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Historical narratives about the COVID-19 pandemic are motivationally biased

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How people recall the SARS-CoV2 pandemic is likely to prove crucial in future societal debates on pandemic preparedness and appropriate political action. Beyond simple forgetting, previous research suggests that recall may be distorted by strong motivations and anchoring perceptions on the current situation.[1–6] Here, based on four studies across 11 countries (total N = 10,776), we show that recall of perceived risk, trust in institutions and protective behaviours depended strongly on current evaluations. While both vaccinated and unvaccinated individuals were affected by this bias, people who identified strongly with their vaccination status—whether vaccinated or unvaccinated—tended to exhibit greater and, importantly, opposite distortions of recall. Biased recall was not reduced by providing information about common recall errors or small monetary incentives for accurate recall, but partially by high incentives. Thus, it seems that motivation and identity influence the direction in which the recall of the past is distorted. Biased recall was further related to the evaluation of past political action and future behavioural intent, including adhering to regulations during a future pandemic or punishing politicians and scientists. Taken together, the findings indicate that historical narratives about the COVID-19 pandemic are motivationally biased, sustain societal polarization and affect preparation for future pandemics. Consequently, future measures must look beyond immediate public health implications to the longer-term consequences for societal cohesion and trust.

Main Text

Since most pandemic restrictions were lifted in early 2023, many societies have been transitioning to a post-pandemic phase.[7] This includes an evaluation of the appropriateness of the measures employed and efforts made to enhance future pandemic preparedness. Any such evaluation necessarily depends on accurate recall of factual data and subjective interpretations at the time (e.g. infection rates and associated risk perceptions). While this information is available from large-scale surveillance and survey data gathered during the pandemic,[8] such evaluations are also influenced by public and media discourses, which are often tinted by personal perceptions and memories. As memory formation is a constructive process, retrospective narratives about historical events such as the pandemic are at risk of significant distortion.[1] Beyond simple forgetting, recall and ex-post evaluation are prone to various forms of bias, reflecting differences in motivation and purpose (e.g. a wish to conform with one's own or prevailing opinion).[1–3,6] For example, people are more likely to remember true or false information from the past depending on pre-existing beliefs or prior behaviours in the context of vaccination, political campaigns, or political riots.[4,5,9]

We argue here that recall and retrospective evaluations of the COVID-19 pandemic are affected by ubiquitous bias.[10–12] Regardless of whether one complied with governments' recommendations to get vaccinated or chose to remain unvaccinated, the pandemic incurred high costs for everyone. When recalling past events or feelings, both vaccinated and unvaccinated individuals may be subject to bias, motivated by self-affirmation and consistency with today's beliefs, perhaps reinforcing the existing polarization based on vaccination status and discrimination against those who differed in this regard.[13–15]

Here, we report four empirical studies exploring the nature and extent of bias in individual historical narratives of the COVID-19 pandemic. Study 1 mapped the extent and direction of recall bias within opinion-based groups and assessed the relationship with evaluations of political action that took place during the pandemic. Studies 2 and 3

investigated the robustness of the bias in recall and evaluation vis-a-vis different mitigation measures. Finally, Study 4 assessed the potential societal implications of this bias and the generalizability of the findings across different countries.

Assessing bias in recall and evaluation

To assess the extent and direction of biased recall and evaluation, one must be able to reliably compare current and past perceptions.[16] For the purposes of Study 1, we surveyed a sample of German adults (N = 1,644) in late 2022. Of these, 74% had received at least one dose of a COVID-19 vaccine. All respondents had previously been surveyed in summer 2020 or winter 2020/2021.[8] At both timepoints, they were asked about their current perceptions of risk (i.e. infection probability and severity, affective risk), trust in government and science, frequency of wearing masks and perceived exaggeration of the pandemic measures, as well as current life satisfaction. In the 2022 survey, respondents were asked to recall their responses to the same items as in the previous survey. Based on their past and current perceptions and recall of the past, we estimated the extent to which recall tended towards one end of the respective scale (directional bias) and the extent to which recall was influenced by past or current perceptions.[16] Vaccination status and vaccination status identification[14] were added as potential moderators in linear regressions. Figure 1 shows how recall was influenced by past and present ratings of the variable in question. Across a range of variables related to perceived risk, trust and behaviour, the findings indicate that recall was strongly linked to current perceptions and that the direction of bias differed according to vaccination status and identification with vaccination status (for regression tables, see Extended Data Tables 1–8). For example, recalled infection probabilities related to present perceptions (main effect: b = 0.74, SE = 0.20, $p < 0.001$) but not past perceptions (main effect: b = 0.16, SE = 0.21, p = 0.447). Vaccinated individuals tended to recall the probability of infection (M = 4.30, SD = 1.63) as higher than it had actually been perceived in the past (M = 3.68, SD = 1.39, d = 0.41) and this tendency increased the more they identified with being vaccinated (as indicated by an

interaction effect in the linear regression: $b = 0.30$, $SE = 0.07$, $p < 0.001$). The opposite effect could be observed for unvaccinated individuals, with stronger identification resulting in lower recalled infection probability (main effect of vaccination status identification: $b = -0.14$, $SE = 0.06$, $p = 0.028$).

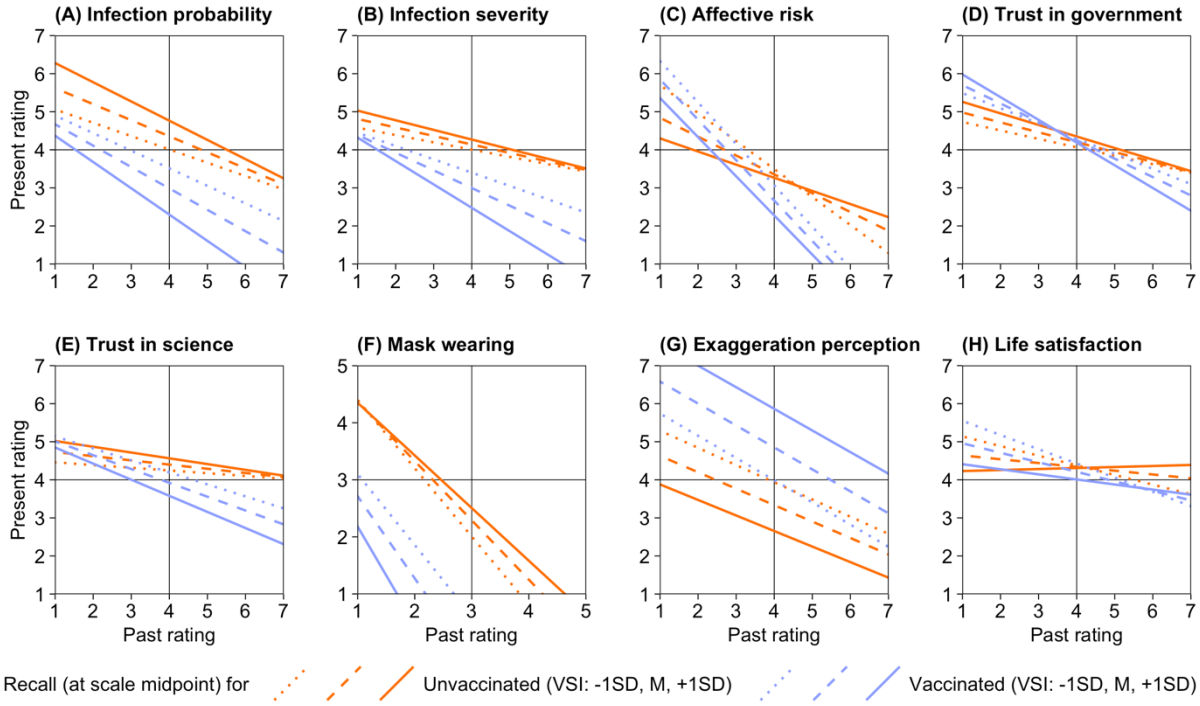

Figure 1. Biased recall of pandemic perceptions and behaviours in Study 1

Note: Each panel shows the results of a linear regression predicting individual recall of past perceptions based on actual past ratings (x-axis) in 2020/2021 and present ratings (y-axis) in late 2022, as well as interactions with vaccination status (colours) and vaccination status identification (VSI; dashed/dotted lines) of $n = 1{,}644$ participants (if not indicated otherwise) for (A) infection probability, (B) infection severity, (C) affective risk, (D) trust in government ($n = 1{,}600$), (E) trust in science ($n = 1{,}489$), (F) mask wearing ($n = 1{,}600$), (G) exaggeration perception and (H) life satisfaction ($n = 1{,}539$). Each line indicates the recall at a fixed value (scale midpoint, e.g. line represents recall = 3 for mask wearing as it was measured on a 5-point scale and recall = 4 for all other variables as these were measured on a 7-point scale) as predicted by past and present ratings. Direction and strength of bias are indicated by the line's position relative to the midpoint of the scale; the angle indicates the extent to which recall is influenced by past and present perceptions (the more tilted towards horizontality, the more influenced by present ratings; the more tilted towards verticality, the more influenced by past ratings). Example: The lines in 1A represent the predicted recall of infection probability = 4 given different past and present ratings. For instance, the dots mark the recall of infection probability = 4 given the actual past rating of 4 for highly identified vaccinated and unvaccinated people. The respective lines are tilted below (vaccinated) and above (unvaccinated) the midpoint. This indicates that people's recall of the probability of infection is influenced by their present rating of the probability, and that this influence goes in different directions for the vaccinated (higher recalled infection probability than actually perceived in the past) and unvaccinated (lower recalled infection probability than actually perceived in the past). As indicated by the dashed lines being closer to the midpoint, the influence of the present rating relative to the past rating is weaker for weakly identified people. See *Study 1 Analyses* in the Methods for more information on the regression models; regression tables are provided in Extended Data Tables 1–8.

As a further indicator for the motivational basis of recall, individual evaluations differed strongly in terms of whether political measures were perceived as appropriate (i.e. justified, effective and based on an honest desire to protect citizens). A regression analysis revealed that perceived overall appropriateness varied by vaccination status (b = -2.20, SE = 0.25, $p < 0.001$), vaccination status identification (b = -0.53, SE = 0.04, $p < 0.001$) and their interaction (b = 0.96, SE = 0.05, $p < 0.001$). For both vaccinated and unvaccinated individuals, appropriateness was rated as medium when identification was low. However, evaluations were increasingly positive among the vaccinated and increasingly negative among the unvaccinated as vaccination status identification increased (for visualization, see Extended Data Figure 1). These results mirror the results for biased recall. In fact, individual appropriateness ratings related to the extent of directional recall bias (r = 0.24, $p < 0.001$; individual directional recall bias could be estimated for n = 1,574 participants based on multiple outcome variables; see *Study 1 Analyses* in the Methods section for details). This indicates that greater bias when recalling the past was associated with a more extreme evaluation of political action—in either direction.

Attempts to reduce recall bias

Assuming that recall and evaluation of the pandemic affect each other,[3] it seems important to explore possible techniques for reducing memory distortion. To that end, Study 2 investigated whether recall bias is reduced (i) when monetary incentives are introduced to encourage accurate recall or (ii) when metacognitive information about widespread recall bias is provided. Both incentives[17,18] and information[19,20] are known to instigate the correction of one's own judgements in other domains.

As these techniques might have differing effects on vaccinated and unvaccinated individuals, our sample included a disproportionally high percentage of unvaccinated individuals[14] and reassessed 3,105 participants from Germany and Austria in January 2023 (71% of whom had received at least one dose of a COVID-19 vaccine). Before asking

respondents to recall their perceptions and behaviours from December 2021, they were randomly assigned to one of two intervention conditions or a control group (no intervention).

To test the effect of incentives, participants were told that more accurate recall would increase their chances of winning a cash prize: 100 euros were raffled among all participants, and more accurate recall resulted in participating more often in the lottery. To test the effect of metacognitive information on the existence of recall bias, participants were told about the extent of this bias in others. Following these interventions, we tested participants' recall and assessed their perceptions of the appropriateness of political action as in Study 1. Inspection of response times indicates that participants read the interventions; in the information (incentive, control) condition, participants took a median time of 94 (61, 45) seconds to read the instructions and recall their answers.

The analysis used the same linear regression as in Study 1; the only difference was that the experimental condition replaced vaccination status identification as a moderating variable (see Extended Data Figure 2 for visual presentation; regression details are provided in Extended Data Tables 10–15; all regressions are based on the full sample of $N = 3{,}105$ participants). Across all variables, the direction of recall bias again differed by vaccination status. Vaccinated respondents tended to overestimate their previous risk perceptions and protective behaviours, with main effects of being vaccinated on infection probability ($b = 0.54$, $SE = 0.12$, $p < 0.001$) and severity ($b = 0.42$, $SE = 0.11$, $p < 0.001$) and avoiding contacts ($b = 0.39$, $SE = 0.17$, $p = 0.022$). Unvaccinated respondents underestimated their previous trust in government and science, with main effects of being vaccinated on trust in government ($b = 0.62$, $SE = 0.12$, $p < 0.001$) and trust in science ($b = 0.53$, $SE = 0.12$, $p < 0.001$). For mask wearing, no significant differences were found between vaccinated and unvaccinated individuals ($b = 0.25$, $SE = 0.16$, $p = 0.122$). Importantly, recall accuracy was not significantly improved by incentivizing accurate recall (indicated by insignificant main effects of incentives in all regressions, $0.146 < p < 0.853$, as well as insignificant interaction

effects of incentives and vaccination status, $0.221 < p < 0.864$) or providing information about widespread bias (indicated by insignificant main effects of information in all regressions, $0.075 < p < 0.731$, as well as insignificant interaction effects of information and vaccination status, $0.161 < p < 0.435$). While the effects of both interventions and their interaction with participant's vaccination status were negligible, equivalence tests indicated they were not equal to zero as confidence intervals overlapped but also exceeded regions of practical equivalence (ROPE; equivalence tests: $p > 0.150$).

As stronger interventions may be more successful in correcting recall bias,[17] Study 3 investigated the effects of considerably higher incentives. In July 2023, 906 vaccinated German participants were asked to recall their perceptions and behaviours from summer and autumn 2021. Half of the participants were told that a more accurate recall would increase their chances of winning a cash prize. Participants learned that one of their recall values will be randomly selected and compared with their past answer. When both are equal, they will received a bonus of 25 euros. The chance of winning the bonus decreased the more the recalled and the true answer diverged (binarized scoring rule[21]).

The analysis utilized similar linear regressions as in the previous studies; the recall of six variables was predicted by past and present answers, condition and their interactions with condition. In some cases, past answers were missing, resulting in slightly reduced samples for the analysis of some variables ($n = 902$ for mask wearing, $n = 859$ for contact avoidance, $n = 881$ for trust in government, $n = 906$ for all other variables). Figure 2 shows that while participants again overestimated past risk perceptions (directional bias reflected by the regression intercepts; infection probability: $b = 1.60$, $SE = 0.07$, $p < 0.001$; severity: $b = 0.66$, $SE = 0.07$, $p < 0.001$), protective behaviours (mask wearing: $b = 0.29$, $SE = 0.16$, $p = 0.071$; contact avoidance: $b = 0.52$, $SE = 0.08$, $p < 0.001$) and trust in the government ($b = 0.37$, $SE = 0.06$, $p < 0.001$), recall of some variables improved when incentives were offered (for regression details, see Extended Data Tables 16–21). For example, the incentive improved the

recall of mask wearing and trust in government, as it reduced the influence of present perceptions (interaction effects of present ratings and being offered an incentive; mask wearing: b = -0.16, SE = 0.07, p = 0.021; trust: b = -0.12, SE = 0.05, p = 0.025) and increased the influence of past perceptions (interaction effect of past trust rating and being offered an incentive: b = 0.20, SE = 0.06, $p < 0.001$). For infection probability, even a main effect was found; directional bias was reduced when an incentive was offered (b = -0.38, SE = 0.10, $p < 0.001$). Interestingly, the incentive also reduced recalled exaggeration perceptions (main effect: b = -0.42, SE = 0.10, $p < 0.001$). Combining all six variables in a mixed effects regression (controlling for multiple answers from the same individual, including n = 5,360 answers, see Extended Data Table 22) revealed that offering an incentive decreased directional bias (main effect: b = -0.35, SE = 0.10, p = 0.001) and increased the influence of past ratings (interaction effect of incentive and past ratings: b = 0.08, SE = 0.02, p = 0.002), indicating a reduction of recall bias. When adding vaccination status identification as an additional moderator to the regressions for each variable (see Extended Data Tables 16–21), it was found to increase recalled risk perceptions (main effect for infection probability: b = 0.21, SE = 0.05, $p < 0.001$; infection severity: b = 0.22, SE = 0.05, $p < 0.001$) and recalled trust in government (b = 0.17, SE = 0.05, $p < 0.001$) while it decreased recalled exaggeration perceptions (b = -0.30, SE = 0.05, $p < 0.001$), confirming the result of Study 1 that greater identification with vaccination status is associated with more biased recall).

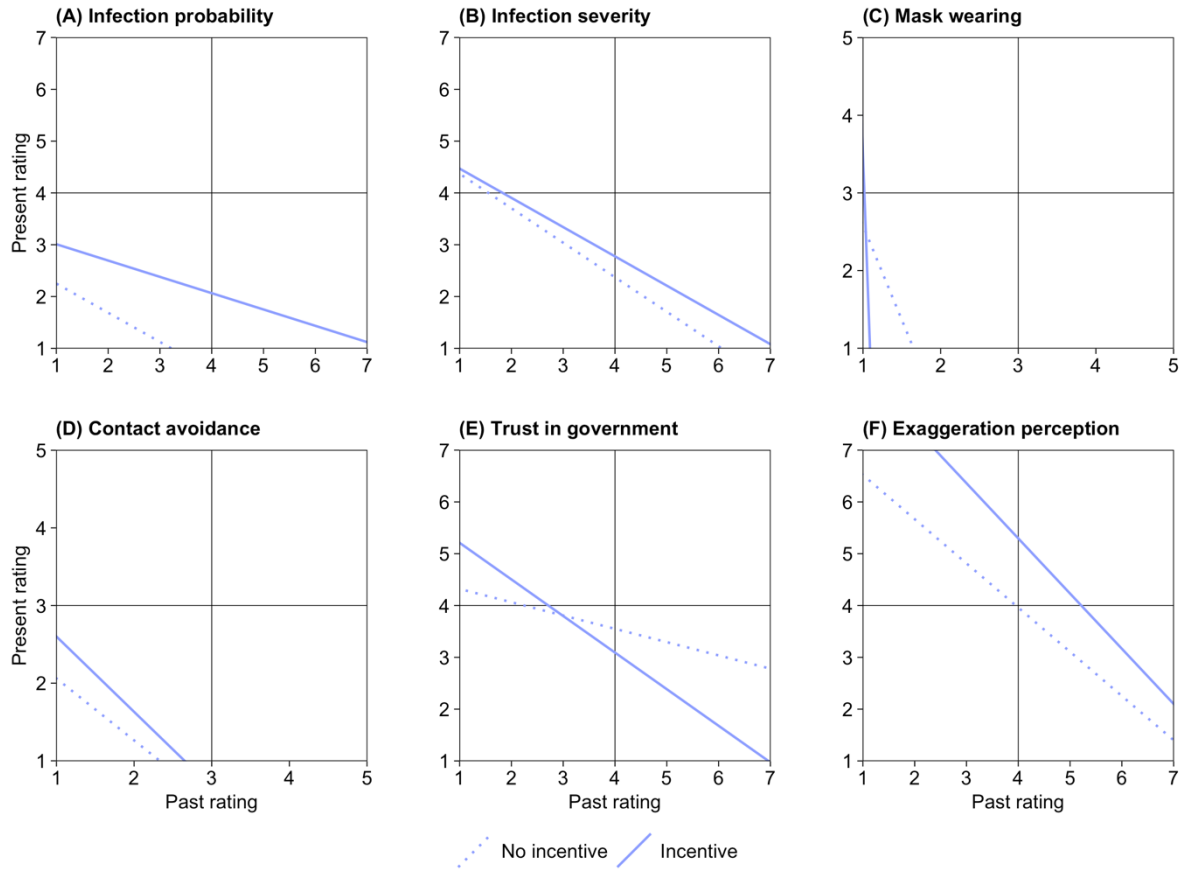

Figure 2. Effects of monetary incentives on reducing recall bias in Study 3
Note: Each panel refers to a linear regression predicting individual recall of vaccinated individuals (n = 906, if not indicated otherwise) based on past (summer and autumn 2021) and present (July 2023) ratings and their interactions with the experimental condition for (A) infection probability, (B) infection severity, (C) mask wearing (n = 902), (D) contact avoidance (n = 859), (E) trust in government (n = 881) and (F) exaggeration perception. Each line visualizes directional bias and how past and present perceptions affect recall at a fixed value (scale midpoint, i.e. recall = 3 for mask wearing and contact avoidance as these were measured on a 5-point scale and recall = 4 for all other variables as these were assessed on a 7-point scale) when recall was (not) incentivized in the experiment. Regression tables are provided in Extended Data Tables 16–21.

As a neutral control item, all participants were asked to recall the time of day when they had participated in the survey in 2021. We assumed that there was no motivational basis for distorting one's recall of this item. Indeed, while recall was positively related to the actual time in 2021 (b = 0.18, SE = 0.04, p < 0.001) as well as the present time (b = 0.22, SE = 0.04, p < 0.001), we found no significant effect of the incentive on recall; the main effect of incentive (b = -0.12, SE = 0.08, p = 0.105) was 50% in ROPE (equivalence test: p = 0.507), the interaction effect with past completion time (b = 0.09, SE = 0.05, p = 0.076) was 66% in ROPE (equivalence test: p = 0.297) and the interaction effect with current time (b = 0.01, SE

= 0.05, p = 0.888) was 100% in ROPE (equivalence test: p = 0.025). Adding vaccination status identification as an additional moderator revealed no main effect of identification or its interactions with the other model variables on the recall of time ($0.115 < p < 0.902$), further supporting the claim that it was not motivationally biased (for regression details, see Extended Data Table 23).

Overall, the results of Studies 2 and 3 indicate that biased recall is relatively stable. Meta-cognitive information about common biases and minor incentives were not sufficient to increase recall accuracy. Yet, stronger incentives could reduce but not eliminate bias. Importantly, incentives appear to only increase recall accuracy when people can be assumed to have some motivation for distortion in pandemic-related variables but not for a neutral control variable. These results thus provide evidence for the motivational nature of biased recall. Finally, individual directional bias (estimable for n = 868 participants) again related to the evaluation of the appropriateness of past political action in Study 2 (r = 0.31, $p < 0.001$) and Study 3 (r = 0.36, $p < 0.001$).

Generalizability across countries

As polarization can be observed in many countries,[13,22] Study 4 investigated the relation between biased estimates of the pandemic and post-pandemic evaluations on a more global scale. We also wanted to explore correlates that might indicate societal tension. Dryhurst et al.'s study[23] conducted in March/April 2020 served as a benchmark, providing data on pandemic perceptions in 10 countries (Australia, Germany, Italy, Japan, Mexico, South Korea, Spain, Sweden, the United Kingdom and the United States) that differ in terms of culture, pandemic impact and government response. We collected data from new samples in these countries (N = 5,121; country sample sizes ranging from n = 498 to 563; below analyses refer to the complete samples). The majority (88%) had received at least one dose of a COVID-19 vaccine (ranging from 72% in Japan to 96% in Spain). Respondents were asked to estimate how many people perceived a high probability and severity of infection and high

government effectiveness at the beginning of the pandemic. A pretest with additional data from Study 1 showed that such population-level estimates relate to individual-level recall as used in Studies 1–3 (for details, see *Study 1 Analyses* in the Methods and Extended Data Table 9). While population estimates are likely to be influenced by other factors (e.g. media exposure and education) and can only be seen as a noisy proxy for individual-level recall, they were considered a viable replacement given that no individual data was available from the past.

Comparing estimates with the benchmark values,[23] we found the majority of participants in all countries overestimated perceived probability of infection (ranging from 65% in the United Kingdom to 92% in Italy), while the majority of participants in all countries except Japan (24%) and Mexico (42%) underestimated perceived severity of the illness in 2020 (ranging from 74% in Spain to 97% in the United Kingdom, also see Figure 3A and Extended Data Table 24). Bias regarding government effectiveness varied by country (the share of participants overestimating this variable ranged from 31% in Italy to 81% in Japan). As in the previous studies, we identified associations between bias and post-pandemic evaluation, but this varied by country (for details, see Extended Data Table 24). For instance, in some countries, estimating COVID-19 as more severe than it had actually been perceived in the past by a representative country sample was associated with the evaluation of political action as more appropriate (r = 0.11 in Australia, 0.13 in Spain, 0.19 in South Korea and 0.21 in Sweden).

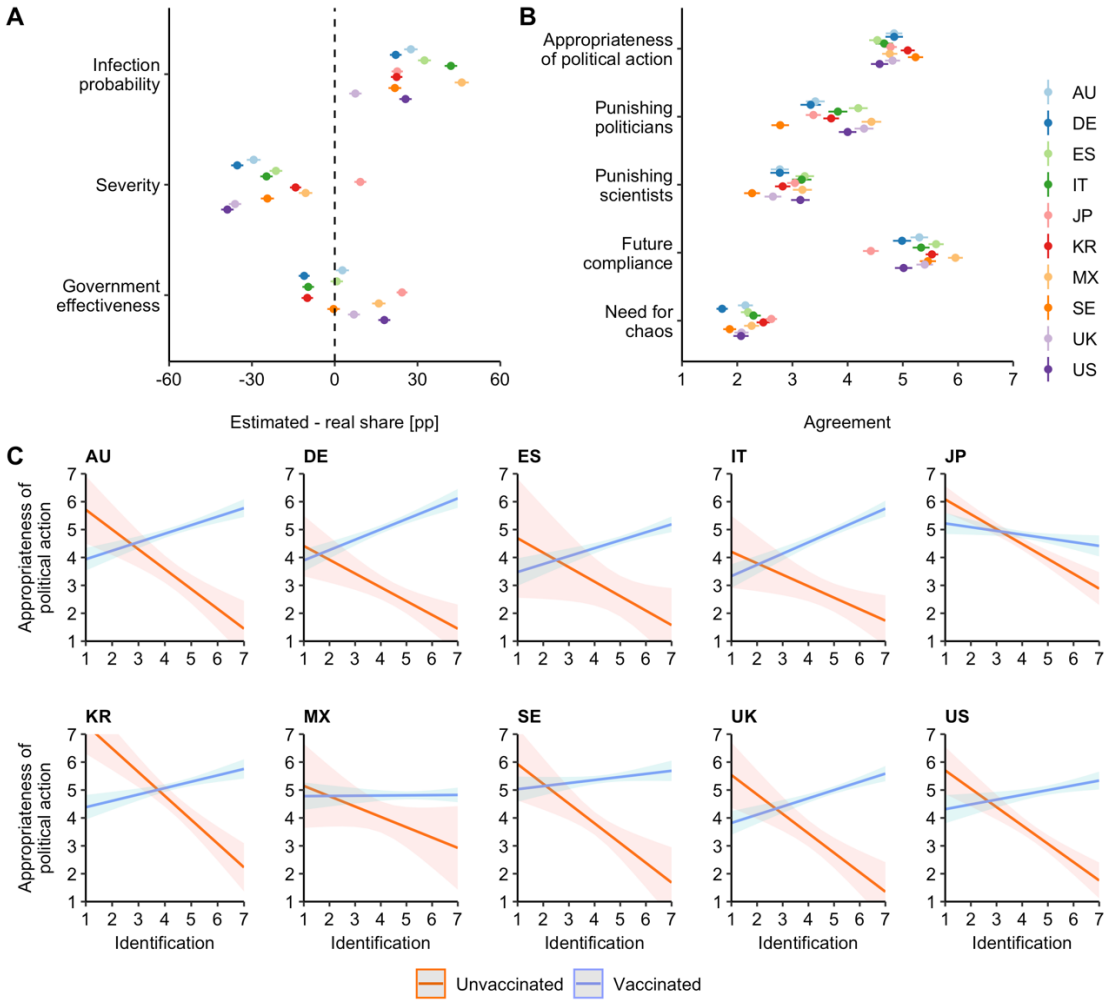

Figure 3. Pandemic perceptions and behavioural intentions across countries in Study 4

Note: Results from Australia (AU, $n = 502$), Germany (DE, $n = 499$), Spain (ES, $n = 498$), Italy (IT, $n = 498$), Japan (JP, $n = 511$), South Korea (KR, $n = 510$), Mexico (MX, $n = 510$), Sweden (SE, $n = 506$), the United Kingdom (UK, $n = 524$) and the United States (US, $n = 563$). (A) Participants' estimates of the share of perceived high levels of infection probability, severity and government effectiveness as reported in a 2020 survey.[23] Dots depict average differences between these estimates and observed values; error bars indicate 95% confidence intervals (CIs; significant differences between two countries can be inferred from non-overlapping CIs). (B) Evaluation of appropriateness of political action, desire to punish politicians and scientists for their handling of the pandemic and intended compliance with regulations and recommendations in any future pandemic, ranging from 1 (very much disagree) to 7 (very much agree); dots depict means, and error bars indicate 95% CIs (significant differences between countries can be inferred from non-overlapping CIs). (C) Linear regression analyses of vaccination status, vaccination status identification and their interaction, predicting mean evaluation of the appropriateness of political action. Lines represent linear fit, with ribbons visualizing 95% CIs. See Extended Data Table 26 for regression details.

Evaluations of the appropriateness of political action during the pandemic were broadly similar across the included countries, with the largest difference between Spain ($M = 4.54$, $SD = 1.69$) and Sweden ($M = 5.23$, $SD = 1.58$, $d = 0.42$, see Figure 3B and Extended Data Table 25). Importantly, in all countries other than Japan and Mexico, evaluations of

political measures were more positive among the vaccinated and more negative among the unvaccinated as vaccination status identification increased (Figure 3C; see Extended Data Table 26 for regression details), echoing the results of the previous studies. Regarding post-pandemic societal tension, we found that between 19% (Sweden) and 49% (Mexico) of participants had a strong desire to punish politicians (above scale midpoint) and between 12% (Sweden) and 27% (Italy) had a strong desire to punish scientists for their handling of the pandemic. When participants evaluated past political action as less appropriate, these desires were stronger (r = -0.32 in Mexico to -0.70 in Germany for punishing politicians; r = -0.47 in Mexico to -0.77 in the United States for punishing scientists). Those who evaluated political actions more negatively were also less inclined to vote (r = 0.09 in South Korea to 0.20 in Germany; non-significant exceptions: r = 0.05 in the United States and 0.07 in Mexico) and had a greater desire to dismantle the entire political order (need for chaos[24]: r = -0.35 in Germany to -0.58 in Sweden). The groups seeking chaos (above the scale midpoint) were small but considerable (ranging from 6% in Germany to 15% in Italy). Finally, post-pandemic evaluations were positively related to intended compliance in a future pandemic in all countries (r = 0.18 in Mexico to 0.56 in Germany) except Japan (r = 0.03). Overall, between 49% (in Japan) and 84% (in Mexico) indicated high (above the scale midpoint) intentions to comply with future pandemic regulations. For all percentages and correlations, see Extended Data Table 25.

The results suggest that while a vaccinated majority has a more positive view of the measures taken during the pandemic, as warranted by respective perceptions of the past, a small segment of society has a strong desire to take revenge on those who spoke out or took

responsibility during the pandemic. In summary, we observed polarized evaluations of the pandemic and indicators of social tension in many countries and across continents.

Discussion

The COVID-19 pandemic has had a profound impact on global society. Around the world, governments and individuals have experienced significant upheaval, and tough decisions were made to mitigate the spread of the virus. The four studies presented here illuminate how past behaviour and today's perceptions influence how individuals recall their attitudes, perceptions and behaviours during the pandemic and how their biased memories continue to affect everyday life and influence future public health responses. In line with previous research on recall bias in the context of IQ test performance and fertility preferences,[17,25] the bias was found to be strong, as it could not be reduced by bias-awareness information or minor monetary incentives; only large incentives partially increased accurate recall.

On a societal level, the observed recall bias is problematic because it may lead to systematically different ideas of how effective and appropriate pandemic interventions were. In addition, the desire to punish those responsible for past pandemic measures may make it difficult to build on 'lessons learnt'. The strong directional character of this bias and the influence of identity in this regard have major implications that warrant further exploration. For instance, memory distortions can be functional in coping with major life events.[26] Therefore, future research could investigate whether people with a larger (vs. smaller) tendency for biased recall of the COVID-19 pandemic may have had some advantages on other psychological dimensions, including psychological functioning during or after the pandemic. Yet, catastrophic events typically require a rapid response, and this works best when people can agree on a way forward. It follows that diverging representations of the past may impede effective future action, and it would be useful to investigate this problem in other crisis contexts, such as climate change.

The studies reported here have some limitations. First, although the tested interventions addressed metacognitive processes, our findings suggest that it may prove more useful to target motivational issues such as identity. Second, the estimate of others' past ratings used in Study 4 can be considered a proxy for individual recall. However, the two concepts may differ, as estimates for the general population may also depend on other factors, such as feelings and thoughts about this population. Third, in Study 4, the observed single effects may further reflect country-specific factors beyond the scope of the present study, and these invite further investigation. Finally, previous research suggests a bidirectional link between identity and (biased) recall of the past.[3] Although our results support the motivational nature of recall bias, it is beyond the scope of the present research to tease the causal directions apart.

In conclusion, the four studies reported here highlight the complex nexus of attitudes, memories and behaviours surrounding the COVID-19 pandemic. Motivational factors related to identity and behaviour in extreme situations seem pivotal in this context, linking the past to biased memories and future behaviours. Researchers and policymakers must pursue a better understanding of these connections to develop more fruitful ways of learning from the past to improve crisis preparedness and response.

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Methods

Study 1

Participants

Participants were surveyed for the first time in summer 2020 or winter 2020/21 (within the COVID-19 Snapshot Monitoring project, COSMO) and for the second time in late 2022. In total, 1,644 individuals participated. They were aged 18–74 years during the first survey (M = 52.68, SD = 12.75); 49% were male, and 51% were female. Unvaccinated participants were oversampled compared to the general population to assess the interaction of vaccine status and vaccination status identification.

Measures

Vaccination status and vaccination status identification

Participants were asked how many vaccines they had received against COVID-19 (recoded to (un-)vaccinated if they received at least one (no) vaccine). Identification with vaccination status was assessed using the 5-item scale by Henkel et al.[27] (sample item: 'I am proud (not) to be vaccinated against COVID-19', measured on a 7-point scale from 'do not agree at all' to 'very much agree').

Pandemic perceptions and behaviours

At both time points, participants were asked how likely it was that they would get infected (*infection probability*, measured on a 7-point scale from 'very unlikely' to 'very likely') and how severe the infection would be (*severity*, measured on a 7-point scale from 'completely

harmless' to 'very severe'). *Affective risk* was assessed by mean-averaging answers to three 7-point items: how often participants thought about the coronavirus, how much they worried about it and how scary they found it (Cronbach's $\alpha = 0.84$ at the first and 0.91 at the second time point).

Participants also indicated how often they had worn a face mask in the previous week (measured on a 5-point scale ranging from 'never' to 'always', participants could choose to not answer at the first timepoint, resulting in $n = 44$ missing answers), how much they trusted the federal government and science to manage the pandemic (measured on a 7-point scale ranging from 'no trust at all' to 'very much trust', participants could choose to not answer at the first timepoint, resulting in $n = 44$ missing answers for trust in government and $n = 155$ missing answers for trust in science) and to what extent they agreed with the statement 'I think the measures that are currently being taken are greatly exaggerated' (measured on a 7-point scale ranging from 'do not agree at all' to 'agree very much'). Finally, participants were asked to assess their overall life satisfaction (on a 7-point scale ranging from 'not at all satisfied' to 'very satisfied', some surveys of the first timepoint did not include the item, resulting in $n = 105$ missing answers).

At the second time point, participants were asked to estimate the share of people who perceived high infection severity, high exaggeration of pandemic measures, high life satisfaction (values 5–7 on the respective 7-point scale presented above) and low trust in government (values 1–3 on the 7-point scale presented above) in a summer 2020 survey. This served to validate the usability of population estimates as individual recall proxies (see Analyses below).

Pandemic recall

At the second time point, participants were asked to recall the time of the first survey. To help them recall the period in question, they were provided with some details of the pandemic situation and a visual showing COVID-19 cases over time. They were asked to recall their

perceptions of risk, their trust in government and science, their mask-wearing behaviour, how exaggerated they had perceived the policies and their life satisfaction during that period (using the same 5- or 7-point scales as before).

Appropriateness of political action

Participants were asked to respond to nine items evaluating how the pandemic was handled, measured on a 7-point scale ranging from 'do not agree at all' to 'agree very much' (example items: 'It has been proved that most corona measures have not worked', 'The Corona measures were a pretext to restrict civil liberties', Cronbach's $\alpha = 0.92$). The items were inspired by a newspaper report.[28]

Analyses

Population models

To assess the effects of past and present ratings on recall for each variable, eight Truth and Bias (T&B) models[29] were estimated. In each model, recall of one variable (e.g. infection probability) was regressed on past and present ratings, along with all their possible interactions with vaccination status and vaccination status identification. For visualization purposes (Figure 1), we plotted all intersections of present and past values that resulted in a predicted recall at the respective variable's scale midpoint (separately for vaccinated and unvaccinated individuals with different levels of identification). Modelling showed the effects of vaccination status and vaccination status identification on directional bias (the extent to which responses tended towards scale endpoints, model intercept) and the force of past ('truth force') and present ('bias force') ratings. To be able to interpret directional bias as an over- or underestimation of recall compared to the past, all models were estimated for a second time, with recall, past and present ratings being centred by the grand mean of past ratings (for regression tables, see Extended Data Tables 1–8.

Individual models

Assuming that recall at the individual level is similarly biased for all variables, we estimated directional bias and the biasing force of past and present ratings for each participant. In calculating each participant's T&B model, only seven variables were included; life satisfaction was excluded, as this hardly differed between participants, and recall of life satisfaction was based almost entirely on current life satisfaction at population level (see Figure 1). Perceptions of exaggeration were inverted (as they correlated negatively with the other variables). All variables were rescaled to range from 0 to 1 before model estimation. Please note that for $n = 70$ participants no individual model could be estimated. For all analyses, the necessary preconditions were met.

Population estimates as proxies of individual recall

To show that individual recall bias is linked to biased population estimates, participants' estimated share of people who perceived high infection severity, low trust in government, high exaggeration of pandemic measures and high life satisfaction were predicted by their individual recall, past and present evaluations of these variables in three multiple linear regressions (see Extended Data Table 9).

Study 2

Participants

Participants were surveyed at two time points: December 2021 and early 2023. In total, 3,105 individuals aged 18–97 years ($M = 49.90$, $SD = 16.02$) participated, of whom 50% were male and 50% were female. Participants were recruited from a panel containing Austrian and German participants who had already taken part several times in surveys around vaccination.[27] The panel included more unvaccinated participants than the general population to reliably observe potential changes in vaccination-related perceptions, intentions and behaviours over time.

Experimental manipulation

At the second time point, participants were randomly assigned to one of three groups. Those in the *incentive* group were told that accurate recall increased their chances of winning a 100 euro prize. For a given variable, correct recall was awarded 5 points; if recall varied by 1 scale unit, 4 points were awarded, and so on. Each respondent's total points determined how often they would participate in the prize lottery. This intervention aimed at incentivising correct recall (i.e. giving people the chance to overrule motivated thinking by valuing a financial win as higher than confirming with one's current opinions). Participants assigned to the *information* group were provided with some written details of another study, in which a selected group of 100 people were asked to recall their perceptions of infection severity, their trust in government and their mask wearing behaviour during December 2021. The information group participants were then asked to guess what proportion of that other group underestimated those three variables. Each of our participants was then given an answer ranging from 10% to 90% (in 10% increments) based on randomly selected individuals from the other study. Thus, some participants were told that 10% of people underestimated perceived infection severity, trust in government and mask-wearing behaviours; others were told that 20% had underestimated these variables, and so on. This procedure generated random variation in the information received. The control group received no such information or incentive. The intervention aimed to raise people's awareness of bias, triggering accuracy concerns.

Measures

As in Study 1, vaccination status and vaccination status identification (Cronbach's $\alpha = 0.75$) were assessed at the second time point. Present and past risk perceptions, trust and protective behaviours, as well as their recall, were assessed. Items queried infection probability, severity, trust in government and science and mask wearing again, plus frequency of avoiding close contact (7-point scale ranging from 'never' to 'always'). Appropriateness of political action was assessed as in Study 1 (Cronbach's $\alpha = 0.92$).

Analyses

Again, as in Study 1, population T&B models[28] were estimated for each of the six variables. On this occasion, however, recall was regressed on past and present values for each variable, along with potential interactions with vaccination status and experimental manipulation. As in Study 1, recall, past and present ratings were again centred by the grand mean of past ratings. Regression details are provided in Extended Data Tables 10–15. For all analyses, the necessary preconditions were met.

Study 3

Participants

Participants were surveyed for the first time between May and October 2021 (within COSMO) and for the second time in July 2023. As the panel provider was not able to reach enough unvaccinated individuals for group comparisons, only vaccinated individuals were invited to participate in the second survey. In total, 906 individuals participated. They were aged 18–74 years during the first survey (M = 50.67, SD = 14.11); 45% were male, and 55% were female.

Experimental manipulation

At the second time point, participants were randomly assigned to one of two groups. Those in the *incentive* group were told that accurate recall increased their chances of winning a 25 euro prize. For payment, for each participant in this group, one recall variable was randomly selected and compared to the original answer they provided in 2021. The probability of winning the prize was then calculated by applying a binarized scoring rule[30] using the following formula: $p = 100 - 100 \times (|\frac{Original\ answer}{y} - \frac{Recalled\ answer}{y}|)$, with y = 6 for 7-point scale items and y = 4 for 5-point scale items. That is, when recall met the original answer, participants received the prize with certainty, and the larger the deviation, the lower the probability of winning the prize. In total, 64% of participants in the incentive group received the prize. Recall in the *control* group was not incentivized.

Measures

As in Studies 1 and 2, present and past perceptions and behaviours, as well as their recall, were assessed. Items queried infection probability, severity, trust in government, exaggeration perception (7-point scales), mask wearing and contact avoidance (5-point scale). As participants could choose to not answer some items at the first timepoint, there are missing answers for past mask wearing (n = 4), contact avoidance (n = 47) and trust in government (n = 25). Participants were further asked to recall the time they completed the 2021 survey (choosing one of seven time intervals). Appropriateness of political action was assessed as in Study 1 (Cronbach's $\alpha = 0.89$).

Analyses

Again, population T&B models[29] were estimated for each of the six pandemic-related variables and the survey completion time. On this occasion, however, recall was regressed on past and present values for each variable, along with interactions with the experimental manipulation. Except for visualization (Figure 2), recall, past and present ratings were again centred by the grand mean of past ratings. Extended models, including vaccination status identification as an additional moderator, were also explored (see Extended Data Tables 16–21). As in Study 1, individual T&B models were calculated to estimate individual directional bias (note that for n = 38 participants no individual model could be estimated). For all analyses, the necessary preconditions were met.

Study 4

Participants

Participants from 10 countries were assessed once between March and April 2023 (N = 5,121). The included countries were Australia (n = 502), Germany (n = 499), Italy (n = 498), Japan (n = 511), Mexico (n = 510), South Korea (n = 510), Spain (n = 498), Sweden (n = 506), the United Kingdom (n = 524) and the United States (n = 564). Participants were aged 18–89 years (M = 46.05, SD = 15.87); of these, 50% were male and 50% were female. The

selection of countries and the criteria for representativeness matched those in the 2020 study by Dryhurst et al.[31]

Measures

Vaccination status and vaccination status identification (Cronbach's $\alpha = 0.72$) were assessed as in Study 1.

Pandemic recall

Participants were asked to guess responses (0–100%) to the following items in a survey conducted by Dryhurst et al.[31] between mid-March and mid-April 2020: the seriousness of COVID-19 ('What percentage of respondents (do you think) said in March/April 2020 that getting sick with COVID-19 can be serious?'), the probability of getting sick with COVID-19 ('What percentage of respondents (do you think) said in March/April 2020 that they would probably get sick with COVID-19?') and the effectiveness of the government's response to the pandemic ('What percentage of respondents (do you think) said in March/April 2020 that the official response in their country was an effective way of dealing with the pandemic up to that point in time?'). Participants were told that we defined 'agreement' in the original study as a rating of 4 or 5 for infection severity and probability (originally measured on a 5-point scale) and a rating of 6 or 7 for government effectiveness (originally measured on a 7-point scale). For each of the items, we compared our participants' guesses with the actual percentage of people, as found by Dryhurst et al.[31]

Appropriateness of political action

This issue was explored using two items from Study 1: 'The corona measures were a pretext to restrict civil liberties' and 'Evidence shows that most corona measures have not worked' (measured on a 7-point scale ranging from 'do not agree at all' to 'agree very much').

Punishment intention

To measure punishment intention, we asked participants to respond to two statements: 'Politicians should be punished for how they handled the corona pandemic' and 'Scientists

who gave advice to the government should be punished for how they handled the corona pandemic' (measured on a 7-point scale ranging from 'strongly disagree' to 'strongly agree').

Voting intentions

Future voting intentions were assessed using the following yes/no question: 'If there was an election next week, would you vote?'

Compliance in a future pandemic

Compliance in a future pandemic was assessed in terms of the following statement: 'If there was a similar but new pandemic coming up, I would comply with measures and regulations.' (measured on a 7-point scale ranging from 'strongly disagree' to 'strongly agree').

Need for chaos

Participants were asked about their agreement with three items developed by Petersen et al.:[32] 'Sometimes I just feel like destroying beautiful things', 'I think society should be burned to the ground' and 'I fantasize about a natural disaster wiping out most of humanity such that a small group of people can start all over' (measured on a 7-point scale from 'strongly disagree' to 'strongly agree', Cronbach's $\alpha = 0.83$).

Ethical approval

The study was conducted in accordance with German Psychological Association guidelines. Ethical clearance was obtained from the University of Erfurt's institutional review board (#20200302/20200501/20211215) and the University of Bamberg's institutional review board (#2023-07/31). All participants provided informed consent to use and share their data for scientific purposes without disclosing their identities. Participants were compensated for their participation by the panel providers.

Data availability statement

Data are available at http://dx.doi.org/10.17605/OSF.IO/BXG7V. Study 2 (https://aspredicted.org/KGF_SNN) and Study 3 (https://aspredicted.org/kk33k.pdf) were preregistered.

Code availability statement

Data analysis scripts are available at http://dx.doi.org/10.17605/OSF.IO/BXG7V.

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Author contributions

All authors designed and performed the research. PS and LH performed the data analyses. All authors wrote and revised the manuscript.

Competing interest declaration

The authors declare no competing interests.