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Working Memory, Fluid Intelligence, and Attention Are Predictors of Multitasking Performance, but Polychronicity and Extraversion Are not

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This study explored predictors of multitasking performance. Based on cognitive psychology research, attention and working memory were assumed to be predictors. Fluid intelligence, polychronicity (as the preference for multitasking and the belief that their preference is the best way to handle things), and Extraversion were argued to be additional predictors. Multitasking performance was measured with the scenario "Simultaneous capacity/Multi-tasking (SIMKAP)" (n = 122). Hierarchical multiple regression analyses revealed that working memory was the most important predictor in addition to attention and fluid intelligence. The latter two constructs contributed significantly to the explained variance, but to a lesser extent. Polychronicity was not a significant predictor, nor was Extraversion. Implications for personnel selection and for time management are discussed.

Working on two deadlines at once, talking on the phone while searching for information on the Internet, trying to concentrate on one task but being interrupted by another, operating several machines simultaneously—multitasking is required in many jobs. However, not everybody is good at it, and individual differences in

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multitasking have important implications for people's performance on the job (e.g., Damos, 1993; Stankov, Fogarty, & Watt, 1989). Because knowledge about predictors of individual differences in multitasking is still limited, this study explored working memory, attention, fluid intelligence, polychronicity, and Extraversion as potential predictors of multitasking performance.

Multitasking can be described as the ability to accomplish "multiple task goals in the same general time period by engaging in frequent switches between individual tasks" (Delbridge, 2000, p. 1). Research on multitasking has a long history (e.g., McQueen, 1917), and previous research used multitasking scenarios as a personnel selection tool (e.g., Stankov et al., 1989), investigated the neuroanatomical correlates of multitasking (e.g., Burgess, Veitch, de Lacy Costello, & Shallice, 2000), and used multitasking intensively to study information processing and executive control processes (e.g., Rubinstein, Meyer, & Evans, 2001). Multitasking has also been mentioned as a potentially useful time-management strategy by some authors (e.g., Britton & Tesser, 1991). Additionally, it is an important feature of microworld simulations of complex work domains such as space flight (Sauer, Wastell, & Hockey, 1999). Instead of *multitasking,* some researchers also use the expression *dual-task* when only two tasks are involved (e.g., Logan & Gordon, 2001), or *task switching* (e.g., Monsell, 2003).

Several job analyses, such as an analysis of managerial jobs at AT&T (Smither, 1992, as cited in Schmitt, DeShon, Clause, Chan, & Delbridge, 1996), have highlighted the importance of multitasking. Pilots, as another example, repeatedly report that multitasking is one of their most important job requirements (e.g., Maschke & Goeters, 1999). In addition, job analysis data from the Occupational Information Network (O*NET) shows that being able to multitask is important for many jobs such as school bus drivers, fire fighting and prevention supervisors, and gaming dealers (cf. E. A. Fleishman, Costanza, & Marshall-Mies, 1999). Furthermore, interruptions, which require at least some multitasking to be handled, are common features of many jobs, from managers (Carlson, 1951) and physicians (Chisholm, Dornfeld, Nelson, & Cordell, 2001) to small-office workers (Rouncefield, Hughes, Rodden, & Viller, 1994).

In contrast to accomplishing tasks sequentially, in multitasking the different tasks are very likely to interfere with one another (Pashler, 1994; Monsell, 2003). Several cognitive psychology models have tried to explain this interference (cf. Meyer & Kieras, 1997; Pashler, 1994). For example, resource allocation theorists such as Kahneman (1973) argue that during multitasking a person's mental resources are shared by the different tasks. Because these mental resources are limited, the tasks interfere with each other. Bottleneck theorists (e.g., Logan, 2002) argue that interference occurs because certain mental operations cannot be divided, resulting in a bottleneck that allows only one task to pass through at a time. Unfortunately, experimental cognitive psychologists are far from agreeing on which theory best explains this interference, and they continue to postulate new models (e.g., Rubinstein et al., 2001). Nevertheless, the cognitive psychology research can still be used to derive two predictors of multitasking performance: attention and working memory.

Attention has been linked to multitasking because the greater the amount of attention people have—and the easier it is for them to (re)focus their attention—the better their multitasking performance should be (Kahneman, 1973). However, cognitive psychologists rarely study individual differences in attention (or attentional capacity; cf. Cohen, 1993) because researchers tend to focus on experiments that test different theories by manipulating experimental conditions among groups. This is probably the reason no researchers have yet tested whether individual differences in multitasking performance can be predicted by individual differences in attention.

Other cognitive psychologists studying multitasking have focused more on working memory (e.g., Meyer & Kieras, 1997). Working memory is the system of the brain that permits the storage and processing of information needed in the execution of tasks (cf. Berti & Schröger, 2003). The construct of working memory incorporates the older construct of *short-term memory,* but it is conceptualized more broadly (cf. Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000; Oberauer, Süß, Wilhelm, & Wittmann, 2003). It not only includes the passive system responsible for the temporary storage of information, but also consists of an active system responsible for the executive control of cognitive processes. If information that has already been stored needs to be transformed, if new relations between elements of information have to be built, if certain cognitive representations or procedures have to be activated whereas others do not, and if ongoing cognitive processes have to be monitored, working memory is necessary because it is assumed to be responsible for such cognitive functions (Oberauer et al., 2000; Oberauer et al., 2003). These executive control processes are important for multitasking. When people work on several tasks at once, their working memory helps them to switch from one task to the other, for example by storing information related to a task that they are not currently working on and controlling attention. Even though cognitive psychologists studying multitasking often refer to working memory (e.g., Meyer & Kieras, 1997), no study has tested from an individual differences perspective whether working memory capacity is related to performance in complex multitasking scenarios. Thus, we included working memory as a predictor of multitasking performance in this study.

A third potential predictor of multitasking performance is fluid intelligence. Fluid intelligence, seen as the ability to reason and to solve novel problems, should also facilitate high multitasking performance because intelligent people's superior mental abilities should help them to cope with the greater demands of multitasking in comparison with single tasks. Some evidence exists that supports this idea (e.g., Ben-Shakhar & Sheffer, 2001; Stankov, 1988). An important question is whether working memory and fluid intelligence explain unique or the same variance of multitasking. On the one hand, working memory and fluid intelligence are highly correlated (e.g., Kyllonen & Christal, 1990), and some authors even claim that the performance in working memory tasks is "not much more than *g*" (Stauffer, Ree, & Carretta, 1996, p. 193). Because intelligence is the single most powerful source of variance of general job performance (Schmidt & Hunter, 1998), a parsimonious way to predict multitasking performance might be to include only fluid intelligence and not working memory. On the other hand, Wittmann and Süß (1999) reported that working memory has incremental validity beyond fluid intelligence in predicting problem-solving ability. Such incremental validity might also be found with regard to multitasking because the construct of working memory captures abilities that are not part of fluid intelligence but that are important for multitasking.

Polychronicity presents another potential source of variability in multitasking. Polychronic people report a preference for doing several tasks simultaneously and the belief that their preference is the best way to handle things (Bluedorn, Kalliath, Strube, & Martin, 1999; Conte & Jacobs, 2003). Unlike the previous predictors, polychronicity therefore does not present an ability construct. It stems from anthropology (Hall, 1959), but researchers have started to use it as an individual differences variable (e.g., Conte, Rizzuto, & Steiner, 1999). Polychronic people might enjoy being involved in several tasks at once because they have found themselves to be good at multitasking. In line with this argument, polychronicity should therefore be related to multitasking performance. However, the only study on the relation between polychronicity and multitasking (Ishizaka, Marshall, & Conte, 2001) did not find a significant correlation between the two constructs. This might be due to the use of a self-developed multitasking scenario with unknown validity, pure error, or a true zero relation between polychronicity and multitasking performance. To explore this further, testing this relation for a second time using a different multitasking measure is important.

A fifth potential predictor is Extraversion. Lieberman and Rosenthal (2001) argued on the basis of recent neuroscience research that multitasking depends on the level of chatecholamines in the prefrontal cortex (cf. Burgess et al., 2000). More precisely, they reasoned that the level of chatecholamines should be neither too high nor too low. Because arousal increases the level of chatecholamines, an arousing situation such as multitasking (Delbridge, 2000) is good only for the performance of individuals with a low baseline level of chatecholamines, and Lieberman and Rosenthal assume that such individuals are extraverts. Thus, according to their approach, Extraversion should be positively correlated with multitasking. They provide some supporting evidence for their idea. They found introverts made more errors in a nonverbal decoding task than extraverts only if they had to work on an additional task (i.e., if they had to multitask).

The five predictor variables can be put in hierarchical order. Attention is the most basic construct because one of the functions of working memory is to control attention (see, e.g., de Fockert, Rees, Frith, & Lavie, 2001; Engle, 2002). Working memory is generally assumed to be a more basic construct than fluid intelligence (e.g., Engle, 2002; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002). That means working memory is considered to be a predictor of higher order cognitive task performance (i.e., fluid intelligence). These arguments imply the following hierarchical order (from bottom to top): attention as the most basic capacity, then working memory, and then fluid intelligence (Schweizer & Moosbrugger, 2004). In addition, polychronicity and Extraversion as (nonability) individual characteristics might explain additional variance that cannot be predicted by the three ability constructs. We took this hierarchical order into account when testing how well attention, working memory, fluid intelligence, polychronicity, and Extraversion predict multitasking performance using hierarchical multiple regression.

METHODS

Participants

Participants were 131 undergraduate and graduate students from various departments of a German university. The data of 9 participants had to be excluded due to missing data, language problems, not completing the study, or being outliers. Of the remaining 122 participants, 77 were women and 45 were men. They were between 19 and 36 years old ($M = 23.26$ years, $SD = 3.35$). All participated voluntarily and received feedback from their test performance (if they desired) and credit toward fulfilling required hours of being a participant in psychological studies.

Multitasking Measure

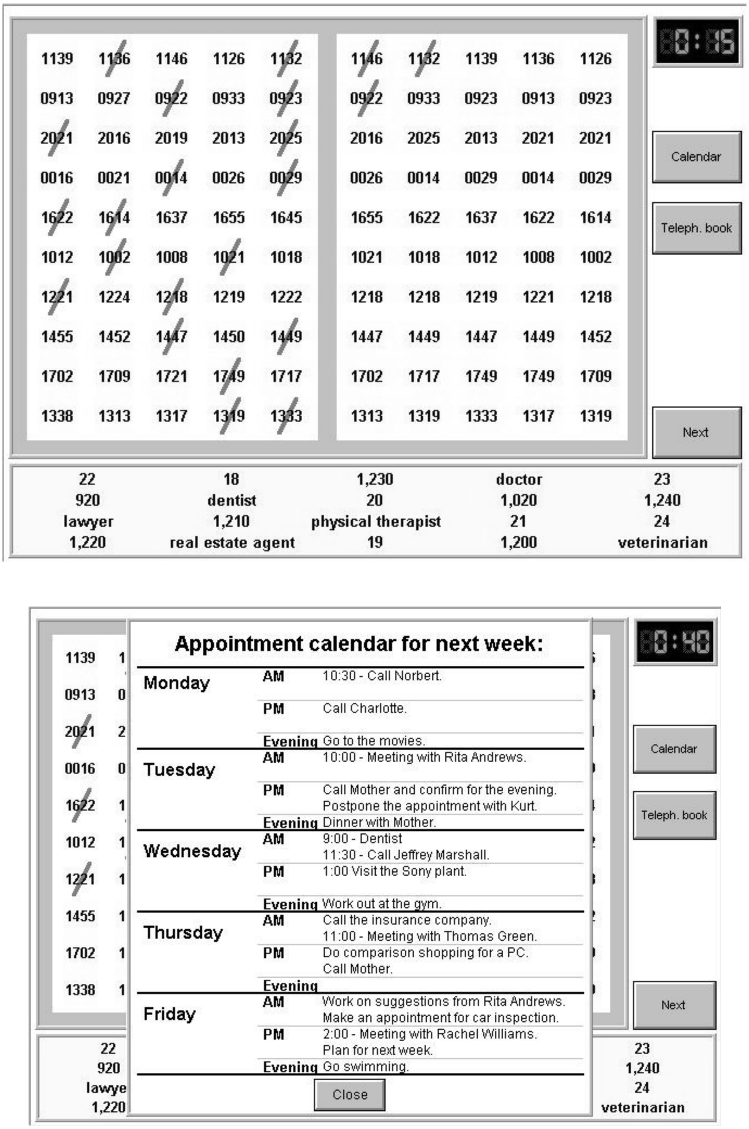
Choosing a good multitasking measure is difficult. In experimental cognitive psychology research into multitasking, the stimulus of the first task typically begins less than 1 sec before the stimulus of the second task (Meyer & Kieras, 1997). Because differences in milliseconds do not usually represent the problems relevant for applied psychology, applied researchers have developed their own scenarios for their studies (e.g., Cellier & Eyrolle, 1992; Ishizaka et al., 2001). However, this use of self-developed scenarios makes evaluating results and comparing studies difficult. Multitasking research could therefore profit from using the Swedish–Austrian scenario called "Simultaneous capacity/Multi-tasking" (SIMKAP for its Swedish name "Simultankapacitetsprovet/Multi-tasking," and its German name "Simultankapazität/Multi-Tasking"; Bratfisch & Hagman, 2003), which is also available in English (Bratfisch, Hagman, & Puhr, 2002) from Schuhfried, a test publishing company in Austria. It was developed as a complex, standardized scenario for multitasking, which can also be used for personnel selection purposes.

This computerized scenario consists of five parts with the final one being the multitasking part and the first four parts introducing the number, letter, figure, and question components. In the first three parts, participants see two fields with several rows of five stimuli each. Rows in the left field contain the same or similar stimuli to rows in the right field, but presented in a different order. Some stimuli in the left field are marked, and the participants' task is to mark the same stimuli in the right field, wherever they are presented. Each row constitutes a separate task. Stimuli consist of four-digit numbers in the first part, letters in the second, and figures in the third. (In the case of figures, participants only have to compare two figures at once.) These three parts take 3 min each.

The fourth part of the scenario consists of 24 intellectually simple questions that are presented via headsets. The questions are either logical–numerical (e.g., "Continue the following series: 2, 5, 8, 11"), logical–verbal (e.g., "Which word differs from the others: cow, pig, horse, house?"), or arithmetic (e.g., "What is 34 minus 7?"). Participants see 20 answers in a field at the bottom half of the screen, but only some of these answers are possible answers to the question. Participants are asked to mark the correct answer by using the computer mouse. This part takes approximately 5 min.

The fifth part (the multitasking phase) is divided into three segments. In the first segment numbers are presented (as in the first part of the SIMKAP); letters are presented in the second segment, and figures in the third segment. While participants are working on these tasks, they are required to solve questions similar to those in the fourth part. At the same time they have to answer additional questions (e.g., "You are invited to lunch. On which day do you have time?"), which are also presented via headsets. The answers to these additional questions can be looked up in a calendar or in a telephone book that are accessed by clicking on them. Some of the questions have to be answered with a delay. A timer appears in the top right corner of the screen and the voice says, for instance, "When it says 1:35 on the timer, answer the following question. …" Figure 1 depicts two screenshots. Participants are given 18 min for the fifth part of the SIMKAP.

During the fifth part, the computer calculates the number of correctly marked numbers, letters, and figures as three speed measures, and the percentage of errors separately for numbers, letters, and figures as three error measures. For the intellectually simple questions and the calendar/telephone book questions, the number of correctly answered questions is calculated. The test's authors (Bratfisch & Hagman, 2003) suggest that an overall measure of simultaneous capacity is calculated by adding the three (standardized) speed measures plus the three (standardized) error measures plus three times the (standardized) number of correctly answered questions. The authors report reliability coefficients between .94 and .97 for this measure. The manual also reports factorial evidence for the independence of the SIMKAP from other tests. In addition, some evidence for its validity has been reported. Braun, Hüttges, Timm, Wieland, and Willamowski (2002) reported



(a)

(b)

FIGURE 1 Two screenshots of a person working on the English version of the Simultaneous capacity/Multi-tasking (SIMKAP) scenario. (a) The person is marking the numbers in the right field that are marked in the left field. (b) The person is looking up information in the calendar to answer the verbally presented question where she plans to go to on Wednesday at 9:00 a.m.

that the SIMKAP scores of 42 call center agents predicted supervisor performance ratings well after 3 months (r = .579; cf. A. Hüttges, personal communication, October 23, 2004). A study of the Swedish navy (Rosmark, 2001) found that the SIMKAP scores of 39 combat boat captain trainees were in good agreement with the overall supervisor ratings that were obtained half a year later.

Tests for the Predictor Variables

Attention. We followed the advice of several attention researchers (e.g., Cohen, 1993; Posner & Boies, 1971; van Zomeren & Brouwer, 1994) to take into account that attention has an intensity aspect and a selectivity aspect. The intensity aspect captures the ability to respond quickly to stimuli briefly presented, which is also called *alertness*. The selectivity aspect captures the ability to focus and to divide attention. Following Sturm's (2002) suggestions, we used tests from the computerized Test Battery for Attentional Performance (TAP; Zimmermann & Fimm, 1993) to measure both aspects of attention. The TAP is a widely used instrument, especially in neuropsychology (e.g., Zoccolotti et al., 2000). The split–half and the odd–even reliability of all TAP subtests used is .98 or .99 (Zimmermann & Fimm, 1993).

Sturm (2002) suggested measuring the intensity aspect with the TAP Alertness subtest. This measures the simple reaction time to a stimulus with or without a warning tone. In this test, participants are instructed to press a button as quickly as possible when a cross (2 cm in diameter) appears in the middle of the screen. The interval between the warning tone and the appearance of the cross varies from 300 ms to 700 ms. The order of block representation is ABBA (in which A = block with warning and B = block without warning), and each block consists of 20 trials. According to Zimmermann and Fimm (1993), the participants' median of the reaction time with and without warning tone should be used as measures of alertness.

Sturm (2002) also recommended measuring the selectivity aspect of attention with two TAP subtests, Go/Nogo and Divided Attention. The Go/Nogo subtest assesses the ability to focus attention. In this test, a square (3 × 3 cm) appears alone in the middle of the screen. Two patterned squares represent the target stimuli and three are nontarget stimuli. A participant is required to press a button if and only if a target is presented. The test consists of 50 successive trials (20 targets and 30 nontargets). A participant's performance is measured by his or her median of the reaction time for correct responses.

In the Divided Attention subtest, participants have to deal with a visual and an acoustic task simultaneously. The visual task consists of a 10 × 10 cm matrix of 16 dots (4 × 4). Seven small x's are superimposed randomly over the dots. When four x's form a square, participants are required to press a button as quickly as possible. In the acoustic task, participants have to react to a series of alternating high (2000 Hz) and low (1000 Hz) tones. Whenever the same tone occurs twice in this sequence, participants have to react as quickly as possible by pressing a button. The test contains 15 visual and 15 acoustic targets out of 85 visual nontargets and 185 acoustic nontargets. According to the authors of the test, the median of the reaction time for responding to squares and tones can be used as measures for this test.

Working memory. Current research stresses the multifaceted nature of working memory (Oberauer et al., 2000; Oberauer et al., 2003). Consequently, working memory should not be measured by only one test. Based on Oberauer et al.'s (2000, revised by Oberauer et al., 2003) model, we chose to measure working memory with three tests: Reading Span, Spatial Coordination, and Switching Numerical. Reading Span was chosen because it is one of the most widely used working memory tasks and assesses the working memory component "storage of information in the context of processing" with verbal material (Oberauer et al., 2003). The Spatial Coordination test was chosen because it measures the same working memory component (storage in the context of processing), but with numerical material. The Switching Numerical test was chosen because it measures the supervision component of working memory with numerical material. All working memory tests were taken from the computerized test battery of Oberauer et al. (2000) and are now described in detail.

In the Reading Span test, syntactically simple sentences with four to seven words are presented sequentially on a computer screen. They remain on the screen for 3 sec, followed by a 1 sec pause, and then by the next sentence. When participants read a sentence, they have to indicate whether the meaning is true or false by pressing the appropriate button. After a series of (three to seven) sentences, participants are required to write down the final word of each of the sentences in the correct order. Participants are given 2 practice trials and 15 test trials. The number of correct words remembered in the right sequence is assessed. Oberauer et al. (2000) reported a Cronbach's α of .84.

In the Spatial Coordination test, participants have to remember the position of dots that appear sequentially in the cells of a 10×10 matrix for 1 sec. The sequence of the (2–6) dots produces a pattern, and participants are required to judge whether the pattern is symmetrical. If it is, they have to reproduce the relative pattern of dots in an empty matrix on the left side of the answer sheet. Otherwise they have to use the matrix on the right side of the answer sheet. The score obtained for this task is the mean number of correctly reproduced dots given that the decision of symmetry is correct. Oberauer et al. (2000) reported a Cronbach's α of .75.

In the Switching Numerical test, the computer screen shows successive displays of a varying number of equal digits. Participants are to alternate between counting the number of digits and reading the digits. The number of digits never equals the value of the digits. Participants are asked to give their answer by using the number pad on the keyboard. During each trial, a short reminder in the top part of the screen informs participants which kind of response should be given. Reaction time is recorded to measure test performance. Oberauer et al. (2000) reported a Cronbach's α of .78.

Fluid intelligence. The Intelligenz–Struktur–Test 2000R (Amthauer, Brocke, Liepmann, & Beauducel, 2001) was used to measure fluid intelligence. It is the most recent version of one of the most frequently used German intelligence tests, and its validity is well established (e.g., Schmidt-Atzert & Deter, 1993). Beauducel, Brocke, and Liepmann (2001) confirmed the structure of the Intelligenz–Struktur–Test 2000R and showed that the Analogies, the Number Series, and the Matrices subtests are particularly good indicators of fluid intelligence. These three subtests were therefore chosen as measures in this study. Amthauer et al. (2001) report a Cronbach's α of .71 for Analogies, .90 for Number Series, and .66 for Matrices.

Polychronicity. This construct was measured with the individualized version (Conte & Jacobs, 2003; Conte et al., 1999) of the Inventory of Polychronic Values (IPV; Bluedorn et al., 1999). Because the IPV was invented to measure polychronicity as a dimension of organizational culture, it contains items such as, "We like to juggle several activities at the same time," whereas the corresponding item in the individualized version is, "I like to juggle several activities at the same time." The IPV has 10 items measured on a 7-point Likert response scale (anchored from *strongly disagree* to *strongly agree*) with higher values indicating a more polychronic attitude. Conte et al. (1999) reported Cronbach's α of .82 and higher and evidence for construct validity (e.g., correlations among participants and peer ratings). The retest–reliability coefficient over a 2-month interval is .78 (Conte & Jacobs, 2003).

The IPV was independently translated from English into German by four Germans who were fluent in English. A fifth person backtranslated a synthesized version into English. A high agreement between the original and the backtranslated version was found.

Extraversion. This construct was measured with the subscale of a German Big Five questionnaire (Borkenau & Ostendorf, 1991, 1993). The measure has 12 items with a 5-point Likert response scale (anchored from *strongly disagree* to *strongly agree*). The manual reports a Cronbach's α of .80 and a retest reliability over 2 years of .76 (Borkenau & Ostendorf, 1993).

Procedure

The testing took place in a diagnostic laboratory, which allowed group testing with up to five participants. Altogether, the testing took around 3 hr for completion. We first introduced participants to the general procedure and asked them to complete a sociodemographic questionnaire as well as the IPV and the Extraversion measure. This part took approximately 15 min. Following this, the participants worked on the SIMKAP for 45 min. Because this is a fully computerized test, all the instructions were presented on screen. For an additional 30 min the participants were asked to work on the TAP, the instructions for which were also given on screen. Participants were then allowed a 5-min break. The second half of the session began with the working memory tests, for which 25 min were allowed. These tests required the participants to note their answers in a special booklet. During the final 45 min the participants worked on the computerized version of the Intelligenz–Struktur–Test 2000R. Importantly, a recent study with an even longer testing session (with similar tasks and participants) did not find fatigue effects (Süß & Schmiedek, 2000), making fatigue effects in this study highly unlikely.

RESULTS

Descriptive Statistics and Reliabilities of the Predictor Variables

Table 1 reports descriptive statistics, reliability estimates, and correlations of single tests. Unfortunately, the TAP does not allow reliability estimates to be calculated. The values reported in Table 1 are shown only for purposes of comparison with other studies and were not used for the analyses. Instead, factor scores were calculated as construct measures of attention, working memory, fluid intelligence, polychronicity, and Extraversion. We used Thurstone's least squares regression approach (as Tabachnik & Fidell, 2001, recommended), in which the factor score coefficients are computed from the original item/test correlations and the correlations between the items/tests and the factors. If Thurstone's approach is used, researchers obtain factor scores that predict the true factors as exactly as possible (for details, see Grice, 2001). An alternative would have been to unit-weight only the salient items/tests (a typical salience cut point being a correlation between items/tests and factors of ± .30) and to sum the raw values. This method yields poorer representations of the true factors, but the results are typically assumed to be more stable (Grice, 2001). For our study, we considered the good representation of the true factors as the important criterion because we were interested (for example) in showing how well the aspect that the attention tasks have in common predicts multitasking performance.

The variables were first z-transformed and, where necessary, recoded so that high scores expressed high performance. Five single-factor analyses were then conducted and one factor was extracted in each analysis. The principal axis factoring was chosen as the extraction method to assess only the reliable part of the variance of each construct. For attention, the factor explained 40.38% of variance; for

TABLE 1
Descriptives, Reliability Estimates, and Correlations for All Single Tests or Subtests

Variable	*M*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Attention–alertness (with warning)	211.33	23.73	—[a]															
Attention–alertness (without warning)	220.65	27.63	.82**	—[a]														
Attention– Go/Nogo	491.38	53.98	.30**	.26**	—[a]													
Attention–divided attention (tones)	553.04	76.89	.31**	.31**	.29**	—[a]												
Attention–divided attention (squares)	770.14	87.93	.37**	.28**	.30**	.43**	—[a]											
Working memory–reading span	3.70	.70	–.14	–.17	–.26**	–.19*	–.25**	.84[b]										
Working memory–spatial coordination	2.51	.53	–.08	–.11	–.19*	–.25**	–.25**	.45**	.67[b]									
Working memory– switching numerical	1,722.13	325.86	.30**	.26**	.24**	.08	.29**	–.24**	–.13	.83[b]								
Fluid intelligence–analogies	12.60	2.63	.03	.13	–.05	.01	–.21*	.15	.21*	–.12	.57[b]							
Fluid intelligence– number series	15.31	3.69	–.17	–.12	–.24**	–.23*	–.33**	.45**	.26**	–.34**	.06	.84[b]						
Fluid intelligence–matrices	11.05	2.67	.09	.14	.02	.06	–.03	.23**	.17	–.19*	.21*	.28**	.51[b]					
Polychronicity	3.75	.85	.13	.10	.04	.09	.11	–.05	–.06	–.03	–.21*	.07	.24**	.84[b]				
Extraversion	3.50	.51	.12	.13	.16	–.03	.07	.05	.00	–.08	–.11	–.03	.08	.15	.82[b]			
SIMKAP: speed measure	119.36	26.46	–.05	–.07	–.14	–.07	–.27**	.24**	.20*	–.31**	.03	.44**	.17	.13	.01	.93[c]		
SIMKAP: error measure	4.35	2.386	–.22*	–.15	–.10	–.04	–.19*	.32**	.26**	–.24**	.23*	.29**	.25**	.11	.00	.11	.60[c]	
SIMKAP: questions	11.53	2.24	–.21*	–.18*	.24**	–.14	–.39**	.39**	.28**	–.42**	.21*	.57**	.21*	.09	.09	.47**	.44**	.82[c]

Note. $n = 122$. SIMKAP = Simultaneous capacity/Multi-tasking scenario.
[a]The program does not allow the calculation of a reliability estimate. [b]Cronbach's α. [c]Reliability estimate obtained using Fleishman and Benson's (1987) formula.
*$p < .05$. **$p < .01$.

working memory, 37.19%; for fluid intelligence, 27.30%; for polychronicity, 37.01%; and for Extraversion, 30.75%. New internal consistency estimates for working memory and fluid intelligence were calculated by combining the reliability estimates for the subtests. The following formula Lienert and Raatz (1998) suggested was used:

$$ {}_{bat}rel = 1 - \frac{k - \sum rel}{k + 2\sum r_{subtests}}, \quad (1) $$

where ${}_{bat}rel$ is the reliability estimate for the test battery, k is the number of subtests, rel is the reliability estimate of subtest t, and $r_{subtests}$ is the correlation between subtests. Working memory had ${}_{bat}rel$ of .78, fluid intelligence a ${}_{bat}rel$ of .73.

SIMKAP Measurement Model

The SIMKAP model was tested with a confirmatory factor analysis (conducted with AMOS 4.0; Arbuckle, 1999). The advice of Hu and Bentler (1998, 1999) was followed to evaluate the global model fit. They recommended the following fit indexes: root mean square of approximation (RMSEA; cut-off ≤ .08) and standardized root mean square residual (SRMR; cut-off ≤ .11). In addition, the χ^2 score and the corresponding probability level as well as the comparative fit index (CFI, cut-off ≈ .95) are provided.

The authors of the SIMKAP scenario (Bratfisch & Hagman, 2003) suggest an overall score that combines the three speed measures (verbal, figural, and numerical), the three error measures (verbal, figural, and numerical), and the number of correctly answered questions. We tested this idea in the following way. First, the three speed measures were z-transformed. Second, the three error measures were also z-transformed as well as recoded so that a high score expressed high performance. Third, the correctly answered questions were divided randomly into three parcels and then z-transformed. The fourth step was the confirmatory factor analysis in which all nine measures loaded on one factor (see Figure 2). However, the model did not fit: RMSEA = .251, SRMR = .180, $\chi^2 = 232.08$ ($df = 27$; $p < .01$), and CFI = .590.

An alternative model was built by having three factors for each kind of measure (speed measures, error measures, and questions). We also allowed error correlations between the measures that use the same material (numbers, letters, or figures). This model fit well: RMSEA = .079, SRMR = .056, $\chi^2 = 36.79$ ($df = 21$; $p < .05$), and CFI = .968 (see Figure 3).

We therefore used these three SIMKAP measures as dependent variables in further analyses: the average of the speed measures, the average of the error measures, and the average of the question parcels. To allow comparisons with other studies, in Table 1 we report the descriptive statistics of these three SIMKAP measures

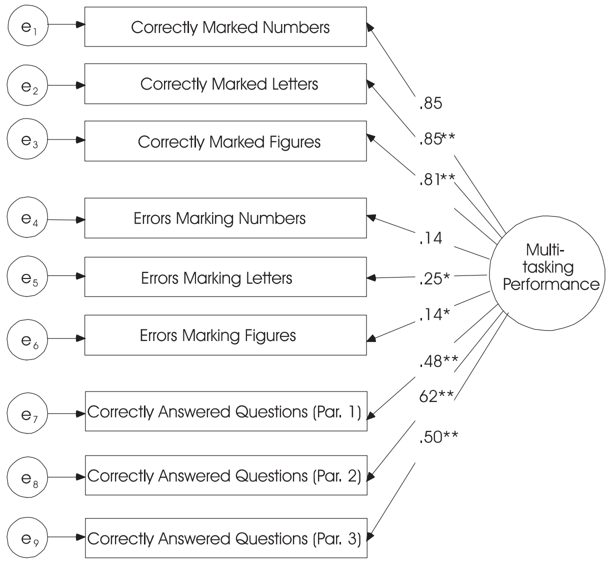


FIGURE 2 The one-factor measurement model of the Simultaneous capacity/Multi-tasking scenario. Par. = Parcel.

without z-transformation. Reliability estimates (shown in Table 1) were obtained by using the following formula (J. Fleishman & Benson, 1987), which is based on the confirmatory factor analysis:

$$rel = \frac{\left(\sum \beta_j\right)^2}{\left(\sum \beta_j\right)^2 + \sum \theta_j^2}, \tag{2}$$

where *rel* is the reliability, β_j represents the loading of item *j* on its factor, and θ_j refers to the error variance for each item.

Table 2 shows the correlations between the factor scores and the SIMKAP measures. Interestingly, polychronicity was related with fluid intelligence, which replicates the results of Conte and Jacobs (2003).

Multiple Regression Analyses

Two sets of hierarchical multiple regression analyses were conducted. In the first set of analyses, the more basic constructs were entered first (i.e., attention as the most basic ability construct, then working memory, then fluid intelligence, and finally polychronicity and Extraversion). The second set of analyses used the reverse order. This procedure was used especially to test whether working memory and attention are needed to predict multitasking performance. The dependent vari-

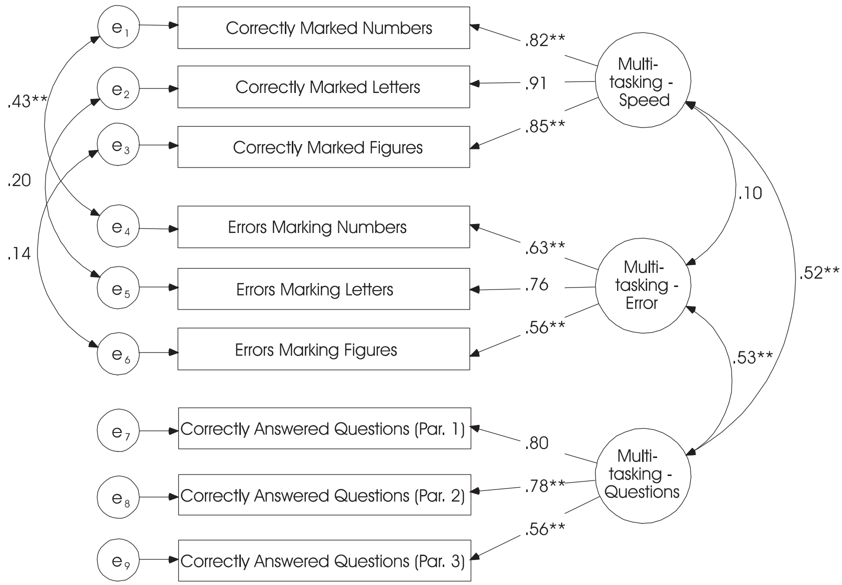


FIGURE 3 The three-factor measurement model of the Simultaneous capacity/Multi-tasking scenario. Par. = Parcel.

ables for each set of multiple regression analyses were the three SIMKAP measures (speed, error, and correctly answered questions).

Tables 3 and 4 describe the results of these regression analyses. The predictors explained 12% to 27% of the variance. Attention was a significant predictor only for the error measures and the questions. Including working memory as the predictor significantly increased the explained variance from 7% to 14% over attention

TABLE 2
Correlations Between Latent Predictors and the Three SIMKAP Variables

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Attention (factor score)							
Working memory (factor score)	.26**						
Fluid intelligence (factor score)	–.05	.32**					
Polychronicity (factor score)	–.13	–.03	.22**				
Extraversion (factor score)	–.12	.05	.05	.17			
SIMKAP: speed measure	.11	.28**	.23**	.13	.01		
SIMKAP: error measure	.22*	.35**	.30**	.14	.01	.11	
SIMKAP: questions	.27**	.44**	.31**	.08	.07	.47**	.44**

Note. $n = 122$. SIMKAP = Simultaneous capacity/Multi-tasking scenario.
$^*p < .05$. $^{**}p < .01$.

TABLE 3
Hierarchical Regression Analysis for Predicting Multitasking Performance (Starting With Attention)

	Speed				*Error*				*Questions*			
Predictor Variable	*Step 1*	*Step 2*	*Step 3*	*Step 4*	*Step 1*	*Step 2*	*Step 3*	*Step 4*	*Step 1*	*Step 2*	*Step 3*	*Step 4*
Step 1												
Attention	.109	.040	.064	.073	.218*	.137	.172	.182*	.272**	.172*	.203*	.218*
Step 2												
Working memory		.269**	.208*	.220*		.314**	.228*	.240*		.392**	.314**	.315**
Step 3												
Fluid intelligence			.169	.141			.238**	.208*			.216*	.198*
Step 4												
Polychronicity				.119				.125				.071
Extraversion				–.018				–.010				.056
ΔR^2		.07**	.03	.01		.09**	.05**	.01		.14**	.04*	.01
Overall R^2	.01	.08**	.10**	.12**	.05*	.14**	.19**	.20**	.07**	.22**	.26**	.27**
Adjusted R^2	.00	.06	.08	.08	.04	.13	.17	.18	.07	.20	.24	.24

Note. $n = 122$. Standardized regression coefficients are shown.
*$p < .05$. **$p < .01$.

TABLE 4
Hierarchical Regression Analysis for Predicting Multitasking Performance (Starting With Polychronicity and Extraversion)

	Speed				*Error*				*Questions*			
Predictor Variable	*Step 1*	*Step 2*	*Step 3*	*Step 4*	*Step 1*	*Step 2*	*Step 3*	*Step 4*	*Step 1*	*Step 2*	*Step 3*	*Step 4*
Step 1												
Polychronicity	.129	.085	.113	.119	.139	.078	.112	.125	.076	.010	.055	.071
Extraversion	–.011	–.013	–.027	–.018	–.012	–.015	–.032	–.010	.054	.051	0.29	.056
Step 2												
Fluid intelligence		.215*	.131	.141		.286**	.184*	.208*		.302**	.171	.198*
Step 3												
Working memory			.242*	.220*			.295**	.240*			.381**	.315**
Step 4												
Attention				.073				.182*				.218*
ΔR^2		.04*	.05*	.00		.08**	.08**	.03*		.09**	.13**	.04*
Overall R^2	.02	.06*	.11**	.12*	.02	.10**	.17**	.20**	.01	.10**	.22**	.27**
Adjusted R^2	.00	.04	.08	.08	.00	.08	.15	.17	.00	.08	.20	.24

Note. n = 122. Standardized regression coefficients are shown.
$^*p < .05$. $^{**}p < .01$.

alone and from 5% to 13% variance over fluid intelligence, polychronicity, and Extraversion. Fluid intelligence predicted only 3% to 5% additional variance if entered after working memory. This increase in R^2 was significant for two of the three SIMKAP variables (the exception being SIMKAP speed as the dependent variable). Neither polychronicity nor Extraversion were significant predictors of multitasking performance. Additional analyses (available from the first author) revealed that the results were not attributable to age differences.

DISCUSSION

This study sought to explain which variables predict multitasking performance. Our results showed that working memory, fluid intelligence, and attention are important predictors. However, multitasking performance was not related to polychronicity nor to Extraversion.

Working memory turned out to be the most important of the predictors investigated. Of all four predictors, working memory yielded the highest correlations with the three SIMKAP measures of multitasking and increased the explained variance to the greatest extent in the hierarchical multiple regression analyses. In particular, working memory explained incremental variance that could not be accounted for by fluid intelligence. This was the case despite a significant correlation between working memory and fluid intelligence, which other authors (e.g., Kyllonen & Christal, 1990) also reported.

Fluid intelligence was also an important predictor of multitasking. This is in congruence with other studies (Ben-Shakhar & Sheffer, 2001; Stankov, 1988). This is also consistent with the finding that intelligence is generally a good predictor of many performance facets (Schmidt & Hunter, 1998).

Attention was the most basic construct we used as a predictor. We found mixed support for a role of attention in multitasking. Independently of whether attention was entered first or last, it predicted two of the three SIMKAP measures, but not the speed measure of the SIMKAP. This is surprising because our latent attention variable included a simple reaction time measure (the Alertness test). In other words, a simple speed measure did not predict the speed component of multitasking. One explanation of this finding is that the individual differences in controlling attention (i.e., working memory), rather than the differences in attention per se, matter for multitasking. Given the complexity of our multitasking scenario, higher cognitive processes are so important that simple perceptual speed might be marginal.

Polychronicity was not a predictor of multitasking performance. We assumed that people prefer working polychronically because they are good at multitasking. This does not seem to be the case. Given that Ishizaka et al. (2001) were also unable to find a significant relation between polychronicity and multitasking performance (with different tasks), the preference for working polychronically might have other reasons than being good at working polychronically. Polychronic individuals might not be particularly concerned with the advantages or disadvantages of multitasking, but simply like the constant changes of work involved in multitasking. Alternatively, people might not be able to judge whether they good at multitasking. Further studies on the relation between polychronicity and multitasking performance could therefore explore whether polychronicity is related only to subjective multitasking performance and not to objectively measured multitasking performance (as in this study). Another explanation of the nonexistent relation between polychronicity and multitasking performance is that participants thought about a more macro kind of multitasking when they filled out the IPV—more macro than the multitasking we measured with the SIMKAP. That means when participants answered the item, “I like to juggle several activities at the same time,” they might have thought about working on two tasks during an hour with rare shifting. The IPV instructions unfortunately do not specify whether a participant should think about a more macro or a more micro kind of multitasking. Therefore, we cannot deduce from the data whether this problem occurred.

Extraversion was not a predictor of multitasking performance either. Based on Lieberman and Rosenthal’s (2001) neuroscientifically inspired arguments, we argued that extraverts would be better at multitasking than introverts. This was not the case, even though Lieberman and Rosenthal found that extraverts are better in a nonverbal decoding task under multitasking condition. Future research could explore whether the differences between tasks in their study and our study are responsible for the different results. We certainly believe that a replication is needed to solve the question of whether Extraversion is related to multitasking performance.

An advantage of our study is that we used the SIMKAP scenario as a measure of multitasking. Because other researchers can thus easily use the same scenario for their research, future research could become easier to compare. In other words, future research could suffer less from the problem that researchers use their own scenarios (e.g., Cellier & Eyrolle, 1992; Ishizaka et al., 2001). However, more research on the internal and external validity of the SIMKAP scenario is needed (e.g., to replicate our measurement model).

A potential limitation of the study is the lack of generalizability of the findings to other populations. Participants in this study were graduate and undergraduate students. However, even though the motivation of students who participate in research might often be low, this should not be a problem in this study. We attracted participants for this study by offering performance feedback in tests that are typically used for personnel selection. Nearly all participants were interested in detailed feedback, and therefore they were most likely motivated.

Future research could investigate the relation of personality constructs other than polychronicity to multitasking. A particularly good candidate is the Type A behavior pattern (TABP). De la Casa, Gordillo, Mejias, Rengel, and Romero

(1998) reported that TABP is related to multitasking, yet Delbridge (2000) could not replicate this. Delbridge, however, did not look directly for a correlation between TABP and multitasking performance. Instead, she had two groups: One group worked on the two tasks serially, whereas the other group had to multitask because the computer switched fast between the two tasks. She then analyzed whether personality variables (e.g., TABP) moderated the performance differences between both conditions, which was not the case. Apart from this special design, her results, however, might also have been affected by specific features of her study because she found a significant performance difference between the single task and the multitasking condition only for one of her tasks. In addition, she did not find any significant moderation effects of personality variables at all. Further evidence regarding the relation between TABP and multitasking comes from Ishizaka et al.'s (2001) study. They argued that researchers should not look primarily at a global score for TABP, but at TABP subcomponents because of the multidimensional nature of TABP. Consistent with this argument, they found some evidence that some TABP subcomponents (i.e., scheduling, list making, and achievement striving) are related to multitasking performance, but not to global TABP. To explore these relations further, future studies on multitasking performance should include a TABP measure.

Further research should also explore which facets of working memory are particularly important for multitasking performance. Our results show the general importance of working memory for multitasking performance, but we used a global latent variable for working memory. Researchers could use Oberauer et al.'s (2003) revised working memory model for a more differentiated view on working memory, thus developing a deeper understanding of how working memory is related to multitasking performance.

Our study also has important practical implications. In terms of personnel selection, it implies that working memory tests could be used to select people for jobs that require a high amount of multitasking (e.g., pilots; see Maschke & Goeters, 1999). Even though using general mental abilities as a predictor is useful, the incremental validity of working memory in predicting multitasking performance beyond fluid intelligence provided support for an enhanced selection procedure. Although several working memory tests are used for research purposes, to our knowledge they have never been used for personnel selection purposes.

A second implication concerns time management because multitasking is a time-management strategy (cf. Britton & Tesser, 1991; König & Kleinmann, 2004). Although multitasking has a positive connotation in Britton and Tesser's (1991) time-management questionnaire, time-management practitioners often advise against multitasking. For example, Mackenzie (1997) wrote "one thing at a time is enough for anybody to be working on" (p. 122). Our results can offer a solution to this controversy: Multitasking might only be an effective time-management strategy for people with a large working memory capacity. However, if people are not aware of the working memory capacity (which is most likely to be the case in standard time-management training), time-management trainers might stay on the safe side and caution against multitasking as a time-management strategy.

In summary, given its importance for many jobs (e.g., Chisholm et al., 2001; Maschke & Goeters, 1999), multitasking has, not surprisingly, long attracted the interest of basic and applied research (cf. McQueen, 1917) and the multitasking literature continues to grow (e.g., Ishizaka et al., 2001). The main contribution of this study to this literature is the linking of basic and applied multitasking research by showing that working memory, a construct deeply rooted in experimental cognitive psychology, is an important predictor of performance in a complex multitasking scenario.

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