Human health as a motivator for climate change mitigation: results from four European high-income countries

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Abstract

Invoking health benefits to promote climate-friendly household behavior has three unique advantages: (i) health co-benefits accrue directly to the acting individual, they are "private goods" rather than public ones; (ii) the evidence base and magnitude of health co-benefits is well-established; and (iii) the idea of a healthy life-style is well-engrained in public discourse, much more so than that of climate-friendly life-style. In previous research assessing the influence of information on health effects on people's motivation to adopt mitigation actions, health co-benefits for the individual were typically confounded with collective health co-benefits, for example from pollution reduction. The present research aims to overcome this limitation by providing information on individual health co-benefits that are unconditional on the actions of others (*direct health co-benefits*). We report effects of this kind of health information on stated preferences to adopt mitigation actions as well as on simulation-based carbon emission reductions in an experimental setting among 308 households in 4 mid-size case-study cities in 4 European high-income countries: France, Germany, Norway and Sweden. For each mitigation action from the sectors food, housing, and mobility, half of the sample received the amount of CO_2equivalents (CO_2-eq) saved and the financial costs or savings the respective action generated. The other half additionally received information on direct health co-benefits, where applicable. For households receiving information on direct health co-benefits, we find a higher mean willingness to adopt food and housing actions, and a greater proportion *very* willing to adopt one or more mitigation actions (OR 1.86, 95% CI 1.1, 3.12); and a greater simulated reduction in overall carbon footprint: difference in percent reduction -2.70%, (95% CI -5.34, -0.04) overall and -4.45%, (95% CI -8.26, -0.64) for food. Our study is the first to show that providing information on strictly unconditional, individual health co-benefits can motivate households in high-income countries to adopt mitigation actions.

Keywords: climate change, health co-benefits, mitigation, household preferences, health, behavior

Introduction

Climate change has far-reaching effects on human health (Myers and Patz 2009, IPCC, 2014, Woodward et al. 2014). The human health effects of climate change have been recognized as one of the greatest threats of mitigation failure (Costello et al., 2009; Patz, Campbell-Lendrum, Holloway, & Foley, 2005; Stern, 2007). However, with transformative mitigation policies, there are also numerous opportunities for health gains, the so-called *health co-benefits*. It is therefore no contradiction, when the latest Lancet report on climate change and health sees climate change as potentially „the greatest global health opportunity of the 21st century" (Watts et al., 2015). Health co-benefits arise when a policy or a behavior, which primarily addresses mitigation, also generates health benefits. One example is using active transport such as cycling or walking instead of fossil fuel powered cars, which not only saves emissions but also increases cardiovascular fitness. Scholars have increasingly advocated the use of health co-benefits of climate-friendly behavior as a motivator for adopting mitigation actions (Nisbet & Gick, 2008, Myers et al. 2012, Sauerborn et al., 2009). Health nevertheless constitutes the most understudied argument in existing climate communication studies, with the few existing studies yielding partially promising, but inconsistent results (Bain et al., 2016; Maibach et al., 2010; Myers et al., 2012).

Unconditional, individual health co-benefits have three advantages for communication and motivation:

(i) health co-benefits can accrue directly to the acting individual in addition to being contingent on other individuals to join in climate-friendly behavior. Conversely, in order to receive health co-benefits, individuals cannot "free ride". Health co-benefits are "private goods" as well as public ones.

(ii) the evidence base for and magnitude of health co-benefits is well-established, and can be gleaned from numerous epidemiological studies (e.g., Haines et al., 2007; Milner et al., 2015; Wilkinson et al., 2009; Woodcock et al., 2009)

(iii) the idea of a healthy life-style is well-engrained in public discourse, much more so than that of climate friendly life-style (Magnusson et al., 2003; DEFRA, 2002).

It may be argued that healthy life-styles, although widely talked about, are not necessarily implemented, and that therefore the health argument does not constitute a helpful addition to the climate change discourse. However, research on consumers` willingness to buy organic food, for example, showed that health impacts constitute a more important argument than environmental impacts – even though the health effects of organically grown food are ambiguous (Honkanen et al, 2006), and the health benefits for the individual consumer are far less supported than those for

the environment (Magnusson et al., 2003). Moreover, it was argued before that conceptualizing environmental actions as health actions may be useful (cf. Staub & Leahy, 2014). Therefore, effects on individual health may be a particularly compelling argument for individuals to implement mitigation actions (see Staub & Leahy, 2014 for a similar argument with respect to pro-environmental behavior more generally). From a policy angle, it is therefore surprising to note that the individual health benefits accruing to climate friendly vior are not (yet) a focus of communication to the public, and are not yet made salient enough in negotiations (Ganten, Haines, & Souhami, 2010; Sauerborn, Kjellstrom, & Nilsson, 2009). Consequently, health co-benefits are still largely underestimated by the public (Maibach et al. 2010). Here we focus on households as the target group for information on health co-benefits. Private households have been identified as key actors in global climate change mitigation (Aall & Hille 2010, Dubois & Ceron 2015, Sovacool 2014), and households in high-income countries influence up to 72% of global greenhouse gas emissions (Hertwich and Peters 2009).

Previous studies have tested the effectiveness of framing actions to reduce emissions—mitigation actions—around their benefits on human health, and yielded inconsistent results. In a national representative US sample, a health benefit frame (but, in contrast, not an environmental risk or national security frame), elicited positive emotional responses such as hopefulness, which are believed to be more in line with mitigation policy support than negative emotional responses such as anger (Myers et al., 2012). In two large US samples, however, a health frame emphasizing the benefits of combatting climate change on human health was ineffective in fostering support for climate change mitigation (Bernauer & McGrath, 2016).

A shortcoming of previous studies that estimated the effectiveness of health co-benefits on people's support for mitigation actions is their confounding with the *collective action problem*. One example is cleaner air, as it is certainly a laudable public health goal—but only achievable by collective action. An individual who chooses to reduce flying is helping to achieve the goal of lower global emissions, but (may) only benefit personally from this action indirectly, i.e. if others contribute as well. Bernauer and McGrath (2016; Supplementary material, p.6) use the framing *"using cleaner forms of energy—such as solar and wind power—will reduce air and water pollution, thereby preventing many forms of illness."*. Such a frame can only be expected to induce behavioral change if the addressee believes that a sufficiently high portion of society also contributes to the collective good of, for example, clean air. The mitigating actions of others are fundamentally uncertain, however, so that people may choose to not contribute to the public good of cleaner air, but to free-ride instead. A counter-example is eating less meat, which also helps to achieve lower emissions and hereby contributes to a public good (Aston, Smith, &

Powles, 2012), but additionally reduces risks for cardiovascular disease, type 2 diabetes and colorectal cancer, a direct and unconditional health co-benefit for the individual (Milner et al., 2015).

Thus, we do not contend that the concept of individual and unconditional health co-benefits will solve the collective action problem - for health effects to achieve a demonstrable climate effect, a sufficiently high portion of society still needs to contribute. However, the fact that some health co-benefits are unconditional on the actions of others render them a particularly valuable tool as they help to preempt the debilitating effects of free-riding.

By confounding direct and unconditional health effects for the individual with common public goods, the effectiveness of framing mitigation in terms of its co-benefits on health cannot be clearly assessed. When studies fail to find a health framing effect (Bernauer & McGrath, 2016), it remains unclear whether people are unresponsive to health arguments, or unwilling to invest in public goods. Conversely, when studies find a health framing effect (e.g., Myers et al., 2012), it remains unclear whether it was the health argument that convinced them, or whether they wanted—or felt obliged—to contribute to a common public good.

The present research therefore aims to overcome this limitation. As previous research could not delineate whether it was health information that did or did not increase people's willingness to adopt mitigation actions, or whether people did or did not want to invest into a common public good, such as an improved climate, we deliver an estimate of the influence of *direct health co-benefits:* health co-benefits that are unconditional on the actions of others to yield an effect on the individual.

In four European high-income countries, we informed one half of participants about direct health co-benefits of adopting a range of actions that are beneficial for the individual adopting the action, irrespective of the action of others; the other half did not receive information on direct health co-benefits. We assessed households' stated willingness to adopt the actions, and calculated the resulting carbon footprint reduction.

Methods

The study was based on the interdisciplinary research project ***HO****usehold* ***P****references for reducing greenhouse gas* ***E****mission in four European high income countries* (HOPE), designed to gather data relevant to household choices for greenhouse gas mitigation from selected case-study cities in France, Germany, Norway and Sweden.

Sample size. Prior to data collection, we determined the sample size needed to detect an experimental effect of information on direct health co-benefits on the stated preferences to adopt mitigation actions as well as on simulation-based carbon emission reductions in a two-group between-subject design (health information given versus no health information given), assuming one-sided testing and a small- to medium-sized effect of d = .3 (based on common effect sizes found in framing studies, e.g. Bain et al. 2012), alpha = .05, and .8 power, and assuming no cluster effect. Based on these considerations, we aimed for a total sample-size of N = 278.

Recruitment and sampling. Households were recruited by sending invitation letters to a random sample of inhabitants on the population registers of the target cities, supplemented by others recruited through responses to media announcements. The sample was stratified by country. Allocation to the group receiving information on direct health co-benefits health was done randomly within each country among households agreeing to participate in the study. In total, 309 households were recruited: 70 from the Communauté du Pays d'Aix (France), 107 from Mannheim (Germany), 58 from Bergen (Norway), and 74 from Umeå (Sweden). Roughly half of households received information on health co-benefits (n=156), the other half did not (n=152,). For one household, coding of which group it belonged to was lost; it was therefore excluded from the analysis, rendering a final sample size of N=308. Interviews with households were carried out between June and November 2016.

Ethics approval and consent to participate. All participants were given written information about the study objectives and modalities (points of assessment, length of questionnaires), data preparation and pseudonymized data storage, the expected amount of commitment, the voluntary nature of participation, and their right to withdraw at any time. Furthermore, participants were informed verbally about the study purpose and procedures and were given the chance to ask questions. All participants provided written informed consent. All countries assure that data processing and storage is done in line with European and national data protection rules. Where necessary the study procedures were approved by an ethical committee. In Norway the Norwegian Center for Research Data approved of the study (44003). In Germany the Institutional Review Board of the Medical Faculty by the University of Heidelberg approved of the study (S-611/2015). In Sweden the study was approved by the Regional Ethical Review Board in Umeå (2015/357-31Ö). In France the project needed to fullfill the obligations of the CNIL (Commission nationale informatique et libertés), no specific ethical approval was necessary.

Data collection procedure: Stated preferences and simulated carbon reduction. In the present study, we report on two different dependent variables: (i) the intention-based actions

where participants rated their preference to adopt each action using a 5-point Likert scale (1=very willing to 5= not at all willing) in round 1; and (ii) the simulation-based actions of achieved carbon reductions when participants were asked to select actions they would like to implement to reduce their carbon footprint in a simulation game in round 2. The carbon emission reduction was calculated by the FCS Tool based on selected mitigation actions.

Households' initial footprint was calculated using a comprehensive on-line carbon footprint calculator (the Footprint Calculation and Simulation-Tool (FCS-Tool), Dubois *et al,* manuscript in preparation), which computed all greenhouse gas emissions in CO_2-equivalents (CO_2e) made by the household in one year (Wiedmann & Minx, 2008) under the headings: *housing*, *mobility*, *food*, and *other consumption.* This provided the baseline estimate of CO_2e emissions for each participating household.

Additional socioeconomic variables of the households, such as age, income, education etc. were assessed in this first step.

During a subsequent on-site visit approx. two to four weeks after assessment of a household's initial carbon footprint, each participant was presented with their initial footprint and asked to consider each of 65 household mitigation actions within their range (i.e. excluding those that were not relevant for the households, or had already been implemented). In the first round (rating of mitigation actions), participants rated their willingness to adopt these mitigation actionss. In the second round (choosing and ranking in voluntary scenario), participants chose the actions, they would actually like to implement, and received real-time feedback on the simulated reduction achieved. If participants did not reach the aim to reduce their carbon footprint by 50% in this round, they entered into a third round (choosing and ranking in voluntary scenario), in which they chose additional actions they would be most likely to implement if they were forced to reduce their carbon footprint by 50% until they reached the requested reduction. Additional information on the data collection procedures is given in the Study protocol of the HOPE study (Herrmann et al. 2017).

Experimental variation of information. Participants were given information specific to their household on the CO_2 reduction and the monetary costs or savings of adopting each possible mitigation action using action cards. For example, participants were asked to rate their preference to replace 60% of meat-based foods with vegetarian options. While all participants received information on the associated costs and CO_2e reduction, only participants in the experimental group additionally received information on direct health co-benefits. For example,

participants were given the additional information that an increase in vegetarian food intake would yield an appreciable *positive* health benefit for them (Fig. 1).

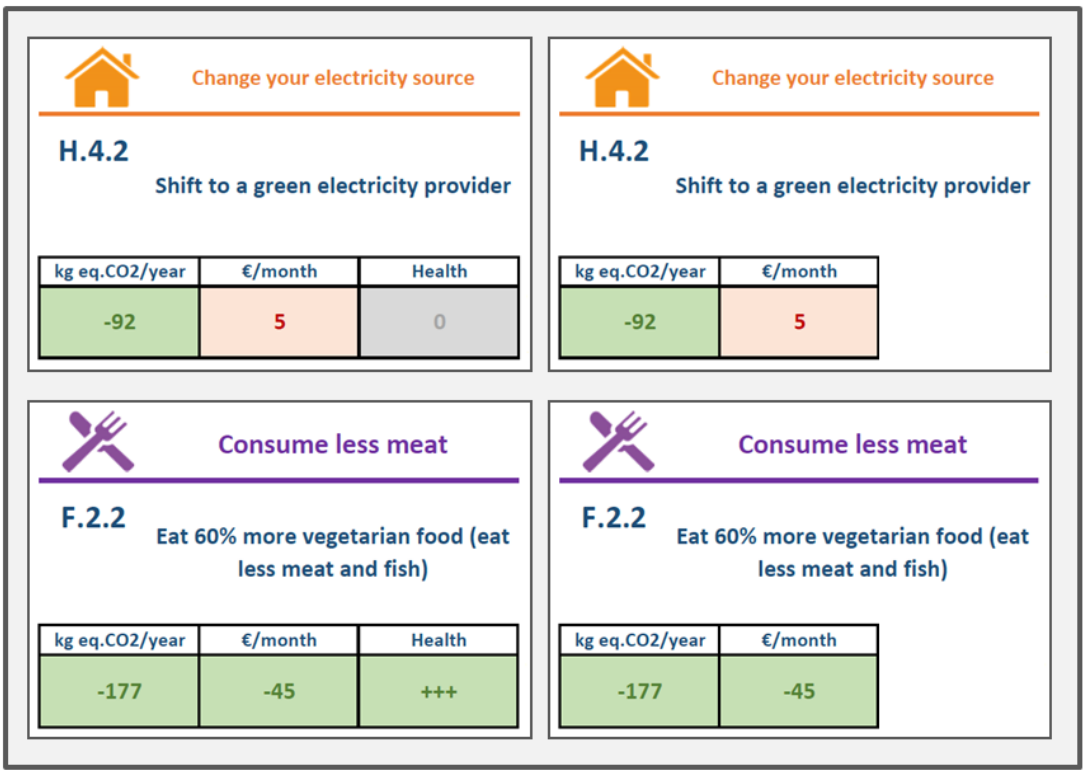

Fig 1. Examples of action cards showing one mitigation action from the sector *housing* and one from the sector food.
Cards on the left panel were given to the experimental group (with health information), cards on the right panel to the control group (without health information). Both groups received information on costs and CO_2 reduction.

Assessment of direct health co-benefits. The assessment of the likely health impact of individual mitigation actions was based on semi-quantitative extrapolation of evidence (an 'expert judgement') from published modelling studies of low carbon interventions in electricity production (Markandya et al., 2006), housing (Wilkinson et al., 2009), transport (Woodcook et al., 2009) and food and agriculture (Milner et al., 2015) for similar European populations. Using this evidence, we classified the likely impact on life expectancy using four categories: small (estimated increase in life expectancy < 1 month); moderate (estimated increase in life expectancy 1-3 months); substantial (>3 months increase), and negative (a decrease in life

expectancy). Eleven of the 65 mitigation actions were judged likely to have a direct positive health impact for the individual (three housing actions, and four each for mobility and food), one (reducing the indoor temperature thermostat setting by 3 degrees Celsius) to have a negative health impact, and 53 to have no clearly positive or negative impact on the individual. No mitigation action in the category of 'other consumption' was deemed likely to have appreciable health impact (see Study Protocol for the detailed list of mitigation actions with health effects, Hermann et al., 2017).

Hypotheses. Three hypotheses were *pre-registered* in the Study Protocol prior to data analysis (Hermann et al., 2017). Specifically, we expected that participants who received additional information on the direct health impact of adopting mitigation actions ('direct health co-benefits') would

1. report a higher stated willingness to implement mitigation actions with health co-benefits compared to households not receiving health information;
2. select higher numbers of mitigation actions with direct health co-benefits compared to households not receiving health information (i.e., comparing households); and
3. select more actions with direct health co-benefits than actions without direct health co-benefits (i.e., comparing actions).

Additionally, we investigate *exploratively*,

1. if the potential impact of information on direct health co-benefits varies by sector (housing, food, mobility); and
2. whether participants who received additional information on direct health co-benefits achieve a higher household carbon footprint reduction in the simulation

Analysis

We present two sets of dependent variables:

(1) **Stated preference to implement**: Analysis of the *proportion* of participants rating each mitigation action with health impact as 'very willing' to implement it; and analysis of the *mean* willingness to adopt actions from one sector.

(2) **Simulated carbon footprint reduction**: Analysis of the difference in carbon footprint achieved by the actions participants said they would implement in a voluntary scenario if asked to aim for a substantial reduction in their household's carbon emissions by 2030.

For the first analyses (1), we report the mean preference to adopt actions from each sector. For a stricter measurement of preference, we additionally tabulate (by health information status) the number and proportion of people very willing to implement each individual action if it is relevant to them (i.e. excluding those for whom the action is not applicable or already implemented), and the proportion very willing to adopt *any* one or more of the actions, together with unadjusted and adjusted odds ratios as obtained from logistic regression analysis. The co-variates used in the adjusted model included: the initial carbon footprint, household type (family with children (yes/no), no. of adults in working age, (no. of adults>=65 years), housing tenure (yes/no), household income, whether a vegetarian household (yes/no), age of the house, city district (self-report: city centre, suburb, or rural by tendency) and country. All quantitative variables were z-standardized prior to inclusion into the regression model. For all preregistered hypotheses we present one-sided testing results (where applicable), and present results both without controlling for the list of covariates (as the specific list of co-variates was not pre-registered), and when including the full list of co-variates to investigate potential differences.

For the calculated changes in simulated household carbon footprints (2), we present evidence (by health information status) of the baseline CO_2e footprint and the change when asked to aim for substantial reduction by 2030, together with the percentage change, and the difference in percentage reduction between those with and without evidence of health impact. Regression-based estimates of the difference in the reduction in CO_2e were adjusted for the same covariates as for analysis (1). For all exploratory hypotheses we present two-sided testing results, together with the full list of covariates to investigate in-depth which households characteristics shape willingness to adopt mitigation actions when presented with their health co-benefits, and to control for baseline differences in the experimental and control group.

Results

The characteristics of study households by health information status are summarized in Table 1. Those receiving health information were broadly similar to those not receiving it, but they were fewer families with children, resulting in a (marginally) lower initial carbon footprint per household. Importantly, however, the initial carbon footprint per capita did not differ between both groups, suggesting overall comparable lifestyles.

Table 1. Household characteristics in groups with and without information on the health impact of each mitigation action.

	Mean (standard deviation) or number *(percent)*		
	Group without information on health impacts (n=152)	**Group with information on health impacts (n=156)**	**Comparison**
Initial carbon footprint per household (tons CO_2e/year)	18,200 *(10,640)*	16,090 *(8,050)*	$t(281.33)=1.96$, $p=.051$
Initial Carbon footprint per capita (tons CO_2e/year)	10,549 *(5,325)*	10,120 *(4,014)*	$t(306)=0.8$, $p=.43$
Housing tenure **Owner** **Tenant**	96 *(63.2%)* 56 *(36.8%)*	95 *(60.9%)* 61 *(39.1%)*	$X(1)=.17$, $p=.73$
Household income (€/month)	3791 *(2124)*	3483 *(1616)*	$t(306)=1.5$, $p=.15$
Whether vegetarian household **No** **Yes**	135 *(88.8%)* 17 *(11.2%)*	146 *(93.6%)* 10 *(6.4%)*	$X(1)=2.19$, $p=.16$
Age of house **Pre-1950** **1950-1989** **1990 or later**	44 *(29.0%)* 72 *(47.4%)* 36 *(23.7%)*	33 *(21.2%)* 79 *(50.6%)* 44 *(28.2%)*	$X(2)=2.64$, $p=.27$
Location **Rural/city outskirts** **Suburb** **Town/city centre**	44 *(28.9%)* 62 *(40.8%)* 46 *(30.3%)*	36 *(23.1%)* 66 *(42.3%)* 54 *(34.6%)*	$X(2)=1.5$, $p=.50$
Country **France** **Germany** **Norway** **Sweden**	36 *(23.7%)* 52 *(34.2%)* 35 *(23.0%)* 29 *(19.1%)*	34 *(21.8%)* 55 *(35.3%)* 38 *(24.4%)* 29 *(18.6%)*	$X(3)=.21$, $p=.98$

Pre-registered hypothesis 1: Preference to adopt mitigation actions across sectors. We compared the mean stated willingness to implement all feasible mitigation measures h were direct health co-benefits exist. In line with our expectation, households who were given

information on direct health co-benefits reported a higher willingness to implement these measures (M=2.70, SD=0.66) than households not provided with information on direct health co-benefits (M=2.60, SD=0.70), t(300)=1.8, p=.03. Results do not change when including the full list of co-variates, F(1)=3.4, p=.03.

Explorative analysis: Preference to adopt mitigation actions: Mean willingness per sector. We conducted regression analyses assessing the impact of the health information on the mean rated willingness to adopt mitigation actions for each of the three sectors for which health co-benefits exist: Food, housing and mobility. For this analysis, we controlled for the list of covariates (Table 1) to assess the health impact over and above small baseline differences between experimental and control group. Figure 2 shows that participants receiving information on health co-benefits were more willing to implement actions in the areas food and housing. Receiving information on health co-benefits did not change participants' willingness to implement any changes in the sector mobility. These results suggest that the differences in overall willingness to implement described above were driven entirely by the food and housing sector.

Fig 2. Results of three regression models estimating the effect of informing participants about health impacts on preference to implement mitigation actions in the sectors housing, food, and mobility, respectively. The health effect on Housing (Panel A), Food, (Panel B), Mobility (Panel C), each controlling for all co-variates entered at once**.** Results of 95% CI that do not include the null in bold.

Explorative analysis: Preference to adopt mitigation actions: Proportion of respondents "very willing". To obtain a more differentiated picture of the impact of the health information, we assessed its effect on each of the 12 mitigation actions with a known health effect separately, and whether providing health information yielded a higher proportion of participants saying they were "very willing" to implement each of these actions. We chose to focus on highest ratings of stated willingness only, as participants with the highest intention to mitigate would realistically be the ones most likely to implement their intentions in the real world. Table 2 provides an overview of the analyses separately for an unadjusted version, and a version adjusted for all covariates. The overall proportion of households 'very willing' to adopt any one or more of the mitigation actions with health impact was appreciably greater in those given health information (adjusted odds ratio 1.86, 95% CI 1.10, 3.12).

Table 2. Numbers (%) and odds ratios (95% CI) for being very willing to implement each of the specified mitigation actions by whethe information on health impact.

Mitigation action	Health impact	Number/denominator and (%) very willing to implement action		
		Without health information	With health information	
Housing				
Insulation of roof/attic	+	13/50 *(26.0%)*	19/49 *(38.8%)*	1.
Insulation of walls	+	9/65 *(13.9%)*	13/62 *(21.0%)*	1.
Improve windows (increase glazing of your windows)	+	16/61 *(26.2%)*	23/62 *(37.1%)*	1.
Lower thermostat setting by 3°C	-	13/141 *(9.2%)*	13/139 *(9.4%)*	1.
Any housing action	**- to +**	**36/152† *(23.7%)***	**49/156† *(31.4%)***	**1.**
Dietary change				
Gradually give up on ready-made meals (e.g. frozen pizza, canned soups)	++	33/87 *(37.9%)*	32/74 *(43.2%)*	1.
Eat 30% more vegetarian food (less meat and fish)	+++	35/138 *(25.4%)*	50/144 *(34.7%)*	1.
Eat 60% more vegetarian food (less meat and fish)	+++	16/138 (11.6%)	18/143 *(12.6%)*	1.
Stop eating meat (and fish?)	+++	2/138 *(1.5%)*	4/144 *(2.1%)*	1.
Any dietary change	**++ to +++**	**57/152† *(37.5%)***	**68/156† *(43.6%)***	**1.**
Travel/mobility				
Shift more than 30% of car journeys to public transport	++	26/118 *(22.0%)*	27/136 *(19.9%)*	0.
Shift to non-motorized transport (walk, bike) instead of public transport	+++	32/103 *(31.1%)*	41/113 *(36.3%)*	1.
Decrease travel by cars public transport and other motorized vehicles by 30%.	++	17/146 *(11.6%)*	20/150 *(13.3%)*	1
Give up your car(s) and other motorized vehicle(s)	++	8/121 *(6.6%)*	5/134 *(3.7%)*	0.
Any mobility action	**++ to +++**	**58/152† (38.2%)**	**63/156† *(40.4%)***	**1.**
Any of the above (i.e. any mitigation action with health impact)	**- to +++**	**100/152†*(65.8%)***	**121/156† *(77.6%)***	**1.**

* -- Initial carbon footprint, household type, tenure, household income, whether vegetarian household, age of house, urban-rural location, countr
† -- Denominator is all households, including those for whom individual actions are already implemented or not relevant

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357 Table 3 examines the differences in the effect of being given health information in relation to
358 household type. There is no clear evidence of statistical interaction (effect modification) here
359 (p=0.12), but the point estimates vary – with households of working age adults without children
360 apparently showing much greater likelihood of being very willing to adopt any of the mitigation
361 actions with health impact (OR 3.12, 95% CI 1.45, 6.68), while the point estimate of the odds
362 ratios for households composed only of members over the age of 65 years was well below unity
363 (0.50, 95% CI 0.10, 2.44).

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Table 3. Odds ratios (95% CI) for being very willing to implement any household mitigation action with health impact: ORs for those given health information *vs* those not given health information by household type

Household type	Odds ratio (95% CI) for willing to implement any mitigation measure		Test of statistical interaction, adjusted model
	Unadjusted	Adjusted for all covariates*	
Families with children	1.24 (0.50, 3.05)	1.16 (0.44, 3.05)	p=0.12
Working age adults, no children	3.05 (1.48, 6.28)	3.12 (1.45, 6.68)	
Adults >=65 years	0.89 (0.26, 3.04)	0.50 (0.10, 2.44)	

* -- Initial carbon footprint, household type, tenure, household income, whether vegetarian household, age of house, urban-rural location, country

Pre-registered hypothesis 2: Selection of mitigation actions with direct health co-benefits, in 'voluntary' and 'forced' scenario. We investigated how many mitigation actions that exert a direct health co-benefit were chosen in the 'voluntary' and the 'forced' scenario. In line with our hypothesis, households given information on direct health co-benefits chose, in the voluntary scenario, more actions that exert direct health co-benefits (M=2.00, SD=1.45) compared to households not given this information (M=1.70, SD=1.23), both without the list of covariates, t(306)=1.8, p=.04, and when controlling for the list of covariates, F(1)=5.61, p=.02. In the forced scenario, there were no differences in the number of actions that exert direct health-co-benefits chosen by households given health information (M=3.2, SD=1.6) compared to households not given health information (M=3.20, SD=1.6), either without the list of covariates, t(306)=0.9, p=.38, or when controlling for the list of covariates, F(1)=1.93, p=.17.

Pre-registered hypothesis 3: Comparison of actions that do and do not exert direct health co-benefits. Eleven mitigation actions were judged to exert positive direct health co-benefits (see Table 2); 53 were judged not to exert direct health co-benefits. To assess whether receiving information on direct health co-benefits affected the popularity of these 11 actions with a known health effect, we first compared all households' overall willingness to implement these 11 actions with households` overall willingness to implement the 53 actions without known health effect. Generally, households were more willing to implement those actions that do not exert direct health co-benefits (M=3.04, SD=.59) than those actions that do exert direct health co-benefits (M=2.63, SD=.69), t(302)=11.4, p<.001. In a next step, we assessed whether this difference was smaller for the group receiving health information. Contrary to our expectation,

this difference was not significantly reduced for households receiving information on health co-benefits (M=.44, SD=.64) compared to not receiving this information (M=.38, SD=.60), t(300)=.84, p=.40.

Exploratory analysis: Impact on carbon footprint. Table 4 reports the results of the simulation exercise in which householders were asked to select the mitigation actions they would implement if required to aim for a substantial reduction in emissions by 2030. As noted above, households given health information had somewhat lower baseline carbon footprints. This was true overall and for the groups of actions relating to housing interventions, food/dietary change, and mobility/transport individually. However, the *percentage* reductions in carbon footprint achieved by the selections made by participants were greater among those given health information. There was evidence of a greater percentage reduction among those given health information with respect to food/dietary emissions (difference in percentage reduction -4.45%, 95% CI -8.26, -0.64, fully adjusted analysis) and for all mitigation actions (difference in percentage reduction -2.70%, 95% CI -5.34, -0.04, fully adjusted). These results indicate that providing information on direct health co-benefits does not just alter the preference to choose health-relevant mitigation actions but also the overall total of emissions (summed across all actions, not just those with health effects).

Table 4. Change in calculated carbon footprint in tonnes CO_2-eq/household/year with simulated 50% target reduction: results wit

	Tonnes CO_2eq emissions/household:				Percent change (95% CI): simulation/baseline*100%	
	Baseline		Simulation: asked to aim for 50% reduction by 2030			
	Without health information	With health information	Without health information	With health information	Without health information	With health information
Housing	3,641	3,204	2,813	2,295	-22.0% (-18.4, -25.7)	-24.2% (-21.2, -27.2
Food	4,855	4,740	3,365	3,086	-31.1% (-28.4, -33.7)	-34.9% (-32.1, -37.6
Mobility/transport	7,007	5,762	5,481	4,527	-23.5 (-20.4, -26.7)	-24.0% (-20.7, -27.3
ALL†	18,200	16,092	14,061	12,148	-23.0% (-21.2, -24.8)	-24.9% (-22.9, -26.8

* -- Initial carbon footprint, household type, tenure, household income, whether vegetarian household, age of house, urban-rural
† -- ALL also includes emissions relating to consumer goods which are not separately shown in the table as choices in consumer go on health.

Discussion

This is the first empirical study to investigate the provision of information on strictly unconditional, individual health impacts (*direct health co-benefits*) of household climate change mitigation actions on householders' preferences to adopt such actions. Our results suggest that being presented with evidence on direct health co-benefits *does* have an appreciable influence on stated preferences to adopt mitigation actions. Specifically, households receiving information on health impacts reported a greater mean willingness to adopt actions from the sectors housing and—particularly—, food, and were even more likely to report the highest level of willingness ('*very* willing') to adopt one or more such actions overall. Moreover, the simulated carbon footprint reductions under the requirement to reduce carbon emissions were appreciably greater overall and in relation to food/dietary change actions as a group.

European households thus seem to be more willing to implement a given mitigation action when given additional information on health co-benefits that arise irrespective of whether others join in, or not. This is a crucial difference compared to previous research (Bernauer & McGrath, 2016; Myers et al., 2012) where health co-benefits were typically contingent on others' behavior. The present results therefore suggest that direct health benefits for the person performing the mitigation action can be a convincing factor when deciding on whether to perform the mitigation action. Please note that these results hold for a *given* mitigation action where additional information on health co-benefits is provided.

The present results, however, also show that mitigation actions that do exert health effects (e.g., shifting from car to public transport) were generally favored less by European households compared to actions that do not exert health effects (e.g., buying more efficient electrical appliances). Also. this intrinsic difference between actions that do versus do not provide health co-benefits was considerably stronger than the difference between providing versus not providing information on health co-benefits for only those actions that do provide health co-benefits.

Taken together, European households' willingness to implement mitigation actions varied significantly depending on the type and sector of the action. However, households' willingness to implement mitigation actions for which direct health co-benefits exist could be increased by making these benefits explicit.

Households did not decrease their simulated carbon footprint in the categories housing and mobility. While households' emissions reduction in the sector food is in line with participants' stated preferences to adopt these actions in their household, the lack of emission reduction in the sector housing is somewhat surprising. A potential explanation for this finding is that the average reduction *potential* of the health-related housing options available to the

households was too low to yield an effect. In fact, differential effects of intent-oriented actions as opposed to impact-oriented actions are in line with previous research. In a sample of Dutch households, participants who indicated they behaved more pro-environmentally did not necessarily consume less energy, and actual household energy use was not reflected by pro-environmental intentions, but rather by household characteristics such as income and household size (Gatersleben, Steg & Vleg, 2002).

Informing about health co-benefits did not increase preferences to adopt in the sector mobility. This finding is in line with previous research demonstrating that behavioral changes in the mobility sector seem particularly difficult to achieve (Goessling, 2017), or particularly dependent on environmental-friendly attitudes (Bopp, Kaczynski & Wittman, 2011)..Another explanation is that the positive health effects of physical activity are more salient among households, than those of a vegetarian diet or well-insulated houses. Thus, providing additional information about the positive health effect of being more physically active might not make a difference.

The effect of the health information is fairly modest (just a few percent greater overall reduction in carbon emissions among those given health information, for example a 4.5 %age point difference for dietary actions), but given that providing semi-quantitative information on direct health co-benefits is an inexpensive and easy-to-implement strategy, these benefits come at low costs.

However, future studies need to demonstrate if and under what circumstances a larger effect of informing about health co-benefits can be achieved. Potential approaches may entail (a) changing the format or (b) the context in which the health information is presented.

Concerning presentation format, the health information consisted of only an indication of the strength and direction of the health effect for each particular action in form of small plus or minus symbols. This may easily be substituted by adding more salient pictographic information about the specifics of the health benefit, (e.g., a heart symbolizing heart diseases) to potentially strengthen its impact.

Concerning presentation context, while providing only rudimentary information on health itself, we presented participants with a rather great amount of information overall, entailing not only health effects of mitigation options, but also associated costs and carbon reduction, all of which were competing for participants' attentional resources. While it is likely that the conditions in our study are more realistic than the artificial setting in many laboratory studies which test the effect of only one piece of information at a time, presenting heath information as the only source of information might yield stronger effects.

Future research could also estimate the impact of providing information on direct health co-benefits versus public health co-benefits on citizens' willingness to implement mitigation actions. This could be done by providing one group of households with information on direct health co-benefits, and a second group with information on public health co-benefits of the same mitigation actions. Moreover, it might me worthwhile to include actions of personal preferences or beliefs regarding health. It could be the case, for example, that the present results were driven mainly by participants who have comparatively high preferences for healthy life choices, particularly since a positive relationship between health behaviors and climate mitigation behavior has been demonstrated (Geiger, Otto & Schrader, 2018). Such research could further elucidate the motivational factors that drive citizens' willingness to implement mitigation actions.

Unlike typical framing studies, the present study did not employ subtle changes in message wording to test the health argument`s effectiveness. Rather, we simply provided participants with health outcomes as an additional piece of information. Thus, we refrained from using persuasive message wordings which might have questionable long-term effects (de Vreese, 2004; Druckman, & Nelson, 2003) and have been considered manipulative and undemocratic (Fischhoff, 2013). The present results are therefore unlikely to depend on subtle differences in message wording - something which might be hard to accommodate for in real-life communication campaigns (cf. Lecheler, & de Vreese, 2013).

On a more general level, what might be the relevance of our results for climate policy strategies and actions? Relying on the insights from our study, we would argue for the following policy recommendations: (a) Whenever relevant, direct health co-benefits should be included in public communication supporting the introduction of new climate policy measures; and (b) introducing health co-benefits in climate policy discourse can trigger a mechanism known as 'policy redressing'. In policy redressing, old programs, for example to mitigate local air pollution, are renewed by linking them up to new climate policy initiatives. A survey of current climate policies in the four countries investigated in the HOPE project showed that health to a very limited degree is linked in any way with policies aimed at reducing households' greenhouse gas emissions (Moberg et al., submitted). The present results suggest there might be a potential for 'redressing' the climate policy discourse by including unconditional, individual health co-benefits.

Our study provides empirical support for the idea that, in European high-income countries, linking up climate policies with direct health effects can support GHG mitigation efforts at two levels: Firstly, by accruing the individual citizen (actor), this can lead to small, but

511 tangible results on households' willingness to adopt suggested climate friendly consumption
512 changes. Secondly, our findings support the idea that underlining the potential health co-benefit
513 may increase the public acceptance of regulation of private consumption to reduce household
514 carbon footprint.
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Declarations of interest

Declarations of interest: none

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