The relation of alexithymia, chronic perceived stress and declarative memory performance: Results from the general population

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A B S T R A C T

Previous evidence showed associations of alexithymia with altered declarative memory performance. However, these findings were not fully consistent and the underlying mechanism remains unclear. Alexithymic subjects may be at specific risk for chronic psychosocial stress, which in turn represents a predictor for poorer memory performance. We investigated independent and interaction effects of alexithymia and chronic perceived stress on declarative memory performance. Data were used from two independent general-population samples from the Study of Health in Pomerania (SHIP). In sample 1 ($N = 1981$), the Auditory Verbal Learning Test, the Toronto Alexithymia Scale (TAS-20) and the Screening Scale for Chronic Stress (SSCS) were applied. In sample 2 ($N = 3799$), the word list of the Nuremburg Age Inventory and TAS-20 were administered to replicate findings. Alexithymia was significantly associated with poorer immediate and delayed word recall. Chronic stress negatively predicted immediate, but not delayed recall. Alexithymia and particularly "Difficulties Identifying Feelings" showed significant associations with chronic perceived stress. Our findings provide clear evidence for an association of alexithymia with impaired declarative memory performance for words. The strong association of alexithymia with perceived chronic stress could contribute to explain the association of alexithymia with stress-related disorders.

1. Introduction

Alexithymia is a personality style characterized by a pattern of cognitive and affective characteristics including difficulties in identifying and describing feelings, a relative lack of fantasy and an externally oriented style of thinking (Sifneos, 1973). With proportions between 10% and 13%, alexithymia has been found to be relatively common in different general population samples (Franz et al., 2008; Salminen et al., 1999). Theoretical considerations and evidence from empirical studies led to the concept of alexithymia as a personality style associated with deficits in the cognitive processing of emotions (Swart et al., 2009; Taylor et al., 1999; Vermeulen et al., 2006). For example, Lane et al. (1996) reported that highly alexithymic subjects were less accurate in matching emotional stimuli with verbal and non-verbal

emotional responses (Lane et al., 1996).

Emotions are considered as important moderators of learning and retrieving information as they enable indexing memories of value and prime their availability to different cognitive domains (Dolan, 2002). Results from different studies stressed the important role for emotions to recall aspects particularly for the declarative memory (Crossen and Wiens, 1994; Helmstaedter et al., 2001). It has been suggested that highly alexithymic subjects show difficulties in linking feelings to memories which may result in poorer memory performance particularly for emotional stimuli (Taylor et al., 1999). However, results from existing studies are inconsistent to some degree: Luminet et al. (2006) found highly alexithymic subjects showing deficits in remembering emotional words compared to students low in alexithymia, while they found no difference in remembering neutral expressions (Luminet et al.,

2006). Findings by Meltzer and Nielson (2010) showed reduced recall of negative emotion words and increased recall of illness-related words in high alexithymic individuals (Meltzer and Nielson, 2010). In contrast, Lundh et al. (2002) found no significant correlation between scores of the 20-item version of the Toronto-Alexithymia-Scale (TAS-20) and measures of memory for emotions in 88 non-clinical subjects (Lundh et al., 2002). Likewise, Suslow et al. (2003) reported that alexithymia was not associated with differences in incidental learning of emotional words in 30 non-clinical subjects (Suslow et al., 2003).

Alexithymic subjects may be at specific risk for experiencing increased levels of chronic psychosocial stress: In general, chronic psychosocial stress has been described as an imbalance of high demands on one hand and a lack of satisfaction of one's needs on the other hand (McEwen, 2004). Chronic stress increases when individual needs, e. g. for appreciation or social support, are not sufficiently satisfied. Different mechanisms of how alexithymia and chronic stress may be linked have been put forward: Early concepts proposed that alexithymia is closely related to immature and neurotic ego defense styles, i. e. dysfunctional mechanisms against conditions of distress (Parker et al., 1998). Also, maladaptive coping styles and thereby reduced capacities to cope with stressful life events were found to be related to alexithymic personality traits (Besharat, 2010; Parker et al., 1998). Moreover, alexithymia was associated with increased interpersonal problems (Spitzer et al., 2005), less perceived social support, fewer social relationships and less social skills (Lumley et al., 1996). Associations of increased perceived stress with alexithymia were found in a non-clinical sample of incoming college students (Kerr et al., 2004). In contrast, to our best knowledge, no existing study investigated the relation of alexithymia and perceived chronic stress in larger community-based samples.

Evidence from previous studies suggests that chronic psychosocial stress is associated with impaired functioning of the declarative memory: Evans and Schamberg (2009) reported that childhood poverty was inversely related to adult working memory performance and that this association is mediated by biological measures of chronic stress (Evans and Schamberg, 2009). In their review and meta-analysis, Sauro et al. (2003) reported that chronic stress affects declarative, but not non-declarative memory and that this effect is partly mediated by the effects of glucocorticoids on the hippocampus (Sauro et al., 2003). However, these results were mainly based on life event reports, while studies investigating effects of perceived psychosocial stress are scarce. For instance, Öhmann et al. (2007) found in a small outpatient sample that individuals exposed to perceived chronic stress showed reduced functioning particularly of the declarative memory (Öhman et al., 2007).

Chronic psychosocial stress is associated with different brain structural and neuroendocrine alterations which may act as mechanism leading to impaired memory functioning. In particular, brain areas like the prefrontal cortex and the hippocampus, regions which are crucial for declarative memory functioning, have each been found to be affected by chronic stress (Lupien et al., 2007; McEwen, 2000). A consistent correlate of chronic psychosocial stress is the activation of the limbic-hypothalamic-pituitary-adrenal axis with increases in adrenocorticotropin and, subsequently, cortisol (Fuchs et al., 2001). In his review, Wolf (2009) reported that stress as well as cortisol treatment were associated with impaired declarative memory performance, particularly by disturbing memory retrieval (Wolf, 2009). He suggested that reduced hippocampal activity represents the neural correlate of this finding. Likewise, Lupien et al. (2005) summarized a series of studies showing that chronically elevated levels of glucocorticoids were associated with both, memory impairments and reduced hippocampal volumes (Lupien et al., 2005). Results from neuroimaging studies showed that the hippocampus is particularly sensitive to the detrimental effects of chronic stress and stress hormones (for review Kim and Diamond, 2002). However, more recent evidence indicates that psychosocial stress impairs memory performance only in emotionally arousing situations (Buchanan et al., 2006; de Quervain et al., 2007). In this context, it has been hypothesized that adrenergic activation of the amygdala in response to emotional arousal is a precondition for transferring the effects of elevated cortisol levels on the hippocampus and thereby on declarative memory performance (Roozendaal et al., 2004, 2003). Given that alexithymia is associated with hyperarousal to emotional stimuli and situational stressors (Martin and Pihl, 1986; Papciak et al., 1985) and different anxiety disorders (Hendryx et al., 1991), alexithymic subjects may be specifically prone to the detrimental effects of chronic stress on hippocampal structures and, subsequently, declarative memory impairment.

In summary, there is some, however inconsistent evidence for an association of alexithymia with impaired declarative memory performance. While most previous studies were mostly based on experimental designs with relatively small and highly selected samples, data from large general population samples are missing. Moreover, the mechanism of how alexithymia may result in impaired memory performance is insufficiently understood. Chronic psychosocial stress has been found to disrupt memory formation and retrieval and may be increased in alexithymic subjects. However, available data from human studies mostly used adverse life events as stress measure. In contrast, we applied a self-rating measure for perceived chronic stress. Also, the association of alexithymia and perceived chronic as not been directly investigated yet. Therefore, the aims of this study were threefold: (1) We sought to investigate whether alexithymia and its subfactors were related to chronic psychosocial stress, (2) whether alexithymia and chronic psychosocial stress was associated with declarative memory performance and (3) whether a combination of these factors (in interaction and mediation analyses) predicted effects declarative memory performance in two large, independent general-population studies.

2. Methods

2.1. General population sample

In this cross-sectional analysis, we used data from the Study of Health in Pomerania (SHIP), a population-based cohort study conducted in the region of West Pomerania (Völzke et al., 2011). A multistage sampling scheme was adopted from the World Health Organization's MONICA Project, Germany. Adult German residents aged 20–79 years were randomly drawn from local registries (SHIP-0: 1997–2001, *N* = 4308). From 2007 to 2010, the "Life-Events and Gene-Environment Interaction in Depression" (SHIP-LEGENDE) study was conducted as an add-on study based on the SHIP-0 sample. All participants of SHIP-0 still alive at 2006 (*N* = 3669) were invited and 2400 agreed to participate in SHIP-LEGENDE. We excluded all participants with missing data, leaving a sample of 1980 subjects.

In 2008 a new, independent sample (SHIP-Trend-0: *N* = 4420, aged 20–84) from the same area was drawn and similar examinations like in SHIP-0 were undertaken. After exclusion of subjects with missing data, our final sample comprised 3799 subjects.

All participants gave written informed consent to the study and scientific use of the data. The study conformed to the principles of the Declaration of Helsinki as reflected by an a priori approval of the Institutional Review Board of the University of Greifswald.

2.2. Instruments

Alexithymia was assessed using the 20-item version of the Toronto Alexithymia Scale (TAS-20) in German language (Bagby et al., 1994). The TAS-20 is a self-rating scale composed of 20 items rated on a 5-point scale (1 = never applies, 5 = applies always). Three different factors have been identified in the TAS-20 and were confirmed in the German version (Bach et al., 1996): (1) Difficulty in identifying feeling, (2) difficulty in describing feeling and (3) externally oriented thinking.

The lifetime diagnosis of major depressive disorder (MDD)

Table 1
Sample characteristics of SHIP-LEGENDE and SHIP-Trend. Mean and standard deviation for continuous variables, counts and percentage for discrete variables.

	SHIP-LEGENDE ($N = 1980$)	SHIP-Trend ($N = 3799$)	Statistics
Immediate recall (mean, sd)	VLMT 24.7 ± 6.2	NAI 5.2 ± 1.3	N/A
Delayed recall (mean, sd)	VLMT 8.0 ± 3.1	NAI 5.7 ± 1.7	N/A
Age (mean, sd)	55.2 ± 13.7	51.2 ± 15.3	$T = 9.7$, $P < 0.001$
Sex	Females $N = 1048$ (53%)	Females $N = 1945$ (51%)	$Chi^2 = 1.5$, $P = 0.22$
School education			$Chi^2 = 40.3$, $P < 0.001$
<10 years	527 (27%)	807 (21%)	
10 years	1050 (53%)	1991 (52%)	
>10 years	403 (20%)	1001 (26%)	
TAS-20 (mean, sd)	44.9 ± 9.6	41.5 ± 9.1	$T = 13.1$, $P < 0.001$
DIF (mean, sd)	12.6 ± 4.5	10.8 ± 4.0	$T = 15.7$, $P < 0.001$
DDF (mean, sd)	11.9 ± 3.4	10.5 ± 3.4	$T = 14.1$, $P < 0.001$
EOT (mean, sd)	20.4 ± 4.2	20.2 ± 4.4	$T = 1.8$, $P = 0.07$
MDD lifetime	329 (17%)	701 (18%)	$Chi^2 = 3.0$, $P = 0.08$

TAS = Toronto-Alexithymia Scale-20, subscales DIF (Difficulties Identifying Feelings), DDF (Difficulties, Describing Feelings), EOT (Externally Oriented Thinking).

according to DSM-IV criteria was determined using the standardized and computerized Munich-Composite International Diagnostic Interview (M-CIDI) (Wittchen et al., 1998). The M-CIDI is a fully structured interview-based instrument for the assessment of eight major classes of DSM-IV diagnoses including MDD over the lifespan. It was developed based on the WHO−CIDI in order to enhance the feasibility while maintaining the reliability (Wittchen et al., 1998). Excellent psychometric properties for the M-CIDI have been shown (Wittchen, 1994). The computer-assisted interview was conducted clinically experienced interviewers (psychologists). We used the lifetime diagnosis of MDD as a dichotomous outcome measure.

In SHIP-LEGENDE, declarative memory functioning was assessed using a slightly abridged version of the Verbaler Lern- und Merkfähigkeitstest (VLMT), the validated and modified German version of the Rey Auditory Verbal Learning Test (Helmstaedter et al., 2001). It requires consecutive learning of a list of 15 semantically unrelated words (e. g. "bell", "drum") over 3 trials with immediate recall after each trial. After the 3 learning trials are complete, a second word list is presented to the participant to include effects of interference. After a delay of 20 min, the participant is asked to recall the first word list without previous announcement. The total number of correctly recalled words of the three immediate recall trials are summed up to reflect aspects of short-term and working memory (Elger et al., 1997). The score of correctly recalled words after delay was used to assess delayed consolidation and recall.

In SHIP-Trend, the word list of the Nuremberg Age Inventory (NAI) was used to assess the declarative memory. The NAI is a German test developed to measure the cognitive abilities during brain aging (Oswald and Fleischmann, 1999). It consists among others subtests of a list of eight words. Eight words are read to the participant, who is asked to recall as many words as possible immediately. After 20 min the participant is asked to retrieve the eight words previously learned from a list containing eight additional distractor words. The number of correctly identified words is summarized to a sum score minus the number of identified distractor words.

Perceived chronic psychosocial stress was measured using a short version short version of the Trier Inventory for Chronic Stress (TICS) (Schulz et al., 2004). The TICS is a self-rating 57-item instrument assessing chronic stress by capturing the dimensions "work overload", "social overload", "pressure to perform", "work discontent", "excessive demands from work", "lack of social recognition", "social tensions" , "social isolation" and "chronic worrying" on a five-point Likert scale. From the 57-item TICS version, the 12-item Screening Scale for Chronic Stress (SSCS) is derived. Each item asks for the frequency of experience within the last three months. Psychometric properties for the TICS were good in a sample of subjects between 16 and 70 years (Petrowski et al., 2012).

Chronic stress as assessed by the SSCS was only measured in SHIP-

LEGENDE, so that results on SSCS effects could not be replicated in SHIP-Trend.

The missings were mainly due to the psychometric variables TAS-20 score, SSCS as well as VLMT and NAI. Subjects with missing data showed no differences in sex and MDD status compared to subjects included in the analyses. But they were significantly older and had lower education level.

2.3. Statistical analyses

In both samples, linear regression analyses were applied in order to calculate predictive effects of alexithymia and its subfactors on immediate as well as delayed recall. In SHIP-LEGENDE, we also examined the relation between alexithymia and chronic perceived stress. Subsequently, we investigated putative direct effects of chronic stress and interactions with alexithymia on immediate and delayed recall. We also investigated the mediating effect of chronic stress on the path from alexithymia to verbal memory. To account for the non-normal distribution of the outcome variables, confidence intervals and p-values were assessed through bootstrap with 1000 replicates. Analyses were adjusted for age, sex, educational level and lifetime major depression. Analyses were performed using the statistical software STATA 13.

3. Results

3.1. Descriptive statistics

Sociodemographic and health related characteristics of SHIP-LEGENDE and SHIP-Trend are given in Table 1.

3.2. Alexithymia and memory performance

Table 2 presents findings of TAS-20, its subfactors and SSCS as predictors of immediate as well as delayed recall while adjusting for age, sex, school education, and lifetime MDD. To account for the effects of multiple testing (3 TAS subfactors and chronic stress on immediate and delayed recall, $N = 8$), the threshold for significance was set at $p < 0.006$.

In SHIP-LEGENDE, we found significant negative associations of TAS-20 total score with both immediate and delayed recall of words ($p = 2.3E\text{-}6$, $p = 8.7E\text{–}6$ respectively). This effect was carried mainly by the externally oriented thinking (EOT) factor, and partly by the difficulties identifying feelings (DIF) factor, while the difficulties describing feelings (DDF) factor showed no significant effects after correction for multiple testing (Table 2, Fig. 1). In SHIP-Trend, these results were partly confirmed with significant effects of TAS-20 total score on immediate recall ($p = 1.3E\text{–}7$), while associations with delayed recall were weaker and did not reach significance level (Table 2). Still, EOT

Table 2

SHIP-LEGENDE and SHIP-Trend. Multiple linear regression analyses with VLMT/NAI immediate and delayed recall as outcome.

	SHIP-LEGENDE ($N = 1980$)		SHIP-Trend ($N = 3799$)	
	Immediate recall	Delayed recall	Immediate recall	Delayed recall
TAS-20	$\beta = -0.06$ **CI: [−0.09, −0.04]** **p = 2.3E–6**	$\beta = -0.03$ **CI: [−0.04, −0.02]** **p = 8.7E–6**	$\beta = -0.01$ **CI: [−0.02, −0.007]** **p = 1.3E–7**	$\beta = -0.005$ CI: [−0.01, 0.001] p = 0.073
DIF	$\beta = -0.09$ **CI: [−0.14, −0.03]** **p = 1.3E–3**	$\beta = -0.05$ **CI: [−0.08, −0.02]** **p = 0.001**	$\beta = -0.02$ **CI: [−0.03, −0.01]** **p = 9.6E–4**	$\beta = -0.007$ CI: [−0.02, 0.006] p = 0.30
DDF	$\beta = -0.08$ CI: [−0.15, −0.01] p = 0.017	$\beta = -0.05$ CI: [−0.09, −0.01] p = 0.013	$\beta = -0.01$ CI: [−0.03, −0.003] p = 0.016	$\beta = -0.003$ CI: [−0.03, 0.004] p = 0.73
EOT	$\beta = -0.16$ **CI: [−0.22, −0.10]** **p = 1.6E–7**	$\beta = -0.07$ **CI: [−0.10, −0.04]** **p = 2.0E–6**	$\beta = -0.03$ **CI: [−0.04, −0.02]** **p = 3.4E–9**	$\beta = -0.02$ CI: [−0.03, −0.004] p = 0.011
SSCS	$\beta = -0.04$ **CI: [−0.07, −0.01]** **p = 4.2E–3**	$\beta = -0.01$ CI: [−0.02, 0.006] p = 0.24	N/A	N/A
SSCS × TAS-20	$\beta = -0.001$ CI: [−0.00; 0.00] p = 0.25	$\beta = -0.001$ CI: [−0.002; −0.00] p = 0.042	N/A	N/A
SSCS × DIF	$\beta = -0.002$ CI: [−0.007, 0.004] p = 0.55	$\beta = -0.002$ CI: [−0.005, 0.0004] p = 0.091	N/A	N/A
SSCS × DDF	$\beta = -0.005$ CI: [−0.01, 0.003] p = 0.22	$\beta = -0.004$ CI: [−0.008, 0.001] p = 0.093	N/A	N/A
SSCS × EOT	$\beta = -0.006$ CI: [−0.01, 0.0005] p = 0.071	$\beta = -0.002$ CI: [−0.006, 0.001] p = 0.13	N/A	N/A

TAS-20: Toronto Alexithymia Scale-20; DIF: Difficulties Identifying Feelings; DDF: Difficulties Describing Feelings, EOT: Externally oriented thinking, SSCS: Screening Scale for Chronic Stress; Each predictor variable tested in a separate model; analyses adjusted for age, sex, lifetime MDD and education; Significant results corrected for multiple testing ($p < 0.006$) printed in **bold**.
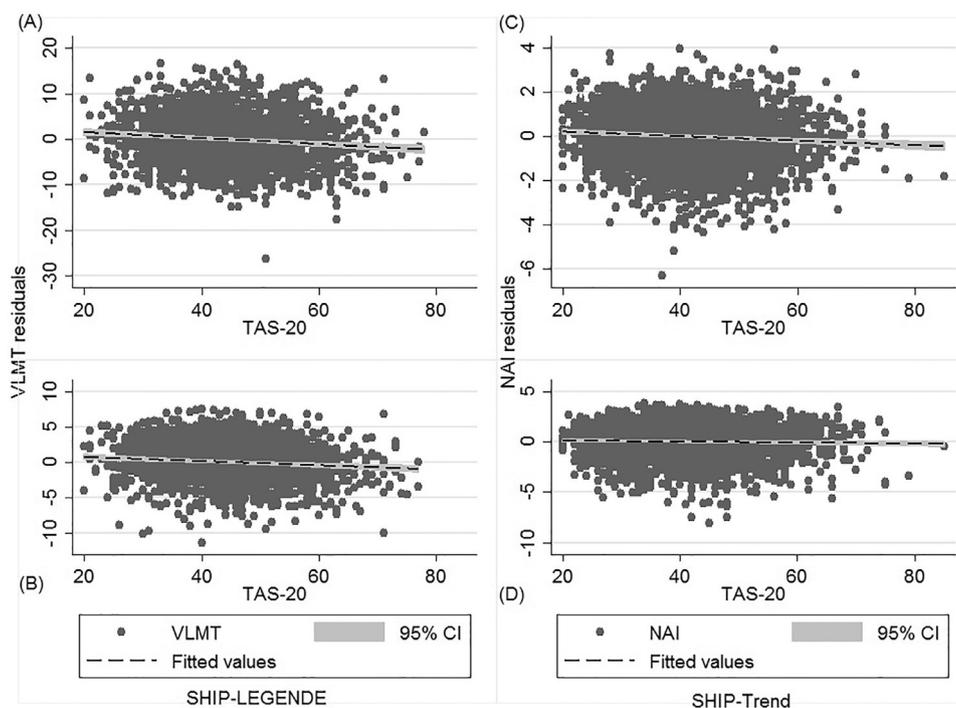

Fig. 1. Direct effect of TAS-20 score on immediate and delayed recall. VLMT and NAI residuals after correction for age, sex, MDD and education. (A) Immediate recall and (B) delayed recall in SHIP-LEGENDE ($N = 1981$), (C) immediate recall and (D) delayed recall in SHIP-Trend ($N = 3799$).

Table 3
Multiple linear regression analyses predicting SSCS in SHIP-LEGENDE.

	SSCS
TAS-20	$\beta = 0.38$
	CI: [0.34, 0.42]
	$P = 9.8E{-}90$
DIF	$\beta = 0.97$
	CI: [0.90, 1.04]
	$p = 7.0E{-}167$
DDF	$\beta = 0.83$
	CI: [0.73, 0.93]
	$p = 3.7E{-}60$
EOT	$\beta = 0.28$
	CI = [0.18, 0.37]
	$p = 1.7E{-}8$

TAS-20: Toronto Alexithymia Scale-20; DIF: Difficulties Identifying Feelings; DDF: Difficulties Describing Feelings, EOT: Externally oriented thinking, SSCS: Screening Scale for Chronic Stress; analyses are adjusted for age, sex, lifetime MDD and education.
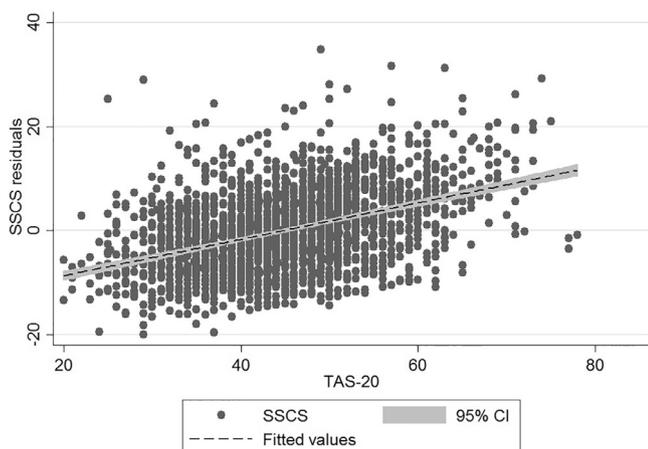

Fig. 2. Direct association between SSCS and TAS-20 in SHIP-LEGENDE ($N = 1981$). SSCS residuals after correction for age, sex, MDD and education.

emerged again as the carrying factor for the associations of alexithymia and memory performance.

3.3. Alexithymia and perceived chronic stress

Alexithymia was positively associated with perceived chronic stress in SHIP-LEGENDE ($p = 9.8E{-}90$). This effect was mainly due to the strong association of DDF and DIF with SSCS (Table 3, Fig. 2).

3.4. Perceived chronic stress and memory performance

SSCS showed a significant negative association with immediate, but not delayed recall in SHIP-LEGENDE ($p = 4.2E{-}3$) (Table 2). Given the strong association between TAS-20 and SSCS (Table 3) we also investigated putative interactional effects between these factors on declarative memory performance. Nominally significant TAS-20 × SSCS effects were found on delayed recall ($p = 0.042$). However, significance was lost when considering the correction for multiple testing. As we observed an association between TAS-20 and SSCS as well as SSCS on immediate recall, we could also test for a mediating effect of SSCS on the path from TAS-20 to immediate recall in SHIP-LEGENDE using the medeff package in STATA (Hicks and Tingley, 2011). We found a significant average causal mediation effect (ACME = −0.26 [−0.53, −0.01]) of alexithymic subjects ($N = 139$) versus non alexithymic subjects ($N = 1841$) (categorized by TAS-20 score < / ≥ 60) with 15% of the negative effect of alexithymia on immediate recall mediated through SSCS.

4. Discussion

Supporting and extending results from previous studies, (Luminet et al., 2006; Öhman et al., 2007; Vermeulen and Luminet, 2009), we found that alexithymia and chronic stress independently predict reduced declarative memory performance. In particular, alexithymia was found to be consistently negatively associated with both immediate as well as delayed recall of words independent from MDD, sex, age, and school education. This effect was mainly carried by the EOT factor. Another major finding of our study is that alexithymia showed significant associations with chronic perceived stress, supporting the view that alexithymic subjects are at particular risk for experiencing high levels of psychosocial stress. This result may represent a mechanism of how alexithymia is linked with different stress-associated mental and physical disorders (Klinger-König et al., 2018; Terock et al., 2015). Given that interaction analyses showed no significant effects after correction for multiple testing on verbal declarative memory performance, our results indicate that the relation of alexithymia and impaired memory performance is more complex and other mechanisms than chronic stress are involved.

Finding that alexithymia is negatively associated with immediate and delayed recall of words corresponds well with results showing that emotions interfere with various steps of learning and retrieving information (for review: Dolan, 2002): For example, there is evidence that emotions influence pre-attentive information processing, i. e. the processing of stimuli even before conscious perception (Esteves et al., 1994) or under conditions of limited attentional resources (Anderson and Phelps, 2001). Emotions are supposed to enhance attention to relevant environmental events, thereby influencing perceptual processing (Evans and Schamberg, 2009; Öhman et al., 2001). Privileged perceptual processing also enables emotional indexing of events of value and thereby facilitates their availability to the long-term memory and other cognitive domains. In the light of these results, our findings suggest that a combination of different processes of memory formation may underlie the association of alexithymia and impaired memory performance. In contrast to the result in SHIP-LEGENDE, alexithymia was not associated with delayed recall in SHIP-Trend. However, the test procedure for delayed recall clearly differed between the cohorts and from the immediate recall in SHIP-Trend which may have contributed to these inconsistencies.

The DIF factor showing negative associations with delayed and particularly immediate recall confirms and extents results from previous studies showing impaired declarative memory performance in subjects high in difficulties identifying feelings (Luminet et al., 2006; Vermeulen and Luminet, 2009). It supports the notion that the ability to identify emotions is important for indexing memories even when these stimuli are not particularly emotionally valenced. This concept is supported by findings from neurobiological studies showing associations of alexithymia with morphological and functional alterations in brain areas relevant to emotion processing and memory formation. For example, Ihme et al. (2013) reported about reduced gray matter volumes of alexithymic subjects in different brain areas including the left amygdala (Ihme et al., 2013). Aust et al., (2013) found that early life stress was associated with reduced volumes of the right hippocampus only in subjects high in alexithymia (Aust et al., 2013).

Chronic perceived stress being negatively associated with immediate, but not delayed recall indicates that early processes of memory formation like perceptive and attentive information processing are particularly affected by chronic stress. This notion is in line with results from different neuroimaging studies: The short-term memory highly depends on the integrity of neocortical regions, particularly the prefrontal cortex (PFC) (Mizoguchi et al., 2000), a brain region relevant

to the conscious control of attentional and perceptual processes. Function and structure of the PFC have been shown to be particularly sensitive to the detrimental effects of lasting psychosocial stress (Arnsten, 2009). For example, Liston et al. (2009) reported that chronic psychosocial stress selectively disrupts attentional control processed by the PFC. Hence, finding a specific reduction of immediate, but not delayed recall in subjects experiencing high levels of chronic stress may reflect disrupted PFC-mediated processes like working memory and attention regulation.

Taken together, in the light of previous studies our findings suggest that alexithymia and perceived chronic stress independently interfere with different processes of memory formation. Specifically, chronic stress may be associated with impaired immediate recall by affecting attention regulation and priming processes mediated in the PFC, while deficits in immediate and delayed declarative memory performance of alexithymic subjects may more depend on deficits in emotion-dependent processes facilitated in limbic brain structures.

Our finding of strong associations of perceived chronic stress with alexithymia provides further support for the "alexithymia-stress hypothesis", stating that alexithymia is related to poor resistance to stress (Martin and Pihl, 1986). While most existing studies tested the reactivity of acute emotional stressors (for example de Timary et al., 2008), there is a paucity of studies investigating the effects of chronic stress conditions on alexithymic subjects. Considering that chronic psychosocial stress is an important risk factor for various mental and physical health conditions including depression, anxiety, chronic pain, cardiovascular disease and metabolic syndrome (Bishop et al., 2004; Blackburn-Munro and Blackburn-Munro, 2001; Melchior et al., 2007; Vitaliano et al., 2002), our finding may contribute to explain the associations of these stress related disorders with alexithymia. Moreover, finding a significant mediating effect of chronic stress on the path from alexithymia to immediate recall of the declarative memory highlights that chronic psychosocial stress is a relevant debilitating factor for alexithymic subjects and may contribute to unfavorable sociodemographic characteristics like lower education and lower socioeconomic status.

Our study has several strengths including the large and well-characterized general-population samples and adjustment for various sociodemographic and clinical factors. However, some limitations need to be acknowledged. First, the cross-sectional design of the study prevents from drawing any causal conclusions. More specifically, it remains unclear whether impaired declarative memory is a result of alexithymia and chronic stress or vice versa. However, the theoretical background and previous findings from experimental studies suggest that difficulties in the cognitive processing of emotions of alexithymic subjects and of subjects experiencing high levels of chronic stress represent a causal mechanism for memory impairments. Second, the study design in both samples included some test procedures which were slightly abridged or modified compared to the original versions in order to minimize the test burden for each participant. Although the procedures clearly differ from the established test procedures, we believe that the outcomes used in this study sufficiently well reflect the performance of the different dimensions of memory performance. Third, in SHIP-LEGENDE and SHIP-Trend, different methods were applied for the assessment of the declarative memory performance. In particular, testing delayed recall in SHIP-Trend was clearly different compared to the procedure in SHIP-LEGENDE and immediate recall in SHIP-Trend. This difference may contribute to explain the inconsistence between the two cohorts. Finally, alexithymia and chronic stress were measured using self-report questionnaires. Although well-established and widely used, the capacity particularly of alexithymic subjects to reflect on ones feelings and the individual abilities to identify and describe them has been called into question. In conclusion, our study provides clear evidence for an association of alexithymia and particularly the DIF and EOT factors with impaired declarative memory performance in the general population, even after controlling for various demographic, behavioral and

clinical covariates. Moreover, to our best knowledge, this is the first study providing evidence for a strong relation of alexithymia with perceived chronic psychosocial stress. Finally, the results of mediation analyses suggest that chronic stress represents a mechanism contributing to the relation of alexithymia and declarative memory functioning. Our results help to clarify the association of alexithymia with different stress-related mental and physical disorders Also, finding impaired memory performance in may help to unfavorable sociodemographic characteristics of alexithymic subjects.

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Conflicts of Interest

HJG received travel grants and speakers honoraria from Fresenius Medical Care and Janssen CILAG. He received
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Supplementary materials

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