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# Remember walking in their shoes? The relation of self-referential source memory and emotion recognition

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**ABSTRACT**

Deficits in the ability to read the emotions of others have been demonstrated in mental disorders, such as dissociation and schizophrenia, which involve a distorted sense of self. This study examined whether weakened self-referential source memory, being unable to remember whether a piece of information has been processed with reference to oneself, is linked to ineffective emotion recognition. In two samples from a college and community, we quantified the participants' ability to remember the self-generated versus non-self-generated origins of sentences they had previously read or partially generated. We also measured their ability to read others' emotions accurately when viewing photos of people in affect-charged situations. Multinomial processing tree modelling was applied to obtain a measure of self-referential source memory that was not biased by non-mnemonic factors. Our first experiment with college participants revealed a positive correlation between correctly remembering the origins of sentences and accurately recognising the emotions of others. This correlation was successfully replicated in the second experiment with community participants. The current study offers evidence of a link between self-referential source memory and emotion recognition.

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Our experience provides clues to understand things new and not immediate to us, including another person in a situation disparate from ours (Buckner & Carroll, 2006). Walking into a café, we feel unhappy seeing a boy holding the last brownie we wanted. We have no difficulty however perceiving his joy. Through such an imagination, our prior experience comes into play at the present moment, allowing us to recognise emotions beyond ours. Here comes the question: if we use ourselves in this attribution of another person's emotion, how would we prevent the contamination from our own feeling toward the immediate situation (Quesque & Rossetti, 2020), as observed in mental disorders with a problematic sense of self (Chiu, Paesen, et al., 2016; Kohler et al., 2010)? The current research investigated whether emotion recognition requires self-referential source memory, a metamemory of how the self has been involved in an event (Mitchell & Johnson, 2000). In two studies involving college and community participants, we demonstrated that their performance on emotion recognition tasks was associated with individual differences in self-referential source memory.

Researchers have operationalised self-referential source memory as the ability to remember whether a piece of information has been processed with reference to oneself (Durbin et al., 2017). One particularly crucial test in psychopathology studies concerns whether participants can retrieve details of cognitive operations such as intention and problem-solving contributory to the sense of self or agency (e.g. "I

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did this" or "I thought this;" Minzenberg et al., 2006). For instance, participants read short sentences such as category-exemplar pairs aloud. In one condition, the item of a category-exemplar pair appears on the computer screen (e.g. "fruit-apple"); in the other condition, only partial information pertinent to the item is shown (e.g. "fruit-ba____"), and the participants generate the remaining part of the word pair. In the follow-up test, the participants are asked whether a given category-exemplar pair had appeared earlier (i.e. item memory) and whether the corresponding exemplar word was self-generated (i.e. source memory). This self-referential aspect of source memory is essential for characterising an experience as originating internally rather than in the environment.

It is well-documented that self-referential source memory can be weakened at disordered mental states. Dissociation, characterised by anomalous experiences regarding the ownership and authorship of bodily sensation, action, and identity (Lynn et al., 2022), was associated with problems in metamemory regarding whether a remembered item was relevant to the self (in patients with a dissociative disorder, Huntjens et al., 2007; in individuals prone to dissociation, Chiu et al., 2012). In acute-stage psychiatric patients, dissociation correlated with a tendency to attribute self-generated words to an external source (Chiu, Tseng, et al., 2016). Patients with schizophrenia, a psychopathology characterised by diminished first-person perception (Sass et al., 2018), had poor source memory for self-generated words (Fisher et al., 2008; Keefe et al., 2002). Source memory errors differentiated schizophrenia spectrum disorders from other disorders in young patients with first-episode psychosis or those at ultra-high risk of psychosis (Spark et al., 2021).

Intriguingly, mental disorders of weakened self-referential source memory show an impairment in reading other people's emotions (i.e. emotion recognition). Individuals with high dissociation proneness made more errors than those with medium or low dissociation proneness in identifying the emotional states of people in photos of affect-charged situations (Chiu, Paesen, et al., 2016). The extent to which patients with schizophrenia made inaccurate emotion recognition was related to whether they remembered that a studied word was self-generated or experimenter-presented (Fisher et al., 2008). However, the source memory measure of the schizophrenia study did not partial out response bias. Their relationship hence remains inconclusive. The current study aims to examine the link between self-referential source memory and emotion recognition with a rigorous design.

While emotion recognition in some circumstances may be achieved by simple perception (e.g. facial pattern recognition), it may involve top-down processes, such as analysing and imagining another person's situation (Newen et al., 2015). Emotion recognition requires differentiating between experienced (i.e. own) emotions and ascribed (i.e. someone else's) emotions, which may tap into self-referential source memory. Witnessing a person crying with a torn handbag, for example, can elicit emotions directly from oneself (e.g. fear of not being helpful or personal distress; Batson et al., 1987; Decety & Lamm, 2009), together with those from imagining the person's situation (e.g. feeling helpless; Batson et al., 1997). To recognise an emotion of the person, the witness may trace the origins of the emotions and identify the one that best fits the effortful process of imagination. Remembering the source of information was important for differentiating between an individual's egocentric viewpoint and the imagined viewpoint of a bystander (Ford et al., 2011; Naito, 2003). Self-referential source memory may be integral to identifying emotions imagined for another person.

We tested whether self-referential source memory is a cognitive correlate of emotion recognition in non-clinical populations. We refrained from using self-report scales as an emotion recognition measure because these may capture susceptibility or motivation to experience another person's emotions (Murphy & Lilienfeld, 2019). Instead we used behavioural tasks that quantify the accuracy of recognising another person's emotions. Participants viewed photos depicting a person in an affect-charged situation. They were tasked with inferring the person's emotional state (emotion recognition) and the extent to which they shared the feeling depicted (emotion sharing). We hypothesised that remembering the act of self-generation may support the identification of another person's emotions in affect-charged situations. Accordingly, enhanced emotion recognition accuracy would be evident among people able to differentiate a previously learned item from a self-generated item. In contrast, we did not formulate a specific hypothesis for the correlation between emotion sharing and self-referential source memory.

Notably, the source attribution process involves both mnemonic and non-mnemonic components. A self-generated response may be produced by response bias rather than genuine memory for the contextual details of a target item (Bayen et al., 1996). We used Multinomial Processing Tree (MPT; Batchelder, 1998; Batchelder & Riefer, 1999) modelling to separately estimate the parameters for decisions attributable to mnemonic components (i.e. source memory and item memory) and others not attributable to mnemonic factors (i.e. source guessing and old–new guessing). If remembering a self-generative origin is a cognitive propensity relevant to the ability to recognise others' emotions, we would expect a positive correlation between self-referential source memory and emotion recognition.

## Transparency and openness

The study design and analysis are not pre-registered. The data and statistical analysis code are publicly available.[1] We report how we determined our sample size, data exclusions, manipulations, and measures in the studies. The study design is approved by the Research Ethics Review Panel of the Faculty of Social Science at The Chinese University of Hong Kong.

## Study 1: Methods

### Participants

Participants were recruited from a university campus in Hong Kong. The inclusion criteria were (a) age between 18 and 25 years and (b) native Cantonese-speaking Chinese who can read Traditional Chinese characters.

Regarding sample size estimation, the only study that investigated the relationship between source memory and emotion recognition (Fisher et al., 2008) reported an average correlation coefficient of .29 for healthy participants (for self- and non-self-generated items, *rs* = .50 and .07, respectively) and clinical patients (for self- and non-self-generated items, *rs* = .23 and .34, respectively). However, the reported values may have been inflated because of response bias. In addition, Ford et al. (2011) reported a correlation coefficient of .18 for source memory and false belief attribution in children.[2] With a mean of .24, a minimum sample size of 134 was suggested for a Type I error probability of .05 and power of .80 using G*Power (Faul et al., 2009). This sample size should be sufficient to reliably detect correlations with a similar effect size using multinomial processing tree modelling (e.g. Schaper et al., 2019). Accordingly, we recruited 159 college students. Forty-three percent were male, with a mean age of 20.9 years old (range = 18–24, *SD* = 1.3).

### Instruments

#### Emotion recognition and sharing

We used the Traditional Chinese version of the Multifaceted Empathy Test (Chiu & Yeh, 2018). The test consisted of 40 photos depicting individuals in affect-charged situations (Dziobek et al., 2008; Foell et al., 2018), equally divided into positive and negative affect valences. Each photo appeared three times, each with a question. The first question asked participants to select the emotion of the depicted person out of a set of four possible answers. The second and third respectively asked participants to rate their level of arousal in response to the photo and the extent to which they felt the same as the person in the photo on a 4-point Likert scale from 1 (*low*) to 4 (*high*). All the trials were self-paced. A blank appeared for 1 s before the next photo. The order of the 40 photos was randomised.

The proportion of correct responses (Question 1) was indexed to emotion recognition. The mean of arousal (Question 2) and feeling (Question 3) ratings was indexed to emotion sharing. Convergent validity was established for both measures. The emotion recognition index correlated positively with the accuracy rate of facial emotion recognition in a morphing task ($r = .33$, $p < .01$, $d = 0.69$, in 80 college students; Chiu, 2023). The emotion sharing index correlated with an inclination to experience emotion contagion ($r = .24$, $p < .01$, $d = 0.49$ in 158 college students; Chiu et al., 2020).

#### Self-referential source memory

We used a computerised Traditional Chinese version of the self-referential source memory test (Chiu et al., 2019), which consisted of simple sentences formed by a subject, verb, and object (Fisher et al., 2008). Two categories of sentences were used, one pertinent to occupations (e.g. "Postmen deliver letters") and the other to animals (e.g. "Monkeys eat bananas"). Eighty sentences were created in accordance with common knowledge among Hong Kong residents. The sentences were randomly assigned to

two lists. The first list was presented in the study phase (40 items, 20 for the self-generated condition and the other half for the non-self-generated condition). The second list provided new sentences during the test phase (40 items). Disparate fonts were used when presenting sentences in the study and test phases to minimise the confounding effect of iconic memory for words. In a paper-and-pencil version of this task, a negative correlation was found between source memory and psychotic symptoms (Chiu, Tseng, et al., 2016), a well-established result in the literature (e.g. Fisher et al., 2008), supporting the convergent validity of this task.

During the study phase, sentences were presented individually on a screen. In the non-self-generation condition, a full sentence appeared, and the participants read it aloud. In the self-generation condition, an incomplete sentence was given with the first Chinese character of a two- or three-character subject as well as a verb and an object. Blank grids were used to indicate missing characters of the subject. The participants generated an appropriate word for the subject that suited the sentence and read it aloud. The sentences of the two subject categories (i.e. animals and occupations) were presented in two blocks, so first all animal sentences then all occupation sentences or vice versa. The sentences of each block were randomised. All trials were self-paced.

The incidental memory test phase followed a 20-min distraction task. The full set of studied sentences was presented randomly, along with new sentences. Only the verb and object from each sentence were shown. The participants first answered whether they learned a sentence during the study phase as an assessment of item memory. If a sentence was recognised as an old item, the participants answered whether the subject of the sentence was generated by themselves, which assessed their self-referential source memory. All the trials were self-paced.

## Procedure

People submitted an online enrolment form for their interest in participating in the study on individual differences in emotion and social skills. They visited our laboratory for individual assessment. The procedure was fully explained, and written informed consent was obtained. Behavioural tests were subsequently performed. Finally, the participants were debriefed and provided with a remuneration of HKD 75 (per hour).

## Statistical analysis for self-referential source memory

Figure 1 shows the decision-making trees for self-referential source memory. We used a well-validated two-high-threshold multinomial model of source monitoring (Bayen et al., 1996). Three trees were constructed for items being studied through self-generation (SG), studied not through self-generation (NSG), and not studied (i.e. new, Nw), respectively. Cognitive states to be estimated were specified, including item memory ($D$), source memory ($d$), old–new guessing (guessing an item as studied, $b$), and source guessing (guessing an item as self-generated with and without item memory, $a$ and $g$, respectively).

The model included eight parameters ($D_{SG}$, $D_{NSG}$, $D_{Nw}$, $d_{SG}$, $d_{NSG}$, $b$, $a$, $g$); however, our experiment had six independent response categories only. For model identifiability, equality constraints were applied to reduce the number of parameters for estimation. We utilised a three-constraint model, $a = g$, $D_{NSG} = D_{Nw}$, and $d_{SG} = d_{NSG}$, of Bayen et al. (1996, Model 5c). We opted for this model due to the unreliable self-generation effect on source memory (McCurdy et al., 2017; Mulligan & Lozito, 2004). We thus equated both source memory parameters (i.e. $d_{SG} = d_{NSG}$).

A latent-trait regression approach (Klauer, 2010) was adopted to estimate the relationship between source memory and external variables, including emotion recognition, emotion sharing, and other covariates. Jobst et al. (2020) showed through simulations that, compared with the individual-model approach and the beta-MPT approach, this approach has the minimum absolute bias between the estimated and true correlation values. The MPT parameters for each participant were obtained using this Bayesian hierarchical approach. For inter-parameter associations, a multivariate normal distribution was assumed for the probit-transformed parameters. Via regression, the external variables were incorporated into the model estimation.

MPT parameters and regression coefficients were computed with the R package *TreeBUGS* using the default priors (Heck et al., 2018)[3]. All external variables were standardised for analysis. Four chains with different starting values were run in parallel,

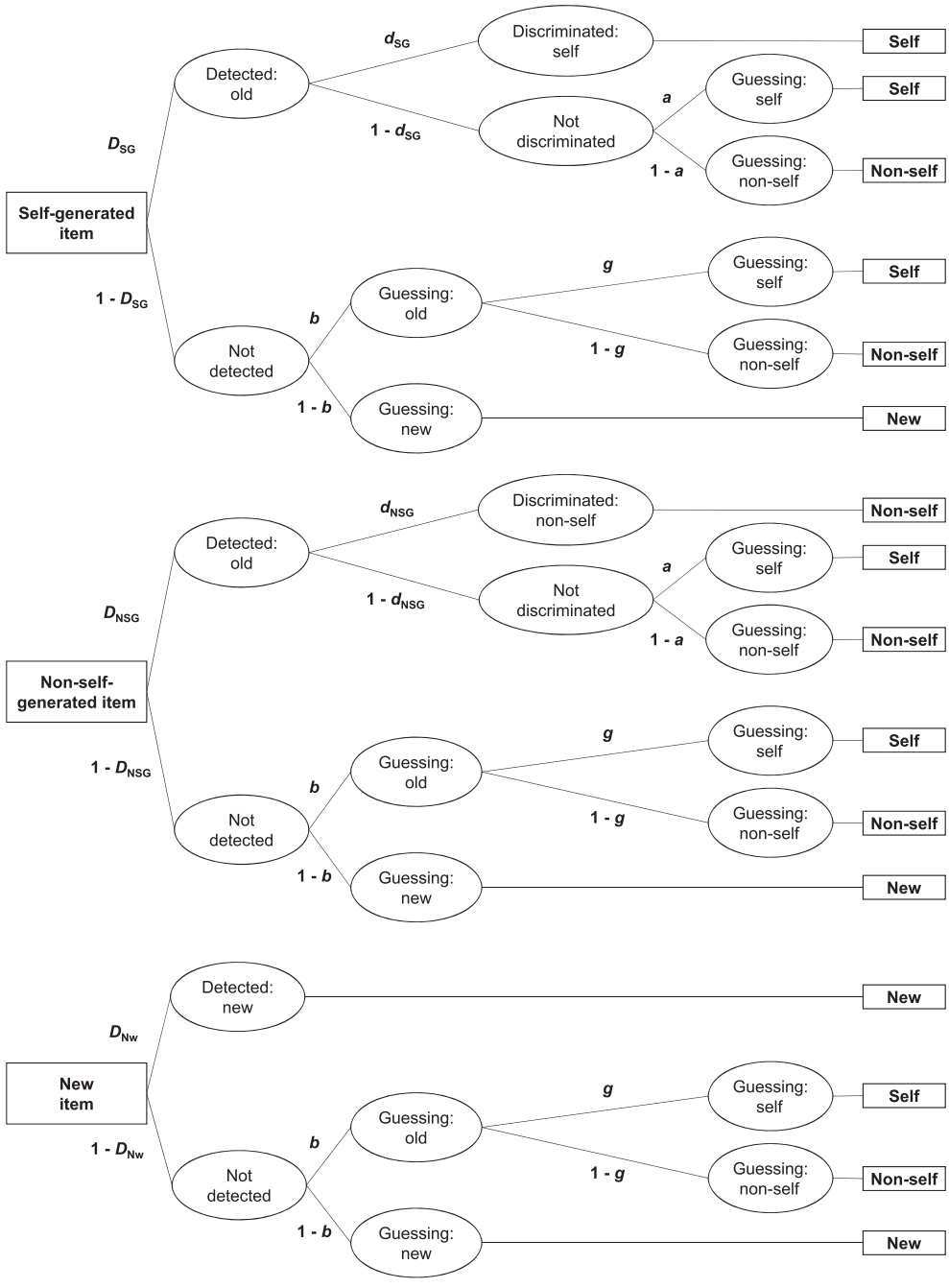


**Figure 1.** The Two-high-threshold Multinomial Model of Source Monitoring Adapted for the Current Study.

Notes. Rectangles on the left and right represent the learning histories of items and possible responses in the test phase, respectively. Ovals represent latent cognitive states of each process. The letters along the links represent the probabilities with which the cognitive states occur. A *D* denotes the probability of having item memory, for the detection of a studied item as old ($D_{SG}$ from self-generation and $D_{NSG}$ from non-self-generation) or a non-studied item as new ($D_{Nw}$). A *d* denotes the conditional probability of having source memory, for the discrimination of a studied item's origin ($d_{SG}$ from self-generation and $d_{NSG}$ from non-self-generation). The remaining denote the conditional probabilities of response bias, including guessing an item as old (*b*) as well as guessing a detected (*a*) or undetected (*g*) item as self-generated. The first tree, for example, represents possible processes for attributing the source of self-generated items. Participants may detect a sentence as old, given the item memory (with probability $D_{SG}$). Subsequently, they may discriminate the sentence as studied in the self-generation condition if the source memory is available (with probability $d_{SG}$). Otherwise, when participants cannot remember the origin of a sentence (with probability $1 - d_{SG}$), they may guess whether self-generation is involved (with probability *a*) or not (with probability $1 - a$). Participants may fail to detect a sentence as old when item memory is not accessible (with probability $1 - D_{SG}$). They may guess that the sentence is old (with probability *b*) and further guess whether self-generation is involved (with probability *g*) or not (with probability $1 - g$). Otherwise they may guess that the sentence was new (with probability $1 - b$).

using 500,000 adaptation samples for each chain. Each chain ran 1,000,000 iterations, with a burn-in period of 500,000 iterations and a thinning rate of 100 (Schaper et al., 2019). The Gelman-Rubin statistic $\hat{R}$ was used to evaluate the convergence of parameter estimation (Gelman & Rubin, 1992). A value of $\hat{R}$ smaller than 1.05 indicates good convergence. Test statistics $T_1$ and $T_2$ and their posterior predictive $p$ values (PPP) reported the model's goodness of fit (Klauer, 2010). $T_1$ indicates the difference between the observed and posterior-predicted mean frequencies using Pearson's $\chi^2$, and $T_2$ indicates a similar difference in covariances. Larger PPP values indicate a satisfactory model fit (e.g. PPP > .05). The 95% Bayesian Credibility Interval (BCI), which indicates the interval in which the true parameter can be found with 95% probability, was reported for the estimation of the MPT parameters and their correlations with external variables. A correlation is deemed reliable if the 95% BCI of the corresponding standardised regression slope excludes zero.

## Study 1: Results and discussion

### Assumptions in model specification

We tested in two steps whether our assumptions for equality constraints held. First, the base model with the constraints $a = g$ and $D_{NSG} = D_{Nw}$ showed a good model fit, $T_1$: PPP = .45, $T_2$: PPP = .16. We further assessed whether item and source memories differed between self-generated and non-self-generated items. First, the difference in item memory was sampled ($\Delta D = D_{SG} - D_{NSG}$). Item memory was better for self-generated items than for non-self-generated items, $\Delta D$ = .31, BCI = [.29, .34], replicating the self-generation effect (Bertsch et al., 2007; McCurdy et al., 2017). Next, the difference in the source memory ($\Delta d = d_{SG} - d_{NSG}$) did not deviate from zero, $\Delta d$ = .03, BCI = [–.19, .28].

Accordingly, the final model included the constraint $d_{SG} = d_{NSG}$. The source memory was denoted by a single parameter, $d$. This more parsimonious model consisted of five parameters: two for item memory ($D_{SG}$ and $D_{NSG}$), one for source memory ($d$), and two for guessing ($b$ and $g$). The model's goodness of fit was acceptable ($T_1$: PPP = .61, $T_2$: PPP = .06). The estimation had good convergence, with $\hat{R} < 1.05$ for all the parameters. Table 1 reports the means and BCIs of the parameter estimates.

**Table 1.** Estimates and Bayesian Credibility Intervals (BCIs) for Parameters of the Two-high-threshold Multinomial Model of Source Monitoring, and for Regression Coefficients of the Parameters on Emotion Recognition and Emotion Sharing in Study 1.

| | | | Regression coefficients | | | |
|---|---|---|---|---|---|---|
| | Parameters | | Emotion recognition | | Emotion sharing | |
| | *M* | BCI | β | BCI | β | BCI |
| $D_{SG}$ | .88 | [.86, .90] | –.02 | [–.25, .21] | .08 | [–.15, .30] |
| $D_{NSG}$ | .57 | [.54, .59] | .25 | [.04, .44] | –.10 | [–.31, .12] |
| $d$ | .63 | [.58, .67] | .25 | [.06, .42] | –.10 | [–.28, .09] |
| $b$ | .06 | [.04, .07] | –.02 | [–.23, .20] | .03 | [–.19, .24] |
| $g$ | .45 | [.40, .51] | –.05 | [–.24, .15] | –.11 | [–.30, .09] |

Notes. For abbreviations, $D_{SG}$ = item memory for self-generated items; $D_{NSG}$ = item memory for non-self-generated items; $d$ = source memory; $b$ = guessing items as studied; $g$ = guessing items as studied through self-generation.

### Association between source memory and emotion recognition

Table 1 also summarises the results of associating MPT parameters with emotion recognition and emotion sharing. We first tested the associations of source memory with emotion recognition and emotion sharing. In line with the hypothesis, source memory correlated positively with emotion recognition, β = .25, BCI = [.06, .42]. No reliable correlation was evident between source memory and emotion sharing, β = –.10, BCI = [–.28, .09].

We further examined the associations of memories and guessings with emotion recognition and emotion sharing. While the item memory for self-generated items did not correlate with emotion recognition, β = –.02, BCI = [–.25, .21], a positive correlation was found between item memory for non-self-generated items and emotion recognition, β = .25, BCI = [.04, .44]. Neither item memory correlated with emotion sharing (for self-generated and non-self-generated items, βs = .08 and –.10, BCIs = [–.15, .30] and [–.31, .12], respectively). No reliable correlations were found for old–new guessing and source guessing, βs = –.11 to .03. The response biases did not relate to emotion recognition or emotion sharing.

Finally, we constructed an additional model to ensure that a similar result would be found when sex was controlled for. The correlation between source memory and emotion recognition remained reliable, β = .24, BCI = [.06, .42].

Study 1 provides the first piece of evidence that self-referential source memory is associated with emotion recognition. Though, the correlation between emotion recognition and item memory for

non-self-generated items was not expected. We conducted a second study with participants recruited from the community to test whether the associations found in young participants with high levels of education could be replicated in people with diverse demographics.

## Study 2: Methods

### Participants

We recruited participants via posters in diverse community settings, social service centres (e.g. leisure and recreation centres, family service centres, educational institutes, and churches), and online advertisements (e.g. Facebook). The inclusion criteria were as follows: (a) age between 18 and 50, (b) native Cantonese-speaking Chinese who can read Traditional Chinese characters, and (c) without intellectual disabilities or pervasive developmental disorders.

One hundred and forty-four participants were included in this study. They were between 18 and 48 years old ($M = 31.43$, $SD = 6.77$), with 28% being male and 66% reporting an educational background equivalent to or above a bachelor's degree.

### Instruments, procedure, and statistical analysis

The experimental design was similar to that of Study 1, except for the inclusion of an intellectual assessment. The Traditional Chinese version of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) was used (Chen & Chen, 2002). A short form comprising two subtests of the WAIS-III, Information and Block Design, was used to estimate the full-scale intellectual quotient (Ringe et al., 2002).

## Study 2: Results and discussion

### Assumptions in model specifications

The fit of the base model was satisfactory with constraints $a = g$ and $D_{NSG} = D_{Nw}$, $T_1$: PPP = .51, $T_2$: PPP = .39. Furthermore, item memory was better for self-generated items than for non-self-generated items, $\Delta D = .29$, BCI = [.26, .32]; no such difference was evident in source memory, $\Delta d = .04$, BCI = [–.15, .26]. Therefore, the final model used was the same as that in Study 1, with the constraint $d_{SG} = d_{NSG}$ imposed. Convergence of parameter estimation was evident, with $\hat{R} < 1.05$ for all parameters. The model's goodness of fit was acceptable ($T_1$: PPP = .52, $T_2$: PPP = .45). Table 2 summarises the parameter estimates and their corresponding BCIs.

### Association between source memory and emotion recognition

We tested the associations of the MPT parameters with emotion recognition and emotion sharing. The results are summarised in Table 2. First, we focused on source memory. Again, a positive correlation was evident between source memory and emotion recognition, β = .22, BCI = [.01, .41]. However, this link to source memory was absent for emotion sharing, β = .01, BCI = [–.20, .21].

We further examined the associations of item memories and guessings with emotion recognition and emotion sharing. No reliable correlation with emotion recognition or emotion sharing was found

**Table 2.** Estimates and Bayesian Credibility Intervals (BCIs) for Parameters of the Two-high-threshold Multinomial Model of Source Monitoring, and for Regression Coefficients of the Parameters on Emotion Recognition and Emotion Sharing in Study 2.

| | Parameters | | Regression coefficients | | | |
|---|---|---|---|---|---|---|
| | | | Emotion recognition | | Emotion sharing | |
| | *M* | BCI | β | BCI | β | BCI |
| $D_{SG}$ | .88 | [.86, .90] | .13 | [–.10, .36] | –.01 | [–.25, .21] |
| $D_{NSG}$ | .59 | [.57, .62] | .03 | [–.20, .26] | –.02 | [–.25, .21] |
| *d* | .63 | [.59, .68] | .22 | [.01, .41] | .01 | [–.20, .21] |
| *b* | .10 | [.08, .13] | –.13 | [–.33, .08] | .03 | [–.18, .24] |
| *g* | .43 | [.37, .49] | –.15 | [–.34, .05] | .12 | [–.07, .31] |

Notes. For abbreviations, $D_{SG}$ = item memory for self-generated items; $D_{NSG}$ = item memory for non-self-generated items; *d* = source memory; *b* = guessing items as studied; *g* = guessing items as studied through self-generation.

**Table 3.** Estimates and Bayesian Credibility Intervals (BCIs) for the Regression Coefficients of the Parameters of the Two-high-threshold Multinomial Model of Source Monitoring on Emotion Recognition and Emotion Sharing when Controlling for Sex, Age, Education Level, and Intelligence in Study 2.

| | Emotion recognition | | Emotion sharing | |
|---|---|---|---|---|
| | β | BCI | β | BCI |
| $D_{SG}$ | .11 | [–.13, .34] | .01 | [–.22, .25] |
| $D_{NSG}$ | .02 | [–.22, .25] | –.01 | [–.24, .22] |
| *d* | .21 | [–.01, .41] | .03 | [–.18, .24] |
| *b* | –.12 | [–.34, .11] | .04 | [–.17, .26] |
| *g* | –.14 | [–.33, .06] | .12 | [–.07, .30] |

Notes. For abbreviations, $D_{SG}$ = item memory for self-generated items; $D_{NSG}$ = item memory for non-self-generated items; *d* = source memory; *b* = guessing items as studied; *g* = guessing items as studied through self-generation.

for either item memory, with βs ranging from −.02 to .13. The positive correlation in Study 1 between item memory for non-self-generated items and emotion recognition may be spurious. No reliable correlations were found for old–new guessing and source guessing, βs = −.15 to .12. The response biases did not relate to emotion recognition or emotion sharing.

Finally, we performed covariate analysis by adding sex, age, education level, and intelligence as predictors in the latent-trait regression models (see Table 3). A similar correlation was obtained between source memory and emotion recognition, β = .21, BCI = [−.01, .41]. Despite the ambiguous BCI, in which the regression weight encompassed 0, the numerical value of β barely changed across both analyses, suggesting that intelligence and demographics did not account for this association.

## General discussion

This study investigated whether the ability to remember a sentence read aloud was self-generated or not (i.e. self-referential source memory) related to the performance of reading another person's emotion in an affect-charged situation (i.e. emotion recognition). It was not surprising that participants could tell sentences self-generated as old better than those not self-generated, a well-documented effect of self-generation on recognition memory (Bertsch et al., 2007; McCurdy et al., 2017). Crucially, it was source memory, being able to remember covert details such as feeling puzzled at the first read of an incomplete sentence or searching a suitable subject beyond reading the sentence aloud, that correlated positively with emotion recognition. The ability to differentiate how remembered sentences were referenced to oneself related to individual differences in emotion recognition.

Through MPT modelling, we teased apart the latent components of the source attribution decision-making process. Emotion recognition positively correlated with the mnemonic rather than the non-mnemonic components of source attribution. Although participants who effectively recognised emotions were better at differentiating whether a sentence was self-generated, their source attribution was random for items without source memory (either accurately recognised or misrecognised as old). Response bias did not explain the link between emotion recognition and source attribution. Additionally, the correlations between emotion recognition and item memory were inconsistent, indicating that the results cannot be attributed to individual differences in general learning abilities. Together, the specific role of self-referential source memory is supported for emotion recognition.

The absence of an association with item memory for self-generated items provides additional insight into emotion recognition. Despite its unified perception, the self can be represented in several ways (Klein, 2012). When an item is generated by oneself, dissociable memory traces exist for old–new judgments and source judgments. Our finding indicates that it is a trace in support of source judgment, a summarising tag at the meta-level (Bell et al., 2012), which is relevant to emotion recognition. In other words, when an observer attempts to read another person's emotions, the ability to trace the mental products available and determine whether they originate from the self may be essential.

Our study provides empirical support for the crucial role of self-referential source memory in emotion recognition. We established a link through two behavioural tasks using the individual difference approach commonly adopted in experimental psychopathology research. The proposed design has two advantages. First, utilising paradigms similar to those used in clinical studies, we provide initial evidence for the association between weakened self-referential source memory and impoverished emotion recognition. Self-referential source memory, a cognitive marker of dissociation and schizophrenia, may contribute to the socioemotional difficulties associated with these mental disorders. Second, paradigms available for investigating emotion recognition do not quantify the source monitoring process (Barrett et al., 2019). This study provides evidence of this association.

Self-referential memory may interact with other factors, such as a negative or stressful social environment, in the acquisition of an emotion recognition ability (Pollak et al., 2000). Children from abusive families whose parents frequently showed hostility and rejection identified angry faces effectively with less sensory input (Pollak & Sinha, 2002). Weakened self-referential source memory may exaggerate this sensitivity to facial expressions of anger, hindering the learning of cues related to other negative emotions that can dynamically emerge in stressful situations. In contrast, preserved or outstanding self-referential source memory may help sharpen the requisite skills for differentiating emotions, even for

individuals from a rejecting family. Through imagining the situations of extrafamilial people such as peers and teachers, knowledge of discrete emotions can be accumulated with broader social exposure.

This study had several limitations. First, the correlational nature of the research design precludes any inference of a causal relationship between self-referential source memory and emotion recognition. Even though we excluded potential third variables such as age and intelligence, we await future research to document causal relations and examine other potential mediators and moderators. Testing the relation of source memory and emotion recognition in a single experimental context appears a useful design (Schaper et al., 2019). Research in children of different ages may test whether better source memory goes along with earlier emotion recognition skills. Second, there are multiple aspects of the self. In addition to the agentic self, the self can be constructed through introspection, such as having a descriptive or autobiographical self (Klein, 2012). Future studies should examine whether this association is evident for other types of self-referential source memory.

Researchers should be cautious when generalising our findings to facial emotion recognition. In the photos of our emotion recognition test, participants viewed not only another person's facial expression but also the person's bodily reactions and environment. Studies have shown that contextual details—the environments in which the targets are situated, the objects nearby, and the body postures and gestures of the targets—contribute significantly to emotion recognition (Aviezer et al., 2011; Leitzke & Pollak, 2016; Ngo & Isaacowitz, 2015). Reading emotions from facial expressions may involve bottom-up mechanisms that do not demand a self-generative act as in emotion recognition from situation imagination (Newen et al., 2015; Quesque & Rossetti, 2020).

An important agenda for future studies is to demonstrate whether weakened self-referential source memory can account for emotion recognition deficits in clinical and subclinical populations (e.g. dissociative conditions, schizophrenia, and schizotypy). The acute phase of a disordered mental state may transiently blur the boundary between the self and the other, confounding the reading of that person's emotions with one's own feelings. Or, anomalies in the neurobiological underpinnings may dilute the sense of self or agency, hampering the differentiation between perceived and imagined situations. Our paradigm provides a feasible way to elaborate on this issue by examining whether self-referential memory relates to impaired emotion recognition. Cognitive training targeting the discrimination between self-generated and non-self-generated mental products, such as mental imagery creation tasks, can be designed to facilitate remembering the sources of self-referential materials.

In conclusion, our research yields important findings relevant to understanding the basic mechanisms pertinent to disorders of the self that are linked to memory and perceptions of emotions. We hope that future researchers will replicate and extend our findings across diverse samples, in both laboratory and clinical contexts.

## Notes

1. Files can be downloaded from the following links: the data (http://gofile.me/4Z3bA/itvUs98Pq) and the statistical analysis code (http://gofile.me/4Z3bA/EjiAZvxU6).
2. Despite the ongoing debate regarding whether another person's emotions can be simply seen without the attribution of an internal state, our hypothesis is drawn on the basis that emotion recognition can involve the use of self-knowledge, that is, the imagination of the person's situation. Hence, we found the study by Ford et al. (2011) relevant, for their test of the association between self-referential source memory and discrimination of the first-person perspective and an imagined perspective for another person.
3. The default priors for estimating the MPT parameters correspond to a uniform distribution in the probability space, which is weakly informative. The default priors for the estimations of the regression coefficients correspond to a univariate normal prior with a mean value of zero, a variance defined by an inverse gamma prior with a shape value of .05, and a scale value of .05.

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## Author contributions

All authors were involved in the revisions of the manuscript and approved the final version of the paper for submission. CDC and APKL conceived the initial research idea. CDC, APKL, and FKLM did the literature review. APKL conducted data analysis with CDC. CDC prepared the first draft with APKL and FKLM.

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

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