Being able to work on several tasks at the same time (multitasking) is an important performance aspect of many jobs. Recent research findings pointed out the important role of working memory for multitasking performance in general. To understand more about the role of working memory in predicting the speed and the error aspect of multitasking performance, this research was based on a newly developed and well-elaborated multidimensional model of working memory (Oberauer, Süß, Wilhelm, & Wittmann, 2003). Its 3 dimensions are storage in the context of processing, coordination, and supervision. In addition, attention and reasoning were controlled when predicting multitasking speed and error. A multitasking scenario, a battery of working memory tests, a battery of reasoning tests, and 2 attention tests were administered to 135 participants. As expected working memory was the best predictor of multitasking performance, followed by reasoning and attention. Working memory components showed a differential validity when predicting multitasking speed and multitasking error: Multitasking speed was predicted mainly by coordination, and
multitasking error mainly by storage in the context of processing. Thus, this study provided a deeper insight into the relevant abilities of multitasking. Implications for personnel selection are discussed.

Nowadays, nearly every job requires good performances on more than one task. Employees have to deal with several simultaneous demands, and good job performance is therefore linked to good multitasking performance. This holds true for many jobs, as shown by data from the Occupational Information Network (O*NET; cf. Peterson, Mumford, Borman, Jeanneret, & Fleishman, 1999) and other job analyses (e.g., Maschke & Goeters, 1999, for airline pilots). In terms of personnel selection, therefore, it would appear to be essential to identify future employees with adequate multitasking abilities. Adequate multitasking abilities can include different aspects. For some jobs it can be necessary to quickly perform two or more tasks at a time (e.g., call-center agents; cf. Braun, Hütting, Timm, Wieland, & Willamowski, 2002), whereas for other tasks the omission of errors might be highly relevant (e.g., pilots). Moreover, some jobs might require both quick and correct multitasking performance. The goal of this study is to explore how individual differences in these two aspects of multitasking performance—speed and error—can be predicted by other constructs, in particular by different working memory dimensions.

Though multitasking research has a long history, it has only recently become a topic in applied research. Multitasking research began at the end of the 19th century, when researchers conducted experiments in which participants were required to take dictation while reading prose, or squeeze a dynamometer while performing arithmetic tasks (Stein, 1896, and Welch, 1898, cited in Logan & Gordon, 2001). Since then, multitasking has been the focus of many studies. However, most of these studies are conducted by cognitive psychologists who are interested in understanding which cognitive processes make multitasking possible and what the costs of multitasking are (e.g., Logan & Gordon, 2001; Meyer & Kieras, 1997; Monsell, 2003; Pashler, 2000). Applied researchers have predominantly looked at simple dual tasks as predictors of the performance of pilots (e.g., Damos, 1993) or managers (Stankov, Fogarty, & Watt, 1989).

Only a small amount of research has been conducted on predicting multitasking performance as an aspect of job performance. Some researchers (De la Casa, Gordillo, Mejias, Rengel, & Romero, 1998; Delbridge, 2000; Ishizaka, Marshall, & Conte, 2001; König, Bühner, & Mürling, 2005) have tried to link multitasking performance to personality constructs. However, the results of such studies have been disappointing: Either there were no significant relations found (e.g., for polychronicity and extraversion, Ishizaka et al., 2001; König et al., 2005) or the relation was small and inconsistent (e.g., for Type-A behavior pattern, De la Casa et al., 1998; Delbridge, 2000; Ishizaka et al., 2001). Thus, this research focuses on ability rather than personality predictors.
Preliminary evidence for a close relation between working memory and multitasking comes from a study conducted by König et al. (2005), in which the working memory measure was found to be the best ability predictor of multitasking performance. However, the authors used an undifferentiated set of only three working memory tasks that were combined for the analyses. This is in conflict with empirical findings showing that working memory is multidimensional (cf. Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002). Thus, their design made it impossible to identify which dimensions of working memory significantly predict multitasking. This follow-up study to König et al. used therefore a much greater set of working memory tasks to explore which aspect of working memory is important for the speed and the error aspect of multitasking performance, respectively.

In contrast to the study by König et al. (2005), this study (employing a new sample) is based on a differentiated model of working memory that was proposed by Oberauer et al. (2003; see also Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000). These authors provided evidence for three functional dimensions of working memory: storage in the context of processing, coordination, and supervision.

Storage in the context of processing is described as “retention of briefly presented new information over a period of time in which the information is no longer present” (Oberauer et al., 2003, p. 169). This ability is essential in a multitasking context: Information has to be kept in mind while performing other tasks in between. The coordination dimension of working memory represents “the ability to build new relations between elements and to integrate relations into structures” (Oberauer et al., 2003, p. 169). Simultaneously executing two tasks might require coordination ability because it might be advantageous to coordinate the two tasks and to integrate them into a larger plan of how to work on these tasks. The third functional working memory dimension, supervision, involves “the monitoring of ongoing cognitive processes and actions, the selective activation of relevant representations and procedures, and the suppression of irrelevant, distracting ones” (Oberauer et al., 2003, p. 169). Supervision might be an important ability within multitasking scenarios, because the suppression of irrelevant interfering information might enhance the processing speed of current tasks. The aim of this study is therefore to test the predictive power of working memory dimensions on multitasking performance using a differentiated model of working memory (unlike König et al., 2005). In addition, this study allows it to be explored whether working memory dimensions differently predict multitasking speed or errors. More precisely, we tested the following hypotheses:

H1: Storage in the context of processing predicts multitasking (a) speed and (b) error.
H2: Coordination predicts multitasking (a) speed and (b) error.
H3: Supervision predicts multitasking (a) speed and (b) error.
ATTENTION AND REASONING
AS ALTERNATIVE PREDICTORS

The role of working memory dimensions in the prediction of multitasking performance should be seen in the context of two other ability constructs, namely attention and reasoning. If attention and reasoning are ignored when analyzing the predictive power of working memory, then the model is underspecified. Underspecification should be avoided because the role of other variables (i.e., the role of working memory dimensions in this context) is artificially increased (cf. König et al., 2005). However, models can also be overspecified by including either many irrelevant variables or variants of the same variables. This can lead to multicollinearity problems and inefficient or even biased estimates. Thus, theoretical arguments should lead to the inclusion (or exclusion) of variables.

Attention should be included because it is believed to be an important basic cognitive function (e.g., Engle, Kane, & Tuholski, 1999; Schweizer, 2005). It provides the foundation for the operation of all other processes of cognition by allocating or controlling processing resources (for excellent reviews on the vast literature on attention see Johnson & Proctor, 2004; Pashler, 1998). Attention should be controlled because Kahneman (1973) proposed that every person has a pool of processing resources available, which could be allocated according to task demands. The ability to divide attention (allocate processing resources) and to focus on relevant information while disregarding irrelevant information (control processing resources) might be helpful in multitasking situations (for mixed support of the role of attention see König et al., 2005). This leads to the following hypothesis:

H4: Working memory dimensions predict multitasking (a) speed and (b) error over and above attention.

General mental ability (GMA) is the best predictor of general job performance (Schmidt & Hunter, 1998). Reasoning is in turn the best predictor of GMA (see Carroll, 1993). Because multitasking is a cognitively demanding aspect of job performance, reasoning ability should also be an important predictor of multitasking. Some empirical evidence already exists showing a correlation between reasoning and multitasking (e.g., Ben-Shakhar & Sheffer, 2001; König et al., 2005; Stankov, 1988), even though the predictive power of reasoning is smaller than the power of working memory (König et al., 2005). An inclusion of reasoning is also important from a practical point of view: a reasoning test is more likely to be used than a working memory test in personnel selection in practice because reasoning is an already established predictor for job performance. Thus, if multitasking performance can be predicted on the basis of a reasoning test score alone, there is no need for the additional use of working memory tests. Though the incremental contribution of an undifferentiated set of
working memory tasks over and beyond reasoning has been shown (see König et al.), the incremental validity of different dimensions of working memory remains to be proven. Thus, we tested the following hypothesis:

H5: Working memory dimensions predict multitasking (a) speed and (b) error over and above reasoning.

METHOD

Participants

The test battery was administered to 135 students of a German university. A completely different sample as in the study of König et al. (2005) was used. Participation ensued on a voluntary basis. Following the testing, the students received performance feedback as well as course credit points for their participation. Fourteen participants had to be excluded due to missing data or previous knowledge of the administered tests, and therefore statistical analyses were conducted with 121 students. The mean age was 22 years ($SD = 3.0$), and 25% of the students were male. Participants were studying the following academic units: psychology (62.8%), economics (10.7%), education (9.1%), and others (17.4%), and had been studying for an average of 3.3 semesters ($SD = 3.54$).

Multitasking

To measure multitasking performance, the Swedish–Austrian multitasking scenario “Simultaneous Capacity” (SIMKAP; Bratfisch & Hagman, 2003) was used, as in the study by König et al. (2005). The SIMKAP is computerized and consists of five parts, with the final part containing the multitasking condition. In the first four parts, single tasks are presented and baseline scores are obtained. Parts one to three require participants to compare numbers, letters, or figures, each presented in two separate windows. Stimulus material marked in the left window must also be marked in the right window. The maximum allotted time for each subtest is set to 3 min.

The fourth part of the scenario consists of 24 intellectually simple questions presented via headsets. These questions are 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?”) in nature. Twenty answers are constantly presented in a field on 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.
In the fifth part, all previous single tasks are combined. The first three parts (numbers, letters, and figures) are presented sequentially, each lasting 6 min and combined with the fourth part. The questions that participants are required to answer for these tasks are similar to those of part four with one exception: some questions have to be answered with a delay or at a certain time (e.g., “When it is 1:35 on the timer, answer the following question …”). For this purpose, there is a clock running in the upper right corner of the screen. Some questions can only be answered by looking up the appropriate information in a diary (e.g., “You are invited to lunch. On which evening do you have time?”) or in a phone book.

During the fifth part, the computer records the number of correctly marked numbers, letters, and figures; these are the speed measures. The computer also measures the percentage of errors separately for numbers, letters, and figures as three error measures. For the questions, the computer records the number of correctly answered questions (the “question measure”). The latter measure is similar to the speed measures because the focus is not on the errors when answering the questions but on answering as many questions as possible within a restricted time period. Thus, results should be similar for speed and question measures but dissimilar for the error measures.

Bratfisch and Hagman (2003) suggested that a total score of simultaneous capacity is calculated by adding the three (z-standardized) speed scores, the three (z-standardized) error scores, and three times the (z-standardized) number of correctly answered questions. This corresponds with a one-factorial model of the SIMKAP. König et al. (2005) were not able to replicate this model and therefore suggested a three-factorial model containing an error factor (verbal, figural, numerical), a speed factor (verbal, figural, numerical), and a factor that was built by the SIMKAP questions (each question [all in all 48] was randomly assigned to one of three item-parcels [16 questions], summed up and divided by the number of items).

The authors of the SIMKAP presented some results to confirm the validity of the SIMKAP. In the manual, evidence is provided for the SIMKAP’s factorial independence from other tests (discriminant validity). In addition, a study conducted within the Swedish Navy (Rosmark, 2001) validated the SIMKAP as a personnel selection tool with supervisor ratings after 6 months. Furthermore, SIMKAP scores predicted supervisor performance ratings of call center agents well after 3 months (A. Hüttges, personal communication, October 23, 2004; see also Braun et al., 2002).

Working Memory

The working memory test battery of Oberauer et al. (2003) was used to measure working memory. It consists of three different kinds of tasks that measure different components of working memory: storage in the context of processing tasks, coor-
dition tasks, and supervision tasks. In addition, choice reaction time tasks (CRTTs) are first administered as a baseline measure for the supervision tasks.

**Baseline tasks.** Eight CRTTs were used. For each two CRTTs, the same type of stimulus material (nouns, numbers, arrows, or patterns) is used, but the decision criteria differ for each task. Participants have to make a quick choice as to whether the stimulus belongs to one category or another (e.g., plant vs. animal), and are required to respond as quickly and correctly as possible by pressing two keys. The tasks are organized into one practice block of 15 trials and five test blocks of 16 trials each. After each block, feedback is given on the number of correct responses.

For the two verbal CRTTs, nouns are used as stimuli. The CRTT “categories” requires a distinction between animal versus plant terms, while the CRTT “syllables” requires a distinction between one versus two syllables. The two numerical CRTTs consist of three-digit numbers, with the CRTT “odd–even” requiring a decision as to whether the presented number is odd or even, and the CRTT “large–small” instructing participants to decide whether the presented number is above or below 500. For the first two spatial CRTTs, arrows are applied as stimuli. In the CRTT “up–down,” participants have to react to the different directions of the arrows (up vs. down), while in the CRTT “above–below” they have to react to the location of arrows within the frame (upper vs. lower half of the frame). Within the other two spatial tasks, 3×3 partially filled matrices are presented. In the CRTT “parts,” participants have to decide whether the matrices consist of either one or two separated parts; in the CRTT “symmetry,” they are required to indicate whether or not the matrices are symmetrical.

To calculate scores (the baseline measures for the supervision tasks), false responses are eliminated as well as reaction times below 200 msec and times exceeding the individual’s mean by three standard deviations or more. The log-transformed reaction times are then aggregated within blocks.

**Storage in the context of processing tasks.** The “storage in the context of processing” component of the working memory model is assessed by tasks in which participants have to memorize stimuli, then perform another task, and finally recall the stimuli. Stimulus material to be remembered (nouns, digits, spatial location of dots, or figures) is presented in immediate succession, and participants then have to perform a series of corresponding CRTTs. To keep the time between learning and recall constant, the CRTTs last for 5 sec regardless of the number of trials the participants perform within this time. Finally, the participants are asked to recall the previously presented stimuli in the correct order. Using this design, four subtests are applied: verbal storage tasks, numerical storage tasks, dots storage tasks, and figures storage tasks. Verbal storage tasks require nouns to be recalled, and in the intervening period between memorizing and recalling, partici-
pants work on the corresponding CRTT “categories.” In the numerical storage
tasks, a series of digits has to be remembered, and the corresponding CRTT is the
CRTT “odd–even.” The dots storage task, which requires the spatial location of
dots to be remembered (within a rectangular frame), is combined with the CRTT
“symmetry.” For the figures storage tasks, participants have to memorize several
partially filled $3 \times 3$ patterns and, in between, perform the CRTT “up–down.”

There are two practice trials for each kind of storage task, followed by 15 test
trials. Memory demands increase during each of the four subtests. For example,
the number of nouns participants have to remember increases from three to seven.

Two scores are obtained: the number of elements correctly remembered (mem-
ory performance) and the log-transformed reaction times for the CRTTs. Because
the correlations between these two subtask scores are usually low, and as it is com-
mon practice to evaluate storage and processing tasks according to memory perfor-
ance only (e.g., Daneman & Carpenter, 1980), Oberauer et al. (2003) suggested
that analyses be based only on the memory scores.

**Coordination tasks.** The “coordination” component of the working mem-
ory model is measured by four tasks: verbal monitoring, numerical monitoring,
flight control, and finding squares. Changing relations between several independ-
ently changing objects have to be monitored and certain critical relations have to
be detected.

The verbal monitoring tasks consist of a $3 \times 3$ matrix with a word in each of the
nine cells. Every 2 sec one randomly chosen word is replaced. The participants
have to detect three rhyming words on either the horizontal, vertical, or diagonal
line. During one trial, 2 to 5 target rows appear within 10 to 20 replacements.

In the numerical monitoring task, three-digit numbers are presented in each of
the nine cells and the participant is required to detect rows with equal last digits.
One randomly chosen number changes every 1.5 sec. Feedback about hits, misses,
and false alarms is given after each trial. Scores are obtained by subtracting false
alarms from hits.

“Flight control” is the first spatial monitoring task. A number of airplanes
(ranging from 5 to 9 during the 15 items) are represented by triangles moving
across the screen in various directions at four different speeds. Mountains (clusters
of brown squares) are located on the screen. Airplanes appear unpredictably on the
border of the screen and “fly” across the screen, always keeping the same direc-
tion. Participants have to keep track of all planes and avoid crashes with other
planes or mountains by stopping the movement of all planes and then redirecting
one. After this, plane movement has to be recommenced. The participants are told
that they start with 100 credit points at the beginning of each trial. Each crash will
cost them 10 points and each movement stop will cost 3 points. The goal is to avoid
.crashes and, at the same time, to stop the planes as rarely and as briefly as possible.
Duration of each movement stop is also measured. Without interruption, each trial
lasts for about 12 sec. Feedback regarding the number of crashes, the points remaining, and the cumulative duration of movement stops is given after each trial. Scores are obtained by counting the number of crashes.

“Finding squares,” the second spatial coordination task, consists of 8 to 12 red dots located within a 10 × 10 matrix. Two randomly chosen dots change their position every 1.5 sec and 20 items are presented. Participants have to press the space bar whenever four dots form a square; position and size of the square are not relevant. Scores are obtained by subtracting false alarms from hits.

Supervision tasks. Supervision is measured by combining two CRTTs using the same kind of stimulus material. The stimuli (words, numbers, arrows, or patterns) appear in a clockwise order in one of four cells of a 2 × 2 matrix. Participants have to switch from one decision rule (e.g., plant vs. animal) in the upper two cells to the second decision rule (one syllable vs. two syllables) in the lower two cells. This design provides approximately 50% switching trials and 50% no-switching trials. There is one practice block and six test blocks with 16 trials each for the four switching tasks. The four subtests are verbal switching, numerical switching, switching arrows, and switching patterns.

General switching costs are derived from the switching tasks and the corresponding CRTTs as an indicator of supervision. General switching costs are defined as the difference between log-transformed no-switching reaction times and baseline reaction times from the two corresponding single CRTTs. Again, false responses, reaction times below 200 msec, and times exceeding the individual’s mean by three standard deviations or more are eliminated when scores are calculated.

Attention

To measure attention, two different tests from the Test Battery of Attentional Performance (Zimmermann & Fimm, 2002) were used (as recommended by Sturm, 2002).

Go/No-Go test (version “condition 2”). This test measures selective attention (Zimmermann & Fimm, 2002). It contains five squares (3 × 3 cm), each showing different patterns. The participants have to memorize two target squares, after which single squares appear separately one after another in the middle of the screen. The participants are instructed to respond to the two memorized target squares. The test consists of 60 successive trials (24 targets and 36 nontargets). The median of the reaction time is then measured.

Divided attention test (version “series 4”). This test measures divided attention and the focus concept as a part of selective attention. Participants have to
attend to two simultaneous tasks (one visual and one acoustic). The visual task consists of a matrix of $4 \times 4$ dots (size: $10 \times 10$ cm), with seven small “x”s superimposed randomly over them. When four “x”s form a square, the participants have to react as quickly as possible by pressing a key. In the acoustic task, the participants have to react to series of alternating high (2000 Hz) and low (1000 Hz) tones; whenever the same tone occurs twice, the participants have to react as quickly as possible by pressing a key. The task contains 15 visual and 15 acoustic targets out of 85 visual nontargets and 185 acoustic nontargets. As the two scores do not correlate highly with each other, the median of the reaction time response to squares and the median of the reaction time response to tones is assessed, yielding two separate scores.

Reasoning

**IST 2000-R (basic module).** The computer-based basic module of the Intelligence Structure Test 2000 R (IST 2000-R; Amthauer, Brocke, Liepmann, & Beauducel, 2001) was administered to measure reasoning ability. This test is a well-established reasoning test in Germany. Participants are required to perform nine subtests with 20 tasks each, and only a limited period of time is given to complete each subtest. First, three subtests that measure verbal reasoning are applied: completing sentences, verbal analogies, and similarities. Next, three subtests to measure numerical reasoning are administered: calculations, number series, and arithmetic signs. Finally, three subtests to measure figural reasoning are administered: figures, cubes, and matrices. Scores are built by aggregating correct scores for the whole test (reasoning). Beauducel, Brocke, and Liepmann (2001) showed that the IST 2000-R is a theoretically well-founded measure of reasoning.

Procedure

Participants were tested in groups of two to five. Every participant took part in two sessions, each lasting between 3 and 3.5 hr, separated by 1 to 2 weeks. The first session began with the attention tasks. Following this, all working memory tasks were administered. During the second session, the SIMKAP was administered, followed by the IST 2000-R. All tests were administered via computer and in German.

Statistical Analysis

In the first step, the one-factorial SIMKAP model (cf. Bratfisch & Hagman, 2003) was tested with a confirmatory factor analysis. In addition, the three-factorial SIMKAP model according to König et al. (2005) was examined. It must be noted
that the one-factorial model does not correspond to the original model by Bratfisch and Hagman (2003), because the authors used no item parcels. The model fit was assessed as recommended by Hu and Bentler (1998, 1999; see also Beauducel & Wittmann, 2005). Hu and Bentler proposed a two-index strategy to evaluate the global model fit with the following recommendations for the fit indexes: root mean square of approximation (RMSEA; cut-off ≤ .06) and standardized root mean square residual (SRMR; cut-off ≤ .11). In addition, the $\chi^2$ score and the corresponding probability level as well as the comparative fit index (CFI, cut-off = .95) are provided (see Marsh, Hau, & Wen, 2004).

All predictor test scores were $z$-transformed. Scores were recoded in such a way that high scores indicated high performance if necessary (e.g., error scores). Following the procedure of König et al. (2005), factor scores were built for each working memory dimension, the attention factor, and reasoning. Five separate factor analyses (principal axis, no rotation, method used deriving factor scores: Bartlett) were conducted (three working memory factors, one attention and one reasoning factor) and one factor was always extracted. The principal axis analysis was chosen to assess only the reliable part of the variance of each construct. We conducted the factor analysis to reduce the number of predictors. This has the advantage that the risk of obtaining significant results—by chance—due to the large number of predictors is reduced. Furthermore, the number of predictors in relation to sample size meets the standards for the application of regression analysis ($N$ required for five predictors = 109; see Tabachnik & Fidell, 2001, p. 117).

Following König et al. (2005), two hierarchical multiple regression analyses were conducted. In the first regression analysis, the factor scores were entered in the following steps: (a) attention, (b) three working memory components, and (c) reasoning. The reason for this order is that most researchers studying the relation between attention, working memory, and reasoning assume that attention is the most basic construct, followed by working memory, whereas reasoning is the most elaborated construct (e.g., Engle, 2002; Oberauer, Schulze, Wilhelm, & Süß, 2005; Schweizer & Moosbrugger, 2004). After that, in the second regression analysis, the factor scores were entered in reverse order.

**RESULTS**

In Table 1, means, standard deviations, and reliability estimates of all subtests are shown.

**Confirmatory Factor Analysis of the SIMKAP**

Because the recommendations of multivariate normality were not met (multivariate kurtosis = 6.48, $c. r. = 2.53, p < .01$) the $p$ value of the $\chi^2$-score was cor-
## TABLE 1
Means, Standard Deviations, and Reliability Estimates

<table>
<thead>
<tr>
<th>Tests</th>
<th>M</th>
<th>SD</th>
<th>Rel</th>
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</thead>
<tbody>
<tr>
<td><strong>Attention tasks</strong></td>
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<tr>
<td>Divided attention squares</td>
<td>761</td>
<td>83</td>
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<tr>
<td>Divided attention tones</td>
<td>761</td>
<td>83</td>
<td>.65</td>
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<tr>
<td>Go/No-Go</td>
<td>503</td>
<td>61</td>
<td>.78</td>
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<td><strong>Working memory tasks</strong></td>
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<td>CRTT categories</td>
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<tr>
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<td>600</td>
<td>130</td>
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<td>General switching costs-arrows</td>
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<td>General switching costs-pattern</td>
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<td>Figures</td>
<td>13.31</td>
<td>3.19</td>
<td>.64</td>
</tr>
<tr>
<td>Cubes</td>
<td>11.02</td>
<td>4.36</td>
<td>.84</td>
</tr>
<tr>
<td>Matrices</td>
<td>11.71</td>
<td>2.73</td>
<td>.54</td>
</tr>
<tr>
<td>Overall reasoning score</td>
<td>120.5</td>
<td>18.6</td>
<td>.91</td>
</tr>
</tbody>
</table>

(continued)
rected by applying a Bollen-Stine correction. A Maximum-Likelihood CFA
(ML-CFA) is very robust against violations of multivariate normality (Hu &
Bentler, 1998, 1999). The skewness and kurtosis of the SIMKAP scores were
within the recommended range (skewness < 2; kurtosis < 7) proposed by West,
Finch, and Curran (1995). Thus a ML-CFA was performed. The one-factorial
model (see Figure 1) could not be confirmed:
\[ \chi^2(27) = 201.85, \quad p < .01; \quad \text{RMSEA} = .232 (.203, .263); \quad \text{CFI} = .67; \quad \text{SRMR} = .164. \]
Instead, the model fit of the three-factorial model (see Figure 2) met all recommendations:
\[ \chi^2(23) = 28.89, \quad \text{n.s.}; \quad \text{RMSEA} = .046 (.000, .093); \quad \text{CFI} = .99; \quad \text{SRMR} = .046. \]
Figure 2 reveals that the correlations between the factors “Questions” and “Errors” (\( r = .52 \)) as well as between the factors “Questions” and “Speed” were moderate (\( r = .57 \)). The correlation between the factors “Errors” and “Speed” was low (\( r = .27 \)). Factor
loadings of the test scores on the corresponding factors were high (\( \alpha = .64 \) to
.93). We also found a significant error correlation of \( r = .31 \) between numerical
errors and numerical speed, which was specified in the model of König et al.
(2005). We used these three SIMKAP measures (the average of the speed mea-
ures, the average of the reverse-coded error measures, and the average of the
question parcels) as dependent variables in further analyses instead of one over-
all measure of SIMKAP performance.

\begin{table}
\centering
\caption{SIMKAP measures}
\begin{tabular}{llll}
\toprule
\textbf{Tests} & \textbf{M} & \textbf{SD} & \textbf{Rel} \\
\midrule
SIMKAP measures & & & \\
\textbf{Speed} & & & \\
\textbf{Numbers} & 124.94 & 37.64 & 95^{a} \\
\textbf{Letters} & 110.28 & 29.63 & 93^{a} \\
\textbf{Figures} & 136.70 & 38.27 & 94^{a} \\
\textbf{Errors} & & & \\
\textbf{Numbers} & 3.41 & 2.78 & —^{e} \\
\textbf{Letters} & 3.73 & 3.08 & —^{e} \\
\textbf{Figures} & 5.25 & 3.21 & —^{e} \\
\textbf{Questions} & 35.55 & 6.48 & .83^{a}/.71^{c}/.84^{d} \\
\bottomrule
\end{tabular}
\end{table}

\textit{Notes.} \( N = 121. \) Rel = Reliability coefficient; CRTT = choice reaction time tasks; SIMKAP = si-
multaneous capacity scenario. Means and Standard Deviations (in ms) are given for untransformed
times for CRTTs, time differences for switching variables, mean raw scores for the monitoring and dual
tasks. The median of reaction times (ms) is given for divided attention and Go/No-Go tasks. The reli-
ability of the verbal reasoning tasks is low due to the homogeneous and highly able sample, causing
ceiling effects and reducing standard deviations.

\(^{a}\)Cronbach’s alpha. \(^{b}\)Split-half reliability. \(^{c}\)Reliability for test batteries (Lienert & Raatz, 1998).
\(^{d}\)Construct reliability (Hancock & Mueller, 2001). \(^{e}\)Could not be calculated. \(^{f}\)Number of correct re-
sponses. \(^{g}\)Relative number of errors.
Factor Scores

As mentioned previously, five factor analyses were run to build factor scores. The explained variances of the working memory components, attention, and reasoning by the variables that built the factor scores, are storage in the context of processing = 43% (verbal storage: $\alpha = .76$, numerical storage: $\alpha = .58$, dots storage: $\alpha = .65$, figures storage: $\alpha = .61$), coordination = 36% (verbal monitoring: $\alpha = .78$, numerical monitoring: $\alpha = .72$, flight control: $\alpha = .40$, finding squares: $\alpha = .37$), supervision (general switching costs) = 30% (verbal switching: $\alpha = .50$, numerical switching: $\alpha = .68$, switching arrows: $\alpha = .61$, switching patterns: $\alpha = .32$), attention = 45% (divided attention [tones]: $\alpha = .80$, divided attention [squares]: $\alpha = .71$, go/no-go: $\alpha = .46$), reasoning = 40% (verbal: $\alpha = .57$, numerical: $\alpha = .64$, figural: $\alpha = .67$). Table 2 shows the correlations between the factor scores and the SIMKAP measures. These correlations were the basis for the hierarchical multiple regression analyses.

Regression Analyses

The results of the regression analyses are described in Tables 3 and 4. The full regression equations (Step 3) showed that the working memory components contributed differently to the prediction of the multitasking performance SIMKAP. Storage in the context of processing significantly predicted only the SIMKAP error score, thus supporting H1b but not H1a. Coordination predicted both speeded
measures of multitasking (the SIMKAP speed and question scores), thus supporting H2a but not H2b. Supervision was not a significant predictor for any of the three SIMKAP scores, thus disconfirming H3a and H3b.

Table 3 also shows that working memory dimensions explained a large amount of variance of multitasking speed and error over and above attention (14% to 24% additional variance). This is in agreement with H4a and H4b. Table 4 also shows that working memory dimensions explained a large amount of variance of multitasking speed and error over and above reasoning (7% to 14% additional variance). This is in agreement with H5a and H5b.

Attention explained 5% to 14% of the variance, but beyond working memory components and reasoning, attention could explain only additional 1% or 5% of
the variance. This increase of explained variance was significant only for SIMKAP speed. Beyond working memory and attention, reasoning was able to explain only small percentages of variance (0 to 3%). If reasoning was entered first, it explained 14% to 24% of variance in predicting SIMKAP but the variance explained by working memory above and beyond reasoning (7% to 14%) was also significant.

**DISCUSSION**

This study shows that a differentiated working memory model with three dimensions (storage in the context of processing, coordination, and supervision) can contribute to our understanding of multitasking performance. In addition, working memory dimensions were found to be differential predictors of multitasking speed and errors. Coordination predicted multitasking speed but not multitasking errors, and storage in the context of processing predicted multitasking errors but not multitasking speed. Reasoning, attention, and the working memory component supervision proved to be less important or even unimportant predictors. All in all, the study provides a deeper understanding of the cognitive abilities necessary for a high performance in multitasking situations and extends the study of König et al. (2005).

The working memory dimensions and attention explained so much of multitasking speed variance that reasoning could add almost nothing to the prediction. Regarding multitasking error variance there was no variance left for reasoning to explain. This extends the finding of König et al. (2005) in an important way: their study can be criticized for using only one latent working memory variable (based on only three tests) and thus did not adequately account for the multidimensional

---

**TABLE 2**

Correlations Between Factor Scores of the Predictors and of the SIMKAP Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td>.20*</td>
<td>.25**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage in the context of processing</td>
<td>.25**</td>
<td>.25**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>.33***</td>
<td>.24**</td>
<td>.46***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reasoning</td>
<td>.24**</td>
<td>.31***</td>
<td>.64***</td>
<td>.55***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIMKAP: Speed&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.36***</td>
<td>.20*</td>
<td>.32***</td>
<td>.47***</td>
<td>.44***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIMKAP: Errors&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.21***</td>
<td>.27***</td>
<td>.48***</td>
<td>.27***</td>
<td>.35***</td>
<td>.23**</td>
<td></td>
</tr>
<tr>
<td>SIMKAP: Questions&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.26***</td>
<td>.23*</td>
<td>.40***</td>
<td>.48***</td>
<td>.48***</td>
<td>.49***</td>
<td>.39***</td>
</tr>
</tbody>
</table>

*Note. N = 121. SIMKAP = simultaneous capacity scenario.*
<sup>a</sup>Aggregated z transformed raw scores.
*<sup>p</sup> < .01. **<sup>p</sup> < .01. ***<sup>p</sup> < .001.
### TABLE 3
Hierarchical Regression Analysis for Predicting the Multitasking Measures of the SIMKAP (Starting With Attention)

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Speed</th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Step 1</td>
</tr>
<tr>
<td>Attention</td>
<td>.37***</td>
<td>.21*</td>
<td>.29***</td>
<td>.21*</td>
<td>.05</td>
<td>.06</td>
<td>.27**</td>
<td>.09</td>
<td>.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage in the context of processing</td>
<td>.11</td>
<td>.00</td>
<td>.43***</td>
<td>.42***</td>
<td>.21*</td>
<td>.08</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>.32**</td>
<td>.24*</td>
<td></td>
<td>.05</td>
<td>.04</td>
<td></td>
<td>.34***</td>
<td>.26**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td>.05</td>
<td>.02</td>
<td>.14</td>
<td>.14</td>
<td>.08</td>
<td>.05</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reasoning</td>
<td>.25*</td>
<td></td>
<td></td>
<td>.03</td>
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<td></td>
<td></td>
<td>.26*</td>
<td></td>
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<tr>
<td>( \Delta R^2 )</td>
<td>.14***</td>
<td>.03*</td>
<td>.24***</td>
<td>.00</td>
<td></td>
<td>.22***</td>
<td>.03*</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Overall ( R^2 )</td>
<td>.14***</td>
<td>.28***</td>
<td>.31***</td>
<td>.05*</td>
<td>.29***</td>
<td>.29***</td>
<td>.07**</td>
<td>.29***</td>
<td>.32***</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted ( R^2 )</td>
<td>.13</td>
<td>.25</td>
<td>.28</td>
<td>.04</td>
<td>.26</td>
<td>.26</td>
<td>.06</td>
<td>.26</td>
<td>.29</td>
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</tr>
</tbody>
</table>

*Note. N = 121. SIMKAP = simultaneous capacity scenario. Standardized regression coefficients are shown.*

*p < .05. **p < .01. ***p < .001.*
<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Speed</th>
<th>Error</th>
<th>Questions</th>
<th>Speed</th>
<th>Error</th>
<th>Questions</th>
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<tbody>
<tr>
<td></td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
<td>Step 1</td>
<td>Step 2</td>
<td>Step 3</td>
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<tr>
<td>Reasoning</td>
<td>.44***</td>
<td>.25*</td>
<td>.25*</td>
<td>.38***</td>
<td>.03</td>
<td>.03</td>
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<tr>
<td>Storage in the context of processing</td>
<td>.02</td>
<td>.00</td>
<td>.43***</td>
<td>.42***</td>
<td>.09</td>
<td>.08</td>
</tr>
<tr>
<td>Coordination</td>
<td>.30**</td>
<td>.24*</td>
<td>.06</td>
<td>.04</td>
<td>.28**</td>
<td>.26**</td>
</tr>
<tr>
<td>Supervision</td>
<td>.05</td>
<td>.02</td>
<td>.15</td>
<td>.14</td>
<td>.06</td>
<td>.05</td>
</tr>
<tr>
<td>Attention</td>
<td>.23**</td>
<td>.06</td>
<td>.06</td>
<td>.09</td>
<td>.07**</td>
<td>.01</td>
</tr>
<tr>
<td>$\Delta R^2$</td>
<td>.07*</td>
<td>.05**</td>
<td>.14***</td>
<td>.01</td>
<td>.07**</td>
<td>.01</td>
</tr>
<tr>
<td>Overall $R^2$</td>
<td>.19***</td>
<td>.26***</td>
<td>.31***</td>
<td>.14***</td>
<td>.28***</td>
<td>.29***</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>.19</td>
<td>.24</td>
<td>.28</td>
<td>.13</td>
<td>.26</td>
<td>.26</td>
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</tbody>
</table>

*Note.* $N = 121$. Standardized regression coefficients are shown. SIMKAP = simultaneous capacity scenario.  
*p < .05, **p < .01, ***p < .001.
nature of working memory. This study, by contrast, was based on the three-dimensional working memory model proposed by Oberauer et al. (2003), and the results can therefore be seen as more trustworthy than those of König et al. While the use of the three-dimensional working memory model is not only preferable for theoretic reasons but also for empirical reasons, König et al.’s general working memory variable explained only 7% to 14% above attention, whereas the use of the three-dimensional working memory model increased the explained variance to a much larger degree (i.e., 14% to 22%).

This study reveals that working memory components provide differential validity in predicting aspects of multitasking performance (speed and errors), a finding that König et al. (2005) could not obtain because of their use of only one latent working memory variable. We expected that all three dimensions of working memory (storage in the context of processing, coordination, and supervision) are important for multitasking speed and multitasking errors. Interestingly, this was not the case. Instead, the data showed a clear pattern. Storage in the context of processing was an excellent predictor of multitasking errors but did not contribute to the prediction of multitasking speed. Coordination proved to be an important predictor of multitasking speed but not of multitasking error. Supervision turned out to be irrelevant for both aspects of multitasking performance. In other words, multitasking speed was mainly predicted by coordination and multitasking errors by storage in the context of processing. Thus, multitasking errors seem to occur due to dysfunctional storage and processing functions. This finding is very important because it implies that errors in multitasking might arise due to a low ability to store information while processing another task. One might hardly work error-free on two or more tasks simultaneously if relevant information of one task is lost while performing the other. However, neither a failure to build and integrate relations into structures nor a failure of cognitive control might lead to errors in multitasking behavior. Because the occurrence of errors is not extensively investigated in differential or work or organizational psychology, this result is very interesting above and beyond multitasking behavior. Regarding multitasking speed, the results indicate that neither the ability to store information while processing nor the ability to supervise cognitive processes are important for fast multitasking. However, fast multitasking seems to require predominantly the ability to construct new relations between elements by establishing mental structures (i.e., the coordination dimension). A different explanation could be that both abilities are related because they both require mental speed. The finding that supervision predicted neither aspect of multitasking performance is somewhat startling. As mentioned in the introduction, it seems very plausible that the suppression of irrelevant interfering information can enhance the processing speed of current tasks. Apparently, to be forced to repeatedly switch between alternating rules (supervision) is something different than trying to achieve two or more competing goals (multitasking).
The role of reasoning in the prediction of both aspects of multitasking performance was found to be small above and beyond working memory and attention (replicating König et al., 2005). Reasoning added only up to 3% of variance. However, the incremental validity of working memory dimension over reasoning was much larger (up to 13%). It is well-known that working memory and reasoning are correlated (Ackerman, Beier, & Boyle, 2005, reported a correlation of .634 between working memory and reasoning [corrected for the unreliabilities], but see Oberauer et al., 2005). Both constructs were also significantly related to all three multitasking performance measures in this study. This leads to the conclusion that the shared variance between reasoning and working memory as well as specific variance of working memory is important for multitasking performance.

The contribution of attention in predicting multitasking speed could be extensively reduced to working memory components or reasoning. Attention only showed a significant incremental validity beyond reasoning and working memory components with regard to the speed measure of the SIMKAP. Attention could also significantly explain multitasking variance as a single predictor. It seems that quickly allocating attention to relevant stimuli is necessary within multitasking scenarios, but this very basic ability obviously is mostly included in the broader concepts of working memory and reasoning.

A potential limitation of this study is the generalizability of the results to other populations. However, the explained variance may be increased for more heterogeneous samples. Future research should also examine organizational samples. Most participants of this study were female, which represents another limitation. Furthermore, we investigated only one of many possible dimensions of attention. Thus, the relationship between multitasking and other dimensions of attention has to be clarified within future studies. This study showed that compared to the study of Koenig et al. (2005) not only the tasks itself (coordination, supervision or storage in the context of processing) moderate validities predicting multitasking behavior. This study also indicates that the use of different tasks for one working memory dimension enhanced validities. Thus, future research should use different tests for one dimension to achieve considerably higher validities.

In spite of this, this study contributes to the literature on working memory in an important way. Most research on working memory focuses on exploring the multidimensionality (e.g., Oberauer et al., 2003) or the prediction of intelligence (Ackerman et al., 2005). The importance of working memory for more applied problems (e.g., multitasking) has been rather neglected, because it was believed that working memory has no incremental validity above and beyond reasoning or that working memory is almost identical with “g” (see Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). Thus, this study is an exception, because it shows how well working memory can predict multitasking performance and which working memory dimensions are especially important for multitasking speed and multitasking error, respectively.
Furthermore, this study replicated the SIMKAP structure found by König et al. (2005), who called for more research on the internal validity of the SIMKAP scenario. Research on the SIMKAP is still sparse, even though the SIMKAP is available through a test publishing company—which means that researchers no longer have to develop their own multitasking scenarios (e.g., Cellier & Eyrolle, 1992).

The results of this study reveal important practical implications for personnel selection. Being able to multitask is an important requirement for many jobs (see, e.g., the O*NET, cf. Peterson et al., 1999), and for some it might be especially important not to make errors (e.g., pilots), whereas for others the speed aspect of multitasking might be more relevant than the error aspect (e.g., call-center agents). The implication of this research is that human resource management professionals should run a careful job analysis to find out whether the speed or the error aspect of multitasking is more important. If the error aspect is more important, the selection procedure should incorporate a test capturing the storage in the context of processing dimension of working memory. If the speed aspect is more important, a test assessing the coordination dimension of working memory should be included in the selection battery. This means that knowing the requirements of a certain job, one can clearly benefit from using the appropriate components of working memory instead of a simple g-measure of working memory (as applied by König et al., 2005).

More generally, this study is an important step toward personnel selection procedures that assess the appropriate cognitive ability for different job requirements, instead of simply using a broad measure of general mental abilities.

REFERENCES


