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4 **Patterns of Ongoing Thought in the Real-World**

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7 Bridget Mulholland^{1*}, Ian Goodall-Halliwell¹, Raven Wallace², Louis Chitiz², Brontë McKeown²,
8 Aryanna Rastan², Giulia Poerio³, Robert Leech⁴, Adam Turnbull⁵, Arno Klein⁶, Wil Van Auken⁶,
9 Michael Milham⁶, Jeffrey Wammes², Elizabeth Jefferies⁷, Jonathan Smallwood²

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13 ¹Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada

14 ²Department of Psychology, Queen's University, Kingston, Ontario, Canada

15 ³Department of Psychology, University of Essex, Colchester, England

16 ⁴Department of Neuroimaging, King's College, London, England

17 ⁵School of Nursing, University of Rochester, Rochester, New York, U.S.A

18 ⁶Child Mind Institute, New York, New York, USA

19 ⁷Department of Psychology, University of York, York, England

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22 * Corresponding author

23 E-mail: 15bbm@queensu.ca (BM)

24 **Abstract**

25 Previous research has indicated that health and well-being are impacted on by both the way we
26 think, and the things we do. In the laboratory, studies suggest that specific task contexts affect
27 this process because the people we are with, the places we are in, and the activities we perform
28 may influence our thought patterns. In our study participants completed multi-dimensional
29 experience-sampling surveys eight times per day for 5 days to generate thought data across a
30 variety of dimensions in daily life. Principal component analysis was used to decompose the
31 experience sampling data, and linear mixed modelling related these patterns to the activity in
32 daily life in which they emerged. Our study replicated the influence of socializing on patterns of
33 ongoing thought observed in our prior study and established that this is part of a broader set of
34 relationship that links our current activities to how our thoughts are organised in daily life. We
35 also found that factors such as time of day and the physical location are associated with reported
36 patterns of thought, factors that are important for future studies to explore. Our study suggests
37 that sampling thinking in the real world may be able to provide a set of comprehensive thinking-
38 activity mappings that will be useful to researchers and health care professionals interested in
39 health and well-being.

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47 **Introduction**

48 A core goal of cognitive science is to understand the processes that support cognition and
49 contemporary work suggests that the content and form of the way we think varies widely across
50 people, places, and activities (Smallwood et al., 2021). Variation in how we think and feel is well
51 known to contribute to health and well-being (Fitzgerald et al., 2008), and the sorts of activities
52 we engage in are also important (Ingram et al., 2020). Consequently, research is needed to
53 determine how thought emerges across these different contexts, particularly within natural
54 environments. This will help build better connections between theoretical models of how we
55 think, and how these will play out in the activities we perform in daily life. One aim of our study,
56 therefore, was to map ongoing patterns of thought and behaviour in a real-world context in order
57 to provide a preliminary description of how thoughts map onto activities in daily life.

58 Important aspects of cognition can be measured in lab-based settings, allowing insight into
59 processes underlying human thought. However, it is difficult to gain similar information in daily
60 life (Kingstone et al., 2003). As noted in Kingstone et al. (2003), research based in natural
61 environments is needed to establish ecological validity within real-world contexts. Consistent
62 with this perspective, previous research suggests that lab-based descriptions of ongoing thought
63 may not generalize to real-world contexts (Ho et al., 2020). Accordingly, it would be useful to
64 gain contextualised measurements of thinking in the real-world to provide a provisional
65 description of the factors that impact the landscape of thinking in daily life.

66 Our study set out to use the technique of experience-sampling (ES) to provide a
67 description of thinking in daily life. ES allows researchers to capture what people are thinking
68 during everyday activities and lab-based tasks (Conner et al., 2009; Smallwood et al., 2021).
69 This technique has been used to provide descriptions of psychopathology (Myin-Germeys et al.,

70 2018) and emotion in the real-world (Zelenski & Larsen, 2000). Studies have also examined how
71 states like mind-wandering emerge in daily life (Franklin et al., 2013; Kane et al., 2007, 2017).

72 Our current study sought to extend these approaches via the use of multi-dimensional
73 experience-sampling (MDES) to map patterns of ongoing thought onto primary activities in both
74 real-world and laboratory settings (Smallwood et al., 2016; Ho et al., 2020). MDES asks
75 participants to describe their thinking across several dimensions (Smallwood et al., 2016). For
76 example, across a “Task” dimension, participants might be asked to score themselves on a 1 to 5
77 Likert scale (1 = Not at all, 5 = Completely) in relation to the associated statement, “My thoughts
78 were focused on the task I was performing” (Smallwood et al., 2016). MDES questions are
79 traditionally decomposed via principal component analysis (PCA) into a low dimensional space,
80 and these dimensions can be visualised as word clouds (see Figure 4). MDES is a powerful
81 technique that can be used to determine associations between patterns of thought, making links
82 to brain activity (Konu et al., 2020; Turnbull et al., 2019), and in the lab can be linked to states
83 like autism (Turnbull et al., 2020) and attention deficit disorder (Vatansever et al., 2019).

84 Recently, McKeown et al. (2021) used MDES to map ongoing thought in the real-world
85 onto primary activities during the first coronavirus disease 2019 (COVID-19) lockdown in the
86 United Kingdom. They found specific behavioural changes resultant of lockdown-reduced
87 opportunities for working and socializing, leading to unique changes in patterns of ongoing
88 thought. One goal of this study was to replicate the influence of socializing on patterns of
89 ongoing thought. We hypothesized that episodic social cognition thought patterns, which relate
90 to thinking about other people, would dominate activities that involved other people, as seen in
91 McKeown et al. (2021).

92 As well as replicating this prior study, we also hoped to understand how the activity that
93 a person is performing in daily life is reflected in their thought patterns, as captured by MDES.
94 In the laboratory, Konu et al. (2021) used MDES to investigate the influence of a task on patterns
95 of ongoing thought in lab-based settings via task mapping. They discovered that thought patterns
96 differ under specific task contexts in lab-based settings. Specifically, episodic social cognition
97 though patterns were present when tasks involved thinking about friends and were absent when
98 watching affective TV clips and engaging in memory tasks (Konu et al., 2021). In contrast,
99 patterns of detailed task focused thoughts were most common when performing tasks that
100 depended on executive control (working memory, task switching). Thus, a second goal of this
101 study was to extend research to examine more generally whether activities in the real-world
102 impact on a person's thinking.

103 We also had two more exploratory aims. Studies have suggested that whether a person is
104 indoors or outdoors can impact on their psychological state (Duvall, 2011; Weng & Chiang,
105 2014). Since natural variation in where participants were when the probe occurred would allow
106 us to sample thinking in a variety of different locations in our study, we also ascertained whether
107 the participants were indoors or outdoors when the probe occurred. Using this data, we explored
108 whether this impacted on their experience. Finally, certain types of activities are more likely to
109 occur at certain times of the day. As a final exploratory goal, therefore, we examined whether the
110 time of the day in which the MDES probe occurred was reflected in the patterns of thought the
111 participants described.

112 In summary, the broad goal of our study was to examine how thinking patterns in the
113 real-world relate to the activity in which the experience occurred. Based on prior work we
114 expected to replicate the influence of socializing on patterns of ongoing thought (McKeown et al.,

115 2021). Second, we aimed to determine whether there is a relationship between activities and
116 ongoing thought patterns in the real-world that parallels those seen in tasks (Konu et al., 2021).
117 Third, we aimed to discover whether MDES was linked to variation in time of day or location.

118 **Method**

119 **Participants**

120 This study was granted initial ethics clearance by the Queen's University Health Sciences
121 & Affiliated Teaching Hospitals Research Ethics Board (HSREB). Participants were recruited
122 between February 2022 and April 2022 through the Queen's University Psychology Participant
123 Pool. This recruitment timeline was determined by the Psychology Participant Pool participation
124 end date. Eligible participants were Queen's University students enrolled in designated first- and
125 second-year psychology courses. Participants gave informed, written consent via electronic
126 documentation prior to taking part in any research activities. Participants were awarded 2.0
127 course credits and also fully debriefed upon the completion of this study. A total of 101
128 participants (women = 82, men = 13, non-binary = 2, did not specify = 3; age: M = 21.11; SD =
129 5.33; and range = 18 to 52) completed MDES surveys with additional stress, environment,
130 location, and activity questions.

131 **Procedure**

132 Participants were emailed a MindLogger Pilot invitation for an applet called
133 "THOUGHTLOG," which they were instructed to accept. MindLogger Pilot is a smartphone
134 application that allows researchers to collect, analyze, and visualize data through custom
135 activities such as surveys, quizzes, digital diaries, and cognitive tasks, using mobile devices
136 (Child Mind Institute, 2022). The THOUGHTLOG applet contained an MDES survey with

137 additional stress, environment, location, and activity questions that participants completed for
138 this study. Participants were required to download the MindLogger Pilot application onto their
139 smartphone to access the THOUGHTLOG applet, and consequently, the MDES survey and
140 additional questions. Participants were notified to complete the THOUGHTLOG applet by the
141 MindLogger Pilot application eight times daily for 5 days between the hours of 7:00 AM and
142 11:00 PM. Each prompt was delivered within a specific 2-hour time interval. The MDES survey
143 and additional questions were not accessible outside of their associated 2-hour time interval.

144 **Multi-Dimensional Experience-Sampling and Additional Questions**

145 Participants were asked 14 multi-dimensional experience-sampling (MDES) questions
146 about the content of their thoughts immediately before being notified by MindLogger Pilot
147 across a variety of dimensions (Table 1). Participants were also asked to rate their stress level
148 immediately before being notified by MindLogger Pilot. Next, participants were asked questions
149 about their social environments immediately before being notified by MindLogger Pilot (Table
150 2). Additionally, participants were asked to indicate their type of location and primary activity
151 immediately before being notified by MindLogger Pilot (Table 3, 4). The primary activity list
152 was developed from the day reconstruction method (Kahneman et al., 2004) and modified based
153 on the activity options in McKeown et al. (2021).

154

Dimension	Questions	Scale Low	Scale High
Task	My thoughts were focused on an external task or activity:	Not at all	Completely
Future	My thoughts involved future events:	Not at all	Completely
Past	My thoughts involved past events:	Not at all	Completely

Self	My thoughts involved myself:	Not at all	Completely
Other	My thoughts involved other people:	Not at all	Completely
Emotion	The emotion of my thoughts was:	Negative	Positive
Modality	My thoughts were in the form of:	Images	Words
Detailed	My thoughts were detailed and specific:	Not at all	Completely
Deliberate	My thoughts were:	Spontaneous	Deliberate
Problem	I was thinking about solutions to problems (or goals):	Not at all	Completely
Intrusive	My thoughts were intrusive:	Not at all	Completely
Knowledge	My thoughts contained information I already knew (e.g., knowledge or memories):	Not at all	Completely
Absorption	I was absorbed in the contents of my thoughts:	Not at all	Completely
Distracting	My thoughts were distracting me from what I was doing:	Not at all	Completely

155 **Table 1.** *Summary of the multi-dimensional experience-sampling (MDES) questions.*

156 *Participants rated statements on a 1 to 5 Likert scale.*

157

Environment	Question	Environment List
Physical	Where you alone, or physically with other people?	Alone
		Around people but not interacting with them
		Around people and interacting with them

Virtual	Where you alone, or virtually with other people?	Alone (e.g., reading messages but not replying, being on a video call but not participating, etc.)
		Around people and interacting with them (e.g., direct communication with another person by text, instant messaging, calling, or video calling, etc.)

158 **Table 2.** *Summary of the social environment questions.*

159

Question	Location List
Where were you?	Inside a home
	Inside a shop
	Inside a workplace
	Inside (other)
	Outside in a city or town
	Outside in nature
	Outside (other)

160 **Table 3.** *Summary of the location questions. If participants selected “Inside (other),” or*

161 *“Outside (other),” they were asked to specify their location.*

162

163

Question	Possible Activity Answers
What were you doing?	Eating
	Homework
	Household chores
	Listening to music
	Napping or resting
	Nothing or waiting
	Personal exercise
	Personal hygiene care
	Physical leisure or sports
	Reading
	Shopping
	Talking in person
	Talking on the phone
	Texting by phone
	Traveling or commuting
	Using a computer or an electronic device
	Walking the dog
	Watching TV
	Working (paid or volunteer)
	Other activity

164 **Table 4.** *Summary of the primary activity questions. If participants selected “Other activity,”*

165 *they were asked to specify their primary activity.*

166 **Analysis**

167 **Code availability statement**

168 All custom code used to prepare data for analysis and figure development is available at

169 <https://github.com/ThinCLabQueens>.

170 **Principal component analysis (PCA)**

171 Common patterns of thought were identified by applying PCA with varimax rotation to all

172 thought data generated from responses to the 14 multi-dimensional experience-sampling

173 (MDES) questions (Table 1) using IBM SPSS (version 28). This is the standard method, as seen

174 in McKeown et al. (2021) and Konu et al. (2021). The loadings from the four components with an

175 eigenvalue >1 were saved for the generation of thought word clouds. These components were

176 also saved for later use as outcome variables for linear mixed modelling (LMM).

177 **Component Reliability**

178 Component reliability analysis was conducted in IBM SPSS (version 28). First, all thought data

179 was randomly shuffled, and then divided into two halves, with each half containing a sample of

180 729 probes. Next, a column titled “subset” was added to the datasheet. Each row was labelled as

181 “1” or “2” to indicate subset. To assess component reliability, PCA with varimax rotation was

182 utilized, with subset included as a selection variable. Further, factor scores were estimated using

183 the Thurstone regression method for all thought data based on the factors generated from each

184 subset. Afterwards, Pearson correlations were run on the factor scores between each of the

185 factors generated from each subset.

186 **Mixed Modelling (LMM), Primary Activity Data**

187 To analyze contextual distributions of thought in relation to activities, LMM was applied to each

188 of the component loadings generated by PCA. Activities were included as a condition of interest,

189 and participants were included as a random factor. This is the standard method, as seen in
190 McKeown et al. (2021), and Konu et al. (2021). LMM loadings were saved for the eventual
191 generation of activity word clouds (Figure 4). This analysis is identical to that found in Konu et
192 al. (2021), with the only exception being the use of activities found in the real-world, rather than
193 lab-based tasks.

194 **Activity Time Dependence**

195 Analysis of activity time was assessed using SPSS version 28. The “time” variable was recoded
196 into bins that divided the 24-hour period into 6 time bins using a visual binning function.
197 Categorization of bins included early morning (00:00:00 - 10:26:40), late morning (10:33:20 -
198 12:26:40), early afternoon (12:33:20 - 15:06:40), late afternoon (15:13:20 - 17:40:00), evening
199 (17:46:40 - 20:26:40), and night (20:33:20 - 23:53:20). A frequency analysis was applied to each
200 time bin to evaluate the frequency of reported activities engaged in by participants.

201 **Linear Mixed Modelling (LMM), Time of Day Data**

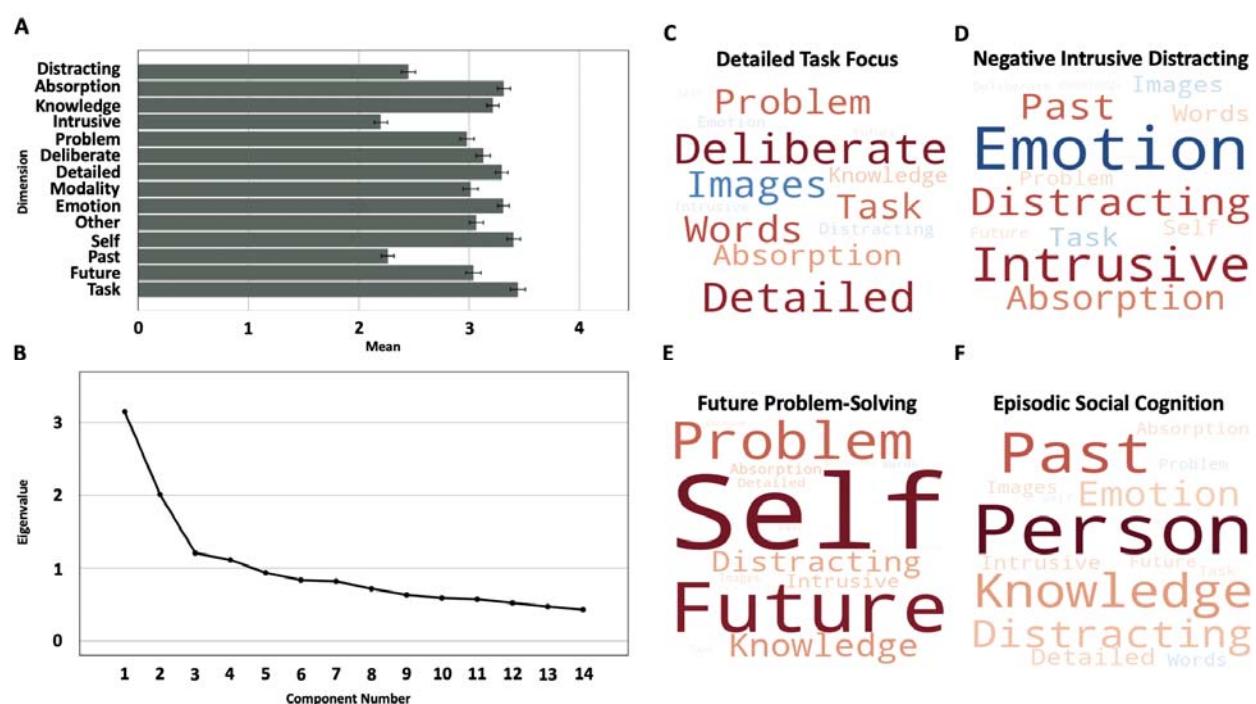
202 To analyzes contextual distributions of thought in relation to time of day, LMM was applied to
203 each of the component loadings generated previously by PCA. Time was included as a condition
204 of interest, and participants were included as a random factor.

205 **Results**

206 **Patterns of Ongoing Thought**

207 First, mean dimension scores from the thought date were calculated and displayed as a horizontal
208 bar graph (Figure 1A). Next, thought data was decomposed using PCA. The associated scree plot
209 generated from PCA indicated a 4-factor solution, determined by an eigenvalue >1 (Figure 1B).
210 PCA loadings (Table 5) from the four components were used to generate thought word clouds
211 (Figure 1C-F). Thought word clouds were labelled based on MDES dimensions that dominated

212 their composition. Component 1 was labelled “detailed task focus” because of significant
213 loadings for “Detailed,” and “Task” (Figure 1C). Component 2 was labelled “negative intrusive
214 distracting” because of significant loadings for “Emotion,” “Intrusive,” and “Distracting” (Figure
215 1D). Component 3 was labelled “future problem-solving” because of significant loadings for
216 “Future” and “Problem” (Figure 1E). Component 4 was labelled “episodic social cognition”
217 because of significant loadings for “Past,” “Knowledge,” and “Person” (Figure 1F). Please note
218 that these terms are used for convenience when discussing these patterns, they do not constitute
219 the only label which could be applied to these patterns.



220

221 **Figure 1.** Patterns of ongoing thought identified through 14 multi-dimensional experience-
222 sampling (MDES) probes. (A) Horizontal bar graph of mean dimension scores. Error bars
223 represent 99% CIs. (B) Scree plot generated from PCA of MDES probe data. (C-F) Words
224 represent experience-sampling items, and primary activities. Larger fonts are items with more
225 importance and colour described direction (warm colours relate to positive loadings). (C)

226 *Detailed task focus thought word cloud. (D) Negative intrusive distracting thought word cloud.*

227 *(E) Future problem-solving thought word cloud. (F) Episodic social cognition thought word cloud.*

228

Dimension	Component			
	1	2	3	4
Task	0.491	-0.258	0.077	0.075
Future	0.054	0.079	0.763	0.124
Past	-0.003	0.507	0.086	0.549
Self	0.041	0.157	0.787	-0.056
Other	-0.001	0.019	-0.021	0.845
Emotion	-0.102	-0.757	0.081	0.209
Modality	0.569	0.195	-0.109	-0.149
Detailed	0.721	0.013	0.187	0.190
Deliberate	0.765	-0.039	0.061	-0.018
Problem	0.505	0.154	0.517	-0.096
Intrusive	-0.073	0.718	0.221	0.177
Knowledge	0.219	0.037	0.386	0.359
Absorption	0.370	0.424	0.223	0.135
Distracting	-0.127	0.591	0.338	0.254

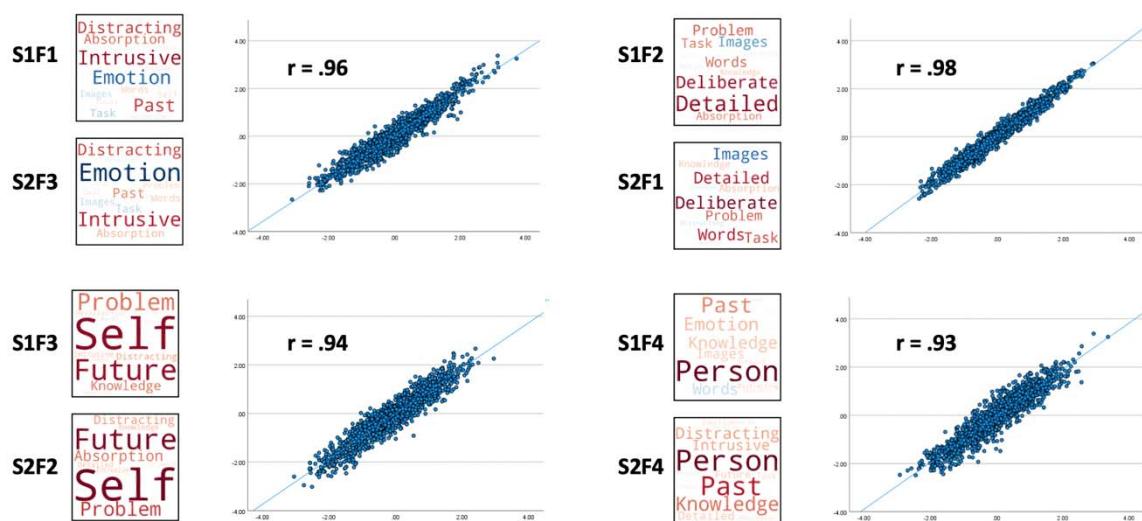
229 **Table 5. Thought data loadings generated by Principal Component Analysis (PCA).**

230 **Component Reliability**

231 To further understand the robustness of the components from our analysis, we conducted a split

232 half reliability for our sample. In this analysis we divided our data into two random samples and

233 then examined how the factors generated in each half of the data related to each other. To
234 compare the robustness of the solutions across a wide range of solutions we completed the
235 component reliability analysis used PCAs with 3-, 4-, and 5-factors extracted (Figure S1, 2, S2).
236 The mean correlation for the set of homologous pairs from each solution was calculated to
237 determine which solution produced the most reproducible factors. The 4-factor solution produced
238 the most reliable factors, with an average homologue similarity score of .953 (min. $R_{Hom.} = .93$,
239 max. $R_{Hom.} = .98$) (Figure. 2).

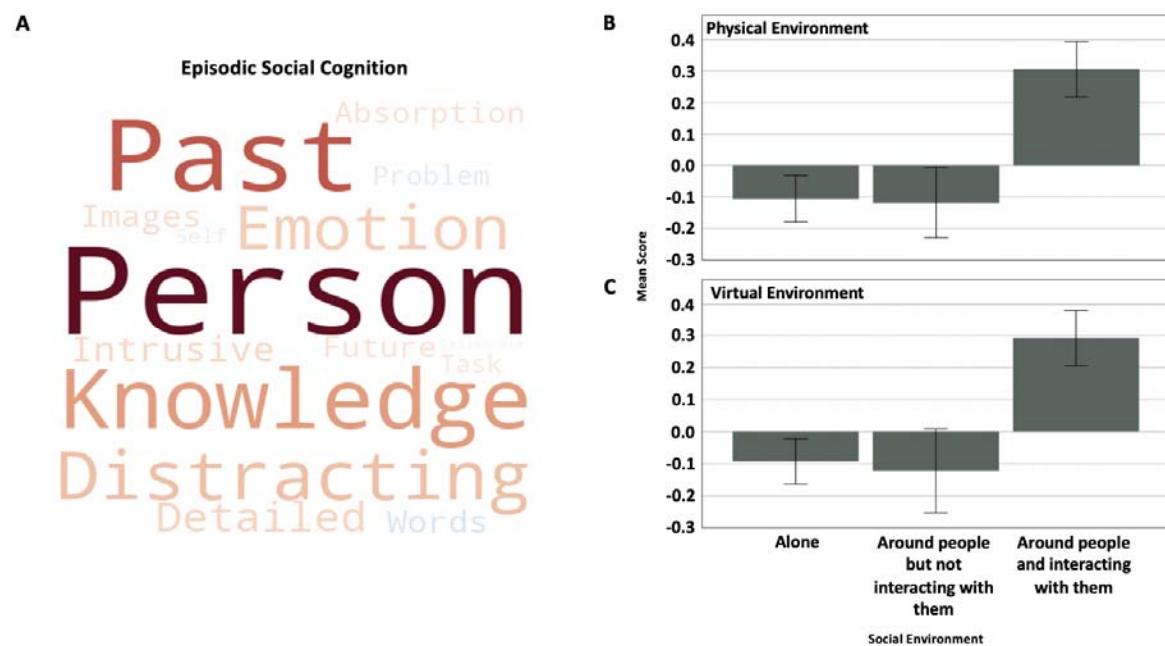


240
241 **Figure 2.** Component reliability analysis. Scatter plot of average homologue similarity. “S”
242 indicates subset, and “F” indicates factor.

243 The Influence of Socializing on Ongoing Thought

244 The first goal of our study was to replicate results from McKeown et al. (2021). To do so, we
245 compared the mean regression factor score for the episodic social cognition thought component
246 across different types of social settings in physical and virtual environments (Figure 3). The
247 episodic social cognition thought component varied significantly across both physical ($F(2, 1403.16) = 20.75, p < .001$) and virtual ($F(2, 1403.32) = 18.83, p < .001$) depending on the
249 reported descriptions of the social environment. Based on the confidence intervals in Figure 3 it

250 is clear that this pattern was prevalent when participants were around people and interacting with
251 them either virtually or in person.



252

253 **Figure 3.** The influence of socializing on ongoing thought. (A) Episodic Social Cognition word
254 cloud. Words represent experience-sampling items. Larger fonts are items with more importance
255 and colour described direction (warm colours relate to positive loadings). (B) Bar chart
256 comparing the mean multi-dimensional experience-sampling (MDES) scores when participants
257 reported they were 1) alone, 2) physically around people but not interacting with them, and 3)
258 physically around people and interacting with them. Error bars represent 99% CIs. (C) Bar
259 chart comparing the mean MDES scores when participants reported they were 1) alone, 2)
260 virtually around people but not interacting with them, and 3) virtually around people and
261 interacting with them. Error bars represent 99% CIs.

262 Thought-Activity Mappings

263 A second goal of our study was to extend research from the laboratory to examine whether
264 associations between activities in the real-world and ongoing activities generalized beyond social

265 interaction. In each case we found a significant association (Detailed Task Focus ($F(17, 1412.78)$
266 $= 11.70, p <.001$), Negative Intrusive Distracting ($F(17, 1388.15) = 3.86, p <.001$), Future
267 Problem-solving ($F(17, 1395.30) = 4.88, p <.001$), Episodic Social Cognition ($F(17, 1399.13) =$
268 $4.53, p <.001$)). To visualize these relationships, we generated a set of word clouds based on the
269 loadings for each component for each activity for each component, and these are displayed in
270 Figure 4. It can be seen that detailed task focus had high loadings when at work or doing
271 homework, negative intrusive distracting thoughts had high loadings when resting or doing
272 homework, future problem solving had high loadings when exercising and episodic social
273 cognition had high loadings when texting, in conversation or on the phone.

274 To further visualize the relationship between ongoing thought and activities, LMM
275 loadings were placed into three-dimensional spaces created by the four components. For
276 simplicity in Figure 5 we generated a 3-dimensional space constructed from the episodic social
277 cognition, future problem-solving and detailed task focus components (Figure 5A) and also
278 included a 2-dimensional space was included to capture the relationship between episodic social
279 cognition and negative intrusive distraction (Figure 5B).

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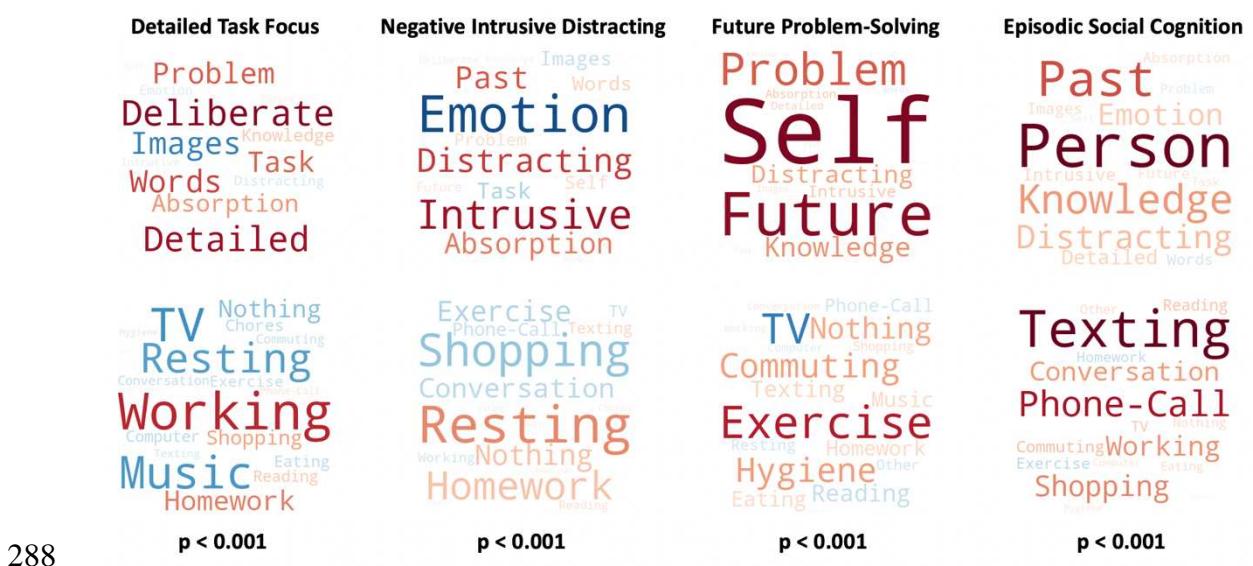
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289 **Figure 4.** Thought and activity word cloud mappings. Words represent the PCA experience-
 290 sampling loadings, and LMM primary activity loadings. Larger fonts are items with more
 291 importance and colour described direction (warm colours relate to positive loadings). See Table
 292 5 and Table 6 for specific component loadings.

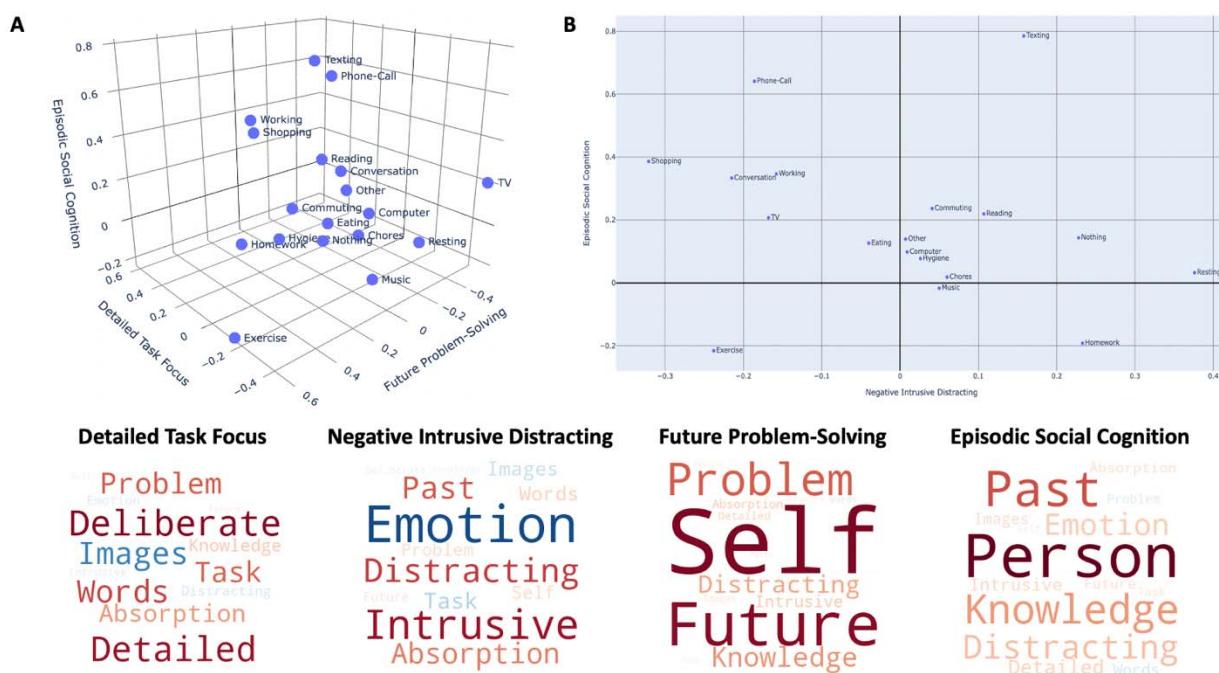
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Activity	Component			
	1	2	3	4
Eating	-0.194	-0.04	0.15	0.126
Homework	0.401	0.233	0.159	-0.192
Chores	-0.201	0.06	-0.025	0.018
Music	-0.455	0.05	0.158	-0.017
Resting	-0.433	0.376	-0.145	0.032
Nothing	-0.321	0.228	0.295	0.143
Exercise	-0.176	-0.238	0.615	-0.216
Hygiene	-0.096	0.026	0.325	0.077

Reading	0.2	0.107	-0.181	0.219
Shopping	0.319	-0.321	0.129	0.386
Conversation	-0.189	-0.215	0.076	0.333
Phone-Call	0.108	-0.186	-0.15	0.641
Texting	-0.135	0.158	0.173	0.785
Commuting	-0.176	0.041	0.323	0.236
Computer	-0.195	0.009	-0.093	0.098
TV	-0.479	-0.168	-0.541	0.207
Working	0.603	-0.158	-0.066	0.346
Other	-0.014	0.007	-0.135	0.139

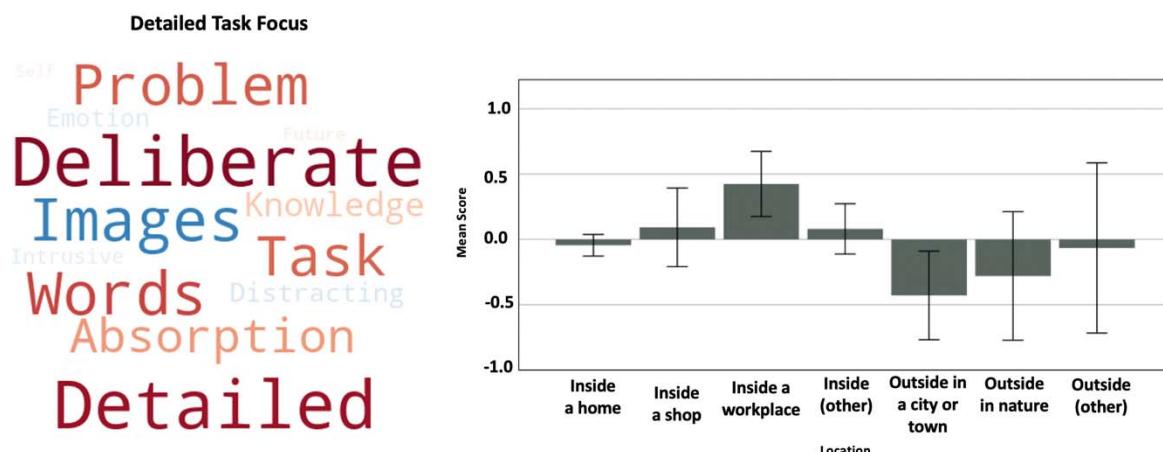
294 **Table 6.** Activity data loadings generated by Linear Mixed Modelling (LMM).

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296

297 **Figure 5.** *Mappings between MDES thought patterns and the activities in daily life. These data*
298 *are presented in (A) 3- and (B) 2-dimensional spaces to provide an alternative way of visualizing*
299 *the relationships between dimensions identified in our study.*



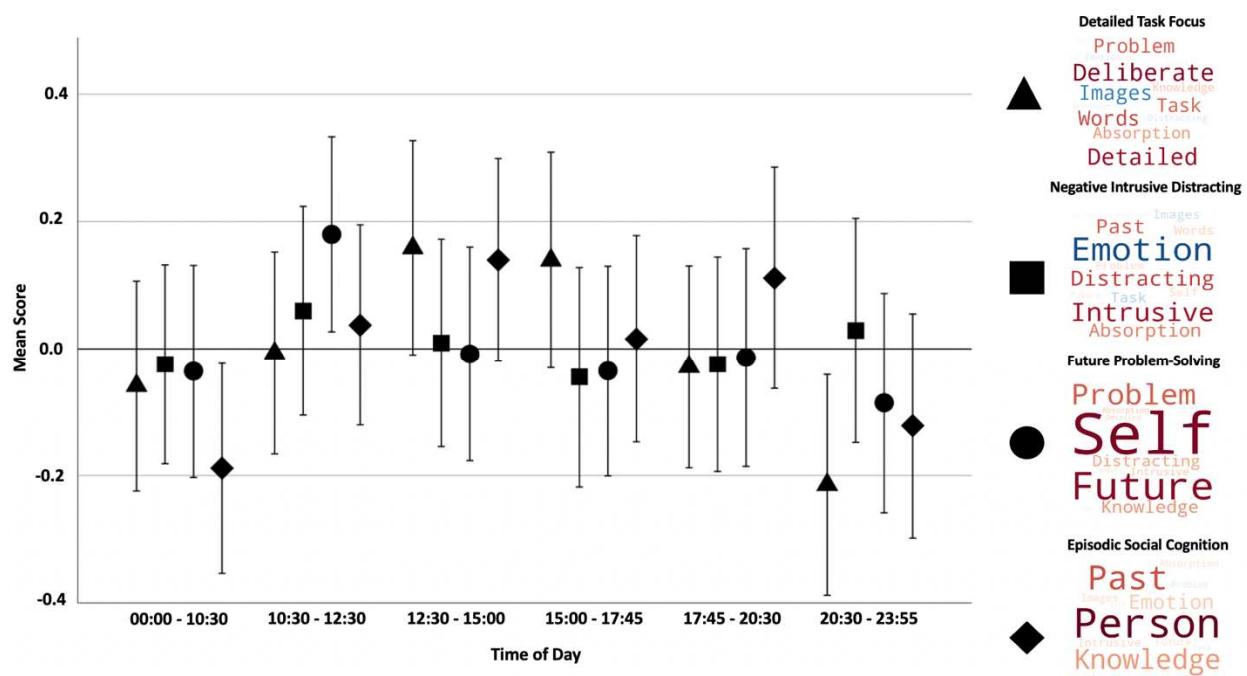
300
301 **Figure 6.** *Results of an exploratory analysis comparing the relationships between the location of*
302 *activities and ongoing thought patterns. We identified that patterns of detailed task focus were*
303 *most prevalent in a work place, and least prevalent outside in either a city or a town. Error bars*
304 *represent 99% CIs.*

305 **The Influence of Physical Location and Time of Day on Ongoing Thought**

306 Having examined the links between activities and thought in daily life, we next turned to our two
307 exploratory goals. First, we explored how physical location (inside or outside) related to the
308 thoughts that people experienced. To do this, we conducted a LMM for each component score.
309 Physical location was significant for the detailed task focus thought component ($F(6, 1391.17) =$
310 $6.51, p < .001$), which was higher when inside a workplace (Figure 6). No difference was found
311 for the other components (Negative intrusive distracting ($F(6, 1369.81) = 1.32, p = .22$), future
312 problem-solving ($F(6, 1376.46) = .91, p = .484$), and the episodic social cognition ($F(6, 1381.34) =$
313 $1.38, p = .221$). Next, we explored how the time of day when experience sampling occurred
314 was reflected in differences in the patterns of ongoing thought that participants reported by

315 conducting separate LMM for each component score. Time of day was significant for patterns of
316 detailed task focus ($F(5, 1408.69) = 4.27, p <.001$) and episodic social cognition ($F(5, 1394.20)$
317 $= 4.20, p <.001$), but not for the negative intrusive distracting ($F(5, 1386.21) = .18, p = .969$) and
318 future problem-solving ($F(5, 1391.13) = 1.92, p = .0881$, Figure 7).

319



320

321 **Figure 7.** Results of an exploratory analysis examining the influence of time of day on ongoing
322 thought patterns recorded by MDEs. The bar chart compares the mean score for experience-
323 sampling responses across different time intervals: the morning (00:00:00 - 10:30), late morning
324 (10:30 - 12:30), early afternoon (12:30 - 15:00), late afternoon (15:00 - 17:45), evening (17:45 -
325 20:30), and night (20:30 – 23:00). Error bars represent 99% CIs.

326 Discussion

327 Our study set out to map patterns of ongoing thought and behaviour throughout real-world
328 contexts. We hoped that measures of experience generated via multi-dimensional experience-

329 sampling (MDES) would be able to differentiate the context in which the probes occurred, in
330 particular the activities that people were performing. First, we sought to replicate the influence of
331 socializing on patterns of ongoing thought found in McKeown et al. (2021). Consistent with that
332 study, we found that participants reported patterns of thought with episodic and social features
333 when they were interacting with people in either a physical or a virtual manner.

334 We also examined if MDES can more broadly capture thinking patterns that reflect the
335 sorts of activities participants performed in the real-world. A prior study had established that in
336 the laboratory, MDES can capture patterns of thought that discriminate between the types of
337 tasks that people performed (Smallwood et al., 2021; Konu et al., 2020). Consistent with this
338 goal, we discovered general associations between the four ongoing thought patterns captured by
339 MDES and the everyday activities people were performing. Detailed task focus thought patterns
340 were most prevalent when people are working and doing homework. This pattern of thought in
341 the lab is known to emerge consistently when participants perform tasks which demand
342 executive control including working memory or task switching (Sormaz et al., 2018, Turnbull et
343 al., 2020; Konu et al., 2021). Future problem-solving thought patterns were present during
344 activities like exercise, commuting, and doing nothing. In the lab this style of thinking emerges
345 when task demands are lower (Turnbull et al., 2020; Ruby et al., 2013), and can be associated
346 with an individual's generating patterns of personal goals with greater details (Medea et al.,
347 2018). Negative intrusive distracting thought patterns were present when resting, doing nothing,
348 and homework. Finally, consistent with an association with social cognition (McKeown et al.,
349 2021; Konu et al., 2021) patterns of episodic social thought were present in activities which
350 likely involve other people including conversations, texting, and shopping. Intriguingly, task
351 studies have shown that this pattern of thought emerges when people make decision on a familiar

352 other (Konu et al., 2021) and brain imaging studies have shown that this pattern of thought is
353 linked to activity in the medial prefrontal cortex (Konu et al., 2020).

354 We also had two more exploratory goals. We first examined how the physical location
355 (inside or outside) was related to the thoughts that people experienced. This analysis identified
356 that detailed task focus thought patterns were present when participants were inside a workplace
357 and absent when they were inside a home, inside a shop, inside (other), outside in a city or town,
358 outside in nature, or outside (other). Location was not significant for negative intrusive
359 distracting, future problem-solving or episodic social cognition thought patterns. Second, we
360 examined how the time of day was reflected in participants responses to the MDES probes. This
361 exploratory analysis found that patterns of detailed task focus were more likely to be reported in
362 the middle of the day, and less likely at night. Similarly, episodic social cognition thought
363 patterns were least present in the early morning, and most common in the early afternoon. Note
364 that these exploratory analyses should not be taken to indicate direct consequences of location or
365 time of day on ongoing experience. Instead, these effects are likely to indicate that the activities
366 themselves are more likely to occur in specific locations or at particular times of the day.
367 Disentangling the specific variables which drive these associations is likely to be important in
368 future studies.

369 In conclusion, our results suggest that patterns of thinking in the real-world indirectly
370 reflects the situation in which experiences emerge. Our study suggests that ongoing activities are
371 likely to be important in the types of thoughts a person has, and that other factors such as
372 location or time of the day may contribution to this phenomenon less directly. This indicates that
373 MDES is able to differentiate between the different situations that people are in within daily life.
374 This highlights the value of MDES as a tool for understanding cognition from an ecological

375 perspective, particularly because this technique can also be used in more controlled settings, such
376 as work that uses this technique in conjunction with brain imaging to reveal the neural correlates
377 of different thought patterns (Turnbull et al., 2019, 2020; Konu et al., 2020). In this way MDES
378 may be a useful tool for bridging the gap between more controlled laboratory settings, where
379 specific features of cognition can be directly manipulated by the experimenter, and more realistic
380 situations in daily life. In this way experience sampling in daily life, and in particular techniques
381 like MDES may be an important next step in building accounts of cognition that are more
382 ecologically valid (Kingstone et al., 2003).

383 Although our data establishes that MDES is a useful tool for mapping cognition in daily
384 life, our data also raise a number of open question that future research could address. First, data
385 collection began during a COVID-19 lockdown, reducing the types of activities participants
386 could self-select, and potentially biasing the patterns of thoughts that our study identified. Thus,
387 while our study clearly shows the utility of MDES and experience sampling (ES), there may be
388 types of activities, and therefore, patterns of experience, that would be captured by ES in daily
389 life outside of a lockdown situation. Additionally, notification response rate and timing varied
390 across participants, which could relate to participant motivation or possibly activity enjoyment or
391 value. Specifically, participants may have been less likely to immediately respond, or to respond
392 at all, to a notification during particularly enjoyable activities. Furthermore, study participants
393 were students enrolled in designated first- and second-year psychology courses, with an average
394 of 21 years. Participant age and occupation is likely to be an important factor in regard to the
395 types of activities self-selected, and thus, the thought components produced in our study may be
396 less generalizable to a broader more representative sample. Lastly, potential thought components
397 are limited by the choice of MDES probes offered to the participants in our study. Although the

398 items we used can dissociate the links between activity and thoughts, with more accurate
399 question this capacity could be improved. For example, during the analysis process, it was noted
400 that the detailed task focus component was negatively anchored by music and TV. Although
401 images may be a useful characteristic of watching TV, it is less useful as a way to characterize
402 their thoughts while they listen to music. Future studies using MDES, therefore, could benefit
403 from breaking the modality probe into three questions, giving participants the opportunity to
404 describe their experience in terms of images, words, and/or sounds.

405 Finally, we close by noting that by sampling thinking in the daily life our results are
406 likely to depend in a complex way on how people select the activities they perform in daily life.
407 Presumably, individuals have a degree of choice about the tasks they perform in daily life that is
408 absent for many laboratory studies (Kahneman et al., 2004; Smallwood et al., 2021). For
409 example, it is likely that more sociable individuals spend more time engaged in forms of social
410 cognition, more athletic individuals engage in exercise more often, and more studious individuals
411 spend more time on their homework. Accordingly, our study suggests that when sampling
412 cognition in naturally occurring situations, temperament or expertise in a specific domain may be
413 indirectly related to the thought patterns they experience, as people may perform activities that
414 they enjoy or are good at when outside of a laboratory setting. This ability to choose the
415 activities in our daily life may be a primary reason why thought patterns in the lab do not always
416 generalise to the real world (Kane et al., 2017; Ho et al., 2020).

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