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REVIEW

Individual differences in everyday multitasking behavior and its relation to cognition and personality

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Abstract

Our ability to multitask—focus on multiple tasks simultaneously—is one of the most critical functions of our cognitive system. This capability has shown to have relations to cognition and personality in empirical studies, which have received much attention recently. This review article integrates the available findings to examine how individual differences in multitasking behavior are linked with different cognitive constructs and personality traits to conceptualize what multitasking behavior represents. In this review, we highlight the methodological differences and theoretical conceptions. Cognitive constructs including executive functions (i.e., shifting, updating, and inhibition), working memory, relational integration, divided attention, reasoning, and prospective memory were investigated. Concerning personality, the traits of polychronicity, impulsivity, and the five-factor model were considered. A total of 43 studies met the inclusion criteria and entered the review. The research synthesis directs us to propose two new conceptual models to explain multitasking behavior as a psychometric construct. The first model demonstrates that individual differences in multitasking behavior can be explained by cognitive abilities. The second model proposes that personality traits constitute a moderating effect on the relation between multitasking behavior and cognition. Finally, we provide possible future directions for the line of research.

Introduction

Multitasking behavior—the ability to perform numerous activities simultaneously—is an amazing capability of our cognitive system. Multitasking has been a subject in experimental psychology for decades (Hommel, 2020). Typical laboratory experiments addressed reaction speed and accuracy in single- versus multiple-task situations, either during simultaneous ("dual task") or alternating ("task switching") task performance (Koch et al., 2018; Lien et al., 2006). A separate line of research is devoted to multitasking performance in real-world tasks. For example, individuals might be required to write texts, manage emails, and receive phone calls at work in parallel. When a phone call occurs, details about the writing task must be held in memory to be retrieved later. Successful completion of real-world affordances generally requires coordination of several different ongoing tasks. The challenges include that different tasks must often be interleaved or interrupted and must be performed without intermediate performance feedback (Burgess, 2000). Moreover, real-world tasks often require complex task sharing (e.g., Beede & Kass, 2006). We will refer to multitasking in real-world scenarios as *everyday multitasking behavior*. This is the focus of the present work.

There are numerous tools for measuring everyday multitasking performance. Craik and Bialystok (2006) used the *breakfast task* as a simulation of daily activities. Here, participants have to monitor the progress of food items that cook at different rates and starting points so that all would be served at the same time. It can be criticized that this scenario requires switching between tasks that are very similar to one another, while in real-world situations the ongoing tasks might be different. In the *day out task* participants are required to plan for a day out, e.g., meeting a friend at a

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museum or for dinner (Schmitter-Edgecombe et al., 2012). Two other measures—the *SynWin* (Elsmore, 1994) and the *Edinburgh virtual errands task* (EVET; Logie et al., 2004) are frequently used. The SynWin relies on tasks based on the simulation of specific work domains as seen for military personnel or pilots. The EVET reflects everyday multitasking, in which test takers need to remember the necessary errands to complete while navigating through a virtual environment. Lastly, the Simultankapazität/Multi-tasking is a generalized and standardized real-life scenario of multitasking (SIMKAP; English: Simultaneous Capacity/Multitasking; Bratfisch & Hagman, 2011; König et al., 2005). In SIMKAP, participants are required to interleave routine (i.e., identifying and marking certain combinations of stimuli in SIMKAP scenario) and problem-solving tasks in cohesive manner with changing circumstances. SIMKAP outcome (i.e., quick and accurate performance) relies on multiple perceptual or cognitive resources that are engaged in successful multitasking performance, like perceptual speed, perceptual accuracy, or memory and intellectual ability.

The efficiency of handling multiple tasks in complex environments differs across individuals. A small fraction of the population, coined *supertaskers*, even seem to be capable of performing multiple tasks with no costs relative to a single task situation (Medeiros-Ward et al., 2015; Watson & Strayer, 2010). Such variations reflect, on the one hand, individual differences in the cognitive abilities that underlie multitasking behavior. Specifically, executive functions support goal-directed behavior and thereby permit people to act in an adaptive manner in multiple tasks—situations (e.g., Miyake & Friedman, 2012). Likewise, working memory supports storage of information in the face of interference (Engle et al., 1999) and is used to build mental representation by integrating information from multiple sources (i.e., relational integration; Oberauer et al., 2003). Divided attention (Bühner et al., 2006), reasoning (Redick et al., 2016), and prospective memory (Burgess et al., 2000) are further candidate skills that correlate with multitasking performance.

Besides cognitive abilities, there is tentative evidence that multitasking proficiency also depends on personality traits. For instance, polychronicity is the individual preference for attending to many tasks at once, as occurs during multitasking behavior (Poposki & Oswald, 2010). Other traits that might be related to multitasking performance are impulsivity (the inability to inhibit actions), and the personality factors of the five-factor model (extraversion, conscientiousness, agreeableness, openness to experience, and emotional stability).

Despite the demonstrable importance of individual differences, there has to date been no attempt to synthesize the evidence linking cognitive abilities and personality factors with multitasking performance. In this work, we review results of studies which addressed individual influences in everyday multitasking behavior, with respect to cognitive abilities and personality traits. We refer to multitasking behavior as an individual's ability to integrate dynamic aspects of actions in a concurrent task environment. A more consolidate definition of multitasking behavior, which incorporates our synthesis, will be provided at the end of this review.

Aim, limitations and outline of the current review

This review article focuses on multitasking ability, i.e., the capability of performing multiple tasks at once. We want to highlight that we deliberately exclude media multitasking (Ophir et al., 2009), an aspect of multitasking activity that is currently highly researched. Research on multitasking behavior and media multitasking historically belonged to two largely independent research domains. Studies on media multitasking rely on self-report questionnaires, which is the reflection of the respondents' perception of their own multitasking experiences, rather than their actual behavior (e.g., Carrier et al., 2009; Lui & Wong, 2012). Also, media multitasking requires people to switch back and forth between tasks, but extensive practice with task switching may have little effect on their actual ability to integrate multiple tasks simultaneously (Alzahabi & Becker, 2013). We, therefore, decided to exclude media multitasking from this review.

Our review differs from previous overview articles on multitasking in several important points. First, the prevailing reviews are in the area of media multitasking (e.g., Cardoso-Leite et al., 2015) or laboratory tasks like dual-task interference (Pashler, 1994), or task switching (e.g., Kiesel et al., 2010; Koch et al., 2018; Monsell, 2003). Moreover, previous work did not account for individual differences (i.e., each person's individuality) in multitasking behavior. Literature has demonstrated that individuals differ widely in their cognitive abilities to execute multiple tasks concurrently (e.g., Himi et al., 2017, 2019; Redick et al., 2016). Therefore, we deem necessary to include individual differences when reviewing multitasking performance. As such, we approach multitasking behavior through the question of "How do people vary in their multitasking ability?" in this review paper.

Prior research used different paradigms for investigating everyday multitasking behavior. This has led to a lack of uniformity in behavioral measurements across studies (Laloyaux et al., 2018). What is more, the behavioral performance may rely on different cognitive abilities in different tasks. For example, Logie et al. (2011) observed that the EVET, but not the breakfast task, is correlated with working memory skills. However, the limitation for this review article is that results cannot be easily aggregated across paradigms.

The outline of the present article is as follows. The methods section contains search and inclusion criteria for the review, as well as a tabular sketch of the methods and results used in the included studies. In two different sections, we then review the relation of cognitive abilities and personality characteristics, respectively, with multitasking behavior. The addressed cognitive abilities are executive functions, working memory, prospective memory, relational integration, divided attention, and reasoning. The addressed personality characteristics are polychronicity, impulsivity, and the five-factor personality model. Each sub-section on cognitive abilities and personality characteristics features a review of the theoretical background, description of the included studies and measures (few studies used self-reports of multitasking behavior), and a synthesis of the results. An integrative summary and discussion will be given. We will conclude our review by highlighting specific challenges for future research.

Methods

Search strategy

The goal of our review was to integrate cognitive and personality perspectives on multitasking behavior into a coherent theoretical framework. Accordingly, we systematically searched for peer-reviewed empirical studies published from 2001 to 2020 through the electronic databases—PsycINFO, PsycARTICLES, and ERIC, using keywords of "multitasking ability", "multitasking skill", and "multitasking ability and personality". In addition, reference lists of selected studies were mined for additional articles and literature reviews were searched. Here, we set 2001 as the starting time for the literature search to include last 20 years of multitasking research.

Inclusion criteria

Studies included in this review had to meet the following conditions: be original papers, written in the English language, and peer-reviewed. Additionally, it had to satisfy at least one of the followings: (a) use objective or self-reported (e.g., daily diary; only in case of personality researches) assessment tools for measuring multitasking behavior, (b) focus on cognitive ability associated with at least one of the cognitive functioning: executive functions (updating, shifting, and inhibition), working memory, prospective memory, relational integration, attention, and reasoning, or (c) focus on personality traits associated with polychronicity, impulsivity, or the five-factor personality approach. All studies reviewed were conducted with young adults. The studies we included were restricted to experimental and correlational studies focusing on behavioral performance measures. Thus, we intentionally excluded the large set of literature on neuroanatomical and cognitive impairment evidence.

Search results

In total, 198 unique records were initially screened after applying the search terms in the three databases, as described above. Following the assessment of these studies for eligibility and removing any duplicates, 28 papers on cognition, and 15 papers on personality factors were identified, based on the criteria for study inclusion. Among these, three investigated both cognition and personality (see Fig. 1 for detailed information). Almost all the studies were based on a correlational or manifest multiple regression approach, whereas only six studies focused on the latent variable relations. Tables 1 and 2 present details of the study characteristics included in this review.

Cognitive correlates of multitasking behavior

Within the domain of human cognition, two main schools of thought—cognitive correlates and cognitive components or task analytical approaches have emerged which have shown to be influenced by individual differences (Pellegrino & Glaser, 1979). The cognitive correlates approach attempts to specify correlations among various cognitive abilities. In comparison, the task analytical approach concentrates on the analysis of the components of the tasks commonly used to assess cognitive abilities.

When addressing both the domains of cognitive correlates and task-analytic approaches, the questions to ask are "What cognitive correlates allow for a high multitasking ability?" and "What does a multitasking test actually measure?". Broadly speaking, the cognitive correlates approach describes the most important cognitive abilities that instigate higher multitasking ability, while task-analytic approach investigates the cognitive structure of the multitasking measures. All through this review, cognitive correlates and task-analytic approaches are considered to explore individual differences in multitasking behavior (for a similar approach; see Unsworth, 2019).

Executive functions

Theoretical background

Miyake et al. (2000) identified three core executive functions: "shifting of mental set", "updating of working memory", and "inhibition of pre-potent responses". These core executive functions would operate in a collaborative fashion

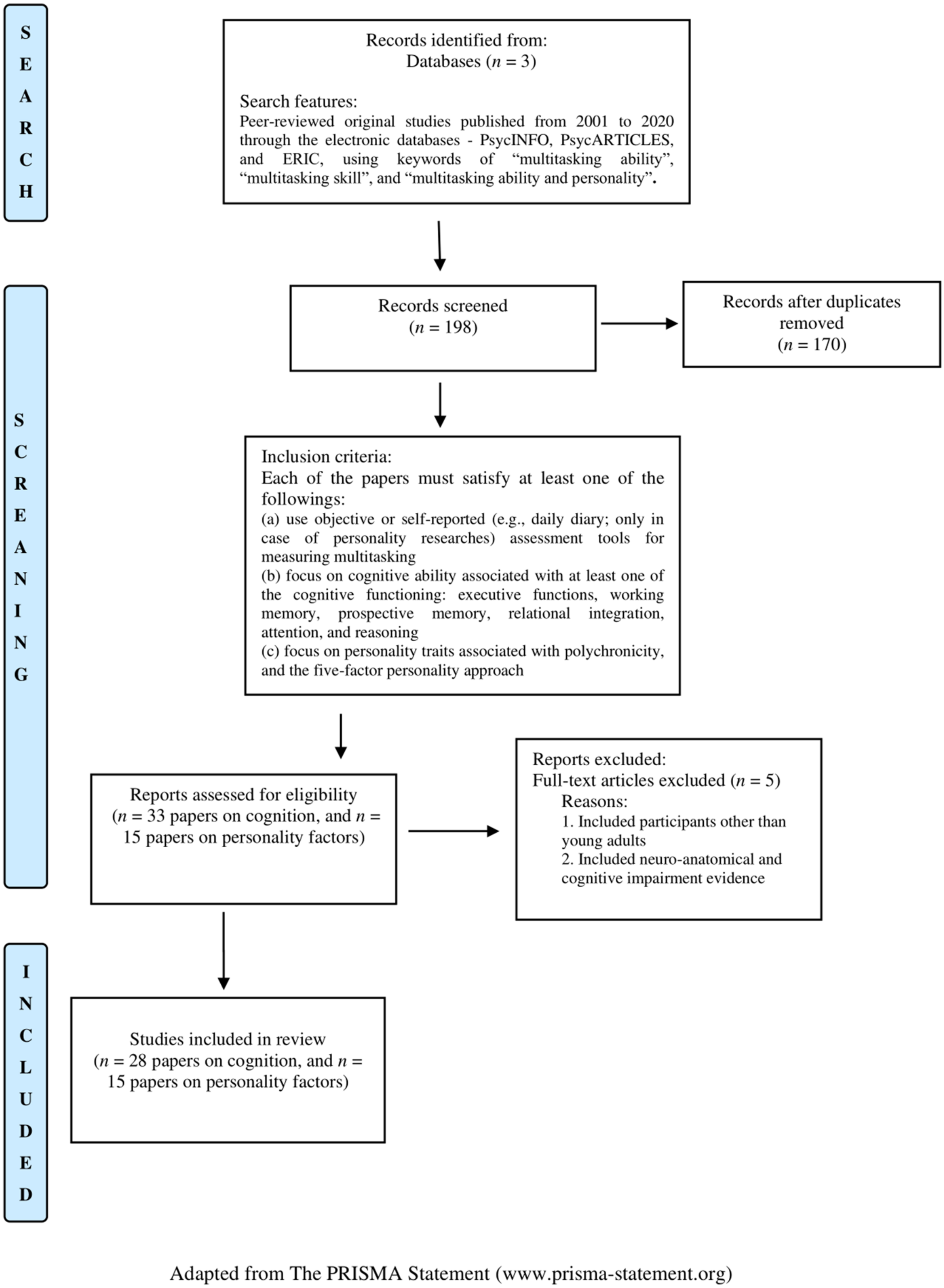

Fig. 1 Flow diagram for the search and inclusion criteria for studies in this review

in planning-related tasks, e.g., multitasking). A more recent model of executive functions was developed by Friedman and her colleagues (e.g., Friedman et al., 2008, 2016; Ito et al., 2015) who suggested that the variance found in these three core executive functions may be explained by a general EF factor—that is common EF, defined as the variance

Table 1 Description of included studies on multitasking behavior and cognitive correlates

First author	*N*	Mean age or range (years)	Multitasking behavior measure	Cognitive correlate	Correlation with the criterion
Bai et al. (2014)	229	18–35	Abstract Decision making	Relational integration	0.36
				Reasoning	0.36
Bühner et al. (2006)	135	22	Simultaneous capacity (SIMKAP)	Working memory	Ranging from 0.20[a] to 0.64[a]
				Relational integration	
				Shifting	
				Attention	
				Reasoning	
Chang et al. (2017)	116	20–30	Edinburgh Virtual Errands Test (EVET)	Working memory	0.25 and 0.50
Colom et al. (2010)	302	28.4	Divided attention task	Working memory	0.35
			Funnel task	Reasoning	0.22
Fischer and Hommel (2012)	48	23.4	Experimental paradigm	Shifting (cognitive control)	Associated
Fischer and Plessow (2015)	Review			Shifting	
Gade and Koch (2012)	Review			Inhibition	
Hambrick et al. (2010)	131	Undergraduate student	SynWin	Working memory	0.3
				Reasoning	0.24
Hambrick et al. (2011)	149	17–35	SynWin	Updating	Partially related
				Shifting (task switching)	n/r
Himi et al. (2019)	202	23.09	SIMKAP	Working memory	0.43[a]
				Relational integration	0.59[a]
				Divided attention	0.56[a]
				Shifting	0.25[a]
				Inhibition	0.53[a]
				Updating	0.61[a]
				Common EF	n/r
				Unique updating	n/r
				Unique shifting	n/r
Hirnstein et al. (2019)	148	32.9	Computerized meeting preparation task	Prospective memory	n/r
Koch et al. (2018)	Review			Shifting (task switching)	
König et al. (2005)	131	19–36	SIMKAP	Working memory	Ranging from 0.28 to 0.44[a]
				Relational integration	Ranging from 0.20 to 0.28
				Shifting	Ranging from −0.24 to −0.42
				Reasoning	Ranging from 0.23 to 31[a]
				Attention	Ranging from 0.22 to 0.27[a]
Logie et al. (2011)	165	19.59	EVET	Working memory	0.23 (verbal span) 0.29 (spatial span)
				Prospective memory	−0.02 (ns)
Lui and Wong (2019)	220	18–31	Multitasking paradigm	Working memory	0.33 and below in magnitude
				Reasoning	
				Processing speed	
Mäntylä (2013)	72	28.35	Computerized task	Updating	0.39

Table 1 (continued)

First author	*N*	Mean age or range (years)	Multitasking behavior measure	Cognitive correlate	Correlation with the criterion
Martin et al. (2020)	171	18–35	Control tower	Inhibition (attention control)	Ranging from −0.04 to 0.44
			SynWin	Reasoning	Ranging from 0.29 to 0.53
			Foster task		
Morgan et al. (2013)	32	University students	Multi-attribute task battery	Working memory	Ranging from 0.20 to 0.65
Redick (2016)	65	University students	SynWin	Working memory	Ranging from 0.49 to 0.52
Redick et al. (2016)	586	University students	SynWin	Working memory	0.77[a]
			Control tower	Inhibition	0.61[a]
			Air traffic control laboratory	Reasoning	0.76[a]
Salvucci and Taatgen (2008)	Review			Inhibition (interference)	
Sanderson et al. (2013)	119	Employee	Multitasking ability test	Deductive reasoning	0.43
Sanderson et al. (2016)	308	Employee	Multitasking ability test	Deductive reasoning	0.63
Sanjram (2013)	60	23.18	Experimental paradigm	Attention	n/r
				Prospective memory	n/r
Szumowska and Kossowska (2016)	117	22.53	DIVA task	Shifting	Associated
Todorov et al. (2014)	80	25.8	Computerized task with four components	Updating	0.5
				Spatial ability	0.24
Todorov et al. (2015)	102 (Study 1)	18–38	Counter task (Study 1)	Spatial ability (Study 1)	0.30 and 0.29
	122 (Study 2)	18–44	Counter task and SIMKAP (Study 2)	Spatial ability, Shifting (Task switching), and relational integration (Study 2)	Associated
Watson and Strayer (2010)	200	18–43	Experimental paradigm	Inhibition (attentional control)	n/r

n/r not reported, *ns* not significant

[a]Factor score

shared by shifting, updating, and inhibition. The rest of the variance could be consumed by unique updating, and unique shifting factors (see Friedman et al., 2008; Friedman & Miyake, 2017, for review). The question how the three specific core executive functions (shifting, updating, and inhibition), as well as common executive functions (unique updating, and unique shifting), influence multitasking behavior is becoming highly recognized in the literature. So far, there have been few studies, which focused on the individual domain of executive functions (e.g., Bühner et al., 2006; Hambrick et al., 2011; Redick et al., 2016), or the topic of multiple domains (Himi et al., 2018, 2019).

Shifting. Shifting allows for enacting cognitive control under varying environmental demands. This might involve task interruption, if the concurrent tasks cannot be performed simultaneously (Altmann & Gray, 2008; Van Bergen, 1968). However, the role of switching or shifting on multitasking behavior is debated. For example, Miyake et al. (2000) found that the ability to shift between tasks did not predict multitasking performance. This is because shifting relies on task-specific cues that allow for a serial task execution, which are absent in multitasking situations (Kieras et al., 2000; Salvucci & Taatgen, 2008).

Updating. Updating represents the core cognitive processing of complex everyday tasks. It works by selecting and maintaining available information in working memory and removing it once it is no longer relevant (Miyake & Friedman, 2012; Palladino & Artuso, 2018). Specifically, it refers to the ability to process multiple simultaneous tasks by keeping track of the current status of ongoing tasks and maintaining interim results. A subcomponent of updating is substitution, the removal of outdated information from memory. Importantly, this process is unique to updating and independent of working memory (Ecker et al., 2014). Besides works by Hambrick et al. (2011) and Himi et al. (2019), the updating factor has not been exclusively studied

Table 2 Description of included studies on multitasking behavior and personality correlates

First author	N	Mean age or range (years)	Multitasking behavior measure	Personality correlate	Correlation with the criterion
Crews and Russ (2020)	103	24.28	In-box exercise	Emotional stability	0.07 and 0.06 (ns)
			Self-report questionnaire	Agreeableness	0.01 and −0.07 (ns)
				Conscientiousness	−0.14 and 0.01 (ns)
				Extraversion	−0.17 and −0.15 (ns)
				Openness to experience	−0.11 and 0.07 (ns)
Grawitch and Barber (2013)	186	19.42	Dual task (experimental paradigm)	Polychronicity	n/r
Guastello et al. (2014)	174	18–23	Computer-based multitasking simulation	Emotional stability	Few associated
				Abstractedness	
				Sensitivity	
				Conscientiousness	
				Extraversion	
				Openness to experience	
Ishizaka et al. (2001)	118	University students	Auditory–visual multitask	Polychronicity	Ranging from 0.04 to 0.16
Kirchberg et al. (2015)	93	n/r	Dairy and self-report	Polychronicity	0.38
				Conscientiousness	−0.04 (ns)
				Extraversion	0.17 (ns)
König et al. (2005)	131	19–36	SIMKAP	Polychronicity	Ranging from 0.09[a] to 0.13[a] (ns)
				Extraversion	Ranging from 0.00[a] to 0.09[a] (ns)
König et al. (2010)	192	< 30 years	Self-report in hypothetical multitasking situation	Polychronicity	0.49
		Between 30 and 39 Between 40 and 49		Impulsivity	0.21
		> 50 years			
Kurapati et al. (2017)	133	University students	Multiattribute Test Battery	Emotional stability	ns
				Agreeableness	ns
				Conscientiousness	ns
				Extraversion	ns
				Openness to experience	Moderator
Lin et al. (2016)	168	26.36	Auditory–visual multitask	Five factors of personality	ns
Mattarelli et al. (2015)	71	34	Diary logs	Polychronicity	n/r
Sanderson et al. (2013)	119	Employee	Multitasking ability test	Polychronicity	Moderator
Sanderson et al. (2016)	308	Most are less than 40	Multitasking ability test	Emotional stability	−0.11 (ns)
				Openness to experience	−0.02 (ns)
				Conscientiousness	−0.16
Sanbonmatsu et al. (2013)	310	18–44	Operation span task	Impulsivity	n/r
				Sensation seeking	
Stephens et al. (2012)	160	19–28	Experimental paradigm	Polychronicity	Positive correlation
Zhang et al. (2005)	42	21.9	Experimental paradigm	Polychronicity	n/r

n/r not reported, *ns* not significant

in relation to multitasking behavior. The unique feature of substitution might be important for predicting multitasking behavior over and above other predictors like working memory (Himi et al., 2019).

Inhibition. Inhibition (sometimes termed attention control) is the ability to hold back irrelevant responses. It might serve as a crucial element of adaptive behavior, like multitasking (Friedman & Miyake, 2017; Gade & Koch, 2012; Himi et al., 2019). Response activations from multiple tasks that are processed simultaneously may interfere with each other (Miller & Durst, 2015), and inhibitory control reduces this task interference (Koch et al., 2010).

Common EF ability. Common EF is a component derived from a multi-component executive functions model.

It refers to the ability to actively maintain task goals during task interference, and thereby direct ongoing processes (Miyake & Friedman, 2012). Common EF allows for goal-directed behaviors to be maintained and to be carried out accurately at the appropriate time (Gustavson et al., 2015). In other words, the common EF refers to goal-management ability during multitasking (as can be seen in Fig. 2).

Studies included

Past studies typically focused on a single component of executive functions. However, in total, we found thirteen empirical studies and three review papers on the topic of multitasking behavior with at least one executive function component (see Table 1). Among these, four of them focused on the executive function component of updating, six on the component of inhibition, and nine were focused on the component of shifting. Furthermore, two studies were based on the component of updating and shifting, and only one study focused on all three executive function components. However, there is only one study (Himi et al., 2019), which investigated the relationship between multitasking behavior and common EF factor, unique updating, and unique shifting.

Measures

Most of the papers presented in this review used a single test as a measure of multitasking. For example, SIMKAP was used by Bühner et al. (2006) and Himi et al. (2019). Other authors used multiple multitasking measures such as Redick et al. (2016), Martin et al. (2020). Watson and Strayer (2010) used a driving simulator and an operation span task simultaneously to assess multitasking ability.

In these studies, the components of executive functions were measured by means of performance-based tasks. However, the exact tool to measure executive functions varied across studies (e.g., Hambrick et al., 2011; Himi et al., 2019). Moreover, Fischer and Hommel (2012) applied an experimental approach, where participants engaged in divergent thinking (flexible task processing mood), convergent thinking (focused task processing mode), and neutral control conditions, and studied shifting task in the context of a dual-task paradigm. The other experimental study, Watson and Strayer (2010) presented two conditions (single and dual-task conditions).

Findings

Past literature presents mixed findings on the role of shifting associated with multitasking behavior. In a review paper, Fischer and Plessow (2015) stated that efficient multitasking is reflected by an individual's ability to adjust multitasking performance to environmental demands. This is achieved by flexible shifting between different processing strategies of multitasking components. Similarly, Koch et al. (2018) presented a review in which shifting (task switching) and dual-tasking was examined conjointly to better understand the functionality of multitasking. The authors integrated task switching (sequential processing) and dual tasking (concurrent processing) by means of their underlying cognitive mechanisms (i.e., cognitive bottlenecks, cognitive flexibility, and cognitive plasticity).

Furthermore, the role of shifting in multitasking is voiced by authors like Todorov et al., (2015; Study 2) and Fischer and Hommel (2012). It is suggested that shifting flexibility during multitasking can be reduced due to the engagement of an individual's cognitive control style prior to task

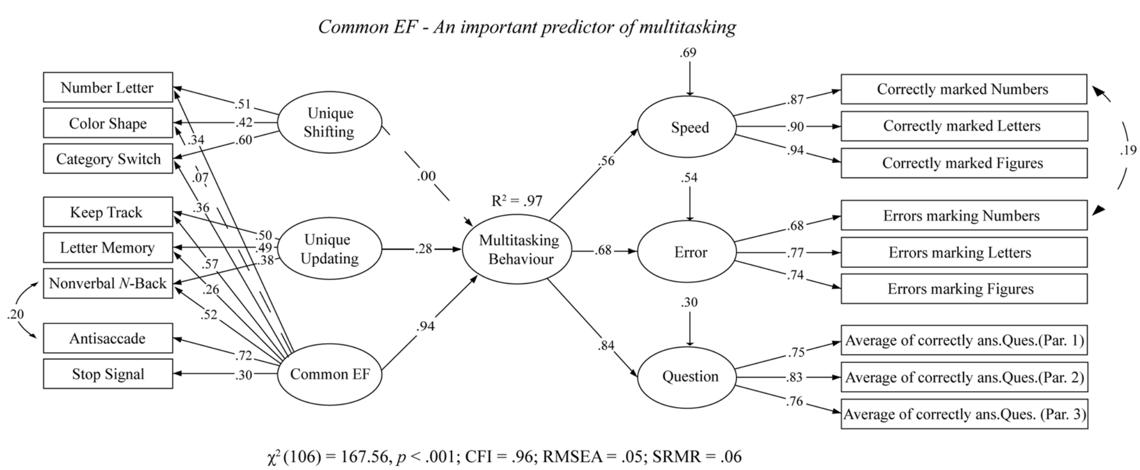

Fig. 2 Structural equation model for common EF and multitasking behavior (modified after Himi et al., 2019). Multitasking behavior is measured with three aspects (speed, error, and question) based on SIMKAP. All significant paths ($p < 0.05$) are indicated by solid lines. Non-significant paths are indicated by dashed lines

completion. In addition, a prior work by Szumowska and Kossowska (2016) involved speed and accuracy aspects of a shifting task to show an individual's need for closure (motivational factor) during multitasking. An interaction between the need for closure and shifting ability serves as a significant predictor of multitasking, in which shifting ability acts as a moderator. All these papers address the importance of shifting for multitasking performance or multitasking prediction. By contrast, many argue that there is positive correlation between multitasking and shifting (excepting König et al., 2005), but no causal relationship (Bühner et al., 2006; Hambrick et al., 2011; Himi et al., 2019). These studies suggest that the cognitive mechanism used for shifting differs from the one used for completing tasks simultaneously.

The relationship between updating and multitasking behavior deserves a special consideration. All studies we included used a single measure of updating except for Himi et al. (2019). One study (Hambrick et al., 2011) found that updating functioned as both a predictor and mediator. Here, it was found to directly predict multitasking and to mediate the relationship between the aptitude test and multitasking performance. Three studies which used a single updating task as a measure of executive functions found it to be related to construct of interest ($r=0.39$, 95% CI [0.17, 0.57], Mäntylä, 2013; $r=0.50$, 95% CI [0.31, 0.65], Todorov et al., 2014; $r=0.30$, 95% CI [0.11, 0.47], Todorov et al., 2015). Importantly, Himi et al. found updating to be a more accurate predictor of multitasking behavior ($r=0.61$; 95% CI [0.52, 0.69]) than working memory ($r=0.43$; 95% CI [0.31, 0.54]) through manifest regression approach. This provides strong indications that updating largely supports multitasking behavior.

Despite the consensus that inhibition might aid the performance of currently relevant tasks in multitasking situations, few studies have actually directly explored this relationship. The limited studies that have investigated this relationship found a correlation between inhibition and multitasking behavior ($r=0.53$; 95% CI [0.42, 0.62]; Himi et al., 2019; $r=0.61$; 95% CI [0.53, 0.66]; Redick et al., 2016). It was also found that at the latent level, the predictor variable accounts for unique variance of multitasking above and beyond fluid intelligence (Martin et al., 2020). However, Redick et al. (2016) showed that inhibition along with capacity act as mediators in the relationship between working memory and multitasking behavior (Redick et al., 2016). Here, inhibition serves as a component of working memory. Moreover, a review by Salvucci and Taatgen (2008) suggested that multitasking emerges from an interaction of autonomous process threads in conjunction with a straightforward mechanism for resource acquisition and conflict resolution. Conflict or interference can occur due to a limitation of resources, especially when using resources for one process delays another. In this regard, Gade and Koch (2012) suggested that multitasking involves inhibition to decide which task is relevant and which one is irrelevant in the current ongoing task while executing numerous tasks causing interference or response conflict. Watson and Strayer (2010) applied this view of inhibition to an experimental approach. They demonstrated that performance worsened in a multitasking task involving driving and performing an operation span task, as compared to a single task condition. Yet, super-multitaskers excel in both conditions because of proper utilization of attention control demands (inhibition), underlining the important role of inhibition.

Although less attention has been given to investigate the nature of the relationship between multitasking behavior and common EF, unique updating, and unique shifting, there is a promising finding (Himi et al., 2019) that common EF and unique updating do impact multitasking behavior as these account for 88% and 8% of variance in multitasking behavior, respectively, as shown by latent variable analysis. Nonetheless, because unique updating contributes minimally, further studies are necessary to clarify this relationship.

Working memory, relational integration, and reasoning

Theoretical background

Many findings suggest that working memory (similar to "storage in the context of processing" in Oberauer et al., 2003; and "complex span" in Engle et al., 1999) accounts for significant variance in multitasking behavior (Colom et al., 2010; Hambrick et al., 2010; Himi & Bühner, 2016; Logie et al., 2011; Morgan et al., 2013; Redick, 2016). Again, Sanbonmatsu et al. (2013) as well as Watson and Strayer (2010) used complex span tasks in form of multitasking for its dual-task nature. Notably, examples of recent process-analytical studies (Kübler et al., 2022a, 2022b) not only stress the role of working memory for task-order coordination in processing temporarily overlapping two (multiple) tasks, but also emphasize the need to refine the working memory content and the related load restrictions for understanding dual-task processing. In particular, the controlled attention phenomenon of working memory (Engle et al., 1999; Kane et al., 2007) has led researchers to propose that working memory could be an important underpinning of multitasking behavior.

Furthermore, the component of relational integration, as described in the facet model of working memory (Oberauer et al., 2003) moves the concept of working memory (basically, storage and processing) beyond the notion of limited storage of past information to achieve present attentional tasks. Relational integration is the belief that the integration of relations among varying elements allows for the concurrent manipulation of information. Recently, Oberauer et al.

(2013) developed a mathematical model, which demonstrated that task-specific stimulus–response link sets can be modeled as a set of dynamic binding processes (i.e., integrating relations) that connect various task elements in working memory. As relational integration and working memory exhibit distinct differences, we differentiate relational integration from working memory.

Another potential construct related to multitasking behavior is reasoning. Prior works (e.g., Bühner et al., 2006; Colom et al., 2010) suggest that reasoning accounts for multitasking behavior because of its reliance on the maintenance of information and the ability to entertain problem-solving strategies. However, reasoning shares considerable variance with working memory (e.g., Bühner et al., 2005; Kane et al., 2007; Kyllonen & Christal, 1990)—go hand in hand. Therefore, Bai et al. (2014) used to assess individual differences in working memory resources through the Raven's Progressive Matrices (Raven, 2000) test, but did not employ any direct working memory measure. In this review, we therefore subsume reasoning under the category of working memory.

Studies included

In total, sixteen studies were included in the analysis. Eleven of them (Table 1) investigated the relationship between multitasking behavior and working memory (e.g., Chang et al., 2017; Redick, 2016), whereas five of them (e.g., Bühner et al., 2006; Himi et al., 2019; König et al., 2005) examined the relationship between relational integration and multitasking behavior. Ten studies examined the relationship between reasoning and multitasking behavior.

Measures

All studies included in this review used performance-based tasks to assess the relationship of working memory or relational integration (coordination) and multitasking behavior. Correlational studies were typically performed by using SIMKAP or SynWin (e.g., Bühner et al., 2006; Redick, 2016), although a counter task (Todorov et al., 2015), an EVET (Logie et al., 2011), or a multi-attribute task battery (MATB; Morgan et al., 2013) could also be used. Lui and Wong (2019) investigated multitasking behavior by applying six different multitasking paradigms (both traditional laboratory and everyday multitasking). Here, the paradigms used were the equal-priority dual-task, the PRP paradigm, continuous tracking and working memory span task, task-switching paradigm with 1:1 cue–task mapping, task-switching paradigm with 2:1 cue–task mapping, and task-switching paradigm with a problem state requirement. Sanderson et al., (2013, 2016) assessed multitasking ability based on problem-solving tasks related to the aspects of deductive reasoning and quantitative ability.

In the methodological approach, diverse working memory models were used to understand multitasking behavior. Typically, the working memory models analyzed in this paper were modeled by the Oberauer et al. (2003) and the Kane et al. (2007) models. For example, Bühner et al. (2006) used the Oberauer et al.'s model, whereas Lui and Wong (2019) and Redick et al. (2016) used the Kane et al.'s (2007) model. Comparatively, relational integration was analyzed through three studies (Bühner et al., 2006; Himi et al., 2019), which used the relational integration tasks based on Oberauer et al. (2003). However, relational integration was also investigated using a variety of techniques. For instance, Todorov et al. (2015) asked participants to coordinate digital time readings, whereas Bai et al. (2014) used an integrating detail task. The most frequently used reasoning measure included in this review was the Raven's Progressive Matrices test (e.g., Bai et al., 2014; Hambrick et al., 2010). However, others used different measures, such as the analytical reasoning test (Colom et al., 2010) or the intelligence structure test (Bühner et al., 2006; König et al., 2005). Lastly, studies by a Sanderson et al., (2013, 2016), which applied a combination of verbal and deductive reasoning tasks to measure general cognitive ability were included. Overall, the majority of studies used a single measure with the exception of three studies (Colom et al., 2010; Martin et al., 2020; Redick et al., 2016) that used multiple measures at the latent construct level.

Findings

Notwithstanding, the measuring tools to assess working memory differ across studies, all the complex span tasks require similar storage and processing procedures. Across the studies, all of them revealed consistent findings that working memory is positively related to multitasking behavior (e.g., Bühner et al., 2006; Chang et al., 2017; König et al., 2005; Logie et al., 2011; Redick, 2016). Morgan et al. (2013) found that working memory is correlated with the four conditions (i.e., baseline, single difficulty, paired difficulty, and difficulty ramp-up) of the MATB (ranging from $r=0.49$ to $r=0.52$). Colom et al. (2010) further found a moderate latent factor correlation between working memory and multitasking behavior ($r=0.32$; 95% CI [0.21, 0.42]). A three-factor solution of multitasking was identified by Lui and Wong (2019). They categorized multitasking into (1) response selection, (2) retrieval and maintenance of task information, and (3) task-set reconfiguration. They found that working memory was specifically correlated with the components of retrieval and maintenance of task information, as well as the task-set reconfiguration.

Despite most of the studies suggest the importance of working memory, this is still debated. Because Himi et al. (2019) and Redick et al. (2016), who, using latent variable analysis, found no significant direct path between working memory (measured with complex span tasks) and multitasking behavior. Himi et al. found no significant relationship between working memory and the criterion, while the model of executive functions was included in the regression equation. Redick et al. found promising relations between components of working memory, rather than working memory itself, and multitasking behavior. Here, the subcomponents of working memory (capacity and attention control) fully mediated the relationship between working memory and multitasking behavior. Working memory itself, however, did not share significant variance with the criterion variable. Critically, in both of the studies working memory was correlated with multitasking, but without inference about a causal relationship. A reason for this variation in findings may be due to the variety of working memory tasks and scoring systems used (see Conway et al., 2005). Interestingly, this suggests that specific subcomponents of working memory (ability to actively maintain task goals and control attention) rather than working memory as a whole may be related to multitasking behavior at the latent variable level.

Upon closer inspection, a different investigation concerning the relationship between working memory and multitasking behavior was conducted by Colom et al. (2010), and Himi et al. (2019). Here, the authors focused on processing scores of working memory (based on secondary task). Because almost all studies used storage scores (based on recalling primary task). Therefore, Himi et al. critically explored whether processing of the secondary task scores contributed to multitasking behavior. However, this study revealed insignificant relations between the two, unlike Colom et al. (2010).

Although few studies have explored the relationship between multitasking behavior and relational integration, those that did found relational integration to be the most important predictor of multitasking (Bühner et al, 2006; Himi et al., 2019). König et al. also found its significant contribution. Even when comparing working memory to relational integration, it was found that relational integration more strongly predicts multitasking in a subsequent large-scale study on many working memory tasks and many relational integration tasks (Himi et al., 2019). Moreover, Bai et al. (2014) studied multitasking behavior in terms of the ability to recover from interruptions during enacting several tasks. They found that relational integration facilities working memory ability, in which it was found to be correlated with both the components of multitasking—"resuming from interruption" ($r = 0.19$; 95% CI [0.06, 0.31]) and "accurately returning to the interrupted task" ($r = 0.36$; 95% CI [0.24, 0.47]). Todorov et al., (2015, Study 2) further indicated that relational integration (coordination) is the main predictor of multitasking behavior through multiple regression analysis. Notably, the effect size (Table 1) is considerably higher in the studies of Bühner et al. and Himi et al., probably due to use of similar relational integration task.

All studies (Table 1) found reasoning to be a solid predictor of multitasking behavior. Using a regression-based approach, Bühner et al. (2006), Colom et al. (2010), Hambrick et al. (2010), and König et al. (2005) showed that reasoning and working memory work hand in hand as predictors for multitasking behavior. Both regression and latent variable analysis revealed that fluid intelligence does predict the criterion (Martin et al., 2020). The strength of the reasoning—multitasking relationship, however, varies greatly across the studies. For example, Redick et al. (2016) found a rather low-strength relationship with reasoning, only contributing to 38.4% of the variance in multitasking. In comparison, Sanderson et al. (2016) found a much higher value that reasoning (i.e., general cognitive ability) uniquely contributed to 95% of the variance in the criterion. However, Redick et al. (2016) also simultaneously used working memory and attention control as predictors, whereas Sanderson et al. only used reasoning. In another study, Sanderson et al. (2013) also found a positive correlation between the two constructs. Importantly, Sanderson et al., (2013, 2016) used a similar type of tasks to measure multitasking behavior as well as cognitive ability in both studies. Therefore, they found a positive correlation between reasoning and the criterion. Additionally, Lui and Wong (2019) found that performance with Raven's matrices is correlated with specific dimensions of multitasking—'retrieval and maintenance of task information', but not with 'response selection and task-set reconfiguration'. Lastly, the two multitasking components were discovered by Bai et al. (2014), in which reasoning is related to both 'resuming from interruption' ($r = -0.26$; 95% CI [-0.37, -0.13]) and 'accurately returning to the interrupted task' ($r = 0.36$; 95% CI [0.24, 0.48]). However, this relationship could be partly attributed to a shared relation of reasoning with working memory.

Divided attention

Theoretical background

In addition to the previously mentioned cognitive constructs, divided attention (i.e., the ability to integrate parallel multiple stimuli) seems to account for variance in multitasking behavior. Taatgen et al., (2009; Experiment 1) demonstrated that the addition of multiple tasks can demand more procedural resources. This leads to a decrease in attentional blink (i.e., temporal inability to use attentional resources), and an increase in task performance. Therefore, this evidence points toward the importance of attention in handling multiple tasks. The very idea of divided attention stems from the classical approach of limited processing capacity (Kahneman, 1973). Accordingly, Himi et al. (2019) found a strong association between divided attention and inhibition (r = 0.56; 95% CI [0.46, 0.65]). This suggests that divided attention is rooted in the ability to focus on one main action while inhibiting conflicting responses (Logan & Gordon, 2001). To date, there exists no sufficient literature concerning if divided attention acts as a predictor of multitasking behavior. Rather, it is assumed that divided attention and multitasking behavior function as a similar construct. In support of this view, Colom et al. (2010) and Thoma et al. (2008) considered a divided attention test as a measure of multitasking behavior.

Studies included

In total, this review includes four studies (Table 1), which considered divided attention and multitasking as separate constructs (Bühner et al., 2006; Himi et al., 2019; König et al., 2005). The three studies (Bühner et al., 2006; König et al., 2005) concerned with the broader term of attention.

Measures

All included studies on the topic of divided attention employed SIMKAP to assess multitasking behavior. However, the first study (König et al., 2005) considered the intensity and selectivity aspects of attention, whereas the second one (Bühner et al., 2006) concentrated on the subcomponents of selective attention itself (focus and divided attention). Himi et al. (2019) were interested in only divided attention. Lastly, Sanjram (2013) used experimental paradigm to understand the role of attention in multitasking behavior, in which participants were presented in two conditions: contracted attention (using non-fading words) and protracted attention (using fading words, which require more attention) and had to do programming (involving multitasking situation. At the same time, they had to perform mouse clicking task (embedding prospective memory), in which they were asked to click mouse as soon as a word appeared in a corner window.

Findings

Divided attention is a relevant construct of multitasking, although the findings regarding the extent to which divided attention can explain multitasking behavior differ. In the first two studies (Bühner et al., 2006; König et al., 2005) it was found that attention contributes significantly to explaining multitasking behavior, however to a lesser extent than working memory does. Conversely, in another paper by Himi et al. (2019), it was found that divided attention serves as a better predictor for multitasking behavior than working memory. Himi et al. found a significantly higher correlation (r = 0.53; 95% CI [0.42, 0.62]; see Table 1) compared to the former two. Moreover, Sanjram (2013) highlighted the importance of attention in multitasking. Participants did more omission error under protracted attention, than contracted attention.

Prospective memory

Theoretical background

In a multitasking environment, another essential aspect of human cognition is the role of memory, involved in carrying out a delayed intention in fulfilling various task demands. This leads to the question of "How do people retain the intended actions and activate them at appropriate times and contexts?" This ability is defined as prospective memory and it refers to remembering what actions need to be performed in the future. Prospective memory is a building block in a multitasking models (e.g., Burgess et al., 2000) where it goes together with working memory to predict multitasking performance. Specifically, many working memory resources are devoted to the intention of prospective events retrieval (Wang et al., 2013). This memory retrieval is handled through the process of self-initiated resource-demanding retrieval or relatively automatic retrieval. Environmental cues have been found to influence the automatic retrieval. The importance of prospective memory can be seen when its failure leads to a decline in task performance (Walter & Meier, 2014).

Studies included

Only three studies examined the relationship between prospective memory and multitasking behavior. Two studies were conducted with young adults by including university students (Logie et al., 2011; Sanjram, 2013), and the other study obtained data from a wider range of ages (Mean age = 32.9 years; Hirnstein et al., 2019).

Measures

In the study by Hirnstein et al. (2019), participants were exposed to a computerized meeting preparation task (Laloyaux et al., 2018) where they had to prepare a room for a meeting and handle several tasks (e.g., preparing table) and distractors (e.g., chair missing) during the process. The other study (Logie et al., 2011) used EVET as a multitasking assessment tool. With respect to prospective memory measure, Logie et al. used the breakfast task. The last one (Sanjram, 2013) used experimental paradigm, as described earlier.

Findings

The findings of these three studies are conflicting: Hirnstein et al. (2019) demonstrated that prospective memory is one of the dependent measures of the computerized meeting task. In comparison, Logie et al. (2011) found that prospective memory did not share any variance with EVET. However, the measures of prospective memory in these studies are generally used to assess multitasking behavior. Nevertheless, Sanjram (2013) found that prospective memory process suffer during handling multiple tasks simultaneously, unless a cue for the next task is identified. The author reasoned that working memory mostly contributes to multitasking in coordinating and maintaining task relevant information, compared to prospective memory.

Integrative summary

The first aim of this review was to identify the relevant cognitive correlates of multitasking behavior in order to establish a theoretical framework of individual differences in the criterion variable. The existing studies reveal that multitasking ability shares variance with certain cognitive constructs, specifically, with the abilities related to updating, inhibition, working memory, relational integration, reasoning, and divided attention, although the magnitude of correlation was not high (discussed below).

The nature of the cognitive tasks

The inconsistent picture derived from the studies reviewed above might result from the large variation in methodologies that were employed. The most obvious difference across studies is the diversity in the nature of the measures of multitasking and other cognitive constructs. To thoroughly look into this aspect, we compared the types of tasks used across studies. Figure 3a represents the tasks used in each study. As visualized, a range of different tasks are used to measure multitasking behavior. As depicted, SIMKAP and SynWin were used about equally often. SIMKAP basically reflects memory, processing speed, perceptual accuracy, and intellectual ability (Bratfisch & Hagman, 2011), whereas SynWin also involves memory, arithmetic processing, and monitoring ability (Elsmore, 1994). In some cases, working memory, divided attention, or task-switching were measured to assess multitasking. The ability-based multitasking measures (i.e., assessing performance during structured activities, in which the test taker is expected to exert less self-direction) can be considered ecologically valid to a certain degree—in the sense that they were constructed to represent everyday multitasking (e.g., interleaving between tasks, differing task characteristics, requiring no feedback etc.; Burgess, 2000). An example of this kind of everyday multitasking is the EVET (such as picking up newspaper, meeting people, turning on cinema etc.; Logie et al., 2004). Although these measures are less artificial than some executive functions tasks (Wisconsin Card Sorting Test), they are still fairly artificial and cover only highly specialized aspects of multitasking (SynWin; developed for military people). Moreover, almost all the reviewed studies include a single measurement tool of multitasking. Future studies therefore should use multiple multitasking measures to generate a common core (latent) factor for multitasking. Similarly, different tasks were used for the same cognitive correlate (Fig. 3b), therefore task heterogeneity might be a reason for the inconsistent findings. This makes it highly difficult to come to definite conclusions about the reasons the

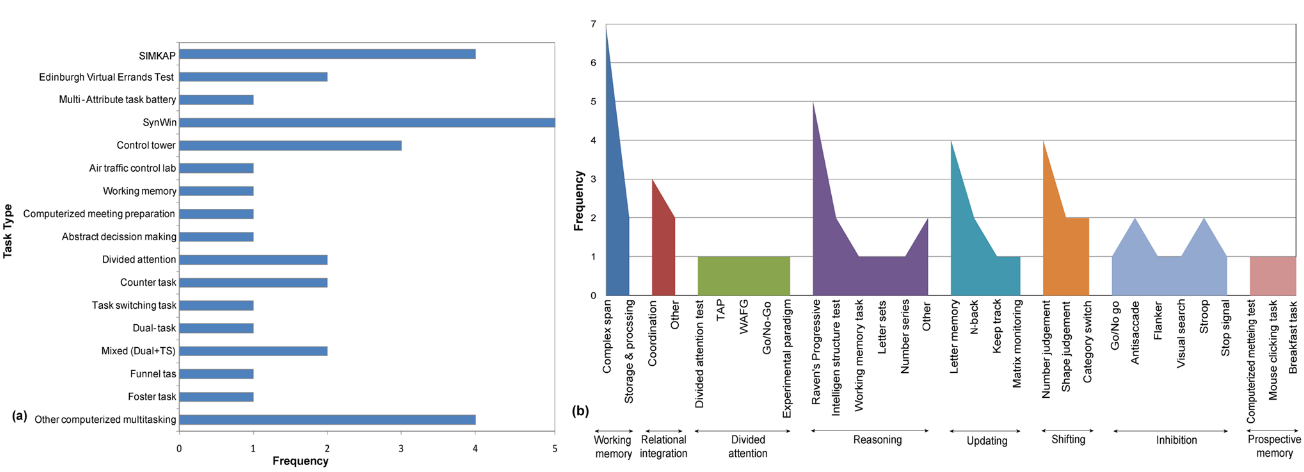

Fig. 3 Frequency of using different types of tasks for the reviewed studies. (**a**) The measures of multitasking behavior in cognitive research, (**b**) The measures of cognitive abilities. Some tasks that cannot be categorized in any of the mentioned paradigms are represented as 'other'. *TS* task switching, *TAP* test battery attentional performance, *WAFG* divided attention test (Vienna test system)

differences in the relationships between the variables of the studies. However, all studies used performance-based measures of cognitive abilities, as a means to control for self-report bias.

Another important aspect of the measures is their reliability. Reporting reliability is a standard practice in individual differences research but only ten studies reported the reliability estimates for the measures of multitasking and other cognitive constructs (see Table 3). All reported measures showed moderate to high reliability, yet, the conclusions that can be drawn from such a small number of studies are extremely limited. We therefore cannot rule out that differences in the measurement accuracy can account for part of the heterogeneity found in the reviewed studies.

However, in these review studies, a possible common method bias has to be kept in mind: individual differences

Table 3 Reliability estimates of the cognitive and personality measures

Studies	Multitasking measures	Reliability	Cognitive and personality measures	Reliability
Bühner et al. (2006)	SIMKAP	Speed: 0.93[a] Error: 0.76[a] Question: 0.84[a]	Working memory Relational integration Shifting Attention Reasoning	Ranged from 0.92[c] to 0.95[c] Ranged from 0.65[b] to 0.85[b] Ranged from 0.43[b] to 0.81[b] n/r 0.91[f]
Crews and Russ (2020)	In-box exercise Self-report questionnaire	n/r	Emotional stability Agreeableness Conscientiousness Extraversion Openness to experience	0.71[b] 0.70 [b] 0.83[b] 0.79[b] 0.74[b]
Hambrick et al. (2011)	SynWin	Baseline: 0.72[b] Emergency: 0.82[b]	Updating Shifting	0.80[e] 0.55[e]
Ishizaka et al. (2001)	Auditory–visual multitask	n/r	Polychronicity	0.89[b]
Himi et al. (2019)	SIMKAP	Speed: from.88[b] to 0.99[b] Question: 0.88[b]	Working memory Relational integration Divided attention Shifting Inhibition Updating	Ranged from 0.55[b] to 0.73[b] Ranged from 0.59[b] to 0.77[b] 0.96[b] Ranged from 0.83[c] to 0.92c Ranged from 0.87[d] to 0.94[b] Ranged from 0.59[b] to 0.86[b]
König et al. (2005)	SIMKAP	Speed: 0.93[f] Error: 0.60[f] Question: 0.82[f]	Working memory Relational integration Shifting Reasoning Attention Polychronocity Extraversion	0.84[b] 0.67[b] 0.83[b] 0.57[b] and 0.84[b] n/r 0.84[b] 0.82[b]
König et al. (2010)	Self-report	0.75[b]	Polychronicity Impulsivity	0.84[b] 0.74[b]
Martin et al. (2020)	Control tower SynWin Foster task	n/r n/r n/r	Inhibition (Attention control) Fluid intelligence	Ranging from 0.31 to 0.71[g] About 0.80
Redick (2016)	SynWin	0.73	Working memory	Ranged from 0.69[b] to 0.83[b]
Redick et al. (2016)	SynWin Control tower Air traffic control laboratory	0.86[b] 0.96[b] and 0.54[b] 0.71[b]	Working memory Inhibition Reasoning	Ranged from 0.57[b] to 91[b] Ranged from 0.61[b] to 0.96[b] Ranged from 0.72[b] to 0.79[b]

Note: only the studies which reported the reliability estimates are listed

n/r not reported

[a]Construct reliability

[b]Cronbach alpha

[c]Split-half reliability

[d]Reliability for difference scores

[e]Reliability calculated by correlating scores on the first block with the second block of the task

[f]Reliability for test batteries

[g]Test–retest reliability

in cognitive multitasking scenarios tend to correlate with other cognitive constructs measured with similar methods (e.g., computerized tests; Bühner et al., 2006; Redick, 2016). This form of bias can inflate or deflate the estimates of the relationship between the constructs. However, most of the reviewed studies that used computerized tasks had a time-separation between the administration of the measures of the predictor and criterion variables (e.g., Bühner et al., 2006; Himi et al., 2019; Redick et al., 2016). This lag might reduce the salience of the predictor variables (Podsakoff et al., 2003).

Relating cognitive abilities with multitasking behavior

The correlations between cognitive abilities and multitasking performance were low or high, overall (ranging between − 0.04 and 0.77). Moreover, the sample sizes were mostly low, rendering the correlation estimates unreliable. An effect size measure for correlation depends on sample size. We created a scatter plot relating the correlations to the sample size of each study (Fig. 4, for a similar approach, see von Bastian et al., 2020). As we can see, the studies generally reported moderate correlations (median $r = 0.36$), and a few studies found correlations larger than $r = 0.60$. The median sample size was $n = 150$. This is far away from a recommended sample size for stable correlation estimates (e.g., $n = 250$ in Schönbrodt & Perugini, 2013). When talking about precision of correlation coefficient, a large sample ensures narrow width of *CI* for precise estimation. As can be seen in Table 1, only six studies used sample size larger than 200. It is recently suggested that sample size should be determined using *CI* width, rather than power (Bland, 2009).

Although it is obviously necessary to switch back and forth between tasks during multitasking (Lin et al., 2016), the literature to date only partly supports a relation between shifting ability and multitasking performance. One reason might be the scoring of shifting abilities. Most of the reported studies used speed-based measures of performance while ignoring the accuracy. Because speed can be traded for accuracy, reaction times alone are not a valid measure of performance, even more so for highly demanding multitasking behavior (see Draheim et al., 2019 for review). In fact, studies which considered both accuracy and speed aspects of task switching (as mentioned by Jewsbury et al., 2015) showed a significant relationship between task switching and multitasking (Szumowska & Kossowska, 2016). Because of this, bin scores (i.e., combining speed and accuracy into a

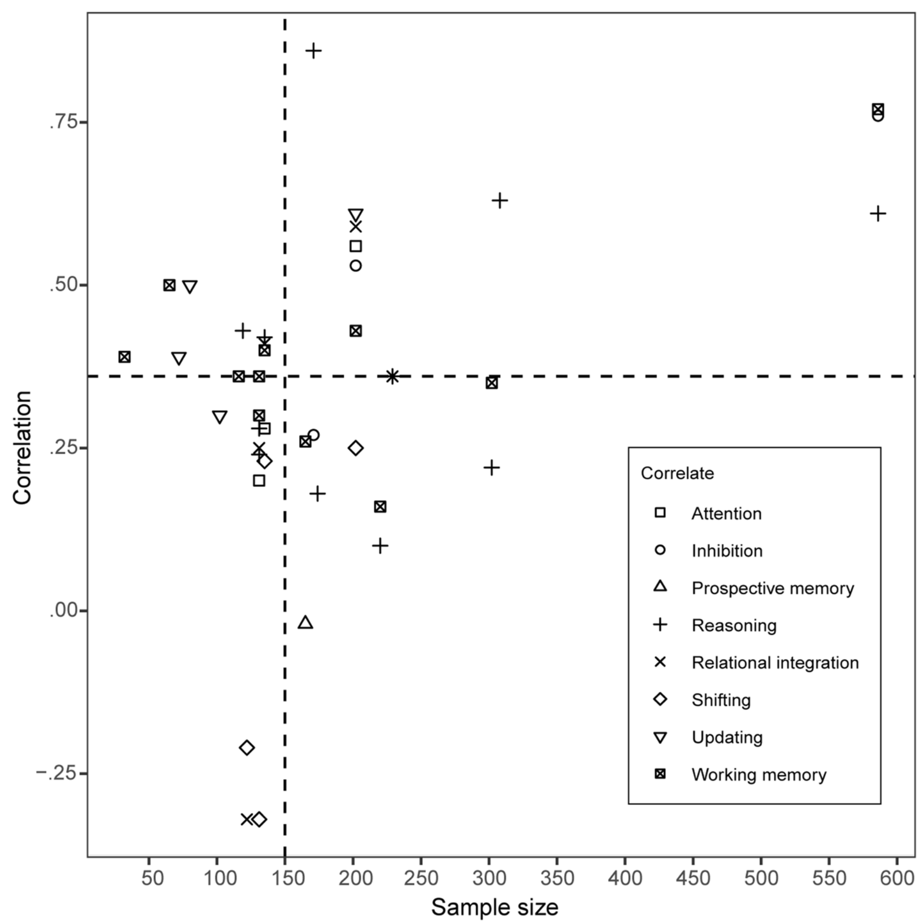

Fig. 4 Correlation between all cognitive correlates and multitasking behavior reported in each study. Studies that report no correlation coefficients are not included in this analysis. In few cases, average correlations are used. The dashed lines depict the median values of the samples size (*x*-axis) and of the correlations (*y*-axis)

single metric; Draheim et al., 2016) or mixing costs (i.e., difference between task repetition in the mixed block and the single blocks; Philipp et al., 2008) may be useful to explain the ability to maintain multiple tasks.

For updating, an interesting association was found with divergent thinking, a holistic-flexible task processing mode (Zabelina et al., 2019), which allows for a higher level of parallel processing (Fischer & Hommel, 2012). Apparently, updating involves creating contextual binding, and removing or inhibiting previous ones (Palladino & Artuso, 2018). Thus, one would expect shared variance between measures of updating and inhibition facilitates to perform multiple tasks concurrently (Himi et al, 2019). The effect might be limited by the low reliability of inhibition measures as acknowledged in many prior works. (e.g., Friedman & Miyake, 2004, 2017; Rey-Mermet et al., 2018; von Bastian & Oberauer, 2013; but see von Bastian et al., 2020).

Furthermore, common EF predicts multitasking behavior (Himi et al., 2019). Both constructs reflect the ability to utilize goal information and to guide task goals; however, these two constructs are conceptually different. Himi et al. speculated that a large amount of common variance between the two may have emerged from the correction for attenuation in the latent variable approach. Despite this, we believe that common EF contributes to the goal-relevant behaviors underlying individual differences in multitasking behavior. A very fascinating picture emerges from prior works: these relations may reflect the effects of the personality trait conscientiousness, as it depends on goal-directedness (Bogg & Roberts, 2013). Thereby, this could indicate the potential role of personality (specially, conscientiousness) in multitasking (discussed below). Lastly, the relationship between multitasking behavior and unique updating or unique shifting is not entirely clear. Future research will need to explore this issue. Overall, it appears as though common EF is related to multitasking behavior more strongly than any other specific executive function component. The importance of common EF for multitasking can be discussed based on the Efficient Task Instantiation Model (Strobach et al., 2014), in which the authors consider dual-task as an efficient executive functioning ability next to the Miyake et al.'s (2000) three core factors, and propose how practice related improvement in dual-task (multitask) performance is related to the optimization of executive function dual task.

Although most of the reviewed studies suggest that working memory (especially the storage component) is a strong predictor for multitasking behavior, Redick et al. (2016) and Himi et al. (2019) found a relatively weak (or non-significant) role of working memory on multitasking behavior. Engle (2018) argued that working memory plays a vital role in performing real-world tasks where actors need to attend to critical tasks and at the same time avoid having attention captured by competing internally or externally generated thoughts. The predictive power of working memory in these studies (Himi et al., 2019; Redick et al., 2016) might be subsumed under the overlapping variance between working memory and other constructs. However, as suggested by Colom et al. (2010) and Redick et al. (2016), the processing component also significantly predicts multitasking behavior (but see Himi et al., 2019). The contents of working memory not only reflect declarative system (knowing what), but also a procedural system (knowing how) to determine how these guide multitasking behavior (Oberauer, 2010).

Working memory differs from relational integration in that working memory refers to the storage and processing of information, whereas relational integration refers to the processing of task rules in doing multiple tasks. Among all the cognitive abilities addressed in this review, relational integration accounts most for multitasking behavior (Himi et al., 2019). The unique mechanism of relational integration seems to be relational thinking. Relational thinking reflects the capacity to monitor and integrate cognitive relations of multiple tasks in a multitasking scenario and it establishes a novel relational representation of how to execute tasks concurrently. If the overlapping variance of relational integration is controlled for working memory, then it contributes to multitasking behavior. Conversely, if the overlap with inhibition is controlled, then it no longer contributes to multitasking performance (Himi, 2018; Himi et al., 2019). This supports the view that the driving force of the relational integration—multitasking behavior relationship is the inhibitory control for the representation of relations. Bühner et al. (2006) and Himi et al. explored this relationship using von Bastian and Oberauer et al.'s (2013) relational integration task and found that it leads to task-specific effects. These findings can be validated by using different kinds of relational integration tasks.

Both reasoning and working memory are good predictors of multitasking behavior (Bühner et al., 2005). However, reasoning has been shown to be a slightly less important predictor of multitasking behavior compared to working memory (e.g., Bühner et al., 2006; Colom et al., 2010; Redick et al., 2016). This is possibly because reasoning tasks such as the Raven's Progressive Matrices test rely to some extent on the maintenance of information (Engle, 2018), so that working memory proficiency becomes a pre-condition for reasoning. It is worth mentioning that the included studies all measured fluid intelligence and not crystallized intelligence, i.e., learned and acculturated knowledge. Crystallized intelligence is seen to be related to cognitive abilities that were not reviewed here (e.g., Friedman et al., 2006), and has been shown to serve as a better predictor of real-world task performance than fluid intelligence (Postlethwaite, 2011).

Fluctuation of attention is an important source of variation in memory and task performance (Unsworth & Robison, 2016). In the same vein, the present findings on divided attention might highlight an effect of attentional resource allocation in concurrent task performance. The tasks intended to measure divided attention typically assess interference control abilities—this is, focusing on relevant information and ignoring irrelevant information at the same time. It seems that divided attention is inhibitory in nature as it involves encoding and retrieving important information from irrelevant information (Kane & Engle, 2000).

In the context of multitasking, prospective memory is the ability to remember the status of multiple ongoing tasks for use in the future (Burgess et al., 2000; Logie et al., 2010). Laloyaux et al. (2018) found that prospective memory, both time-based and event-based, is central to multitasking in schizophrenic patients. Specifically, this everyday memory construct correlates with inhibition (McAlister & Schmitter-Edgecombe, 2013), which in turn contributes to the performance of multiple tasks (Bisiacchi et al., 2009). However, some studies found contradictory evidence for the impact of prospective memory on multitasking behavior. For instance, Logie et al. (2011) found no shared variance between prospective memory (measured with breakfast task) and multitasking (measured with EVET), even though this breakfast task is also used as a multitasking measure in another study (Craik & Bialystok, 2006). However, the influence of prospective memory in multitasking can be explored by using different measures of multitasking, other than EVET. Quite naturally, no concrete evidence was found that prospective memory is needed for multitasking but prospective memory might be important (Logie et al., 2010). Therefore, further investigation is necessary to determine this relationship.

Formulating a conceptual model

Our integrative summary has revealed some overlap between mechanisms that underly the reviewed cognitive abilities, thus, appears inappropriate to consider the role of each cognitive ability with multitasking performance in isolation. We primarily propose that the relationship between multitasking behavior and higher-order cognition can be explained by a shared cognitive mechanism among working memory (storage and processing/complex span), reasoning, and relational integration (e.g., Bühner et al., 2005; Chuderski, 2014; Oberauer et al., 2008). Thus, these concepts can be developed into a common working memory model. Our integrated model (Fig. 5) represents how common EF (emerged from updating, shifting, and inhibition; Friedman et al., 2016), common working memory (emerged from storage and processing/complex span, relational integration, and reasoning), and divided attention can contribute to explaining multitasking behavior and underlines the broadness of the construct. Prospective memory was not included in the conceptual model because of lack of direct evidence. The overlap between the constructs does not imply a particular causality: for example, the correlation between common working memory and divided attention does not necessarily mean that working memory or divided attention is integral for multitasking behavior. Rather, it could be other way around, such that multitasking ability contributes to working memory (i.e., complex span tasks being essentially dual-tasks) or divided attention tasks (sometimes used to measure multitasking; see Fig. 3a). Also, an altogether different construct, such as attention control, could contribute to both.

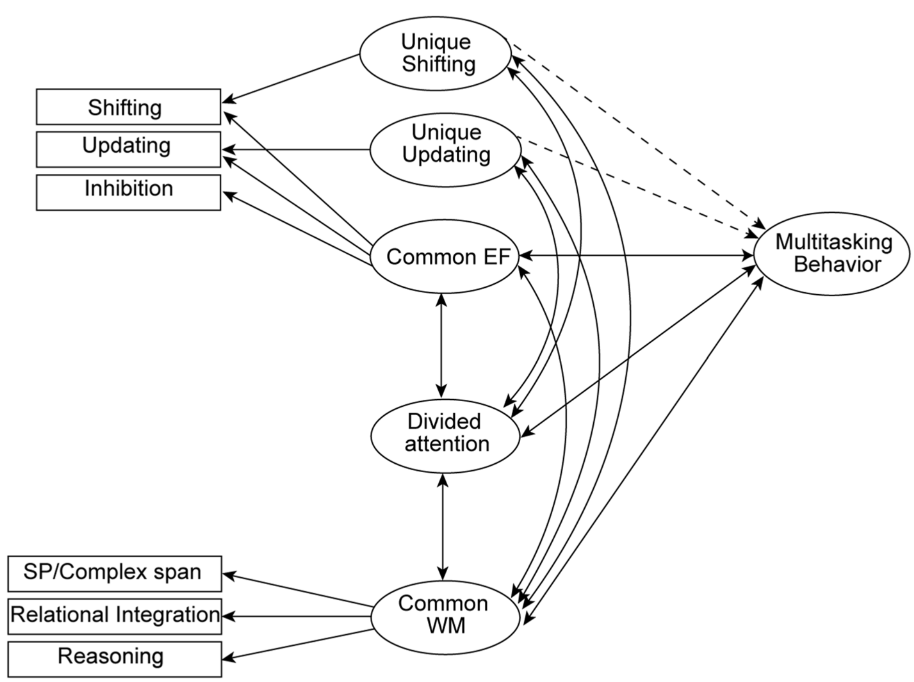

Fig. 5 Conceptual model for the cognitive abilities responsible for multitasking behavior. The dashed lines from unique shifting and unique updating to multitasking behavior represent lack of evidence. *Common WM* common working memory

In this sense, Vergauwe et al. (2020) assumed multitasking to be involved in working memory and demonstrated that a domain-general factor can account for working memory performance as well as multi-tasking performance. In line with this view, there might be no causal role of working memory and divided attention for multitasking behavior, and therefore, simply state a correlational path between them in our conceptual model. The other construct integrated in the conceptual model is common EF. Common EF is also termed attention control in the literature (for a review, see von Bastian et al., 2020) and was found to influence super-multitasking ability (Watson & Strayer, 2010). Conversely, a multitasking test has also been proposed as a measurement tool of executive functions (e.g., the *multitasking in the city test*; Jovanovski et al., 2012). Therefore, we modeled a bidirectional path from common EF to multitasking behavior. However, this conceptual model is still in need of an empirical test.

Personality correlates of multitasking behavior

In the previous section, we reviewed a large body of findings regarding the relationships between multitasking behavior and different cognitive abilities. Previous research (e.g., König et al., 2005) has identified cognitive ability as a key determent of performance in a multitasking environment. However, personality often explains significant variance in behavior across situations and thus might be a further factor for multitasking performance (Rushton et al., 1983). In this section, we examine the relationship between multitasking behavior and personality factors (polychronicity, impulsivity, and five-factor model).

Polychronicity

Theoretical background

Polychronicity is defined as the preference for structuring time to excel well in multitasking. The concept was first introduced as a component of cultural tendency and reflected how cultures perceive time (Hall, 1959). However, there is a considerable body of literature suggesting that polychronicity drives multitasking behavior. Poposki and Oswald (2010) proposed that polychronicity represents a stable tendency to perceive multitasking as enjoyable and rewarding rather than stressful, thus indicating that multitasking performance is the product of ability and motivation/affect. Polychronicity plays a central role in the motivation of individuals to perform multiple tasks simultaneously (König et al., 2010). Multitasking environments (such as that of air traffic controllers, receptionists, etc.) might require certain amount of polychronicity attitude, otherwise people experience discomfort when they engage in behaviors that conflict with their beliefs or preferences (cognitive dissonance theory; Festinger, 1957).

Studies included

In total, nine studies (Table 2) that have examined the relationship between multitasking behavior and polychronicity were included. Among them, two studies (Stephens et al., 2012; Zhang et al., 2005) implemented an experimental approach.

Measures

Two studies used multitasking performance tests and three used self-report measures of multitasking (Table 2). In a hypothetical workplace situation, König et al. (2010) assessed the tendency to engage in multitasking. Kirchberg et al. (2015) used diary and self-report measures to capture variation in multitasking after daily work, while Mattarelli et al. (2015) also employed diaries to compile all the activities and events that occurred during the previous day. Polychronicity was measured using self-report questionnaires in these six correlational studies. With respect to experimental studies, Stephens et al. (2012) and Zhang et al. (2005) both employed three conditions, but contained different leveling of the conditions. For the former experiment, participants were assigned into a monochronic/single-task condition, dovetailing/sequential task condition, and polychronic/simultaneous condition. However, for the latter one, monochronic, polychronic, and neutral conditions were employed, and a simulator was used to measure multitasking performance of all participants (control station software, i.e., critical thinking; Cooper & Dougherty, 2001). Similarly, in another experimental study, Grawitch and Barber (2013) used two conditions: multitasking (combining primary and distracter tasks) and non-multitasking conditions.

Findings

Many studies suggest that an individual's preference for doing multiple tasks in a laboratory situation is transferrable into actual multitasking behavior encountered in the real world (Kirchberg et al., 2015; König et al., 2010; Mattarelli et al., 2015). However, polychronicity was often not directly related to multitasking ability. Sanderson et al. (2013) found that polychronicity moderates the relationship between multitasking ability and job performance. Likewise, Grawitch and Barber (2013) found an indirect positive relation between polychronicity and multitasking that was moderated by self-control. Finally, Kirchberg et al. (2015) reported that polychronicity boosts an individual's psychological well-being and consequently improves performance. As for the two experiments, Stephens et al. (2012) demonstrated that people in a polychronic condition, compared to a monochronic and a sequential condition, tended to feel an increased work pace and workload. Similarly, Zhang et al. (2005) showed that polychronic compared to monochronic individuals tended more to performing dual tasks simultaneously and also produced less errors in this condition. In contrast, König et al. (2005) opposed this relationship, and claimed that preference for multitasking is different from actually engaging in multiple tasks.

Impulsivity

Theoretical background

Impulsivity, is an important dimension of behavior and reflects the claim that demands are met immediately (Barratt, 1994). Impulsivity overlaps with poor sustained attention (Helton, 2009) and executive functions (Cheung et al., 2004), suggesting that highly impulsive individuals may have a diminished capacity to block out distractions and focus on a single task instead of multiple tasks. Most of the previous studies have examined the association between media multitasking (i.e., multitasking activity) and impulsivity (e.g., Minear et al., 2013; Ralph et al., 2014; Shin et al., 2019), but fewer studies have emphasized its relationship with multitasking ability.

Studies included

Only two studies (König et al., 2010; Sanbonmatsu et al., 2013) examining the relationship between multitasking ability and impulsivity were included.

Measures

Multitasking ability was measured either using a complex span task (Sanbonmatsu et al., 2013) or self-report questionnaires (König et al., 2010), whereas impulsivity is measured by the self-reported Barratt Impulsiveness Scale (Barratt, 1994) in both studies.

Findings

König et al. (2010) found that impulsivity had a significant positive weight on multitasking behavior ($r = 0.21$; 95% CI [0.07, 0.34]). On the contrary, Sanbonmatsu et al. (2013) found individuals who score higher in trait impulsivity score significantly lower in multitasking ability.

Five-factor personality model

Theoretical background

We consider the five-factor model of personality (Costa & McCrae, 1992) because the literature reflects an increasing popularity of the big-five traits in contemporary psychological research (John, 2012). This model describes the tendencies of how people behave in five broad personality dimensions: agreeableness (gentle, cooperative vs irritable, short-tempered), conscientiousness (organized, systematic vs careless, irresponsible), emotional stability (resilient vs excitable), extraversion (sociable vs less sociable), and openness to experience (curious vs indifference). Prior works explored the correlation between personality traits and multitasking behavior (e.g., Ishizaka et al., 2001). For instance, emotional stability (neuroticism) had a significant indirect effect on multitasking performance (partially mediated by anxiety), whereas extraversion showed a non-significant relationship (Poposki et al., 2009). On the other hand, Lieberman and Rosenthal (2001) suggested that an extravert would be better at multitasking than an introvert. In fact, extraversion, agreeableness, conscientiousness, and openness are typically considered positive sides of an individual's character, as these contribute to monitor and regulate one's cognitive skills (Ayhan & Turkyilmaz, 2015).

Studies included

In total, seven studies (Table 2), exploring personality traits in conjunction with multitasking behavior were included, in which three studies (e.g., Crews & Russ, 2020; Lin et al., 2016) concentrated on all five facets of personality. Kirchberg et al. (2015) focused on conscientiousness and extraversion, König et al. (2005) considered only extraversion, and Sanderson et al. (2016) focused on emotional stability, openness to experience, and conscientiousness. Conversely, Guastello et al. (2014) incorporated 16 primary personality factors and five global traits.

Measures

Multitasking behavior was mostly measured by administering computerized ability-based tasks, except Kirchberg et al. (2015), Konig et al. (2010), and Mattarelli et al. (2015) studies, which used diary and self-report measures to capture variation in multitasking after daily work. Measures of personality traits were obtained with self-rated Likert-type questionnaires.

Findings

Findings on the role of personality traits for multitasking behavior are almost null. Lin et al. (2016), and Crews and Russ (2020) found no significant correlation between any of the five factors and multitasking behavior (measured with performance-based task). However, in Crews and Russ (2020), self-report multitasking attitude was found to be correlated with openness ($r = 0.23$; 95% CI [0.04, 0.41]). Kurapati et al. (2017) showed that openness moderates the relationship between multitasking ability and planner task performance (i.e., reflecting adaptive behavior while handling complex situation). In Sanderson et al. (2016), multitasking performance was neither related to emotional stability nor openness to experience. However, the criterion is negatively correlated with conscientiousness, although this correlation was low ($r = -0.16$; 95% CI [-0.27, -0.05]). König et al. (2005) reported that extraversion is not a significant predictor of multitasking ability. Finally, Guastello et al. (2014) found multitasking behavior to be positively correlated with dominance and abstractedness and negatively correlated with sensitivity, where abstractedness and sensitivity are the opposite poles of agreeableness. Emotional stability, extraversion, openness to experience, and conscientiousness (used as self-control) showed no relation with multitasking in this study. It, thus, cannot be concluded that any of the five factors of personality are directly related to multitasking behavior.

Integrative summary

The current review integrated research findings on the topic of individual differences in multitasking behavior. Particularly, in this section individual differences were examined in terms of the personality characteristics of polychronicity, impulsivity, and the Big-Five personality model. Based on limited research, overall findings indicate a markedly low relationship between multitasking behavior and personality constructs. Specifically, polychronicity is found to be related (but not directly, rather acts as moderator) to multitasking, whereas impulsivity shares both positive and negative relations with the criterion variable. However, the role of the five-factor model on multitasking behavior is almost null, with conscientiousness and openness being the only two factors showing a slight relationship. We created another scatter plot, again relating the correlations of multitasking with personality traits to the sample size of each study. As we can see in Fig. 6, there are null correlations (i.e., close to 0) between personality and multitasking (median $r = 0.03$; ranging from -0.02 to 0.49). The median sample size is $n = 131$, again far from the required sample size ($n = 250$; Schönbrodt & Perugini, 2013). The studies included in this review used performance-based measures of multitasking

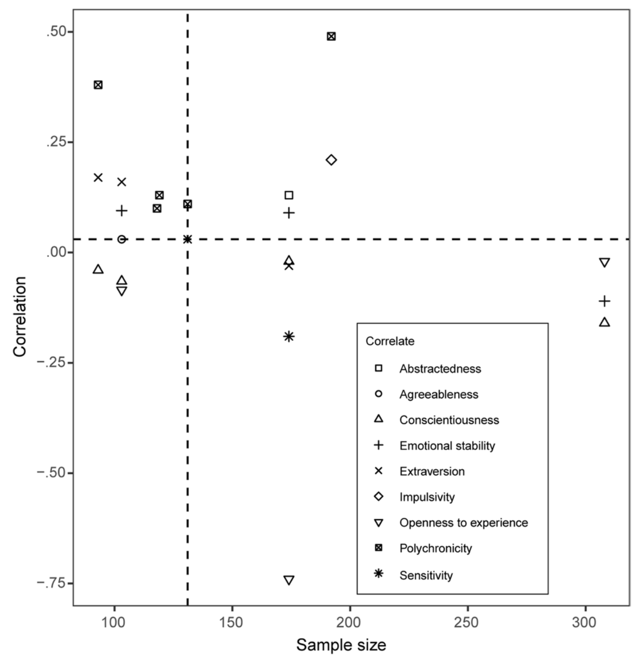

Fig. 6 Correlation between all personality correlates and multitasking behavior reported in each studies. Studies that report no correlation values are not included in this analysis. In few cases, average correlations are used. The dashed lines depict the median values of the samples size (x-axis) and of the correlations (y-axis)

(except Crews & Russ, 2020; Kirchberg et al., 2015; König et al., 2010; Mattarelli et al., 2015), whereas the personality traits were mostly assessed through self-report questionnaires (Fig. 7). Notably, the self-report-based reviewed studies have reduced the common method bias by minimizing the scale properties shared by measures of the criterion and predictor variables (e.g., developing a survey by including day level diary data for multitasking measure, and Likert-type scales for polychronicity and impulsivity measures; Kirchberg et al., 2015). However, personality might substantially correlate with self-report-based measures of multitasking. This may, for example, be a reason for the significant relationship between polychronicity and multitasking, as depicted in Table 2. Moreover, self-report measures are prone to biases, such as social desirability, which limits their reliability and the putative correlation with multitasking performance. Moreover, most of the studies used manifest regression models instead of latent variable analysis. Also, only few studies (e.g., König et al., 2005, 2010; see Table 3) reported the reliability of the personality trait measurements.

The literature synthesis shows polychronicity as the most relevant personality correlate. Polychronic individuals have a belief to excel in environments that require multitasking and translate this belief to successful performance (Sanderson et al., 2013). However, polychronicity and actual multitasking ability are distinct. More specifically, where

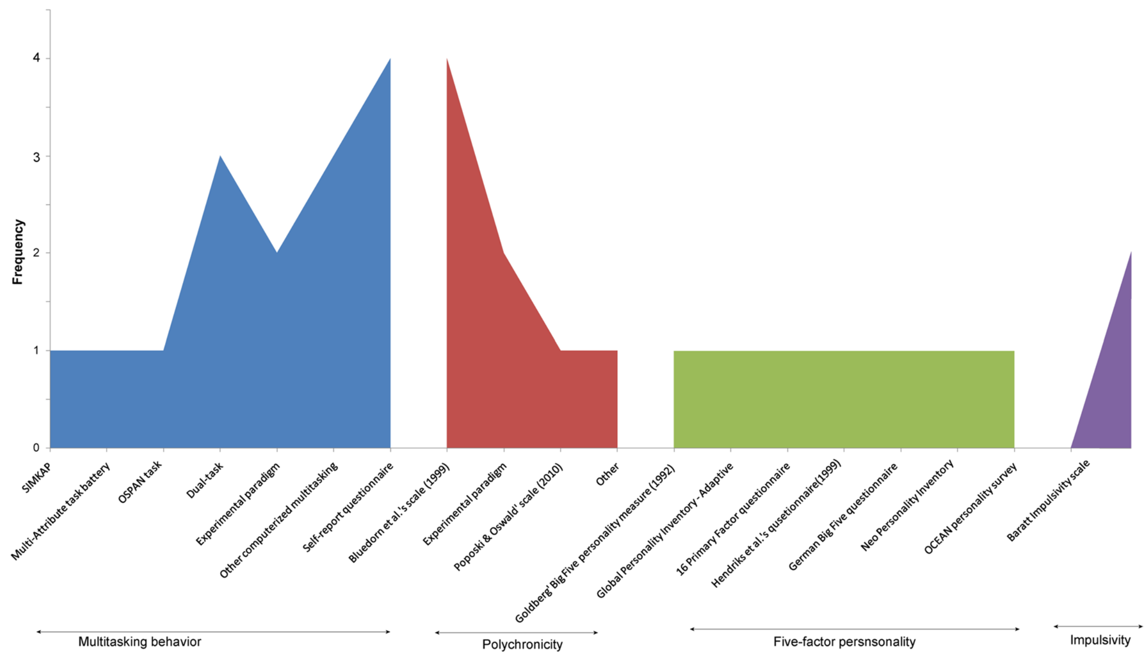

Fig. 7 Frequency of using different types of multitasking and personality measures in personality research

polychronicity is a preference, multitasking is an ability (i.e., a behavioral aspect of polychronicity). Theoretically, there is no necessary link between real multitasking ability and preferring to do several things at a time (see Spink et al., 2008). For example, some people might feel pressured by their environment to do several things at the same time without actually liking it (Cotte & Ratneshwar, 1999). For this reason, polychronicity is not necessarily directly correlated with multitasking. However, both constructs are related to cognitive ability and performance (Goel & Schnusenberg, 2019). A preference for multitasking along with confidence in one's cognitive skills might enhance performance. Nevertheless, Kirchberg et al. (2015) concluded that highly polychronic behavior is related to higher affective well-being. Therefore, the authors suggested recruiting high polychronic employees so that they can easily adapt to a multitasking job environment. Polychronicity might moderate the relationship between cognitive abilities and multitasking performance: polychronics with higher levels of cognitive ability would multitask significantly better than non-polychronics with high levels of cognitive ability.

Impulsivity has been found to be linked with poorer cognitive ability (Cheung et al., 2004). Impulsive people show deficits in their ability to inhibit pre-potent responses, which might lower multitasking ability. Moreover, Ahmed et al. (2017) found that impulsivity in young people is associated with anxiety, stress, and depression. As a result, impulsiveness seems to negatively influence multitasking performance, although Dickman and Meyer (1988) argued that high impulsivity allows a person to perform simple and brief time available tasks more efficiently. However, drawing a conclusion about the impulsivity—multitasking behavior relationship based on only two reviewed studies would be premature. Future research on this topic may be useful.

Most of the studies investigating the influence of personality traits on multitasking behavior employed the five-factor model. Guastello et al. (2014) recommended using the 16 primary personality factors (16 PF; Cattell, 1947) to predict multitasking performance. The five-factor model corresponds to the global traits of Cattell and Mead (2008)—resulting from higher-order factor analysis, which indicates a source of error variance between the final factor and first-order factors. This might be a reason for why null relationships were found between the five-factor model and multitasking behavior in most of the previous works (e.g., König et al., 2005; Lin et al., 2016). Through our literature synthesis, we show that only conscientiousness (describing a person's tendency to accomplish duties and goals; Sanderson et al., 2016) and openness (reflecting a person's willingness to be creative; Crews & Russ, 2020; Kurapati et al., 2017) are a predictive factor for multitasking performance. Similar results were reported in a meta-analysis by Poropat (2009). Explicitly, the meta-traits of *stability* (a combination of conscientiousness, emotional stability, and agreeableness) and *plasticity* (a combination of extraversion and openness) emerge from individual variation in the functions of serotonergic and dopaminergic systems and this individual variation may be predictive for the engagement and restraint of behavior (Hirsh et al., 2009). Furthermore, stability often shows a negative relation with performance in behavioral tasks, whereas plasticity appears to have positive relations. Accordingly, Sanderson et al. (2016) found a negative correlation between conscientiousness and multitasking behavior, and Crews and Russ (2020) reported a positive relation between openness and the criterion (measured via self-report). Sanderson et al. reasoned that individuals high in conscientiousness tend to be methodical, and thus perform multitasking less effectively, reflecting intelligence compensation hypothesis. This finding is also in line with Lange (2013). However, since the Sanderson et al.'s sample was restricted to organizational employees and other studies hint toward a positive correlation between conscientiousness and cognitive abilities, especially when the sample comprised not only highly educated participants (Murray et al., 2014), this negative correlation might be an artifact of sample selection. We believe that there are strong arguments for this: high conscientiousness is associated with high performance, due to the achievement striving facet of conscientiousness (Costa & McCrae, 1992). The goal-directed nature of conscientiousness might contribute to explain the common EF—multitasking behavior relationship (similar to the relationship between procrastination and common EF in Gustavson et al., 2015).

The association between openness and multitasking is not strongly empirically supported, but seems theoretically justified. This assumption was derived in part from behavioral research relating facets of openness to a battery of tests of working memory and other cognitive functions associated with the prefrontal cortex (DeYoung et al., 2005). The 'environmental enrichment hypothesis' (Ziegler et al., 2012) assumes that more openness leads to more challenging and new opportunities, by fostering an enriched environment, which in turn enhances cognitive abilities (e.g., fluid intelligence). It indicates that people perceive multitasking as a novel context, therefore, utilize their curios and imaginative skill to perform well while handling multiple tasks. Therefore, conscientiousness and openness (but not other factors of personality) might contribute to explaining multitasking behavior. However, until further research on this topic is conducted, this merely remains speculation.

Formulating a conceptual model

Solely polychronicity, conscientiousness, and openness show slight relations with multitasking behavior. The available data thus do not clearly support the view that personality directly contributes to the criterion. Rather, personality may have a moderating effect on the association between multitasking behavior and cognitive ability, as has been suggested for polychronocity (Sanderson et al., 2013) and openness (Kurapati et al., 2017). Moreover, only one study (Sanderson et al., 2016) showed a (slight) negative correlation between conscientiousness and multitasking. Therefore, we must not simply focus on the association between personality and multitasking, rather we must attempt to more deeply understand this relation by specifying the conditions under which it occurs and does not occur (moderator models; Chaplin, 2007). Personality is an individual's relatively stable intrinsic structure of thinking, feeling, and behaving (Roberts & Mroczek, 2008). The focus of personality on behavioral control has been demonstrated in prior works (Duckworth & Kern, 2011). Personality traits such as conscientiousness or openness to experience predispose individuals to goal-directed behavior or novel and creative ideation and are thus an important mechanism for explaining the extent to which cognitive resources are utilized to adapt novel and challenging task environments, like multitasking. More specifically, higher conscientiousness has significant beneficial effects on executive functions (Fleming et al., 2016) and openness to experience is related to intelligence and working memory (DeYoung et al., 2009). Executive functions, working memory, and intelligence, on the other hand, are related to multitasking behavior.

Therefore, we propose another new conceptual model (Fig. 8) in which the multitasking-cognitive abilities relationship is moderated by individual differences in personality types. In the context of moderating effects of personality, individuals with certain personalities may be more responsive to integrating distinct cognitive abilities in order

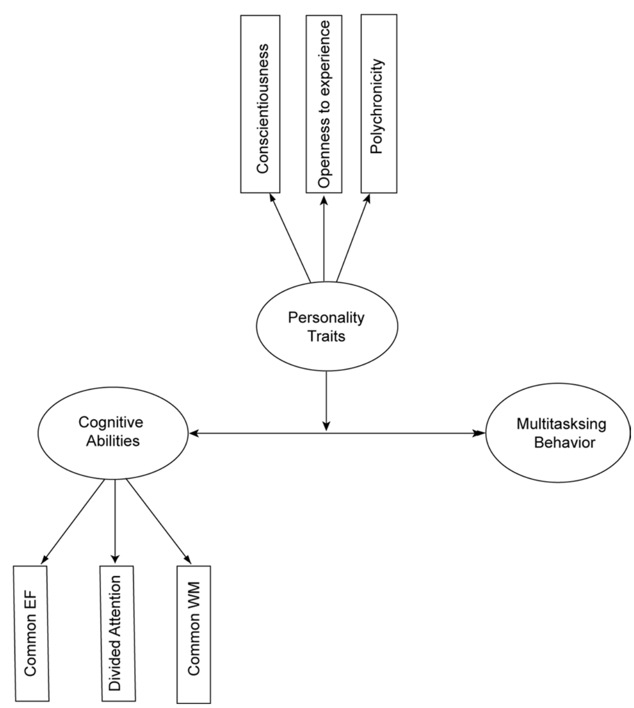

Fig. 8 Conceptual model relating cognitive abilities, personality traits, and multitasking behavior. *Common EF* common EF, *Common WM* common working memory

to perform multitasking. However, this model is fully hypothetical and has not yet been empirically tested.

General discussion

This synthesis offers the first comprehensive and empirical summary of cognitive and personality correlates of multitasking, thus providing potential new insights in the field from an individual differences approach. The main goal of this study was to display multitasking as a psychometric construct. Here, individual differences in the criterion are integrated into a general framework of cognitive abilities and personality traits, based on prior evidence. We combined studies from differential and (few) experimental approaches, which is rare in review literature (Cronbach, 1957; Unsworth, 2019). Our present review has demonstrated that there are substantial individual differences in multitasking behavior, and this variation is related to several cognitive abilities and personality traits. Nevertheless, multitasking behavior can be explained by cognitive abilities beyond personality correlates. Therefore, we propose two conceptual models to account for multitasking behavior. The first model (Fig. 5) illustrates that individual differences in cognitive abilities directly relate to differences in multitasking behavior. The second one (Fig. 8) posits that the strength of the relationship between multitasking behavior and cognitive abilities is affected by personality traits.

How does multitasking behavior work?

As described in the conceptual models (Figs. 5 and 8), we can see the most relevant cognitive abilities are common EF and common working memory, which simultaneously contribute to multitasking behavior. The interesting question is how multitasking behavior depends on these correlates.

In a review of the threaded cognition theory of multitasking behavior (Salvucci & Taatgen, 2008), the execution of multiple tasks threads is synchronized by a serial cognitive processor that is allocated across multiple processing resources. In accordance with this concept, individual differences in multitasking rely on multiple abilities that take effect depending on actual task demands. Therefore, we can define multitasking behavior as the combination of multiple cognitive processes used to interleave everyday-life related routine and problem-solving tasks in a cohesive manner, and that are dependent on changing circumstances. Emphasizing the importance of different cognitive abilities, it is thus necessary to define the four characteristics of individual differences in multitasking behavior: (1) variability in the capacity of working memory, such as, updating the information in memory, (2) variability in managing task goals in the face of interference, (3) variability in integrating individual pieces of task information to build a relational structure of multiple tasks, and (4) variability in the adaptation to attention control. Personality traits have not been found to be directly involved in multitasking behavior. Therefore, it is not considered in this above definition. Note that this definition is solely a correlational statement. To move the field forward, researchers must evaluate and validate the proposed models of multitasking behavior.

However, these characteristics could explain our previously mentioned question “How do people vary in their multitasking ability?” In the multitasking context, individuals adopt a certain behavioral strategy depending on their internal cognitive skills as well as their personality types. Moreover, shows that only median $r = 0.36$, which clearly indicates there is more to multitasking behavior than the investigated cognitive abilities. It seems that multitasking behavior is affected by how our cognitive system selects tasks. Generally, when we engage in multitasking situations, we adapt and try to control attentional demanding tasks. For this, our metacognitive strategies might play an important role (Fazeli et al., 2017). Neal et al. (2017) showed that the ability to maintain and monitor multiple task goals—our everyday multitasking performance—is related to metacognition. However, consistent strategy use helps minimizing demands on processing resources by facilitating interruption recovery (Bai et al., 2014) as well as maximizing overall performance in response to changes in task difficulty (Mittelstädt et al., 2018). Other studies found a relationship between strategy use and multitasking behavior (Hambrick et al., 2010; Logie et al., 2011). It seems likely that individuals vary in how effectively task execution strategies activate the underlying cognitive processes of multitasking behavior.

Limitations

Despite the comprehensiveness of this review, there are several limitations, which need to be addressed. A first caveat is the rather narrow range of the literature included in this review, in which the ability-based and self-report multitasking measures were used. This limits the conclusions that can be drawn from the present study. However, the self-report measures included here are limited to studies on the relationship between multitasking and personality.

Another limitation pertains to the unbalanced sample demographics. In the studies we addressed, the sample demographics were not balanced in terms of gender. For example, 73.3% of participants were women in Himi et al. (2019), while female participants made up only 30% in the sample of Colom et al. (2010), and 60% in Redick et al.’s (2016) study. This is important, as the role of gender may influence multitasking behavior. Notably, some studies have claimed that men are better at multitasking than women (e.g., Colom et al., 2010), whereas others have claimed the opposite effect (Stoet et al., 2013). Other studies deny both and have found no difference between genders (Lin et al., 2016; Redick et al., 2016). Based on the sample demographics chosen for this review, the generalizability of this research might be minimal.

Aside from the sample issue, while this review focused on many cognitive and personality factors in relation to multitasking behavior, it did not include analysis of the factors of spatial ability, planning, or sensation seeking as predictors. These are important constructs to examine as it has been shown that individuals with efficient spatial abilities are prone to better multitasking performance than individuals with less developed spatial abilities (Morgan et al., 2013). To monitor multiple tasks, spatiotemporal task coordination is required, because people often rely on spatial representations when processing temporal information (Mäntylä, 2013; Todorov et al., 2014). However, spatial ability is highly correlated with working memory and reasoning (Süß et al., 2002). Inevitably, multitasking involves a combination of multiple abilities, and it primarily requires visuospatial abilities as well as verbal processing and so on. It is therefore difficult to consider all the variables in one paper. This current review paves the way for future research to include the other related constructs.

Finally, an important concern to address is our reasoning for performing a qualitative literature review. We admit that there is probably a need for quantitative synthesis (meta-analysis) to investigate this topic. However, qualitative synthesis is, in essence, a literature review that follows specific guidelines to minimize subjectivity and provide a highly reliable review of evidences. Therefore, we think the use of a qualitative synthesis is justified for our review work. Of course, a quantitative (meta-analysis) review is still needed to be performed by combining studies to determine patterns as well as examining reasons for contradiction as a means to improve the statistical power and precision of estimates (Akobeng, 2005). For this reason, we suggest that future research could perform a systematic and quantitative investigation of the related predictors of multitasking behavior.

Future directions

Understanding the source of relationship

Most importantly, the source of the correlation between each single cognitive ability and multitasking ability is undetermined. This is because proficiency in the cognitive mechanisms is interrelated. For example, the correlation between multitasking behavior and working memory might actually reflect an indirect effect of common EF via multitasking behavior (as visualized in Fig. 5). With respect to personality traits, the direction of causality remains inconclusive, this is, whether multitasking behavior induces personality traits differences or whether individuals with these differences gravitate more toward multitasking types of behavior. Although researchers found relationships of cognitive and personality traits with multitasking behavior, almost all of these studies relied on a cross-sectional or correlational approach, thus leading to a lack of directionality. Multitasking is mentally taxing—requires coordination of attention control and cognitive load—thus involved in prefrontal cortex activation. In particular, activation of the rostral anterior cingulate cortex is initiated (Deprez et al., 2013; Dreher & Grafman, 2003). This area appears significant as people with frontal lobe lesions showed impairment in organizing and completing several tasks (Burgess et al., 2000; Roca et al., 2011). Therefore, to address the question of source of relationship, longitudinal studies, based on the behavior-genetics method are needed.

A requirement of using appropriate multitasking measures

As we mentioned at the beginning of this review, there are some controversies regarding multitasking measures, emphasized by Redick et al. (2016) "… investigation of one particular multitask context may provide information that applies mainly to that particular context, and not multitasking in general" (p. 1474). For example, SynWin requires participants to perform tasks that are typical for navy and marine individuals. Again, few tasks have not been properly validated. For example, the computerized meeting preparation task possesses poor ecological validity, as participants must perform unrelated tasks (Laloyaux et al., 2018). Furthermore, some tasks mainly focus on specific cognitive functions, such as the breakfast task which is used to assess prospective memory. Additionally, from the current review, it is also clear that most of the studies rely on one specific multitasking test, except for a few variations. For instance, Redick et al. (2016) measured multitasking using varied sets of multitasks, and from there generated a common multitasking ability. Himi et al. (2019) also tested participants using a single computer-based scenario in which participants had to work on four tasks. Multiple measures (i.e., speed, error, and question) derived from a single SIMKAP scenario could collude task-specific effects, but it is also common practice to generate multiple indicators which are emerged from an individual task (as seen in measuring fluid intelligence; Colom et al., 2010). Nonetheless, it seems that the field requires a consistent measurement of multitasking behavior.

Call for latent variable approach

An important concern is whether single or multiple measures of a construct of interest should be used. The fewer tests are used, the higher the construct-specific variance in a certain task will be. Moreover, single measure can have poor psychometric properties. In addition, most of the literature involved in this current review are based on a correlation or a manifest multiple regression approach (including single measures), instead of latent variable relations. A correlation between a single measure of criterion and a single measure of predictor is indicative that a relationship exists, but it does not provide much information regarding the robustness of the relation due to idiosyncratic task effects. Therefore, it will be crucial for future research to include latent variable analysis. These generally have multiple measures per construct for minimizing task-specific variance and allow for simultaneous consideration of all the predictor variables by controlling the influence of the third variable and avoiding type II error.

Call for replication studies

One significant consideration that may go missing from the aggregation of published works was that only few studies attempted to replicate the overlapping variance of the criterion with cognitive constructs. We are aware of the importance of replication and reproducibility toward the progress of science, but replication studies in psychological science are scarce at best (Makel et al., 2012). It is for this very reason that future work should call for more preregistered replication studies on multitasking behavior to provide more accurate estimates of its effect size and confidence interval.

Conclusion

Our review proposed a novel approach to investigate the nature of the cognitive and personality resources supporting multitasking behavior. We organized correlational and experimental research on multitasking according to two important issues: individual differences in cognition and personality. Subsequently, we synthesized research evidence and observed that both cognition and personality (indirectly) share commonalities in explaining multitasking behavior. Undoubtedly, the findings advocate that individual differences in multitasking behavior emerge from multiple sources. Taken together, successful multitasking behavior relies on managing competing demands on one's time and resources to achieve the desired outcomes and prevent undesired outcomes. These cognitive control processes differ strongly between individuals. The architecture of multitasking behavior can best be explained as a by-product of one's ability to uphold a structural representation of information in memory through dealing with interference, as well as to integrate cognitive relations of multiple task information in a cohesive manner. Along with this structural representation, personality is included as a moderating effect to this architecture. The proposed conceptual models provide a framework for future research. In a broader context, this review provides a theoretical and correlational framework (even though without assumptions about causality), which can be used to increase our understanding of individual differences in human multitasking ability as well as help with training and selection in the jobs, where multitasking is crucial.

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Availability of data and material Data is added as supplementary file.

Code availability Code is available on request.

Declarations

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