Feasibility of EI-MAG, a Working Memory App, in Younger and Older Adults

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Abstract: This study explored the feasibility of the German WM application EI-MAG in younger and, in a first attempt, older adults. Contrary to previous applications, EI-MAG is group-administrable and tablet-based. 89 older and 35 younger adults were administered six self-reliant WM tasks and given a questionnaire addressing sociodemographic background, health status, perceived app characteristics, and technology experience. The percentage of participants completing all tasks and subtest completion rates decreased across age groups. The feasibility in older adults was associated with chronic diseases, vision, dependence on hearing aids, touchscreen sensitivity, and ease with tapping and use. Results are discussed regarding the hindering factors for older adults identified in previous research. With the development of practice assessments, EI-MAG seems potentially suitable for use in older adults.

Keywords: working memory, older adults, aging, technology, tablet-based assessment

Working memory (WM) is a capacity-limited cognitive system for the temporary storage and manipulation of currently relevant information (Baddeley, 1986, 2000). Developmental changes in WM across the lifespan are well documented (Alloway & Alloway, 2013; Brockmole & Logie, 2013; Gathercole, 1998; Grégoire & van der Linden, 1997; Grivol & Hage, 2011). Functional capacity improves during childhood, peaks in young adulthood, and then steadily declines. As executive functions including WM are dispositive for everyday functioning, concerning activities like dressing or medication adherence in healthy (Bell-McGinty et al., 2002; Cahn-Weiner et al., 2002; Grigsby et al., 1998; Insel et al., 2006) and clinical older adults (Cahn et al., 1998; Tomaszewski Farias et al., 2009), it is important to examine those functions as risk factors. Because the proportion of older adults in the population is growing, there is a demand for standardized tools for the economic assessment of WM in this age group to provide appropriate support.

In addition to traditional paper-and-pencil tests, a growing number of computerized cognitive testing batteries are available for older adults. A review by Charalambous et al. (2020) analyzed 25 apps and tools for detecting dementia and cognitive impairment. The authors discovered a huge availability of self-regulated testing tools, albeit mostly with uncertain quality because of missing norm and psychometric data. Previously, Zygouris and Tsolaki (2015) had already dealt with 17 computerized batteries and noted their advantages, such as accurate automatic stimulus presentation and data recording, standardized administration, reduced experimenter- and assessment-related biases, and efficient and economic data collection. However, computerized cognitive tests for older adults have limitations, including a "lack of normative data and psychometric standards" (Zygouris & Tsolaki, 2015, p. 13), which agrees with the results of Charalambous et al. (2020). Whereas most test batteries cited in the review by Zygouris and Tsolaki (2015) were computer-based, recent years have seen further development concerning touchscreen or tablet-based assessment (Gorodeski et al., 2019; Scanlon et al., 2016; Tsoy et al., 2020). This runs parallel to the additional advantages over digital assessment per se (cf. Zygouris & Tsolaki, 2015), such as high flexibility and mobility through the use of touch displays, but also raises new questions of feasibility in older adults. To the best of our knowledge, no comparable WM instruments are available for older adults in the German language. The reviews by Charalambous et al. (2020) and Zygouris and Tsolaki (2015) did not include any, either.

To sum up, there is a need for a touchscreen- or tablet-based self-administered cognitive testing app in German with a certain psychometric quality to ensure the reliable and meaningful measurement of WM functioning. EI-MAG (Eichstätt Working Memory Assessment; Oesterlen et al., 2016), a tablet-based self-administered WM test battery based on Baddeley's (1986) WM model, provides the

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potential to fill this gap. Previous studies show good feasibility and initial evidence for psychometric quality among children, adolescents, and young adults (Oesterlen et al., 2018; Oesterlen & Seitz-Stein, 2019, 2021); norm data are still in progress. So far, EI-MAG has not been used in older adults, which is why the current study investigates its feasibility in this age group, in a first attempt and as a basis for further studies. Therefore, we compared the feasibility of EI-MAG among a convenient sample of three age groups of older adults with those of younger adults using two different measures besides the WM performance, the percentage of completed EI-MAG, and the subtest completion rate. For both, we expected the well-documented age decline (cf. Babcock & Salthouse, 1990; Bopp & Verhaeghen, 2005; Dai et al., 2018; Grivol & Hage, 2011). We also explored factors potentially related to the feasibility, like health, technical experience, and characteristics of the App EI-MAG.

Method

Participants

89 older adults between 64.0 and 87.2 years (*M* = 74.6 years, *SD* = 5.8, 69 female) and 35 younger adults between 18.5 and 29.2 years (*M* = 21.7 years, *SD* = 2.3, 31 female) participated in this study. Older adults were recruited from various recreational activity groups (e.g., yoga group, senior centers, groups of regulars). Contact partners were personally informed about the study on WM, who passed the information to group members and requested their participation. Volunteers were then scheduled for group data collection. No information is available on specific selection criteria. All participants except for one were living in a flat or house without the need for special nursing services; the one participant lived in a nursing home. In a questionnaire, the participants rated themselves predominantly as self-reliant. Younger adults were university students from the Catholic University of Eichstätt-Ingolstadt. Only participants who were fluent in German and self-reliantly capable of understanding and providing written informed consent were considered eligible. Further demographic variables (e.g., health) are considered below. For subsequent analyses, we further subdivided the older adults into groups of n = 23 youngest-old, ranging from 64 to 69 years (*M* = 67.2 years, *SD* = 1.6, 15 female), n = 47 middle-old, ranging from 70 to 79 years (*M* = 75.1 years, *SD* = 3.0, 38 female), and n = 19 oldest-old, aged 80 + years (*M* = 82.2 years, *SD* = 2.0, 16 female). Older adults received a small present for their participation, younger adults received course credit or a small present. The study was conducted according to the principles expressed in the Declaration of Helsinki.

Procedure

All participants were tested in groups of 5 to 15 participants in a single session. Each participant first completed six WM tasks and then answered a paper-and-pencil questionnaire constructed by the authors assessing demographic data, health status, characteristics of EI-MAG, and technology experience. To control for sequence effects, the six WM tasks were presented in four different orders counterbalanced across participants and within younger and older adults (see Appendix, Table A1). The sessions lasted between 37 and 63 minutes (*M* = 51 minutes, *SD* = 8) and took place in quiet rooms of the recreational facilities or the university building. WM tasks were presented on Samsung Galaxy 4 10.1 tablet devices with a 10.1″ screen and a screen resolution of 1,280 × 800 pixels and on-ear headphones of the model Sennheiser HD 201.

Measures

WM Performance

WM performance was assessed using six span tasks of the tablet-based, group-administrable application EI-MAG (Oesterlen et al., 2016). After receiving general instructions by the examiner, the participants completed the tasks self-reliantly, with standardized task-specific instructions via headphones. Two pretests ensured that basic preconditions for EI-MAG were met. One pretest served as an audio test: Participants were asked to reproduce a sequence of two auditorily presented color words in a 3 × 3 visually displayed matrix of different colors, whereby the volume of the auditory presentation could be adjusted. The second pretest was a simple reaction time task ensuring that participants had the visuomotor skills needed to perform subsequent WM tasks.

The visuospatial sketchpad was measured by the Corsi block and matrix task (Baddeley, 1986). At the beginning of the Corsi block, nine gray blocks could be seen, unsystematically placed on a white background. Then, a sequence of single blocks turned orange. Each block lit up for 1,000 ms with an interonset interval of 300 ms. After a noise that appeared for 500 ms, the participants had to recall the sequence by tapping the corresponding blocks in the same order as presented before. In the matrix participants had to remember patterns of black squares in a white 4 × 4 matrix. The matrix disappeared after 500 ms per black square, then a white matrix appeared, and the participants had to tap all the squares that have been black before.

The word and digit span tasks were used to assess the phonological loop (Baddeley, 1986). In the word span, a series of monosyllabic words was presented via headphones in 1.5-s intervals. The beginning of an item series was marked with a short high-pitched tone, the ending with a long low-pitched tone. The participants had to tap the correspondent pictures in a 3x3 matrix in the presented order.

The digit span is equivalent to the word span but uses digits as items instead of words. The auditorily presented digits have to be tapped in a number pad (from 1 in the upper left corner to 9 in the lower right corner) in the same serial order. The word span backward and the digit span backward measure the central executive (Baddeley, 1986). They work the same way as the word and digit span, the only difference being that the presented items must be recalled in the backward serial order.

Each task started with a short practice phase to ensure that the instruction had been understood correctly. At least two series in a row out of four series with a length of two items had to be recalled correctly to start the test phase. If participants failed to do so, an icon told them to raise their hands so that the examiner could provide an oral 1:1 instruction. The test phase commenced with a series of the length of two items. If the participant repeated two of three series of the same list length correctly, the following series were increased by one item. As soon as the participant failed to reproduce two of three series of the same list length, the subtest was stopped and the next subtest began.

Questionnaire

A paper-and-pencil self-report questionnaire was administered to assess sociodemographic background, health status, perceived characteristics of EI-MAG, and technology experience. Health status was assessed via 12 questions: General health (from “very bad” to “very good”), health compared to others of the same age (from “much worse” to “much better”), health satisfaction (from “not satisfied at all” to “very satisfied”), and vision and hearing (from “very bad” to “very good”) had to be rated on a 5-point Likert scale. Additionally, participants had to answer with “yes” or “no” whether they suffered from chronic diseases, took regular medication, or wore glasses. Health-related limitations in everyday life during the last 6 months were rated on a 3-point Likert scale from “not handicapped at all” to “handicapped at lot.” The participants had to indicate whether they had hearing aids (“yes” or “no”; if “yes”: “on the left,” “on the right,” or “on both sides”), if they wrote left-handed, right-handed, or with both hands, and whether they suffered from a neurological or mental health disorder (“yes,” “no” or “no response”; if “yes,” they had to indicate which one). Concerning the evaluation of the app EI-MAG, eight features were rated on a 4-point Likert scale from “does not apply at all” to “applies fully” (e.g., “The pictures and symbols within the tasks were sufficiently large” or “Tapping on the screen was easy for me”). To measure technology experience, the participants were asked about ownership (either “yes” or “no”), experience (5-point Likert scale from “no experience” to “a lot of experience”), and frequency of use (“less often” – “once a month” – “once a week” – “once a day”) for several devices. For the current study, only tablet and smartphone are regarded relevant as touch devices.

Results

Feasibility of EI-MAG

The feasibility of the tablet-based EI-MAG tasks in younger and older adults is understood as its applicability. We investigated this by comparing younger and older adults in different age groups using two different measures: the percentage of participants within each age group completing all six subtests of EI-MAG, that is, the percentage of completed EI-MAG; and the proportion of subtests completed by every single participant averaged over each age group, also referred to as subtest completion rate. Successful completion of a subtest means that at least two series of two items were recalled correctly. Because prior analysis showed significant differences between the group of younger adults and the entire group of older adults in both measures (percentage of completed EI-MAG: $t(120.20) = 7.34$, $p < .001$, subtest completion rate: $t(93.90) = 6.14$, $p < .001$), we report only the more detailed analysis concerning the younger adults and the three age groups of older adults in the following. With increasing age, fewer participants completed the whole EI-MAG program. In total, 97% of the younger adults, 74% of the youngest-old, 51% of the middle-old, and 32% of the oldest-old completed all six subtests. A univariate ANOVA with age group as between-subjects factor showed a significant age effect, $F(3, 120) = 12.858$, $p < .001$, $\eta_p^2 = .243$. More specifically, Bonferroni-adjusted Games-Howell posthoc analyses revealed significant differences between the younger adults and the middle-old ($p < .001$) as well as the oldest-old groups ($p < .001$). For all other comparisons, we found no differences (ps > .028).

Similarly, there was a decreasing trend in the subtest completion rate across age groups (see Figures 1A and 1B), but this trend was clearly weakened compared to the completion of the whole EI-MAG program. Whereas the younger adults had a mean subtest completion rate of 100%, the youngest-old completed 96% of the subtests, the middle-old 84%, and the oldest-old 68%. The subtests that failed most often were the word span backward, which failed in 28.1% of the three groups of older adults, and the Corsi block, which failed in 20.2% (digit span backward: 18.0%, matrix: 14.6%, word span: 12.4%, digit span: 5.6%). A univariate ANOVA with age group as between-subjects factor confirmed that the age effects in the subtest completion rate were significant, $F(3, 120) = 13.529$,

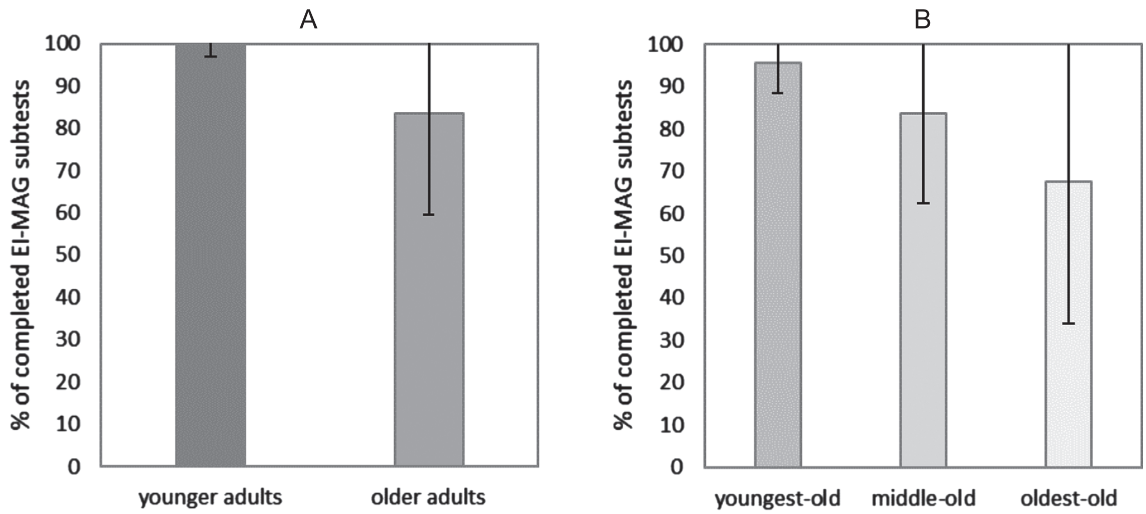

Figure 1. Means and standard deviations for the younger and older adults (A), respectively, the three age groups of older adults (B).

p < .001, η_p^2 = .253. Bonferroni-adjusted Games-Howell post hoc analyses showed significant differences between the younger adults and the middle-old (p < .001) as well as the oldest-old (p = .003). All other comparisons were not significant (ps > .009).

All in all, the results show that younger adults and the youngest-old had no difficulties completing the tablet-based EI-MAG tasks, whereas middle-old and oldest-old adults faced some feasibility issues.

Factors Associated with Feasibility

To identify factors that may be relevant for the limited feasibility of EI-MAG in older adults, we considered their questionnaire data on health status, characteristics of EI-MAG, and technology experience. For each of these domains, we compared the groups with complete (n = 47, M_{age} = 72.3, SD_{age} = 5.2, 35 females) and incomplete EI-MAG (n = 42, M_{age} = 77.1, SD_{age} = 5.4, 34 females) within the older adults, using t-tests for independent samples or chi-squared tests (for dichotomous variables), respectively. It should be noted that not all items were answered by all participants, which is why the number of participants differs between the analyses. For subtest completion rate, the second measure, regression analyses controlled for age and sex were conducted to find predictors for feasibility.

Health Status

Rather surprisingly, concerning the first measure, older adults who completed EI-MAG significantly more often reported having chronic diseases than those who did not, t(79.24) = −2.74, p = .008, d = −0.60. In addition, there were tendencies toward significance for vision and hearing aids, with the group of incomplete EI-MAG showing lower vision and higher dependency on hearing aids. Apart from that, we found no significant health-related differences between the groups (all descriptives and results in Appendix, Table A2).

Results concerning the subtest completion rate agree with those results: Simple linear regressions were significant for chronic diseases, R^2 = .26, R = .51, F(3, 79) = 9.36, p < .001, 95% CI [1.78, 19.63], self-rated vision, R^2 = .29, R = .54, F(3, 82) = 10.98, p < .001, 95% CI [0.90, 14.98], and dependence on hearing aids, R^2 = .32, R = .57, F(3, 82) = 12.87, p < .001, 95% CI [−31.12, −4.87]. All other regressions did not become significant.

Characteristics of EI-MAG

As to the percentage of completed EI-MAG, older adults with complete EI-MAG reported significantly more often that tapping was easy than those with incomplete EI-MAG, t(70.66) = −2.11, p = .039, d = 0.47. All other characteristics did not seem relevant (further descriptives and results in Appendix, Table A3).

In line with that, simple linear regression concerning the subtest completion rate was significant for easy tapping, R^2 = .28, R = .53, F(3, 79) = 10.43, p < .001, 95% CI [2.10, 15.20]. Additionally, the regressions for easy use, R^2 = .23, R = .48, F(3, 78) = 7.85, p < .001, 95% CI [0.10, 12.08], and touchscreen sensitivity, R^2 = .24, R = .49, F(3, 78) = 8.29, p < .001, 95% CI [0.64, 11.90], were significant. All other regressions did not become significant.

Technology Experience

Concerning the percentage of completed EI-MAG, older adults with complete EI-MAG owned and used smartphones significantly more often than those with incomplete

EI-MAG, $t(50.50) = -4.09$, $p < .001$, $d = 1.10$; $t(46) = -2.22$, $p = .032$, $d = 0.68$. Additionally, they reported significantly more experience with smartphones, $t(57) = -2.23$, $p = .029$, $d = 0.61$. No other variable of technology experience was relevant (further descriptives and results in Appendix, Table A4). None of the simple linear regressions for the subtest completion rate was significant.

Besides these three domains (health status, characteristics of EI-MAG, and technology experience), older adults with complete EI-MAG had significant higher academic levels than those with incomplete EI-MAG, $t(78.36) = -2.97$, $p = .004$, $d = 0.62$. The simple linear regression for subtest completion rate and the highest academic graduation was not significant.

WM Development

To assess WM development across age groups, we calculated separate univariate ANOVAs with age group as between-subjects factor for each of the six EI-MAG subtests. The results showed significant age-related performance declines for each subtest (more details in Appendix, Table A5). Subsequent Bonferroni-adjusted Games-Howell posthoc tests revealed that younger adults' performance was consistently higher compared to the youngest-old, middle-old, and oldest-old (ps < .004). Within the group of older adults, there were no significant performance differences (ps > .105) – with one exception: The youngest-old achieved significantly higher digit span scores than the middle-old ($p = .017$).

Discussion

This study aimed to examine the feasibility as applicability of the self-reliant, tablet-based WM instrument EI-MAG (Oesterlen et al., 2016) in a sample of younger and three age groups of older adults and to identify factors associated with potential limitations of applicability in the latter. In fact, older adults faced some challenges in performing the EI-MAG tasks. Whereas feasibility was comparable in younger adults (M = 21.7 years) and the youngest-old (M = 67.2 years), the middle-old (M = 75.1 years), and oldest-old (M = 82.2 years) were less able to complete the whole EI-MAG program and achieved lower subtest completion rates. The results reflect the expected age-related decline in WM functioning in older adults (cf. Babcock & Salthouse, 1990; Bopp & Verhaeghen, 2005; Brockmole & Logie, 2013; Dai et al., 2018; Grivol & Hage, 2011). Younger adults had higher performance scores than older adults in all subtests. However, there were no further performance declines from the youngest-old, across the middle-old, to the oldest-old, as previous research would suggest (e.g., Bopp & Verhaeghen, 2005). A selection bias because of the tablet-based assessment mode may be responsible for this finding. Possibly only the fittest of the oldest-old were able to complete the tasks at all, leveling out differences within the older adults.

The results also showed much variance in the performance of older adults (see Figures 1A and 1B). Because WM functioning generally varies considerably in older adults (cf. Martin & Kliegel, 2014; Schneider & Lindenberger, 2018), the feasibility may be confounded with the variance of WM performance itself.

Subsequent analyses of questionnaire data provide indications that vision and dependence on hearing aids may have influenced the feasibility of EI-MAG in older adults. This is in line with feedback by the testing assistants, who reported on interferences between hearing aids and the headphones that were necessary to fulfill the tasks in a group setting. Analyses also showed that chronic diseases play an important role in the feasibility of EI-MAG. Since the questionnaire did not enquire about these diseases more specifically, we can only offer tentative explanations. One speculation might see technology experience as compensation for perceived disease. Other health-related factors did not seem to play a role in successfully performing EI-MAG. Regarding EI-MAG itself, the analyses revealed that older adults' evaluation of the app and its characteristics was generally positive. All app-related aspects were rated on average at 3.5 or higher on a scale from 1 to 4 (from "not correct at all" to "correct"). Ease with tapping, ease of use, and touchscreen sensitivity were associated with feasibility. However, older adults with complete and incomplete EI-MAG differed concerning the ownership, experience, and frequency of smartphone use. But these aspects did not predict the subtest completion rate, maybe because of the control for age and sex, and therefore seem to play a minor role in the feasibility.

Note that the interpretation of the questionnaire results is limited by a rather high number of missing values. Since most missing values are noticed for items on technology experience, some participants may have only filled in the questions when they had had experience with the respective device. This could also explain why the tablet experience did not seem relevant. Missing values may also be because of tiredness, as the questionnaire was filled after the WM tasks. Future studies could provide verbal instructions besides the written ones to avoid misunderstandings, and a separate setting for the questionnaire or a longer break in between EI-MAG and the questionnaire.

Older participants were recruited via several activities that require a certain independence in daily life and therefore good WM functioning. The sample was inconspicuous concerning different education variables, e.g., highest academic level (Statistisches Bundesamt, 2020, November

25). For the younger adults, the sample may be selective as we only tested university students who are generally digital smart.

Other studies that found good feasibility of tablet-based, self-reliant tasks in older adults differ from ours in several aspects. First, participants' mean age was lower (e.g., M = 61.0 years in Fredrickson et al., 2010; M = 57.3 in Jongstra et al., 2017) in some of the studies. The youngest-old in our study reached similar completion rates to younger adults, which allows us to assume that the feasibility of EI-MAG would have been better in a generally younger sample of older adults. Second, all studies mentioned involved at least one session with a 1:1 examiner-subject interaction, in which technology use and tasks were explained or practiced (Fredrickson et al., 2010; Jongstra et al., 2017; Scanlon et al., 2016; Tsoy et al., 2020). Our study, in contrast, involved group settings, and 1:1 instruction was provided only in the case of misunderstanding the task. Each EI-MAG subtest starts with a practice phase. In case of failure, a raising hands icon indicates the participant is requesting help by the examiner. Concerning a rather high number of failed subtests, strikingly few 1:1 instructions were documented by the examiners. Many older adults must have tapped away the icon and proceeded the task without fully understanding the task. The inhibition level to ask for help seems to be higher in a group setting, as it could disrupt the other participants or publicly display one's inability. Also, compared to home or 1:1 sessions, excitement, fear, or peer pressure may be higher in group settings, affecting the performance in older adults. Third, some of these studies involved several test sessions and reported practice effects (Fredrickson et al., 2010; Jongstra et al., 2017; Tsoy et al., 2020). Jongstra et al. (2017) assume that technical challenges and task misunderstandings first had to be overcome before the tasks could be performed more reliably. Similarly, Fredrickson et al. (2010) report that, whereas only 85% of the subjects were able to complete the first assessment, all completed the test at the last of five assessments. As Wood et al. (2010) show, task repetition cannot only improve performance but also reduce computer anxiety. We had only one session and hence no opportunity for practice improvements across time. Fourth, some studies included only those persons who knew how to handle touch devices and possessed a smartphone (Jongstra et al., 2017) or had comparably small proportions of subjects with no computer experience (e.g., Fredrickson et al., 2010, 16% with no experience). In the current study, 47% had no to very little experience with tablets (28% missings), and 38% with smartphones (34% missings).

A comparison of former results and the results of this first attempt of implementation of the group administrable tablet-based EI-MAG App seems promising. Many aspects are in line with former studies, and the differences stated above give starting points for improving EI-MAG feasibility for use in older adults.

Conclusion

All in all, with a growing older population and the relevance of WM for the maintenance of everyday functioning in older age, economic and standardized WM tests are in high demand. Tablet-based, self-reliant WM tasks as used in EI-MAG could fit these needs and seem to be potentially suitable for older adults. Following this first attempt, further studies with more balanced subsamples should be conducted. The development and testing of practice trials to enhance familiarity with touch devices and group situations appear to be inevitable to improve the feasibility and guarantee reliable and valid measurement of WM functions. Further developmental and diagnostic research should aim at the improvement of feasibility in older adults, on the one hand, and provide fine-grained age norms for EI-MAG, on the other hand.

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Appendix

Table A1. Frequencies of task orders for younger and older adults, and for the whole sample

Task order	Younger adults (*n* = 35)	Older adults (*n* = 89)	Total (*N* = 124)
1: Corsi block, word span, digits backward, matrix, digit span, words backward	9	24	33
2: Matrix, words backward, digit span, Corsi block, digits backward, word span	8	22	30
3: Word span, digits backward, Corsi block, digit span, words backward, matrix	9	22	31
4: Digit span, words backward, matrix, word span, digits backward, Corsi block	9	21	30

Table A2. Health-related descriptives, *t*-, and chi-squared tests for the comparison of older adults with complete and incomplete EI-MAG

	EI-MAG complete			EI-MAG incomplete					
	n	*M*	*SD*	*n*	*M*	*SD*	Test(*df*)	*p*	Cohen's *d*
General health	47	3.70	0.69	39	3.56	0.60	$t(84) = -0.98$	.329	0.12
Health compared to others at the same age	47	3.72	0.80	40	3.63	0.74	$t(85) = -0.59$	.556	0.12
Health satisfaction	47	3.96	0.62	40	4.02	0.77	$t(85) = 0.45$	.652	0.09
Chronic diseases*	46	59.00	50.00	37	30.00	46.00	$\chi^2(1) = 6.93$	**.008**	0.60
Regular medication*	47	83.00	38.00	40	83.00	39.00	$\chi^2(1) < 0.01$	.953	< 0.01
Neurological or mental health disorder*	45	11.00	32.00	36	6.00	23.00	$\chi^2(1) = 0.78$	.377	0.20
Health-related limitations in everyday life during the last 6 months	46	2.33	0.63	40	2.45	0.55	$t(84) = 0.96$	.340	0.20
Glasses*	44	86.00	35.00	36	83.00	38.00	$\chi^2(1) = 0.14$	.706	0.08
Vision	47	3.89	0.67	39	3.62	0.63	$t(84) = -1.97$	.052	0.41
Hearing aids*	46	9.00	29.00	40	23.00	42.00	$\chi^2(1) = 3.18$	.075	0.39
Hearing	45	3.93	0.78	41	3.71	0.72	$t(84) = -1.40$	.167	0.29
Writing hand	46	1.00	0.00	39	1.00	0.00	–	–	–

Note. Significant results are printed in bold. *The data of these variables represent percentages.

Table A3. Descriptives, *t*-, and chi-squared tests for the comparison of older adults with complete and incomplete EI-MAG concerning the perceived characteristics of EI-MAG

	EI-MAG complete			EI-MAG incomplete					
	n	*M*	*SD*	*n*	*M*	*SD*	Test(*df*)	*p*	Cohen's *d*
Sufficient display size	45	3.80	0.41	36	3.78	0.54	$t(79) = -0.21$	.833	0.04
Easy operation	45	3.62	0.61	37	3.38	0.68	$t(80) = -1.70$	.092	0.37
Sufficient size of images and symbols	46	3.80	0.40	37	3.76	0.50	$t(81) = -0.48$	.630	0.09
Clear acoustic of instructions	45	3.56	0.66	39	3.54	0.72	$t(82) = -0.11$	.910	0.03
Easy tapping	45	3.71	0.55	38	3.42	0.68	$t(70.66) = -2.11$	**.039**	0.47
Sufficient button size	45	3.89	0.38	40	3.73	0.55	$t(68.21) = -1.57$	.122	0.34
Touch sensitivity	45	3.64	0.68	37	3.43	0.69	$t(80) = -1.40$	.166	0.31
Sufficient contrast of images and symbols	45	3.84	0.42	37	3.73	0.56	$t(65.94) = -1.03$	.308	0.23

Note. Significant results are printed in bold.

Table A4. Descriptives, *t*-, and chi-squared tests for the comparison of older adults with complete and incomplete EI-MAG concerning technology experience

	EI-MAG complete			EI-MAG incomplete					
	n	*M*	*SD*	*n*	*M*	*SD*	Test (*df*)	*p*	Cohen's *d*
Tablet ownership*	30	37.00	49.00	27	22.00	42.00	$\chi^2(1) = 1.42$	.234	0.33
Smartphone ownership*	33	67.00	48.00	22	18.00	40.00	$\chi^2(1) = 12.45$	**< .001**	1.09
Experience with tablet	39	1.92	1.06	25	1.56	1.04	$t(62) = -1.34$	.184	0.34
Experience with smartphone	37	2.49	1.41	22	1.68	1.21	$t(57) = -2.23$	**.029**	0.61
Frequency of tablet use	29	2.00	1.25	18	1.89	1.37	$t(45) = -0.29$	.777	0.09
Frequency of smartphone use	32	2.91	1.42	16	1.94	1.44	$t(46) = -2.22$	**.032**	0.68

Note. Significant results are printed in bold. *The data of these variables represent percentages.

Table A5. Descriptives and ANOVA results for the comparison of WM performance in younger adults, youngest-olds, middle-olds, and oldest-old

	Younger adults			Youngest-old			Middle-old			Oldest-old					
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*F*(*df*, error)	*p*	η_p^2
Corsi block	35	5.74	1.05	18	3.69	1.14	40	3.20	1.23	13	2.69	1.05	$F(3, 102) = 39.91$	**< .001**	0.54
Matrix	35	7.51	0.85	23	4.54	1.85	41	3.71	1.30	12	4.38	1.51	$F(3, 107) = 54.75$	**< .001**	0.61
Word span	35	5.27	0.84	23	3.52	1.01	40	3.44	0.96	15	3.30	1.10	$F(3, 109) = 30.07$	**< .001**	0.45
Digit span	35	6.14	0.94	23	5.04	0.95	44	4.13	1.36	17	4.47	1.29	$F(3, 115) = 20.53$	**< .001**	0.35
Words backward	35	4.63	0.93	22	3.20	0.81	34	2.78	0.80	8	3.19	1.28	$F(3, 95) = 26.88$	**< .001**	0.46
Digits backward	34	5.50	1.13	23	3.70	0.75	38	3.29	0.96	12	3.25	1.10	$F(3, 103) = 35.02$	**< .001**	0.51

Note. Significant results are printed in bold.