

Loneliness and emotion regulation in daily life[☆]Lameese Eldesouky^{a,*}, Amit Goldenberg^{b,c,d}, Kate Ellis^a^a Department of Psychology, The American University in Cairo, Egypt^b Harvard Business School, Harvard University, United States^c Department of Psychology, Harvard University, United States^d Digital, Data and Design Institute, Harvard University, United States

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ABSTRACT

There is a growing understanding that emotion regulation (ER) abilities can be an important buffer for loneliness. However, most of this research is cross-sectional. Thus, it is unknown whether loneliness is associated with ER in momentary evaluations and can predict within-person changes in ER. We addressed these questions through ecological momentary assessment, where 169 Egyptian adults reported their loneliness and ER (social sharing, suppression, reappraisal, positive reframing, rumination) five times daily for 14 days. Loneliness negatively predicted social sharing at the within-person level and positively predicted rumination at the between-person level. However, loneliness was not linked to reappraisal, positive reframing, or suppression at the between or within-person levels. The results indicate that the global associations between loneliness and ER replicate previously established results for social sharing and rumination, but not suppression, reappraisal, or positive reframing in daily life. At the same time, the effects of loneliness on different strategies in daily life depend on whether they are at the within-person or between-person level.

1. Introduction

Loneliness—a negative feeling that results from unfulfilled social needs and a desire for more satisfying relationships (Hawkley & Cacioppo, 2010)—is an urgent public health problem in today's world (Holt-Lunstad, 2022). Greater loneliness is linked to poorer mental and physical health (e.g., Holt-Lunstad, 2021; Smith et al., 2020). In the past decade, extensive efforts have been made to decrease loneliness (Eccles & Qualter, 2021; Masi et al., 2011). While the obvious intervention target may be people's ability to enrich their social world (Masi et al., 2011), there is an increasing understanding that the ways people control their emotional experience and expressions (i.e., emotion regulation; ER) is also highly relevant for social connection (English & Eldesouky, 2020). Thus, this study's aim was to extend prior research on loneliness and ER (e.g., Preece et al., 2021; Tan et al., 2022) by examining how loneliness predicts ER in daily life.

1.1. Emotion regulation strategies

We focus on five ER strategies that are commonly used in daily life

(Brans et al., 2013; Heiy & Cheavens, 2014): social sharing, expressive suppression, cognitive reappraisal, positive reframing, and rumination. *Social sharing* targets how emotions are expressed by discussing them with others (Rimé et al., 1992). *Expressive suppression* also targets how emotions are expressed, but involves inhibiting their expression (e.g., Gross, 1998). *Cognitive reappraisal* targets the cognitive aspects of emotional stimuli by reframing their meaning (Gross, 1998). *Positive reframing* is a specific reappraisal tactic that involves reframing emotional stimuli in terms of their positive aspects (Carver, 1997). *Rumination* targets the cognitive and attentional aspects of emotional stimuli by repeatedly thinking about them in a negative, unconstructive manner (Nolen-Hoeksema et al., 2008).

Of all the ER strategies, some seem to be more associated with the quality of social connection than others, making them especially relevant for loneliness. Correlational studies suggest that frequent social sharing, reappraisal, and positive reframing are associated with greater social connection. Social sharing can strengthen social bonds (Bucich & MacCann, 2019) by amplifying emotional expression, which is important for communication (English & Eldesouky, 2020). Meanwhile, higher reappraisal is linked to greater marital satisfaction by helping one

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take others' perspectives (Finkel et al., 2013). Higher trait positive reframing is also linked to greater relationship satisfaction (Samios & Baran, 2018), perhaps because it helps one see positive aspects of their relationship (Finkel et al., 2013). Compared to these strategies, frequent suppression and rumination are associated with lower social connection. Higher trait suppression is linked to lower relationship quality, partly because it decreases emotional expression, which can hinder communication (English & Eldesouky, 2020). Meanwhile, higher trait rumination is linked to greater relationship anxiety and avoidance, perhaps because it can amplify focusing on negative aspects of a relationship (Reynolds et al., 2014).

1.2. Loneliness and emotion regulation

To determine how lonelier individuals use the aforementioned strategies, we consider the resources needed for ER. According to the selection, optimization and compensation with ER framework, resources can shape the ER strategies people use (Urry & Gross, 2010). Resources are defined as internal abilities and environmental affordances (Urry & Gross, 2010). Two major resources are *social resources*, or access to people one can trust and feel comfortable with, and *cognitive resources*, or cognitive abilities, such as attentional control and executive functioning.

Social resources are essential for social sharing given the social risks of emotional expression (e.g., vulnerability, rejection; Clark & Taraban, 1991). Having reduced social resources may instead motivate suppression, which people often use to protect themselves from negative social judgments (Spokas et al., 2009). Lonelier individuals have minimal social resources, including reduced access to people they feel socially safe with (Best et al., 2021) and few positive social interactions (Hawkey & Cacioppo, 2010). Thus, they might be less likely to engage in social sharing. Moreover, lonelier individuals often try to protect themselves from social threats (Hawkey et al., 2008). Thus they may be more likely to use suppression. Past studies support these hypotheses by showing that trait loneliness is negatively associated with trait social sharing, but positively associated with trait suppression (e.g., Preece et al., 2021; Tan et al., 2022; Verzeletti et al., 2016).

Social resources may also motivate the use of reappraisal and positive reframing by providing alternative and beneficial appraisals (Urry & Gross, 2010). Having fewer social resources might instead motivate one to fixate on the same appraisals and thus, use rumination. Nevertheless, cognitive strategies also require cognitive resources to generate meaningful appraisals (Milyavsky et al., 2019). Lonelier individuals have reduced cognitive resources, including poor attentional control and executive functioning (Cacioppo & Hawkey, 2009). Given their limited social and cognitive resources, lonelier individuals may be less likely to use reappraisal and positive reframing. Even when lonelier individuals form appraisals, their appraisals tend to be negative (Wong et al., 2022). Thus, lonelier individuals may be more likely to use rumination. Studies support these hypotheses by showing that trait loneliness is negatively linked to trait reappraisal and positive reframing, but positively linked to trait rumination (e.g., O'Day et al., 2019; Preece et al., 2021; Vanhalst et al., 2018).

While previous studies have examined links between loneliness and ER, they were cross-sectional. Thus, they were limited to examining between-person effects, or the extent to which people vary from each another (i.e., how lonelier individuals regulate compared to less lonely individuals; Fleeson, 2001). Longitudinal studies however, can be used to also examine within-person effects, or how an individual's own behavior varies across contexts (i.e., how people regulate when feeling lonely; Fleeson, 2001). There are also however, other limitations to past work, which include not accounting for relationship status and the social context (i.e., being alone), which are key social factors that positively correlate with loneliness (Hawkey et al., 2008). Moreover, previous work was only conducted in Western samples (e.g., American, Australian), which limits their generalizability to other cultures.

1.3. The present study

The present study investigated the association between loneliness and ER in daily life. We hypothesized that loneliness would (1) negatively predict social sharing, reappraisal, and positive reframing, but (2) positively predict suppression and rumination. Although between- and within-person effects can differ (e.g., Kashdan & Nezlek, 2012), we held the same hypotheses for both because of the minimal daily research on this topic. We tested these hypotheses using ecological momentary assessment (EMA), an intensive longitudinal method that repeatedly measures constructs in daily life (Bolger et al., 2003). To address limitations of prior research, we also assessed relationship status and the social context as control measures, but they were not the main focus. We also conducted this research in a non-Western sample (i.e., Egyptian). However, given the minimal research on loneliness and ER across cultures, we did not have unique predictions. The study was not pre-registered. Study materials, data, and code are on the Open Science Framework: https://osf.io/8qra3/?view_only=1463f6eee7544d07a0c05205193da9d1.

2. Material and methods

2.1. Participants and procedure

A sample of 316 Egyptian community-based adults completed a baseline self-report battery as part of a larger ER study (Eldesouky et al., 2023). Convenience sampling was used and participants were recruited through study flyers, social media channels, and social and professional networks throughout various regions in Egypt. Of the total sample, 169 adults participated in the EMA portion (87 % female, 13 % male; $M(SD)_{age} = 26.75(7.88)$, 18–65 years). There are concerns regarding a priori power analyses for EMA studies (Bolger et al., 2012). Unlike many traditional research designs, the parameter estimates of EMA studies depend on multiple factors besides effect size, including average compliance, study length, and maximum daily responses. Some of these factors are unknown a priori and cannot be controlled by the researcher. Given these concerns, it may be most accurate to conduct power analysis for EMA studies post-hoc (Bolger et al., 2012). Thus, we conducted a post-hoc power analysis in R using the *pwr* and *EMAtools* packages to produce power curves based on the sample size, average participant response number ($N = 15.29$), study length ($N = 14$), and maximum daily responses ($N = 5$). We had over 80 % power to detect medium effects ($d = 0.50$), which were found in prior work on trait loneliness and ER (e.g., Preece et al., 2021).

The study was approved by the Institutional Review Board at the American University in Cairo (Approval No 2019-2020-114) and all participants provided consent. Participants completed demographic measures as part of the baseline self-report battery. The following day, participants part-took in the EMA portion, where they reported on loneliness and ER five times daily for 14 days. Participants were texted the survey link randomly within 1–3 h intervals throughout their preferred waking period (e.g., 11 am–11 pm). Survey measures were translated into Arabic and back-translated into English. Eight-six percent of participants completed the surveys in English, while 14 % completed them in Arabic. Three participants were excluded for not completing any surveys, leaving a total of 166 participants.

2.2. Experience sampling measures

2.2.1. Loneliness

Loneliness was assessed using the item “How lonely do you feel right now?” and rated on a 5-point scale (1 = not at all; 5 = extremely).

2.2.2. Emotion regulation

Participants were asked “Since the last prompt, I managed by emotions by” and presented with a checklist of ER strategies: social sharing (I

talked about my feelings, Brans et al., 2013), suppression (I kept my emotions to myself, Emotion Regulation Questionnaire; Gross & John, 2003), reappraisal (I thought about the situation in a different way; Brans et al., 2003), and positive reframing (I looked for something good in what is happening; Brief COPE, Carver, 1997). The data included additional ER strategies, but we do not focus on them because they are less relevant for social connection or occurred relatively infrequently. The items and exploratory analyses for these strategies are in the Supplementary Material (SM).

2.3. Control measures

2.3.1. Relationship status

Relationship status was measured with the following options: single, in a relationship, engaged, and divorced/widowed. The distribution was 57 % single, 22.6 % married, 14.8 % in a relationship or engaged, and 5.6 % divorced or separated. Given the minimal percentages in many categories, we created a category separating single (single, divorced/widowed) and non-single (in a relationship or engaged, married) participants.

2.3.2. Social context

Social context was assessed in each EMA survey with the item “Are you alone right now?” (yes or no) and referred to not having in-person company.

2.4. Analysis plan

Analyses were conducted in R (Version 4.3.1; R Core Team, 2023). Across the 14 days, there were 2488 momentary observations. Participants completed an average of 15 surveys ($M = 15.29$; $SD = 16.31$; $Mdn = 7$), with 21 % overall compliance. There was large variation in the number of surveys completed (range: 1–68). The average compliance is relatively low compared to prior EMA studies (e.g., Brans et al., 2003; Heij & Cheavens, 2014). However, the compliance rates of these studies are based on Western samples (e.g., Australia, America). Studies with Arab samples indicate that missing data as high as 70 % is common and may be due to hesitation in trusting authority (Benstead, 2018). Many Arab countries also have poor telecommunication infrastructure (Aker & Mbiti, 2010), which affects EMA administration.

The analyses were conducted using all 166 participants. Sensitivity analyses were also conducted to determine whether the findings hold when removing participants with especially low compliance (see SM). Preliminary analyses included calculating descriptives (means, frequencies), intraclass correlation coefficients (ICC), and intercorrelations between variables¹. Binomial variables (ER strategies [0 = not used, 1 = used], social context [0 = not alone, 1 = alone]) were dummy-coded. Null binomial models were conducted when calculating ICCs for ER and social context. Cramer's V-test was used for correlations involving binary variables. Pearson's correlation tests were used for correlations involving numerical variables. Cramer's V values range from 0 to 1, with small effect sizes ranging from 0.10 to 0.19, medium effects ranging from 0.30 to 0.49, and large effects being 0.50 and greater (Kim, 2017).

Main analyses were conducted using multi-level modeling (MLM) given the data's two-level structure (Level 1: moments; Level 2; persons; Bryk & Raudenbush, 1992). Lagged models were conducted to approximate the causal relationship between loneliness and ER. We examined the effects of loneliness at sampling moment $t-1$ on each ER strategy at sampling moment t . However, because loneliness referenced the present (right now), whereas ER referenced the past (since the last survey), lagging loneliness to $t-1$ would conceptually put loneliness in the same

timeframe as ER. Thus, we lagged loneliness to $t-2$ instead of $t-1$ to predict ER at t , while controlling for the relevant strategy at $t-1$. Following recommendations by Bolger and Laurenceau (2013), loneliness was simultaneously tested as a between-person (Level 1) and within-person (Level 2) predictor. Between-person effects were calculated by grand-mean centering loneliness across the sample and averaging loneliness for each participant. Within-person effects were calculated by subtracting each participant's grand mean from the overall grand mean. Logistic MLM was used because ER was a binary outcome.

We also conducted exploratory analyses to examine whether ER predicts loneliness. This involved using a lagged linear MLM model to test the effects of ER at sampling moment $t-1$ on loneliness at sampling moment t , controlling for loneliness at $t-1$. Given that ER referenced the prior sampling moment, it was conceptually lagged and thus, we did not formally lag it. To reduce Type I error, all strategies at the between and within-person levels were included as simultaneous predictors of loneliness. We describe the results below and report details in the SM.

In all analyses, random intercepts were included. One set of models was conducted without control measures (relationship status, social context) and a second set included control measures (see SM). Numerical variables were standardized, resulting in standardized beta coefficients for simpler effect size interpretation.

3. Results

3.1. Preliminary analyses

Table 1 shows the descriptive statistics, ICCs, and intercorrelations between variables. Strategy frequencies varied, with suppression used the most (31.8 %) and positive reframing used the least (7.88 %). The ICC for loneliness was 0.56, reflecting that a little over half of the variance was due to between-person differences. ICCs for ER ranged from 0.38 (social sharing) to 0.50 (suppression), suggesting sufficient variation within individuals across moments. Correlations were larger at the between- (Cramer's $V = 0.74$ – 0.94) than the within- (Cramer's $V = 0.56$ – 0.71) person level.

3.2. Main analyses: Loneliness predicting emotion regulation

Table 2 shows the lagged MLM results for loneliness predicting ER. Within-person loneliness negatively predicted social sharing, as expected. Thus, when people felt lonely at the preceding timepoint, they were less likely to subsequently use social sharing. At the between-person level, loneliness positively predicted rumination, also as expected. Thus, people who felt lonelier on average in preceding timepoints were more likely to ruminate later. However, loneliness did not predict reappraisal, positive reframing, or suppression at any level. Most findings were unchanged after including control variables; see SM.

3.3. Exploratory analyses: Emotion regulation predicting loneliness

Within-person suppression and rumination positively predicted loneliness; see SM. Therefore, when people used suppression or rumination at the prior timepoint, they felt lonelier later. Between-person rumination also positively predicted loneliness; see SM. Thus, people who frequently endorsed rumination in prior timepoints reported greater subsequent loneliness. Social sharing, reappraisal, and positive reframing did not predict loneliness.

4. Discussion

This study extends prior cross-sectional studies on loneliness and ER (e.g., Preece et al., 2021; Tan et al., 2022) by examining their association in daily life. Consistent with previous studies, loneliness negatively predicted social sharing and positively predicted rumination in daily life. However, daily loneliness did not predict reappraisal, positive

¹ Descriptives, ICCs, and intracorrelations for ER strategies are also reported in Eldesouky et al. (2023). However, no information was reported for loneliness or social context.

Table 1
Descriptive statistics and intercorrelations between study variables.

Variable	<i>M(SD)</i>	ICC	1.	2.	3.	4.	5.	6.	7.
1. Loneliness	2.71(1.39)	0.56	–	0.70	0.70	0.68	0.71	0.71	0.69
2. Social sharing	12.14 %	0.38	0.94	–	0.60	0.60	0.61	0.58	0.60
3. Suppression	31.84 %	0.50	0.92	0.79	–	0.56	0.58	0.58	0.61
4. Reappraisal	8.72 %	0.47	0.89	0.77	0.75	–	0.57	0.56	0.59
5. Positive reframing	7.88 %	0.44	0.93	0.80	0.80	0.75	–	0.56	0.58
6. Rumination	14.43 %	0.41	0.91	0.78	0.80	0.74	0.75	–	0.63
7. Social context	40 %	0.35	0.91	0.81	0.83	0.80	0.88	0.82	–

Note. *M(SD)* = mean with standard deviation in parentheses for numerical variables and overall percentage of occasions endorsed for binary variables. ICC=Intraclass correlation coefficient. ER strategies were dummy-coded as 0 = not used, 1 = used. Social context was dummy-coded as 0 = not alone, 1 = alone. Correlations above the diagonal are within-person, whereas correlations below the diagonal are between-person. Correlations involving binary variables reflect Cramer's V values. Correlations involving numerical variables reflect Pearson's correlation values. Significant effects are bolded ($p < .05$).

reframing, or suppression. Thus, global associations between loneliness and ER only replicate for some strategies in daily life. At the same time, effects either emerged at the between- or within-person levels. Thus, the ways chronically lonelier individuals regulate their emotions may not reflect how people in general regulate during transient loneliness.

4.1. Daily links between loneliness and emotion regulation

Social sharing and rumination may be especially important for loneliness given that their associations with loneliness replicated across prior studies (e.g., Preece et al., 2021; Tan et al., 2022) and our study. Nevertheless, these associations did not emerge at both the between and within-person levels. Perhaps loneliness had a within-person effect on social sharing because social sharing requires another person (Rimé et al., 1992). Thus, people may need a context where they can share their emotions. Interestingly however, people were not more likely to suppress their emotions when feeling lonely. Thus, people might still express emotions, even without discussing them. Given that lonelier individuals fear negative social judgments (Hawley et al., 2008), perhaps loneliness makes them more cautious of what emotions they express and with whom. To understand the effects of loneliness on strategies targeting expression, studies can examine the moderating role of contextual factors linked to loneliness (e.g., feeling safe, Best et al., 2021; interaction quality, Cacioppo & Hawley, 2009).

Perhaps loneliness had a between-person effect on rumination because its processes are rooted in habitual thinking, rather than context. Notably, despite having fewer cognitive resources (Cacioppo & Hawley, 2009), lonelier individuals were not less likely to use reappraisal or positive reframing. Thus, they may still form meaningful appraisals, but focus on negative ones (Wong et al., 2022). One explanation may be that lonelier individuals construe their time alone negatively (Rodríguez et al., 2020). Thus, to better understand the effects of loneliness on cognitive strategies, studies may examine the specific thoughts of lonelier individuals.

More generally, the effects of loneliness on ER at different levels may inform our understanding of how loneliness affects well-being. Chronic loneliness negatively impacts relationship closeness, whereas transient loneliness can enhance social connection (Hawley & Cacioppo, 2010). Perhaps chronically lonely people use strategies that are particularly damaging for relationships, further amplifying their loneliness. However, transient loneliness may influence ER in a manner that enhances social connection in the long-run.

Nevertheless, it is important to replicate these findings in other cultures. People from collectivistic cultures (i.e., interdependent and focused on others), such as Egypt, are less lonely than people from individualistic cultures (i.e., independent and focused on the self; Barreto et al., 2021), partly because they have more social resources (Hofstede, 1980). Thus, while lonelier individuals have reduced social resources (Best et al., 2021; Cacioppo & Hawley, 2009), being in a collectivistic culture may buffer this deficit, subsequently affecting their ER. It is also important to note that our sample was mostly female, which

may have mitigated the effects or made it difficult to detect other effects. Females are less lonely than men worldwide and have greater social support (Barreto et al., 2021). Thus, future research should replicate this work in samples with a more equal gender distribution.

4.2. Practical implications

These findings have implications for understanding the relationship between loneliness and ER. Loneliness predicted a lower likelihood of social sharing, which could lessen the opportunity for social bonding (Bucich & MacCann, 2019). Furthermore, loneliness predicted a greater likelihood of rumination, which might increase relationship anxiety and avoidance (Reynolds et al., 2014). In other words, loneliness might motivate regulating in a manner that further minimizes social connection. Initial evidence for this idea comes from our exploratory findings, where rumination also predicted loneliness. Therefore, it may be useful to continue using loneliness interventions that target ER (Masi et al., 2011). Nonetheless, there were not bi-directional relationships for all strategies. Perhaps a strategy's effect on loneliness depends on whether it has the potential to enhance social connection versus actively disrupts it, with the latter being more detrimental for loneliness.

Meanwhile, varying links between loneliness and ER at different levels suggest different interventions are needed for transient versus chronic loneliness. Transient loneliness interventions might focus on contextual factors. For example, helping people feel safer when feeling lonely might motivate them to share their emotions. However, chronic loneliness interventions might focus on personality factors. For instance, targeting the negative attentional bias (Wong et al., 2022) of lonelier individuals might decrease habitual rumination. Given that these ideas are speculative, future research is needed to examine how much different contextual and personality factors can change.

4.3. Limitations and future directions

This research has some important limitations. First, the sample had low compliance, partially due to factors beyond our control (e.g., poor telecommunication infrastructure). However, low compliance might affect the ability to detect small effects. Thus, there might be effects of loneliness on other strategies in daily life, but they were difficult to detect. Second, despite using lagged analyses, the study design is limited in its ability to make causal claims. Experiments can be used to manipulate loneliness and determine whether it influences ER. Lastly, while we considered social context, the frequency of being alone may have been over-reported if people waited to complete surveys until they were alone. Furthermore, future studies can account for other factors important for loneliness and ER (e.g., relationship satisfaction) besides social context and relationship status.

5. Conclusions

This study examined the associations between daily loneliness and

Table 2
Lagged multi-level modeling analyses with loneliness predicting emotion regulation in daily life.

Predictor	Social sharing			Suppression			Reappraisal			Positive reframing			Rumination		
	b(SE)	z	p	b(SE)	z	p	b(SE)	z	p	b(SE)	z	p	b(SE)	z	p
Intercept	-3.30			-1.65			-3.40			-3.65			-2.81		
Loneliness _{between t-2}	-0.57(0.30)	-1.85	0.06	0.35(0.21)	1.67	0.09	-0.41(0.26)	-1.57	0.11	-0.49(0.30)	-1.59	0.11	0.58(0.26)	2.22	0.02
	[-1.17, -0.50]			[-0.06, 0.77]			[-0.93, 0.10]			[-1.09, 0.11]			[0.06, 1.09]		
Loneliness _{within t-2}	-0.26(0.12)	-2.08	0.03	0.05(0.08)	0.66	0.50	-0.10(0.13)	-0.78	0.43	0.01(0.15)	0.03	0.97	-0.04(0.11)	-0.41	0.67
	[-0.50, -0.01]			[-0.11, 0.22]			[-0.37, 0.16]			[-0.30, 0.31]			[-0.27, 0.18]		
ER strategy _{t-1}	0.61(0.28)	2.15	0.03	1.74(0.18)	9.28	<0.001	1.60(0.38)	4.15	<0.001	1.86(0.37)	5.00	<0.001	1.48(0.24)	6.16	<0.001
	[0.05, 1.16]			[1.37, 0.21]			[0.84, 2.36]			[1.13, 2.59]			[1.01, 1.95]		
Level 2 residual effect	2.51(1.58)			1.71(1.30)			1.39(1.18)			2.21(1.48)			1.99(1.41)		

Note. b(SE) = standardized beta coefficient with standard errors in parentheses and 95 % confidence intervals; Between = between-person level; Within = within-person level; Level 2 residual effect reflects the variance and standard deviation. ER strategies were coded as 0 = not used and 1 = used. Loneliness t-2 and ER strategy t-1 reflect loneliness and ER at the prior sampling moment, respectively. Significant effects are bolded ($p < .05$).

ER. Loneliness negatively predicted within-person social sharing and positively predicted between-person rumination. Loneliness did not predict reappraisal, positively reframing, or suppression. The results partly replicate cross-sectional associations found between loneliness and ER. They also suggest that the effects of daily loneliness on ER vary across within and between-person levels.

CRedit authorship contribution statement

Lameese Eldesouky: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Amit Goldenberg:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Kate Ellis:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Data availability

I have shared the link to my data/code

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.paid.2024.112566>.

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