The German Multifactorial Memory Questionnaire (MMQ) — Psychometric properties, normative data, and the impact of neuropsychiatric symptoms

Table 1

Variable	mean	sd	min	max
Age	51.18	17.63	19.00	86.00
GDS	1.84	2.34	0.00	11.00
BAI	5.47	5.12	0.00	25.00
PCS	39.99	3.47	20.73	48.44
MCS	44.54	5.62	22.79	53.61
CPI	1.96	0.56	1.00	4.00
CPI attention	1.88	0.61	1.00	4.00
CPI executive	2.01	0.64	1.00	4.33
CPI memory	1.93	0.61	1.00	4.00

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Methods

Please refer to the manuscript for all information. Only analyses are reported here.

Participants

Table 1 in this script only includes the metric infos. The categorical information from the analyses above have been added to the table by hand.

Results

Psychometric properties

Variability. Prior to computing percentiles, the shape of the distribution for each scale was analyzed to test for normal distribution. All skewness and excess kurtosis values were well within the range of -1.0 to 1.0 for the three MMQ scales, indicating normal distribution (Satisfaction: skewness = -0.92, kurtosis = 0.55; Ability: skewness = -0.59, kurtosis = 0.48; Strategy: skewness = 0.13, kurtosis = 0.05; Fig. 2A). Further details of the distribution of each MMQ scale, including mean and standard deviation for the calculation of standardized norm scores like z-scores are provided in Table 2.

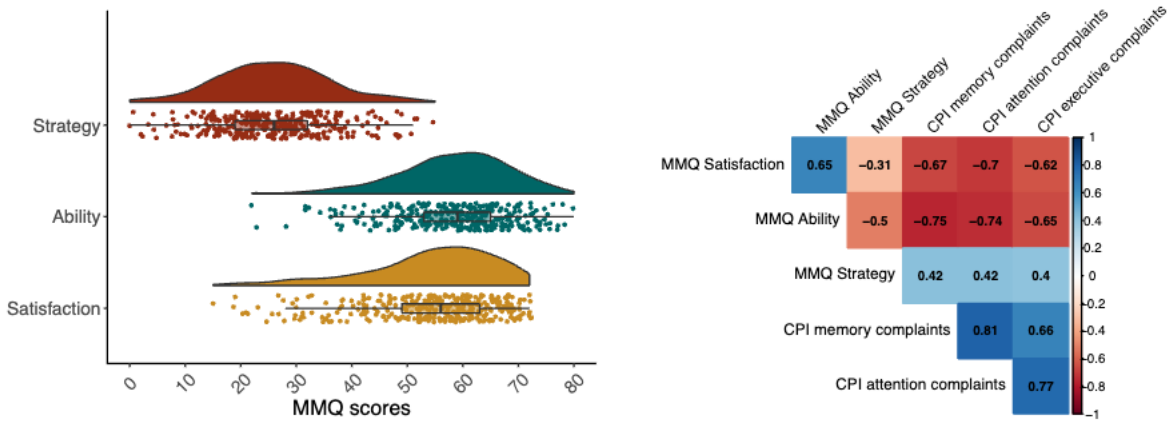

Figure 1. **A** MMQ variability: Raincloud plots illustrating the normal distribution of MMQ scales. **B** MMQ validity: Construct validity correlation matrix of MMQ scales showing significant Pearson correlation coefficients with CPI scales.

Validity. To assess the validity of the German MMQ, we analyzed its associations with the scales memory, attention, and executive complaints of the CPI. As shown in Fig. 2B, less complaints in all CPI domains were strongly associated with a higher MMQ Satisfaction and self-rated Ability and a medium-sized decrease in use of strategies in the MMQ. Detailed test statistics on the correlations of the MMQ scales with questionnaire measures can be found in Table 3.

Table 2

Distribution and retest information of the MMQ scales in the German normative group.

	n	mean	sd	se	min	max
mmq.mmq_c	336.00	54.26	11.67	0.64	15.00	72.00
mmq.mmq_a	336.00	58.21	10.04	0.55	22.00	80.00
mmq.mmq_s	336.00	25.99	9.95	0.54	0.00	55.00
mmq.mmq_s_internal	336.00	10.32	6.09	0.33	0.00	34.00
mmq.mmq_s_external	336.00	15.67	5.20	0.28	0.00	28.00

Reliability. We found excellent internal consistency for the MMQ scales Satisfaction (α = .93, 95% CI [.92, .94]) and Ability (α = .90, 95% CI [.89, .92]) and good internal consistency for the MMQ Strategy scale (α = .84, 95% CI [.81, .86]). As reported in Table 2, we also found good test-retest reliability for the scales Satisfaction and Ability and acceptable test-retest reliability for the MMQ Strategy scale after an average interval of eight months (range: 3.30 - 9.13, SD = 1.27). Table 2 also provides reliable change scores for each scale (95% CI), i.e., the number of points that indicate a clinically significant change on the respective scale.

Correlates of metamemory

Demographic variables and questionnaire data. Age had a small but significant association with MMQ Satisfaction ($r = -.11$, 95% CI $[-.21, .00]$, $t(334) = -1.97$, $p = .050$) and Ability ($r = -.13$, 95% CI $[-.24, -.03]$, $t(334) = -2.45$, $p = .015$), but not with Strategy ($t(334) = -1.44$, $p = .150$). Men and women did not differ with respect to memory satisfaction ($t(334) = 1.28$, $p = .201$) or self-rated ability ($t(334) = 0.98$, $p = .328$), but men scored on average 2.41 points more on the Strategy scale than women (d = -0.24,

$t(334) = -2.07$, $p = .039$). The level of education did not impact any of the three MMQ scales (Satisfaction: $\chi^2(3) = 0.62$, $p = .892$; Ability: $\chi^2(3) = 0.50$, $p = .918$; Strategy: $F(3, 332) = 0.90$, $p = .443$). Considering the very small effect of age on Satisfaction and Ability, and the small effect of gender on Strategy, we decided to include all age groups into one normative sample in accordance with the original MMQ normative data by Troyer & Rich (2018). The normative data using percentile ranks for Satisfaction and Ability are presented in Table 3 and for the Strategy scale in Table 4 with recommendations for interpretation provided in Table S2.

Based on the acquired questionnaire data (Fig. 2), we found that higher scores on MMQ scales Satisfaction and Ability were correlated with lower depressiveness (GDS), lower anxiety (BAI), less sleep problems (PSQI), and better mental health (SF-12), while the opposite pattern was observed for the Strategy scale. Physical health (SF-12) was not correlated with any of the collected measures. Detailed statistics on the correlations can be found in Table 3. Interestingly, the effect that higher anxiety and depressiveness are associated with lower Satisfaction and Ability was already seen at subclinical levels of anxiety (BAI) and depressiveness (GDS) with a gradual decrease of Ability and Satisfaction scores from minimal to mild and moderate anxiety and depressiveness (Fig. 3). Importantly, this is not specific to clinically relevant severe levels. In fact, even participants with mild compared to no or minimal anxiety or depressiveness show significantly lower subjective memory ability (BAI: $d = 0.47$, $t(311) = 3.42$, $p = .001$, ; GDS: $d = 0.87$, $t(328) = 4.31$, $p < .001$) and memory satisfaction (BAI: $d = 0.51$, $t(311) = 3.70$, $p < .001$; GDS: $d = 1.15$, $t(328) = 5.75$, $p < .001$).

Neuropsychiatric correlates of memory satisfaction and self-rated memory ability across the lifespan. Next, we calculated two regression models, using Satisfaction and Ability as the respective outcome measures, to account for the intercorrelation between age and the significant questionnaire measures. Here we found that depressiveness, anxiety, and sleep problems remained significant predictors for memory satisfaction and self-rated

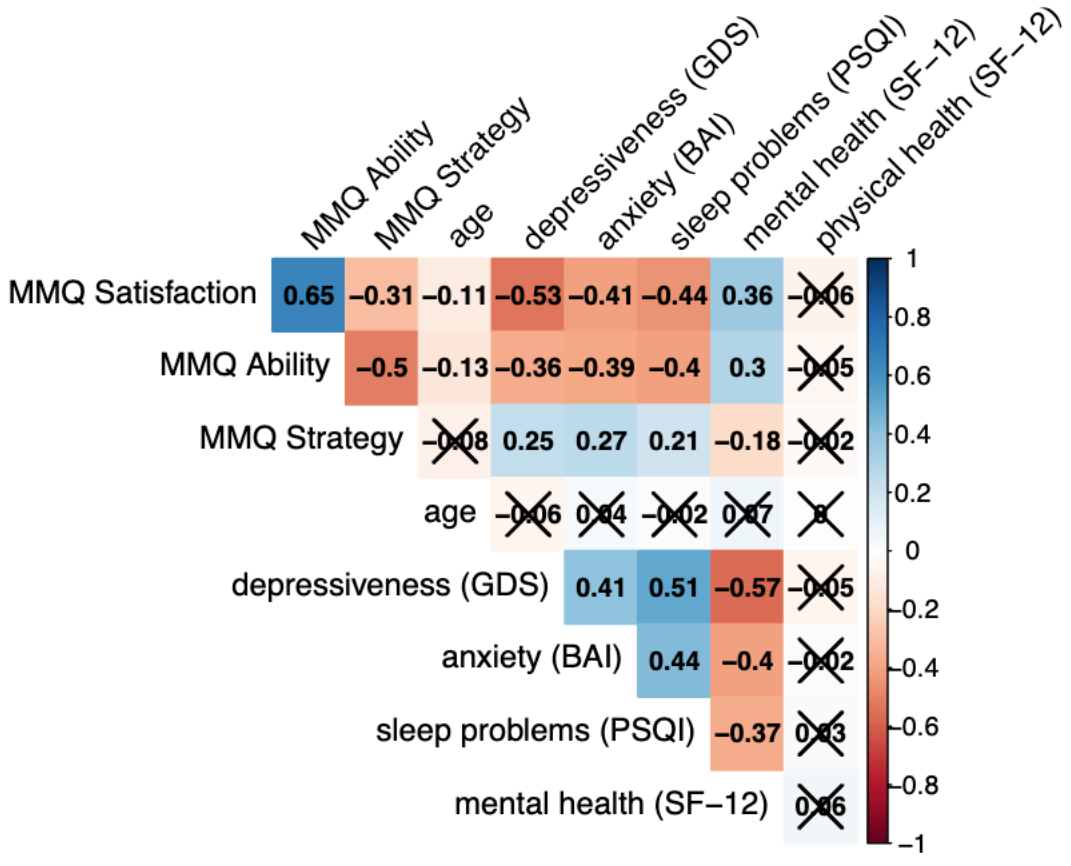

Figure 2. **Correlation matrix of the MMQ scales with age and neuropsychiatric self-report measures.** Pearson correlation coefficients are portrayed for significant correlations and show that MMQ Satisfaction and Ability scores decrease minimally with increased age and increase with lower depressiveness (GDS), anxiety (BAI), and sleep problems (PSQI), and better mental health (SF-12), with reversed pattern for Strategy scores.

ability respectively, but mental health did not (Satisfaction: $t(330) = 0.59$, $p = .556$; Ability: $t(330) = 1.12$, $p = .263$). Regression models using the significant predictors age, GDS score, BAI score, and PSQI score explained 36% of the variance in the Satisfaction score ($F(4, 331) = 47.32$, $p < .001$) and 25% of the variance in the Ability score ($F(4, 331) = 27.97$, $p < .001$). To address the question how these significant predictors affect the self-rated ability and memory satisfaction across the lifespan, we defined three age groups, i.e., young (18 - 40 years), middle-aged (41 - 60 years), and older adults (61 - 86 years) and calculated

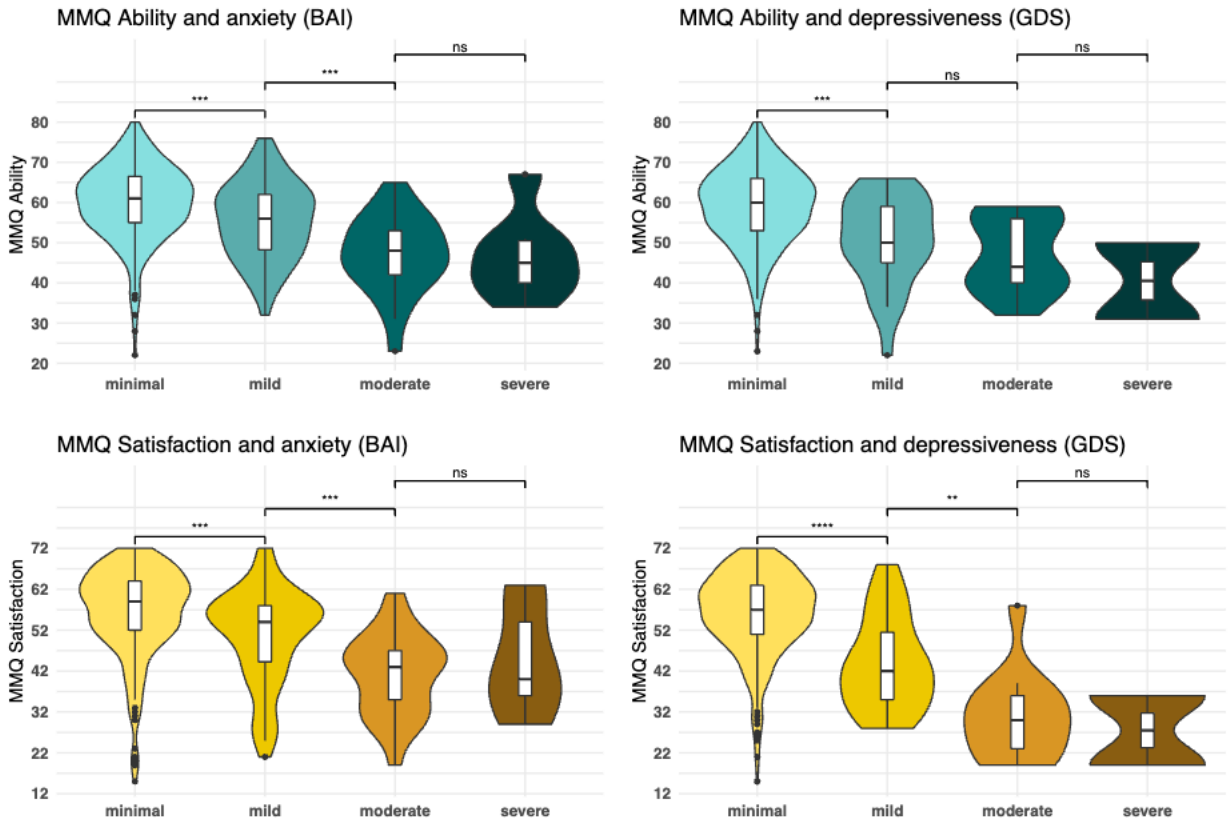

Figure 3. **MMQ Ability and Satisfaction scores across levels of anxiety and depressiveness.** Increases of anxiety and depressiveness levels from minimal to mild already significantly decrease self-rated ability and satisfaction. Participants with severe levels, who are excluded from other analyses, are portrayed behind the grey shading, and do not differ significantly in their Ability and Satisfaction scores in comparison to participants with moderate anxiety and depressiveness.

separate regression models for each age group with the MMQ scales Ability and Satisfaction as outcome measures (Fig. 5). Interestingly, we observed a differential impact of the three factors on metamemory, although they did not differ between age groups (depressiveness: $\chi^2(2) = 2.16$, $p = .340$; anxiety: $\chi^2(2) = 3$, $p = .223$; sleep: $\chi^2(2) = 2.11$, $p = .349$): Depressiveness was associated with poorer memory satisfaction in all age groups, but relevant for self-rated ability only in older adults. Anxiety affected both memory satisfaction and self-rated ability, but only in young and older adults. Lastly, sleep problems were associated with memory satisfaction in middle-aged adults and self-rated memory ability in young and middle-aged adults.

Supplementary information

Table 3

Correlations of MMQ scales with questionnaire data

	Satisfaction, r	Satisfaction, 95% CI	Satisfaction, t(334)	Satisfaction, df	Satisfaction, p	Ability, r	Ability, 95
CPI – memory	-.67	[-.72, -.60]	-16.34	334	< .001	-.75	[-.80, -.70]
CPI – attention	-.70	[-.75, -.64]	-18.00	334	< .001	-.74	[-.78, -.68]
CPI – executive	-.62	[-.68, -.55]	-14.46	334	< .001	-.65	[-.71, -.59]
GDS	-.53	[-.61, -.45]	-11.50	334	< .001	-.36	[-.45, -.27]
BAI	-.41	[-.49, -.32]	-8.18	334	< .001	-.39	[-.47, -.29]
PSQI	-.44	[-.53, -.35]	-9.03	334	< .001	-.40	[-.49, -.31]
SF-12, mental health	.36	[.27, .45]	7.09	334	< .001	.30	[.20, .39]
SF-12, physical health	-.06	[-.17, .04]	-1.18	334	.239	-.05	[-.15, .06]