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Health Protective Behaviours during the COVID-19 pandemic: Risk Adaptation or Habituation?

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Highlights

- Health protective behaviours considerably varied from March 2020 to September 2021.
- Engagement in protection was positively associated with the COVID-19 death incidence.
- Time exerted however a negative effect on the adoption of protective behaviours.
- Risk adaptation and habituation explain the response to the health threat over time.

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Health Protective Behaviours during the COVID-19 pandemic: Risk Adaptation or Habituation?

Abstract

Many epidemiological works show that human behaviours play a fundamental role in the spread of infectious diseases. However, we still do not know much about how people modify their Health Protective Behaviours (HPB), such as hygiene or social distancing measures, over time in response to the health threat during an epidemic. In this study, we examined the role of the epidemiological context in engagement in HPB through two possible mechanisms highlighted by research in the field of decision-making under risk: risk adaptation and risk habituation. These two different mechanisms were assumed to explain to a large extent the temporal variations in the public's responsiveness to the health threat during the COVID-19 pandemic. To test them, we used self-reported data collected through a series of 25 cross-sectional surveys conducted in France among representative samples of the adult population, from March 2020 to September 2021 (N=50,019). Interestingly, we found that both mechanisms accounted relatively well for the temporal variation in the adoption of HPB, which is remarkable given their different assumptions about the underlying social cognitive processes involved in response to a health threat. These results suggest that strengthening the incentives for people to adopt HPB is crucial in critical settings, and that public health interventions should be designed to counter risk habituation effects over time.

Keywords: Risk adaptation, risk habituation, prevalence-elasticity, health protective behaviours, COVID-19

1. Introduction

The COVID-19 pandemic highlighted the need to better understand the complex interplay between human behaviours and the epidemiological environment in which people live. However, the role of such context in the decisions that people make to prevent or control the risk of infection during epidemics or pandemics remains largely unknown. Moreover, while epidemiologists and biomodelers have developed increasingly sophisticated epidemiological models to predict the spread of infectious diseases, these models are still insufficiently based on individual human behaviours (Lorig et al., 2021; Verelst et al., 2016). Instead, the individual decisions to adopt Health Protective Behaviours (HPB) for preventing or reducing health risks are simply ignored or represented by an exogenous proportion of the population which is considered as protected, independently from the evolution of the infection risk over time. Although some epidemiological models attempted to endogenize the protection decision, like economic-epidemiological models, the way to model the relationship between the adoption of HPB and the epidemiological context remains a major issue. Therefore, it seems important to investigate here the relationship between the adoption of HPB and contextual variables through two different social cognitive mechanisms: risk adaptation and risk habituation.

1.1. Social and epidemiological context

Our paper examines individual decisions to engage in HPB during the COVID-19 pandemic in France from March 2020 to September 2021. Thus, the studied period covers four epidemic waves. During the first wave in Spring 2020, people did not have prior experience with the virus and they were not used to being protected. In addition, there were not enough facemasks to protect the entire population. The French government implemented a strict lockdown from 17 March to 10 May 2020 to reduce the spread of the epidemic. After this lockdown, restrictions were progressively lifted. A second lockdown was imposed during the

second wave, from 30 October to 14 December 2020, in which people had to stay at home but schools remained open. After the second wave, the incidence level was still high, which motivated the French government to maintain restrictions through many curfews from 15 December 2020 to 19 June 2021. During this period, to control the third epidemic wave, a third lockdown was implemented from 3 April to 2 May 2021, in which travel was allowed within a 10-km radius of one's home. From June to September 2021, restrictions were lifted, although France was experiencing the fourth epidemic wave. At the same time, from 26 December 2020, people were allowed to be vaccinated according to their age. Since 15 June 2021, vaccination has been available for all French adults. Furthermore, from 1 July 2021, access to leisure activities and long distance public transport was subject to holding a health pass obtained following vaccination or a negative COVID test.

In France, management of the pandemic crisis was essentially based on hospitalisation rates, and the evolution of the reproduction number of the disease. Other countries, like the United Kingdom, based their policies on the dynamics of human behaviour to avoid demotivating people, but were accused of mismanaging the crisis (Abbasi, 2020). It is clear that the responsiveness of human behaviour to the epidemiological context is a crucial element in predicting the spread of the pandemic and in reducing the health threat. An epidemiological context can be defined by a large range of variables related to the strength and severity of the infection, such as the incidence of cases and deaths in the region, the contagiousness of the disease, the proportion of immunised or naive patients, the hospitalisation or death rate, and so on. In this research, we focused on the actual risk of being infected and the time of exposure to the threat, as these two contextual variables are central to specific social cognitive mechanisms - risk adaptation and risk habituation - which have been proposed in the literature to explain temporal variation in an individual's engagement in HPB (Johnson and Mayorga, 2020; Raude et al., 2019; Loewenstein and Mather, 1990).

1.2. Risk adaptation

During the last decades, a variety of definitions of the term 'adaptation' have been used in the social and behavioural sciences. Initially developed by biologists, this term is now widely employed in the fields of psychology, sociology, anthropology, and even geography. Here, we will use the American Psychological Association's definition, according to which adaptation refers to "modification to suit different or changing circumstances. In this sense, the term often refers to behaviour that enables an individual to adjust to the environment effectively" (APA, 2022)[1]. Consistent with this definition, the term generally refers in public health to a set of measures that people take to reduce or eliminate a given health risk. More precisely, the concept of risk adaptation embraces the idea that engagement in preventive behaviours depends on the risk magnitude. Applied to infectious diseases, adaptation implies that individuals engage in HPB depending on observable changes within the epidemiological context. If individuals have an accurate perception of risk, then they are likely to be more cautious when the risk of being infected increases (and conversely). In health economics, the adaptation to infectious risk through HPB is captured and measured through a concept called "prevalence-elasticity". This concept was developed by Geoffard and Philipson (1996) to explain the temporal and spatial variations in the adoption of HPB when faced with the risk of HIV infection. In a SI (Susceptible-Infected) model representing the HIV epidemic, they analysed the incentives of an individual to adopt HPB to avoid catching the disease. An individual is assumed to compare the cost of protection (the loss in utility from being protected rather than exposed) with the expected cost of risking infection (the expected future utility of being infected rather than susceptible). Geoffard and Philipson demonstrated that the individual protective decision related to AIDS/HIV depends on prevalence level. If the current level is higher than a

[1] Available online: https://dictionary.apa.org/adaptation (accessed September 22, 2022).

prevalence threshold, then the individual prefers to be protected in the current period. In the reverse case, he chooses to be exposed. This pioneering work pushed epidemiological models to take account of risk adaptation, leading to "economic-epidemiological models" (Chan et al., 2015; Reluga, 2010), some of which are related to the COVID-19 epidemic (Farboodi et al., 2021; Makris, 2021).[2] It is now natural to model the probability of engaging in HPB as a positive function of the prevalence level.

In their seminal study, using longitudinal data collected from surveys conducted in San Francisco from 1983 to 1992, Geoffard and Philipson showed that men reduce their exposure to the risk of being infected with HIV as the prevalence rate among the respondents increases. In other words, they adopt prevalence-elastic HPB. Moreover, many other empirical studies have since found such a behaviour towards the risk of HIV infection (Guillon and Thuilliez, 2015). Among these studies, the decision to engage in HPB depends on either the prevalence level (Oster, 2012; Young, 2007) or the incidence level (Godlonton and Thornton, 2013; Boucekkine et al., 2009). The existence of prevalence-elastic HPB was also shown for other diseases. There is strong evidence that the use of mosquito nets is positively correlated with Malaria prevalence in tropical countries (Picone et al., 2017; Seban et al., 2013). In other studies investigating diseases for which vaccination exists (and immunisation is achieved), such as measles, it was found that parents were more likely to vaccinate their children as prevalence increases (Philipson, 1996). In the same way, more individuals were found to be vaccinated as the annual duration of the influenza epidemic increased (Mullahy, 1999). Regarding influenza vaccination, individual decisions were positively influenced by the influenza prevalence, not only for the current year but also that of the previous year (Li et al., 2004).

[2] See McAdams (2021) for a literature review on economic-epidemiological models.

To the best of our knowledge, Battiston and Gamba (2021) are the only researchers to have found a positive relationship between HPB and COVID-19 prevalence. More precisely, using temporal data collected from March to April 2020 during the strict lockdown in Italy, they showed a negative correlation between the initial COVID-19 prevalence level and the basic reproduction number, meaning that individuals adopted HPB in response to the high initial infection risk. Other studies focusing on the relationship between HPB and perceived risk offered mixed evidence. Indeed, some studies highlighted a positive and significant relationship (Wambua et al., 2022; Qin et al., 2021; Schneider et al., 2021) whereas others showed no significant effect of perceived risk on the adoption of HPB (Fullerton et al., 2021; Zickfeld et al., 2020). In the current study, we will test whether the adoption of HPB changes over time with the actual infection risk, which was captured through the death incidence level.

1.3. Risk habituation

Contrary to that of risk adaptation, the concept of risk habituation has not been extensively investigated in the field of infectious diseases. In psychology, the term "habituation" refers generally to the process of growing accustomed to a threatening situation or stimulus. More precisely, it can be defined as "the diminished effectiveness of a stimulus in eliciting a response, following repeated exposure to the stimulus" (APA, 2022)[3]. In public health, risk habituation refers to the mechanism through which "people tend to underestimate progressively or neglect risks as a health threat becomes increasingly familiar" (Raude et al., 2019). The habituation effect thus provides an explanation for the reduced effect (or the absence of effect) of infection risk on the adoption of HPB over time. Such an effect was suggested to explain the lack of correlation between perceived risk and protective measures in the literature. Based on longitudinal data, Lima (2004) showed that people living closer to an incinerator have

[3] Available online: https://dictionary.apa.org/habituation (accessed September 22, 2022).

a lower estimation of risk and adopt less extreme attitudes, which suggests habituation effects in terms of attitudes and risk perception. Previously, in the field of technological risk, such effects were also found on the basis of cross-sectional data. For instance, van der Pligt et al. (1986) highlighted a familiarity effect for residents living near a nuclear power station. Indeed, they were more optimistic than people living further from the station.

In the current literature, a habituation effect has only been highlighted to explain changes in perceptions of the risk of being infected by mosquito-borne diseases. Using a longitudinal study of a large epidemic of a mosquito-borne disease, Raude et al. (2019) found that the adoption of preventive behaviours varied positively with disease prevalence, validating the hypothesis of risk adaptation. However, they also showed that participants' perceived personal risk of infection decreased over time. This latter phenomenon could be the result of a risk habituation effect. Overall, the hypotheses of risk adaptation and risk habituation are usually presented as competing to explain engagement in HPB, but they are not necessarily incompatible. Indeed, individuals can adopt HPB as a response to an increase in disease incidence and this effect can also decrease over time.

It should be noted that in the context of the COVID-19 pandemic, similar concepts to that of risk habituation - such as "behavioural fatigue" or "pandemic fatigue" - have been increasingly used and discussed. In particular, pandemic fatigue was cited for a long time by some countries, like the United Kingdom, as the reason that people were unable to comply with health recommendations such as self-isolation (Reicher and Drury, 2021; Abbasi, 2020). They hypothesised that pandemic fatigue would have thus led the public authorities to delay the implementation of lockdown policies. Pandemic fatigue has been defined by the World Health Organization (2020) as "demotivation to follow recommended protective behaviours, emerging gradually over time and affected by a number of emotions, experiences and perceptions". Nonetheless, this definition is not canonical and fatigue could be based on many explanations

(Michie et al., 2020). Moreover, there is still a debate as to whether the phenomenon really exists. Indeed, some authors consider that pandemic fatigue could be simply a naive construct or a policy contrivance (Harvey, 2020). This conclusion is supported by the engagement in hygiene measures and social distancing that has remained high since the beginning of the COVID-19 epidemic in some cross-sectional studies (Dixon et al., 2022; Smith et al., 2022). However, others found a decreasing trend of engagement in social distancing, which could be evidence in favour of such a phenomenon (Schaner et al., 2022; Franzen and Wöhner, 2021). In particular, based on longitudinal data collected in 14 countries from March to December 2020, Petherick et al. (2021) showed that mask wearing was associated with a linear increase in adherence to this behaviour, but physical distancing was associated with a decline over time, which was increasingly low, with small rebounds in later months.[4]

In our study, rather than using the concept of fatigue, which is still subject to many criticism, we thought it more relevant to investigate the mechanism of risk habituation. The difference between these concepts is that risk habituation clearly rests on a precise definition, as the term refers to an increasingly smaller response to a repeated threatening stimulus over time, whereas the demotivation concept underlying the notion of pandemic fatigue appears to be much more ambiguous. Although there exists evidence to support a temporally decreasing trend in the adoption of preventive behaviours, the "fatigue" concept is not well grounded theoretically, which prevents correctly capturing and measuring it. That is why we tested instead the risk habituation hypothesis, which seems to provide a more credible and refutable explanation of the demotivation to act phenomenon which was documented during the pandemic. For this purpose, we will examine whether there exists a correlation between time of exposure and the adoption of preventive behaviours, controlling for actual infection risk.

[4] For mask wearing, it seems that the authors did not take account of the shortage in masks that occurred at the beginning of the epidemic, which could naturally explain the linear increase over time that they observed.

Therefore, the main objective of this paper is to test the validity of the hypotheses of risk adaptation and risk habituation in the context of the COVID-19 pandemic, by determining to what extent an individual's engagement in HPB in response to a health threat is driven by these two important contextual factors.

2. Materials and methods

2.1. Participants and procedure

Our study of the attitudes towards the COVID-19 infection risk is based on cross-sectional data, collected through 25 online surveys conducted from March 2020 to September 2021 in France. Samples, which comprise N=50,019 responses, were representative of adults residing in France. Indeed, a stratified sampling method was adopted to recruit participants based on sex, age, occupation, community size and region recorded during the 2016 national general census conducted by the National Institute of Statistics and Economic Studies (INSEE).[5] Ethical approval was granted by the University Hospital Institute "Mediterranee Infection" Ethics Committee Marseille, France and the EHESP School of Public Health Office for Personal Data Protection.

The period covered a strict lockdown, two mild lockdowns and many curfews. Table 1 provides the number of observations concerned by national restrictions in France since the beginning of the epidemic.

[Insert Table 1]

2.2. Measures

[5] Surveys were conducted by the BVA research institute (https://www.bvagroup.com/en/about-us/).

In this research, the relationship between engagement in HPB and death incidence level was analysed. The latter corresponds to the number of deaths per day (7-day moving average). We captured the COVID-19 infection risk by the death incidence level rather than the prevalence level or the incidence level, which expresses numbers of COVID-19 cases, for two reasons. Firstly, these variables were not reliable due to the underdetection of symptomatic COVID-19 cases (Pullano et al., 2021; Shaman, 2021). Secondly, it is likely that individuals were more affected by the number of serious cases rather than the number of symptomatic and non-symptomatic cases (Wambua et al., 2022; Qin et al., 2021). The death incidence level is a good proxy for the number of serious cases.

We measured engagement in HPB to reduce the risk of COVID-19 infection by asking participants to report whether in the last days they had adopted the following behaviours: "Avoid close contacts with other people" (social gatherings with people who do not live at home), "Do not shake hands", and "Wash hands often". The first behaviour corresponds to a social distancing measure while the others are related to hygiene measures. Participants answered "Yes, systematically", "Yes, often", "Yes, sometimes", or "No, never". As explained in a preliminary study (Raude et al., 2020), the responses revealed a ceiling effect in favour of the upper limit of the scale. That is why we created a dichotomous variable for each behaviour, coded as 1 for the "high compliance" response ("Yes, systematically"), and coded as 0 for the other options merged into a "lower compliance" category. Percentages of participants who reported engaging in HPB over time and death incidence level are displayed in Figure 1. For each percentage, we calculated 95% confidence intervals. The mask wearing has been excluded from our analysis because of the shortage at the beginning of the epidemic in France.

[Insert Figure 1]

As it was assumed that legal restrictions implemented in France since March 2020 may moderate the effect of infection risk on social distancing behaviours, we included in our analysis an index capturing the variations in restrictions over time. More precisely, the stringency index, developed by the Oxford COVID-19 Government Response Tracker (OxCGRT), indicates the strictness of 'lockdown style' policies, the purpose of which is primarily to restrict people's behaviour (Hale et al., 2022). It is an average score that falls between 0 and 1, comprising containment and closure policy indicators and a public information campaign indicator.

In each of our surveys, we also collected sociocultural and demographic variables. A wide range of items was included in the questionnaire, such as sex, age, education level (higher or lower than the High School Diploma) and socioeconomic status (high: self-employed and entrepreneurs, managerial and professional occupations, intermediate professions; low: employees, workers; inactive: students, others). Moreover, participants were asked how they perceived their financial situation (bad: "I cannot get there without debts", "I hardly get there"; good: "it is correct", "it is okay", "I am comfortable"). They also had to report whether they had personally suffered from signs or symptoms indicating a possible COVID-19 infection since February 2020 ("yes" or "no"). Finally, we asked participants to indicate the number of rooms in their housing and the living area to determine whether their housing was overcrowded, which might influence the number of social gatherings. Descriptive statistics of these sociocultural and demographic variables are provided in Table 2.

[Insert Table 2]

2.3. Statistical analysis

Our study focuses on the relationship between the engagement in HPB we measured and the epidemiological context represented by the infection risk (risk adaptation) and time (risk

habituation). As a first step, we used comparison tests to investigate whether the three preventive behaviours were associated with these two variables. We proceeded by t-tests to compare the mean death level according to the adoption of each HPB. Results are indicated in Table 3. Furthermore, we compared the proportions of individuals engaging in each HPB over time by Pearson's chi-square tests.

As a second step, we focused on the social distancing behaviour, which is avoiding close contacts with other people, because it exhibits more variance over time and varies more with the death incidence level than the two hygiene behaviours, in particular handwashing. Table 4 provides the results of Pearson's chi-square tests and t-test to assess the association between each sociocultural and demographic variable and the engagement in social distancing. To expand upon the determinants of the probability of adopting social distancing, as well as to control for the influence of sociocultural and sociodemographic variables, we performed a multivariate analysis. Table 5 reports the results of Probit regressions, in which the probability of avoiding close contacts with other people was the dependent variable. In Model (1), in order to estimate whether social distancing was incidence-elastic, we estimated a baseline specification in which we included the death incidence level, the stringency index, and time expressed by the number of days since 16 March 2020 (announcement by the French President of the strict lockdown). In Model (2), we added sociocultural and demographic variables to highlight potential differences in the degree of engagement in social distancing among participants.[6] In Model (3), we considered six interaction terms between the death incidence level and sociocultural and demographic variables to study whether the effect of these latter variables depended on infection risk. Finally, in Model (4), we controlled for context by

[6] These variables are: *Sex* equal to 1 if the participant if female; *Age* expressed in years; *History of COVID-like symptoms* equal to 1 if the participant reports an experience of COVID-19 infection; *Completed secondary school* equal to 1 if the participants holds the High School Diploma; *Low* equal to 1 if the participant's socioeconomic status is low; *Inactive* equal to 1 if the participant is inactive; *Financial situation* equal to 1 if the participant's financial situation is bad; and *Housing overcrowding* equal to 1 if the participant's housing is overcrowded.

including survey fixed effects. They capture the effects of time-specific variables - the death incidence level, the stringency index and naturally the survey day - which cannot be estimated with this specification.

As a last step, we measured the size of the relationship between the infection risk and engagement in social distancing, controlling for sociocultural and demographic variables. Table 6 reports the Probit COVID-19 incidence elasticities associated with Model (2) in Table 5. All data were treated and analysed using STATA 16.

3. Results

As shown in Figure 1, the engagement in HPB varies depending on whether the behaviour is related to hygiene or social distancing. From March 2020 to September 2021, the percentages of participants reporting systematically not shaking hands with other people and washing hands often varied from a minimum of 58.8% (31 August-7 September 2021) to a maximum of 92.8% (14-16 April 2020) and from a minimum of 58.6% (31 August-7 September 2021) to maximum of 76.5% (30 March-1 April 2020) respectively. By contrast, the percentage of participants reporting systematically avoiding close contacts with other people varied from a minimum of 32.8% (31 August-7 September 2021) to a maximum of 90.3% (30 March-1 April 2020). Thus, not shaking hands and handwashing, which correspond to hygiene measures, exhibit a lower variance than the reduction of contacts with other people, which relates to social distancing. Overall, contrary to hygiene measures, we do not observe in France that engagement in physical distancing has remained high over time.

We examined the relationship between the adoption of HPB and the two aforementioned contextual variables. We can identify in Figure 1 the different epidemic situations since March 2020. Our data covers the four first epidemic waves in France (2020 spring, 2020 autumn, 2021 winter and spring, 2021 summer). The death incidence level corresponding to different survey

times varied from a minimum of 12 (20-22 July 2020) to a maximum of 772 (14-16 April 2020) deaths per day. In particular, it is interesting to note that an increase (reduction) in the death incidence level corresponds to an increase (reduction) in the engagement in social distancing, except for 5 surveys. To better visualise the relationship between the adoption of HPB and the infection risk, we represented the mean adoption level in function of the number of deaths per day in Figure 2. Each graph suggests an increasing relationship between both variables. We confirmed the existence of such an association by comparing the mean death incidence level according to engagement in HPB. As shown in Table 3, there is a significant positive association between the death incidence level and the engagement in each HPB.

[Insert Figure 2]

[Insert Table 3]

Figure 1 also highlights the trends of adoption of a variety of preventive behaviours over time. Indeed, between the first and the last survey wave, the percentages of participants reporting systematically not shaking hands with other people and washing hands often decreased by 33.59 points and 17.97 points respectively. At the same time, the percentages of participants adopting social distancing decreased by 57.53 points. To test whether these differences reflect a negative temporal trend, we looked at the differences in the proportions of people engaging in preventive behaviours. The proportions are significantly different for each behaviour ("Avoid close contacts with other people": $\chi^2(24)=7{,}280.9$, $p<0.01$; "Do not shake hands": $\chi^2(24)=2{,}641.2$, $p<0.01$; "Wash hands often": $\chi^2(24)=393.24$, $p<0.01$), which suggests a negative trend of time on the engagement in HPB.

As social distancing - i.e. avoiding close contacts with other people - is the HPB that varies the most with the infection risk and over time, our multivariate analysis of the relationship between the engagement in HPB and the epidemiological context focused on this

behaviour. As reported in Table 5, death incidence level is positively correlated with the decision to engage in social distancing. This relationship is robust to the effects of legal restrictions and the effects of sociocultural and demographic variables. It seems that participants reacted to the infection risk by avoiding social gatherings, that is social distancing seems to be an incidence-elastic behaviour.

[Insert Table 4]

[Insert Table 5]

To measure precisely how the engagement in social distancing varies with the death incidence level, we also examined the average partial effect and the elasticities of engagement with respect to the death incidence level derived from Model (2). We see in Table 6 that 100 additional deaths per day increases on average the probability of engagement in social distancing by 2.4 percentage points. Furthermore, the elasticity at the average and the average of elasticity are smaller than 1, meaning that the engagement in social distancing is weakly elastic to the infection risk.

[Insert Table 6]

We also investigated the effect of time on the adoption of social distancing. Our multivariate analysis in Table 5 confirms the negative effect of time on the probability of adopting social distancing. This negative effect is robust, regardless of legal restrictions and sociocultural and demographic variables. The mechanism of risk habituation states that people are increasingly less sensitive to the stimulus with time. Here the stimulus is the infection risk, which is captured by the death incidence level. That is why we analysed whether the effect of time depends on the death incidence level. In this way, Model (3) included an interaction term

between time and death incidence level. This interaction term was negative and significant, meaning that the negative effect of time slightly increases with the infection risk.

Furthermore, our results concern the effects of legal restrictions and sociocultural and demographic variables on the probability of adopting social distancing. As indicated in Model (2) in Table 5, the probability of adopting social distancing increases with the stringency index, suggesting that people tended to comply with restrictions imposed by the French government. Regarding sociocultural and demographic variables, Table 4 displays significant differences in the engagement in social distancing. Model (2) in Table 5 allows us to confirm that being a woman, being elderly, having a low socioeconomic status or being inactive, and living in overcrowded housing were found to be associated with a higher degree of engagement in social distancing. Moreover, contrary to the univariate analysis in Table 4, feeling poor was positively correlated with the adoption of social distancing. By contrast, no significant effect on the engagement in social distancing was found for having been infected by COVID-19 infection or holding a High School Diploma.

Because individuals could react differently to the infection risk depending on their sex or their socioeconomic status for example, we also examined the interactions between the death incidence level and sociocultural and demographic variables in Model (3). First, it appears that the interaction term between sex and incidence was positive and significant. Women were typically more cautious than men in epidemic times, and this difference in reaction to the health threat is increasing with the death incidence level. More counter-intuitively, Model (2) showed that the wealthier participants were, the less cautious they were. In Model (3), the interaction terms between socioeconomic status and the engagement in social distancing were negative and significant, revealing that this relationship depended on the death incidence level. Thus, we observed a convergence mechanism between socioeconomic status, in terms of social distancing, as the death incidence level increased. In other words, wealthier people tended to

be more negligent than poorer people when the number of deaths per day was low, and they became more cautious as the number of deaths per day increased.

4. Discussion

On the basis of the existing literature, we identified two possible mechanisms explaining the adoption of HPB during an epidemic and tested them against the behaviours reported by the adult population in a series of 25 cross-sectional surveys conducted during the two first years of the COVID-19 pandemic in France. These mechanisms, that are risk adaptation and risk habituation, may be considered competitive, or even mutually exclusive to explain human behaviour in response to an emerging health threat. In other words, either the engagement in HPB depends on risk magnitude, or it depends on time. To the best of our knowledge, our study is the first to reveal the simultaneous existence of risk adaptation and habituation in the dynamic of HPB during an epidemic. On the one hand, we showed that the engagement in social distancing was a positive function of the COVID-19 infection risk, confirming the mechanism of risk adaptation. Social distancing is an incidence-elastic preventive behaviour during an epidemic but the elasticity is smaller than 1, meaning that the engagement in social distancing is only slightly elastic to the death incidence level. Previous literature showed such incidence- or prevalence-elastic behaviours in epidemics such as HIV, HPV, malaria, measles or influenza, but not during the COVID-19 epidemic. This exception may be due to the implementation around the world of exceptionally stringent policies affecting social behaviours in the attempt to control the spread of the disease (Al-Zubaidy et al., 2021). On the other hand, we found a negative effect of time on the engagement in social distancing. Moreover, this negative effect seems to increase with the infection risk, suggesting that people get progressively accustomed to the risk over time. This is therefore difficult to maintain barrier measures at the same high level in the long term. Regarding infectious diseases, risk habituation is still an overlooked

process in the literature and we believe that it may represent a promising concept for future research.

Our study also contributes to the behavioural literature on epidemics by exploring the influence of sociocultural and demographic variables on the decision to engage in preventive behaviours. During the COVID-19 epidemic, as in previous epidemics (Bish and Michie, 2010; Seale et al., 2020), numerous studies showed that being a woman, being elderly or having a high level of formal education was positively associated with a higher probability of adopting preventive behaviours (Papageorge et al., 2021; Smith et al., 2021; Wright and Fancourt, 2021; Faasse and Newby, 2020). Consistent with this literature, we found that being a woman and being elderly was indeed positively correlated with the probability of engaging in social distancing. Moreover, women's HPB positively depended on the death incidence level, reflecting the fact that women are commonly more risk-averse than men (Croson and Gneezy, 2009). By contrast, having some college education did not have any significant effect on this behaviour. Surprisingly, we also found that a high socioeconomic status or perceived wealth was associated with a less protective behaviour. This relationship also depended on the death incidence level. The negligent behaviour associated with a high economic status reduced the infection risk. In other words, while more socio-economically advantaged people are less likely to engage in social distancing than those who are more disadvantaged, a convergence trend was observed among socioeconomic status when the infection risk increased.

Our study was motivated by the need to better understand how to model the individual interactions between HPB and the epidemiological context. Indeed, most epidemiological modellers still assume that the decision to engage in protection is exogenous, i.e., independent of the epidemiological context, or follows a fixed behavioural pattern (Lorig et al., 2021; Verelst et al., 2016). Based on our results, we recommend that models account for the adoption of HPB as a positive function of the infection risk and a negative function of time. To date, only

a few models, such as the economic-epidemiological models, have integrated infection risk and time as parameters. In these models, the expected cost of being infected increases with the infection risk, which makes the individual more likely to engage in protection, and future benefits and costs of being exposed or protected are discounted at a rate that represents the preference for the present. However, it should be noted that economic modelling is not the only one to include these variables, since agent-based models (Lorig et al., 2021), and more recently transmission models (Weitz et al., 2020), also integrate the infection risk and time in the agents' decision rule. Our results confirm the importance of developing these various types of modelling in future research (Bedson et al., 2021; Ferguson, 2007).

Our results may also help inform policy-makers on how to control the spread of future epidemics. On the one hand, risk adaptation means that people tend to adjust their HPB as a function of the spread of the disease. As shown in our study, people seem to use external cues to action based on epidemiological data to deal with the threat during an epidemic. In this context, when the epidemic situation is becoming critical, it could be relevant for policy-makers to support external cues, by implementing non-pharmaceutical interventions such as nudges which promote social distancing and hygiene measures. For instance, messages or posters were widely used during the pandemic and proved effective (Dai et al., 2021 ; Lunn et al., 2020). We believe that their use should be reinforced during the peak of the epidemic. On the other hand, while risk adaptation is a personal mechanism that is complementary to public action, risk habituation effects threaten the control of the spread of the epidemic, as people are less worried about contracting the disease and decreasingly responsive to the infection risk over time. In this matter, the challenge for policy-makers could be to deter habituation behaviours; here again it may be done by using behavioural nudges, i.e. messages disseminated over time.

Numerous studies focus on the effects of nudges on protective behaviours. In a systematic review, Epton et al. (2022) were interested in the effectiveness of interventions and

behaviour change techniques which promote adherence to physical distancing. They showed that future punishment, with government fines, are ineffective. By contrast, providing feedback on behaviour, through proximity buzzers, providing information about health consequences, with loss-framed messages on posters, and restructuring the physical environment, via directional systems, are effective techniques to promote physical distancing. Other techniques are still little tested in the existing studies and deserve more attention. Among them, social comparison and the provision of information about others' approval are techniques already used to nudge desirable behaviours in other contexts (Allcot and Kessler, 2019; Bicchieri and Xiao, 2009). There is some evidence that such nudges influenced engagement in social distancing during the COVID-19 pandemic (Martínez et al., 2021). Future experimental studies are welcomed to analyse how these nudges, based on social norms, might amplify the mechanism of risk adaptation whilst mitigating that of risk habituation.

4.1. Limitations

Although our study identifies significant effects of death incidence level and time on the adoption of social distancing, important mechanisms other than risk adaptation and risk habituation could contribute to explain these effects. Moreover, risk adaptation is captured in our analysis by the positive and significant effect of the death incidence level on the probability of engaging in social distancing. We assumed that this effect was caused by the fact that infection risk motivates people to take protective measures against COVID-19. Nonetheless, other factors could explain the variation of preventive behaviour with the infection risk. The main one is the above-mentioned constraint derived from social norms during an epidemic. Indeed, regarding the COVID-19 epidemic, perceived social norms were found to drive intentions (Scholz and Freund, 2021) and engagement in preventive behaviours (Hensel et al., 2022). As the death incidence level increases, the weight of social norms could encourage

people to engage in social distancing due to social pressure, but not due to fear of being infected. Other factors motivating an individual's responsiveness to the infection risk could be the desire to protect others or the desire to avoid future restrictions imposed by the government. In the absence of measures of these variables, it is not possible to favour one explanation over another.

In the same vein, our results are suggestive of a risk habituation effect, but we were not able to prove directly that people became accustomed to the infection risk over time. Indeed, we found a negative and significant effect of time on the probability of adopting social distancing. However, this negative effect could be due to a decrease in risk perception over time. Moreover, contrary to the hypothesis of risk adaptation, testing the hypothesis of risk habituation requires collecting longitudinal data among individuals. The problem with repeated cross-sectional data is that they do not capture how the preferences of individuals change over time. Our study compares the responsiveness to the infection risk of many individuals at different periods, but risk habituation is an individual mechanism that requires comparing the responsiveness of the same individual at different periods. In the literature, only a few studies of the COVID-19 epidemic use longitudinal data (Schaner et al., 2022; Petherick et al, 2021; Qin et al., 2021) and these studies generally cover only the first year of the pandemic, which prevents studying habituation to the infection risk over a sufficiently long period.

5. Conclusion

In this study, we investigated the relationship between the engagement in HPB and the epidemiological context. The objective was to determine whether the mechanisms of risk adaptation and risk habituation contributed to explaining engagement in HPB during the COVID-19 epidemic. Using 25 cross-sectional surveys conducted in France from March 2020 to September 2021, we found the infection risk was positively associated with the probability of engaging in HPB, consistent with a mechanism of risk adaptation. The engagement in HPB

was also found to decrease over time, which suggests a phenomenon of risk habituation. These results should encourage epidemiological models to consider the decision to engage in HPB as a positive function of the infection risk and a negative function of time. The existence of risk habituation should also be subject to special attention by policy-makers in the control of the spread of the epidemic. Finally, even though this study is the first to simultaneously highlight the existence of risk adaptation and risk habituation in an individual's HPB, the identification of these two mechanisms could be improved. In particular, we believe that future studies should be based on longitudinal data covering many epidemic stages and should control for social and cognitive variables that interfere with the decision to engage in HPB.

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Table 1: Legal restrictions in France since March 2020.

National restriction	Length	Observations	Description
First lockdown	17/03/20-10/05/20	10,013 (5 survey waves)	Strict lockdown in which people had to stay at home.
Second lockdown	30/10/20-14/12/20	4,000 (2 survey waves)	Mild lockdown in which people had to stay at home but schools were open.
Curfew to 6 p.m.	16/01/21-19/03/21	6,001 (3 survey waves)	Obligation to stay at home between 6 p.m. and 6 a.m.
Curfew to 7 p.m.	20/03/21-18/05/21	2,000 (1 survey wave)	Obligation to stay at home between 9 p.m. and 6 a.m.
Third lockdown	03/04/21-02/05/21	2,001 (1 survey wave)	Mild lockdown in which travel was allowed within a 10-km radius from his home.

Note: Other legal restrictions were imposed at the national level but no data were collected during these periods.

Table 2: Descriptive statistics.

Number of participants	50,019
Sex	
Male	46.1%
Female	53.9%
Mean age	49.23 (16.37)
History of COVID-like symptoms	
Yes	17.8%
No	82.2%
Completed secondary school	
Yes	71%
No	29%
Socioeconomic status	
High	48.9%
Low	38.9%
Inactive	12.2%
Financial situation	
Good	81.3%
Bad	18.7%
Housing overcrowding	
Yes	7.6%
No	92.4%

Note: Standard error in parentheses.

Table 3: Association between the death incidence attributable to COVID-19 and the engagement in three HPB.

	Mean death incidence level		
	Avoid close contacts with other people	Do not shake hands	Wash hands often
Yes	291.08	253.34	241.51
No	169.98	169.80	221.44
Difference	$\Delta = 121.10$***	$\Delta = 83.54$***	$\Delta = 20.07$***

Note: t-test for comparing the mean death incidence level according to engagement in the HPB. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Association between each sociocultural and demographic variable and the engagement in social distancing.

	Percentage/mean level of individuals engaging in social distancing	Association
All participants	53.8%	
Sex		$\chi^2(1) = 41.57$***
Male	52.2%	
Female	55.1%	
Age	51.11 (16.00)	$\Delta = 4.11$***
History of COVID-like symptoms		$\chi^2(1) = 29.67$***
Yes	51.2%	
No	54.3%	
Completed secondary school		$\chi^2(1) = 21.20$***
Yes	53.1%	
No	55.4%	
Socioeconomic status		$\chi^2(1) = 25.06$***
High	54.7%	
Low	53.4%	
Inactive	51.3%	
Financial situation		$\chi^2(1) = 1.23$
Good	53.7%	
Bad	54.3%	
Housing overcrowding		$\chi^2(1) = 4.64$**
Yes	52.1%	
No	53.9%	

Note: Standard error in parentheses. t-test for comparing the mean age according to the engagement in social distancing. Pearson's chi-square tests for comparing the proportions of individuals engaging in social distancing according to each sociocultural and demographic variable. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Effect of incidence and sociocultural and demographic factors on the probability of avoiding close contacts with other people.

	Probit estimation			
	(1)	(2)	(3)	(4)
Incidence	0.000657***	0.000685***	0.00112***	
	(4.00e-05)	(4.04e-05)	(0.000147)	
Stringency index	0.0194***	0.0199***	0.0196***	
	(0.000614)	(0.000619)	(0.000628)	
Time	-0.00103***	-0.00105***	-0.000322***	
	(4.18e-05)	(4.23e-05)	(5.80e-05)	
Incidence × Time			-4.04e-06***	
			(2.30e-07)	
Sex		0.171***	0.0933***	0.176***
		(0.0124)	(0.0185)	(0.0125)
Incidence × Sex			0.000367***	
			(6.52e-05)	
Age		0.0136***	0.0130***	0.0140***
		(0.000424)	(0.000617)	(0.000428)
Incidence × Age			3.54e-06*	
			(2.13e-06)	
History of COVID-like symptoms		0.00961	0.0102	0.00850
		(0.0156)	(0.0156)	(0.0157)
Completed secondary school		0.000514	0.00273	0.00235
		(0.0145)	(0.0145)	(0.0146)
Socioeconomic status				
Low		0.0362**	0.118***	0.0324**
		(0.0142)	(0.0204)	(0.0143)
Inactive		0.118***	0.228***	0.122***
		(0.0215)	(0.0312)	(0.0217)
Incidence × Low			-0.000392***	
			(6.96e-05)	
Incidence × Inactive			-0.000504***	
			(0.000107)	
Financial situation		-0.0460***	-0.0838***	-0.0488***
		(0.0157)	(0.0231)	(0.0158)
Incidence × Financial situation			0.000156*	
			(8.02e-05)	
Housing overcrowding		0.0929***	0.0960***	0.101***
		(0.0234)	(0.0234)	(0.0237)
Constant	-1.127***	-1.916***	-1.966***	0.556***
	(0.0405)	(0.0526)	(0.0619)	(0.0507)
Survey fixed effects	No	No	No	Yes
Observations	50,019	50,019	50,019	50,019
R-squared	10.07	11.84	12.45	13.28

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Probit COVID-19 incidence elasticities.

Dependent variable: Avoid close contacts with other people			
	Average partial effect	Elasticity at the average	Average of elasticity
Incidence	0.00024***	0.1166***	0.0889***
	(1.39e-05)	(0.0069)	(0.0050)

Note: Estimates derive from the model (2) in the Table 5, including stringency index, time, sex, age, history of COVID-like symptoms, education level, socioeconomic status, financial situation and housing overcrowding. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Percentages of participants engaging in HPB and death incidence level over time. Error bars are 95% confidence intervals.

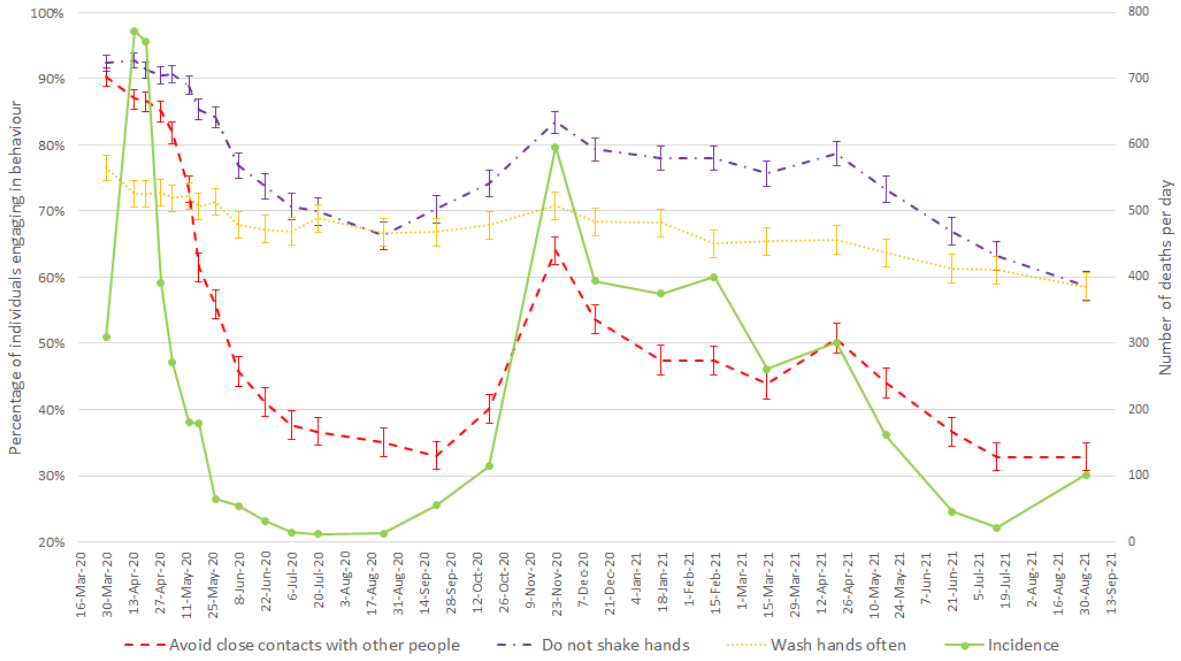
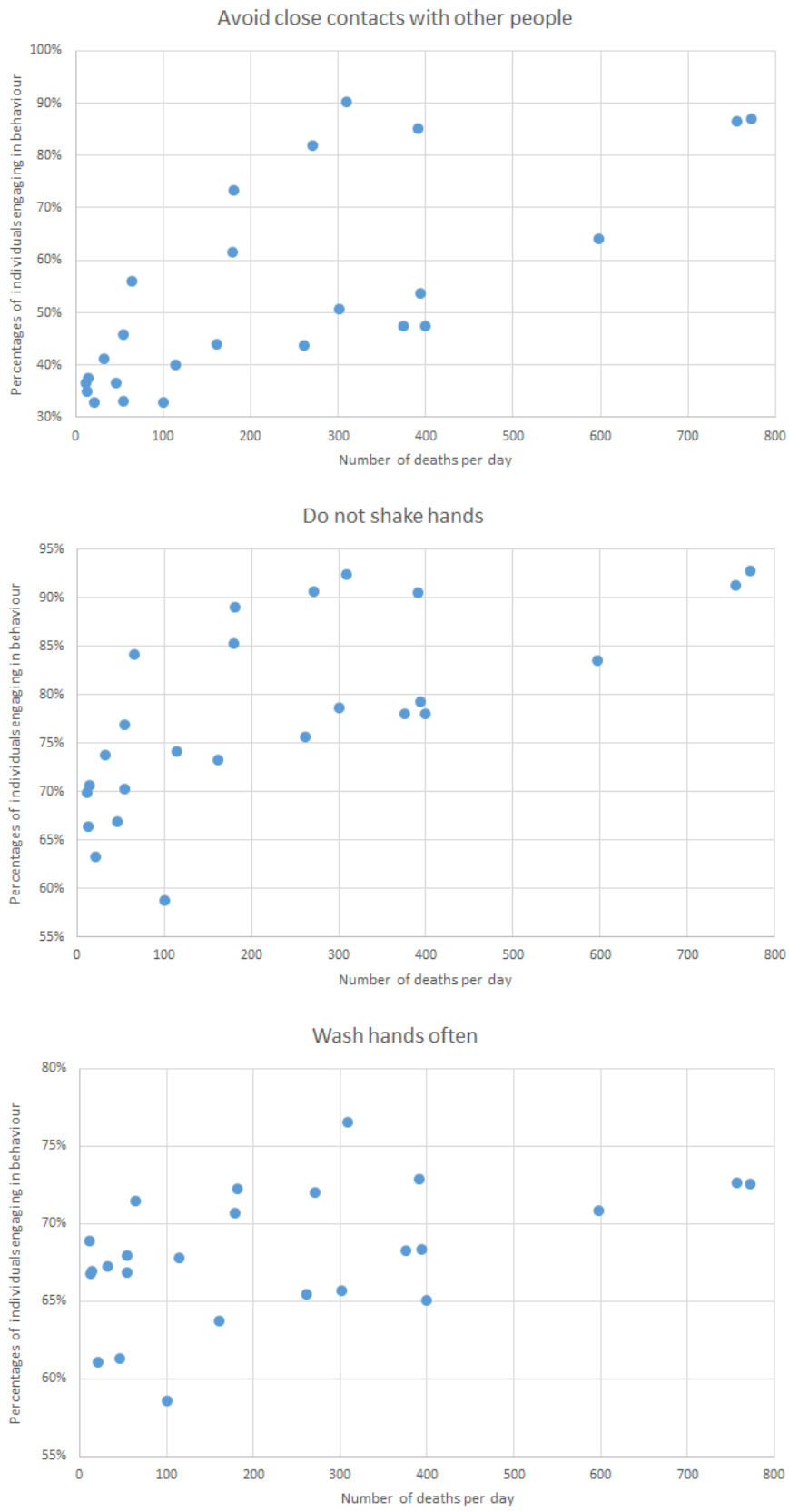
Figure 2: Association between death incidence and the engagement in each HPB.