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ORIGINAL ARTICLE

What is a task? An ideomotor perspective

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Abstract Although multitasking has been the subject of a large number of papers and experiments, the term task is still not well defined. In this opinion paper, we adopt the ideomotor perspective to define the term task and distinguish it from the terms goal and action. In our opinion, actions are movements executed by an actor to achieve a concrete goal. Concrete goals are represented as anticipated sensory consequences that are associated with an action in an ideomotor manner. Concrete goals are nested in a hierarchy of more and more abstract goals, which form the context of the corresponding action. Finally, tasks are depersonalized goals, i.e., goals that should be achieved by someone. However, tasks can be assigned to a specific person or group of persons, either by a third party or by the person or the group of persons themselves. By accepting this assignment, the depersonalized task becomes a personal goal. In our opinion, research on multitasking needs to confine its scope to the analysis of concrete tasks, which result in concrete goals as anticipated sensory consequences of the corresponding action. We further argue that the distinction between dual- and single-tasking is dependent on the subjective conception of the task assignment, the goal representation and previous experience. Finally, we conclude that it is not the tasks, but the performing of the tasks, i.e. the actions that cause costs in multitasking experiments.

Introduction

Task is an important concept in psychology and action science. However, despite a growing body of literature addressing opportunities and limits of human dual- or multitasking, the term task is still poorly defined. More than 20 years ago, Rogers & Monsell (1995, p. 208) acknowledged "that it is difficult to define with precision, even in the restricted context of discrete reaction tasks, what constitutes a 'task'". More recently, Schneider & Logan (2014) stated that this plea for a definition has largely been ignored since then. In the following, we argue that a definition of the term task is required to constrain the scope of multitasking research, to clarify how many tasks a person performs, and to broaden our understanding of interference between tasks.

In everyday language, tasks are usually understood as demands that are generally achievable by an action or a set of actions, e.g. bake a cake, be a good student, or switch on the light. However, the required actions may not be specified by the assignment of the task. Tasks may differ in their levels of abstractness and may consist of several less abstract subtasks, which can be completed sequentially or simultaneously (e.g. learning for the exam, attaining lessons, participating in an experiment, press a button).

Conversely, in cognitive science papers, "the term task can be basically understood as 'what subjects have to do in an experiment'" (Philipp & Koch, 2010, p. 383) or, in more formal terms, is defined as a "representation of the instructions required to achieve accurate performance of an

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activity" (Schneider & Logan, 2014, p. 29). Kiesel et al. state that "tasks entail performing some specified mental operation or action in response to stimulus input" (2010, p. 850). Yet, these statements are descriptions rather than definitions of a task, and do not help to differentiate distinct tasks.

The vague definition of the term task leads to serious ambiguities in the understanding of multitasking behavior and its cognitive underpinnings. To give an example, it remains unclear if bimanual coordination tasks such as playing piano should be regarded as a single task (Monno, Temprado, Zanone, & Laurent, 2002; Wolff & Cohen, 1980), or if playing with the right hand and the left hand must be seen as two independent tasks and thus as a case of dual-task behavior (Franz, Swinnen, Zelaznik, & Walter, 2001; Swinnen & Wenderoth, 2004). According to the former assumption, professional pianists would simply accomplish a single task and there would be no reason to predict interference between actions of the left and the right hand at all. However, if the latter assumption holds, pianists would perform a dual-task but bypass interference or crosstalk. As a consequence, such dual-task skills would question theories postulating a bottleneck and arguing that tasks can only be processed sequentially (Pashler, 1994). Freedberg, Wagschal, & Hazeltine (2014) argue that the distinction between single and dual task is not determined by objective criteria but rather "depends on how the participants conceive of their task" (2014), p. 1698). This view is supported by experiments of Dreisbach, Goschke, & Haider (2007; Dreisbach & Haider, 2008, 2009), who observed that the way participants are instructed changes their perception about the task being a single or dual task. Recently, McIsaac, Lamberg, & Muratori (2015) suggested a taxonomy of dual-tasks. They propose that "dual tasking is the concurrent performance of two tasks that can be performed independently, measured separately and have distinct goals" (McIsaac et al., (2015), p. 2). However, in their concept, it remains unclear which performance exactly is considered as a task and what "distinctiveness" means with respect to goals.

The goal of this paper is to bring more clarity to the blurred concept of a task. In agreement with McIsaac et al. (2015), we propose that a task relates to an action to be executed and a goal to be achieved. In our opinion, it is helpful to adopt an ideomotor perspective that takes the mutual relationship between actions and goals into account. The ideomotor perspective surely narrows the scope of our task definition, however, it serves to explicate tacit assumptions. Moreover, it will help scientists from other theoretical fields to sharpen their understanding of the term task by accepting or rejecting parts of our assumptions.

The ideomotor perspective

Every action, from complex action sequences studied in sports and exercise sciences to simple button pressing used in cognitive psychology, elicits perceptual consequences. According to the ideomotor principle (Herbart, 1825; James, 1890; see Hommel, Müsseler, Aschersleben, & Prinz, 2001 for a more recent formulation), behavior is selected, initiated, and controlled by an anticipation of the sensory consequences that will follow from the respective action. The bidirectional associations between actions and their sensory consequences are acquired in two phases. In the first phase, associative links between cognitive representations of actions and effects are established. The associations are learned by producing movements, either randomly or reflexively, and observing the sensory consequences. Importantly, Elsner & Hommel (2004) revealed that this learning relies on predictability (i.e., contingency) and temporal proximity (i.e. contiguity).

In the second step, these associations are used to intentionally re-produce previously learned effects (Elsner & Hommel, 2001; Jordan & Rumelhart, 1992). Thus, the representation of the intended effects directly trigger the corresponding action pattern (for reviews, see Hommel, 2013; Shin, Proctor, & Capaldi, 2010) and this close link of mental representations of goals, associated motor patterns and actually perceived effects provide the basis of action control.

Unfortunately, the term goal is ill-defined as well. The definition of 'goal' has to take different levels of abstractness into account (Hommel, Brown, & Nattkemper, 2016; Monsell, 2003). Abstract goals (like "be a good student") can be achieved in multiple ways by a series of different actions, and the actual achievement of abstract goals may eventuate a considerable amount of time after the actions. Concrete goals (like "pressing a button as quickly as possible") are achieved by ideomotor actions, whereas abstract goals will not be associated with sensory consequences and therefore will not lead to actions. Rather, "at best, they can be helpful when looking for a concrete, sensory action goal" (Hommel et al., 2016, p. 65). For example, the abstract task of being a good student will provide the context for the compliance with a task, like pressing a button as quickly as possible (see Fig. 1).

Our narrow definition of concrete goals overcomes the problem that different nested abstract goals, such as being a good student, smarming over the professor, and earning course credit, can be achieved by just a single action—pressing a button. Although in this example, three nested abstract goals are achieved (and therefore, three nested abstract tasks are performed) through the same single

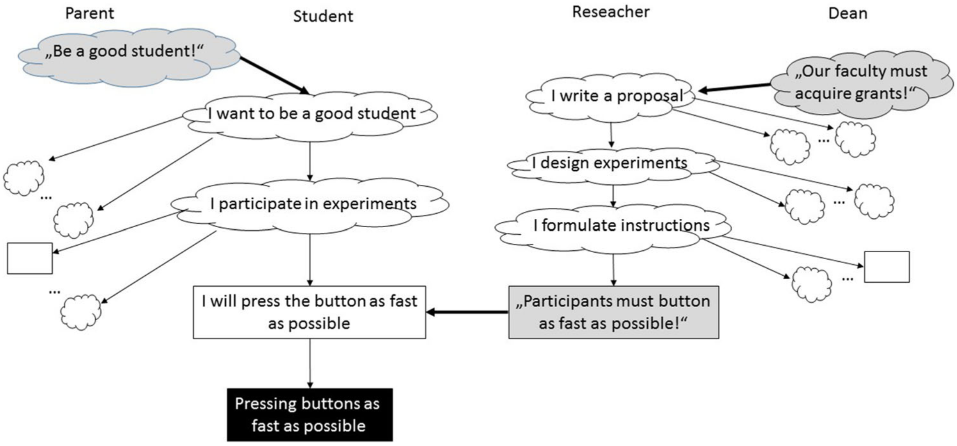

Fig. 1 Hierarchy of tasks, goals, and actions. Tasks are marked with a gray background, goals with a white background and the action with a black background. In this example, the dean formulates the task to acquire grants. He or she assigns this task to the researcher. By accepting this assignment, the task becomes the researcher's personal goal. Abstract goals and tasks are in clouds, concrete goals and tasks in rectangles. The empty clouds and rectangles indicate that abstract goals could have several (concrete or abstract) subgoals. Bold arrows indicate the assignment of a task to a specific person. The abstract goals form the context of the concrete goal, in this case to comply with the researcher's task assignment

action, this behavior would not be considered as multitasking.

Having defined actions and goals, we now turn to the definition of a task. Goals and tasks share central features, in that they represent future states that usually differ from the current state. Both, goals and tasks, can relate to relative abstract or concrete states. We suggest that the difference between the two is that a goal is personal, meaning that it is bound to a specific person striving for this goal. On the contrary, a task is not bound to a specific person, because it describes what has to be done by *any* participant. However, the link between a task and a goal is that a task can be assigned by a third party (a single person, a group of persons or an institution to a person or a group of persons. Of course, it is possible to assign a task to oneself, too). It is then the duty of every single person to decide whether he or she accepts the task assignment. If he or she does, the depersonalized task becomes a personal goal of that specific person.

The abstractness of a goal and the associated sensory consequences may depend on the level of expertise and the amount of practice of action, however. This has direct implications for the conceptualization of a task. We tackle two questions, which need to be addressed when analyzing dual-tasking or multitasking behavior. (a) What separates a task-driven motor behavior from behavior that would not be regarded as task-driven? (b) When can behavior be considered as driven by a single task, and when do we speak of dual- or multitasking? In the following sections, we no longer focus on the difference between goal and task, but presuppose that a person, who was assigned a specific task, accepts this assignment as his or her personal goal.

A task or not a task?

As mentioned above, the abstractness and the representation of a goal may be dependent on the experience an individual has with the corresponding action. Learning research has shown that practice does not only improve performance of that activity, but that it can also lead to a qualitatively different mode of processing. This change in processing mode is commonly referred to as automatization.

Automatization is mostly regarded as a process that evolves continuously over time, without any discontinuities from a least automatic processing mode to a most automatic processing mode. Models and theories of automatization have been developed for different domains of activities. For motor activities, Fitts & Posner (1967) developed a three stage model of motor learning. In the cognitive phase, the learner has to identify the goals of the actions and develop strategies to reach these goals. In the associative phase, cognitive processes are not only focused on the control of the actuators, but movements are associated with situational constraints. In the automatic phase, the actor can achieve the action's goals without conscious attentional processes being involved. Although Fitts and Posner define different stages, they conceptualize continuous transitions from stage to stage, rather than a clear-cut entry into a certain stage. For bimanual coordination tasks, Puttemans, Wenderoth, & Swinnen (2005) showed significant changes in brain activation in the course of learning from the cognitive stage to an advanced level of automatization.

Similarly, Shiffrin & Schneider (1977) demonstrated a transition from conscious to automatic processing in the course of learning for perceptual tasks. For instance, they argued that children learning to read are required to process features, letters, words and their meaning but these parts of this learning process can be automatized, and so they concluded that conscious, or controlled, processing is limited but can be used for complex learning.

In the present article, we aim at discussing whether, from an ideomotor perspective, the transition from a non-automatic to an automatic activity equals the transition from a task to a non-task. Ideomotor theory conceptualizes motor cognition as a combination of automatic and non-automatic subcomponents (Thomaschke, Hopkins, & Miall, 2012a, b). Non-automatic motor components are typically associated with action planning. That is, for example, deciding which hand to use, which object to grasp, which object to avoid. Action planning operates on largely categorical representations, is relatively slow, and is mostly accompanied by conscious awareness (Glover, 2004; Thomaschke, 2012). These non-automatic components are concerned with the selection of action options in an ideomotor fashion (i.e. based on their goals). For automatic action components, there are two different concepts of how automatization can be explained, the directions-of-processing approach and the levels-of-control approach (Neumann, 1984). According to the directions-of-processing approach, automatic processing meets three main criteria: it operates without capacity, it is not demanding attention, and—most important in the context of this article—it is driven by bottom-up processes and not by intention (Schneider & Shiffrin, 1977; but see Neumann, 1984). The levels-of-control approach claims that action parameters are specified by three sources, skills, input information, and attentional processes. In the case of underspecification, skills and input information are lacking or not specific enough, so attentional processes are necessary to specify the action parameters. In the case of overspecification, input provides the information in several variants, e.g. multiple apples in a tree, each of which specifies the action of grasping (Neumann, 1989). Attentional processes are needed to specify the choice of the concrete goal. How these choice problems relate to multitasking is discussed in Broeker et al. (2017) in this issue. If skills and input information specify action parameters, there is no need for attentional processes (Neumann, 1984, 1989). Action is then controlled by an automatic subroutine, where the anticipated effects do not necessarily rise to awareness. Blakemore, Wolpert, & Frith (2002) presented an overview of empirical evidence in favor of the latter approach. They found that awareness of movement only happens when the discrepancy between intended and actual sensory consequences becomes large.

With respect to a task definition, the question of whether automatic activities are goal-directed, i.e. controlled by anticipated sensory consequences, becomes important. The two concepts of automatization would offer different answers to this question. Within the direction-of-processing approach, automatic activities are not under intentional control. As a consequence, they are not directed towards an intended goal, not controlled by sensory consequences and cannot be considered as driven by a task. Following the levels-of-control approach, automatic activities are goal-directed and thus must be seen as driven by a task. Blakemore et al. (2002) developed their approach to automatization from the theory of internal models, which is highly compatible with the ideomotor approach. Both approaches stress the importance of a goal as anticipated sensory consequences for controlling action, although ideomotor theory does not contain a forward signal. As such ideomotor theory is more focused on perception as controlling factor in action, whereas internal models emphasize motor control (Gentsch, Weber, Synofzik, Vosgerau, & Schütz-Bosbach, 2016). Consequently, with the ideomotor perspective, we regard highly learned automatic activities as goal-directed actions and thus as driven by a task.

One task or multiple tasks?

The human cognitive system is adept at integrating related information. The consideration of task integration is important when analyzing multitasking behavior because task integration could turn a seeming dual task into a single task. In implicit learning, in particular, task integration refers to the concept of an old evolutionary system that binds information that covaries in the world, which has often been demonstrated in serial-reaction time studies with a covarying secondary task (Keele, Ivry, Mayr, Hazeltine, & Heuer, 2003; Schmidtke & Heuer, 1997). The integration of related information, or features, broadly equaling the understanding of task-integration, can be explained through approaching its influencing top-down and bottom-up factors. While the top-down factors impose features on the task based on individual processing habits or preferences, bottom-up factors explain how participants extract relevant co-occurring features from a task.

If action is controlled by its sensory consequences, then it is likely that the integration of related information also occurs on the level of these sensory consequences or effects. Introducing distal effects into the experimental setting allows for dissociating the action (e.g. "press button") from the action's goal (e.g. "switch on the light"). As Hommel (1993) nicely demonstrated, the introduction of a goal has serious consequences for action control and—in his experiment—inverts the Simon effect. In a striking experiment, Mechsner, Kerzel, Knoblich, & Prinz (2001) had participants rotate two levers under a table. The lever's rotation was transmitted to a rotation of flags visible above the table. For one lever, this transmission was done in a crooked ratio, e.g. 4:3. The participant's goal was to produce an antiphase rotation of the two flags, which required a 4:3 ratio of lever rotations. This is a strong evidence for information integration on the level of goals. Others also showed that even actions between two co-actors are coded in terms of one's own effects (e.g. Pfister, Dignath, Hommel, & Kunde, 2013) or joint effects (e.g. Konvalinka, Vuust, Roepstorff, & Frith, 2010). Hence, two tasks, which can be coded in terms of their (joint) sensory consequences, can potentially be integrated into a single task (for an overview, see Mechsner, 2004).

A further factor to be considered is combination-specific learning. On the one hand, Hazeltine, Teague, & Ivry (2002) demonstrated no impact of combination-specific learning when they presented to their participants stimuli for a visual-manual and an auditory-vocal task. Unlike most dual-task experiments, they did not use the same set of stimuli for training and test sessions, but introduced some stimulus combinations in the test session only. Beyond the expectation that dual-task costs would be reduced because of the learning of stimulus pairs, they found equally elaborate performance for unpracticed stimulus combinations compared to practiced combinations, and concluded that combination-specific learning and integration had not occurred. On the other hand, a chord task experiment by Hazeltine, Aparicio, Weinstein, & Ivry (2007) showed that a large portion of performance improvement could be explained by the learning of specific piano chords. In their task, participants pressed either three out of five piano-like keys with one hand for an individual chord, or six out of ten piano-like keys (2 × 5) with both hands for a combined response. Results show that although both novel and practiced individually performed chords were similar in quality, slower performance for unpracticed chords occurred for combined responses, suggesting combination-specific learning for simultaneous task execution. The authors suggested that these contrasting results emerged from different use of modalities. Whereas the chord task required the same modalities, distinct modalities in the earlier study might have reduced the likelihood of forming associations between the two tasks. Also Hazeltine, Aparicio, Weinstein, & Ivry (2007) hypothesized that the chord task, which in contrast to the earlier study forced participants to produce simultaneous responses, fostered an integrated representation and increased the likelihood of conceptualizing the experiment as one task. The significance of the diverging results is important for the aspect of "separating information" as highlighted above. If simultaneous, same-modality tasks lead to the integration of two tasks, then participants may either be unable to perform each task as a single-task after learning them as a dual-task or perform the secondary task comparatively deficient together with a different primary task (Wohldmann, Healy, & Bourne, 2010).

Another top-down factor is the type of practice. Several experiments found dual-task performance to be better compared to single-task performance when the dual-task had been trained as such. Performance on a time production task, for example, was better when simultaneously performed with an alphabet-counting task because participants felt the secondary task aided the primary task, e.g. in an arbitrary rhythm (Healy, Wohldmann, Parker, & Bourne, 2005). Researchers concluded that participants learned procedures that eased simultaneous performance and that primary and secondary task were treated as, and merged into, a fully integrated set of requirements of a single functional task. As elaborated earlier, performance changes could be also attributed to automatization of one or both tasks. However, Ruthruff, van Selst, Johnston, & Remington (2006) argued that automatization is distinct from task-integration. According to a task-integration hypothesis, dual-task practice would be more effective than single-task practice and reduce or eliminate dual-task costs. An automatization hypothesis would predict successful dual-tasking independent of whether single- or dual-task conditions have been practiced.

Additionally, instructions may lead to task integration. In a task switching experiment (Dreisbach et al., 2007), participants had to react to eight different stimuli (words) with the respective key press. Participants received different instructions, yet defining the same actions. One group had to perform eight tasks with each task corresponding to an S-R mapping. Another group received instructions that integrated four S-R mappings to one distinct task with respect to the word color, resulting in two different integrated tasks. Although in this experiment task integration was highly disadvantageous and led to significantly higher reaction times, participants were unable to separate the integrated tasks. In another experiment, Dreisbach & Haider (2008) also analyzed switch costs and were able to prove that it was also possible to integrate all eight S-R mapping into one single task with the appropriate instructions.

In addition to top-down factors, there is some evidence about the influence of bottom-up factors on task-integration. One basic idea is that mechanisms of covariation or statistical learning allow the extraction of structure (Chun & Jiang, 1999; Turk-Browne, Jungé, & Scholl, 2005) and that task integration will occur when covariations in one or more dimensions, such as time or space in the stimulus environment, exist (Schmidtke & Heuer, 1997; Reber, 1989; Heuer & Schmidtke, 1996).

To illustrate the idea of covariation learning of specific stimulus–response contingencies, consider a typical serial-reaction time (SRT) task (Nissen & Bullemer, 1987). Participants typically exhibit faster reaction times (RTs) in blocks of trials that follow a specific sequence and prolonged RTs in blocks with random sequence. This difference is taken as an indicator of covariation learning. Taking this further, Schmidtke & Heuer (1997) combined this SRT with an auditory go/no go task that required a pedal press upon hearing high-pitched tones. Tones were either random, in five-element or in a six-element sequence. When tone sequences of six elements were combined with visual sequences of six elements, participants were able to reduce reaction times and the mean number of attempts to learn the sequence. Schmidtke & Heuer (1997) argued that the additional tone-counting task could be integrated into the sequence of alternating repeated visual cues. In another paper, Heuer & Schmidtke (1996) already claimed that primary-task stimuli and secondary-task stimuli are not processed separately but as an "integrated sequence of alternating visual and auditory stimuli" (p. 132). It has further been argued that the integration of two simultaneously presented tasks is likely to occur when there is consistency in the task requirements (Wohldmann et al., 2010), when it is perceived as resource-saving or at least as reducing the number of action goals (Donk & Sanders, 1989; Lehle & Hübner, 2009) or when there is a large similarity between stimulus and response modalities and they are not perceived as distinct (Hazeltine et al., 2007). Theories of associative learning thus concluded that either the degree of similarity between individual stimuli properties or combined properties of stimuli define the strength of associations, and thus participants' representations of the tasks and the propensity to integrate them (Freedberg et al., 2014; Philipp & Koch, 2010).

Conclusion

We define a task as an abstract, depersonalized description of a future state. A task can be assigned to a person, and if that person accepts this assignment, it becomes their personal goal. According to the ideomotor perspective, concrete goals are coded as anticipated sensory consequences of the corresponding action, while abstract goals form the context that constrain the number of possible concrete goals. We confine our considerations regarding the definition a task to concrete goals. This restriction helps to clarify the scope of scientific investigations concerned with dual- or multitasking. Results obtained from concrete dual-task experiments, such as button pressing and tone counting, may not transfer to abstract dual-tasks, such as being a good student and preparing for a lecture. With these specifications, we argue that actions that were automatized through extensive learning must be regarded as tasks, because they are initiated and controlled by intentional processes, albeit not necessarily associated with conscious awareness. Therefore, activities, such as walking or the control of posture, must be treated as tasks. This is in line with the current opinion, where researchers use walking or postural control as one task in dual-task experiments (McIsaac & Benjapalakorn, 2015; Woollacott & Shumway-Cook, 2002; Yogev-Seligmann, Hausdorff, & Giladi, 2008).

The conception of a task as one single integrated task or as two independent single tasks is highly dependent on top-down processes and can be influenced by instructions or experience. There is experimental support that this integration occurs on the level of the sensory consequences of the respective actions (e.g. Mechsner et al., 2001). In addition, bottom-up processes serve to detect covariations in perception or action. Exploitation of these covariations also leads to task-integration (e.g. Schmidtke & Heuer, 1997). Consequently, it is not possible to define a distinction between dual- and single-tasks independent of experience of the participants, presentation of the instructions or features of the situation. This subjective characteristic demands the analysis of participants' behavior on an individual level. Caution is needed to avoid circular explanations of dual-task behavior: dual-task costs should not serve to prove the processing of two single tasks and at the same time be used as dependent variable to measure dual-task costs.

Finally, we considered the difference between action and task. In our opinion, the main difference is the depersonalization of a task. A task can be undertaken by another person or can be delegated to another person. Moreover, a task can be assigned to a team or an institution. Additionally, a task is not necessarily associated with observable behavior. In contrast, an action is intrinsically tied to a specific actor, the person that is performing the task by achieving his or her goal, and always includes a motor behavior that can be observed. Therefore, there is no problem assigning multiple tasks to a participant—in an experiment or in real life. The problematic part is to achieve multiple goals and to execute multiple actions. Consequently, it is more appropriate to speak of "multi-action" instead of "multi-tasking".

Compliance with ethical standards

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