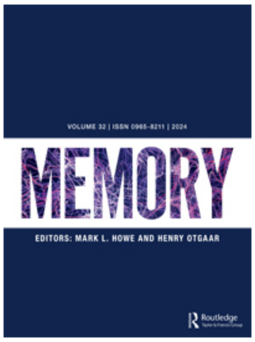

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Time and memory distrust shape the dynamics of recollection and belief-in-occurrence

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ABSTRACT
The current study examined how people's metamemory judgments of recollection and belief-in-occurrence change over time. Furthermore, we examined to what extent these judgments are affected by memory distrust – the subjective appraisal of one's memory functioning – as measured by the Memory Distrust Scale (MDS) and the Squire Subjective Memory Scale (SSMQ). Participants ($N = 234$) studied pictorial stimuli and were tested on some of these stimuli later in the same session, but were tested on other stimuli 1, 2, 4, 8, and 17 days later. Recollection and belief ratings were correlated highly and followed similar declining patterns over time. However, belief decreased relatively more slowly than recollection, such that the discrepancy between recollection and belief increased over time. Memory distrust moderated the association between recollection and belief, with this association being weaker among people who reported greater (versus lower) memory distrust. Memory distrust also interacted with retention period to predict memory judgments. Two measures of memory distrust diverged in their predictive power. In particular, only the MDS predicted the spontaneous reporting of nonbelieved memories. Our results provide support to the theoretical perspective that belief-in-occurrence is a summative judgment informed not only by recollective phenomenology but also by metamemorial beliefs.

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Recollection; autobiographical belief; forgetting; memory distrust; metacognition

Retrieved memories of experienced events often comprise both a vivid sense of recollection and a strong belief that the experienced event took place. Research, however, has shown that people can have strong belief in the occurrence of an event despite having no recollection of the event. They can also have a sense of recollecting an event despite not believing (strongly) that this event ever occurred, which is termed as nonbelieved memory (NBMs, Mazzoni et al., 2010; Otgaar et al., 2014; Scoboria et al., 2017; Scoboria & Talarico, 2013). That is, autobiographical recollection and the belief in an event's occurrence are related yet distinct constructs (Clark et al., 2012; Mazzoni et al., 2010; Otgaar et al., 2014).

The dissociation of recollection and belief-in-occurrence judgments

The dissociation of recollection and belief-in-occurrence judgments can be observed in several ways. Scoboria et al. (2014) demonstrated that recollection and belief-in-occurrence (hereafter, we simply refer to as "belief" in the introduction section) reflect two distinct latent constructs that are correlated moderately positively (Study 1). Moreover, the magnitude and direction of association can differ between different kinds of event representations, with the positive correlation being smaller for nonbelieved memories than for believed memories (Study 2). Importantly, Scoboria and colleagues showed that there was a double dissociation between predictors of recollection and belief: some characteristics that predicted recollection well (e.g., perceptual, re-experiencing, emotion intensity, event specificity) did not predict belief well, whereas some characteristics that predicted belief well (e.g., plausibility) did not predict recollection well.

Theoretical perspectives on recollection and belief

Blank (2017) argued that recollection-belief divergences such as nonbelieved memory arise from normal metacognitive monitoring and control processes that balance recollection and reality constraints. From this perspective, autobiographical belief is the summative evaluation of the truth status of the remembered events at the time of retrieval (Otgaar et al., 2014; Scoboria et al., 2014). The

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inputs of this evaluation include not only the recollective features of the memory representation, but also diverse information ranging from general knowledge of the world (e.g., as bases of plausibility judgments) to social information (e.g., Otgaar et al., 2017; Scoboria et al., 2018). Since this information might plausibly change in each instance of remembering, the truth status assigned to the events could therefore also be continuously revisited and substantially altered. For example, it might result in a change of memory statements such as retraction of having been abused (Blank, 2017; Li et al., 2023; Ost, 2017).

Further expanding on this theoretical framework, researchers have argued that memory distrust, the belief about one's memory functioning can also impact the memory validation process (Nash et al., 2022; Zhang, Battista, et al., 2022; Zhang, Nash, et al., 2023; Zhang, Qi, et al., 2023). For example, Zhang, Battista, et al. (2022) and Zhang, Otgaar, et al. (2022) argued that people differ in the extent to which they trust their recollections, with those people who are more sceptical about their own memory functioning (i.e., high memory distrust) giving less credence to their recollections than their low memory distrust counterparts. Following this logic, Zhang, Battista, et al. (2022) and Zhang, Otgaar, et al. (2022) examined the relationship between memory distrust and nonbelieved memories and found that people with high (versus low) memory distrust were more likely to report experiencing nonbelieved memories. Similarly, Nash et al. (2022) found that people who spontaneously reported a nonbelieved memory – operationalised there as any event that the participant scored lower on belief than on recollection – scored on average higher on a measure of memory distrust than did people who reported no nonbelieved memory.

Memory distrust is also associated with strategies that people use for verifying memories (Zhang, Nash, et al., 2023). People with high (versus low) memory distrust, when confronted with a suggestion that their memory might be wrong, are more likely to prefer using low-cost but less reliable verification strategies (e.g., seeking information from other people), thus exhibiting a stronger cheap-and-easy strategy bias (Nash et al., 2017; Wade et al., 2014). Moreover, in other research, people who were more (versus less) concerned about falsely remembering showed a more conservative response bias (i.e., a bias to make "new" judgments in a recognition task), suggesting that people may consider their memory ability and adjust their response criterion for better accuracy during a memory test (Zhang, Qi, et al., 2023). Evidence is therefore accumulating that people use their subjective appraisals of their own memory functioning to calibrate how they evaluate specific memory recollections. One way to further explore the dissociation between recollection and belief, as well as the role of memory distrust, is to examine the said dynamics in a longitudinal design.

Memory in time: forgetting, recollection, and belief

More than one century ago, Ebbinghaus (1885/1962) empirically examined how memory fades over time, following which, a wealth of research has been conducted examining the patterns and mechanisms of forgetting (e.g., Fisher & Radvansky, 2018, 2019, 2022; Rubin & Wenzel, 1996). Although ample evidence suggests that memory decays in a decelerating fashion (see Rubin & Wenzel, 1996 for a review), recent research has shown that under certain conditions (e.g., high-level learning), forgetting curves can be linear (Fisher & Radvansky, 2018; 2019; 2022).

Despite this important work on forgetting, the temporal patterns of metacognitive judgments are still ill-explored. One recent study using movie materials found that people's memory confidence ratings decreased over the course of one week, despite their memory accuracy remaining stable across this period (Frisoni et al., 2023). Belief judgments, on the other hand, have not been examined from a longitudinal angle (for the distinction between belief and confidence judgments, see Scoboria et al., 2014). Understanding how recollection and belief change over time holds theoretical importance. For example, most people hold certain beliefs about forgetting (i.e., that our memories decay over time, Koriat et al., 2004) and may thus give greater credence to recollections if they are more recent than distant (Nash et al., 2017). Therefore, we might observe an increased recollection-belief divergence over time as a result of people's general beliefs about forgetting.

According to Blank (2017), forgetting can have different effects on recollection-belief divergence depending on whether or not the experience can be semantically integrated into one's knowledge structures. In cases when an event becomes an integral part of these knowledge structures, a weakening of recollective features over time may not result in a decrease in belief. For example, although the recollection of a childhood birthday celebration can fade away as time passes, the belief in that event's occurrence can remain stable as it becomes an integral part of the autobiography. However, if the event cannot be incorporated into one's knowledge structure, the belief in that event's occurrence will be inferred only at the moment of retrieving the decayed recollections, perhaps leading to weaker belief. Limited evidence is available to examine whether and to what extent this hypothesis is valid, demanding longitudinal research on recollection and belief changes.

The current study

In the current study, we examined how judgments of recollection and belief change over time, as well as how time and memory distrust influence the recollection-belief relationship. We asked participants to encode six blocks of pictorial stimuli and tested participants'

Table 1. Order of blocks in recognition tasks.

Group	1st test (day 1)	2nd test (day 2)	3rd test (day 3)	4th test (day 5)	5th test (day 9)	6th test (day 18)
Retention (in days)	0	1	2	4	8	17
A ($n = 38$)	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
B ($n = 30$)	Block 2	Block 3	Block 4	Block 5	Block 6	Block 1
C ($n = 38$)	Block 3	Block 4	Block 5	Block 6	Block 1	Block 2
D ($n = 42$)	Block 4	Block 5	Block 6	Block 1	Block 2	Block 3
E ($n = 40$)	Block 5	Block 6	Block 1	Block 2	Block 3	Block 4
F ($n = 46$)	Block 6	Block 1	Block 2	Block 3	Block 4	Block 5

Note. *n* refers to the number of participants assigned to each group in the final sample.

memories about these stimuli one random block at a time over three weeks (see Table 1). This design allowed us to examine the effect of time on recollection and belief while controlling both for individual differences in memory ability (via multiple measurements of the same participants over time) and for the testing effect, a phenomenon in which retrieval practice enhances memory retention compared with mere studying (see van den Broek et al., 2016 for a review). Given that the materials selected for the current study were unlikely to be personally relevant to the participants and integrated into their autobiographical knowledge, we expected that autobiographical belief would show a similar reduction to that of recollection.

To measure memory distrust, participants also completed the adapted Squire Subjective Memory Questionnaire (SSMQ, Squire et al., 1979; van Bergen et al., 2010) and the Memory Distrust Scale (MDS, Nash et al., 2022). The former assesses people's concern about forgetting (i.e., memory omission errors) while the latter measures people's concern about misremembering events that did not happen (i.e., memory commission errors). Based on previous findings on nonbelieved memories (Nash et al., 2022; Zhang, Battista, et al., 2022; Zhang, Otgaar, et al., 2022) and memory verification (Zhang, Nash, et al., 2023), we expected that memory distrust would be associated not only with objective recognition memory performance but also the divergence of recollection and belief judgments, with high memory distrust (versus low memory distrust) people relying less on their recollection when making belief judgments, and thus reporting more nonbelieved memories. Here, we defined a nonbelieved memory as any event representation for which belief was rated at least two scale-points lower than recollection; however, we return later to consider the implications of this operationalisation.

Additionally, Zhang, Battista, et al. (2022) reported that people who engage in more (versus less) frequent voluntary and involuntary autobiographical memory recall are more likely to recall NBMs. We also included the measures of voluntary and involuntary autobiographical memory recall (Berntsen et al., 2015) in the present study, and examined their associations with recognition, recollection, belief, and nonbelieved memories. However, these results are peripheral to the current study's main aims and are therefore reported in the supplementary materials.

Method

Participants

Sample size planning

As the current study examines how recollection and belief judgments change over time, the emphasis is placed on gaining accurate estimates of these temporal patterns. One way to ensure the reliability of the estimates is to increase the sample size and thus narrow down the standard error (SE). We therefore aimed for the estimates to have a standard error of 0.10.[1] In previous studies, the standard deviations of the recollection and belief ratings were around 1.6 points on the relevant measurement scales described below (e.g., Li et al., 2020). Based on this standard deviation and the aimed SE, a sample size of 256 individuals is needed.

Two hundred and fifty-seven participants were recruited from the crowdsourcing platform Connect (https://account.cloudresearch.com/). Participants who signed up for Session 1 were invited to complete all later sessions. For each subsequent session, there was a small percentage of participants who failed to return (return rates ranged from 89.45% to 94.53%). Specifically, only 231 participants completed the final session which included trait measures and demographics. One participant reported having seen the photo materials before and nineteen participants failed at least one attention check embedded in the trait measures.[2] Therefore, their data were excluded from all analyses.

Further, we excluded the data of any data collection sessions (around 80 individual sessions in total across all participants) for which the participant provided the wrong group number and therefore were presented with incorrect blocks of test stimuli (per the counterbalancing schedule). All valid memory test data were included in the analyses regardless of whether the participants completed all or only some of the six sessions since the (Generalised) linear mixed model [(G)LMM] approach could accommodate missing data like this. As a result, the current study contained memory test data from 234 participants ($n_{\text{male}} = 113$, $n_{\text{female}} = 98$, $n_{\text{gender-not-specified}} = 23$; $M_{\text{age}} = 40.26$, $SD_{\text{age}} = 12.47$)[3] and trait measure data from 211 participants.

A sensitivity analysis for within-subject ANOVA for the effect of Time ($n_{\text{group}} = 1$, $n_{\text{measurement}} = 6$) shows that with $\alpha = .05$ and $1-\beta = .90$, a sample of 234 could reliably detect an effect of $f = 0.077$ and above.[4] A second sensitivity analysis for linear multiple regression ($n_{\text{tested predictors}} = 1$, $n_{\text{total predictors}} = 2$) was run for the association between memory distrust and recollection or belief. A sample of 211 could reliably detect an effect of $f^2 = 0.061$ and above (G*Power 3.1; Faul et al., 2009). Given that linear mixed modelling (LMM) could handle missing data and has been shown to produce robust estimates even when distributional assumptions are violated (Schielzeth et al., 2020), in the analyses reported below we opted for LMM instead of linear models.[5]

Participants were compensated under the following scheme. For the encoding and the first recognition task (Session 1), all participants were compensated with \$2.50. For Sessions 2–5 of the study, participants received \$0.90 for each session. For Session 6, participants received \$1.80 as compensation. If participants missed one or more of the recognition tasks, they would not receive compensation for the missed session(s).

All the experimental materials, code scripts as well as anonymized data are available at OSF (https://osf.io/g7xwn/). We preregistered the design of the study at OSF (https://osf.io/d9x8m). The current study acquired ethical approval from the Ethical Committee at the Faculty of Psychology and Neuroscience, Maastricht University before data collection [ERCPN-OZL_246_167_12_2021_S3].

Materials

Experimental stimuli

We randomly selected a total of 180 scenes from the OASIS, an open-access stimulus set containing 900 colour images with normative ratings for valence and arousal (Kurdi et al., 2017; https://www.benedekkurdi.com/%23oasis, see https://osf.io/sqjfb for the random selection process). The stimuli from OASIS depict a broad spectrum of natural or social situations (e.g., buildings or car accidents). To minimise potentially unnecessary emotional impact on participants, we only selected pictures with a mean valence rating of 3 or more and an arousal rating of up to 5 (on 7-point scales).

We then randomly divided these 180 scenes into six 30-scene blocks. Within each block, 15 scenes were randomly selected to always appear during the encoding phase of the study (hereafter referred to as old scenes) whereas the remaining 15 scenes were presented only during the later recognition tests (hereafter referred to as new scenes). Using Kurdi et al.'s norming data we performed between-subject two-way ANOVAs to ensure that there was no statistically significant difference in mean level of arousal and valence ratings between different blocks and old-vs.-new scenes (see Table A1 in the Appendix). We counterbalanced the test order of different blocks (see Table 1) but did not counterbalance old and new scenes in each block. That is, for all participants, the same 90 scenes were presented during encoding while the remaining 90 scenes served as fillers in the recognition tasks.

Memory Distrust. We used two validated measures of memory distrust. First, we used the SSMQ as adapted by van Bergen et al. (2010), which has 18 items and measures participants' subjective beliefs about their susceptibility to making memory omission errors such as forgetting (e.g., "my ability to pay attention to what goes on around me is" from −4 = *Disastrous* to 4 = *Excellent).* Second, we used the Memory Distrust Scale (MDS) by Nash et al. (2022), which has 20 items and measures participants' subjective beliefs about their susceptibility to making memory commission errors such as false memories (e.g., "I am sometimes uncertain whether an event that I recall really happened to me, or whether I saw it on TV or in a movie" from 1 = *Strongly disagree* to 7 = *Strongly agree*). To ease the comparison of results, we reverse-coded participants' SSMQ scores so that higher scores in both scales reflect higher levels of memory distrust. Both scales showed excellent internal consistency in the current sample (SSMQ: Cronbach's $\alpha = .94$, McDonald's $\omega = .95$; MDS: Cronbach's $\alpha = .97$, McDonald's $\omega = .98$).

Measures for exploratory purpose

Involuntary and Voluntary Memories. To measure the frequency with which people engage in involuntary and voluntary autobiographical recall, we included the Involuntary Autobiographical Memory Inventory (IAMI) plus 10 questions measuring voluntary recall (VAMI, Berntsen et al., 2015). The IAMI is a 20-item scale (e.g., "Imaginary future events pop into my mind by themselves – without me consciously trying to evoke them" rated from 1 = *never* to 5 = *once an hour or more*) that examines the frequency of involuntary autobiographical memory recall and thus reflects memory recall without deliberate attempts of retrieval. VAMI, on the other hand, measures the frequency of voluntary autobiographic memory recall (e.g., "After an event has happened, I willfully and deliberately think back to it in my mind and try to remember it"). Both scales showed excellent internal consistency in the current sample (IAMI: Cronbach's $\alpha = .96$, McDonald's $\omega = .97$; VAMI: Cronbach's $\alpha = .94$, McDonald's $\omega = .95$).

Procedure

Participants completed the study online, and the experimental procedure is presented in Figure 1.

Session 1

In Session 1, participants first read the information letter and were informed of the aim of the study, the potential risks and benefits, and the compensation for this study. After giving informed consent, participants were informed that they would now view 90 images which they should view attentively and try to memorise as many details as possible. Each scene from the 90 selected scenes was presented for 5 sec in blocks of 15, with an inter-stimuli interval of 1 sec. At the end of each block, we added a graphic slider question asking participants to slide a bar to a specific number, serving as a reminder of attentiveness. Then the page automatically turned over to the next block after 10 sec (see Figure 2). The order of the six different blocks as well as the order of the stimuli within each block were randomised for each participant. At the

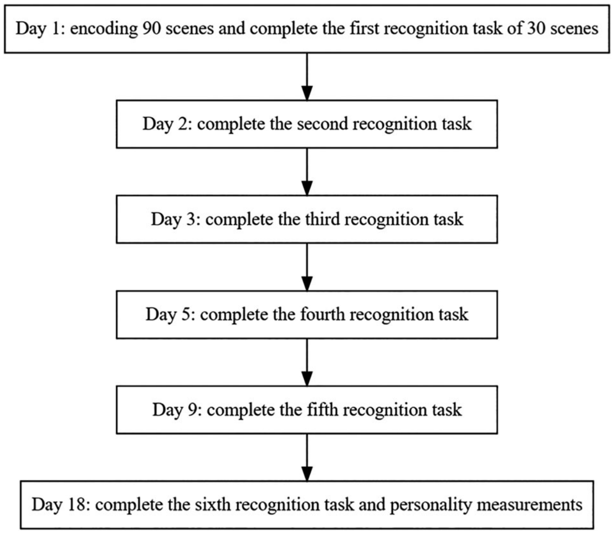

Figure 1. Flowchart of the procedures.

end of the encoding task, the participant was randomly assigned to one of six groups that determined the order of the blocks in their recognition tasks (Table 1).

Next, participants completed the Positive and Negative Affect Schedule expanded form (PANAS-X, Watson & Clark, 1994) as a filler task; we did not track the time participants spent on the distraction task but estimate that this should normally have taken approximately 2–3 min. Afterwards, participants first read an instruction of the memory task, which outlined the difference between recollection and belief (see Appendices – Instruction Memory Task). Then they completed the first memory test of a subset of the encoded stimuli, according to their assigned group. Specifically, one block of fifteen "old" scenes from the encoding phase, plus 15 "new" scenes that had not appeared in the encoding phase, were presented one by one in random order, and participants were asked to indicate whether each scene was presented in Session 1 ("Have you seen the exact scene during Session 1?" Options: *yes* or *no*). For each scene, participants were also then asked to judge their feeling of recollection ("Do you actually remember that this scene has appeared in Session 1?") and their belief in occurrence ("Do you believe that this scene has appeared in Session 1, regardless of whether you remember or not?") on 7-point Likert-like scales (Recollection: 1 = *Not at all*, 7 = *Completely;* Belief: 1 = *Definitely did not happen*, 7 = *Definitely did happen*). Embedded in the old/new recognition task, we added a graphic slider question asking participants to slide a bar to a specific number, serving as a reminder of attentiveness. The procedures of Day 1 are summarised in Figure 2.

Session 2–6

One day after participants had completed the first memory test, they were notified through *Connect* to sign up for the next memory test, and the same also occurred on later days for the third to sixth memory tests, per the experiment schedule. As there is evidence that memory decays more rapidly shortly after encoding and then more slowly as time passes, we tested participants' memory with increasing intervals as time elapsed (see Figure 1). The second to sixth memory tests were the same as the first memory test, except that different stimuli were tested as per the block randomisation schedule. At the end of the sixth memory test, participants completed the measures of memory distrust, IAMI, VAMI, and demographic questions including age and gender.

Data analysis overview

All data analyses were carried out in R (version 4. 2.2; R core team, 2021). All anonymized datasets and Coding scripts are available on OSF (https://osf.io/g7xwn/). Given the multilevel nature of our data and the fact that not all participants completed all sessions (i.e., missing values), we opted for (Generalised) linear mixed modelling [(G)LMM], which produces robust estimates even when distributional assumptions are violated (Schielzeth et al., 2020). QQ plots and residual plots against fitted values were inspected for the reported models to ensure the soundness of our analyses. For all the analyses reported in the results section, a p value $< .05$ was considered as statistically significant and the effect sizes in the (G)LMMs were reported in the form of estimated explained variance (Pseudo-R^2, Nakagawa & Schielzeth, 2013).

We examined the effect of time on the recognition rates, recollection, and belief-in-occurrence scores of presented and non-presented stimuli using (G)LMM with the lme4 package (Bates et al., 2014). These models included Test number (with backward difference contrast) as a fixed effect and included random intercepts for participant ID and stimulus ID as well as random slopes for participant ID. To explore whether recollection and belief differed in their patterns of temporal change, the LMM included retention period (in days, but log-transformed since the decline patterns were not linear; see Figure 3), judgment

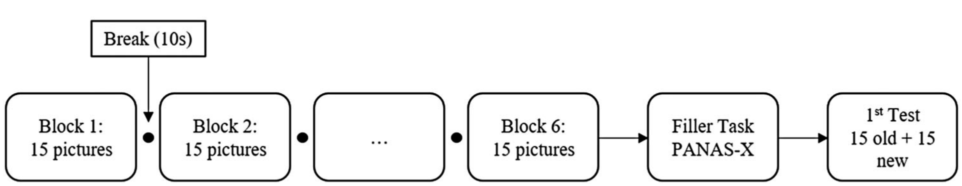

Figure 2. Overview of the first experimental session on day 1.

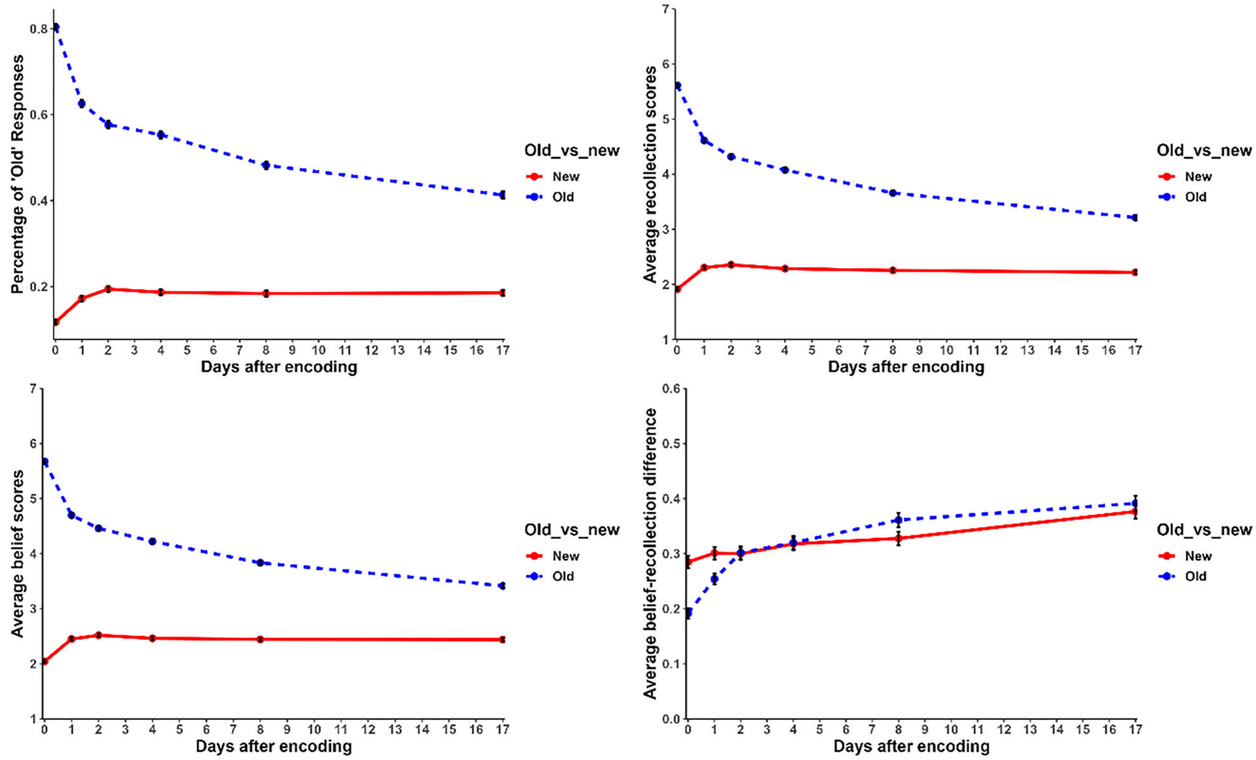

Figure 3. Temporal changes of recognition, recollection, belief-in-occurrence, and the discrepancy between recollection and belief in occurrence.

Note. Belief-recollection difference was calculated by taking the absolute value of (belief score − recollection score). Error bars refer to the 95% CIs of the estimates, without accounting for the non-independency.

type (recollection vs. belief), and their interaction terms as fixed effects, and included random intercepts for participant ID and stimulus ID as well as random slopes for participant ID. The above analyses deviated from the pre-registered analyses in the following ways: (1) we did not specify to code Test number as a categorical variable with backward difference contrast in the pre-registration; (2) we examined the effect of time on test results of new and old stimuli separately instead of together, to provide a clearer understanding of the findings; and (3) in our analysis comparing recollection and belief, we included log-transformed retention period instead of time points as a fixed effect.

To examine the role of memory distrust in recognition, recollection, and belief, we performed a series of (G)LMM. Further, we conducted GLMM analyses to examine whether memory distrust was associated with the occurrence of NBM. We included random intercepts for participant ID and stimulus ID in these models. These analyses were not pre-registered. Nonbelieved memory is often operationalised in experimental research based on the differences between recollection scores and autobiographical belief scores on a 7-point or 8-point scale, and defined as an event representation with relatively higher recollection ratings than belief ratings. Some researchers opt for a minimum 1-point difference (e.g., Scoboria & Talarico, 2013) while others use a 2-point difference on an 8-point scale (e.g., Otgaar et al., 2017; Wang et al., 2017). In these analyses, we decided to opt for the more stringent criterion; therefore, a memory was labelled as an NBM if participants gave a recollection score two or more points higher than their belief score on a 7-point scale.

Results

How do recognition, recollection, belief-in-Occurrence, and belief-recollection discrepancy change over time?

As the top-left panel of Figure 3 shows, the correct recognition of old stimuli (i.e., the hit rate) declined over time following an Ebbinghaus-type decay curve, whereas the correct rejection of new stimuli (i.e., the correct rejection rate) remained stable after initially increasing over the first day. Looking at our other outcome variables, these patterns over time were very similar to those for recognition. Specifically, for old stimuli, there were clear and decelerating decreases over time in both recollection and belief. However, for new stimuli, there was a slight increase in recollection and belief during the first 2 days (see also Table A2 in the Appendix).

When we calculated a discrepancy score for each picture by subtracting the recollection rating from the belief rating and then taking the absolute value, we found that for old items this discrepancy increased sharply over the first 2 days of testing, before continuing to increase more shallowly (see bottom-right panel of Figure 3). For new items, in contrast, the discrepancy scores increased very gradually and at a rather stable rate from the first test onwards.

To analyse these descriptive patterns more formally, we performed (generalised) linear mixed models [(G)LMM] with either recognition response (Yes-Old vs. No-New) or the recollection or belief rating as the dependent variable. We included Test number as a fixed effect with backward contrast coding, whereby each test was compared with the previous test. We also included random intercepts for participant ID and stimulus ID as well as random slopes for participant ID. As shown in the top half of Table 2, the recognition of these old pictures also showed a clear and consistent pattern of decline, with the Test 4 vs. 3 contrast being non-significant, and likewise, both recollection and belief scores for old (i.e., actually presented) stimuli decreased over time, with all the contrasts being statistically significant.

As for participants' responses to new stimuli, false recognition of these stimuli increased significantly from Test 1 to Test 2, but there were no significant test-by-test increases in false recognition after Test 2 (see the bottom half of Table 2). Similarly, there were significant increases in the (false) recollection and belief of these new items from Test 1 to Test 2, after which no further test-by-test changes in these variables were statistically significant. In short, from the descriptive results as well as from the (G)LMMs (Table 2), the temporal patterns of both recollection and belief were very similar, which can also be seen from the very strong overall correlation between belief and recollection scores ($r = .96$).

Discriminability and bias over time

Based on signal detection theory (SDT; Green & Swets, 1966), we calculated SDT indices from the recognition data of each memory test for each participant using the *psycho* package (Makowski, 2018).[6] D′ is a measure of sensitivity/discriminability, with higher values indicating a better ability to discriminate old stimuli from new stimuli. In contrast, beta and c are measures of response bias (see Stanislaw & Todorov, 1999). Beta is calculated based on the likelihood ratio of the two distributions (noise and signal) while c is the distance between the response criterion and the unbiased point, expressed in units of standard deviations. A higher value of either Beta or c would indicate a greater tendency to recognise stimuli as new instead of old (i.e., a more conservative response criterion). Below, we performed and reported analyses with all the indices to offer a more complete view of the data.

As shown in Table 3, discriminability decreased significantly over time; that is, participants became less able to discriminate between old and new stimuli as time elapsed. As for response criterion, when it was indexed using criterion c, there was some indication that people became more likely to say "New" as time elapsed, however, this pattern was not mirrored by the analyses using beta. Given that beta is a ratio and therefore not normally distributed, the regression estimates could be less reliable than those of c.

Table 2. Responses to stimuli over time.

	Old stimuli								
	Recognition			Recollection			Belief		
Fixed Effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	0.44	0.10	<.001	4.22	0.09	<.001	4.35	0.09	<.001
Test 2 vs. 1	−1.12	0.10	<.001	−0.93	0.08	<.001	−0.91	0.08	<.001
Test 3 vs. 2	−0.30	0.09	.001	−0.34	0.09	<.001	−0.28	0.09	.001
Test 4 vs. 3	−0.15	0.08	.076	−0.26	0.08	.002	−0.25	0.08	.001
Test 5 vs. 4	−0.38	0.08	<.001	−0.42	0.07	<.001	−0.39	0.07	<.001
Test 6 vs. 5	−0.34	0.08	<.001	−0.40	0.07	<.001	−0.39	0.07	<.001
Random Effects (ICC)									
Participant		.21			.21			.21	
Stimulus		.09			.06			.05	
Pseudo-R^2 (fixed/total effects)		.10/.42			.10/.39			.10/.38	
	New stimuli								
	Recognition			Recollection			Belief		
Fixed Effects	***B***	***SE***	***p***	***B***	***SE***	***p***	***B***	***SE***	***p***
Intercept	−2.26	0.14	<.001	2.25	0.09	<.001	2.42	0.09	<.001
Test 2 vs. 1	0.92	0.14	<.001	0.36	0.06	<.001	0.37	0.06	<.001
Test 3 vs. 2	0.17	0.11	.098	0.06	0.06	.280	0.07	0.06	.208
Test 4 vs. 3	−0.06	0.11	.601	−0.08	0.05	.131	−0.07	0.05	.179
Test 5 vs. 4	0.01	0.10	.942	−0.04	0.05	.467	−0.03	0.05	.631
Test 6 vs. 5	0.14	0.09	.124	−0.01	0.05	.884	0.02	0.05	.673
Random Effects (ICC)									
Participant		.27			.29			.28	
Stimulus		.18			.11			.11	
Pseudo-R^2 (fixed/total effects)		.03/.50			.01/.45			.01/.44	

Note. ICC refers to intra-class correlation.

Table 3. The effect of time on discriminability and bias.

	D′			β			c		
Fixed effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercepts	1.21	0.04	<.001	1.87	0.05	<.001	0.39	0.03	<.001
Test 2 vs. 1	−0.72	0.06	<.001	−0.02	0.12	.837	0.15	0.03	<.001
Test 3 vs. 2	−0.25	0.06	<.001	0.01	0.12	.917	0.04	0.04	.319
Test 4 vs. 3	−0.06	0.06	.299	−0.04	0.12	.755	0.05	0.04	.158
Test 5 vs. 4	−0.19	0.06	.002	0.07	0.12	.578	0.11	0.04	.003
Test 6 vs. 5	−0.24	0.06	<.001	−0.22	0.12	.084	0.08	0.04	.012
Random effects									
		ICC			ICC			ICC	
		.52			.20			.51	
Pseudo-R^2 (fixed/total)		.23/ .63			.003/ .20			.07/ .55	

Note. ICC refers to intra-class correlation.

Comparing changes in recollection vs. Belief

To examine whether participants’ recollection ratings for old and new stimuli changed over time differently than did their belief ratings, we performed two LMM for either old or new stimuli, which included Judgment type (recollection vs. belief), the log-transformed retention period (in days), and their interaction term, all as fixed effects, plus random intercepts for participant ID and stimulus ID and random slopes of retention period as well as Judgment for participant ID. As shown in Table 4, the interaction term in the “old stimuli” model was statistically significant, such that belief ratings decreased slightly more slowly over time than recollection ratings. For new stimuli, whereas false belief increased slightly more quickly than did false recollection, this trend was not statistically significant.

How is memory distrust associated with participants’ judgments?

To examine whether memory distrust was associated with participants’ responses to old and new stimuli, we performed a series of (G)LMMs for their recognition, recollection, or belief of either old or new stimuli. In all models, we included both participants’ MDS scores and their SSMQ scores as fixed effects, and random intercepts for participant ID and stimulus ID. To remind the reader, we reverse-scored the SSMQ such that higher scores on both the MDS and SSMQ could be interpreted as indicating higher levels of memory distrust. The two scales were moderately correlated, $r = .39$, 95% CI [.27, .50], consistent with previous research (e.g., Nash et al., 2022; Zhang, Qi, et al., 2023).

As shown in Table 5, the MDS and SSMQ showed divergent predictive effects in these models. Specifically, the MDS – which, as a reminder, measures participants’ beliefs about their susceptibility to memory commission errors – positively predicted the (false) recognition of new stimuli, and also positively predicted both recollection and belief of new stimuli (i.e., it was associated with greater levels of false recollection and false belief). For old stimuli, the MDS was not a significant predictor of recognition, recollection, or belief.

Regarding SSMQ scores – which index participants’ beliefs about their susceptibility to memory omission errors – these scores negatively predicted the false recognition of new stimuli (despite the SSMQ having been reverse-scored), and also negatively predicted the correct recognition of old stimuli. SSMQ scores were also negatively associated with recollection and belief scores for both old and new stimuli.

Further moderation analyses, including log-transformed retention period and its interaction terms with MDS as well as SSMQ (both standardised), revealed interesting divergent findings. As shown in Table 6, Time moderated the associations between memory distrust (as measured by both the MDS and the SSMQ) and recognition, recollection, and belief of old as well as new stimuli. Similar to Zhang, Nash, et al. (2023), to better interpret these interactions we reproduced this analysis with a different approach, classifying people who scored in the top or bottom 33% of MDS scores, or SSMQ scores, as “memory distrusters” and “memory trusters” respectively, and we plotted the recognition, recollection, and belief over time for these groups.

The left panels of Figure 4 show these data for the MDS measure. In the early tests after encoding, MDS memory distrusters – compared with trusters – showed weaker (correct) recognition, recollection, and belief of old stimuli. However, these differences between trusters and distrusters became smaller and disappeared over time. In

Table 4. Difference in temporal change between recollection and belief

	Old stimuli			New stimuli		
Fixed Effects	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	5.32	0.09	<.001	2.16	0.09	<.001
Time	−0.78	0.03	<.001	0.06	0.03	.017
Judgment (Belief vs. Recollection)	0.06	0.03	.068	0.13	0.03	<.001
Time * Judgment	0.05	0.02	.012	0.03	0.01	.072
Random Effects (ICC)						
Participant		.22			.33	
Stimulus		.05			.10	
Pseudo-R^2 (fixed/total effects)		.09/.35			.004/.41	

Note. Time refers to the log-transformed retention period (in days). ICC refers to intra-class correlation.

Table 5. The association of memory distrust with memory judgments.

	Recognition – Old			Recognition – New			Recollection – Old			Recollection – New			Belief – Old			Belief – New		
Fixed effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercepts	0.39	0.08	<.001	−2.17	0.13	<.001	4.25	0.09	<.001	2.19	0.08	<.001	4.39	0.09	<.001	2.36	0.08	<.001
MDS	−0.04	0.07	.557	0.44	0.08	<.001	0.07	0.08	.369	0.46	0.06	<.001	0.06	0.08	.404	0.44	0.06	<.001
SSMQ	−0.15	0.07	.028	−0.34	0.08	<.001	−0.27	0.08	.001	−0.32	0.06	<.001	−0.22	0.08	.004	−0.27	0.06	<.001
Random effects																		
		ICC			ICC			ICC			ICC			ICC			ICC	
Participant		.17			.20			.18			.22			.18			.21	
Stimulus		.07			.17			.05			.12			.05			.11	
Pseudo-R^2 (fixed/total effects)		.01/ .24			.03/.40			.01/ .23			.06/ .37			.01/ .23			.05/ .36	

Note. ICC refers to intra-class correlation. SSMQ scores were reverse-coded for ease of comparison with MDS scores.

contrast, in the early tests after encoding, MDS distrusters showed the strongest (false) recognition, recollection and belief for new stimuli, and although these differences also became smaller over time, they remained statistically significant even by the final memory test.

The right panels of Figure 4 show that different patterns of findings emerged for the SSMQ measure. Specifically, memory distrusters and trusters as classified by the SSMQ showed similar recognition, recollection and belief across old and new stimuli in the early tests (Tests 1 and 2). However, from Test 3 onwards, SSMQ memory distrusters (relative to trusters) showed larger declines in their correct recognition, recollection and belief of old stimuli, and showed smaller increases in their false recognition, recollection and belief of new stimuli. It is also worth noting that while the differences between MDS trusters and distrusters were most prominent in their responses to new stimuli, the differences between SSMQ trusters and distrusters were most prominent in their responses to old stimuli (The plots in log scale can be accessed at https://osf.io/kb495).

To extend our understanding of the old/new recognition data, we conducted linear mixed model analyses for the SDT indices, using both MDS and SSMQ scores as fixed effects, and random intercepts for participant ID in all models. As shown in Table A3 in the appendices, MDS was a negative predictor of discriminability d' whereas SSMQ was not. Furthermore, the MDS and SSMQ diverged in their relationship with the bias indices. Specifically, the MDS was negatively associated, whereas the SSMQ was positively associated, with beta and c. Put differently, these analyses suggest that despite us having reverse-scored the SSMQ to afford comparability of interpretation with the MDS, these two memory distrust scales had very different results: a higher MDS score was associated with a more liberal bias (i.e., a greater tendency to recognise pictures as Old) whereas a higher SSMQ score was associated with a more conservative bias (i.e., greater tendency to recognise pictures as New). Additional linear models for each memory test revealed that the patterns were consistent across tests, with the exception that neither the regression coefficients of MDS (beta: $b = -0.15$, $SE = 0.11$, $p = .167$; c: $b = -0.04$, $SE = 0.03$, $p = .174$) nor SSMQ (beta: $b = 0.13$, $SE = 0.11$, $p = .233$; c: $b = 0.05$, $SE = 0.03$, $p = .128$) reached statistical significance in the first test. Note that these results are in contrast with those of Zhang, Qi, et al. (2023), who found that MDS scores (but not SSMQ scores) were correlated positively with beta, not negatively, in a Chinese sample. We discussed these divergent results in the Discussion section.

Memory distrust moderates belief-recollection correspondence

We were next interested in exploring whether people with high versus low memory distrust would demonstrate different levels of association between their recollection

Table 6. Time Moderates the Association of Memory Distrust with Recognition, Recollection, and Belief

	Old stimuli								
	Recognition			Recollection			Belief		
Fixed Effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	1.33	0.10	<.001	5.35	0.09	<.001	5.42	0.09	<.001
Time	−0.65	0.02	<.001	−0.78	0.02	<.001	−0.73	0.02	<.001
MDS	−0.21	0.08	.006	−0.15	0.08	.070	−0.14	0.08	.081
SSMQ	−0.01	0.08	.847	−0.08	0.08	.343	−0.06	0.08	.481
Time*MDS	0.11	0.02	<.001	0.15	0.02	<.001	0.14	0.02	<.001
Time*SSMQ	−0.09	0.02	<.001	−0.13	0.02	<.001	−0.11	0.02	<.001
Random Effects (ICC)									
Participant		.18			.20			.19	
Stimulus		.08			.05			.05	
Pseudo-R^2 (fixed/total effects)		.09/.33			.11/.33			.10/.32	
	New stimuli								
	Recognition			Recollection			Belief		
Fixed Effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	−2.53	0.13	<.001	2.07	0.09	<.001	2.22	0.08	<.001
Time	0.24	0.02	<.001	0.08	0.01	<.001	0.10	0.01	<.001
MDS	0.61	0.09	<.001	0.51	0.06	<.001	0.50	0.06	<.001
SSMQ	−0.36	0.09	<.001	−0.29	0.06	<.001	−0.24	0.06	<.001
Time*MDS	−0.11	0.02	<.001	−0.04	0.01	.001	−0.04	0.01	<.001
Time*SSMQ	−0.01	0.03	.805	−0.03	0.01	.027	−0.02	0.01	.093
Random Effects (ICC)									
Participant		.20			.22			.21	
Stimulus		.18			.12			.11	
Pseudo-R^2 (fixed/total effects)		.05/.41			.06/.38			.06/.36	

Note. Time refers to the log-transformed retention period (in days). Specifically, Time = log (Retention days +1), which means for Test 1, Time is equal to log (1) = 0. The regression coefficients of MDS and SSMQ, therefore, indexed their associations with recognition, recollection, and belief in Test 1 and not the main effects. ICC refers to intra-class correlation.

and belief judgments. To address this question, we performed linear mixed models with belief ratings as the dependent variable, and recollection ratings, either MDS scores or SSMQ scores (standardised), and their interaction terms all as fixed effects. We included random intercepts for participant ID and stimulus ID. With memory distrust measures standardised (i.e., mean = 0), the coefficients of recollection represent the average association between recollection and belief. The results of these models showed that memory distrust moderated the association between recollection and belief, as indicated by the significant interaction term, with this association being weaker among people with greater (versus lower) levels of memory distrust as measured via both the MDS and the SSMQ (see Table 7). The moderation effect could also be observed by the variance explained in each group, with recollection explaining greater variance in belief scores among memory trusters than among distrusters (MDS: Pseudo $R^2_{\text{truster}} = .95$, Pseudo $R^2_{\text{distruster}} = .88$; SSMQ: Pseudo $R^2_{\text{truster}} = .95$, Pseudo $R^2_{\text{distruster}} = .86$).

Nonbelieved memories

A different way of exploring a similar question is to ask how frequently participants reported nonbelieved memories, and to what extent these nonbelieved memories were associated with memory distrust. Here we operationalised nonbelieved memories as events for which participants' recollection ratings were >= 2 scale-points greater than their belief ratings. That is to say, we did not require nonbelieved memories to involve a very strong recollection with a very weak sense of belief, although the results we report below were consistent when we used different operationalizations of nonbelieved memories (for the report, see https://osf.io/uce69). As can be expected based on the strong correlation between recollection and belief judgment, on average the rate of nonbelieved memories was low (old stimuli: 1.05%, new stimuli: 0.87%). Ninety-one participants (38.89%) formed at least one nonbelieved memory according to our operationalisation.

We first performed linear mixed models with NBM (Yes or No) as the dependent variable, memory distrust (either SSMQ or MDS) as the fixed effect, and random intercepts for participant ID and stimulus ID. The results of these models showed that the MDS ($B = 0.69$, $SE = 0.16$, $p < .001$, Pseudo-$R^2 = 0.07$) but not the SSMQ ($B = 0.29$, $SE = 0.17$, $p = .079$, Pseudo-$R^2 = 0.01$) was a positive predictor of participants' likelihood of reporting an NBM. When MDS and SSMQ scores were both entered into a model simultaneously (Pseudo-$R^2 = 0.07$), the MDS remained as a significant positive predictor ($B = 0.68$, $SE = 0.17$, $p < .001$) and the SSMQ was not ($B = 0.03$, $SE = 0.17$, $p = .856$). The same patterns held when we examined nonbelieved memories for presented and non-presented stimuli separately, with MDS scores being the only significant, positive, predictor of nonbelieved memories in both cases.

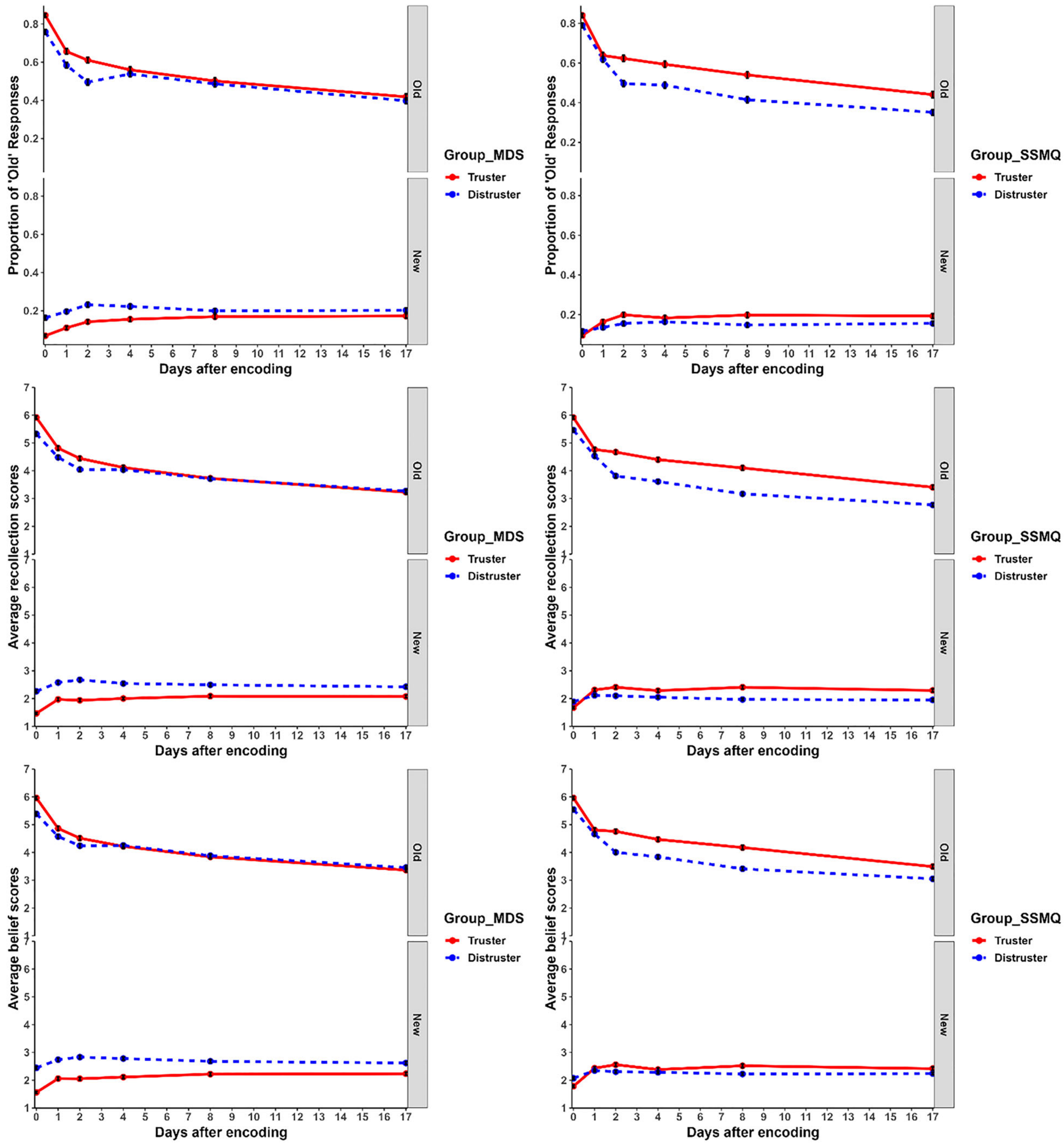

Figure 4. Temporal changes of recognition, recollection, belief-in-occurrence among memory trusters and distrusters.

Note. The left panels were grouped based on MDS scores; the right panels were grouped based on SSMQ scores. Error bars refer to the 95% CIs of the estimates, without accounting for the non-independency.

Discussion

In the current longitudinal study, we collected a rich dataset of recognition memory along with recollection and belief-in-occurrence judgments across 18 days, as well as individual difference measures. We analysed the temporal changes of recollection and belief as well as the belief-recollection association over time, and we examined how aspects of memory distrust were associated with response bias and how they moderated the recollection-belief association. In the following sections, we discuss our findings in detail and their significance to relevant theory.

Temporal changes in recognition, recollective features and belief judgments

Consistent with the literature on forgetting (see Rubin & Wenzel, 1996 for a review), rates of forgetting in our recognition data were steeper at the beginning and became

Table 7. Memory Distrust Moderates the Belief-Recollection Association

	SSMQ Model			MDS Model		
Fixed Effects	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercept	0.37	0.02	<.001	0.38	0.02	<.001
Recollection	0.93	0.002	<.001	0.93	0.002	<.001
Memory Distrust	0.09	0.02	<.001	0.07	0.02	.001
Recollection * Memory Distrust	−0.02	0.001	<.001	−0.01	0.001	<.001
Random Effects (ICC)						
Participant (Intercept)		.16			.16	
Stimuli (Intercept)		.01			.01	
Pseudo-R² (fixed/total effects)		.91/.93			.91/.93	

Note. ICC refers to intra-class correlation. SSMQ scores were reverse-coded for ease of comparison with MDS scores.

shallower as time passed. Moreover, while hit rates decreased over time, the correct rejection rate remained relatively stable. Although we used pictorial stimuli that are more complex than, for example, words, and could allow for better encoding, we did not observe a linear decline in correct recognition as suggested by Fisher and Radvansky (2019, 2022). The reason could be that the design did not allow for higher levels of learning. For example, in Fisher and Radvansky's study (2019), participants first learned the materials and then engaged in cued recall and received feedback on their performance until they reached a criterion of two perfect cued recall tests. In contrast, in the current study, each stimulus was only presented once for 5 s during the encoding, and participants received no instruction of encoding strategies or feedback on their learning.

Importantly, recollection and belief ratings for presented stimuli showed almost identical temporal patterns of decelerating change over time (which we discuss below). Likewise, the patterns seen in recognition of non-presented stimuli were also mirrored in the recollection and belief ratings: while there was an initial increase in recollection and belief ratings for non-presented stimuli, the ratings did not further increase as time progressed. The results therefore suggest that the decrease in sensitivity over time was driven primarily by the decay of memory traces of presented stimuli rather than by increased false recognition of non-presented stimuli (i.e., false alarms). This pattern, however, might not be a universal feature of recognition memory. The low false recollection ratings and false alarm rates might be a result of using distinct pictures as fillers and it could be possible that false recollections would increase over time if studies use other types of stimuli (e.g., words). We should also be particularly careful in drawing strong conclusions here given that we did not counterbalance old and new scenes in this study.

Recollection versus belief: when do we expect them to diverge?

In our study, recollection and belief judgments were nearly perfectly correlated and changed similarly over time. These results may seem at odds with the notion that recollection and belief are distinct constructs (Blank, 2017; Mazzoni et al., 2010; Otgaar et al., 2014; Scoboria et al., 2014). However, in our view, the results were consistent with current theorising. Recollection is typically reliable and people by and large trust their recollections when there is no other contradicting information (Blank, 2017). In a highly controlled experimental setting as in our study, there was little information other than participants' recollections of the stimuli that could be used to validate the truth status of the remembered event. For example, there was no confirmatory or disconfirmatory social input in response to participants' judgments nor did the stimuli vary widely in plausibility of prior exposure. Further, as mentioned earlier in the introduction, the stimuli employed in the current study were not self-relevant and thus unlikely to be incorporated into one's autobiographical knowledge, making the belief judgment rely closely on the remaining recollective features (Blank, 2017). Therefore, it should not be a surprise that overall recollection and belief ratings were highly correlated in the current study.

However, our analyses suggested that as time progressed, people relied less on their recollection when deciding the truth status of their memory, reflected in the increasing belief-recollection discrepancy over time. People have general beliefs about forgetting (Koriat et al., 2004) such as the belief that our memory becomes less vivid and reliable over time. These beliefs might have caused people to rely less on their sense of recollection when validating a more temporally distant (versus recent) experience (Nash et al., 2017). The results comparing temporal changes between recollection and belief also support this calibration hypothesis. It could be that while evaluating the truth status of the events, people take into consideration that their memories decay over time and adjust their appraisals accordingly, resulting in a slower change in belief compared to recollection for presented stimuli.

More interestingly, consistent with the conceptualisation of memory distrust (Nash et al., 2022; van Bergen et al., 2010), people who were more (versus less) sceptical toward their memory functioning showed greater belief-recollection divergence as indexed by the negative interaction term between recollection ratings and memory distrust (Table 7), even in the current experimental setup where participants received no social information about whether each picture had been seen before. This result dovetails with previous findings showing that people who are sceptical about their memories accept social information more easily (Zhang, Qi, et al., 2023) and are less invested in verifying their memory when confronted (Zhang, Nash, et al., 2023). Together, these results lend support to the claim that people's beliefs about memory, either general (e.g., the belief of forgetting) or specific (e.g., subjective appraisals of one's own memory functioning) might shape their inferences from their memory phenomenology.

Response criterion over time and its association with memory distrust

Given that people hold a general belief about forgetting (Koriat et al., 2004), it might be expected that as time progresses, on average, people would take into account the forgetting and respond more liberally (i.e., a bias to make "old" judgments). However, analyses of response bias did not find sufficient support for such a pattern, and in fact there were some limited indications (from *c*) that people may have responded more conservatively as time passed.

Analyses of the relationship between response criterion and aspects of memory distrust revealed similarly unexpected results. The MDS and SSMQ are proposed to measure two conceptually different aspects of memory distrust, with the former emphasizing distrust toward making commission errors and the latter focusing on omission errors (Nash et al., 2022). If people indeed took into consideration their subjective appraisals of their own memory when making recognition judgments, we might expect people who claim to make more (versus less) commission errors to adopt a more conservative bias as a means to compensate for this perceived inadequacy, whereas we might expect those people who claim to make more (versus less) omission errors to have a more liberal bias. In reality, we observed the exact opposite results: people who scored high (versus low) on the MDS were more likely to have false recollections and beliefs about non-presented stimuli and therefore, more likely to judge non-presented stimuli as "old". On the other hand, people who scored high (versus low) in memory distrust on the SSMQ reported lower recollection and beliefs for both presented and non-presented stimuli, which led to lower hit and false alarm rates.

Moreover, we found that the associations between memory distrust and recognition, recollection, and belief changed over time. Memory distrusters (versus trusters) classified by MDS scores reported lower recollection and belief for old stimuli, but higher false recollection and false belief for new stimuli; in the first three tests, they were also less likely to make correct "old" judgments but more likely to make incorrect "old" judgments, which is partially consistent with the findings of Zhang, Qi, et al. (2023). In subsequent tests, MDS distrusters and trusters performed similarly in recognising old stimuli. However, MDS distrusters performed consistently worse than trusters in identifying new stimuli. SSMQ distrusters and trusters performed similarly in the early memory tests, but distrusters reported lower recollection and belief for old and new stimuli in later tests and were less likely to make hit and false alarm responses.

Taken together, the results suggest that people's responses to the two memory distrust measures conveyed good insight into their tendencies to make different kinds of memory errors; perhaps even factoring in beliefs and knowledge about when those errors are likely to have occurred (e.g., SSMQ memory distrust only shaped metamemory judgments after an initial period of forgetting had elapsed). We should, however, contrast our results with those of Zhang, Qi, et al. (2023, Study 2), whose participants completed a recognition task of 40 stimuli (20 targets and 20 fillers). Their results showed that MDS scores (but not SSMQ) were associated with a more conservative – not liberal – recognition bias and lower hit rates, which is partially consistent with our findings from the first memory test but in contrast with the overall pattern across tests.

A closer comparison between the two studies provides potential explanations for the divergent results. In Study 2 of Zhang, Qi, et al. (2023), participants were incentivized with a small cash prize for accurate recognition performance (i.e., top 10% performers in the memory test received the cash prize), and they received feedback allegedly from another participant after they made their judgments. These two features were, however, absent in the current study. Compared to the current setup, in which participants' responses held no consequence, the feedback and the cash incentive might have ultimately enhanced participants' tendency to calibrate their recognition responses by considering their beliefs about their tendency to make commission errors.

As argued by Blank (2017), the decision as to how much to trust one's recollection should depend partly on how much is at stake. When the stake is low (as in the current study), it is reasonable to simply rely on one's recollections when making belief and recognition judgments. Put differently, whereas people who believe they make a lot of memory errors may indeed – all else being equal – make more memory errors, their self-insight may also equip these people to be good at *avoiding* memory errors in circumstances where there is a strong incentive to engage in memory monitoring. However, the SDT results from Zhang, Qi, et al. (2023) were only based on the first test right after encoding. It is therefore, possible that even with such an incentive structure to be accurate, the association between memory distrust and memory reporting will shift as time elapses as observed in the current study. These discrepant findings, and the attempts to account for them theoretically, merit further investigation.

The many faces of nonbelieved memories

Mazzoni et al. (2010) first defined nonbelieved memory as an event representation accompanied by strong recollective properties yet weak belief-in-occurrence. This definition captures many of the events that participants describe when directly asked about nonbelieved memories (e.g., Brédart & Bouffier, 2016; Scoboria et al., 2015; Zhang, Battista, et al., 2022; Zhang, Otgaar, et al., 2022). Yet in such surveys, and in other studies that use indirect cueing (e.g., Scoboria & Talarico, 2013) or experimental manipulations (e.g., Otgaar et al., 2017; Wang et al., 2017), participants often report nonbelieved memories that do not match Mazzoni et al.'s definition. Indeed, even in direct-cueing surveys, people rate their nonbelieved memories as close to 5 on average in terms of recollection (i.e., not at ceiling) and their belief ratings close to 3 (i.e., not at floor), on 7-point Likert scales (Scoboria et al., 2017). Using cluster analysis, Scoboria and colleagues found three types of nonbelieved memories: (1) "classic" nonbelieved memory (high recollection and low belief, as conceptualised by Mazzoni et al., 2010), (2) "grain-of-doubt" nonbelieved memory (high recollection with slightly but meaningfully decreased belief), and (3) weak nonbelieved memory, in which both recollection and belief were moderate. Crucially, for all subtypes of nonbelieved memories, belief ratings were statistically lower than recollection ratings.

The heterogeneity of nonbelieved memories poses challenges to research on this topic, and for future syntheses of this literature it is important to operationalise nonbelieved memories clearly, and to distinguish studies that use differing operationalizations. Here we identified nonbelieved memories wherever participants' recollection judgments were >= 2 scale-points greater than their belief judgments (e.g., Otgaar et al., 2017; Wang et al., 2017; Zhang et al., 2024), which, in essence, focuses on instances of "recollection-belief divergence" (Blank, 2017) rather than a "classic" NBM definition (Mazzoni et al., 2010). Whereas our conclusions were robust to adopting alternative definitions, including a more "classic" definition, it is important to emphasize that we found very few spontaneous "classic" nonbelieved memories in the current study.

Theoretical and practical implications

Building on previous work (Otgaar et al., 2014; Scoboria et al., 2014; Scoboria & Henkel, 2020), we have expanded the discussion of autobiographical belief formation by emphasizing the roles of beliefs and appraisals in this process (Nash et al., 2022; Zhang, Battista, et al., 2022; Zhang, Otgaar, et al., 2022). Our results in many ways corroborate the current theoretical discussions regarding autobiographical belief and recollection. First, belief-in-occurrence judgments showed a different temporal pattern in comparison with the confidence judgments from Frisoni et al. (2023), supporting that belief-in-occurrence and confidence judgments are two different metacognitive judgments (Otgaar et al., 2014; Scoboria et al., 2014). Second, as stated by Blank (2017), from a functional perspective, memory should generally be reliable for guiding future behaviours, and it is therefore normative for people to believe their recollections. However, belief-recollection divergence can occur as a result of a normal and healthy "reality-check" process. In our study, we found this indeed to be the case: without external information, belief-in-occurrence judgments were strongly correlated with the recollection judgments. However, even under this situation, both general and specific memory beliefs seemed to influence the extent to which recollections and autobiographical beliefs were correlated.

Moreover, by comparing the divergent results regarding the MDS-response bias relationship as well as the interactions between memory distrust and retention period, we offered new insight into the interplay between different factors in the validation process. It is important to stress that although our results are consistent with Blank's (2017) reasoning, the correlational nature of our data cannot substantiate the causal claim. That is to say, we cannot confidently conclude that people used their sense of recollection to inform their judgments of belief-in-occurrence, rather than vice versa.

In addition, our results showed the divergent predictive power of the two facets of memory distrust on memory performance. High MDS scores were associated with increased false recollections, false beliefs, and false alarm rates whereas high (reverse coded) SSMQ scores showed the opposite pattern, despite both being validated measures of "memory distrust" that are positively correlated with each other. We also found support that memory distrust toward making commission errors, as measured by the MDS, was a better predictor of nonbelieved memories (of both presented and not-presented stimuli) than was memory distrust towards making omission errors as measured by the SSMQ, thus adding evidence to this line of research (e.g., Nash et al., 2022). These results provided strong evidence for the recent argument that memory distrust is not unidimensional (Nash et al., 2022).

When discussing the practical relevance of research findings regarding memory, researchers have argued that even a one−detail difference can influence the legal proceedings of criminal investigations (Otgaar et al., 2022). For example, an eyewitness might incorrectly report (or fail to report) the colour of the suspect's hoodie, leading the investigation toward a possible dead end. With this in mind, the practical relevance of the findings related to memory distrust can be revisited. On average, trusters categorised by the MDS made 11.82 ($SD = 10.90$) commission errors across sessions while distrusters made 17.14 ($SD = 13.43$) commission errors, 95% $CI_{\text{mean diff}}$ [−9.33, −1.31]. On the other hand, trusters categorised by the SSMQ made an average of 32.67 ($SD = 17.37$) omission errors while distrusters made 41.80 ($SD = 14.34$) omission errors in total, 95% $CI_{\text{mean diff}}$ [−14.45, −3.82]. These preliminary analyses suggest that the impact of memory distrust on eyewitness memories could be practically relevant.

Limitations and future directions

Based on previous theoretical work showing that belief-in-occurrence is influenced by recollective features (e.g., Blank, 2017; Otgaar et al., 2014), we performed a series of tests whose results were largely consistent with this theoretical perspective. However, it should be noted again that the current study did not experimentally manipulate recollective features to test the causal relationship and offered only correlational evidence. Second, although it is common sense that memory decays over time, and previous research has shown that people indeed have beliefs about forgetting over time (Koriat et al., 2004), the current study did not measure these general beliefs. Third, the moderation analyses with retention period and memory distrust, although revealed interesting results, could suffer from the fact that we only measured memory distrust at the end of the study. There were also limitations in the study design, which could limit the generalizability of our findings. Specifically, we did not counterbalance the encoding items and the filler items and there were unequal number of participants across counterbalancing groups. However, it is reassuring that our stimuli analysis did not find statistically significant differences in valence or arousal ratings across encoding and filler items in each block and that the temporal pattern of recollection and belief judgments were similar across groups (for the plots, see https://osf.io/ac2v6). We therefore believe that any confounds that arose from insufficient counterbalancing were likely very small. Several key analyses reported, including SDT analyses and analyses on the moderation effect of memory distrust on recollection-belief correspondence, were not preregistered. Therefore, it is important to conduct preregistered direct or conceptual replications with counterbalanced design to revisit these findings. As mentioned earlier, nonbelieved memories are a heterogeneous phenomenon, future research could explore the relationship between time and subtypes of nonbelieved memories. Finally, based on theory (Blank, 2017), we speculated above that the inconsistent results regarding the association between MDS and response bias are due to the incentive structure or the stake of remembering. We encourage researchers to follow up on this hypothesis and embark on a well-designed empirical test.

Conclusion

Recollection and belief-in-occurrence are two related but distinct aspects of remembering. The current study showed that without external information, belief was correlated highly with recollection. However, the belief-recollection discrepancy increased over time. Moreover, people with high (versus low) memory distrust differed in the temporal pattern of their memory judgments and seemed to rely less on recollection when making belief judgments. Although no causal evidence can be provided, these results are consistent with the perspective that belief is the end product of a memory validation process, in which both internal (i.e., recollection) and external information (e.g., general knowledge, social information) are weighed to reach a final belief judgment.

Notes

1. Given that the current study is the first (to the best of our knowledge) examining recollection and belief judgments in a longitudinal design, we did not have a clear expected effect size. Therefore, we decided to power for estimate precision (Lakens, 2022) and relied on heuristics to decide the criterion of SE = 0.1 (i.e., equivalent to a 95% CI range of approximately 0.4; SE = (upper limit–lower limit)/3.92).
2. The memory test data of all participants who did not complete the final session were included in the analyses, since no information on the embedded attention checks was available.
3. The demographic data for some participants are missing as not all participants returned for the final session, in which we collected the demographic data and trait measures.
4. The α and 1-β levels, as specified in our pre-registration, were based on heuristics given that we had no strong conviction regarding the seriousness of Type 1 and 2 errors in the current context.
5. Given the complexity of the (G)LMM models, we were not knowledgeable enough to run sensitivity analyses for these models. The analyses for alternative LM approaches are reported to serve as close estimates.
6. The *psycho* package automatically calculates nonparametric indices A′ and b′′d as well. The analyses' outcomes did not notably differ between the parametric and nonparametric indices; we therefore only report the parametric indices in the manuscript.

Data availability statement

All data and analyses scripts are at https://osf.io/g7xwn/.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Table A1. Analyses on Stimuli Valence and Arousal Ratings

Model	Effect	F statistics	*p*-value	η^2
Arousal	Old vs. New	F (1, 168) = 1.57	.213	=.009
	Block	F (5, 168) = 0.97	.441	=.028
	Old vs. New * Block	F (5, 168) = 1.87	.102	=.053
Valence	Old vs. New	F (1, 168) = 0.00	.978	<.001
	Block	F (5, 168) = 0.59	.709	=.017
	Old vs. New * Block	F (5, 168) = 0.50	.779	=.015

Instruction Memory Task

We will now show you a range of scenes which can either be new scenes not presented before or old scenes from Session 1. Please look at each scene carefully and decide whether you have seen this image before. After making the judgment of the old vs. new of each scene, you will answer two questions about your recollection of this scene and your belief whether you have seen this scene in Session 1.

It is important to note that recollection and belief are relatively independent.

For example, you may have vivid recollections of some experience and have a strong sense that the event really happened, something referred to as believed memory. However, you could also have vivid recollections but don't really think that the recollected event happened (e.g., from imagination or a movie). Or in other cases, you have a strong sense of what happened but don't really have a clear recollection (e.g., reconstructing a blackout experience)

Table A2. Descriptive statistics of memory performance.

		Recognition		Recollection		Belief	
Category	Time Point	*M*	*SD*	*M*	*SD*	*M*	*SD*
Old	1	0.80	0.40	5.62	2.11	5.67	2.04
	2	0.63	0.48	4.61	2.39	4.70	2.31
	3	0.58	0.49	4.32	2.42	4.46	2.33
	4	0.55	0.50	4.08	2.38	4.22	2.31
	5	0.48	0.50	3.66	2.35	3.83	2.28
	6	0.41	0.49	3.21	2.19	3.42	2.15
New	1	0.88	0.32	1.91	1.64	2.05	1.63
	2	0.83	0.38	2.30	1.82	2.45	1.80
	3	0.81	0.40	2.36	1.87	2.52	1.86
	4	0.81	0.39	2.28	1.82	2.46	1.84
	5	0.82	0.39	2.25	1.81	2.44	1.82
	6	0.81	0.39	2.22	1.74	2.44	1.77

Table A3. The association of memory distrust with discriminability and bias.

		D′			β			c	
Fixed effects	*B*	*SE*	*p*	*B*	*SE*	*p*	*B*	*SE*	*p*
Intercepts	1.26	0.04	<.001	1.88	0.05	<.001	0.40	0.03	<.001
MDS	−0.20	0.05	<.001	−0.25	0.06	<.001	−0.08	0.03	.005
SSMQ	0.06	0.05	.203	0.21	0.06	<.001	0.11	0.03	<.001
Random effects									
		ICC			ICC			ICC	
		.32			.17			.44	
Pseudo-R^2 (fixed/total)		.04/.34			.03/.20			.04/.46	

Note. ICC refers to intra-class correlation. SSMQ scores were reverse-coded for ease of comparison with MDS scores.