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ORIGINAL RESEARCH

Interoceptive sensitivity as a proxy for emotional intensity and its relationship with perseverative cognition

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Background: Technical advancement in military cyber defense poses increased cognitive demands on cyber officers. In the cyber domain, the influence of emotion on decision-making is rarely investigated. The purpose of this study was to assess psychophysiological correlation with perseverative cognitions during emotionally intensive/stressful situations in cyber military personnel. In line with parallel research on clinical samples high on perseverative cognition, we expected a decreased interoceptive sensitivity in officers with high levels of perseverative cognition.

Method: We investigated this association in a sample of 27 cyber officer cadets.

Results: Contrary to our hypothesis, there was no relationship between the factors.

Discussion: Cyber officers might display characteristics not otherwise found in general populations. The cyber domain may lead to a selection process that attracts different profiles of cognitive and emotional processing.

Keywords: cyber, perseverative cognitions, interoception, decision-making

Introduction

In recent years, the human element in critical decision-making is of particular interest in the military cyber domain. Systematic research in this domain is still scarce.[1] Selected military personnel who work within the cyber domain may possess different cognitions from the general public, and the need for systematic research on predictors of performance in cyber officers is particularly pressing, given the large-scale consequences in the physical domain even seemingly small decisions in the cyber domain can have.[2–4] Technical advancement in military cyber defense poses increased demands on cyber officers. Often, cyber officers are required to make decisions in complex situations with incomplete information and with exposure to quantities of data that exceed processing capabilities. These situational characteristics promote the use of "mental shortcuts", that is, cognitive heuristics such as intuitive decisions and the unconscious use of emotionally salient information.[5] It is unknown how differences in individual intuitive decision-making operationalized as interoceptive accuracy are related to cadets' emotion regulation efficiency in regards to controlling unwanted cognition occurring as ruminative or worrying thoughts.

Emotion regulation, interoception, and decision-making

Emotion regulation is the conscious or nonconscious control of emotion, mood, or affect.[6] A typical challenge for emotion regulation processes is the overcoming of

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perseverative thoughts. Perseverative thinking is understood as a cognitive process where attentional resources repetitively focus on one's subjective experience of meaningful situations.[7] Although positive aspects of repetitive thinking have been associated with constructive, reflective thinking enhancing understanding and perspective taking,[8,9] repetitive negative thoughts directed toward the past (ruminative thinking) are considered to be maladaptive, unconstructive, and a risk factor for emotional stability.[10] As opposed to ruminative thoughts, the term "worrying" describes perseverative thinking focusing on concerns and threats and is directed toward the future. Higher tendencies toward perseverative thinking (both rumination and worrying) increase the probability of sustained negative affect and are a consequence of cognitive disinhibition.[10] Perseverative thinkers tend to fixate on a problem and associated feelings, hesitate to take action,[11,12] and are also more ineffective and inactive where interpersonal problem-solving is required.[13,14] This decreases one's ability to efficiently cooperate in problems requiring teamwork and reduces the probability of receiving social support.[15,16] The effects of mental states on cognitive performance and decision-making have been previously discussed in clinical and non-clinical contexts.[17] Findings showing altered cognitive functions in depressed samples might hint at potential effects in nonclinical populations in situations of intense physical and mental stress. In the context of military cyber operations as a part of traditionally structured sociotechnical systems, communicative challenges between technical experts and higher-ranking nontechnical commanders bear additional risks where cognitive agility and control are insufficient.[18] Therefore, perseverative thinking interferes with decision-making and leads to neediness and self-criticism. Emotion regulation processes are also influenced by somatic processes, which interact with cognitions through neural pathways that influence decision-making.[19]

The term interoception refers to how the brain receives, perceives, and integrates internal somatic signals from the body and has been related to emotional states.[20–22] Garfinkel et al[21] differentiated between three interoceptive constructs: interoceptive accuracy, interoceptive sensibility, and interoceptive awareness. While interoceptive sensibility and awareness are subjective judgments and cannot be directly measured, interoceptive accuracy is an objective measurement of one's perception of bodily sensations. Higher interoceptive accuracy has been related to higher emotional intensity, more intuitive and heuristic-driven decision-making styles, and generally a stronger impact of emotion-related information on decision-making processes.[23]

Interoceptive awareness is the ability to sense internal somatic changes,[24] integrate these experiences into emotionally influenced decision-making,[25] and is considered to be a physiological marker for the intensity of emotional states.[20,26] Integration of afferent somatic information is effective in intuitive decision-making situations[25,27,28] but can be negatively affected by other cognitions such as self-efficacy.[29] However, heightened interoceptive awareness increases the use of adaptive emotion regulation strategies, including reducing negative affect that can arise from perseverative cognition.[26,30–32]

Integrating emotion regulation in cyber military operations

Previous findings

The majority of research on the effects of perseverative thinking is based on healthy and clinical samples.[9,33] This study focuses on officer cadets of the Norwegian Defence Cyber Academy (NDCA), whose officers are selected through their scores in natural sciences and physical fitness and through personality traits, but their emotion regulation styles (i.e., rumination) are not seen as part of their selection criteria. Previous studies with similar aged participants in their late adolescence suggest that officer cadets may be vulnerable to maladaptive emotion regulation styles,[25] but relationships between perseverative cognitions and decision-making styles have, to the best of our knowledge, not yet been reported. Officer cadets entering military training are usually recruited out of high school to attend university and military training simultaneously. Understanding how perseverative cognitions relate to cognitive control and intuitive decision-making styles in individuals working in the cyber domain may give insights into how cognitions may influence cyber performance.

Previous studies focusing on age-related cognitive changes showed that younger participants (age <24 years) had higher levels of rumination and depression scores than older groups.[25] Recent research on decision-making strategies from cyber cadets has shown that emotion regulation can affect performance in counterintuitive situations.[29] Both processes, interoception and rumination, are known to influence decision-making and executive functions.[25] Research from clinical and nonclinical groups suggests relationships of perseverative cognition and interoception,[34–36] but this link has not yet been investigated in this particular sample.

Given the lack of research on the potential link between perseverative thinking and interoceptive accuracy, we used a cross-sectional design and expected a negative association

between perseverative thinking and interoceptive accuracy based on clinical literature suggesting reduced interoception to be positively related to depression severity.[37] We argue that a lack of cognitive control and resulting perseverative thoughts (toward negative events in the past [rumination] or potential negative future outcomes [worrying]) create and maintain emotional states that interfere with decision-making processes in subsequent tasks. Emotional states can exert a subtle but powerful interference with risk-relevant decision-making in demanding situations.[38,39] Whether these clinical findings can be extended to a healthy and highly functional and very selective sample of officer cadets is the subject of this study.

Methods

Sample description and procedure

The sample comprised a complete cohort (N=27; 24 males; M_{age} = 21.7, SD_{age} = 0.71) of Cyber Defence Officer cadets enlisted in the NDCA. Students accepted for the NDCA undergo a rigorous assessment and selection process focusing on physical fitness, general intelligence, and cyber domain-specific abilities, which is most likely to increase homogeneity on numerous performance and psychological measures. The participants were contacted 3 weeks before a laboratory session and were asked to fill out questionnaires. All participants were informed that participation was voluntary and were asked to sign an informed consent. Upon accepting to participate in the investigation, participants filled out self-report questionnaires, and then 1 week later, attended data collection for psychophysiological data. Participants were not compensated for their participation.

Measurements

Positive affect and negative affect

The PANAS (Positive Affect and Negative Affect Scale)[40] consists of 20 words related to positive affect (PA; 10 items) and negative affect (NA; 10 items). PANAS is a summative questionnaire with answers ranging from 1 – "not at all" – to 5 – "a lot".[41] Positive affect items include "interested" and "excited", and negative affect items include "distressed" and "upset". Participants are asked to respond according to their usual levels of affect. Cronbach's α ranges from 0.86 to 0.90 for PA and from 0.84 to 0.87 for NA.[40] This scale is highly correlated with depression checklists.[41]

Perseverative cognitions encompass past- (rumination) and future-directed cognitions.

Rumination was measured with the Response Style Questionnaire (RSQ)[42] and consists of 10 items with two subscales, brooding (five items) and reflective rumination or pondering (five items). Items are on a 4-point Likert scale from 1 – "almost never" – to 4 – "almost always". Example items for the brooding subscale include "Why can't I handle things better" and for reflective pondering "Go away by yourself and think about why you feel this way". The RSQ shows good internal reliability (Cronbach's α=0.89).

Worry was measured with the Penn State Worry Questionnaire (PSWQ).[43] The scale is a 5-point Likert scale ranging from 1 – "Not at all typical of me" – to 5 – "Very typical of me". The PSWQ shows good internal reliability (Cronbach's α=0.96).

Interoceptive accuracy was operationalized as cardioceptive accuracy (IA) and the assessment followed the protocols established by Schandry.[44] Participants were asked to count their heartbeat silently without any help of measuring pulse or using devices. Task instructions were presented verbally. The task consisted of four blocks of 15, 35, 45, and 25 s, with a short resting period of 30 s between trials. Simultaneous verbal and visual cues signaled start and end of each trial. After each trial, participants were asked the number of perceived heartbeats. Cardiac activity was assessed via photoplethysmographic sensors of the ALIVE® system (SomaticVision, CA, USA) attached to three fingers on the non-dominant hand. This method has been validated and used in studies in several domains.[45,46] Werner et al[47] has shown the specific brain areas responsible for intuitive decision-making through neuroimaging studies.[20,48]

Data reduction and statistical analysis

Statistical analysis was done with SPSS v.22. All variables were centered and standardized for analysis. Correlational analysis was used to test the hypothesis. Alpha (*a*) levels for hypothesis testing was set at the 0.05 level (two-tailed).

Ethical considerations

Participants signed informed consent prior to the study and were debriefed about the study's purpose after completing the data collection. Participants were informed that they could withdraw from participation at any time and without any consequences throughout and after the session. The study has been approved by the Norwegian Social Science Data Services (NSD; project number 43901).

Results

Descriptive statistics and alpha scores for the measurements are presented in Table 1.

All data were tested for normal distribution (Table 2). All perseverative cognition factors (rumination, worry) were

Table 1 Descriptive statistics (N=27)

	Cronbach's α	Mean	SD	Minimum	Maximum
IA	0.935	0.66	0.24	0.08	0.97
PANAS Positive affect	0.763	31.88	4.63	23.00	41.00
PANAS Negative affect	0.708	17.78	4.35	11.00	26.00
RSQ-Brooding	0.728	2.10	0.569	1.20	3.20
RSQ-Reflective	0.858	2.09	0.745	1.00	3.60
RSQ-Total	0.813	2.10	0.542	1.20	3.10
Worry	0.918	42.52	12.63	26.00	71.00

Abbreviations: IA, interoceptive awareness cardiac perception task; PANAS, Positive Affect and Negative Affect Scale; RSQ, Response Style Questionnaire.

Table 2 Shapiro–Wilk tests of normality (*df*=23)

	Statistic	Sig.
PANAS Positive affect	0.974	0.789
PANAS Negative affect	0.944	0.224
RSQ-Brooding	0.955	0.372
RSQ-Reflective	0.957	0.407
RSQ-Total	0.963	0.480
Worry	0.957	0.401
IA (% correct)	0.891	0.017

Abbreviations: IA, interoceptive awareness cardiac perception task; PANAS, Positive Affect and Negative Affect Scale; RSQ, Response Style Questionnaire; Sig., significance.

normally distributed except for interoceptive accuracy. All analyses involving interoception were done using nonparametric analyses (Spearman's ρ). In comparison to previous studies, the mean levels of interoceptive accuracy,[28,47] positive affect and negative affect,[41] and perseverative cognitions[36] were in the range of previous studies on normal populations.

To test the hypothesis, interoceptive accuracy was expected to negatively correlate with perseverative cognitions (rumination and worry), a correlational analysis (Spearman's ρ) was performed, which showed no relationship on any variables (Table 3; Figures 1 and 2). Results of the correlational analysis found no significant associations between interoceptive accuracy and variables reflecting perseverative cognitions (i.e., RSQ-Reflective and Worry; Table 3). Consistent with previous research,[9] ruminative brooding (RSQ-Brooding) was significantly correlated with worry, but no other significant relationships were observed. All correlational analyses were also performed with bootstrapping (in bold) for better statistical power. Bootstrapped values were no more significant than the original results.

Discussion

This study examined the relationship of perseverative thinking and interoceptive accuracy in cyber cadets. Expected correlations between interoceptive accuracy and the measures of perseverative cognitions (rumination, brooding, and worrying)[49] showed no relationships and the hypothesis must be rejected. Based on the effect sizes and broad confidence intervals (Table 3), false-negative results (type II errors) are hardly unlikely. It must be noted that interoceptive sensitivity was related to positive affect and negative affect to control for affective states as in other studies,[50] but these relationships also did not appear.

In this sample, even after bootstrapping, the relationship of interoceptive accuracy to perseverative cognitions and affect did not support previous findings.[20,30] These results might be due to several factors. The sample is selected for specific duties in the NDCA, and the selection process may filter out certain personality variables that are otherwise found in a normal or clinical sample. The selection process for the specific job requirements may attract persons with these capabilities. The term "Hybrid Space" has been used to describe the connection between the cyber and physical domains, and how people operate within it.[3,18] While previous research has identified that complementary decision-making styles and job demands must be identified for selection processes,[51,52] Hybrid Space operators may need specific cognitive skill sets to perform efficiently, but those requirements are still unknown to date due to the novelty of the domain. A cyber security officer's job may have certain aspects that require officers to separate these cognitive processes. Cyber security officers working in a "Hybrid Space"[3,18] may be required to disengage these cognitive processes since there are no defined expectations and strategies for succeeding.

Cyber officers may seek out environments that are better adapted to their cognitive style. Research has shown that person–environment fit determines performance. Cools et al[53] found that cognitive styles and cognitive climate had separate influences on behaviors. Armstrong et al[54] describe the needs for empirical studies identifying cognitive styles and demands of the person–environment fit as described by the Hybrid Space framework, and this research attempts to integrate findings in other domains that might be relevant due to lacking previous research.

Table 3 Correlations (*P*; N=27)

	IA[a]	1	2	3	4	5
1. PA	–0.273 (0.177)					
	CI (–0.591; 0.119)					
	–0.284 (0.189)					
2. NA	0.159 (0.446)	0.208 (0.319)				
	CI (–0.235; 0.508)	CI (–0.186; 0.544)				
	–0.010 (0.964)	**0.205 (0.348)**				
3. RSQ-B	**–0.**153 (0.466)	0.168 (0.423)	0.316 (0.133)			
	CI (–0.503; 0.241)	CI (–0.226; 0.515)	CI (–0.072; 0.621)			
	–0.274 (0.206)	**0.284 (0.190)**	**0.270 (0.212)**			
4. RSQ-R	0.020 (0.922)	–0.266 (0.188)	0.168 (0.424)	0.315 (0.125)		
	CI (–0.362; 0.396)	CI (–0.586; 0.126)	CI (–0.226; 0.515)	CI (–0.073; 0.620)		
	–0.051 (0.819)	**–0.203 (0.353)**	**0.111 (0.614)**	0.228 (0.295)		
5. RSQ-Total	**–0.**123 (0.557)	–0.105 (0.617)	0.286 (0.176)	0.746 (<0.001)	0.867 (<0.001)	
	CI (–0.480; 0.270)	CI (–0.466; 0.287)	CI (–0.106; 0.601)	CI (0.510; 0.877)	CI (0.726; 0.938)	
	–0.186 (0.395)	**0.009 (0.969)**	**0.228 (0.296)**	**0.712 (<0.001)**	**0.846 (<0.001)**	
6. PSWQ	0.012 (0.956)	–0.131 (0.534)	0.105 (0.624)	0.523 (0.009)	0.385 (0.057)	0.554 (0.005)
	CI (–0.369; 0.390)	CI (–0.486; 0.262)	CI (–0.286; 0.466)	CI (0.179; 0.753)	CI (0.006; 0.667)	CI (0.220; 0.771)
	–0.089 (0.688)	**–0.104 (0.636)**	**0.091 (0.680)**	**0.505 (0.014)**	**0.356 (0.096)**	**0.533 (0.009)**

Notes: Bootstrapped correlations are in bold (*P*). [a]Spearman's Rho correlation, all other correlations are Pearson's *r*.

Abbreviations: IA, interoceptive awareness cardiac perception task; NA, PANAS Negative affect; PA, PANAS Positive affect; PSWQ, Penn State Worry Questionnaire; RSQ-B, Rumination Styles Questionnaire Brooding; RSQ-R, Response Style Questionnaire Reflective; RSQ-Total, Rumination Styles Questionnaire Total.

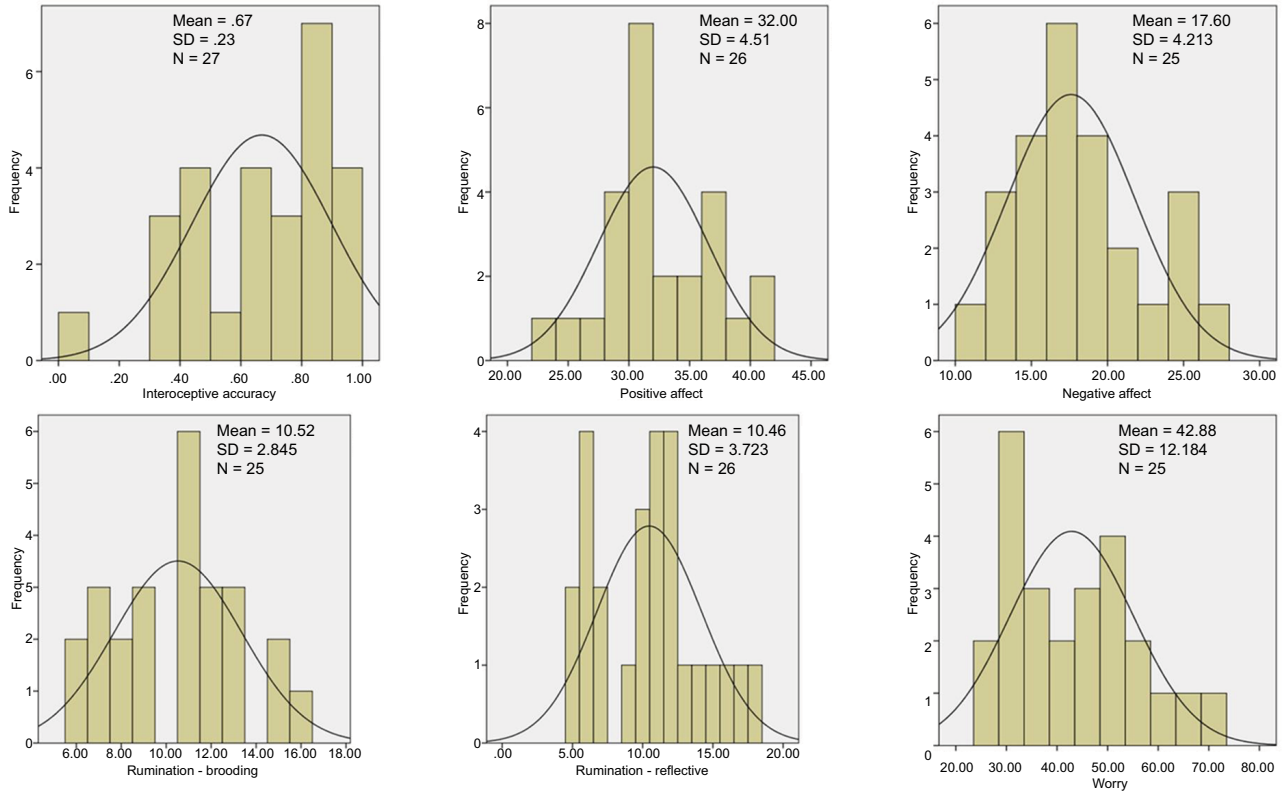

Figure 1 Histograms of factors. (**A**) Interoceptive sensitivity; (**B**) positive affect; (**C**) negative affect; (**D**) brooding; (**E**) reflective rumination; (**F**) worry.

Limitations and strengths of the study

There are several aspects that could lead to Type II errors. The low number of participants (N=27) in the study could easily influence results of the study. However, a large body of research on cognitive styles, decision-making, and interoception applying the same paradigms (interoception and

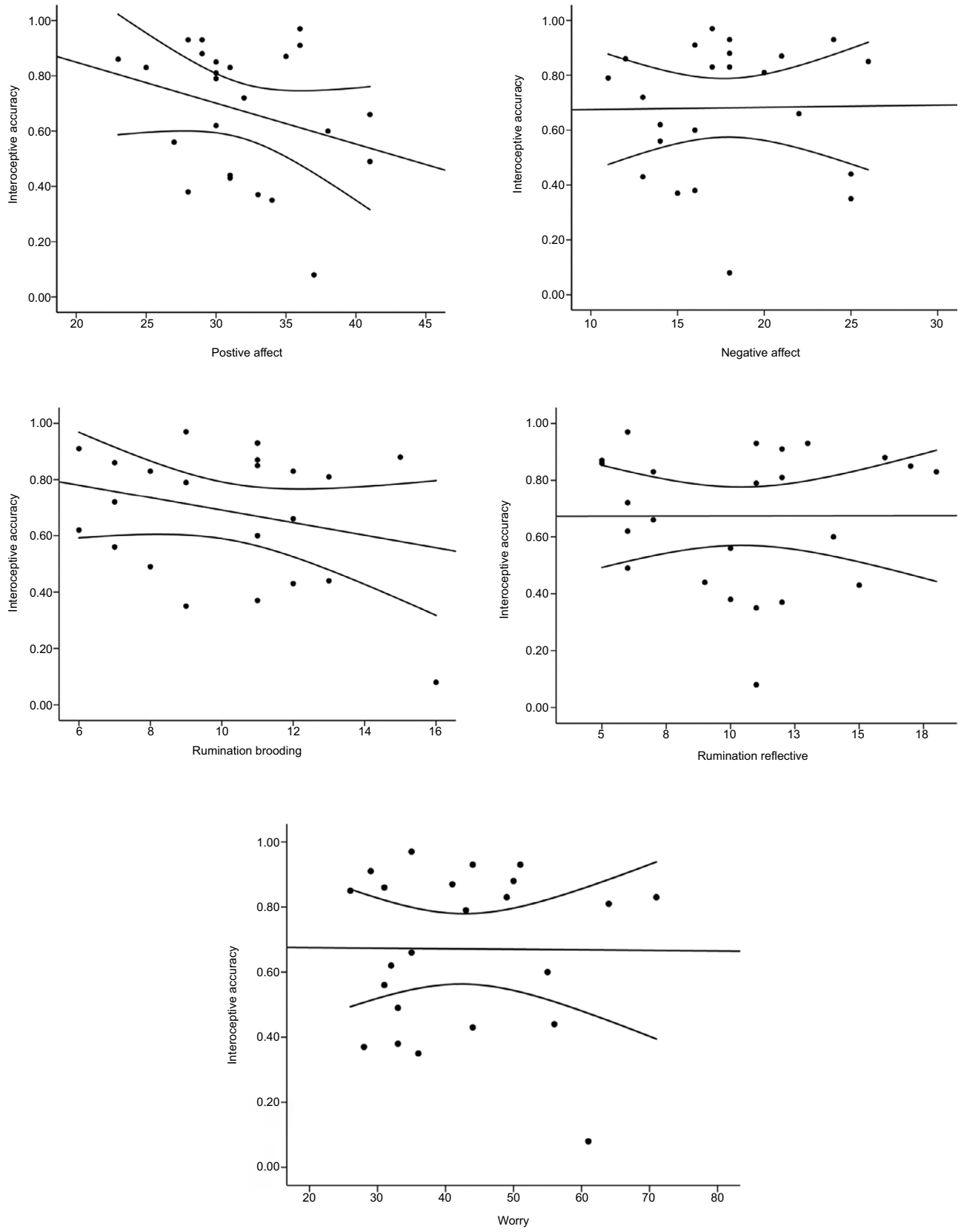

Figure 2 Scatterplots for all variables.

self-reports) conducted in other laboratories, as well as in our own, worked with sample sizes like ours, and resulted in robust findings and medium effect sizes.[5,28–30]

Correlation directions changed or initial correlations were strengthened in the same direction after bootstrapping, but the relatively narrow confidence intervals and the very weak correlation coefficients (<0.100) also decrease the risk of type II errors. This research looked at perseverative cognitions and interoception, but other emotion regulation strategies could, or cognitive processes might, show opposite results (i.e., this sample represents the general population).

The moderate size of the cohort studied, even if a full cohort, combined with the nature of cross-sectional designs does not allow for generalization to more experienced officers in active duty, and the previous professional experience of participants is not accounted for. Including a similar control group could have accounted for these shortcomings. The finding that the sample does not differ from the general population on affect states shows that they may experience affect as other comparable populations, but that perseverative cognitions may not influence their emotion regulation and decision-making strategies, as found in previous studies.

Conclusion

The results from this study show that cyber domain officer cadets may differ in their rumination patterns from other comparable age groups. The cyber domain may lead to a selection process that attracts different profiles of cognitive and emotional processing. The relevance of individual differences in cognitive styles and potentially systematic but unintended biases resulting from self-selection and selection procedures are important to understand due to their implications for later job performance. Future research should focus on integrating both individual styles and environmental demands, and how the person–environment fit can better help explain the abilities needed while accounting for the task demands the Hybrid Space proposes.

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Disclosure

The authors report no conflicts of interest in this work.

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