AMERICAN PSYCHOLOGICAL ASSOCIATION

Journal of Experimental Psychology: Learning, Memory, and Cognition

© 2022 American Psychological Association
ISSN: 0278-7393

2023, Vol. 49, No. 7, 1091–1098
https://doi.org/10.1037/xlm0001165

The Impact of Affective Information on Working Memory: A Psychometric Approach

Annette Brose[1], Johanna M. Grosse Rueschkamp[1], Peter Kuppens[2], Denis Gerstorf[1], and Florian Schmiedek[3]

[1] Department of Psychology, Humboldt-Universität zu Berlin
[2] Faculty of Psychology and Educational Sciences, KU Leuven
[3] DIPF | Leibniz Institute for Research and Information in Education, Frankfurt/Main, Germany

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

It has been debated whether working memory (WM) performance is modulated by the valence of the stimuli that are being processed. A recent meta-analysis revealed that at the behavioral level and in individuals without mental health problems, mean-level performance differences in WM tasks with neutral versus affective conditions are small to negligible. We took this finding an important step further by employing a psychometric approach. This is an important refinement of previous work because even in the absence of mean-level differences, differential processing of affective versus nonaffective information may still be occurring. We examined whether at the construct level, 2 latent WM factors could be distinguished in capturing the processing of neutral and affective stimuli, respectively. Applying confirmatory factor analyses (N = 183 university students) to a battery of 18 tasks (3 n-back paradigms crossed with 3 stimulus types and neutral vs. affective valence), the 2 factors correlated perfectly. This result was replicated when neutral stimuli were analyzed together with either positive or negative stimuli. Based on individual differences, the processing of affective versus nonaffective stimuli in WM therefore cannot be distinguished, at least not in a student sample of younger adults.

Keywords: working memory, affect, emotion, psychometric approach

Supplemental materials: https://doi.org/10.1037/xlm0001165.supp

Working memory (WM) can be defined as "the ensemble of components of the mind that hold a limited amount of information temporarily in a heightened state of availability for use in ongoing information processing" (Cowan, 2017). WM is relevant for controlled cognitive processing (Barrett et al., 2004), and individual differences in WM capacity are strongly related to intelligence (Süß et al., 2002). Yet, the relevance of WM extends beyond cognition. For example, a recent meta-analysis showed that repetitive negative thinking as common in individuals prone to affective disorders is related to "difficulty discarding no longer relevant material from working memory" (Zetsche et al., 2018, p. 56). Relatedly, there is a growing literature on how WM processing of affective information relates to well-being and psychopathology (e.g., Levens & Gotlib, 2010). In this literature, it is argued that WM operating on affective information is distinct and qualitatively different from WM processing neutral information, and that it should therefore merit separate study and attention. Yet, strong evidence for this claim is yet missing. The aim of the present study was therefore to examine the notion that WM operating on affective information is distinct from its application to nonaffective information using a psychometric approach.

Specifically, we aimed to investigate the potential modulatory effects of stimuli's valence on WM performance on a number of empirical-theoretical bases. WM training with affective but not neutral stimuli has been shown to have transfer effects on performance on an emotional Stroop task (Schweizer et al., 2011). Also, people with higher well-being performed better on updating positive, but not negative stimuli in WM (Pe et al., 2013). Relatedly, depressed patients were found to be slower in disengaging from sad and faster in disengaging from happy facial expressions in n-back tasks in comparison to healthy controls (Levens & Gotlib, 2010). These findings may speak for valence-specific processing of material in WM, with potentially far-reaching consequences, for example on designing interventions for patients with affective disorders.

Yet, meta-analytic evidence recently revealed that at the behavioral level and in individuals without mental health problems, mean-level performance differences in WM tasks with neutral

This article was published Online First August 25, 2022.

Annette Brose https://orcid.org/0000-0001-6774-2189

This article was supported by a Grant awarded to Annette Brose by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), BR 3782/3-1 as well as the Caroline von Humboldt Award awarded to Annette Brose by the Humboldt-Universität zu Berlin in 2014. We thank Madeline Pe for thoughtful discussions when planning this study.

The study was approved by the Ethics Committee of the Department of Psychology, Humboldt-Universität zu Berlin.

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

Correspondence concerning this article should be addressed to Annette Brose, who is now at the Department of Education and Psychology, Freie Universität Berlin, Schwendener Straße 27, 14195 Berlin, Germany. Email: annette.brose@fu-berlin.de

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

versus affective conditions were small to negligible (Schweizer et al., 2019). The authors analyzed performance differences in tasks containing affective versus neutral task-irrelevant distractors and tasks requiring the processing of affective versus neutral stimuli in WM. The virtual absence of valence-related performance differences is in line with the argument that while affective information generally receives some prioritization over the processing of neutral information (Pessoa, 2009), it would not override the primary goals related to task performance on the WM tasks (Schweizer et al., 2019). More precisely, WM performance requires goal-directed processing to be successful. Emotional stimuli, in comparison to neutral, generally receive enhanced perceptual processing, which results in better encoding and memory (Dolcos et al., 2017). Given the latter, one might speculate whether affective stimuli, when processed during some WM task, affect the efficiency of WM (e.g., pursuing task goals such as continuously updating stimuli might be impeded because affective stimuli, once processed, might be more difficult to be expelled from WM when no longer relevant; Joormann & Gotlib, 2008). Such effects are, however, unlikely when considering the low affective significance of stimuli in WM tasks—they should not override goal-directed behavior, at least not in psychologically healthy adults (Schweizer et al., 2019).

In the current study, we took the meta-analysis' finding an important step further by employing a psychometric approach. We examined whether at the construct level, two latent WM factors can be distinguished, one processing neutral stimuli and one processing affective stimuli. This psychometric approach is an important refinement of previous work because even in the absence of mean-level differences, it may still be that differential processing of affective versus nonaffective information occurs. In other words, this research complements that by Schweizer et al. (2019) because mean-level differences provide no information regarding whether individuals' performance scores' rank orders are correlated across tasks, and thus, whether the tasks measure the same underlying ability. Especially given the possibility of specific associations between the processing of affective—but not neutral—information in WM and some outcome variable (see above), it is important to know whether two latent abilities can be distinguished, and if so, whether they require specific attention for example in the development of WM trainings or interventions.

Similar to Schweizer et al. (2019), we did not expect to find distinguishable valence-dependent WM abilities in a student sample of younger adults. Individual differences in WM capacity seem to emerge because individuals' ability to establish, maintain, and update temporary bindings between items and context information differ (Oberauer, 2019; Wilhelm et al., 2013). For employing these abilities, as is common in WM tasks, the content of the items should not matter if one's goal is to stay on task. That is, we expected that WM can shield the salience of affective information, in accordance with the idea that WM may serve to regulate emotion, for example because high load in WM reduces resources for affective processing (Mikels & Reuter-Lorenz, 2019). Only if one's goal structure changes during WM engagement, for example when a stimulus signals the requirement of regulation, WM performance may be interrupted. However, in accordance with Schweizer et al. (2019), we do not expect that this prioritization is generally taking place during WM task performance.

We developed a battery of three different *n*-back type WM subtasks for examination, crossed with three stimulus types and neutral versus affective valence, resulting in 18 subtasks. Our focus lay on affective information on WM in cases the information was task-relevant, and not on potential effects of distractors' affective valence on WM. The use of multiple task types and stimulus materials allowed us to examine the potential distinctiveness of WM when processing affective and neutral stimuli at the latent or construct level, thus avoiding erroneous conclusions due to task-specific effects (Schmiedek et al., 2014).

Method

Participants

This study included 183 university students (48% women, age range: 20–32, M = 24, SD = 3.1). Participants were recruited via online advertisements, university mailing lists and flyer boards. Originally, 189 persons commenced the study. Two participants stopped during session 1 without letting the instructors know why; four did not return for session 2 without notice and could not be reached by phone or e-mail any longer[1]. To approximate our sample's mental health status, we compared our sample's means on the WHO well-being index (WHO-5) and Center for Epidemiological Studies Depression (CES-D) scale with norm values as established in the German population (929 adults between 14 and 39 years in case of the WHO-5; Brähler et al., 2007; 1298 adults between 14 and 80 years in case of the CES-D; Hautzinger & Bailer, 1993). This focus on mental health status and specifically affective well-being/disorder was chosen as vulnerability in experiencing affective distress might increase distinct processing of affective and neutral material (see introduction). According to confidence intervals (CI), WHO-5 scores in our sample, 95% CI [14.68, 15.94], were lower than those reported by Brähler, 95% CI [18.05, 18.67]. Also, CES-D scores in our sample, 95% CI [15.43, 18.11], were higher than reported by Hautzinger and Bailer, 95% CI [13.74, 14.86]. In view of percentiles, 21% of our participants were above the cutoff value potentially indicating depressive disorder as established in the German population (sum score of 23; Hautzinger & Bailer, 1993). Participants received monetary compensation for participation (10€/hour). The following measures of this study are not included in the analyses: indicators of stress, well-being and emotion regulation.

Procedure

Participants expressed their interest to participate by following an online link provided on the advertisement. Participants were then contacted by telephone and invited for two laboratory

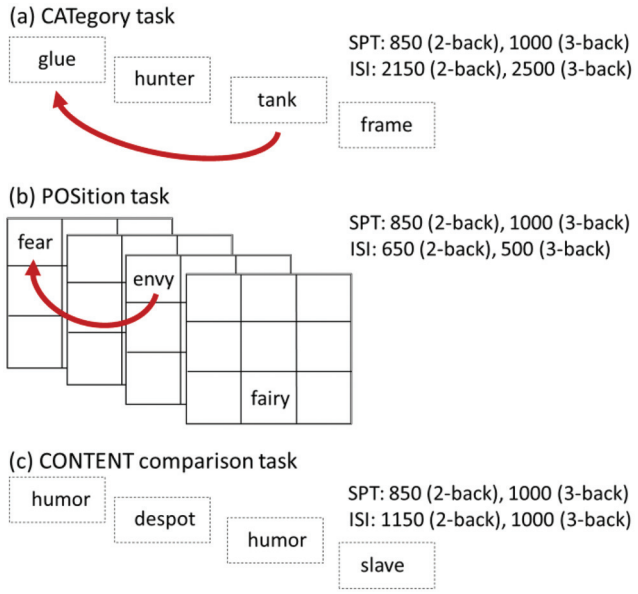
[1] Please note that according to the following descriptive statistics, the individuals dropping out of the study do not obviously differ from the remaining sample (i.e., most scores lie within one *SD* above/below the sample mean; exceptions are positive affect where one drop-out score was about 1.5 *SD*s above the mean, as well as perceived stress where one drop out score is the highest of all scores): M_{age} = 24,78, SD_{age} = 3.11, age range drop-outs = 21–27; $M_{CES\text{-}D}$ = 16.77, $SD_{CES\text{-}D}$ = 9.34; CES-D range drop-outs = 10–22, $M_{negative\ affect\ (na)}$ = 2.26, SD_{na} = 0.63; na range drop-outs = 2.00 – 2.80; $M_{positive\ affect\ (pa)}$ = 3.39, SD_{pa} = 0.61; pa range drop-outs = 3.40 – 4.30; $M_{perceived\ stress(ps)}$ = 2.73, SD_{ps} = 0.64; ps range drop-outs = 1.60 – 4.30. These comparisons are limited to measures that were assessed in Session 1, and to four out of six individuals because the other two quit before working on the self-report questionnaires.

sessions, each lasting 2.5 hr. Sessions were held in groups of two to five participants, all working on personal computers. The interval in-between sessions was approximately 1 week.

Measures

WM was measured with three common *n*-back type tasks (see Figure 1), the Category (CAT) task (e.g., Pe et al., 2013), the Position (POS) task (e.g., Schmiedek et al., 2009), and the Content Comparison (CONTENT) task (Braver et al., 1997). We used *n*-back type tasks because they measure WM capacity well (e.g., Schmiedek et al., 2009). Each of the task types was presented with three stimulus types (pictures, words, faces) and two valences of stimulus types (neutral, affective), resulting in 3 (task type) x 3 (stimulus types) x 2 (valence) = 18 subtasks. As for stimulus material, we worked with subsets of validated sets of pictures (Lang et al., 1993), words (Grandy et al., 2020), and faces (Ebner et al., 2010). To have a sufficient number of neutral pictures, the set was complemented with freely accessible, license-free pictures from pixabay (https://pixabay.com). More information on stimulus material is provided in the Supplemental Materials S1 to S4. All subtasks were measured with two levels of memory load (2-back, 3-back). Each subtask was repeated three times (i.e., three blocks per subtask), with 26 stimuli (2-back tasks) and 27 stimuli (3-back tasks) per block, and with eight of them being targets. In all affective versions of the tasks, half of the stimuli were positive and half were negative. Also, we allowed a maximum of three items of the same valence in a row.

Figure 1
Examples of the Three N-Back Task Types Under Study



Note. 2-back versions of the three task types with words as stimulus material; SPT = stimulus presentation time; ISI = inter stimulus interval; (a) represents the neutral version of the CAT task in which participants evaluated whether a word belongs to the category (objects or persons) as the word presented two steps back; (b) represents the affective version of the POS task in which participants evaluated whether the position of a word is the same as of the one two steps back; (c) represents the affective version of the CONTENT task in which participants evaluate whether a word is the same as the word presented two steps back; SPTs and ISIs were constant across different subtasks of one task type. See the online article for the color version of this figure.

The CAT Task

Stimuli were presented sequentially in the middle of computer screens. Participants indicated whether a stimulus belonged to the same category as the stimulus presented two (three) steps back. In the *picture* subtasks, the neutral categories were 'living being versus object', and the affective categories were 'positive versus negative content'. In the *words* subtasks, the categories were 'person versus object' (neutral) and 'positive versus negative content' (affective). In the *faces* subtasks, the categories were 'young versus old neutrally looking faces' (neutral) and 'happy versus sad faces' (affective).

The POS Task

Stimuli were presented at varying positions in a 3-by-3 grid. Participants were asked to indicate whether a stimulus occurred in the same position as the stimulus two (three) steps back. The *picture* subtasks contained either neutral or affective (positive and negative) pictures; the *words* subtasks contained neutral or affective words, and the *faces* subtasks contained either neutral or affective faces.

The CONTENT Task

Stimuli were presented sequentially in the middle of computer screens. Participants were asked to indicate whether a stimulus was identical to that presented two (three) steps back. Four of the eight targets and two of the nontargets were also repeated in nontarget positions of the series. In the *picture* subtasks, only neutral pictures or only positive and negative pictures were presented. In the *words* subtasks, only neutral words or only positive and negative words were presented. In the *faces* subtasks, only neutral faces or only positive and negative faces were presented.

The 2-back tasks were presented in session 1, the 3-back tasks in session 2. Task order was held constant across sessions: CAT subtasks (1.1: pictures, 1.2: words, 1.3: faces); POS subtasks (2.1: pictures, 2.2: words, 2.3: faces); CONTENT subtasks (3.1: pictures, 3.2: words, 3.3: faces). All task types were instructed by the experimenters. The *picture* subtasks of the CAT task (1.1) were preceded by four practice trials in both sessions. All other tasks were preceded by two practice trials. The tasks were solved by pressing yellow (targets, right side) or blue (nontargets, left side) marked keys on the keyboard. New blocks were started by pressing the space bar.

Data Preprocessing and Statistical Analyses

Accuracies and reaction times (RTs) of single items were set to missing if RTs were low. Specifically, for each task, we determined the reaction time (RT) at which the sample's performance was above chance level. This varied between 250 ms. in the 2-back version of the POS task and 340 ms. in the 3-back version of the CAT task. We then aggregated accuracy scores and RTs of correct items per block, kept only those blocks for subsequent analyses in which the percentage of correctly answered items was above chance level, and then examined the reliabilities at the subtask level (18 subtasks, see Table 1; e.g., six blocks of the CAT task: pictures, neutral version, including 2- and 3-back blocks).

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 1
Descriptive Statistics and Reliability Estimates for All Subtasks

	Accuracy					Reaction time				
Subtasks	*M*	*SD*	Kurt.	Skew	Rel.	*M*	*SD*	Kurt.	Skew	Rel.
CAT_pic_aff	75	8.3	−0.45	0.25	0.76	1,045	275	0.25	0.89	0.94
CAT_pic_neu	79	9.2	−0.39	−0.18	0.76	956	257	0.91	1.11	0.93
CAT_word_aff	77	10.0	−0.54	−0.11	0.80	1,030	288	−0.32	0.59	0.95
CAT_word_neu	81	9.7	−0.37	−0.33	0.81	956	251	0.22	0.83	0.95
CAT_faces_aff	84	9.2	0.20	−0.63	0.79	855	226	0.71	1.00	0.94
CAT_faces_neu	87	8.5	0.24	−0.80	0.80	812	204	0.80	1.08	0.95
POS_pic_aff	87	7.8	2.06	−1.27	0.73	643	121	0.34	0.46	0.92
POS_pic_neu	87	7.8	1.02	−1.17	0.77	627	115	0.53	0.41	0.92
POS_word_aff	88	7.1	2.18	−1.36	0.75	591	109	1.05	0.54	0.92
POS_word_neu	88	7.7	2.67	−1.37	0.76	586	107	1.24	0.55	0.93
POS_faces_aff	88	7.2	3.35	−1.54	0.72	565	104	1.17	0.62	0.92
POS_faces_neu	90	7.0	2.81	−1.52	0.77	554	101	1.53	0.68	0.93
CONTENT_pic_aff	90	5.5	8.44	−1.84	0.70	645	99	1.61	0.61	0.93
CONTENT_pic_neu	90	5.6	1.45	−1.01	0.69	627	96	1.31	0.52	0.93
CONTENT_word_aff	89	6.0	1.63	−1.15	0.71	595	110	3.72	1.26	0.93
CONTENT_word_neu	88	6.6	1.35	−1.14	0.74	592	104	2.43	0.99	0.92
CONTENT_faces_aff	86	5.9	2.07	−0.92	0.67	608	87	2.40	0.55	0.92
CONTENT_faces_neu	86	6.1	1.19	−0.68	0.70	607	87	3.09	0.52	0.92

Note. CAT = category task; POS = position task; CONTENT = content comparison task; pic, word, faces = stimuli were pictures, words, faces; aff, neu = stimuli were affective, neutral; Kurt. = Kurtosis; Rel. = reliability (α).

Given acceptable reliabilities (see Table 1), mean accuracies and RTs across six blocks were computed for each subtask and used for subsequent analyses. Data was analyzed using Mplus Version 8.3.

Results

Tables 1 and 2 provide descriptive statistics and correlation matrices of all dependent variables.

Confirmatory Factor Analyses

All aggregated task scores were modeled simultaneously by employing confirmatory factor analyses. Following usual practice in the analysis of WM (e.g., Wilhelm et al., 2013), we gave priority to the analysis of accuracy scores and then also considered RTs. We specified nested models with one or two WM factors (either distinguishing between neutral and affective stimuli or not). We started with models that included two kinds of method factors: for task type and for stimulus material. These method factors were specified as being orthogonal to the WM factor(s), and only two of each kind of method factors were explicitly modeled (Eid, 2000; see Figure 2). Having observed mainly small loadings on the stimulus-material factors, but high correlations between the faces tasks within each task type, we removed the stimulus-type method factors, but kept the three residual correlations among the faces subtasks[2] (see Figure 2). The CONTENT task served as reference factor for task type (we had modeled all three possibilities, and this was the best fitting model). In accordance with modification indices, we additionally modeled a correlation between the task type factors, and in the RT models, we included additional residual correlations (i.e., correlations between the neutral and affective versions of the CAT task with pictures, the POS task with pictures, the CONTENT task with pictures, and the CONTENT task with words; please see Figure 2). Removing the former would result in only very minor decrease of model fit (Supplement S8, Models 6 and 13); removing the latter results in RMSEA and CFI-values indicating inacceptable model fit (Supplement S8, Models 7 and 14).

For answering our central research question, we first specified two correlated WM factors (affective vs. neutral). All nine subtasks with affective stimuli were indicators of the affective WM factor; the nine neutral subtasks were indicators of the neutral WM factor (see Figure 2). Model estimation terminated normally; model fit was acceptable, RMSEA = .06, CFI = .97, SRMR = .03. Yet, the latent variable covariance matrix was not positive definite because the correlation between the two WM factors was estimated to be 1.01, *SE* = .01, clearly pointing to the indistinctiveness of the two WM factors. We thus continued modeling only one WM factor, with all 18 subtasks loading on it. This model did not indicate any problems, and model fit was acceptable, RMSEA = .06, CFI = .97, SRMR = .03. Importantly, difference-testing between models revealed no loss of fit when modeling only one WM factor, $\Delta\chi^2 = 1.38$, $p > .05$. These analyses suggest that individual differences in processing affective are indistinguishable from individual differences in processing neutral stimuli in WM. Results were robust to choosing a different task type as reference method factor.

RTs were analyzed employing the same model as for accuracy scores. The 2-factor WM model, RMSEA = .08, CFI = .98, SRMR = .03, revealed a correlation between the WM factors of 1.00, *SE* = .001. Model fit did not decrease when only one factor was modeled, $\Delta\chi^2 = .05$, $p > .05$. Thus, again, WM factors for neutral and affective content could not be distinguished.

[2] Results of models with an additional orthogonal factor for tasks with faces, included because faces are known to be processed distinctly (Hildebrandt et al., 2011), are reported in Supplement S8, Models 3, 4, 10, and 11. The model fit indices suggest superiority of modeling task-specific residual correlations instead of modeling latent faces factors. Also, most loadings on the faces factors were small and not significantly different from zero, which does not speak for the same latent ability for processing faces to cause variation on our tasks with faces. We thus kept residual correlations instead of modeling an additional orthogonal factor for faces.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Table 2
Correlations Among All Tasks: Accuracy (Upper Triangle), Reaction Time (Lower Triangle)

Task	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CAT_pic_aff (1)	.75	.73	.71	.61	.59	.33	.33	.36	.41	.27	.39	.37	.35	.37	.34	.28	.34
CAT_pic_neu (2)	***.94***	.74	.75	.65	.66	.44	.43	.43	.51	.35	.43	.48	.40	.46	.43	.33	.42
CAT_word_aff (3)	***.88***	***.88***	.83	.70	.71	.50	.47	.55	.50	.36	.46	.52	.43	.52	.54	.45	.49
CAT_word_neu (4)	***.90***	***.92***	***.95***	.73	.69	.48	.42	.49	.48	.33	.44	.56	.46	.45	.48	.38	.44
CAT_faces_aff (5)	***.87***	***.90***	***.90***	***.92***	.80	.53	.42	.46	.51	.46	.52	.48	.47	.55	.55	.41	.47
CAT_faces_neu (6)	***.87***	***.90***	***.89***	***.91***	***.95***	.53	.45	.55	.55	.48	.52	.51	.51	.56	.62	.46	.53
POS_pic_aff (7)	***.67***	***.68***	***.71***	***.70***	***.72***	***.74***	.76	.67	.70	.66	.58	.54	.51	.48	.50	.48	.45
POS_pic_neu (8)	***.67***	***.68***	***.71***	***.67***	***.71***	***.74***	***.96***	.68	.70	.68	.61	.54	.50	.54	.50	.45	.39
POS_word_aff (9)	***.61***	***.62***	***.66***	***.63***	***.67***	***.68***	***.89***	***.91***	.75	.67	.60	.56	.52	.52	.56	.50	.44
POS_word_neu (10)	***.61***	***.62***	***.62***	***.61***	***.66***	***.66***	***.86***	***.89***	***.94***	.71	.66	.63	.64	.62	.59	.57	.54
POS_faces_aff (11)	***.60***	***.62***	***.60***	***.60***	***.65***	***.66***	***.88***	***.89***	***.92***	***.92***	.77	.58	.58	.53	.52	.50	.49
POS_faces_neu (12)	***.57***	***.59***	***.56***	***.56***	***.62***	***.64***	***.85***	***.87***	***.90***	***.93***	***.96***	.63	.61	.59	.58	.54	.58
CONT_pic_aff (13)	***.59***	***.60***	***.62***	***.60***	***.67***	***.67***	***.78***	***.78***	***.78***	***.80***	***.82***	***.82***	.75	.62	.66	.63	.57
CONT_pic_neu (14)	***.60***	***.60***	***.64***	***.62***	***.68***	***.68***	***.76***	***.77***	***.78***	***.79***	***.81***	***.80***	***.96***	.69	.63	.58	.59
CONT_word_aff (15)	***.60***	***.62***	***.64***	***.63***	***.69***	***.67***	***.75***	***.74***	***.73***	***.74***	***.76***	***.75***	***.88***	***.88***	.75	.52	.54
CONT_word_neu (16	***.62***	***.62***	***.67***	***.64***	***.70***	***.68***	***.75***	***.74***	***.75***	***.75***	***.75***	***.74***	***.87***	***.87***	***.96***	.63	.61
CONT_faces_aff (17)	***.58***	***.60***	***.60***	***.56***	***.67***	***.65***	***.70***	***.73***	***.75***	***.78***	***.79***	***.78***	***.86***	***.87***	***.83***	***.86***	.73
CONT_faces_neu (18)	***.57***	***.59***	***.58***	***.56***	***.64***	***.65***	***.71***	***.73***	***.76***	***.78***	***.77***	***.78***	***.86***	***.87***	***.83***	***.85***	***.94***

Note. CAT = category task; POS = position task; CONTENT = content comparison task; pic, word, faces = stimuli were pictures, words, faces; aff and neu: stimuli were affective or neutral; all correlations were significant; for the ease of use, this table is also provided in Excel (please see Supplement S7). All correlations provided in this table, including the estimates in italics and bold, are statistically significant, $p < .05$.

Follow-Up Analyses

In the preceding, we chose but one approach to test whether WM and aWM can be distinguished. Another is to fit an aWM factor that is orthogonal to the other factors, including a WM factor specified by all tasks. The model fit indices of these models indicate that they fit the data about as good as of those reported in the article (Supplement S8, Models 5 and 11). The additional aWM factors, however, are difficult to interpret: in the case of accuracy, loadings range between −.10 and .15, with the exception of one loading being −.43. In the case of RT, loadings range between −.08 and .13. This seems to underscore the preceding results according to which the general salience of affective versus neutral information apparently does not differentially affect WM processing.

One possibility for the indistinctness of aWM and WM is that such distinctness may only occur if the mental representation of the affective content reaches some threshold. The different task types require processing affective information to a different degree. The CAT task requires evaluation of the stimuli content. This is not the case in the POS or CONTENT tasks, which merely require remembering the position or the content. Affective information should therefore be processed most deeply in the CAT task, and differential processing of affective versus neutral information might only become apparent here. We thus examined whether performance on the CAT tasks was modulated by valence, using a model with two WM factors (one neutral and one affective) as well as two residual correlations (the *faces* and *pictures* subtasks, the latter being suggested by modification indices). Model fit for the two-factor model and using accuracy scores was good, RMSEA = .01, CFI = 1, SRMR = .01, with the correlation between the neutral and affective WM factors being 1.00, *SE* = .01. Model fit did not decrease when only one WM factor was modeled, $\Delta\chi^2 = .02$, $p > .05$. When using RTs, model fit of the two-factor model was good according to the CFI and SRMR, RMSEA = .11, CFI = 1.00, SRMR = .01; the WM—affective WM correlation was 1.00, *SE* = .003. Again, model fit did not decrease when only one factor was modeled, $\Delta\chi^2 = 2.28$, $p > .05$.

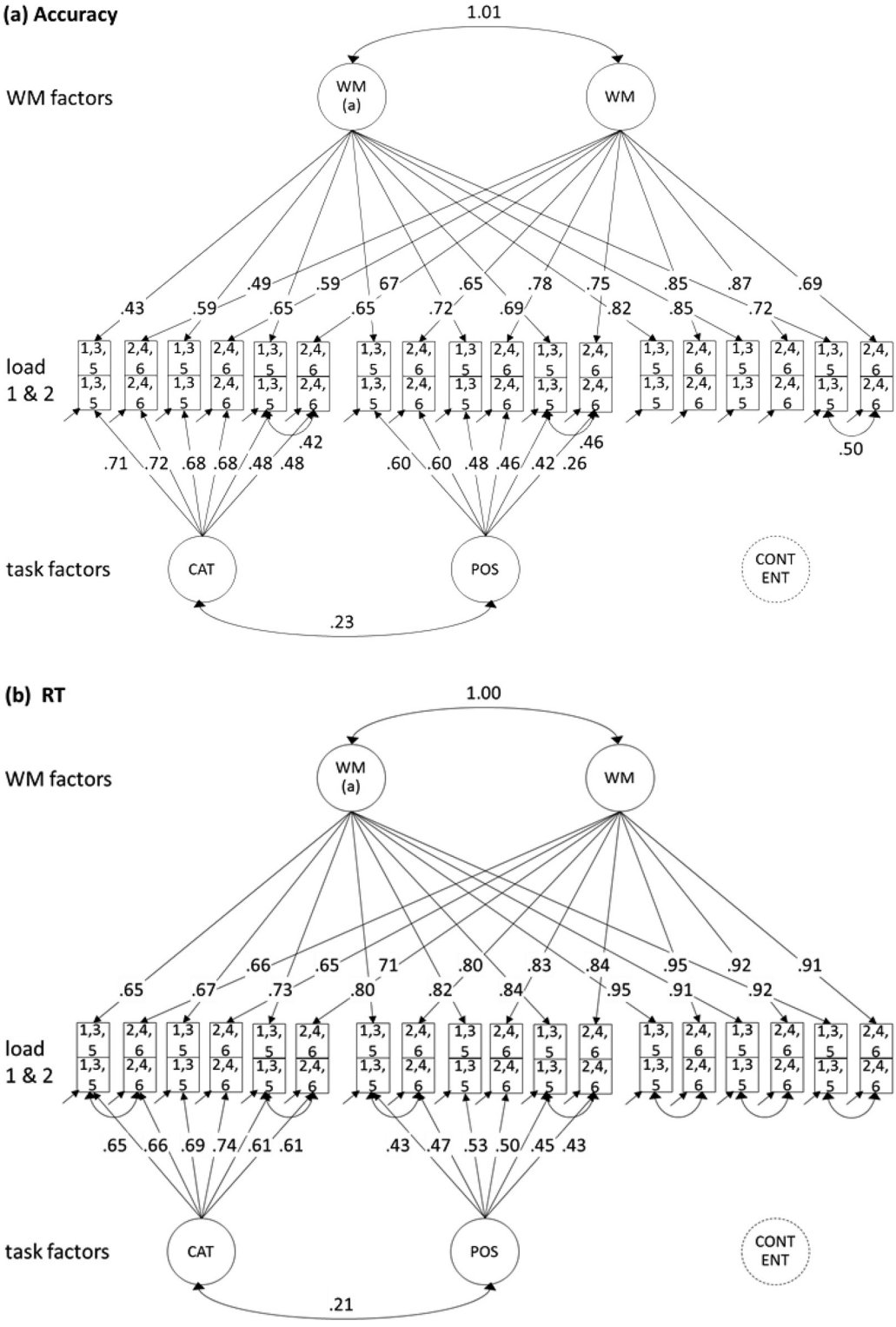
As a third set of follow-up analyses, we examined whether a neutral WM factor could be distinguished from affective WM factors with either negative or positive stimuli. Valence-specific effects of targets emerged in the recent meta-analysis by Schweizer et al. (2019), with specifically positive stimuli enhancing WM performance. For that reason, we aggregated negative and positive stimuli separately. For descriptive information on these variables, please see Supplement S5 and S6. We then repeated the analyses described above (nested factor models with one or two WM factors and the CONTENT task as reference method factor similar to that represented in Figure 2). In neither of the analyses could a WM factor be distinguished from an affective WM factor: accuracy, positive versus neutral: $\Delta\chi^2 = 2.01$, $p > .05$; accuracy, negative versus neutral: $\Delta\chi^2 = 1.06$, $p > .05$; RT, positive versus neutral: $\Delta\chi^2 = .03$, $p > .05$, RT negative versus neutral = $\Delta\chi^2 = 1.99$, $p > .05$. Information on model fit of the respective models is provided in Supplement S5 and S6.

Discussion

This study clearly demonstrates that individual performance differences do not indicate that affective and neutral stimuli are processed differentially in WM in a student sample of younger adults. All attempts of this study to differentiate two latent WM abilities, one processing neutral and one processing affective information, indicated the opposite—the indistinctness of two WM factors. This included how accurately participants performed on tasks as well as their reaction times. Also, this result remained unchanged if processing neutral information was analyzed in relation to either positive or neutral information. Furthermore, even when the affective content of the stimuli was made explicit to participants by having them categorize stimuli into negative and positive items (i.e., in the CAT task), the rank order of participants' WM performance was stable across neutral and affective task versions.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

Figure 2
Results of CFA Models (Standardized Estimates)



Note. WM = working memory (with affective stimuli, a); CAT = category task; POS = position task; CONTENT = content comparison task; residual correlations are among faces versions of the tasks.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.

This study clarifies that not only mean-level differences in WM performance on tasks with neutral and affective information are small to negligible (Schweizer et al., 2019)—peoples' performance rank orders also are entirely stable when they engage in WM tasks with affective versus neutral stimuli. These findings contradict prior findings in the literature that suggested differential processing of affective information in WM (e.g., Dai et al., 2015). Instead, individual differences in WM performance were shown to be robust to the salience of affective material and to its valence. This finding has various consequences. Given a correlation of 1.00 between the two latent WM factors that we specified, differential associations between processing affective versus neutral information on the one hand and some outcome variable (e.g., a well-being indicator) can be ruled out. Put differently, the predictive variance of WM and affective WM scores entirely overlaps in case of correlations of 1.00, which implies that such scores have identical effects on third variables. Also, WM trainings, if designed for younger adults, do not need to differentiate between affective and neutral stimuli, and attempts to train specifically "affective" or "emotional WM" (e.g., Leone de Voogd et al., 2016), here referring to the processing of affective versus neutral stimuli in WM, is prone to fail—there is no such ability next to WM.

The scope of this study's results is constrained to (a) affective material at the target level, (b) the behavioral level of analysis, (c) WM measures of the *n*-back type task, and (d), younger adults. Regarding (a), the distinctness between processing neutral and affective information has also been examined in view of distractors (i.e., task-irrelevant stimuli presented while engaging in some WM task). From this study's results, it cannot be inferred whether the ability to inhibit distraction from such stimuli is differentially affected by the valence of distractors. Also, according to a recent conceptualization, one may view affective working memory as the ability to mentally represent and manipulate emotional feelings per se, in contrast to processing stimuli such as emotional faces that may, or may not induce feelings (i.e., Mikels & Reuter-Lorenz, 2019). Operationalizing WM in accordance with this proposition (e.g., Frank et al., 2021) may lead to a WM factor separable from neutral WM. Besides, and (b), it seems well plausible that at the neural level, differential processing might have emerged (cf. Schweizer et al., 2019). In view of (c), it seems worth investigating whether WM tasks with more emphasis on the maintenance component (e.g., complex span tasks; Unsworth & Engle, 2007) differentiate between affective and neutral information, because affective content, if to be memorized during the performance of some secondary tasks, might distract more from the latter than neutral content, and more so than in the *n*-back task with strong demand on fast updating. More generally, it would be desirable to do the same kind of study with different kinds of WM paradigms as to determine whether results are generalizable to other paradigms. Ideally, one would do a study that includes different paradigms, so that one could model broader (a) WM factors and account for the paradigm-related variance with additional method factors if necessary. Finally (d), this study requires replication with other samples, for example patients suffering from affective disorders or older adults, as affective information is comparatively more salient to them (e.g., Gotlib & Joormann, 2010; Scheibe & Carstensen, 2010). It might be that the threshold at which affective content of stimuli affects WM performance is reached much earlier in these populations (cf., Schweizer et al., 2019). Controlled processing as required for temporarily maintaining and updating bindings between items in WM may be disturbed by affective information when it is highly salient to individuals (e.g., by eliciting regulation efforts), or when affective information distracts attention. Please note in this context that the student sample of our study had lower levels of well-being and higher levels of depressive symptoms than found in larger representative samples, albeit our study's average levels on the latter were below thresholds indicating clinical relevance (i.e., a sum score of 23; Hautzinger & Bailer, 1993). Still, these reduced levels of affective well-being should, if anything, come with increased differentiation between affective and neutral material, which may increase doubts that more differentiation between WM and aWM will be found in clinical samples.

We recommend that researchers interested in the potentially differential associations between WM processing affective information and more distal outcomes (e.g., well-being) in specific populations also take a latent variable approach to determine the distinctness of WM processing affective (vs. neutral) information. Without this, it cannot be ruled out whether potential effects are specific to task- or stimulus-types but do not generalize to the latent ability (Schmiedek et al., 2014). Also, empirically remaining on the task level will reduce the chances of revealing robust and replicable effects that might eventually be relevant for designing interventions for who would benefit from controlling overly-salient or maladaptive affective information.

To conclude, WM in younger adults seems to be a firm processing system. Once engaged, its capacity seems robust against the salience of affective information in general and against the salience of positive or negative information in particular. Whether the WM system is used for processing affective or neutral information does not matter for the resulting observable individual differences in WM capacity.

References

Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin*, *130*(4), 553–573. https://doi.org/10.1037/0033-2909.130.4.553

Brähler, E., Muehlan, H., Albani, C., & Schmidt, S. (2007). Teststatistische Prüfung und Normierung der deutschen Versionen des EUROHIS-QOL Lebensqualität-Index und des WHO-5 Wohlbefindens-Index [Testing and standardization of the German version of the EUROHIS-QOL and WHO-5 quality-of life-indices]. *Diagnostica*, *53*(2), 83–96. https://doi.org/10.1026/0012-1924.53.2.83

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A parametric study of prefrontal cortex involvement in human working memory. *Neuroimmage*, *5*(1), 49–62. https://doi.org/10.1006/nimg.1996.0247

Cowan, N. (2017). The many faces of working memory and short-term storage. *Psychonomic Bulletin & Review*, *24*(4), 1158–1170. https://doi.org/10.3758/s13423-016-1191-6

Dai, Q., Rahman, S., Lau, B., Sook Kim, H., & Deldin, P. (2015). The influence of self-relevant materials on working memory in dysphoric undergraduates. *Psychiatry Research*, *229*(3), 858–866. https://doi.org/10.1016/j.psychres.2015.07.068

Dolcos, F., Katsumi, Y., Denkova, E., & Dolcos, S. (2017). Factors influencing opposing effects of emotion on cognition: A review of evidence from research on perception and memory. In I. Opris & M. Casanova (Eds.), *The physics of the mind and brain disorders. Springer series in*

cognitive and neural systems (Vol. 11, pp. 297–341). Springer. https://doi.org/10.1007/978-3-319-29674-6_14

Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—a database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods*, *42*(1), 351–362. https://doi.org/10.3758/BRM.42.1.351

Eid, M. (2000). A multitrait-multimethod model with minimal assumptions. *Psychometrika*, *65*(2), 241–261. https://doi.org/10.1007/BF02294377

Frank, C. C., Iordan, A. D., Ballouz, T. L., Mikels, J. A., & Reuter-Lorenz, P. A. (2021). Affective forecasting: A selective relationship with working memory for emotion. *Journal of Experimental Psychology: General*, *150*(1), 67–82. https://doi.org/10.1037/xge0000780

Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: Current status and future directions. *Annual Review of Clinical Psychology*, *6*(1), 285–312. https://doi.org/10.1146/annurev.clinpsy.121208.131305

Grandy, T. H., Lindenberger, U., & Schmiedek, F. (2020). Vampires and nurses are rated differently by younger and older adults-Age-comparative norms of imageability and emotionality for about 2500 German nouns. *Behavior Research Methods*, *52*(3), 980–989. https://doi.org/10.3758/s13428-019-01294-2

Hautzinger, M., & Bailer, M. (1993). *Allgemeine Depressions-Skala (ADS). Deutsche Form der Center of Epidemiological Studies Depressions Scale (CES-D)*. Beltz.

Hildebrandt, A., Wilhelm, O., Schmiedek, F., Herzmann, G., & Sommer, W. (2011). On the specificity of face cognition compared with general cognitive functioning across adult age. *Psychology and Aging*, *26*(3), 701–715. https://doi.org/10.1037/a0023056

Joormann, J., & Gotlib, I. H. (2008). Updating the contents of working memory in depression: Interference from irrelevant negative material. *Journal of Abnormal Psychology*, *117*(1), 182–192. https://doi.org/10.1037/0021-843X.117.1.182

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*(3), 261–273. https://doi.org/10.1111/j.1469-8986.1993.tb03352.x

Leone de Voogd, E., Wiers, R. W., Zwitser, R. J., & Salemink, E. (2016). Emotional working memory training as an online intervention for adolescent anxiety and depression: A randomised controlled trial. *Australian Journal of Psychology*, *68*(3), 228–238. https://doi.org/10.1111/ajpy.12134

Levens, S. M., & Gotlib, I. H. (2010). Updating positive and negative stimuli in working memory in depression. *Journal of Experimental Psychology: General*, *139*(4), 654–664. https://doi.org/10.1037/a0020283

Mikels, J. A., & Reuter-Lorenz, P. A. (2019). Affective working memory: An integrative psychological construct. *Perspectives on Psychological Science*, *14*(4), 543–559. https://doi.org/10.1177/1745691619837597

Oberauer, K. (2019). Working memory capacity limits memory for bindings. *Journal of Cognition*, *2*(1), 40. https://doi.org/10.5334/joc.86

Pe, M. L., Koval, P., & Kuppens, P. (2013). Executive well-being: Updating of positive stimuli in working memory is associated with subjective well-being. *Cognition*, *126*(2), 335–340. https://doi.org/10.1016/j.cognition.2012.10.002

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences*, *13*(4), 160–166. https://doi.org/10.1016/j.tics.2009.01.006

Scheibe, S., & Carstensen, L. L. (2010). Emotional aging: Recent findings and future trends. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *65B*(2), 135–144. https://doi.org/10.1093/geronb/gbp132

Schmiedek, F., Hildebrandt, A., Lövdén, M., Wilhelm, O., & Lindenberger, U. (2009). Complex span versus updating tasks of working memory: The gap is not that deep. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(4), 1089–1096. https://doi.org/10.1037/a0015730

Schmiedek, F., Lövdén, M., & Lindenberger, U. (2014). A task is a task is a task: Putting complex span, n-back, and other working memory indicators in psychometric context. *Frontiers in Psychology*, *5*, 1475. https://doi.org/10.3389/fpsyg.2014.01475

Schweizer, S., Hampshire, A., & Dalgleish, T. (2011). Extending brain-training to the affective domain: Increasing cognitive and affective executive control through emotional working memory training. *PLoS ONE*, *6*(9), e24372. https://doi.org/10.1371/journal.pone.0024372

Schweizer, S., Satpute, A. B., Atzil, S., Field, A. P., Hitchcock, C., Black, M., Barrett, L. F., & Dalgleish, T. (2019). The impact of affective information on working memory: A pair of meta-analytic reviews of behavioral and neuroimaging evidence. *Psychological Bulletin*, *145*(6), 566–609. https://doi.org/10.1037/bul0000193

Süß, H.-M., Oberauer, K., Wittmann, W. W., Wilhelm, O., & Schulze, R. (2002). Working memory capacity explains reasoning ability and a little bit more. *Intelligence*, *30*(3), 261–288. https://doi.org/10.1016/S0160-2896(01)00100-3

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, *114*(1), 104–132. https://doi.org/10.1037/0033-295X.114.1.104

Wilhelm, O., Hildebrandt, A., & Oberauer, K. (2013). What is working memory capacity, and how can we measure it? *Frontiers in Psychology*, *4*, 433. https://doi.org/10.3389/fpsyg.2013.00433

Zetsche, U., Bürkner, P. C., & Schulze, L. (2018). Shedding light on the association between repetitive negative thinking and deficits in cognitive control—A meta-analysis. *Clinical Psychology Review*, *63*, 56–65. https://doi.org/10.1016/j.cpr.2018.06.001

Received February 12, 2021
Revision received February 8, 2022
Accepted May 18, 2022 ■

This document is copyrighted by the American Psychological Association or one of its allied publishers.
This article is intended solely for the personal use of the individual user and is not to be disseminated broadly.