The Temporal Stability of Skilled Dual-Task Performance

TILO STROBACH[1]

Department of Psychology, General Psychology, Humboldt University Berlin (Germany)

PETER A. FRENSCH

Department of Psychology, General Psychology, Humboldt University Berlin (Germany)

TORSTEN SCHUBERT

Department of Psychology, Experimental Psychology, Ludwig-Maximilians University Munich (Germany)

Recent studies showed that practice reduces performance costs in dual-task compared with single-task situations remarkably. We assume that this is due to acquired skills which enable improved dual-task processing after practice. In the present study, we examined the stability of these dual-task related skills over time. Therefore, we tested the dual-task performance of a visual and auditory task in a session conducted 6 weeks after the practice was finished. Our analyses showed that the task performance was robust in single-task and dual-task situations of the visual task. The data of the auditory task revealed impaired performances after the long delay. In particular, skills of single-task processing were less robust than skills related to dual-task performance. We assume that the stability of the processing skills in the component tasks is associated to the level of task automatization at the end of practice. However, future studies have to examine the stability of dual-task performance in more detail.

Introduction

The combined performance of two concurrent tasks often leads to decreased task performance compared with the separate performances of the component tasks (e.g. Pashler, 1994; Schubert, 1999; Welford, 1952). Usually, it is assumed that specific processing mechanisms interfere with each other in dual-task situations and that the result of this interference is indicated by dual-task costs, i.e. longer processing times and/or increased error rates in dual-task compared to single-task situations. However, recent studies have shown that prolonged practice with the tasks may lead to an impressive improvement of dual-task performance (e.g., Hazeltine; Teague, & Ivry, 2002; Ruthruff, Johnston, & Van Selst, 2001; Van Selst, Ruthruff, & Johnston, 1999; Spelke, Hirst, & Neisser, 1976). Some studies even demonstrated perfect dual-task performance as indicated by the complete elimination of dual-task costs after prolonged dual-task practice (Hazeltine et al., 2002; Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; Schumacher et al., 2001).

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[1] Anschrift: Tilo Strobach, Department of Psychology, General Psychology, Rudower Chaussee 18, D-12489 Berlin, email: tilo.strobach@psychology.hu-berlin.de. Gefördert durch Deutsche Forschungsgemeinschaft (DFG), Projekt Schu-1397/2-3; Fr 1471/ 8-3.

The finding of a practice-related decrease of dual-task costs (and even of their complete elimination) suggests that learning takes place during dual-task practice. As a result of these learning processes, participants acquire a skill that allows them to improve the dual-task processing and, even more importantly, to process two tasks concurrently in some situations in a perfect manner. Both the precise learning mechanisms leading to the acquisition of this skill (e.g., Ruthruff et al., 2001; Ruthruff, Van Selst, Johnston, & Remington, 2006) as well as the stability of the acquired skill are still a matter of debate (e.g., Bherer et al., 2005). The later question in particular is of considerable interest in the present study because its investigation would allow to specify the nature of the skill that underlies improved dual-task performance. Additionally, this issue is of actual concern for a number of recent studies investigating practice-related improvements of different types of attentional mechanisms (Green & Bavelier, 2003).

The aim of the present study was, therefore, to re-assess the dual-task performance of highly-skilled participants after a longer pause. In more detail, participants performed a dual-task paradigm consisting of a visual-manual task and an auditory-verbal task according to the procedure described by Schumacher et al. (2001) for 10 sessions. The use of the Schumacher et al. procedure was thought to lead to a strong reduction of dual-task costs after practice. After the tenth session, we introduced a pause of no less than six weeks during which participants had no further contact with the dual-task situation. After the pause, we conducted a post-test session with exactly the same dual tasks used originally. The comparison between the performance of participants in the last practice session (i.e., before the pause) and the post-test session (i.e., after the pause) allows us to assess the stability of dual-task skill over time.

The stability of acquired skills has been investigated in a number of different domains and with a variety of different paradigms, though not specific for the domain of dual-task performance. Many studies suggest that forgetting of the acquired memory trace over time may represent one important factor affecting the stability of skills. A number of reasons have been proposed that may be responsible for the loss of a skill as a result of forgetting, e.g., decay (Brown, 1958), interference (Keppel, Postman, & Zavortink, 1968) or a combination of the two (Altmann & Gray, 2002). Evidence suggesting forgetting of acquired knowledge with time of a performance pause has been reported for different situations, e.g., Ebbinghaus (1885/ 1913), and more specifically for complex tracing tasks (Eysenck & Willett, 1966), recall of social information (Macrae & MacLeod, 1999), artificial grammar (Tamayo & Frensch, 2007) and other tasks. Willingham and Dumas (1997), in particular, reported findings suggesting lack of retention and of performance savings in a re-learning situation when participants performed an implicit serial response time task after a long pause.

Importantly, applied to the dual-task situation in which participants perform two choice reaction-time tasks, forgetting might be related to any part of the task components including the processing of sensory and motor information and the retrieval of the corresponding translation of stimulus to response information (e.g., Ahissar, Laiwand, & Hochstein, 2001; Van Selst et al., 1999). However, if forgetting is especially related to the dual-task specific part of the acquired skill, then a time-related deterioration should be especially strong in the dual-task compared to single-task situations after a long pause. An example for dual-task specific knowledge is the coordination of processing streams of simultaneously performed component tasks (e.g., Hirst et al., 1980).

In contrast, a number of studies showed that task performance may improve even after practice has finished. Examples of improved performance after a pause have been reported in studies investigating basic skills of visual discrimination (Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994; Stickgold, James, & Hobson, 2000), motor adaptation (Huber, Ghilardi, Massimini, & Tononi, 2004) or the performance of motor sequences (Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002) after sleep. The obtained improvement is often explained by the assumption of processes of memory consolidation which cause that skill representations gradually acquire permanence (Bosshardt et al., 2005) and that they are converted into an optimal integrated memory trace (Stickgold, 2005). According to this hypothesis, we assume improved performance in single tasks and dual tasks over time when skills related to both situations are improved (e.g., processing stages of the component tasks). However, when the improvement is limited to dual-task specific skills then we should observe a pause-related performance improvement specifically for the dual-task situations.

However, two arguments challenge an assumption of improved dual-task performance over time. Findings showing memory consolidation were revealed in post-test sessions that followed only one practice session. Contrary, the post-test session in the present study was conducted after participants performed ten practice sessions. Whereas participants showed processes of memory consolidation after very minimal practice of task skills, we conducted a post-test session with highly-skilled participants. Although some studies showed ongoing processes of memory consolidation even after two practice sessions on following days (e.g., Duke & Davis, 2006; Walker et al., 2003), no study exists that showed signs of memory consolidation after extensive practice (i.e., ten practice sessions). We assume that the impact of sleep on the performance of highly skilled participants is extremely reduced and processes of memory consolidation are negligible.

Furthermore, memory consolidation was investigated in tasks including very basic procedural visual and motor skills. The present dual-task situation, instead, comprises mechanisms of regulating goal-directing behaviour in complex situations with interfering information (Schubert & Szameitat, 2003). Therefore, it is uncertain whether findings of performance gains after practice may be attributed to situations similar to the present dual-task paradigm.

A further possibility for the impact of a pause on performance is that performance in single and dual tasks is robust over time, i.e. remains stable. Stable task skills would be indicated by the lack of a difference between the performance measured before and after the pause. (Note that different reasons may be responsible for the lack of a difference between the performance measures before and after the pause; these reasons will be discussed later.).

In the literature, there are only a few studies providing empirical data that may be related to the issue of the stability of dual-task performances over time. For example, Ruthruff et al. (2001) conducted post-test sessions in which five of six participants of a previously conducted learning study performed a further dual-task situation (Van Selst et al., 1999). However, unfortunately, due to the administration of different component tasks in the post-test compared to the learning sessions it is impossible to draw exact inferences about the stability of the dual-task performance on the basis of these findings. In a further study, Ruthruff, Johnston, Van Selst, Whitsell, and Remington (2003) investigated the remaining sixth participant of the Van Selst et al. study. The authors conducted the identical dual-task situation before and after a pause of 14 months. However, the results obtained immediately after the pause were not fully reported by Ruthruff et al. (2003), which again limits the value of the study for our purposes.

In a further study, Bherer et al. (2005) analyzed the performances of groups of young and older participants in a dual-task situation after a pause of four to six weeks. Because older participants showed a general slowing in both single- and dual-task trials equal dual-task costs were observed between old and young participants after the pause (Bherer, personal communication, April 16, 2007). Although, this finding suggests robust dual-task performance over time, it needs to be treated with caution because only a few participants appeared for the follow-up session compared to the learning session (Bherer et al., 2005).

While systematic knowledge on the stability of the dual-task skill seems rather rare, findings in related research areas might provide a more revealing picture. For example, performance in the so-called task switching paradigm in which participants have to switch consecutively between two tasks is assumed to share some common processes with dual-task performance (e.g., Band & van Nes, 2006; Lien, Schweikert, & Proctor, 2003; West, 1996). Kramer, Hahn, and Gopher (1999) investigated the stability of task-switching skill in a group of young and older participants. They found that task-switching performance in both groups was robust over two months. However, it may be inappropriate to generalize findings with the task-switching paradigm to the dual-task situation because despite the number of similarities between the paradigms, there are a number of important differences as well (Pashler, 2000).

Taken together, there seems to exist a rather heterogeneous pattern of results concerning the stability of dual-task skill and prior findings with related paradigms seem to have limited generalizability. Therefore, the present study is the first to systematically investigate the stability of dual-task skill over time.

EXPERIMENT

Participants practiced a dual-task situation for 10 sessions and performed a post-test session after a pause of six weeks without practice. Participants performed identical visual and auditory tasks in single- and dual-task conditions before and after the pause.

Methods

Participants. Nine participants (undergraduates, mean age = 25.9 years, 4 females) participated in the experiment and received payment of € 80 plus performance-based bonuses. All participants had normal or corrected-to-normal vision.

Apparatus and component tasks. Participants concurrently conducted two speeded choice reaction tasks. In the visual task, participants responded manually to a white stimulus appearing at the left, central, or right position arranged horizontally on the computer screen. Whereas only circles were presented in session 1 to 8, the presentation of circles and triangles was intermixed in session 9 to 11. The stimuli appeared equally balanced in these sessions. However, only the data of trials with circle presentations are of current interest and will be described in the following sections. Three white dashes served as placeholders for the possible positions of the visual stimuli. They appeared as a warning signal 500 ms before the visual stimulus, a circle, was presented. The stimulus remained visible until the participant responded or until a 2.000 ms response interval had expired. Half of the participants responded to the stimuli by making a spatially compatible key press with the index, middle, and ring fingers of their right hand. The remaining participants responded with the ring, middle, and index fingers of their left hand. The responses were recorded with a button box connected to the experimental computer.

In the auditory-verbal task, participants responded to sinus-wave tones presented with frequencies of either 300, 950, or 1650 Hz by saying “ONE”, “TWO”, or “THREE” (German: “EINS”, “ZWEI”, “DREI”), respectively. A trial started with the presentation of three dashes on the computer screen. After an interval of 500 ms, the tones were presented for 40 ms. The trial was finished when the participant responded verbally or a 2.000 ms response interval had expired. To analyze the accuracy of each response, the experimenter recorded the verbal responses. The reaction time was recorded via a voice key connected to the experimental computer.

After correct responses in the visual and in the auditory task the RTs were presented for 1500 ms on the screen. Following incorrect responses, the word “ERROR” (German: “FEHLER”) appeared. A blank interval of 700 ms preceded the beginning of the next trial in both component tasks.

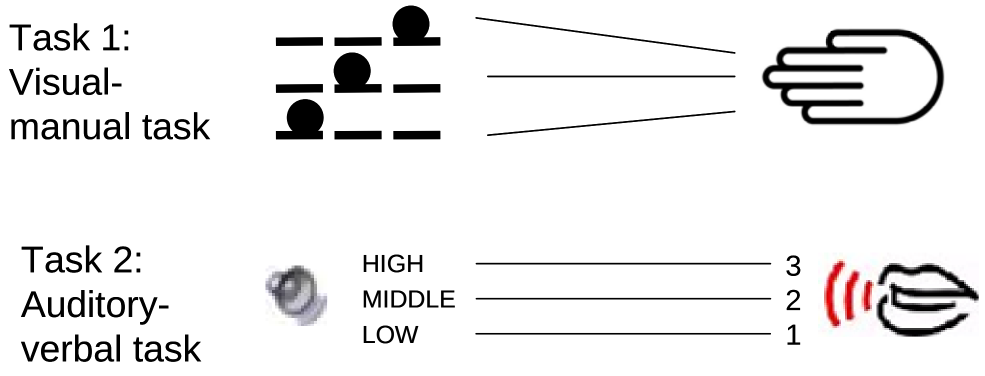

Figure 1. Illustration of the visual-manual and the auditory verbal task conducted in the present experiment.

Design and Procedure. Participants performed 11 experimental sessions. Whereas the first 10 sessions were conducted on successive days, there was a pause of approximately (i.e., in any case no less than) six weeks before the post-test session. Importantly, the sessions directly before (session 10) and after the pause (session 11) were identical.

Two different types of trials were presented during the experiment: (1) single-task trials in which only one stimulus (visual or auditory) was presented and (2) dual-task trials in which a visual and an auditory stimulus were presented simultaneously and participants were instructed to put equal emphasis on both stimuli. The trials were presented in three different types of experimental blocks: (1) blocks with the visual task as single tasks, (2) blocks with the auditory task as single tasks (*single-task blocks*), and (3) blocks with the visual and the auditory task as single and as dual tasks (*mixed blocks*). Single-task blocks consisted of 45 trials in the sessions 1 to 8 and 48 trials in sessions 9 to 11. In mixed blocks, 30 single (15 visual and 15 auditory task trials) and 18 dual-task trials were presented in sessions 1 to 8. In sessions 9 to 11, 24 single- (12 visual and 12 auditory task trials) and 18 dual-task trials were presented in mixed blocks. The stimuli were presented in random order in each block and participants were instructed to respond as fast and as accurate as possible regardless of whatever else was presented on a trial.

During the first session, participants conducted six single-task blocks of each task type in an alternate order counterbalanced across participants. Each subsequent session proceeded as follows: Participants began with two single-task blocks (1 of each task type) and subsequently performed 14 blocks consisting of four single-task blocks (2 of each task type) and 10 mixed blocks (in session 2 only eight mixed blocks). Excluding the initial two blocks, single-task blocks were alternated and separated by two mixed blocks. The procedure of the last three sessions was identical to the prior sessions, except that the 19 blocks (6 single-task and 13 mixed blocks) followed the two initial blocks. Again, single-task blocks were alternated and separated by two mixed blocks. Half of the subjects started each session with a visual single-task block and the other half with an auditory single-task block.

Table 1. Overview of the task conditions in the present experiment.

Sessions	Task conditions
1	single tasks
2 – 10 (i.e., before pause)	single and dual tasks
pause of > 6 weeks	
11 (i.e., after pause)	single and dual tasks

Results

In the main analysis of the present study, the dependent variables were the reaction time (RTs) in single tasks (limited to trials in single-task blocks) and dual tasks and the error rates in single tasks and dual tasks. The difference between both (i.e., performance in dual-task minus performance single-task trials) reflects the amount of dual-task costs. We conducted separate analyses for the RTs and for the error rates in the visual and the auditory task. As correct dual-task trials we defined trials with correct responses in the visual and in the auditory task. Only trials with two correct responses were included in the RT analysis of the dual-task data. The remaining trials were excluded from the analysis.

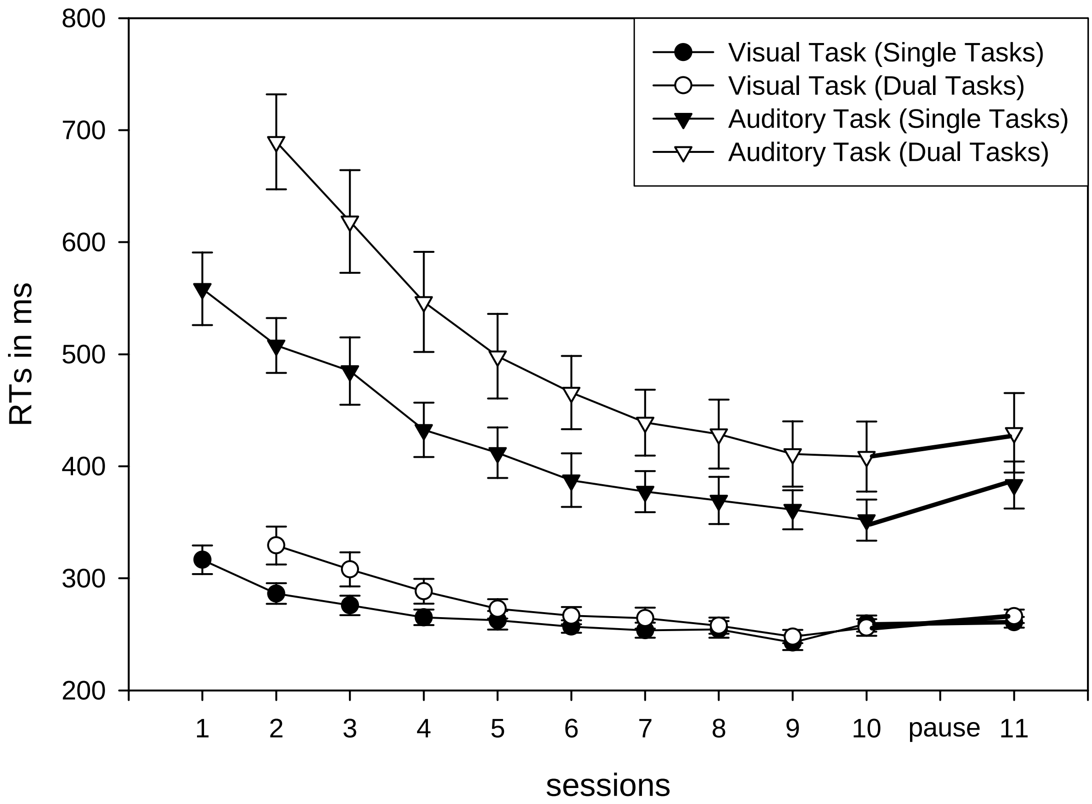

Figure 2. Mean dual-task RTs by session (session 1 to session 11) and trial type (single tasks vs. dual tasks) for the visual and the auditory tasks (bars represent standard errors).

First, we analyzed the effect of practice on the dual-task performance for the learning period before the pause, i.e., for the learning sessions 2 to 10. For that purpose, we conducted a two-way repeated measures ANOVA with the within-subject factors session (session 2 – session 10) and trial type (single tasks vs. dual tasks). As shown in Figure 2, the mean RTs in the visual task decreased during practice as reflected by an effect of session, F (8, 64) = 24.321, $p < .001$. Participants responded faster in single-task (262 ms) than in dual-task situations (277 ms), F (1, 8) = 5.927, $p < .05$. The dual-task costs in the RTs of the visual task decreased during practice as indicated by an interaction of session and trial type, F (8, 64) = 5.302, $p < .001$. The costs were reduced from the beginning (session 2: 43 ms; $p < .05$) to the end of practice where they vanished completely (session 10: -3 ms; $p > .62$). For the visual task, the analysis of errors (Table 2) showed a marginal effect of trial type, F (8, 64) = 5.192, $p < .06$, with lower error rates in single (2.3 %) than in dual tasks (4.9 %). The dual-task costs in the errors decreased significantly over practice as demonstrated by the interaction of session and trial type, F (8, 64) = 2.376, $p < .05$. Whereas the error analysis showed dual-task costs in session 2 (5.9 %; $p < .01$), the costs were eliminated in session 10 (2.0 %; $p > .18$). The factor session showed no significant main effect on the error rate.

For the auditory task, we obtained a significant effect of session on the mean RTs, F (8, 64) = 41.513, $p < .001$ (Figure 2), indicating a general improvement of the task performance during practice. Furthermore, the analysis showed an effect of the factor trial type on the RTs, F (1, 8) = 18.829, $p < .01$, with lower RTs in single (409 ms) than in dual task trials (500 ms). Participants improved their dual-task performance during practice as is reflected by the significant interaction of session and trial type, F (8, 64) = 17.588, $p < .001$. The dual-task costs were reduced extensively from session 2 (182 ms) to session 10 (57 ms) but were still present at the end of practice (session 2: $p < .001$ vs. session 10: $p < .05$) in the auditory task. As shown in Table 2, for the auditory task the error analysis showed a significant difference between single-task (3.0 %) and dual-task situations (4.9 %), F (1, 8) = 5.555, $p < .05$. There was a slight decrease of the dual-task costs during learning as demonstrated by a marginal interaction between session and trial type F (8, 64) = 1.859, $p < .10$. However, dual-task costs in the error rates were not eliminated after practice, i.e., some costs remained in session 10 (2.8 %; $p < .018$). The factor session revealed no significance in the analysis of errors.

Taken together, our results indicate a strong improvement of the dual-task performance after extensive dual-task practice for the RT and the error data in the visual task and for the RT data in the auditory task. This reduction supports results of previous studies of dual-task practice (e.g., Van Selst et al., 1999). It is important to note that despite the improvement of dual-task performance, we found no complete elimination of the dual-task costs (Hazeltine et al., 2002; Schumacher et al., 2001). Although the costs were eliminated in the visual task, they remained significant in the auditory task.

Table 2. Percent of errors (standard errors) by session (session 1 to session 11) and trial type (single tasks vs. dual tasks) for the visual and the auditory tasks.

	Visual task		Auditory task	
Sessions	Single tasks	Dual tasks	Single tasks	Dual tasks
1	0.91 (0.28)	-	5.22 (1.33)	-
2	1.23 (0.59)	7.05 (1.37)	2.80 (0.83)	7.05 (1.37)
3	1.65 (0.34)	4.44 (0.91)	3.79 (1.20)	4.44 (0.91)
4	1.81 (0.43)	4.05 (0.78)	1.81 (0.54)	4.05 (0.78)
5	1.81 (0.37)	3.96 (1.25)	2.72 (0.39)	3.96 (1.25)
6	2.30 (0.31)	4.59 (1.10)	2.72 (0.41)	4.59 (1.10)
7	3.05 (0.38)	5.65 (1.96)	3.70 (0.79)	5.65 (1.96)
8	2.80 (0.63)	4.41 (1.35)	2.96 (0.64)	4.41 (1.35)
9	2.89 (0.48)	4.38 (0.95)	3.50 (0.52)	4.38 (0.95)
10	3.47 (0.65)	5.49 (1.15)	2.72 (0.49)	5.49 (1.15)
Pause of > 6 weeks				
11	1.74 (0.35)	4.11 (0.57)	2.08 (0.43)	4.11 (0.57)

To analyze the temporal stability of skilled dual-task performance after extensive practice, we compared the performance of the participants in single- and dual-task trials between the session 10 and session 11. Both sessions were separated by a pause of more than 6 weeks. For that purpose, we conducted an ANOVA with the factors session (session 10 vs. session 11) and trial type on the RTs and the error rates in the visual and the auditory tasks.

Visual task: Importantly, there were neither significant effects nor an interaction of the pause on the RTs in the visual task (Figure 1). This finding, in particular, suggests a comparable level of dual-task performance before and after the pause and is indicative for robust skill acquisition in the visual task. The error analysis of the visual task showed an effect of session, F (1, 8) = 9.275, $p < .05$. Error rates were lower in session 11 (2.9 %) than in session 10 (4.5 %). Though the interaction of session and trial type revealed no significance, F (1, 8) < 1, we suggest that this performance improvement was rather due to an unspecific effect and not due to a specific effect of the pause on dual-task-related skills The factor trial type was also significant, F (1, 8) = 5.896, $p < .05$, with lower error rates in single-task (2.6 %) than in dual-task trials (4.8 %). Thus, the present RT analyses of the visual task revealed no specific effects of forgetting or consolidation over time. However, the results of the error rates suggested overall task improvement after the pause. Though the results were similar in single-task and dual-task conditions, we interpret this finding by the assumption that the observed improvement is not specific for the dual-task related skills.

Auditory task: The RT analysis of the auditory task showed a marginal effect of session, F (1, 8) = 4.898, $p < .06$, with slightly faster responses in session 10 (380 ms) than in session 11 (407 ms). Thus, the pause led to an increase of the RTs in the auditory task in the session after compared to the session before the pause. In addition, participants were faster in single tasks (368 ms) than in dual tasks (419 ms), F (1, 8) = 9.369, $p < .05$. Interestingly, the interaction of both factors revealed significance, F (1, 8) = 7.523, $p < .05$. The RTs in the single-task conditions increased by 31 ms ($p < .05$) and the RTs in the dual-task conditions by 21 ms ($p > .09$) from session 10 to session 11. Because of this different amount of the pause-related performance decrement in single-task and dual-task trials, the resulting dual-task costs slightly decreased after the pause from 57 ms (session 10) to 46 ms (session 11). The error analysis showed only an effect of trial type, F (1, 8) = 11.017, $p < .05$, with lower error rates in single (2.4 %) than in dual tasks (4.8 %). No effect of session or an interaction was revealed. In sum, we found decreased task performance after the pause in the RT data of the auditory task with a stronger impairment in single tasks than in dual tasks and no effect of the pause on the error rate.

Discussion

In the present study, we investigated the effects of extensive dual-task practice and the temporal stability of skilled dual-task performance in a situation requiring the simultaneous performance of a visual and an auditory task. For that purpose, we examined the performance of participants six weeks after they had completed an extensive period of 10 consecutive days of intense dual-task practice. A comparison of the dual-task performance before and after the pause reveals the degree of stability of the acquired dual-task skills over time.

The analysis of the practice-related changes during the dual-task practice showed a strong improvement of the task performance in the visual and in the auditory tasks. This improvement was more pronounced in dual- than in single-task conditions. Consequently, the additional performance costs appearing in dual-task situations were extremely reduced after 10 practice session, thus, replicating findings of prior studies on effects of practice on dual-task performance (e.g. Hirst et al., 1980; Ruthruff et al., 2003, 2006; Van Selst et al., 1999). Whereas the costs were completely eliminated in the visual task, some costs remained in the auditory task which is in contrast to other studies that showed complete elimination of costs in both component tasks in a similar paradigm (Hazeltine et al., 2002; Schumacher et al., 2001; but see Tombu & Joliceour, 2004).

The administration of a long pause of dual-task practice had different effects on task performance depending on the specific component task to be performed. For the visual task, the corresponding analysis of the data in the single-task and dual-task conditions revealed stability of skills when considering RT data and, interestingly, it revealed an improvement in the error analysis after the pause of six weeks. Thus, unlike findings of decreased task performance after a long delay (e.g., Ebbinghaus, 1885/ 1913; Tamayo & Frensch, 2007; Willingham & Dumas, 1997) the acquired skills in the present visual task do not suffer from forgetting after a long pause. Instead, the acquired skills allowed stable or improved performance even after the pause. Importantly, however, this conclusion holds true when considering performance in both, i.e., single-task and in dual-task trials. There are no signs for an effect of the pause that might depend on whether the visual task was performed either alone or together with the auditory task. So, we assume that robustness of skills in the visual task over time is not exclusively attributed to skills related to dual tasks but is associated to single-task and dual-task related skills.

The analysis of the auditory task revealed impaired performances in single-task and dual-task conditions after a long pause of six weeks. The impairment was stronger in single-task than in dual-task trials. In particular, this difference between single- and dual-task trials caused a decreased amount of dual-task costs before and after pause, with smaller dual-task costs after the pause. On first glance, this finding should be interpreted by the assumption of an improvement of dual-task skills compared to the single-task skills. However, based on the finding that RTs in dual-task trials increased in the session after the pause compared to the session before the pause we refrain from an interpretation of the related finding with the assumption of a specific memory consolidation for dual-task-related skills in the auditory task. In contrast, in our view, the findings of the auditory task show that the skills acquired in dual-task situations are impaired by the introduced performance pause but this impairment is, simply, less pronounced in dual-task compared to single-task trials.

The observed discrepancy regarding the temporal stability of the skills in visual and auditory component tasks is an interesting finding and needs further consideration. In detail, in the visual task, we did not find any dual-task costs before and after the pause. Johnston and Delgado (1993) argued that the complete reduction of performance costs in dual-task situations can be explained by an automatization of the processing of the component tasks. The automatization leads to a bypass and a parallel processing of bottleneck processes. We suggest that, once acquired, a skill that enables perfect dual-task performance seems to be stable over a long lasting pause. The finding of relatively stable dual-task performance over time is indicative for robust or even improved dual-task skills for the visual task, which is not affected by processes of forgetting. According to Shiffrin and Schneider (1977), robustness over time is a characteristic of the complete automatization of task processing. This explanation is consistent with the assumption of a highly automatic processing of the visual task in the present study after extensive practice.

It is important to note, however, that the finding of stable performance over time might be explained by a dynamic interaction of processes that are associated with forgetting and memory consolidation. Here specifically, the latter may result in some compensation of dual-task performance when forgetting of a skill over time is accompanied by a similar improvement of the dual-task skill (e.g., by memory consolidation). Future studies are necessary to disentangle the compensatory explanation from the robustness explanation.

For the auditory task, however, the findings showed decreased performances after the pause. Such impairments of performance after a long pause are often associated with processes of forgetting where acquired memory representations decay after some time. As the analysis of the practice sessions showed some dual-task costs still remaining at the end of practice after 10 sessions. Based on these findings we suggest that skills acquired during the practice of the auditory tasks were not completely automatic but still comprised non-automatic processes (Ruthruff et al., 2006). According to Shiffrin and Schneider (1977), these processes can be subject to dynamic changes over time and this, in particular, may result in forgetting of task skills of the auditory task after some time. Thereby, the differentiation of automatic and non-automatic processes provides an appropriate approach for explaining the differences in performance stability in the visual and the auditory tasks over time.

However, what may be the reasons for the different levels of automatization in the present visual and auditory tasks? According to Ruthruff et al. (2006), the different degrees of the compatibility relations between stimuli and responses in the component task may be one reason for different degrees of automatization in the two tasks. We assume that an increasing degree of compatibility of S-R translations is associated with increased automatization of the component task processing. Based on this assumption we used a spatially highly-compatible task (i.e., the visual task) where stimulus and response codes show a highly “natural” dimensional overlap and we used a task with an arbitrary S-R mapping (i.e., auditory task) where there is no pre-learned relationship between stimulus and response information. Adapted to the present task situation, we found stability in the highly spatial-compatible task but deterioration in the task with an arbitrary S-R mapping. Therefore, the present data are consistent with the assumption that an increased level of automatization may be achieved in tasks with a larger degree of S-R compatibility (as in the visual task) compared to tasks with arbitrary S-R mapping (as in the auditory task).

An important issue which needs to be discussed relates to the questions what specific skills will be improved as a result of dual-task practice and how this contributes to the overall improvement of dual-task performance. Mechanisms on two levels were proposed in previous studies to explain improved dual-task performance after practice: (1) mechanisms on the level of component tasks (e.g., Ahissar et al., 2001; Ruthruff et al., 2003, 2006) and (2) mechanisms on the level of inter-task coordination (Hirst et al., 1980; Kramer, Larish, & Strayer, 1995). The comparison of performances of single tasks and dual tasks before and after the pause might allow some conclusions whether mechanisms of the component task processing or the mechanisms related to dual-task specific skills (e.g., inter-task coordination) are stable or change over time. In detail, we assume that similar performance differences between single-task conditions and dual-task conditions over time (i.e., similar dual-task costs before and after the pause) rather indicate effects of mechanisms not exclusive for skills of dual-task performance. By contrast, different costs in dual-task situations before and after the pause show pause-related effects rather associated to dual-task skills. Most of the findings of the presented study (i.e., RTs and error rates in the visual task and error rates in auditory task) revealed similar performance differences between single-task and dual-task condition. Therefore, we assume the stability is not limited to skills related to dual tasks. The analysis of RTs in the auditory task showed that the dual-task costs are reduced over time. As indicated, however, both single and dual tasks reflect deteriorated performances after the pause. Therefore, we refrained to interpret this finding as an indicator for improved dual-task skills after pause. Further studies including the comparison of groups with dual-task practice and groups with single-tasks practice will be necessary to investigate exactly the question which mechanisms are attributed to the stability of the dual-task performance over time. That is, because the practice of component tasks in dual-task situations provides the acquisition of dual-task related skills. The separate practice, however, does not provide the acquisition of these skills exclusively related to dual tasks (Hirst et al., 1980).

In sum, the present investigation revealed that the stability of single-task and dual-task performance over time is based on the specific characteristics of the component tasks that constitute the dual tasks. The analysis of a visual task before and after a pause showed that the performance skills of single and dual tasks are highly robust. The data of an auditory task, instead, showed impaired task performance in single-task and dual-task conditions after the pause where skills of single tasks were more impaired than dual-task related skills. We assume that these task-dependent outcomes are based on the different levels of automatization of these tasks at the end of practice. However, the question whether a pause has different influences on types of mechanisms associated to improved dual-task performance remains to be considered in future studies.

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