception is driven by irrational emotions (e.g. fear), which in turn are fuelled by incomplete information about the risks associated with certain industries and technologies (Williams & Noyes, 2007). As such, training should be viewed as an attempt to furnish people with the complete information about the hazard. Specifically for the CoronaMelder, fear for privacy breaches and data leaks continue to prevent people from adopting this solution (Fraser et al., 2020; Parker et al., 2020). Instructing them about the actual specifications of this privacy-by-design Bluetooth-based app could elucidate them about which data is being stored, where and for how long it is being kept, and with whom it is being shared. Hence, through training, people's irrational emotions with respect to the risks of the CoronaMelder can be restricted by knowledge rather than remaining speculative.

Finally, warning people about the hazard has the function of alerting them to trigger appropriate safety behaviour while discouraging at-risk behaviour. Any effective warning should therefore grab the attention of the individual and at the same time it should provide useful information. As such, for a warning to be effective it should equally contain iconic features and informational features (Williams & Noyes, 2007; Wurtele & Maddux, 1987). Its efficacy is moreover enhanced when the channel used to convey the warning is considered credible and trustworthy. Provided that these functionalities are already encompassed in the capabilities of the CoronaMelder, these functionalities could be extended with the provision of live information regarding the spread of the virus in the proximity of the user. By doing so, the user can directly be urged on the preferred protective actions (e.g. avoid a particular area) while the credible source of information can ensure that these measures are indeed being followed.

Thus, in times when the hazard cannot be eliminated or controlled, the Ministry should focus on its citizens in order to steer how they react to it. Once the desired behaviour is ensured, the Ministry can focus on increasing the adoption rate of the CoronaMelder such that it can make efficient use of the prospective benefits. The next section will therefore illustrate practical ways for the Ministry of Health to increase the adoption of the CoronaMelder.

8.4 Informed decision-making to increase adoption

As of now, only 16% of the population is actively using the CoronaMelder app. A practical way to increase the adoption of the app is derived from existing health practices, where people's inclination to adhere to a treatment is enhanced by involving them in the decision-making process (Geller, 2001). The app could therefore be profiled as a tool to participate in a person's health trajectory with respect to the coronavirus' development. This could for instance be realised by outlining the crucial role of the individual both as user and as key information provider for the technology's added value. By doing so, it will become evident that not only the government and the provincial health authorities (GGD GHOR Nederland) are necessary for the app's functionalities, but that these functionalities are also dependent on the responsibilities of each actor in the outlined tripartite.

Using the demographic characteristics of the users as a starting point, another solution is provided by the design of an effective and targeted communication strategy. Even though empirical findings about the adoption of contact-tracing apps indeed confirmed that increasing age and education indicate a reliable predisposition to download the apps, other characteristics complicate the categorization of such an adoption behaviour (Ebbers et al., 2021; Lockey et al., 2021). Among others, a similar study outlined that income and trust in the government resulted to be key explanatory factors for the observed downloading rates. More specifically, the lower the income and the more left-leaning the political orientation, the lower the adoption (Lockey et al., 2021). Considering these characteristics, efforts can be centred towards targeted risk communication and politically engaged promotion to enhance the widespread adoption of the app. For example, specific media could be deployed to target the unaffected group such as social media promotion rather than television promotion to indeed be seen by the younger population. Furthermore, left-winged and right-winged parties could equally engage in the promotion of the CoronaMelder, such that the political propensity is also considered.

Going from enhancing the individual's intrinsic motivation towards a more practical driver for adoption, cooperation with offices and other social gathering organizations could increase the widespread utilization of the app as part of the re-opening of the economies. A recent CNV research among 900 Dutch employees stated that one out of five employees experience unsafe situations working again at the office and more than 50% of them fear for contagion at the department due to the new Delta-variant (CNV, 2021). The CoronaMelder could therefore be implemented by employers as an additional safety measure to provide his or hers employees with an increased feeling of safety. The monitoring of the coronavirus infection rate at the office could thus increase people's willingness to work at the office rather than at home, and this practice will furthermore increase the adoption of the app.

With the re-opening of the economies to the international trade, the widespread adoption of the app could also be enhanced through the interoperation with other apps. As of now, all European Member States have deployed mobile contact-tracing apps, except for Bulgaria, Luxembourg, Sweden, and soon Greece, Slovakia, Romania (European Commission, 2021). Although they have been developed locally, they are all interoperable with the other apps, excluding the French and the Hungarian apps. Art. 6d.9 section 4 of the Dutch *Wet Publieke Gezondheid* 2008 has already outlined this general objective, but the operationalization of this international network has not yet been effectuated because of lacking international agreements specifying how data sharing will be ensured from a privacy perspective. Thus, guaranteeing that the apps are interoperable also at a political level will enhance the functionalities of the CoronaMelder outside the national boarders. This capability could therefore make travellers aware of a possible contagion in foreign countries and, thus, motivate the adoption of the app even more.

From collaboration at an organizational level to integration at a technical level, it might represent a potential to merge the technical characteristics of various coronavirus-specific digital solutions into one. The Covid-19 pandemic has seen the rise of numerous mHealth interventions, including the CoronaMelder and the CoronaCheck. They have been presented to the users as different personal solutions, each focusing on a different aspect of the pandemic (the former focusing on contact-tracing and the latter on the vaccination registration). These solutions have developed with separate legal, political and technical trajectories as their independency provided a faster implementation time. However, as the health urgency is no longer pressing, it would be advised to explore opportunities to merge them into one solution, while retaining their separate legal and political characteristics. Qatar's ETHERAZ app serves as an example: the app provides the personal QR code to which the vaccination of the user has been registered and at the same time a colour visualizes a possible contagion (green = not contagious, yellow = possibly contagious needing a test, red = contagious). Resultingly, the mandatory characteristics of the vaccination registration app, benefits the integrated contact-tracing capability. By doing so, various technologies have been implemented into one simple, easy to use and effective solution, while ensuring widespread adoption.

Although the above mentioned suggestions to increase the adoption have yet to be empirically validated, the current health crisis urges the Ministry to be creative in times when evidence-based remedies cannot be ensured. As such, these recommendations provide valuable insights for further experiments.

8.5 Conclusion

Chapter 8 answered the final sub-question: *In which way should contact-tracing apps such as the CoronaMelder app become an integral part of behaviourally-informed health policy?* As part of the complex dynamic characteristics of the current pandemic situation, the value of the app can better be comprehended as a valuable means to shape the Dutch society into a more desirable way, namely one where social interactions are re-established and health safety is ensured. The Ministry can enhance the behavioural compliance of its citizens with the issued measures, and thereby with the CoronaMelder's recommendations, by influencing their perceived risk. This can be achieved through open and consistent communication of the threats, providing them with complete information about the implemented solutions and through the effective usage of warnings activating people to engage in safe behaviour. Enhancing people's compliant responses is followed by increasing the actual adoption of the app, as its benefits become visible with its widespread utilization. This can be achieved by making people aware of their crucial role in enhancing the effectiveness of the app, but also by specifically targeting groups that present low adoption rates. Moreover, the CoronaMelder could become a supplementary safety measure in offices to increase the adoption among the working population. Ensuring that the app is interoperable at an international level could furthermore motivate people to install the app when crossing the national boarders. Finally, providing one simple and user-friendly solution that combines the various digital solutions offered by the Ministry on a technical level, could additionally result in increased utilization rates.

9 Reflection

In the interpretation of the principle outcomes of this research it should be noted that this study is not exhaustive and therefore, caution should be exercised in the generalization of these findings. This chapter discusses the limitations of the model results and the generalizability of the given outcomes. First, the critical assumptions and model limitations are presented, including their effect on the findings to be then followed by the discussion of generalizability of the results.

9.1 Critical assumptions and limitations of the study

Various assumptions emerged during the conceptualization, the formalization and subsequent validation of the model. This section exposes the critical assumptions that affect the model to explicit the bias, present throughout the analyses. The model limitations set the preliminary boundaries of the eventual outcome and therefore they are presented first. The chosen research method is the second topic of this scrutiny as it limited the sphere of potential outcomes to the research. The recommendations to optimize the evaluated socio-technical system are therefore the result of these two groups of assumptions.

9.1.1 Model limitations

The model provided a systematic representation of a formal theory. The identified variables and their interrelationships are thus deductive, but they represent an ideal more than a reality. This model was furthermore stylized to capture variances in behaviour due to the CoronaMelder utilization and as such, the first limitation is provided by the exploratory characteristics of the model. The model was moreover drawn on a number of existing theories but the HBM was the model par excellence as analogy was possible between the applications of the existing model and the field of interest. The included variables were, therefore, deliberately chosen to provide insight into the prevalent cognitive constructs of the individual person, excluding those predictors external to the individual (e.g. media attention, peer pressure, anxiety). The final critical assumption is provided by the definition attributed to each construct, as this definition was specifically designed for the present study. These assumptions are explored as follows.

9.1.1.1 Behaviour: Assumptions and limitations

In the study, the dependent variable was defined as *protective risk behaviour*. This variable differed from the typically studied *preventive behaviour* in HBM, as it was not only defined as any activity started by a healthy individual to prevent or detect illness when asymptomatic (Champion et al., 2002). In fact, this variable was defined as representing both adaptive and maladaptive behaviour. These two poles were identified by the degree with which the respondents agreed with the statement expressing to follow a certain rule. By not fully agreeing with that statement, however, the respondent only expressed his limited agreeance with following that specific rule; he/she did not express its agreeance to do the opposite instead. As such, this definition should be reminded when translating the outcomes of the study to real world situations. Moreover, protective risk behaviour as intended in this study, also specified the symptomatic context, hereby diverging from the original identification of a healthy subject, although hypothetically speaking.

Another limitation is provided by the categorization of behaviour, which in this study was performed on the sole basis of the type of measure included. Other studies have preferred to differentiate among habitual behaviours (e.g. washing of hands) and those which require a conscious decision (e.g. wearing a face mask), whereas others discriminated on the basis of frequency (e.g. using hand sanitizer or having a vaccination) or on the level of being mandated by law (e.g. properly washing of hands compared to the curfew). As a result, the same conceptual model could provide different outcomes depending on the definition of behaviour. This should therefore be recollected when the model results are being compared to new findings.

9.1.1.2 Covid-19: Assumptions and limitations

This study assumed that all participants had equal understanding of the Covid-19 although no reference was made to their knowledge. Moreover, the geographical spread of the respondents was not considered in this study, whereas it could be that people living in highly urbanized areas have a different understanding of the consequences of, for instance, entering crowded places, than people living in rural areas. The omission of these characteristics could therefore limit the accuracy of the model. Moreover, the temporal dependability of this study on the stage of the pandemic was not accounted for. The respondents could have answered differently if this study were to have been conducted at the onset of the virus, when the effects of the virus still had to be defined. Time and space were therefore not considered, whereas this contextual variable might influence the outcome.

9.1.1.3 Mitigation measures: Assumptions and limitations

With respect to the mitigation measures there are several critical assumptions. The first limitation is provided by the assumption that the rules within one category are treated as equal. However, RIVM's longitudinal study outlined the differences in people's perceptions of them and as such, this study underestimates these differences. Another limitation is provided by the reduced complexity of the mitigation measures involved. As mentioned, they operate on different levels (micro-level and meso-level) but they have nonetheless been compared with each other. The extended social structure of the meso-level category could result in a more complex decision-making process than assumed by the conceptual model. Other agents could, for example, determine people's compliance with them (e.g. offices demanding personnel to work on-site). This assumption therefore limits the insight in the degree of personal freedom in the studied behaviour.

9.1.2 Research method limitations

The start of this research provides the foremost limitation of this study, resulting in a misfit between the goal and the research methodology. The main question was to identify the occurrence of compensatory behaviour due to the application of the CoronaMelder and as such it would have been optimal to study people's compliant behaviour prior to the introduction of the CoronaMelder and after the adoption of the app. However, this study was initiated several months after the introduction of this digital solution and as such, it was decided to study the differences in behaviour between users and non-users. Moreover, the causality identified through the applied cross-sectional design is limited compared to a longitudinal study even though it is assumed to be adequate to the explorative nature of this research.

Moreover, the studied behaviour was not directly observed by the researcher but it was rather a representation of the declared behaviour by the respondent. This bias is also visible in the respondents' answers to the hypothetical questions regarding their compliant behaviour when using the CoronaMelder. People tended to overestimate their positive behaviour, perceiving the direction of the desired answer[1]. This rational bias could be removed by observing their behaviour

[1] Not included in the model analysis, but the summary of these results are presented in Appendix E.

first-hand, to correctly understand how people react in a given situation. However, the adjustment to the sampling method would also need an alteration to the conceptual model, as rational cognitive constructs have only been included so far.

9.2 Reflection on the validity of the model

For this research is was decided to obtain a new sample of data from a small portion of the same population to assess the external validity of the Basic Model outcomes. Although preferred to internal validation, this method was not fully unbiased. To start, only 11 people were consulted. This limited sample size could affect the portion of error involved as reducing the sample size increases the impact of an individual's answer on the measured outcome. Therefore, the surveyed population could have biased the validity outcomes. Furthermore, no distinction was made among the mitigation measures whereas the hygiene and mobility measure model outcomes resulted to differ from the distancing outcomes. The confidence of the validity results is consequently affected, and for further research it is advised to validate each part separately. Continuing with the sampling method, people's compliance with the statements was again stated and not observed by the researcher. A choice experiment could have properly identified the cause and effect involved in such a decision-making process but time restrictions prevented this validation method to be employed.

The second part of this research was validated by means of a sensitivity analysis to outline the correctness of the multinomial logistic regression results in identifying users and non-users a priori, based on their demographic and health characteristics. Given the inconclusive validation results, however, the addition of another validation technique could have enhanced the accuracy of the outcomes. For instance, by wild bootstrapping, which specifies the validity of the outcomes by means of a resampling method, randomly creating new samples from the original population (Giancristofaro & Salmaso, 2003). However, more robust scientific findings on this topic should be available to enhance the comparability of the results.

The final discussion on behaviourally-informed politics could advantage from expert validation as no form of validation was performed on this part. Political experts could judge the applicability of the provided recommendations and the viability of those actions in the near future. As of now, recommendations on this part remain speculative also due to the evidence-based characteristics of the Dutch political scene for preferring to implement validated solutions. Open-mindedness is therefore a prerequisite for the experts involved in this part.

9.3 Reflection on the generalizability of the results

The determination of the generalizability of the results to the Dutch population was determined by the sample demographical composition based on gender, age and education level. As previously stated, other characteristics have not been considered thereby limiting the comparability of the sample under different conditions. Furthermore, being an explorative study, the outcomes of this research cannot be defined as being conclusive as replication has not yet proved the applicability of these results to other sample populations. As such, another sample could still outline the observed dependencies, but the size and the dimensionality of the causality could differ. The problem of transportability has not yet been challenged through repeated work, and resultingly the observed causalities are constrained by the sample population.

10 Conclusions and recommendations

In this final chapter, the main question is answered through the revision of the four sub-questions. The following section discusses what these findings contribute to the Ministry of Health but also what they add to the scientific community. The chapter then ends with recommendations for future research.

10.1 Answering of sub-questions

The sub-questions are presented one by one together with the answers obtained through the investigation of the previous chapters. The second and third sub-question were answered at the same time. By means of their consecutive outline, the effect of the CoronaMelder on people's compliance with the mitigation rules will be outlined.

SQ1: In which way can the CoronaMelder app's effect on the user behaviour be modelled to also incorporate risk compensating behaviour?

According to the Health Belief Model, people adapt their behaviour in the instance that they feel threatened by their current behavioural patterns. As such, perceived susceptibility and perceived severity are believed to reduce the occurrence of risky behaviour. When people value the outcome to have an acceptable cost, they are more eager to perform the action. With perceived benefits come perceived barriers which are inversely related to behaviour. Thus, the higher the barriers, the lower the people act in its favour. Moreover, people must feel themselves capable to overcome the perceived barriers to take action. Other cognitive studies have suggested the influence of attitude on behaviour in concurrence with perception as well as the effect of attitude on perception. Attitude should therefore be included, although specific to the hazard being studied. To incorporate the Risk Homeostatic Theory, the CoronaMelder variable was modelled to directly decrease the perceived susceptibility and perceived severity and as a result, to indirectly decrease compliant behaviour. Furthermore, to exclude the possibility of the utilization of the CoronaMelder as an inherent risk-averting attitude, the correlation among these variables was believed to be absent. However, the findings of the cross-sectional study have outlined a misfit of the measurement model first and structural model second. This conceptualisation should therefore be revised to eliminate the highest correlations among the constructs and to correct for proper factor loading.

SQ2: In which way does the CoronaMelder app influence people's behavioural perception? *And* **SQ3: To what extent does the CoronaMelder app affect people's behaviour?**

The conceptual model was applied to obtain six basic models: two per mitigation category (hygiene measures, distancing measures, mobility measures) differentiating among asymptomatic and symptomatic contexts. First of all, the CoronaMelder was found not to have a significant direct effect on perception and consequently, the app did not have a significant indirect effect on behaviour. As such, the app cannot be linked to the risky behaviour. So, even though users outlined a higher compliance to the mitigation measures compared to non-users, this discrepancy could not be explained to be influenced by the utilization of the app. This difference was present both in the asymptomatic and in the symptomatic context, although the latter situation was characterized by an overall increase in compliance to the rules. Further investigation outlined the dependence of the CoronaMelder adoption on age and education characteristics as well as being a person at risk and having previously contracted the virus. In fact it resulted that older higher educated people were more likely to install the app as well as individuals at risk and those who had previously been infected. Possibly other characteristics from the emotional realm could explicate the variances presented in the perceived threat and the behavioural evaluation of the hygiene measures and the mobility measures.

SQ4: In which way should contact-tracing apps such as the CoronaMelder app become an integral part of behaviourally-informed health policy?

As part of the complex dynamic characteristics of the current pandemic situation, the value of the app can better be comprehended as a valuable means to shape the Dutch society into a more desirable way, namely one where social interactions are re-established and health safety is ensured. The Ministry can enhance the behavioural compliance of its citizens with the issued measures, and thereby with the CoronaMelder's recommendations, by influencing their perceived risk. This can be achieved through open and consistent communication of the threats, providing them with complete information about the implemented solutions and through the effective usage of warnings activating people to engage in safe behaviour. Ensuring people's compliant behaviour should simultaneously be followed by an increase in the actual adoption of the app, as its benefits become visible with its widespread utilization. This can be achieved by making people aware of their crucial role in enhancing the effectiveness of the app, but also by specifically targeting groups that present low adoption rates. Moreover, the CoronaMelder could become a complementary safety measure in offices to increase the adoption among the working population. Guaranteeing that the app is interoperable at an international level could furthermore motivate people to install the app when crossing the national boarders. Finally, providing one simple and user-friendly solution that combines the various digital solutions offered by the Ministry on a technical level, could additionally result in increased utilization rates.

10.2 Answering of main research question

The main research question as outlined at the beginning of this thesis was:

What is the effect of the CoronaMelder on people's conduct with respect to the mitigation measures issued by the Dutch Ministry of Health during the Covid-19 pandemic?

The focus of this research was to explore the integration of the Risk Homeostatic Theory with the Health Belief Model in an attempt to identify the occurrence of risky behaviour due to the implementation of the CoronaMelder. This research was therefore mostly explorative as previous theoretical models could not be identified to represent the causal inference of digital interventions on cognitive responses. Therefore, this study conceptualized a behavioural model to outline the interplay of attitude and perception on behaviour as well as the mediating effect of the app.

The applicability of the model was then analysed through a representative data sample obtained through an online survey. In total, the answers of N=776 respondents were considered for this study. The results of this exploration provided a misfit with the conceptual model, indicating divergence with the real-world decision-making process. However, from these outcomes it could still be concluded that the CoronaMelder was not causing alterations in the user's perceived susceptibility and perceived severity. As such, the app could not be attributed to behavioural changes and thus, it is not considered responsible for risky behaviour. In all, the respondents were found adhere to the hygiene, distancing and mobility measures issued by the Ministry.

As the added value of the CoronaMelder continues to exist, the knowledge surrounding the influence of the demographic and the health characteristics on the adoption of the app can be applied to enhance its utilization by the Dutch population. Several political actions were therefore identified to correctly implement this preventing measure as part of the national mitigation strategy while considering behavioural changes as a crucial part for its effectiveness.

10.3 Recommendations for the Ministry of Health

The behavioural consideration of the CoronaMelder's impact favours the utilization of the app as a supplementary measure during the pandemic, especially in face of the re-opening of the economies. The dynamic interdependency between interventions, people and policy dictates the impossibility to define a static policy and therefore, the Ministry is recommended to preserve the temporal character of the *Tijdelijke wet notificatieapplicatie Covid-19*. The subsequent discussion about its efficacy should not be dominated by the question whether the app corrected the problem, but rather by the consideration of its contribution in curbing the spread of the virus together with the other mitigation measures.

Although the CoronaMelder was not found to influence perception nor behaviour, certain adaptations can be recommended to affect people's perception of threat thereby influencing their compliant behaviour. The app could integrate effective warnings to alert people about the live contagion risk in their area, cueing appropriate safety behaviour. Safe behaviour can furthermore be ensured by open and transparent communication about the course of the outbreak as it enhances people's trust in the national strategy during the pandemic. In line with honest communication, the Ministry should instruct the people about the process of data collection and storage implemented by the app, as privacy issues still fuel people's fear towards actively using the app.

Finalizing with the recommendations to increase the app's adoption, the Ministry is advised to employ targeted marketing to reach the portions of the population with the lowest adoption. This could be actuated through the utilization of specific media channels and by adding a political engagement to the promotional messages. The Ministry could moreover seek the cooperation with offices and other social gatherings, by presenting the app as a complementary measure to their safety measures. Going beyond the national borders, the Ministry is recommended to spur the definition of the international agreements to take advantage of the interoperability of the various contact-tracing apps at an international level. Lastly, the Ministry should explore the integration of the CoronaMelder with the CoronaCheck as one simple and user-friendly solution in which the contact-tracing capability could benefit from the widespread adoption of the other technology.

10.4 Further research

A first recommendation is provided by the conceptualisation of risky behaviour with constructs specific for the type of hazard as general constructs might interfere with the expected theoretical relations among them. Further exploration should moreover identify the controlling effect of demographic and health characteristics (e.g. age, education, being at risk and having previously contracted the virus) on each construct to substantiate the difference contracted in the observed behaviour.

This study moreover recognized the existence of internal determinants of behaviour, ranging from personal characteristics, to attitudes and perceptions. However, the emotional response to the hazard type was omitted from this analysis. It would therefore be advised to study the mediating effect of personality traits and emotional responses such as anxiety and trust. As attitude was moreover not found to be a determinant for the utilization of the CoronaMelder, it could result valuable to study the relation between external drivers (e.g. media attention) and the adoption of the app. Thus, future research should focus of the implementation of theory-driven behavioural studies, including both the cognitive and the emotional realms.

Additionally, further research could investigate which incentives motivate people to engage in safe behaviour rather than at-risk behaviour when they expect to gain something positive and/or avoid something negative from the latter. This knowledge could be implemented in the general conceptualisation of inherent risk compensating behaviour, simplifying the positioning of digital solutions in this framework.

It would however be advised to design a longitudinal study throughout the participant's exposure to the hazard including observational as well as experimental designs. In the ideal world, these studies would be carried out prior to the introduction of the digital intervention and after its implementation as to appropriately understand the impact of it on protective behaviour. These findings would then represent a confident contribution to the scientific world about the holistic understanding on the influences on protective behaviour after the implementation of a tool such as the CoronaMelder.

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Appendix A: Survey questions

Page 1

{OpeningStatement}

Geachte heer, mevrouw,

Zoals u misschien weet, heeft het Ministerie van Volksgezondheid, Welzijn en Sport (VWS) op 10 oktober een app gelanceerd in de strijd tegen het coronavirus, CoronaMelder. De app stuurt een melding als u enige tijd in de buurt bent geweest van iemand die ook CoronaMelder gebruikt en die besmet is met het coronavirus.

Bovendien stuurt de app dan een aantal adviezen. Eén van de adviezen is om u te laten testen op het coronavirus. Zo weet u of u besmet bent geraakt en kunt u voorkomen dat u het virus onbewust op anderen overdraagt. Als u zelf met het coronavirus besmet bent, kunt u dit (vrijwillig) in de app laten weten. Dan waarschuwt de app mensen met wie u in contact bent geweest.

Het doel van deze vragenlijst is om het gebruik van CoronaMelder beter in kaart te brengen. Ook zijn we benieuwd naar hoe mensen zich houden aan de algemene gedragsmaatregelen. Niet-gebruikers van de app zijn ook uitgenodigd om deze vragenlijst in te vullen.

Het onderzoek wordt uitgevoerd door een onderzoeker van de Technische Universiteit Delft in opdracht van het Ministerie van VWS als onderdeel van een master afstudeerproject.

Graag horen wij uw mening, maar uiteraard is het invullen van de vragenlijst geheel vrijwillig. De gegevens zullen anoniem worden verwerkt, waardoor de onderzoeker niet kan zien wie u bent. Eventuele persoonlijke informatie die u vrijwillig doorgeeft, wordt na Juli 2021 vernietigd. Het invullen van deze vragenlijst duurt ongeveer 15 minuten.

Dit onderzoek is beoordeeld en goedgekeurd door de "Human Research Ethics Committee (HREC)" van de Technische Universiteit Delft. Voor eventuele opmerkingen of klachten over dit onderzoek kunt u contact opnemen met via hrec@tudelft.nl. De geanonimiseerde data zal verder dan worden gepubliceerd op 4TU.ResearchData onder de FAIR richtlijnen (Findable, Accessible, Interoperable and Reusable) voor een periode van 10 jaar. Open Access is gelimiteerd door het type licentie (CC BY-NC) dat het niet mogelijk maakt om de data te gebruiken voor commerciële doeleinden.

Indien u vragen heeft over dit onderzoek, kunt u contact opnemen met M. Costanzo via m.costanzo@minvws.nl.

Alvast bedankt voor uw tijd.

Toestemming

Ik heb bovenstaande informatie gelezen en ga akkoord met mijn deelname aan het onderzoek. Ik geef de onderzoekers toestemming om mijn antwoorden te gebruiken en aan de onderzoekers ter beschikking te stellen voor wetenschappelijk, beleidsrelevant en maatschappelijk relevant onderzoek.

Geeft u toestemming om mee te doen aan dit onderzoek?

- JA, ik geef toestemming, ik doe mee aan dit onderzoek (7)
- NEE, ik geef geen toestemming, ik doe niet mee aan dit onderzoek (8)

Page 2
{IntroGeneral}

De CoronaMelder app is ontwikkeld door het ministerie van Volksgezondheid, Welzijn en Sport en wordt nu landelijk gebruikt in de strijd tegen het coronavirus.

U krijgt een aantal algemene vragen over het coronavirus, over de algemeen geldende gedragsregels en over de app. Verder krijgt u een aantal statements die naar uw gedrag vragen en uw redenen daarachter. U kunt de vragen ook beantwoorden als u de app niet gebruikt.

Mocht u hierna benaderd willen worden om aan aantal antwoorden verder toe te lichten, kunt u uw mailadres achterlaten. In totaal zullen er 10 mensen geloot worden voor een nagesprek.

(Van der Laan et al., 2020, 2021)

Page 3
Er volgen eerst een aantal basis vragen over uw gesteldheid.
RiskGroupSelf (RG_self)

Het RIVM heeft de risicogroepen van het coronavirus gedefinieerd als mensen die ouder dan 70 jaar zijn of die een kwetsbare gezondheid (hartpatiënten, diabetes, lagere weerstand, afwijkingen van de luchtwegen, ernstig overgewicht) hebben.

Zit u in de risico groep?

1. Ja (1)
2. Nee (0)

Page 4
RiskGroupOther (RG_other)

Hoe vaak komt u door uw **werk en/of (privé) zorgtaken** op minder dan 1,5 meter afstand van mensen die ouder dan 70 jaar zijn of die een kwetsbare gezondheid (hartpatiënten, diabetes, lagere weerstand of afwijkingen van de luchtwegen) hebben?

- Nooit (1)
- Soms (2)
- Regelmatig (3)
- Vaak (4)
- Altijd (5)

(Van der Laan et al., 2020, 2021)

Page 5
CoronaInfectionSelf (CIS)

Bent u besmet (geweest) met het coronavirus?

1. Ja, ik weet het zeker want ik heb mij laten testen en de uitslag was positief (1)
2. Ja, ik denk het wel maar ik heb mij nooit laten testen (2)

3. Nee, ik weet het zeker want ik heb m ij laten testen en de uitslag was negatief (3)
4. Nee, ik denk het niet maar ik heb mij nooit laten testen (4)
5. Wil ik niet vertellen (99)

Page 6
CoronaInfectionOther (CIO)

Zijn er mensen in uw directe omgeving besmet (geweest) met het coronavirus? Meerdere antwoorden zijn mogelijk.

1. Ja, mijn partner. (1)
2. Ja, een of meerdere huisgenoten (geen partner). (2)
3. Ja, een of meerdere familieleden. (3)
4. Ja, een of meerdere vrienden. (4)
5. Ja, een of meerdere collega's/studiegenoten. (5)
6. Ja, een of meerdere kennissen. (6)
7. Anders, namelijk: …. *[string]* (7)
8. Nee, niemand. (0)
9. Weet ik niet. (99)

(Van der Laan et al., 2020, 2021)

Page 7
Vaccination (VAC)

Begin januari zijn we in Nederland begonnen met vaccineren tegen het coronavirus. Vaccinatie tegen het coronavirus is vrijwillig; het is uw keuze of u zich wilt laten vaccineren of niet. Heeft u een vaccinatie tegen het coronavirus gehad?

1. Ja (1)
2. Nog niet, maar de afspraak staat al wel gepland (2)
3. Nog niet, maar ik wil een afspraak maken (zodra ik een uitnodiging ontvang) (3)
4. Nog niet, ik twijfel nog of ik me wil laten vaccineren (4)
5. Nee, want ik wil me niet laten vaccineren (5)
6. Wil ik niet vertellen (99)

(Hooijmans, 2021)

Page 8
Er volgen nu een aantal uitspraken over hoe u denkt over uw risico op besmetting.
PerceivedRiskForInfection (RI)

Bent u het oneens of eens met de volgende uitspraken?

RI_SUS_SELF_1 Ik loop in de komende twee maanden risico op een besmetting met het coronavirus.
RI_SUS_SELF_2 Er is een grote kans dat ik in de komende twee maanden besmet raak met het coronavirus.
RI_SUS_OTHER_3 Als ik besmet raak met het coronavirus is de kans groot dat ik anderen zal besmetten.
RI_SEV_SELF_4 Ik vind het erg om besmet te raken met het coronavirus.
RI_SEV_SELF_5 Een besmetting met het coronavirus heeft voor mij grote lichamelijke, psychische of economische gevolgen.

RI_SEV_OTHER_6 Ik vind het erg als ik andere mensen besmet met het coronavirus.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

(Van der Laan et al., 2020, 2021)

Page 9
Attitude_TrustInGovernment (ATT_trust)

De overheid waarborgt uw veiligheid en de veiligheid van ons land. Bij rampen, calamiteiten en noodsituaties worden maatregelen ingevoerd om deze veiligheid te garanderen.

Over het algemeen, bent u het oneens of eens met de volgende uitspraken?

Als het gaat om <u>crisis bestrijding</u>, dan....

ATT_trust_1_COMP... vind ik de overheid heel kundig.
ATT_trust_2_BEN... doet de overheid haar best om burgers goed te helpen.
ATT_trust_3_INT... legt de overheid eerlijk uit was er aan de hand is.
ATT_trust_4 ... kan ik de overheid goed vertrouwen.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

(Grimmelikhuijsen & Knies, 2017)

Page 10
{IntroMaatregelen}

Het kabinet heeft sinds Maart 2020 een aantal maatregelen geïntroduceerd om de verspreiding van het coronavirus tegen te gaan en de druk op de ziekenhuizen te verlichten. Deze maatregelen betreffen onze persoonlijke routines en de manier waarop we werken, maar ook de manier waarop we met elkaar omgaan.

De drie groepen gedragsregels die van belang zijn voor de survey zullen per onderdeel specifiek worden benoemd. We beginnen eerst met een aantal <u>algemene</u> vragen over de gedragsmaatregelen.

Page 11
CoronaSpecificAttitude (ATT_CM)

Bent u het oneens of eens met de volgende uitspraken?

Fixed:
ATT_CM_General_1 Ik doe erg mijn best om te voorkomen dat ik besmet raak met het coronavirus.
ATT_CM_Importance_2 Ik vind de voorgeschreven gedragsregels overbodig.

Randomly (and evenly displayed) 3 chosen from:
ATT_CM_PublicAreas_3a Ik vind het belangrijk om mij te houden aan de voorgeschreven gedragsregels in publieke binnenruimtes.

ATT_CM_PublicAreas_3b Ik vind het onnodig om mij te houden aan de voorgeschreven gedragsregels in publieke binnenruimtes.
ATT_CM_Home_4a Ik vind het verantwoord om mij ook thuis te houden aan de voorgeschreven gedragsregels.
ATT_CM_Home_4b Ik vind de voorgeschreven gedragsregels thuis nutteloos.
ATT_CM_Motivation_5a Ik vind het fijn om mij te houden aan de voorgeschreven gedragsregels.
ATT_CM_Motivation_5b* Ik vind dat ik mij niet hoef te houden aan de voorgeschreven gedragsregels.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

Page 12
HygieneRules (HYG)

De komende vragen richten zich op de hygiëne maatregelen:

- Was je handen vaak en goed (meer dan 10 keer op een dag).
- Hoest en niet in je elleboog.
- Schud geen handen.
- Verplicht dragen van een mondkapje in het OV.
- Verplicht dragen van een mondkapje in publieke binnenruimtes.

Bent u het oneens of eens met de volgende uitspraken?

HYG_BEN1 Het heeft voor mij persoonlijke voordelen om de hygiëne maatregelen te volgen.
HYG_BEN2 De hygiëne maatregelen helpen om de verspreiding van het coronavirus tegen te gaan.
HYG_BAR1 Het heeft voor mij persoonlijke nadelen om de hygiëne maatregelen te volgen.
HYG_BAR2 De hygiëne maatregelen zijn nutteloos in de strijd tegen de verspreiding van het coronavirus.
HYG_SEE1 Ik ben in staat om de hygiëne maatregelen te volgen.
HYG_SEE2 De hygiëne maatregelen zijn makkelijk te volgen.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

Page 13
HygieneRulesBehaviour_nosymptoms (HYG_BEH_nosympt)

Stelt u eens voor: u hebt **geen** symptomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

HYG_BEH_nosympt_1 Ik was mijn handen regelmatig, bijvoorbeeld als ik thuis kom of als bij anderen op bezoek ga.
HYG_BEH_nosympt_2 Ik hoest en nies in mijn elleboog.
HYG_BEH_nosympt_3 Ik draag een mondkapje in publieke binnenruimtes.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 14
HygieneRulesBehaviour_symptoms (HYG_BEH_sympt)

Stelt u eens voor: u hebt **wel** symptomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

HYG_BEH_sympt_1 Ik was mijn handen regelmatig, bijvoorbeeld als ik thuis kom of als bij anderen op bezoek ga.
HYG_BEH_sympt_2 Ik hoest en nies in mijn elleboog.
HYG_BEH_sympt_2 Ik draag een mondkapje in publieke binnenruimtes.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 15
SocialDistancingRules (SOC)

De komende vragen richten zich op de afstandsmaatregelen:

- Houd 1.5 meter afstand.
- Vermijd drukke plekken.
- Beperk het bezoek thuis tot maximaal 1 gast per dag en houd 1.5 meter afstand.
- Beperk de groepsgrootte buiten tot maximaal 2 personen en houd 1.5 meter afstand.

Bent u het oneens of eens met de volgende uitspraken?

SOC_BEN1 Het heeft voor mij persoonlijke <u>voordelen</u> om de sociale maatregelen te volgen.
SOC_BEN2 De sociale maatregelen helpen om de verspreiding van het coronavirus tegen te gaan.
SOC_BAR1 Het heeft voor mij persoonlijke <u>nadelen</u> om de sociale maatregelen te volgen.
SOC_BAR2 De sociale maatregelen zijn nutteloos in de strijd tegen de verspreiding van het coronavirus.
SOC_SEE1 Ik ben in staat om de sociale maatregelen te volgen.
SOC_SEE2 De sociale maatregelen zijn makkelijk te volgen.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

Page 16
SocialDistancingRulesBehaviour_nosymptoms (SOC_BEH_nosympt)

Stelt u eens voor: u hebt **geen** symptomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

SOC_BEH_nosymptoms_1 Ik houd 1,5 meter afstand van vrienden, familie en collega's.
SOC_BEH_nosymptoms_2 Ik vermijd drukke plekken op het werk, op verjaardagen of in de winkelstraat.
SOC_BEH_nosymptoms_3 Ik ontvang maximaal 1 persoon thuis per dag.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 17
SocialDistancingRulesBehaviour_symptoms (SOC_BEH_sympt)

Stelt u eens voor: u hebt **wel** sypmtomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

SOC_BEH_symptoms_1 Ik houd 1,5 meter afstand van vrienden, familie en collega's.
SOC_BEH_symptoms_2 Ik vermijd drukke plekken op het werk, op verjaardagen of in de winkelstraat.
SOC_BEH_symptoms_3 Ik ontvang maximal 1 persoon thuis per dag.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 18
MobilityRules (MOB)

De komende vragen richten zich op de mobiliteitsmaatregelen:

- Werk thuis, tenzij dit echt niet mogelijk is.
- Reis met het OV alleen indien noodzakelijk.
- Reis niet naar het buitenland.
- <u>Verplicht</u> thuis zijn tijdens de avondklok tussen 22:00 en 4:30 uur, tenzij noodzakelijk beroep.

Bent u het oneens of eens met de volgende uitspraken?

MOB_BEN1 Het heeft voor mij persoonlijke <u>voordelen</u> om de bewegingsmaatregelen te volgen.
MOB_BEN2 De bewegingsmaatregelen helpen om de verspreiding van het coronavirus tegen te gaan.
MOB_BAR1 Het heeft voor mij persoonlijke <u>nadelen</u> om de bewegingsmaatregelen te volgen.
MOB_BAR2 De bewegingsmaatregelen zijn nutteloos in de strijd tegen de verspreiding van het coronavirus.
MOB_SEE1 Ik ben in staat om de bewegingsmaatregelen te volgen.
MOB_SEE2 Ik vind de bewegingsmaatregelen makkelijk te volgen.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutraal (3) / een beetje mee eens (2) / helemaal mee eens (1)

Page 19
MobilityRulesBehaviour_nosymptoms (MOB_BEH_nosympt)

Stelt u eens voor: u hebt **geen** symptomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

MOB_BEH_nosymptoms_1 Ik reis <u>niet</u> met het OV, tenzij het niet anders kan.
MOB_BEH_nosymptoms_2 Ik werk thuis, tenzij het niet anders kan.
MOB_BEH_nosymptoms_3 Ik blijf binnen van 22.00 uur 's avonds tot 04.30 uur 's ochtends.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 20
MobilityRulesBehaviour_nosymptoms (MOB_BEH_nosympt)

Stelt u eens voor: u hebt **wel** sypmtomen.

In hoeverre houdt u zich dan aan de volgende maatregelen?

MOB_BEH_symptoms_1 Ik reis <u>niet</u> met het OV, tenzij het niet anders kan.
MOB_BEH_symptoms_2 Ik werk thuis, tenzij het niet anders kan.
MOB_BEH_symptoms_3 Ik blijf binnen van 22.00 uur 's avonds tot 04.30 uur 's ochtends.

Nooit (5) / Soms (4) / Regelmatig (3) / Vaak (2) / Altijd (1)

(Hooijmans, 2021)

Page 21
CoronaMelder (CM)

Als laatste onderdeel, volgt er nu een korte uitleg over de CoronaMelder app.

De CoronaMelder app wordt (vrijwillig) gedownload op elke smartphone. Na activatie, blijft de app actief. De app stuurt een melding als u enige tijd in de buurt ben geweest van iemand die besmet is met het coronavirus. Zo kunt u te weten komen of u besmet bent geraakt en kunt u voorkomen dat u het virus zonder dat u het weet weer op anderen overdraagt. Als u zo'n melding ontvangt, krijgt u een aantal adviezen, bijvoorbeeld: (1) om u te laten testen als u ook klachten hebt die bij het coronavirus passen, en (2) om 10 dagen thuis te blijven. Als u zelf het coronavirus heeft, kunt u dit (vrijwillig) via de app laten weten. Dan waarschuwt de app weer mensen met wie u contact hebt gehad. De melding blijft anoniem. Hieronder ziet u een plaatje van de CoronaMelder app.

<plaatje>

Welke situatie geldt voor u?

1. Ik gebruik de CoronaMelder app op dit moment. (2)
2. Ik heb de CoronaMelder app in het verleden wel gebruikt maar nu niet meer. (1)
3. Ik heb de CoronaMelder app nooit gebruikt. (0)
4. Ik wist niet wat de CoronaMelder app was voordat ik aan deze survey begon. (99)

(Van der Laan et al., 2020, 2021)

Page 22
CoronaMelder app & maatregelen (CM_HYG_nosymp, CM_SOC_nosymp, CM_BEW_nosymp)

De CoronaMelder app stuurt u een melding als u enige tijd in de buurt bent geweest van iemand die besmet is met het coronavirus.

Stelt u zich voor: U heeft **een** melding ontvangen over een mogelijke besmetting en u hebt u **geen** symptomen.

In hoeverre bent u van plan de volgende maatregelen na te leven?

BEH_CM_HYG_nosympt_1 Ik was mijn handen regelmatig, bijvoorbeeld als ik thuis kom of als bij anderen op bezoek ga.
BEH_CM_HYG_nosympt_2 Ik hoest en nies in mijn elleboog.
BEH_CM_SOC_nosympt_1 Ik houd 1,5 meter afstand van vrienden, familie en collega's.
BEH_CM_SOC_nosympt_2 Ik vermijd drukke plekken op het werk, op verjaardagen of in de winkelstraat.
BEH_CM_BEW_nosympt_1 Ik reis <u>niet</u> met het OV, tenzij het niet anders kan.
BEH_CM_BEW_nosympt_2 Ik werk thuis, tenzij het niet anders kan.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutral (3) / een beetje mee eens (2) / helemaal mee eens (1)

(Hooijmans, 2021)

Page 23
CoronaMelder app & maatregelen (CM_HYG_symp, CM_SOC_symp, CM_BEW_symp)

De CoronaMelder app stuurt u een melding als u enige tijd in de buurt bent geweest van iemand die besmet is met het coronavirus.

Stelt u zich voor: U heeft **een** melding ontvangen over een mogelijke besmetting en u hebt **wel** symptomen.

In hoeverre bent u van plan de volgende maatregelen na te leven?

BEH1a_CM_HYG_symptoms Ik was mijn handen regelmatig, bijvoorbeeld als ik thuis kom of als bij anderen op bezoek ga.
BEH1b_CM_HYG_symptoms Ik hoest en nies in mijn elleboog.
BEH2a_CM_SOC_symptoms Ik houd 1,5 meter afstand van vrienden, familie en collega's.
BEH2b_CM_SOC_symptoms Ik vermijd drukke plekken op het werk, op verjaardagen of in de winkelstraat.
BEH3a_CM_BEW_symptoms Ik reis met het OV alleen als het écht niet anders kan.
BEH3b_CM_BEW_symptoms Ik werk thuis, tenzij het niet anders kan.

Helemaal mee oneens (5) / een beetje mee oneens (4) / neutral (3) / een beetje mee eens (2) / helemaal mee eens (1)

(Hooijmans, 2021)

Page 24
{IntroDemographicVar}

U bent bijna klaar!

De laatste vragen gaan over u als persoon.

Page 25
DemographicVariables_household (GEN)

Ik ben...

1.	Man	(1)
2.	Vrouw	(2)
3.	Wil ik niet zeggen	(99)

Page 26
DemographicVariables_household (AGE)

Wat is uw leeftijd?

1.	15-35 jaar	(1)
2.	36-55 jaar	(2)
3.	56-75 jaar	(3)
4.	76 jaar of meer	(4)

Page 27
DemographicVariables_household (EDU)

Wat is uw hoogst genoten opleiding?

1.	Basisonderwijs	(1)	(low)
2.	VMBO, MBO 1, AVO Onderbouw	(2)	(low)
3.	MBO 2, 3, 4	(3)	(middle)
4.	HAVO, VWO	(4)	(middle)
5.	HBO	(5)	(high)
6.	WO of hoger	(6)	(high)

Page 28
DemographicVariables_household (HOU)

Met hoeveel mensen <u>deelt</u> u een keuken en/of woonkamer?

1.	Met niemand, ik woon alleen	(0)
2.	Met 1 person	(1)
3.	Met 2 of meer personen	(2)
4.	Wil ik niet zeggen	(99)

Page 29
Validation (VAL)

Voordat u de survey verlaat, heeft de onderzoeker nog een laatste verzoek.

Wilt u nog **één keer** benaderd worden door M. Costanzo om uw antwoorden verder toe te lichten?

1.	Ja	(1)
2.	Nee	(0)

[if VAL = 1]

M.Costanzo mag mij eenmaal benaderen op dit mailadres: [*string].*

Page 30
{IntroEnding}
Hartelijk dank voor uw deelname aan dit onderzoek.

Total 7.5 min

Appendix B: Dimension reduction results

Rotated Component Matrix[a] (Hygiene measures N=261)

	Component						
Column1	1	2	3	4	5	6	7
ATTben	0.839						
ATTcomp	0.887						
ATTgen	0.899						
ATTint	0.892						
BAR1							
BAR2							
BEH1_nosympt						0.558	
BEH2_nosympt						0.846	
BEH3_nosympt						0.477	
BEN1		0.180					
BEN2		0.364					
S.ATTgen	0.090	0.358	0.307	0.317	-0.022	0.429	0.279
S.ATTimp	0.285	0.677	0.097	0.238	0.001	0.119	0.052
SEE1			0.786				
SEE2			0.845				
SEVother3				0.160			0.779
SEVself1				0.558			0.453
SEVself2				0.788			0.135
SUSother3					0.341		
SUSself1					0.882		
SUSself2					0.876		

Extraction Method: Principal Component Analysis.

a. Rotation converged in 7 iterations.

Rotated Component Matrix[a] (Distancing measures N=263)

	Component						
Column1	1	2	3	4	5	6	7
ATTben	0.830						
ATTcomp	0.891						
ATTgen	0.923						
ATTint	0.840						
BAR1							-0.007
BAR2							0.154
BEH1_nosympt		0.721					
BEH2_nosympt		0.685					
BEH3_nosympt		0.832					
BEN1						0.267	
BEN2						0.246	
S.ATTgen	0.133	0.485	0.319	0.404	-0.034	0.082	0.270
S.ATTimp	0.328	0.236	0.039	0.369	0.065	0.571	0.099
SEE1			0.798				
SEE2			0.748				
SEVother3				0.802			
SEVself1				0.727			
SEVself2				0.192			
SUSother3					0.622		
SUSself1					0.849		
SUSself2					0.862		

Extraction Method: Principal Component Analysis.

a. Rotation converged in 8 iterations.

Rotated Component Matrix[a] (Mobility measures N=252)

	Component						
Column1	1	2	3	4	5	6	7
ATTben	0.865						
ATTcomp	0.891						
ATTgen	0.906						
ATTint	0.889						
BAR1							0.242
BAR2							0.408
BEH1_nosympt						0.799	
BEH2_nosympt						0.792	
BEH3_nosympt						0.214	
BEN1			-0.145				
BEN2			0.401				
S.ATTgen	0.155	0.164	0.570	0.383	0.033	0.163	-0.102
S.ATTimp	0.311	0.266	0.224	0.305	0.095	-0.011	-0.635
SEE1		0.678					
SEE2		0.764					
SEVother3				0.236			
SEVself1				0.701			
SEVself2				0.854			
SUSother3					0.377		
SUSself1					0.855		
SUSself2					0.867		

Extraction Method: Principal Component Analysis.

a. Rotation converged in 8 iterations.

Appendix C: Factor loadings threshold

Using the suggested significance test at α=0.01 (two-tailed test), the obtained factor loadings for each category are presented in Table X. These loadings represent the doubled critical values (CVs) obtained from the interpolation of the values from Stevens (2002). The interpolation was followed using $y = -0.0002x + 0.2629$, where *x = sample size (n)* and *y = critical value (CV)*. For instance, the factor loading for the hygiene measures with N=261, should be at > 2*(0.211) in absolute value to be considered significant for a reliable component.

Table 33: Critical values based on sample size (Stevens, 2002)

Critical Values for a Correlation Coefficient at α = .01 for a Two-Tailed Test

n	*CV*	*n*	*CV*	*n*	*CV*
50	.361	180	.192	400	.129
80	.286	200	.182	600	.105
100	.256	250	.163	800	.091
140	.217	300	.149	1000	.081

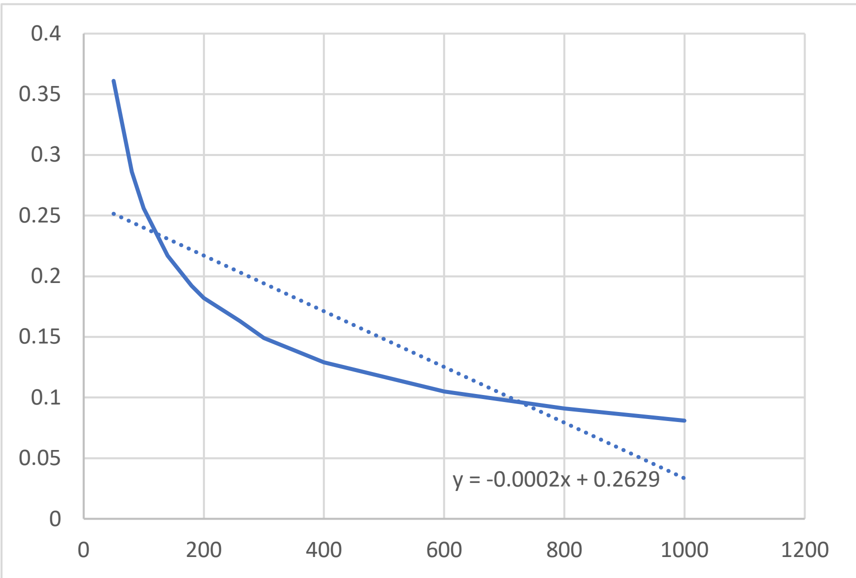

Figure 15: Interpolation equation to obtain critical values for other sample sizes

Table 34: Obtained critical values for the specific mitigation categories' samples

Category	**Sample size**	**CV**	**Factor loading**
Hygiene	261	0.211	|0.421|
Distancing	263	0.210	|0.421|
Mobility	252	0.213	|0.425|

Appendix D: Multinomial logit regression results

Case Processing Summary

		N	Marginal Percentage
CM_users	,00	541	69.7%
	1,00	235	30.3%
Valid		776	100.0%
Missing		1	
Total		777	
Subpopulation		112	

Model Fitting Information

		Model Fitting Criteria	Likelihood Ratio Tests		
Model	Model	-2 Log Likelihood	Chi-Square	df	Sig.
Demographic	Intercept Only	316.526			
	Final	282.103	34.424	4	0.000
Health	Intercept Only	377.888			
	Final	364.496	13.392	4	0.010

Classification

		Predicted		
Model	Observed	,00	1,00	Percent Correct
Demographic	,00	528	13	97.6%
	1,00	228	7	3.0%
	Overall Percentage	97.4%	2.6%	68.9%
Health	,00	541	0	100.0%
	1,00	236	0	0.0%
	Overall Percentage	100.0%	0.0%	69.6%

Goodness-of-Fit

Model		Chi-Square	df	Sig.
Demographic	Pearson	107.357	107	0.472
	Deviance	123.751	107	0.128
Health	Pearson	255.711	128	0.000
	Deviance	226.029	128	0.000

Pseudo R-Square

Demographic	Cox and Snell	0.043
	Nagelkerke	0.061
	McFadden	0.036
Health	Cox and Snell	0.017
	Nagelkerke	0.024
	McFadden	0.014

Likelihood Ratio Tests					
		Model Fitting Criteria	Likelihood Ratio Tests		
Model	Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Demographic	Intercept	319.922	37.819	1	0.000
	GEN	283.067	0.964	1	0.326
	AGE	294.801	12.698	1	0.000
	EDU	304.468	22.365	1	0.000
	HOU	282.215	0.113	1	0.737
Health	Intercept	365.341	0.845	1	0.358
	RG_self	369.405	4.910	1	0.027
	RG_other	364.564	0.068	1	0.794
	CIS	368.436	3.941	1	0.047
	VAC	366.372	1.877	1	0.171

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

Parameter Estimates										
									95% Confidence Interval for Exp(B)	
Model	CM_users[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	Lower Bound	Upper Bound
Demographic	,00	Intercept	2.660	0.377	49.777	1	0.000			
		GEN	0.034	0.060	0.318	1	0.573	1.034	0.920	1.162
		AGE	-0.344	0.097	12.481	1	0.000	0.709	0.585	0.858
		EDU	-0.304	0.065	21.706	1	0.000	0.738	0.650	0.839
		HOU	0.009	0.031	0.091	1	0.763	1.009	0.949	1.073
Health	,00	Intercept	0.369	0.391	0.893	1	0.345			
		RG_self	-0.377	0.169	5.008	1	0.025	0.686	0.493	0.954
		RG_other	-0.020	0.077	0.068	1	0.794	0.980	0.844	1.139
		CIS	0.160	0.088	3.291	1	0.070	1.173	0.987	1.395
		VAC	0.035	0.041	0.713	1	0.399	1.035	0.955	1.122

a. The reference category is: 1,00.

Appendix E: Stated behaviour results

The left-hand side of Figure 16 and Figure 17 outline the observed behaviour of users and non-users in the studied two symptomatic contexts. The right-hand side of Figure 16 and Figure 17 outline the stated behaviour of users and non-users in the studied two symptomatic contexts. The stated behaviour scores are the result of vignette questioning, where also non-users were asked to respond with the hypothetical utilization of the CoronaMelder. As shown, the differences among users and non-users dissipate in the hypothetical situation. Another divergent aspect is provided by the lowest relative compliance with the mobility measures in the hypothetical situation, whereas the observed lowest relative compliance was found for the distancing measures.

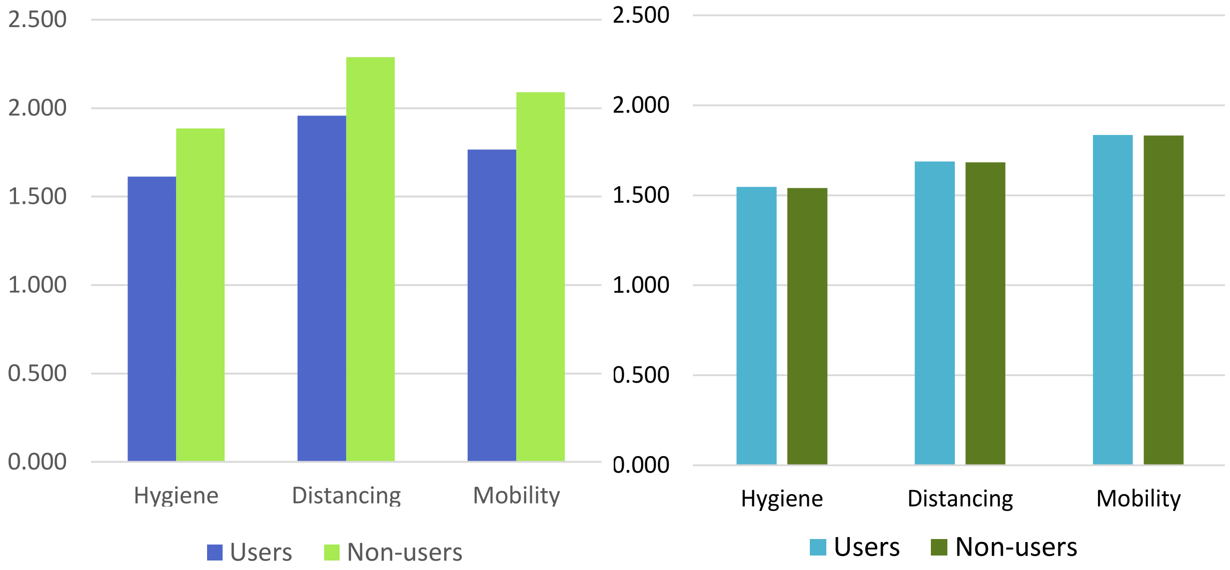

Figure 16: Observed behavioural compliance (**left**) and the stated behavioural compliance (**right**) of users and non-users in the asymptomatic context.

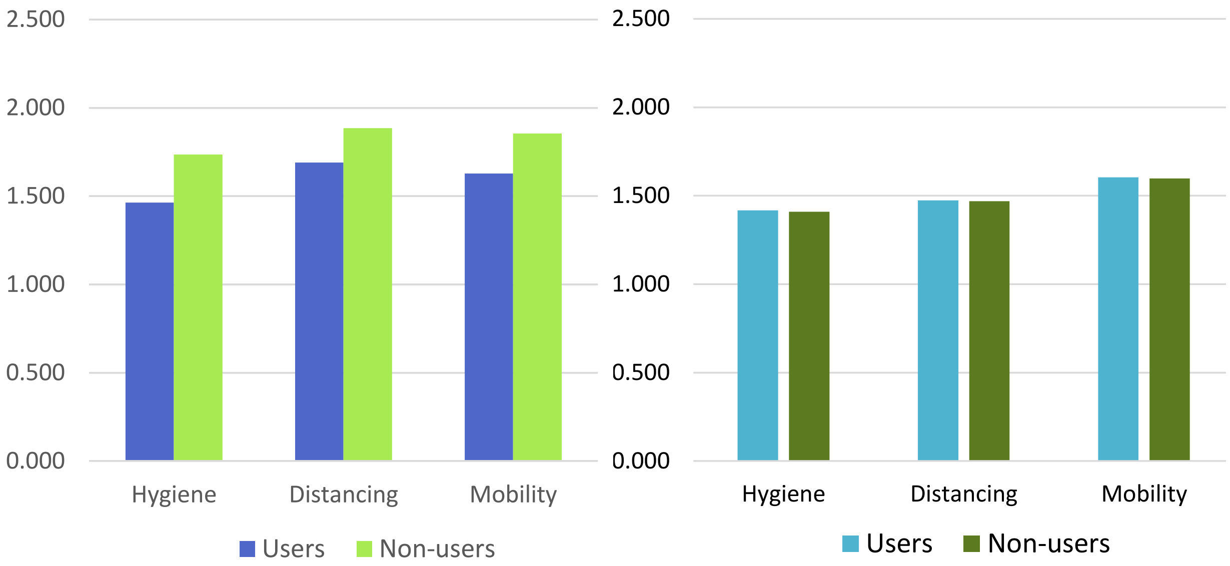

Figure 17: Observed behavioural compliance (**left**) and the stated behavioural compliance (**right**) of users and non-users in the symptomatic context.