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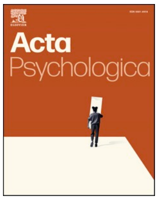

Monitoring goal-irrelevant effects interferes with concurrent tasks

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ABSTRACT

Our actions cause manifold environmental changes. Monitoring these action effects serves at least two vital functions: While the *validation* of currently relevant effects assesses goal-achievement, *screening* for currently irrelevant effects accumulates knowledge about potential action-effect relationships. However, monitoring the perceptual consequences of our actions presumably impairs performance in concurrent tasks. Here, we investigated how effect relevance modulates monitoring costs by manipulating instructions in three dual-task experiments. We found performance decreases not only after validation of goal-relevant action effects but to a smaller extent also after screening of goal-irrelevant action effects. These results suggest that effect monitoring is a rather fundamental limitation of dual tasking.

1. Introduction

Humans change their perceptions by their actions. While some perceptions are intended consequences of the action (i.e., they are relevant, they are goals), other perceptual changes might occur as a foreseeable byproduct (i.e., they are irrelevant, they are not goal-related). For example, when writing a text, the letters on the screen are relevant, they are the typist's goal. In contrast, the sound of the keys or the feeling of the forearm moving underneath the sleeves are irrelevant, the typist would consider the goal accomplished even without those perceptions.

Agents monitor the perceptual changes caused by their actions. This monitoring of action effects serves at least two vital functions. First, by processing the currently relevant effects, agents can assess whether the intended and actual outcomes match (i.e., whether they achieved their goals, Miller et al., 1960). This has been called the *validation* function (Wirth, Janczyk, & Kunde, 2018). Second, by processing currently irrelevant effects, agents can acquire new action-effect links (Elsner & Hommel, 2001). If a system is monitoring presently goal-unrelated effects, it can detect reliable co-occurrences of own behavior and environmental consequences that might become relevant later. This has been called the *screening* function. While the validation of action-effect links presumes goals that the produced effects are compared with, screening for action-effect relations could potentially take place constantly.

Recent evidence shows that monitoring of action effects interferes with concurrent tasks. Consider a dual-tasking study by Wirth, Janczyk, and Kunde (2018). In Task 1, participants were instructed to produce an object (i.e., an action effect) on a screen by pressing a key. During the display of this action effect, the imperative stimulus for Task 2 came up. As the only temporal overlap between both tasks was the display of Task 1 effects, variations in the performance of Task 2 arguably had to originate from the monitoring of these effects. The duration of the proposed monitoring process was manipulated by instructing participants to produce effects that were spatially incompatible (rather than compatible) to a keypress. Lengthening the effect monitoring process in Task 1 delayed ($\Delta = 39$ ms, Exp. 1) responding in Task 2 (for a similar influence by delaying effect onset, see Kunde et al., 2018; $\Delta = 30$ ms, Exp. 1). Several aspects of this delay have been scrutinized, like that it stems from a postponed start of the second task (Wirth, Janczyk, & Kunde, 2018), that it is influenced by expectations (Wirth, Steinhauser, et al., 2018), or that apparently the same neural system is engaged that is also engaged in error monitoring (Steinhauser et al., 2018).

Yet, in almost all previous studies participants were explicitly instructed to produce these effects on purpose, and hence, the monitored action effects were goal relevant. This renders it unclear whether the detrimental impact of effect monitoring on another concurrent task is due to the validation or the screening function. Put differently, does effect monitoring delay other tasks only when the action effect is intended, and goal achievement is checked, or also when irrelevant side effects are explored? It is hard to judge from existing literature which function is most important. On one hand, there is evidence that task-relevant feedback and task-irrelevant action contingent effects evoke similar event-related potentials (Band et al., 2009). On the other hand, visual action effects do not grab attention when they are completely unpredictable (Kumar et al., 2015) and thus, their intentional

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production cannot be a goal of the actor (Hommel & Wiers, 2017).

To disentangle these functions, we conducted three dual-tasking experiments. In the first task, manual actions produced visual effects that varied either regarding the compatibility to the action (Exp. 1) or expectancy (Exp. 2 and 3). The relevance of these effects was manipulated by altering the instructions. In one condition, participants were asked to produce these effects as a goal. In another condition, they were told that the effects are irrelevant byproducts of the task. We assumed that the monitoring of action effects draws on scarce attentional resources, thereby interfering with the processing of a concurrent task (Pashler, 1994; Welford, 1952, 1967). Consequently, the second task served to measure the ongoing monitoring of these effects. The central question was whether the effect features of the first task would differentially impact the performance in the second task, depending on the instructions.

2. Experiment 1

To test the potential contribution of effect relevance on previously reported monitoring costs, we held the superficial aspects of stimuli and responses constant but framed the task in two different ways. Participants responded to the color of a fixation cross in a puzzle piece by a left or right keypress (Task 1; see Fig. 1). This response added another puzzle piece on the screen: either on the side of the keypress (compatible effect) or on the respectively other side (incompatible effect). Shortly after the presentation of this perfectly foreseeable effect, the imperative stimulus for another choice reaction task came up (Task 2). We expected incompatible action effects in Task 1 to lengthen effect monitoring and thus to delay processing in Task 2, as observed before.

Crucially, instructions varied. In one condition, participants were told to "add a puzzle piece to the [left/right] side by pressing the [left/right] key" (Effect-Instruction). In another condition, they were told to "press the [left/right] key, which will produce a task-irrelevant [left/right] puzzle piece" (Response-Instruction). Hence, while the tasks were superficially identical, the goal of Task 1 (and thereby the relevance of the action effect) was manipulated via instructions. If only the validation function (i.e., relevant effects) impaired subsequent performance, spatially incompatible effects should impact Task 2 only with the Effect-Instruction, leading to a statistical interaction between Task 1 instruction and Task 1 compatibility in Task 2 performance. If, however, the screening function (i.e., all effects) caused monitoring costs, spatially incompatible effects should impact Task 2 irrespective of the instructions.

2.1. Participants

Forty-eight participants were recruited ($M_{\text{age}} = 26.5$ years, $SD = 6.5$), provided written informed consent and received monetary compensation. This sample size allows for counterbalancing of block order and at an alpha of .05, it provides a power of >.95 to detect monitoring costs in Task 2, assuming effect sizes as found in previous research (Wirth, Janczyk, & Kunde, 2018; Exp. 5, $d_z = 0.55$). One participant was removed from the final sample due to unusually slow responses and was replaced.

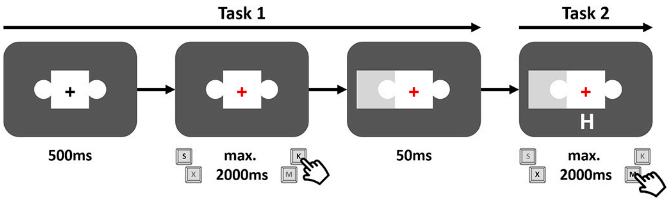

Fig. 1. Trial procedure. For Task 1, participants responded to the color of the fixation cross by pressing the S or K key. This response added either a spatially compatible or an incompatible puzzle piece. After this visual action effect, a white letter appeared to which participants had to respond with the X or M key (Task 2). This trial shows the Effect-Instruction (red fixation cross) and the incompatible mapping (right button press ➔ left effect). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Apparatus and stimuli

For Task 1, the stimuli were pictures of puzzle pieces with connectors at both sides and a centrally presented colored fixation cross. The color of the fixation cross (S1; red, green, blue, or yellow) required a middle finger response (R1) on the "S" or "K" keys of a QWERTZ keyboard. As action effects (E1), these keypresses produced puzzle pieces at either the left or the right side of S1 with the horizontal location in alignment with the position of the "S" and "K" keys on the keyboard. Hence, these action effects were either spatially compatible (e.g., a right keypress producing a puzzle piece on the right side) or spatially incompatible (e.g., a right keypress producing a puzzle piece on the left side). Before each block, participants were instructed about the spatial compatibility and relevance of the puzzle piece in the next block ("add a puzzle piece to the [left/right] side by pressing the [left/right] key" or "press the [left/right] key which will produce a task-irrelevant [left/right] puzzle piece").

For Task 2, participants had to categorize a letter (S2; "H" vs. "S"). S2 was presented centrally below the puzzle piece in white font and required an index finger response on the "X" or "M" key (R2).

2.3. Procedure

The onset of a puzzle piece with a grey fixation cross marked the beginning of a trial. After 500 ms, the fixation cross changed color. Depending on the task context, one of two colors appeared. The Response-Instruction task context mapped two colors to specific responses (yellow = press the left button, blue = press the right button), the Effect-Instruction task context mapped two colors to specific effects (red = produce a left puzzle piece, green = produce a right puzzle piece).

Immediately after R1 was given, E1 appeared and stayed on screen until the trial ended. If no response key was pressed 2000 ms after S1 target onset, the trial counted as an omission, no E1 appeared, and the outline of the central puzzle piece turned red with onset of Task 2 as error feedback.

S2 was presented 50 ms after E1 onset and called for R2. The two tasks were always presented in this order with no temporal overlap (except for the display of E1) between the tasks. Again, if no key was pressed for 2000 ms, the trial counted as an omission. If both tasks were answered correctly, the next trial started immediately after R2. Otherwise, written feedback was presented at the end of the trial for 500 ms in red color.

Participants completed 24 blocks consisting of 40 trials, with each combination of the two possible S1 per block (red vs. green with the Effect-Instruction; blue vs. yellow with the Response-Instruction) and the two possible S2 ("H" vs. "S") presented ten times. Task context (Effect-Instruction vs. Response-Instruction) and R1-E1 relationship (compatible vs. incompatible) were manipulated within participants, between blocks (6 consecutive blocks per combination). To counterbalance the order of the four possible condition blocks between participants, task context was counterbalanced between the first and second half of the experiment, and R1-E1 relationship was then counterbalanced within each task context. Additionally, the S2-R2 mapping was counterbalanced between participants.

2.4. Results

2.4.1. Data treatment

Raw data and analysis scripts for all experiments are publicly available at osf.io/q48ay. For reaction time (RT) analyses, we excluded trials with errors (Task 1: 6.9%, Task 2: 10.6%). The remaining trials were screened for outliers, and we removed trials in which RTs for Task 1 or Task 2 deviated more than 2.5 *SDs* from the corresponding cell mean, computed separately for each participant and condition (5.6%). The final sample for RT analyses consisted of 79.9% of the original trials. Data were analyzed via 2 × 2 ANOVAs with R1-E1 relationship (compatible vs. incompatible) and task context (Effect-Instruction vs. Response-Instruction) as within-subjects factors (see Fig. 2).

2.4.2. Task 1

2.4.2.1. RTs. Task 1 RTs were lower in Response-Instruction blocks (502 ms) than in Effect-Instruction blocks (522 ms), $F(1, 47) = 7.54$, $p = .009$, $\eta_p{}^2 = .14$. No other influences were observed, all $Fs < 1$.

2.4.2.2. Error rates. Task 1 error rates were higher in Effect-Instruction blocks (7.8%) than in Response-Instruction blocks (5.9%), $F(1, 47) = 7.31$, $p = .010$, $\eta_p{}^2 = .13$. Further, there were more errors in blocks with an incompatible R1-E1 mapping (7.7%) than in blocks with a compatible mapping (6.1%), $F(1, 47) = 7.07$, $p = .011$, $\eta_p{}^2 = .13$. The influences of task instructions and compatibility of R-E mapping did not interact, $F < 1$.

2.4.3. Task 2

2.4.3.1. RTs. Task 2 RTs were not influenced by the task context, $F < 1$, but were faster after compatible action effects (491 ms) than after incompatible action effects (503 ms), $F(1, 47) = 10.60$, $p = .002$, $\eta_p{}^2 = .18$. The experimental manipulations did not interact, $F(1, 47) = 0.56$, $p = .458$, $\eta_p{}^2 = .01$.

2.4.3.2. Error rates. No influences on Task 2 error rates were observed, all $Fs < 2.32$, all $ps > .133$.

2.5. Discussion

Exp. 1 addressed possible influences of effect relevance on previously observed effect monitoring costs. Task 1 required participants to respond to the color of a fixation cross and Task 2 had them categorize a letter. In Task 1, participants produced a foreseeably spatially compatible or incompatible effect with their response. While the demand of monitoring E1 was varied by this compatibility of the R1-E1 relationship, the reason for monitoring E1 was manipulated by altering the task context via the instructions. Task 2 served to measure the monitoring costs.

We found that the task context influenced the ease of producing a response to Task 1. While this could reflect that the pursuit of two goals is harder than the pursuit of only one goal (Hommel & Wiers, 2017; Janczyk & Kunde, 2020), it could likewise reflect the choice of fixation cross colors. Further, and in line with previous studies, producing a foreseeable incompatible effect was more difficult (Kunde et al., 2012; Pfister et al., 2014; Wirth et al., 2015). Also replicating previous results, responses in the unrelated Task 2 took longer after incompatible effects than after compatible effects, reflecting longer effect monitoring in the first task. Crucially, while this demand of monitoring influenced Task 2 RTs, the relevance of the monitored effects had no detectable influence on Task 2 performance.

In Exp. 1 we increased monitoring costs by manipulating effect compatibility. Effects that violate long-term links between actions and effects (left actions rarely produce changes on the right side) take longer to monitor. Exp. 2 aimed at replicating the main results of Exp. 1 by another means to manipulate effect monitoring duration, by presenting effects that did or did not violate action-effect links established in the experiment itself.

3. Experiment 2

The instructions were varied as in Exp. 1, but responses in Task 1 were now mapped to effects that had no pre-experimental or natural (spatial) relationship. Instead, one response made a stimulus grow, whereas the alternative response made the stimulus shrink. This mapping was kept constant for participants during the experiment. Based on previous research we expected that participants acquire these short-term action-effect links even if the action effect is irrelevant to the task (Elsner & Hommel, 2001). Occasionally, the R1-E1 mapping was violated: In 10% of the trials, responses produced effects that were usually produced by the respectively other response. We expected that such violations would lengthen effect monitoring and thus delay responding in the second task.

3.1. Method

Forty-eight new participants ($M_{\text{age}} = 27.5$ years, $SD = 7.9$) were recruited. Apparatus, stimuli, and procedure were as in Exp. 1, but the action effect was changed: R1 no longer added a spatially (in)compatible puzzle piece; rather, the central puzzle piece was scaled up or down as an action effect (E1). This R1-E1 relationship was no longer manipulated between blocks, but on a trial-to-trial basis: In 90% of the trials, the expected action effect was displayed, while in the remaining 10%, the unexpected action effect was displayed. Task 2 remained unchanged.

Participants again completed 24 blocks consisting of 40 trials, with each of the four possible combinations of S1 and S2 presented nine times for expected and one time for unexpected action effects. Block order, R1-E1 mapping and S2-R2 mapping were counterbalanced between participants.

3.2. Results

The data were treated as in Exp. 1. After excluding trials with errors (Task 1: 4.5%, Task 2: 9.6%) and outliers (5.4%), the final sample for RT analyses consisted of 82.6% of the original trials. The data were again analyzed via 2 × 2 ANOVAs with R1-E1 relationship (expected vs. unexpected) and task context (Effect-Instruction vs. Response-Instruction) as within-subjects factors (see Fig. 3).

3.2.1. Task 1

3.2.1.1. RTs. Task 1 RTs were lower in Response-Instruction blocks (484 ms) than in Effect-Instruction blocks (505 ms), $F(1, 47) = 11.44$, $p = .001$, $\eta_p{}^2 = .20$. No other influences were observed, all $Fs < 1.75$, all $ps > .192$.

3.2.1.2. Error rates. No influences on Task 1 error rates were observed, all $Fs < 2.29$, all $ps > .137$.

3.2.2. Task 2

3.2.2.1. RTs. Task 2 RTs were not influenced by the task context, $F(1, 47) = 1.28$, $p = .264$, $\eta_p{}^2 = .03$, but were faster after expected action effects (508 ms) than after unexpected action effects (520 ms), $F(1, 47) = 15.56$, $p < .001$, $\eta_p{}^2 = .25$. The experimental manipulations did not interact, $F(1, 47) = 1.73$, $p = .195$, $\eta_p{}^2 = .04$.

3.2.2.2. Error rates. No influences on Task 2 error rates were observed, all $Fs < 1$.

3.3. Discussion

The results of Exp. 2 replicate the key finding of Exp. 1: Again, Task 2 reaction times increased with higher effect monitoring demands in a

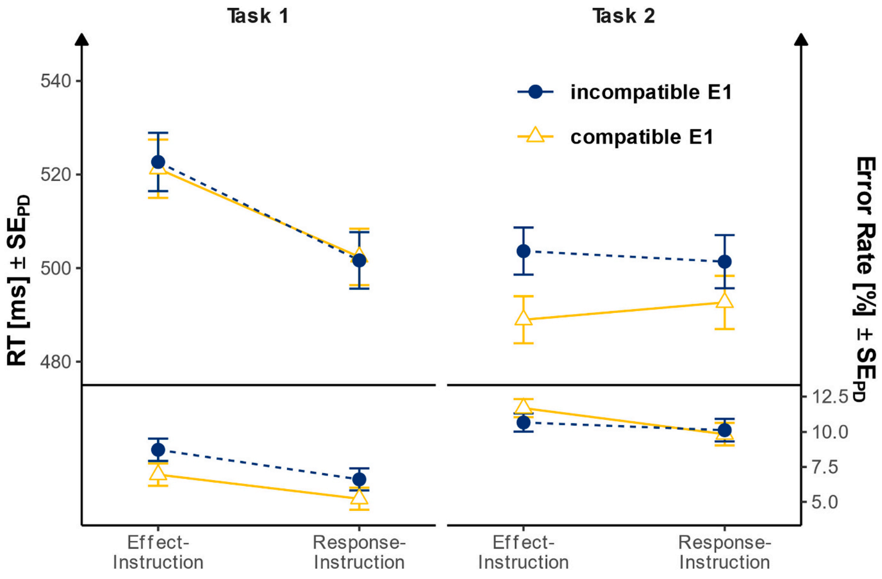

Fig. 2. Results of Experiment 1. Response Times (RTs; top) and Error Rates (bottom) for Task 1 (left) and Task 2 (right). Yellow triangles represent trials with compatible effects, whereas blue points represent trials with incompatible effects. Error bars denote the standard error of paired differences, computed separately for each comparison of compatibility (Pfister & Janczyk, 2013). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

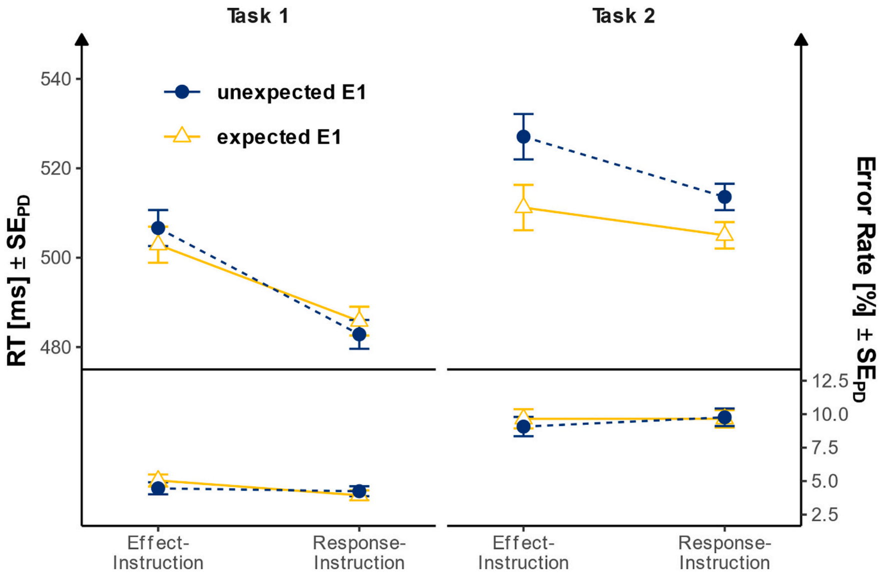

Fig. 3. Results of Experiment 2. Response Times (RTs; top) and Error Rates (bottom) for Task 1 (left) and Task 2 (right). Yellow triangles represent trials with expected effects, whereas blue points represent trials with unexpected effects. Error bars denote the standard error of paired differences, computed separately for each comparison of expectedness (Pfister & Janczyk, 2013). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

previous task, which this time originated from unexpected action effects. Contrary to Exp. 1, participants now had to build this expectancy based on newly emerging R1-E1 relationships. Despite this adjustment, we again found no modulation of the monitoring costs by the task context, as indicated by the nonsignificant interaction in Task 2 reaction times.[1] While in both Exp. 1 and Exp. 2 the action effects in the Response-Instruction condition were evidently irrelevant for performing the task, the Task 2 RTs show that they are evidently not irrelevant for task performance. Hence, increased effect monitoring, whatever its cause, affects other tasks even if the effects are not relevant.

4. Experiment 3

Although in neither experiment manipulations of task instructions and effect monitoring duration (by R1-E1 compatibility in Exp. 1 and R1-E1 expectancy in Exp. 2) interacted significantly, there were descriptively larger monitoring costs for the conditions that emphasize the production of E1. This suggests that even though the relevance of effects is not a necessary precondition of monitoring, it might still modulate its magnitude. Consequently, Exp. 3 investigated action effects that are (or are not) directly relevant for performing the task. To make monitoring of the produced action effects part of the task requirement, participants now had to count the number of unexpected action effects in the Effect-Instruction condition. Further, to rule out any possible carry-over effects, task context was manipulated between participants, and the sample size was doubled.

4.1. Method

Ninety-six new participants ($M_{\text{age}} = 30.4$ years, $SD = 10.2$) were

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[1] When pooling the data from both experiments ($N = 96$) and conducting a 2 × 2 × 2 mixed ANOVA with R1-E1 relationship (low monitoring demand vs. high monitoring demand) and task context (Effect-Instruction vs. Response-Instruction) as within-subjects factors and experiment (compatibility manipulation vs. expectancy manipulation) as between-subjects factor, R1-E1 relationship and task context also did not interact, $F(1, 94) = 1.86$, $p = .176$, $\eta_p^2 = .02$.

recruited online. 6 participants were removed from the final sample due to high error rates (>30%) and were replaced.

Stimuli and procedure were comparable[2] to Exp. 2, but the Effect-Instruction condition now required participants to report the number of unexpected events at the end of each block. Further, task context was manipulated between participants. This allowed mapping each R1 to only one S1 (red vs. green). Participants again completed 24 blocks consisting of 40 trials. To achieve a variable number of odd trials per block, trials were now randomized over the whole experiment instead of within each experimental block. Task context, S1-R1 mapping, R1-E1 mapping and S2-R2 mapping were counterbalanced between participants.

4.2. Results

The data were treated as in Exp. 1 and 2. After excluding trials with errors (Task 1: 4.3%, Task 2: 8.1%) and outliers (5.8%), the final sample for RT analyses consisted of 84.0% of the original trials. The data were analyzed via 2 × 2 ANOVAs with R1-E1 relationship (expected vs. unexpected) as within-subjects and task context (Effect-Instruction vs. Response-Instruction) as between-subjects factor (see Fig. 4).

4.2.1. Task 1

4.2.1.1. RTs. No influences on Task 1 RTs were observed, all $Fs < 1$.

4.2.1.2. Error rates. No influences on Task 1 error rates were observed, all $Fs < 1$.

4.2.2. Task 2

4.2.2.1. RTs. Task 2 RTs were lower with the Response-Instruction (552 ms) than with the Effect-Instruction (724 ms), $F(1, 94) = 53.43$, $p < .001$, $\eta_p{}^2 = .36$. Further, Task 2 responses were faster after expected action effects (585 ms) than after unexpected action effects (692 ms), $F(1, 94) = 108.36$, $p < .001$, $\eta_p{}^2 = .54$. The experimental manipulations interacted, $F(1, 94) = 82.43$, $p < .001$, $\eta_p{}^2 = .47$, with a large influence of the R1-E1 relationship on Task 2 RTs with the Effect-Instruction, $t(47) = 9.88$, $p < .001$, $d = 1.43$, $\Delta = 201$ ms, and a smaller, but still highly significant influence with the Response-Instructions, $t(47) = 3.97$, $p < .001$, $d = 0.57$, $\Delta = 14$ ms.

4.2.2.2. Error rates. Task 2 PEs were lower with the Response-Instruction (7.4%) than with the Effect-Instruction (9.4%), $F(1, 94) = 4.70$, $p = .033$, $\eta_p{}^2 = .05$. Further, Task 2 responses were more accurate after expected action effects (8.0%) than after unexpected action effects (8.8%), $F(1, 94) = 4.13$, $p = .045$, $\eta_p{}^2 = .54$. The experimental manipulations interacted, $F(1, 94) = 8.79$, $p = .004$, $\eta_p{}^2 = .09$, with an influence of the R1-E1 relationship on Task 2 PEs with the Effect-Instruction, $t(47) = 2.89$, $p = .006$, $d = 0.42$, $\Delta = 1.9\%$, and no influence with the Response-Instructions, $t < 1$.

4.3. Discussion

Exp. 3 extends the results of the first two experiments. In line with Exp. 1 and 2, explicitly irrelevant action effects in Task 1 influenced performance in Task 2, implying that screening for action-effect contingencies is a cause for dual-tasking costs. These screening costs were similar in magnitude to those observed in the first two experiments, suggesting that the previously observed slowing after irrelevant effects was not caused by carry-over effects from the within-manipulation of task context. In contrast to Exp. 1 and 2, however, we observed significantly larger monitoring costs for relevant effects in Exp. 3, where we employed a stronger relevance manipulation. Hence, although all action effects were processed, the intensity of this processing depends largely on the goals currently pursued. Considering the descriptive decrease in Task 2 performance we found in the first two experiments, this can be seen as a tentative hint that the monitoring costs observed in previous research represent a mixture of both screening and validation of action effects, and that their share to the observable slowing in Task 2 might be dependent on the exact wording of the instructions.

5. General discussion

The present experiments investigated the origin of previously reported performance decrements emerging after action effects with increased monitoring demand. As the action effects were goal-relevant in most previous research, it was unclear whether performance decrements originate from validating goal-relevant effects or from screening for further goal-irrelevant effects.

To disentangle these two possibilities, we manipulated the task instructions: While participants were instructed to produce a certain effect in one half of the experiment, this action effect was nominally task-irrelevant in the other half. In the first two experiments, altering the relevance of action effects did not mitigate the monitoring costs in Task 2: Performance decrements ($\Delta = 12$ ms) following effects with high monitoring demand were not reduced significantly by different instructions. This data pattern suggests that previously reported effect monitoring costs are not constrained to goal-relevant action effects, but also emerge when irrelevant effects are screened. In the third experiment, explicitly requiring participants to monitor the action effects increased the observed monitoring costs. This suggests that while screening takes place constantly, certain goals entail the need to validate the produced perceptual changes, thereby impairing performance in concurrent tasks further ($\Delta = 14$ ms for screening vs. $\Delta = 201$ ms for screening plus validation of action effects).

A previous observation already hinted at the detrimental impact of effect screening. Spatially incompatible action effects (as compared to compatible effects) delay processing in a second task even when this effect is uncontrollable (Wirth, Janczyk, & Kunde, 2018, Exp. 5). It is tempting to assume that unpredictable effects can barely be a goal of the actor, indicating that any ensuing influences of these effects were due to screening rather than validation. Yet, whether participants nonetheless pursue these action effects as relevant goals, despite only being successful at chance level, remained unsettled with that study. The present instruction manipulation directly compares relevant and irrelevant effects and thus, we can now conclude on solid empirical footing that effect screening is a cause of dual task decrements.

What exactly causes this observable impact on subsequent tasks is yet to be investigated. While the present study rules out that monitoring is evoked only by relevant effects, feature binding has likewise been rejected as primary mechanism (discussed in Wirth & Kunde, 2020). On this spot, we would like to advance two further possible candidates. One viable explanation is that a generic monitoring system triggers an unspecific *stop*-signal after detecting an expectancy-violation (Wessel, 2018), even if the violated expectancy is irrelevant for the current goal. Hence, monitoring costs could be restricted to action effects that are unexpected. This notion receives support from reports that oddball stimuli (Steinhauser & Kiesel, 2011; Wessel et al., 2012) and spatially incompatible action effects (Steinhauser et al., 2018) engage the same neural system that is engaged in error monitoring.

Likewise, the modality overlap between the action effect of Task 1 and the imperative stimulus of Task 2 could be crucial. As both E1 and S2 rely on spatially separated visual information, potentially possible parallel perceptual processing might be peripherally constrained by longer fixations on unexpected effects (Brockmole & Boot, 2009). This would delay the perceptual stage of Task 2, explaining why monitoring

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[2] To facilitate online data collection, the instructions were in English instead of German.

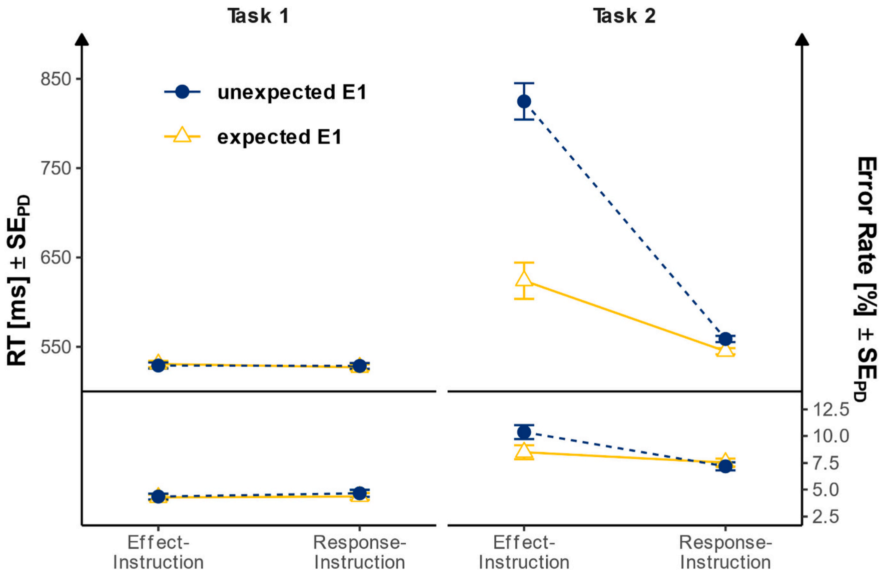

Fig. 4. Results of Experiment 3. Response Times (RTs; top) and Error Rates (bottom) for Task 1 (left) and Task 2 (right). Yellow triangles represent trials with expected effects, whereas blue points represent trials with unexpected effects. Error bars denote the standard error of paired differences, computed separately for each comparison of expectedness (Pfister & Janczyk, 2013). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of visual action effects seems to postpone visual second tasks (Wirth, Janczyk, & Kunde, 2018; Wirth, Steinhauser, et al., 2018). Hence, monitoring costs could occur even if the monitored action effect is completely expected (Kunde et al., 2018).

6. Conclusion

We set out from the notion that agents must check what they cause, that they must monitor their action effects. Previous research reported that performance in a concurrent task deteriorates when participants monitor goal-relevant action effects. Here, we found smaller (but reliable) performance decrements when participants monitor irrelevant action effects. Thus, our findings indicate that effect monitoring is a rather fundamental limitation of dual tasking. Having an eye on what you cause seems to be a process that is not easy to switch off. Having an eye on this effect monitoring process is certainly worthwhile when it comes to further explaining why doing two things at once is hard.

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Declaration of competing interest

None.

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