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Cluster-based characterization of consistencies in individuals' thought profiles at rest in a cohort of 1779 French university students

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Abstract
Is ongoing conscious thought spontaneous and situation-related, or is it recurrent and dependent on psychological dispositions? The answer is critical for resting-state functional connectivity (RSFC) paradigms that seek to correlate neuroanatomical states with conscious mental states. The goal of the present study was to characterize individual resting state thought profiles (RSTPs) and identify the recurrent ones, i.e., that could both be predicted by personality traits and predict subsequent negative affective states. The 1779 participants had a mean age of 22.1 years, 71.8% were females, and 71.8% were undergraduates. We collected the form and content of their thoughts during a 15-min RSFC session with a computerized retrospective self-questionnaire (ReSQ 2.0). Subsamples of participants also completed online autoquestionnaires assessing their psychological maturity and trait negative affectivity (with a four-day gap on average, N = 1270) and subsequent depressive and anxious states (1.4 years later on average, N = 922). Based on the multiple correspondence and clustering analyses of the ReSQ 2.0 responses, we identified six RSTPs distinctive by their content scope, temporal orientation, empathetic concern, and emotional valence. Multivariate analyses revealed that the probability of experiencing five of the six RSTPs was predicted by trait negative affectivity interacting with psychological maturity. Among them, a negatively valenced RSTP also increased the likelihood of subsequent negative affective states, suggesting its stable and recurrent nature. Identifying recurrent RSTPs is helpful for the future understanding of RSTPs' contribution to RSFC. Additionally, it will be relevant to test whether acting on psychological maturity can alter the relationship between ongoing conscious thought and negative affectivity.

Keywords Resting state · Individual thought profiles · Psychological maturity · Negative affectivity

Introduction

In the late twentieth century, neuroscientists discovered that the *resting state (RS)*, a functional neuroimaging paradigm used as an experimental control for goal-oriented tasks, involved the spontaneous coactivity of different sets of separated brain regions, referred to as *functional connectivity (FC)* (Biswal et al., 1995; Greicius et al., 2003). Meanwhile, the RS was associated with conscious autobiographic mentation, such as past recollection, future plans, and considerations of others (Andreasen et al., 1995; Ingvar, 1974; Mazoyer et al., 2001). The extent to which spontaneous brain activity is related to conscious mental fluctuation remains a substantial controversy in the neuroscience community. For some, unconstrained conscious cognition alone does not account for the greatest part of intrinsic neural activity that would instead be involved in plasticity and synaptic homeostasis mechanisms. These authors point out that resting state functional connectivity (RSFC) is stable within individuals but consider ongoing cognition to be a fluctuating and transitory state "varying from scan to scan within an individual" and unable to explain RSFC variability (Gratton et al., 2018; Laumann & Snyder, 2021; Snyder & Raichle, 2012). In contrast, other authors and we argue that RSFC modulation partly results from ongoing conscious cognition (Andrews-Hanna et al., 2010; Doucet et al., 2012; Mckeown et al., 2020; Smallwood et al., 2016; Wang et al., 2018a, 2018b). Considering the relative stability of RSFC, the *recurrence* of individuals' ongoing conscious thought is an essential premise for assuming such a mental-neural relationship.

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From the *person–situation debate* (Fleeson & Noftle, 2008), current research suggests that consistencies in individuals' ongoing conscious thought are "pervasive or broad enough to be meaningfully described in terms of personality traits" (Funder 2001). Recently, consistent self-generated thoughts were linked to both neural states and dispositional traits (Karapanagiotidis et al., 2021). Moreover, research has demonstrated some individual persistence of ongoing mental states. Individuals displayed the same thought contents in either the laboratory or the scanner (Delamillieure et al., 2010; Konu et al., 2020), and social, future-directed, and negative thought contents were shown to translate from the laboratory to daily life (Linz et al., 2021). Interestingly, individual differences in the occurrence of task-unrelated thoughts showed consistency over six months (Rummel et al., 2021). In addition to temporal persistence, self-reported mental experiences were related to characteristic dimensions of individuals' personality (Diaz et al., 2014; Kane et al., 2017; Kienzle, 1985; Singer, 1975; Zhiyan & Singer, 1997), cognitive skills (Singer & Antrobus, 1963; Wang et al., 2020, 2018a, 2018b), and affective styles (Andrews-Hanna et al., 2013; Fox et al., 2018; Konu et al., 2021).

To capture the complex and multifaceted nature of ongoing conscious thought, research of the last decade has increasingly used multidimensional techniques aimed at characterizing thought *patterns* (Andrews-Hanna et al., 2013; Brennan et al., 2021; Engert et al., 2014; Konu et al., 2020, 2021; Linz et al., 2021; Martinon et al., 2019; Poerio et al., 2017; Ruby et al., 2013a, 2013b; Ruby et al., 2013a, 2013b; Smallwood et al., 2016; Sormaz et al., 2018; Stawarczyk et al., 2013; Turnbull et al., 2021; Wang et al., 2020, 2018a, 2018b, 2018a, 2018b). Evidence linking thought patterns to dispositional *traits* was mainly obtained outside of the scanner (Andrews-Hanna et al., 2013; Engert et al., 2014; Konu et al., 2021; Linz et al., 2021; Poerio et al., 2017; Ruby et al., 2013a, 2013b; Ruby et al., 2013a, 2013b; Wang et al., 2020, 2018a, 2018b). Although RS neuroimaging is considered an efficient technique for relating brain to mental activity at the trait level (Gonzalez-Castillo et al., 2021), only two studies of thought patterns have been conducted in a scanner, one linking them with cognitive skills (Wang et al., 2018a, 2018b) and the other with well-being (Vatansever, 2020). To fill this gap, our study is the first to characterize the relationships of thought patterns in the scanner with personality traits and negative affectivity.

Considering that individual ways of thinking can be classified, we first sought to identify *resting state thought profiles* (RSTPs) by implementing a multidimensional data analysis strategy to cluster RSTPs from different components of thought. Second, we assumed that ongoing conscious thought is predominantly recurrent, and we could detect dispositional RSTPs, i.e., ones that could be predicted by personality *traits* and predict *subsequent* psychological *states*. The present study is part of a larger project to assess important health issues in *young adults*. Thus, we focused on psychological features relevant to this population: *psychological maturity* (at the trait level) and *negative affectivity* (at the trait and state levels). In the framework of Cloninger's psychobiological model of personality, psychological maturity is a *character trait* that grows in a step-like manner as a person matures in insight through learning from personal and social experiences over the lifespan (Josefsson et al., 2013; Wong & Cloninger, 2010). The progression of psychological maturity is particularly noticeable in late adolescence and early adulthood (Caspi et al., 2005; H. W. Marsh et al., 2013). To our knowledge, relations of psychological maturity with thought patterns have never been described. Regarding negative affectivity, we specifically examined *depression* and *anxiety* outcomes. Globally, the prevalence of depression is steadily increasing in the age range of our sample, and women, overrepresented in the present study, are more affected than men by depression and anxiety (WHO, 2017). The prevalence of anxiety is also exceptionally high among French students (Montagni et al., 2020; Tran et al., 2017). In previous research, depression has been linked to rumination, a process characterized by repetitive negative thinking (Belvederi Murri et al., 2019; Nolen-Hoeksema et al., 2008). Additionally, the self-generated thoughts of individuals with major depressive disorder have been described as predominantly negative and more self-related and past-oriented relative to the thoughts of healthy controls (Hoffmann et al., 2016). In young adults, higher anxiety has been associated with worrying and rumination (Fresco et al., 2002) and less positive future episodic thinking (Marsh et al., 2019). Moreover, individuals characterizing their thoughts as more negative during autobiographical and experience sampling paradigms scored higher on constructs related to depressive and negative affective states (Andrews-Hanna et al., 2013; Ruby et al., 2013a, 2013b). Thus, we expect each RSTP to have its specific relationships with the individual psychological features, namely: psychological maturity and negative affectivity.

Methods

Design, study population, and data collection

Data were collected from the larger internet-based Students Health Research Enterprise (i-Share) project (https://research.i-share.fr/), a longitudinal cohort launched in February 2013 to evaluate the health aspects

of French university students. i-Share was conducted under the guidelines of the Declaration of Helsinki and approved by the appropriate French national regulatory agency (Commission Nationale de l'Informatique et des Libertés, CNIL, registration number [DR-2013–019]). Students were encouraged to participate through active promotion campaigns (via information stands at registration, university emails, lectures, flyers, social media, and newsletters). Inclusion criteria were to understand written French, to be 18 years old or above, to be officially registered at a University or higher education institute and to provide informed consent for participation. The i-Share participants voluntarily completed web-based questionnaires regarding their sociodemographic characteristics and mental health. Following initial participation, the i-Share participants were invited to complete a follow-up questionnaire every year. Those recruited at the Bordeaux site were also given the information regarding MRi-Share, the i-Share neuroanatomical substudy held between November 2015 and November 2017 and approved by the Bordeaux CPP SOMIII Ethics Committee (Tsuchida et al., 2021). Students interested in contributing to MRi-Share who received all the pertinent information were checked for the absence of any cause for exclusion (i.e., (1) age over 35 years; (2) pregnancy or nursing; (3) claustrophobia; and (4) contraindications for head MRI), gave their informed written consent, and received compensation for their participation.

The MRi-Share participants form the study's original sample (N = 1870). They completed the RS questionnaire immediately after a neuroimaging acquisition session of ~ 45 min. The RSFC acquisition lasted the last 15 min of the scanning session, during which participants were instructed to "keep their eyes closed, relax, refrain from moving, stay awake, and let their thoughts come and go." Compliance with the instruction was checked by questions included in the RS questionnaire. After removing participants with unusable RSFC data (N = 62), who failed to complete the RS questionnaire (N = 27) adequately, and who fell asleep *very often* at rest (N = 2), the RS questionnaire sample included 1779 students.

Individual traits (i.e., psychological maturity and trait negative affectivity) were collected online with a four-day gap on average (SD: 25 days) of RS questionnaire responses as part of the i-Share baseline mental health survey (from July 2013 to September 2019, N = 1270). Measures of subsequent negative affective states (i.e., depressive and anxiety symptomatology) were collected online 1.4 years on average (SD: 6.5 months) and a minimum 16 days after the RS questionnaire responses as part of the i-Share follow-up mental health survey (from December 2016 to December 2019, N = 922).

RS questionnaire 2.0 (ReSQ 2.0)

The ReSQ 2.0 is the new release of a self-report questionnaire providing a multidimensional assessment of self-generated mental activity at rest. The ReSQ 2.0 was computerized, unsupervised, and retrospective. Retrospective techniques are well suited for targeting trait-level mental activity (Gonzalez-Castillo et al., 2021) and preserve the natural time course of ongoing conscious thought, as not interrupting participants to report their experience is essential for RSFC (Martinon et al., 2019). The ReSQ 2.0 included 24 main items (Table SI-1), 16 focusing on thought content (timeline, body sensation and self, social, ongoing experimental situation, learning, and emotional valence), and eight focusing on thought forms (visual and musical imagery, language, and dynamics). ReSQ 2.0 items were selected from prior validated RS questionnaires, namely, the ReSQ (Delamillieure et al., 2010), Amsterdam Resting State Questionnaire (ARSQ 2.0, (Diaz et al., 2014), and New York Cognition Questionnaire (NYC-Q, (Gorgolewski et al., 2014), or the experience sampling method (Ruby et al., 2013a, 2013b; Wang et al., 2018a, 2018b). Their correspondence with the main items of prior studies is summarized in Table 1.

Responses were given on a 4-point Likert scale ranging from "never" to "very often," except for *emotional valence* (negative; neutral; positive), *dynamics* (maximum of 3 themes; > 3 themes – logical order; > 3 themes – random order), *voice vividness* (nonapplicable; rather vague; rather precise), and *image vividness* (nonapplicable; few details; moderate details; many details).

For control purposes, the ReSQ 2.0 included four items assessing vigilance: the frequency of eye-opening and drowsiness (evaluated on a 4-point Likert scale) and the length of last night's sleep and time to last meal (reported in hours). A final question aimed at self-assessing the quality of the entire set of responses.

Counts were calculated for each category of the ReSQ v2.0 items.

Personality and affectivity self-assessments

Psychological maturity

Psychological maturity was assessed using the short French version of the Temperament and Character Inventory (TCI) (Cloninger, 1987, 1994, 2004; Pélissolo & Lépine, 2000) previously validated in a population of young adults (Adan et al., 2009; Rigozzi & Rossier, 2004). Psychological maturity was calculated as the sum of two character traits, *self-directedness* (the executive ability of an individual to control, regulate, and adapt behavior to fit the situation in accordance with personal goals) and *cooperativeness* (individual differences in accepting other people and measures

Table 1 Correspondence between the types of thoughts assessed by the ReSQ 2.0 and main factors previously identified with RS questionnaires or experience sampling methods

ReSQ 2.0	Delamillieure et al., 2010	Diaz et al., 2014	Gorgolewski et al., 2014	Wang et al., 2018a, 2018b
Past	Memory reminiscence		Past	Past
Future	Prospective thought	Planning	Future	Future
Imagination				
Cardiorespiratory awareness	Somatosensory awareness	Somatosensory awareness		
Somatosensory awareness	Somatosensory awareness	Health concern (pain)		
Physiological needs		Somatosensory awareness		
Thermal sensation	Somatosensory awareness			
Self		Self		Self
People		Theory of mind	Friends	Other
Empathy				
Surroundings				Focus
Remaining time				Focus
Instructions				Focus
Lectures				
Leisure				
Emotional valence	Emotion charge (±)	Comfort	Positive/Negative	Emotion
Images	Visual mental imagery	Visual thought	Images	Images
Images vividness			Vague/Specific	Detail, vividness
Voices vividness			Vague/Specific	Detail, vividness
Inner speech	Inner Speech	Verbal thought	Words	Words
Voices	Auditory mental imagery	Verbal thought	Words	Words
Music	Inner musical experience			
Multiform				
Dynamics		Discontinuity of mind		Evolving
-	Processing of numbers			Habit, Deliberation

features related to agreeability vs. self-centered aggression and hostility) (Cloninger, 2004; Josefsson et al., 2013). Each character trait was answered on a 5-point Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree," with dimension scores ranging from 8 to 40 and psychological maturity scores ranging from 16 to 80.

Trait negative affectivity

According to a recent review, the State-Trait Anxiety Inventory – Y form (STAI-T) (Spielberger, 1993) can capture a higher-order *trait* such as negative affectivity/neuroticism that characterizes both anxiety and depression (Knowles & Olatunji, 2020). Trait negative affectivity was assessed using the French version of the STAI-T and rated with a 20-item scale. Each item was answered on a 4-point Likert-type scale ranging from 1 = "no" to 4 = "yes." We used total scores that could range from 20 to 80. Trait negative affectivity levels could be categorized as follows: very slight (< 35), slight (36–45), moderate (46–55), high (56–65), and very high (> 65).

Depressive state

The intensity of the depressive symptomatology over the preceding *two weeks* was assessed with the French version of the Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001), a self-report scale commonly used in psychiatry with a clinical interview to detect and monitor depression in primary care (Levis et al., 2019; Trangle et al., 2016). For each item, which corresponds to nine DSM-IV criteria used to diagnose depressive disorders, the participants had to answer the question: "Over the last two weeks, how often have you been bothered by any of the following problems?" Items were scored on a 4-point Likert scale from 0 ("not at all") to 3 ("nearly every day"). We used the total score ranging from 0 to 27 as a generic measure of the depressive state.

Anxious state

Anxiety severity over the preceding *two weeks* was assessed with the French version of the Generalized Anxiety Disorder 7-item (GAD-7) scale (Spitzer et al., 2006). The GAD-7 is a brief questionnaire widely used in primary care to detect

anxiety symptoms (Kroenke et al., 2007). We used the total score ranging from 0 to 21 as a generic measure of the anxious state.

Data analysis

All statistical analyses were performed in *RStudio* statistical software using R Version 4.0.0. The figures were created with the following packages: *ggplot2*, *fmsb,* and *effects*. An alpha level of 0.05 was used for the significance threshold of hypothesis tests that were all 2-sided. Post hoc analyses were carried out with the *R* package *emmeans* and indicated by "*p*-bon" when Bonferroni corrected for the multiplicity of tests. When appropriate, the unstandardized slope coefficient (*b*) with its 95% confidence interval (CI) was reported as the effect size (Baguley, 2009). All references for R and its packages are provided at the end of the SI.

Did gender/sex affect individual psychological features?

Mean scores, scatter indicators, and distributions were used to describe the psychological features of the participants who completed the mental health questionnaire at baseline (N = 1270) and follow-up (N = 922). Gender/sex-based distributions were compared using Student's *t* tests (when normal) and Mann Whitney U tests (when skewed), each Bonferroni corrected for six tests.

Could the types of thought be clustered into RSTPs?

To identify individual similarities and differences from a multidimensional perspective, we implemented multiple correspondence analysis (MCA) (Greenacre & Blasius, 2006) followed by cluster analysis (Lebart et al., 1984; Ludovic Lebart et al., 1995) with the *R* packages *FactomineR* and *Factoshiny*. By weighting the χ^2-distance between categorical items, the MCA was a preprocessing step to code the ReSQ 2.0 category items into a set of continuous variables (their coordinates on the components) before a clustering process to identify specific profiles.

MCA

To map thought types, we applied the MCA (Greenacre & Blasius, 2006) to the 24 categorical ReSQ v2.0 items related to thought form and content and estimated the relationships between all their categories (n = 94). We limited the analysis to the number of MCA components that could separate new categories (i.e., categories that had not been separated by previous components) and considered only categories with a dimensional contribution greater than the mean dimensional contribution and cosine squared greater than 0.1.

Cluster definition

We implemented a clustering process based on a mixed algorithm to identify homogeneous subgroups of individual thought profiles. We performed agglomerative hierarchical clustering with Ward's method using the Euclidean distance between individual coordinates on the MCA components before applying aggregation around mobile centers (K-means) to improve the robustness of the final results. We used two criteria to examine a range of potentially informative clustering solutions. First, we visualized the clustering tree to check for instability and overclustering. Regardless of the particular clustering method, the clustering tree displays how clusters are divided as resolution increases, which clusters are clearly separated or related to each other, and how samples change groups as more clusters are produced (Zappia & Oshlack, 2018). Second, we used the *R* function *NbClust* to determine the number of clusters designated by most of 26 conventional clustering validity indices (Charrad et al., 2014).

Cluster characterization

To examine differences in thought form and content across members of the clusters, the relationship between each ReSQ 2.0 item and the X-class partition was assessed and tested for significance with a Pearson χ^2 test (p-bon < 0.002). We then characterized each cluster with the overrepresented categories to describe the RSTPs. Since the categories were used to create the factor map, hypothesis testing cannot be applied as usual and was used to select *descriptive* information. The difference between the overrepresented categories and the overall sample proportion was tested using the hypergeometric test (p-bon < 0.008). The p value was used to calculate a test value (i.e., the quantile of the standard normal distribution z_p) that measures the difference between the proportion in the class and the overall sample in the number of standard deviations of a normal distribution. By ordering the z_p values, the most characteristic categories of each class can be quickly identified (Ludovic Lebart et al., 1995).

Did age and gender/sex modulate thought types and RSTPs?

Since ongoing conscious thought varies according to sociodemographic factors (Andrews-Hanna et al., 2013; Christian et al., 2013; Diaz et al., 2014; Turnbull et al., 2021), we estimated the modulation of thought types and RSTPs by age and gender/sex.

We used adjacent-category logit modeling of ordinal responses to evaluate the influence of age and gender/sex on the distribution of responses to the ReSQ v2.0 items. We chose *proportional odds assumption modeling* to estimate a

single constant coefficient for moving from one category to the adjacent category, resulting in fewer parameters (Agresti, 2019). For each ReSQ 2.0 item, the adjusted odds ratio (aOR) of belonging to an adjacent category of the Likert scale was estimated with its 95% CIs (1) for one additional year of age and (2) for women relative to men. All models included social and vigilance potential confounders (education field, current level of education, time to last meal, length of last night's sleep, eye-opening, and drowsiness). Ordinal logistic regressions were implemented with the *VGAM* R package, and the significance of aORs was estimated with the Wald test Bonferroni corrected for 24 tests.

Age and gender/sex relationships with odds of RSTPs were estimated using a multinomial logistic regression analysis implemented with the *R* package *nnet*. Social (field and current level of education) and vigilance variables (eye-opening, drowsiness, time to last meal, and length of last night's sleep) were included in the model as potential confounders.

Was the likelihood of experiencing an RSTP related to trait negative affectivity and psychological maturity?

To identify relationships between psychological traits and RSTPs, we estimated the likelihood of each RSTP by implementing a multinomial logistic regression analysis with the *R* package *nnet* on the data obtained from the subset of participants who answered mental health questionnaires at baseline (N = 1270). A two-way interaction term between trait negative affectivity and psychological maturity, and their main effect, were introduced as RSTP's predictors in the model with the addition of sociodemographic (age, gender/sex, field, and current level of education) and vigilance variables (eye-opening, drowsiness, time to last meal, and length of last night's sleep) as confounders. These analyses were Bonferroni corrected for the multiplicity of tests.

Could RSTPs predict subsequent negative affective states?

To explore whether RSTPs could predict subsequent negative affective states, we used the subset of participants who answered mental health questionnaires at follow-up (N = 922). We investigated the relationship of RSTPs with depressive and anxious states (PHQ-9 and GAD-7 scores respectively) by implementing two negative binomial regression models with the *R* package *MASS*. This method is recommended because it handles heteroscedasticity arising from count data that are discrete positive values (Huang & Cornell, 2012; Sroka & Nagaraja, 2018). The RSTP (six levels) was entered into the models as an independent predictor of PHQ-9 (model 1) and GAD-7 (model 2) scores. Psychological maturity, age, and gender/sex were added to the models to control for their potential confounding effects. These analyses were exploratory and were not corrected for the multiplicity of tests.

Results

Participants and sample description

Participants were aged 18 to 35 years (mean = 22.1, SD = 2.3, range: 18.1–34.9) with a large proportion of females (71.8%) and undergraduates (71.8%). A majority (52.4%) studied medical sciences; 20.8% studied humanities; and 12.8% studied science, technology, engineering, and mathematics (STEM). On average, the participants had eaten in the last 4 h and slept 7 h the night before the scanning session. Most of them *never* or *rarely* opened their eyes (95.8%) and *never* or *rarely* fell asleep (93.7%) during rest in the scanner. The subsamples have similar sociodemographic characteristics to the main sample (Table 2).

Table 3 summarizes the individual psychological features of the subsamples who completed the mental health survey questionnaires (N = 1270 at baseline and N = 922 at follow-up).

The mean scores of self-directedness (20.56 ± 5.26) and cooperativeness (22.12 ± 3.13), i.e., the two components of the maturity score (42.69 ± 6.83), were consistent with a prior study using the TCI-56 in a French-speaking sample of the same age range (Rigozzi & Rossier, 2004). The mean maturity score was equal between men (42.23 ± 7.12) and women (42.85 ± 6.72). The mean trait negative affectivity score (52.48 ± 4.62) was in the *moderate* range (46–55). No individuals scored in the extreme classes (*very slight*: < 35 and *very high*: > 65) of trait negative affectivity (Spielberger, 1993), except one participant scoring 66. The mean and median trait negative affectivity were approximately 10 points higher than those reported in the literature for matching samples (i.e., undergraduates with a higher proportion of females and medical students) (Neveu et al., 2012; Roberts et al., 2016; Vigneau & Cormier, 2008). This level is close to negative affectivity (assessed with the STAI-S) previously observed during exams (Cipra & Müller-Hilke, 2019). Men (50.99 ± 4.98) had a significantly lower mean negative affectivity score than women (53.02 ± 4.52; $t_{(1,582)} = 6.98$, p-bon < 0.001), which is consistent with the literature (Sakin Ozen et al., 2010; Sandin et al., 2001; Tran et al., 2017). At follow-up, the mean scores for depressive (PHQ-9: 5.26 ± 4.48) and anxious (GAD-7: 4.15 ± 4.14) states were lower than levels previously observed in student populations (Farrer et al., 2016; Zhou et al., 2020) but higher than those of the general population (Hinz et al., 2016; Löwe et al., 2008). Compared to men, women were on average significantly more depressed (men: median = 3 (interquartile range (IQR) = 5) vs. women: median = 4

Table 2 Characteristics of the study samples, i-Share/MRi-Share cohorts, 2013–2019

	MRi-Share	MRi-Share ∩ i-Share mental health survey	
		Baseline	*Follow-up*
Sociodemographic	N = 1779	*N = 1270*	*N = 922*
Age, mean (SD)	22.1 (2.29)	22.0 (2.25)	21.9 (2.26)
Women, n (%)	1278 (71.8%)	935 (73.6%)	701 (76.0%)
Education field, n (%)			
Humanities	370 (20.8%)	280 (22.0%)	187 (20.3%)
Medical	932 (52.4%)	664 (52.3%)	503 (54.6%)
STEM	227 (12.8%)	164 (12.9%)	117 (12.7%)
Other	250 (14.0%)	162 (12.8%)	115 (12.5%)
The current level of education, n (%)			
Undergraduate	1277 (71.8%)	927 (73%)	695 (75.4%)
Graduate	433 (24.4%)	298 (23.5%)	202 (21.9%)
PhD	69 (3.9%)	45 (3.5%)	25 (2.7%)
Native language			
French (FR)	1718 (96.6%)	1226 (96.6%)	894 (97%)
Bilingual (FR included)	12 (0.7%)	12 (0.9%)	8 (0.8%)
Not French	49 (2.8%)	32 (2.5%)	20 (2.2%)
Vigilance			
Hours to last meal, mean (SD)	1.67 (3.64)		
Hours length of last night's sleep, mean (SD)	7.13 (1.40)		
Eye opening, n (%)			
Never	892 (50.1%)		
Rarely	813 (45.7%)		
Often + Very often	72 + 2 (4.2%)		
Drowsiness, n (%)			
Never	1262 (70.9%)		
Rarely	406 (22.8%)		
Often	111 (6.2%)		

Table 3 Psychological individual features according to gender/sex

	Range	Median	Mean (SD)		
			Overall	Men	Women
Baseline			*N = 1270*	*N = 335*	*N = 935*
Character					
Self-Directedness (SD)	8–40	20	20.56 (5.26)	19.96 (5.56)	20.78 (5.13)
Cooperativeness (CO)	14–36	22	22.12 (3.13)	22.27 (3.10)	22.07 (3.15)
Maturity (SD + CO)	23–66	42	42.69 (6.83)	42.23 (7.12)	42.85 (6.72)
Trait negative affectivity					
STAI-T	37–66	53	52.48 (4.62)	50.99 (4.58)	53.02 (4.52) ***
Follow-up			*N = 922*	*N = 221*	*N = 701*
Depressive state					
PHQ-9	0–26	4	5.26 (4.48)	4.44 (4.52)	5.51 (4.43) ###
Anxious state					
GAD-7	0–21	3	4.15 (4.14)	3.07 (3.89)	4.49 (4.17) ###

Women compared to men, p-bon < 0.001: *** Student's *t* test, ### Mann Whitney U test

(IQR = 5.5); Z = -4.29, p-bon < 0.001) and more anxious (men: median 2 (IQR = 4) vs. women: median = 3 (IQR = 6); Z = -5.52, p-bon < 0.001), a well-known gender difference (Altemus et al., 2014).

Distribution of thoughts assessed with the ReSQ 2.0

The thought type distributions are summarized in Fig. 1. Thoughts occurred as images (85.2%) or inner language (80.1%) for a great majority of the students and most often simultaneously (71.6% of the participants) (Fig. 1A). Images were *moderately* detailed for 27.4% and *very* detailed for 56.9% of the participants. Thoughts in music or voices were less frequent, involving approximately 1/3 of students (36.4% and 31.7%, respectively), and voice vividness was described as *rather precise* by slightly less than one out of two participants (47.5%). Thoughts most often related to multiple themes organized randomly or logically and much more rarely focused on up to three themes (68%, 20%, and 12% of participants, respectively). Regarding thought content (Fig. 1B), based on responses in the *often* + *very often* categories, we observed the following distributions: a large majority of the students thought about the future (78.9%) or themselves (74.4%) and approximately half thought about the past (55.2%) or timeless imaginative scenes (45.7%). The participants were also preoccupied with the ongoing situation in the scanner; 65.5% thought about the instructions; 58.2%, the surroundings (noises, etc.); 52.5%, their cardiorespiratory rate; 48.3%, the remaining time; and 46.1%, somatosensory sensations (whether it was painful or not). Few students felt thermal sensations (12.6%), yet more than 1/4 of them (27.3%) experienced physiological needs (e.g., hunger, thirst, or urge to urinate). Regarding learning, 1/3 of students (32.9%) thought about lectures, and 1⁄4 (24.7%) thought about leisure activities. Half of the participants (49.1%) thought about people, and 28.4% experienced empathy. Hence, empathetic students accounted for 1/3 of those who thought about people. Notably, 70% of those who empathized *very often* thought about others *very often*, and 70% of those who empathized *often* thought about others *often*, suggesting a positive linear relationship between the frequency of thoughts directed toward people and empathy. Finally, *neutral* and *positive* thoughts were equally distributed in the sample (approximately 46% of students), with a low frequency of *negative* thoughts (8.3%).

Types of thought can be clustered into six RSTPs

To identify individual RSTPs, we first implemented an MCA on all ReSQ 2.0 thought categories (N = 94, Fig. SI-1) to preprocess the data before applying a combined partitioning method based on hierarchical clustering and K-means aggregation (Fig. SI-2). We found a 6-class partition to be the most appropriate.

The ReSQ 2.0 categories characterizing each profile are shown in Fig. 2. The strength of the relationship between a profile and a category, estimated with the $\ddagger_p$ value, is available in Table SI-2 and symbolized by three levels of dot size in Fig. 2. The first profile (RSTP-1, 9% of the participants) was characterized by students who thought *very often* about themselves and other people with empathy, *very often* in the form of inner speech and *vivid* images and voices, and *very often* simultaneously. They also *very often* thought about past, leisure, future, and imaginative scenes. Finally, RSTP-1 was characterized by *negatively valenced* thoughts, as was the fourth profile (RSTP-4, 16% of the participants). However, unlike RSTP-1, RSTP-4 was not specifically linked to empathy, images, voices, imagination, or leisure. In RSTP-4, thoughts occurred *very often* as inner speech and about the ongoing experience (instructions, remaining time, and surroundings), somatic and cardiorespiratory sensations, self, future, and lectures, and thoughts were *often* about people, thermal sensations, and physiological needs. RSTP-1 and RSTP-4, both characterized by *negative* thoughts, were distinguishable from the unique RSTP associated with *positive* thoughts, the third profile (RSTP-3, 21% of the participants), based on three items: in RSTP-3, inner speech and self were not characteristic, and future thoughts were *rare*. Like in RSTP-1, the students experiencing RSTP-3 thought *very often* in the form of *vivid* images and voices, simultaneously, and about past and imaginative scenes. However, they "only" *often* thought about people with empathy.

The three remaining profiles were all characterized by *neutral* thoughts. All ReSQ 2.0 items, except music, characterized the second profile (RSTP-2, 28% of the participants). The students experiencing RSTP-2 answered exclusively with the medium categories (*rarely*, *often, vague, or moderate)* and randomly thought about more than three themes. In contrast to the RSTP-2, the fifth (RSTP-5, 20% of the participants) and sixth (RSTP-6, 5% of the participants) profiles included students who frequently responded with the extreme *never* category (12 items each). RSTP-5 students thought exclusively in images with *few* details and *rarely* about themselves and the future. In contrast to RSTP-5 students, RSTP-6 students *never* thought in the form of images. They *very often* thought about instructions, surroundings, their cardiorespiratory rate, and not more than three themes.

Finally, when considering the temporal orientation of thoughts, it is noteworthy that for all profiles except RSTP-3, rates of future and self-focused thoughts were similar, suggesting a positive linear association between these two aspects of thought content.

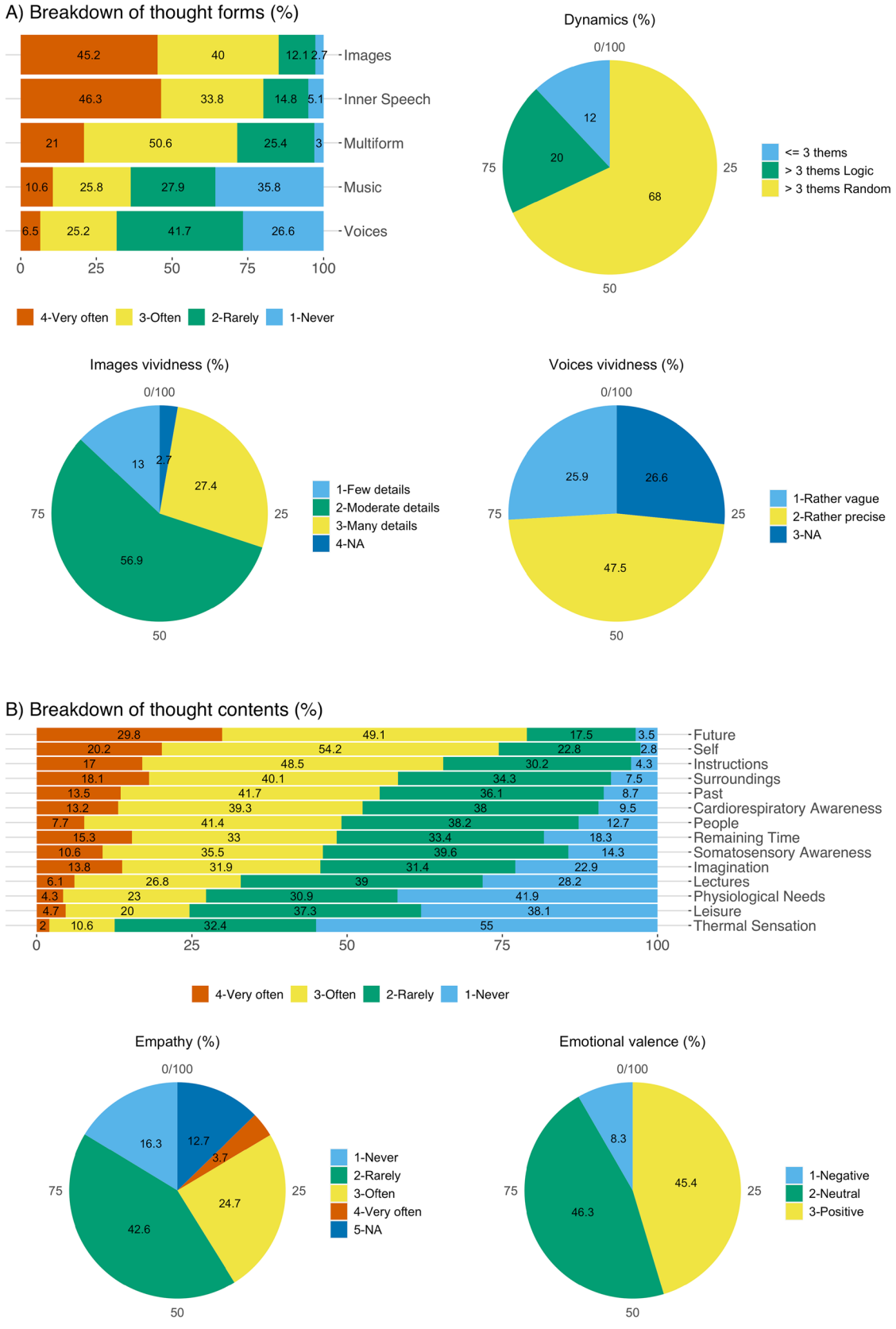
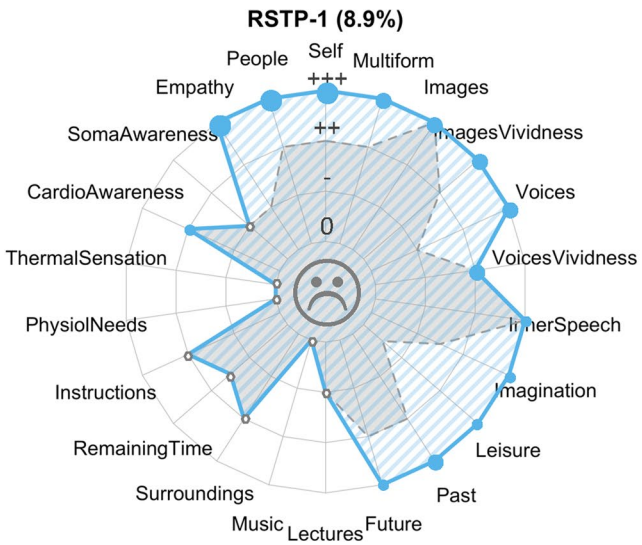
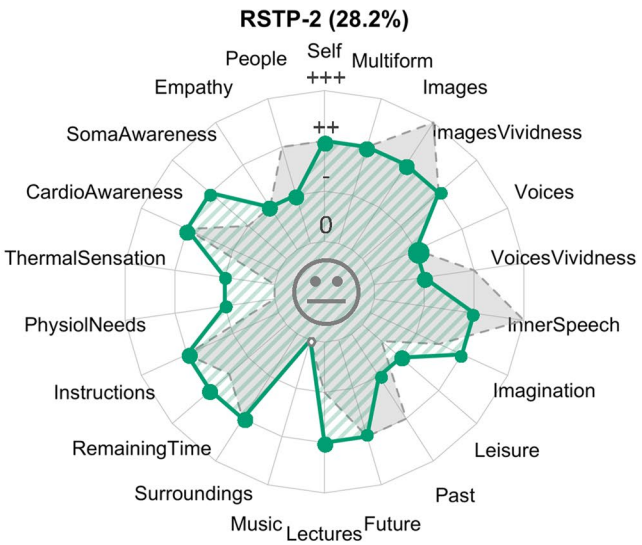
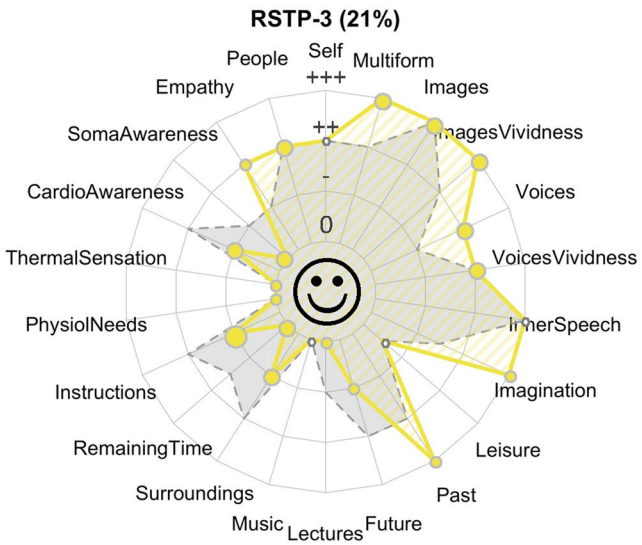
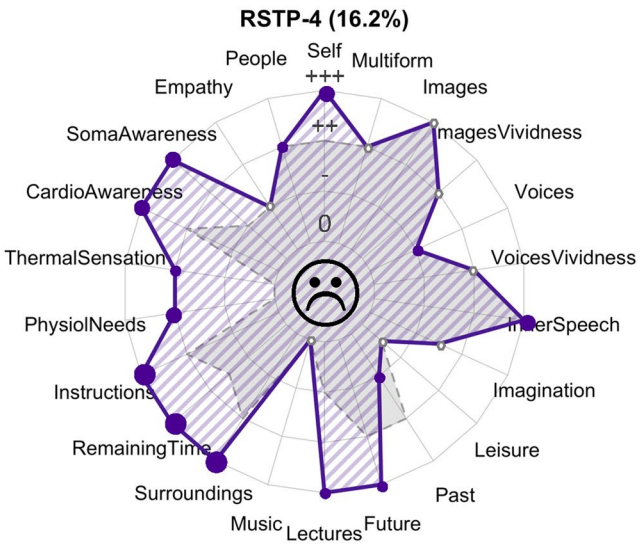


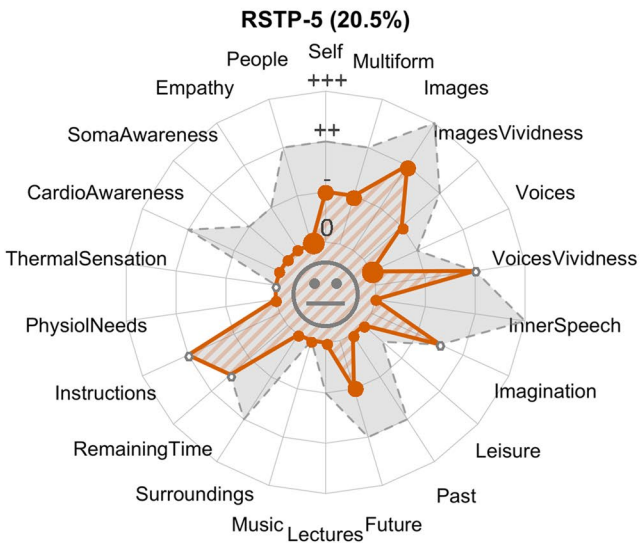
Fig. 1 Distribution of the types of thought in the 94 categories of the ReSQ 2.0

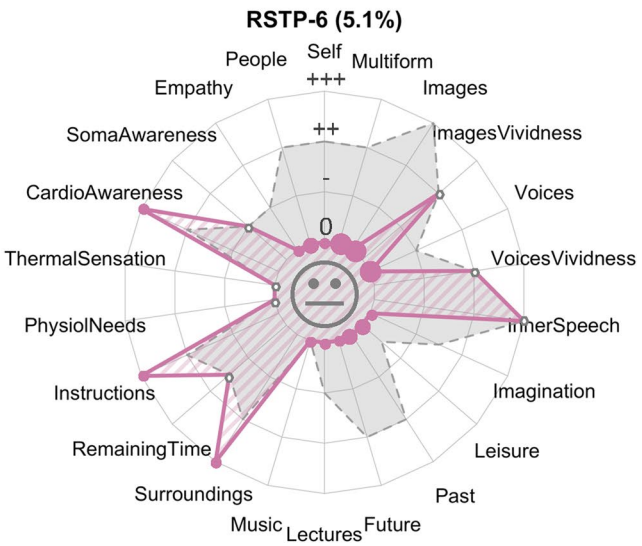

RSTP-1 (8.9%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0


RSTP-2 (28.2%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0


RSTP-3 (21%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0


RSTP-4 (16.2%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0


RSTP-5 (20.5%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0


RSTP-6 (5.1%)
People
Self
Multiform
Empathy
Images
SomaAwareness
ImagesVividness
CardioAwareness
Voices
ThermalSensation
VoicesVividness
PhysiolNeeds
InnerSpeech
Instructions
Imagination
RemainingTime
Leisure
Surroundings
Past
Music
Lectures
Future
+++
++
-
0

◂**Fig. 2** Characterization of the six RSTPs by the ReSQ 2.0 categories (N = 1779). Each RSTP was characterized by the overrepresented categories of the ReSQ 2.0 items significantly related to the 6-class partition. The strength of the relationship between a profile and a category was estimated with the z_p value and is represented by three different levels, i.e., small: z_p = [2.66-5.96] (small dots), medium: z_p = [5.97-11.93] (medium dots), and large: z_p = [11.94-20.56] (large dots). Blank dots indicate statistical independence between the ReSQ 2.0 item and the profile. The smileys depict the emotional valence (positive, neutral, or negative), and the strength of the relationship with the profile is coded by gray smiley for z_p = [2.66-5.96] and black smiley for z_p = [5.97-11.93]. The background gray profile represents the most frequent categories in the overall study sample. 0 = never, - = rarely, + + = often, + + + = very often, except for *voice vividness*: - = rather vague, + + = rather precise and *image vividness*: - = few details, + + = moderate details, + + + = many details.

Age and gender/sex were differentially related to the types of thought and RSTPs

As participants aged one year (Fig. SI-3), we observed significantly lower odds of thinking about remaining time (aOR = 0.95, 95% CI [0.93, 0.98], *p*-bon = 0.017), music (aOR = 0.96, 95% CI [0.93,0.98], *p*-bon = 0.020) and vivid voices (aOR = 0.95, 95% CI [0.93, 0.98], *p*-bon = 0.047) at either threshold category. Aging did not significantly predict the occurrence of any RSTPs.

Women were at significantly lower odds than men of having imaginative (aOR = 0.70, 95% CI [0.62, 0.78], *p*-bon < 0.001) or leisure (aOR = 0.67, 95% CI [0.60, 0.76], *p*-bon < 0.001) thoughts at either threshold category. Conversely, women were at significantly higher odds than men of experiencing negative thoughts (aOR = 1.50, 95% CI [1.26, 1.79], *p*-bon < 0.001) and thinking about thermal sensations (aOR = 1.67, 95% CI [1.42, 1.93], *p*-bon < 0.001), about the future (aOR = 1.61, 95% CI [1.40,1.84], *p*-bon < 0.001), and about the instructions (aOR = 1.41, 95% CI [1.23, 1.63], *p*-bon < 0.001) at either threshold category (Fig. SI-3). Consistently, being a woman significantly increased the likelihood of expressing RSTP-4 (aOR = 1.69, 95% CI [1.24, 2.30], *p*-bon < 0.001), which was characterized by negative thoughts and higher rates of thinking about thermal sensations, the future, and the instructions (Fig. 2).

RSTP probability varied according to the interaction between trait negative affectivity and psychological maturity

We performed a multinomial logistic regression analysis to identify psychological trait predictors of RSTPs in the subsample of 1270 students who had completed the online mental health survey questionnaires. Trait negative affectivity interacted with psychological maturity to significantly modify the probability of each RSTP (LR $\chi^2_{(df = 5)} = 12.50$; $p = 0.0285$). Bonferroni-corrected post hoc analyses are summarized in Table SI-3 and illustrated in Fig. 3, depicting the

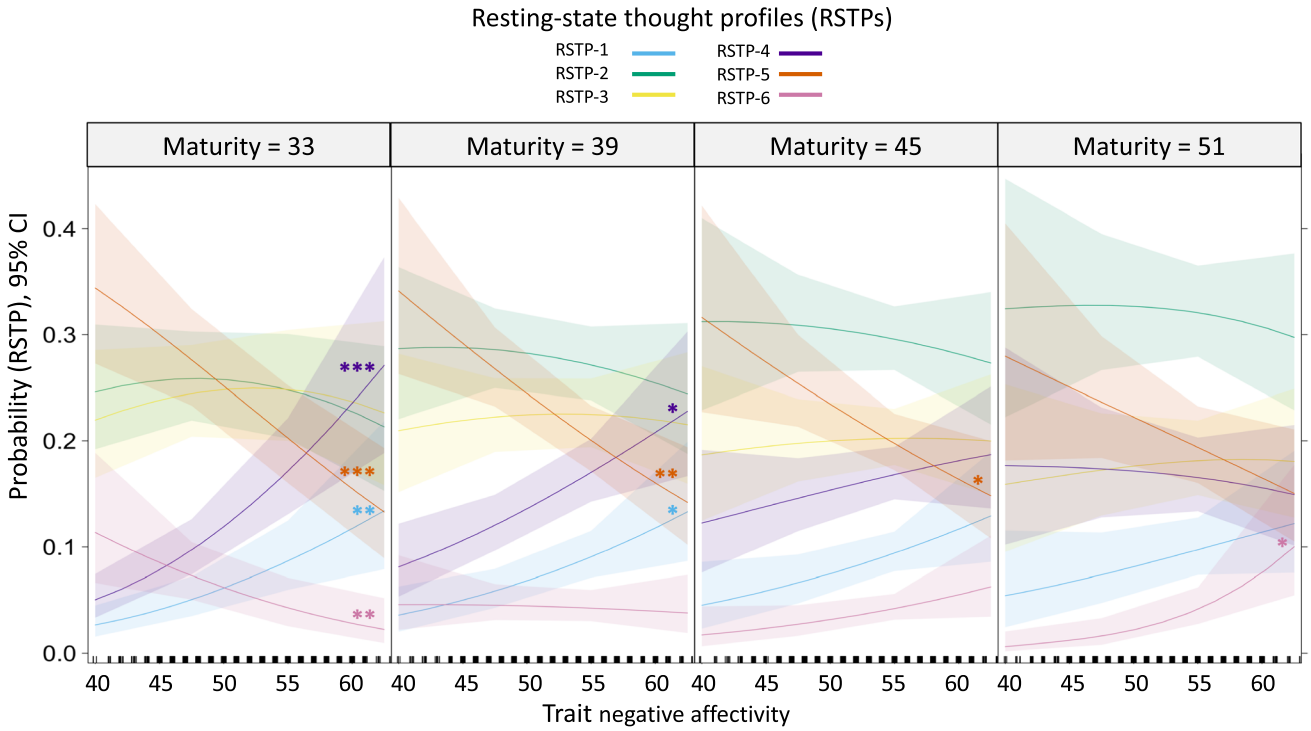


Fig. 3 Probability of each RSTP according to trait negative affectivity (cut points: slight < 45, moderate = 46 to 54, and high > 55) and psychological maturity (four equidistant points as an illustration of each quartile). *p*-bon < 0.05*, 0.01**, 0.001***

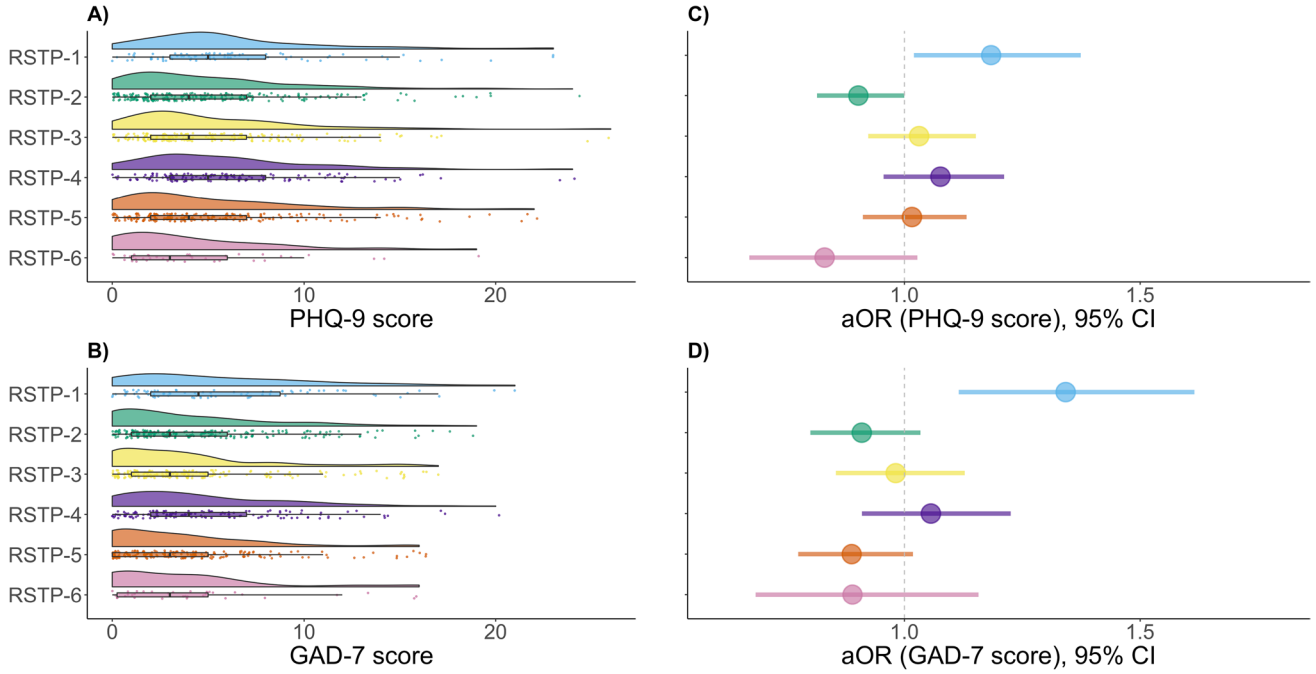


Fig. 4 (**A**-**B**) Distribution of PHQ-9 and GAD-7 scores and (**C**-**D**) their aORs according to RSTP (adjusted for age, gender/sex, and psychological maturity). A 95% CI that does not cross the dashed line indicates significant uncorrected higher (> 1) or lower (< 1) odds

probability of each RSTP as a function of trait negative affectivity for each maturity quartile. Trait negative affectivity was a negative predictor of RSTP-5 with a significant effect for the first three quartiles of psychological maturity. In contrast, trait negative affectivity was a significant positive predictor of RSTP-1 and RSTP-4, yet only in the lower half of the maturity level. Regarding RSTP-6, trait negative affectivity was a significant negative predictor in immature students but a significant positive predictor in the most mature students. Finally, independent of trait negative affectivity, psychological maturity was a significant negative predictor of RSTP-3, an effect that did not survive the Bonferroni correction. Psychological maturity also tended to positively predict RSTP-2, but this relationship was not significant.

RSTPs predicted higher or lower odds of subsequent depressive and anxious states

Having established that the likelihood of RSTPs varied according to trait negative affectivity in interaction with psychological maturity, we explored whether RSTPs could predict subsequent depressive and anxious states (N = 922). The two negative binomial regression models revealed significant differences in PHQ-9 and GAD-7 scores as a function of RSTP (PHQ-9: $\chi^2_{(5, 916)} = 12.46$, $p = 0.0289$, Fig. 4A; GAD-7: $\chi^2_{(5, 916)} = 17.54$, $p = 0.0036$, Fig. 4B). According to uncorrected post hoc analyses, RSTP-1 significantly increased the likelihood of endorsing subsequent symptoms of both depression (PHQ-9: aOR = 1.18, 95% CI [1.02, 1.37], $p = 0.0262$, Fig. 4C) and anxiety (GAD-7: aOR = 1.34, 95% CI [1.11, 1.61], $p = 0.0019$, Fig. 4D). RSTP-2 significantly decreased the likelihood of endorsing subsequent depressive symptomatology (PHQ-9: aOR = 0.90, 95% CI [0.81, 1.00], $p = 0.0494$), a trend that was visible to a lesser extent for anxiety (GAD-7: aOR = 0.91, 95% CI [0.80, 1.03], $p = 0.1472$). RSTP-6 and RSTP-5 tended to reduce the likelihood of endorsing subsequent depressive and anxious states, respectively (PHQ-9: RSTP-6: aOR = 0.83, 95% CI [0.67, 1.03], $p = 0.0871$; GAD-7: RSTP-5: aOR = 0.89, 95% CI [0.77, 1.02], $p = 0.0887$).

Discussion

We proposed a new classification of thought patterns at rest into six profiles (RSTPs) using a clustering method that provided more accurate and extensive thought patterns than in prior studies. Five of the six RSTPs were predicted by trait negative affectivity in interaction with psychological maturity, which we identify here for the first time as a major influencing factor. Four RSTPs (one especially) were predictive of subsequent depressive and anxious states, measured on average 1.4 years later. Finally, by its dual ability to predict subsequent negative affective states and be predicted by psychological traits, the negatively valenced RSTP-1 can be assumed to be stable and recurrent.

Below, we discuss the contribution of RSTPs, in relation to individual psychological features, to the characterization of the (1) dynamics, (2) temporal orientation, and (3) emotional valence of ongoing conscious thought. We next discuss the relationship we discovered between RSTPs and psychological maturity. We finally compare the six RSTPs to those previously described in the literature before concluding and considering some implications of our study.

Dynamics

Two RSTPs showed particular dynamics. RSTP-2 had a higher proportion of individuals with many random thoughts and was consistently associated with all types of thought content. In contrast, RSTP-6 included more individuals thinking about three or fewer themes and, accordingly, the most "never" responses. Between these two extremes, the four other RSTPs provided a quick snapshot of the thought dynamics for the vast majority of students (88%) who reported thinking about more than three themes. By providing a simultaneous view of the frequency of all types of thoughts, RSTPs facilitate mapping their presence-absence, help visualize their scope, and synthesize the dynamics of their occurrence.

Temporal orientation

Seventy-nine percent of the students frequently thought about the future, ranking it the top type of thought and making it the least specific. The students were also often centered on the here-and-now, as evidenced by the ranking of thoughts about instructions (3rd; regularly experienced by 65% of the participants), surroundings (4th; regularly experienced by 58% of the participants), and cardiorespiratory rate (6th). Orientation toward the past was the least frequently experienced aspect of temporal thought, but these thoughts still involved more than one in two students (55%). Our results add to prior studies showing that, in isolation, the temporal orientation of thoughts is moderately characteristic of ongoing conscious thought (Stawarczyk et al., 2013) and illustrate the value of the clustering approach for finding specificities among the many combinations of thought types.

Here, frequencies of future-oriented and self-focused thoughts were strictly identical across all profiles except one (RSTP-3). A positive correlation between self-relevant and future-oriented thoughts has been consistently observed (Andrews-Hanna et al., 2013; Brennan et al., 2021; Diaz et al., 2014; Engert et al., 2014; Kanske et al., 2017; Linz et al., 2021; Ruby et al., 2013a, 2013b; Smallwood et al., 2016; Sormaz et al., 2018; Stawarczyk et al., 2013; Turnbull et al., 2021), and it has been explained that future-oriented thinking means the anticipation and planning of personally relevant future goals (Baird et al., 2011; Smallwood et al., 2011; Stawarczyk et al., 2011). Moreover, we observed that greater self-focused/future-oriented thoughts were consistently associated with negative emotions (in RSTP-1 and RSTP-4), an observation consistent with results obtained in individuals scoring low in narcissism (Kanske et al., 2017) but opposite to previous observations that thoughts about the future are on average more positive (Andrews-Hanna et al., 2013; Beaty et al., 2019; Spronken et al., 2016). The discrepancies between our and others' results suggest that temporal orientation and emotional valence of thoughts are not unequivocally linked. Accordingly, past-oriented thoughts were overexpressed in the *negatively valenced* RSTP-1, consistent with prior results relating negative thoughts and brooding rumination focused on past experiences (Andrews-Hanna et al., 2013; Beaty et al., 2019; Raffaelli et al., 2021; Smallwood & O'Connor, 2011). However, this association was not specific, as past-oriented thoughts were *rare* in the *negatively valenced* RSTP-4 yet *very frequent* in the *positively valenced* RSTP-3, suggesting that past-oriented thoughts cannot be used as a flag of emotional valence. Interestingly, RSTP-1 and RSTP-3, both past-oriented, were characterized by empathetic thoughts, i.e., turned toward people and their emotional feelings. These two *empathetic* RSTPs also shared multimodal and realistic mental representations and imaginative thoughts. Empathetic RSTPs involved episodic recollections and imaginary scenes incorporating people and characters with many visual and voice contents that could be negatively or positively valenced. Since past-oriented thoughts were previously shown to moderately correlate with vividness (Beaty et al., 2019), we further assume that the social content rather than the temporal orientation of thoughts was responsible for the vividness of empathetic RSTPs, in line with prior studies showing that thoughts experienced with more vividness and imagery were more likely to involve other people (Andrews-Hanna et al., 2013). Thus, past-oriented thoughts seemed to highlight empathetic concerns, an interpretation reinforced by the equivalent frequency of empathetic and past-oriented thoughts in five of the six RSTPs and consistent with the previously observed positive association between other-related and past-oriented thoughts (Engert et al., 2014; Kanske et al., 2017; Konu et al., 2021; Ruby et al., 2013a, 2013b; Smallwood et al., 2016; Turnbull et al., 2021).

Emotional valence

Emotional valence is an important feature of ongoing conscious thought often discussed in terms of well-being (Andrews-Hanna et al., 2013; Engert et al., 2014; Poerio et al., 2013; Raffaelli et al., 2021; Smallwood & Andrews-Hanna, 2013; Vatansever, 2020). Here, 54% of the students experienced negative or positive thoughts, and all RSTPs were significantly related to either negative (n = 2), positive

(n = 1), or neutral (n = 3) emotional valence. Since temporal orientation failed to explain the emotional valence of thoughts in our sample (as discussed above), we next consider other sources of variability.

Although *negatively valenced* thoughts were mainly in the minority of the overall sample (8%), consistent with the mild average positive affect bias of self-generated thoughts (Fox et al., 2018), they were overexpressed in RSTP-1 and RSTP-4. Relative to other RSTPs, both negatively valenced RSTPs overexpressed self-focused/future-oriented thoughts and inner speech. This specific association between thought content and form was also observed independently of emotional valence (Stawarczyk et al., 2013; Vatansever, 2020), which is consistent with the mnemonic functions (reminders to do things), action planning, and decision-making previously associated with inner speech (D'Argembeau et al., 2011; Morin et al., 2011). Additionally, relative to the unique *positively valenced* RSTP-3, RSTP-1 overexpressed empathetic thoughts and RSTP-4 overexpressed concerns related to the here-and-now. Finally, RSTP-4 shared almost all of the same thought types as RSTP-2, but they were much more frequent in RSTP-4. Overall, this suggests that the high frequency of specific thought profiles is related to negative valence and highlights the need to consider both thought contents and their frequency. To this end, RSTPs appear to be a precious tool for "quantifying an individual's full profile of thought content" (Andrews-Hanna et al., 2013).

Regarding relationships between RSTPs and psychological features, low levels of trait negative affectivity (i.e., STAI-T scores) were predictive of a higher probability of the emotionally neutral RSTP-5 (except for the most mature students). In contrast, both negatively valenced RSTP-1 and RSTP-4 were more likely to occur as trait negative affectivity increased (at least in less mature students). Our findings add to prior research showing that people experiencing trait negative affectivity (i.e., higher neuroticism assessed with the NEO Five-Factor Inventory-3) endorsed more worry-based thought content in daily life (Kane et al., 2017). As psychological state predictors, RSTPs were associated with an increased or decreased likelihood of subsequent negative affective states. RSTP-1 predicted higher odds of subsequent negative affective states (i.e., PHQ-9 and GAD-7 scores), in line with prior studies (Andrews-Hanna et al., 2013; Poerio et al., 2013; Ruby et al., 2013a, 2013b). RSTP-2 decreased the probability of subsequent depressive and, to a lesser extent, anxious states. RSTP-6 and RSTP-5 also tended to reduce the likelihood of subsequent depressive and anxious states, respectively. The predictive character of RSTP-1 and RSTP-2 (and, to a lesser extent, RSTP-5 and RSTP-6) strengthens the assumption that they reflect individual psychological dispositions. In contrast, the negatively valenced RSTP-4 did not predict subsequent negative affective states, although its probability was increased by trait negative affectivity in the immature students (similar to RSTP-1). Thus, RSTP-4 seemed to capture situational influences rather than dispositional ones. In line with this interpretation, RSTP-4 was highly characterized by bodily sensations and situational concerns during the RS scan. RSTP-4 appears to represent an anxious profile of thinking, an assumption that could explain why RSTP-4 was more likely in women than men since, compared to men, women were more anxious (in the present and previous studies) and at higher risk of claustrophobia in MR scanners (Dewey et al., 2007). Overall, these results illustrate the ability of our method to separate variability related to dispositional traits from that related to the situation.

Psychological maturity

Psychological maturity was related to almost all RSTPs, in line with prior research showing a link between isolated ongoing thought types and both self-directedness and cooperativeness character traits (i.e., the two components of psychological maturity) (Diaz et al., 2014). As mentioned above, the positive relationship between high trait negative affectivity and negatively valenced RSTPs (RSTP-1 and RSTP-4) was observed only among the less mature students. The relationships between RSTPs and immaturity could result from a wide range of dysfunctional personality styles involving thwarted goals or disrupted relationships (as in depression or anxiety) (Gutiérrez et al., 2008; Josefsson et al., 2013). Meanwhile, higher maturity levels tended to be associated with an increased likelihood of RSTP-2, an emotionally neutral and well-balanced RSTP. Consistently, high maturity levels were previously associated with emotional stability (i.e., a low level of neuroticism assessed using the revised NEO Personality Inventory, NEO-PI-R) (Aluja & Blanch, 2011; Capanna et al., 2012; Cloninger, 2010; De Fruyt et al., 2000) and a sense of comfort during RSFC (Diaz et al., 2014). Additionally, as psychological maturity increased, we observed a decrease in the likelihood of empathetic RSTPs (RSTP-1 and RSTP-3), characterized by emotionally toned, social episodic, and imaginary thoughts. Similarly, Kane et al. (2017) showed that agreeableness (i.e., a dimension of the NEO-PI-R positively related to psychological maturity Aluja & Blanch, 2011; Cloninger, 2010; De Fruyt et al., 2000)) tended to negatively predict daydreams and fantasy. Moreover, the high frequency of voices and inner speech characterizing empathetic RSTPs complies with the social-assessment function of self-talk described by Brinthaupt and Dove (2012). Overall, our results strongly suggest that a greater maturity level leads to less social and (positively or negatively) emotionally toned thought content. This idea concurs with the recent report of a decline in openness to feelings and social potency in personality development across adulthood (Schwaba et al., 2022). Thus, for the first time, psychological maturity appears to be a substantial new variable in future research about ongoing conscious thought.

In contrast, age only slightly affected isolated thought types, a finding that did not replicate prior results (Christian

et al., 2013; Diaz et al., 2014; Turnbull et al., 2021) and was unrelated to RSTPs. The small age range of the study sample may explain this lack of effect.

RSTPs relations to previously described patterns of thought

In addition to reflecting individual dispositions, RSTPs seemed to capture the stable internal structure of ongoing conscious thought. Indeed, RSTP-1 is similar to the frequently described pattern, either in healthy or depressed individuals, combining self-focused, past-oriented, and negatively valenced thoughts (Andrews-Hanna et al., 2013; Hoffmann et al., 2016; Raffaelli et al., 2021; Vatansever, 2020) and sometimes other-oriented thoughts (Ruby et al., 2013a, 2013b). RSTP-4 resembles patterns that connect negative thoughts with one's surroundings (Brennan et al., 2021; Konu et al., 2021), internal allocation of attention (Gruberger et al., 2013), fewer off-task thoughts, greater future focus, and higher daily life subjective stress (Linz et al., 2021). RSTP-3 appears very close to the positive, spontaneous thought about others (Vatansever, 2020) and the "episodic social cognition" dimension described in several studies (Engert et al., 2014; Konu et al., 2020, 2021; Linz et al., 2021; Smallwood et al., 2016; Turnbull et al., 2021). Finally, RSTP-5 (exclusively involving images) and RSTP-6 (exclusively involving inner speech) match the extremes of the "modality" dimension that contrasts images and words (Brennan et al., 2021; Martinon et al., 2019; Poerio et al., 2017; Sormaz et al., 2018; Turnbull et al., 2021; Vatansever, 2020; Wang et al., 2018a, 2018b). Thus, our method appears as effective as the gold standard experience sampling in characterizing the *interindividual* variability of ongoing conscious thought and will help compare independent samples.

Limitations

A set of limitations should be considered to interpret the findings appropriately.

First, a sampling bias could have arisen. Participants were mainly female students, which may have increased the relative proportion of RSTP-4 where women were overrepresented. Moreover, the mean trait negative affectivity at baseline was higher than usual, corresponding to levels observed in stressful situations (e.g., exams (Cipra & Müller-Hilke, 2019)). As the i-Share project explicitly focuses on "student health," a selection bias toward health-worried students is possible that may have potentiated the analyses' sensitivity to negative affectivity. Adding health concern items to the ReSQ 2.0 (as in the ARSQ 2.0) would help identify and estimate the effects of this potential bias in future studies.

Second, the experimental design has at least two areas for improvement. Assuming the relative stability of psychological traits, we collected them before and after ReSQ 2.0 responses with a four-day gap on average. An improved experimental design would collect psychological traits exclusively before administering the ReSQ 2.0, an anteriority prerequisite for causation. Furthermore, only one RSTP was distinctly predictive of subsequent affective states. The difficulty in showing the predictive properties of RSTPs may be explained by the interval between the two measures, which was of 1.4 years on average. It can also be assumed that for neutral and positive RSTPs, it is more difficult to observe a negative prediction (i.e., a decrease in negative affective states likelihood, as tested here) than a positive prediction (i.e., an increase in positive affective states likelihood, not tested here). Thus, adding a positive measure of well-being in future designs could strengthen the identification of stable and recurrent RSTPs.

Third, to confirm the reliability of our method, it would be necessary to replicate the present protocol with a large independent sample.

Implications

From the person-situation debate, this study provides evidence supporting the consistency of ongoing conscious thought at rest. Our results suggest that trait negative affectivity and psychological maturity are two individual psychological dispositions strongly linked to conscious thought profiles. Despite their stability, these two personality traits remain flexible over a lifetime (Caspi et al., 2005; Lenze & Wetherell, 2011; H. W. Marsh et al., 2013). Thus, further studies would help to investigate whether acting on negative affectivity and maturity could change how we think or, conversely, whether changing our conscious way of thinking can change our negative affectivity and maturity.

From a research perspective, the fine characterization of RSTPs we promote should facilitate the detection of relationships between ongoing conscious thought and RSFC. If RSFC depends on conscious thought, different profiles of thought at rest should be associated with varying patterns of RSFC. Furthermore, it appears necessary to better understand the specific relationship between recurrent RSTPs and RSFC and, therefore, the ability of RSTPs to explain the individual stability of RSFC.

Conclusion

The new method we propose has many advantages making it a valuable tool for studies aiming to correlate RSFC to ongoing conscious thought. 1. RSTPs help visualize the scope of thoughts at rest and synthesize their dynamics,

facilitating interindividual comparisons. 2. RSTPs quantify thought profiles with unprecedented accuracy and details. 3. Among negatively valenced thoughts, RSTPs can separate a dispositional from a situational profile. 4. RSTPs look like thought patterns independently described in the literature, suggesting their generality.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12144-022-04185-6.

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Authors' contribution **SC**: Conceptualization, Methodology, Formal analysis, Visualization, Writing—original draft, review & editing. **MJ**[#]: Conceptualization, Methodology, Investigation, Writing—review & editing. **EM**[#]: Conceptualization, Methodology, Investigation, Writing—review & editing.

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Data availability The datasets generated and analyzed during the current study are not publicly available as they contain information that could compromise research participant consent. However, data are available from the corresponding author upon reasonable request and with permission of the principal investigator of the i-Share project.

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent Informed consent was obtained from all individual participants included in the study.

Competing interests On behalf of all authors, the corresponding author states that there is no conflict of interest.

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