Intention Framing in Time-Based Prospective Memory

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Research on prospective memory has paid no attention to the way in which the intentions to be remembered are framed. In two studies on time-based prospective memory, participants had to remember multiple delayed intentions framed as time rules (i.e., respond every 7 min, every 10 min) or as a series of corresponding instances (i.e., respond at Times 7, 10, 14, 20, 21, 28, 30, etc.). We appraised the effects of intention framing on intention learning, intention representation, strategies used to set the upcoming intention, cognitive load (monitoring cost), and prospective memory performance. Study 1 involved three time rules and corresponding instances. The results showed that time rules are learned faster than corresponding instances and that intention frames shaped the way intentions were mentally represented. Furthermore, the rule frame was associated with a more cognitively demanding incremental planning strategy to establish the upcoming intention, whereas the instance frame promoted the serial recall of intentions. Study 2 replicated the results on representations and strategies with four time rules and corresponding sets of instances, and it showed better prospective memory performance following the instance frame than rule frame. Together, these studies show that two alternative ways of framing multiple delayed intentions in the same prospective memory task induce significant differences in the way intentions are represented, in the cognitive strategies used to set the upcoming intention, and in performance. Theoretical and applied implications of the results for the prospective memory field are discussed.

Keywords: prospective memory, time-based prospective memory, intention framing, rules, instances

Although everyday intentions may appear in many guises, the format of delayed intentions, or *intention framing*, has received no attention in prospective memory (henceforth PM). For example, instructing patients to take medications every third hour (intentions as rules) may not be the same task as asking them to take the pills at specific hours (intentions as instances), especially when patients have to take multiple medications at different hours. Although these two ways of framing the PM task are both well specified and temporally isomorphic (mapping the same objective deadlines), they may be psychologically dissimilar, trigger diverse cognitive strategies for establishing the upcoming intention, and lead to different performance outcomes. The goal of the investigations presented in this article was to understand whether a variation in how intentions in a time-based PM task are framed (as time rules vs. instances) affects intention learning, intention representation, strategies used to establish the next intention, cognitive load (monitoring cost), and PM performance.

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PM studies have produced very valuable insights into the processes underpinning both time-based tasks and event-based tasks (e.g., Einstein et al., 2005; Kliegel et al., 2007; McDaniel & Einstein, 2000). The Preparatory Attentional and Memory Processes theory (PAM; Smith, 2003, 2017) underlined the role of cognitively effortful monitoring in PM tasks (e.g., Smith, 2003), in the context of an interaction between preparatory attentional processes and retrospective memory processes. According to the multiprocess (MP) framework (Anderson et al., 2017; Scullin et al., 2018; Shelton & Scullin, 2017), PM performance may involve both cognitively effortful monitoring processes and more reactive and automatic ones, depending on the features of the task and the availability of contextual hints (Einstein & McDaniel, 2005; Scullin et al., 2013). Time-based PM tasks are generally found to be more demanding and difficult than event-based ones (e.g., Sellen et al., 1997), given the greater involvement of strategic monitoring processes, even if cognitive costs and PM performance also depend on the features of the task to be performed (e.g., cue focality; Einstein & McDaniel, 2005; McDaniel & Einstein, 2000), contextual hints (for context-sensitive allocation of monitoring, see Smith et al., 2017), intention specificity (Hicks et al., 2005), and individual differences in monitoring and working memory (Einstein & McDaniel, 2005; Smith & Bayen, 2005). For what concerns the aspect investigated in this paper, PM task demands can also be influenced by the way intentions are presented, because intention framing can shape how intentions are represented and thus affect the cognitive strategies used for intention setting, and eventually PM performance. As we will explain, this may occur especially when multiple intentions have to be remembered.

Unfortunately, the great majority of research on PM has not considered the influence of how intentions are presented and has focused on how individuals remember single (repeated) intentions (e.g., Hicks et al., 2005; McDaniel & Einstein, 2000; Sellen et al., 1997). Only a few studies have investigated how individuals remember multiple intentions (Cicogna et al., 2005; Hicks et al., 2005; Kubik et al., 2020; Occhionero et al., 2010; Rendell & Craik, 2000; Smith et al., 2017; Smith et al., 2014), but, even in these cases, no specific attention has been paid to the role of intention framing. The same considerations hold for the studies on monitoring of multiple time deadlines (e.g., Craik & Bialystok, 2006; Mäntylä, 2013; Todorov et al., 2014). Similarly, even if some studies have dealt with mental representations in event-based PM (see Scullin et al., 2018) or with PM processes in relation to task specificity or cue focality (e.g., Einstein et al., 1995; Hicks et al., 2005), these investigations did not consider the effects of intention framing.

Possibly, the influence of intention framing went unnoticed in previous time-based PM research partly due to a main focus on remembering a single (recurrent) intention in rather simple tasks (e.g., Ceci & Bronfenbrenner, 1985; Mäntylä et al., 2009).[1] Indeed, the psychological dissimilarity of different intention frames may not appear clearly when a single intention has to be remembered and the task complexity is low, as in most PM studies, because individuals can easily switch between representations (every third hour ⟵⟶ 1, 4, 7 p.m.). More generally, considering the reactive and unpredictable nature of most event-based PM tasks (cf. "press the key when X appears"), intention framing effects might be less evident in event-based PM but more evident in PM tasks that rely on predictable deadlines with explicit demands on goal-directed planning and proactive task monitoring, for instance when multiple delayed intentions have to be remembered (e.g., take the red pill every second hour, the yellow pill every six hours, and the white pill every ten hours). Interestingly, some studies in event-based PM with multiple intentions show that when contextual hints allow participants to anticipate their relative proximity to an upcoming deadline, they strategically activate monitoring processes that seem similar to the ones operative in time-based PM tasks (e.g., Smith et al., 2017; see also Bowden et al., 2017). However, even in these studies, the relations among intention framing, intention representation, intention-setting strategies, and PM performance have not been studied.

Despite the lack of PM research on intention framing, influential research programs in other areas of cognition offer theoretical reasons and empirical evidence suggesting that framing may matter also for PM. For instance, several problem-solving studies have demonstrated the psychological dissimilarity of tasks that can be formally considered as isomorphs (e.g., Hayes & Simon, 1974; Kotovsky et al., 1985; Simon & Hayes, 1976), with problem representation being determined pretty directly by the way the problem is presented (including written instructions). For example, Kotovsky et al. (1985) showed that the locus of large performance differences between different isomorphic versions of the Tower of Hanoi problem resides in the dissimilar mental representations of the task, associated with a varying degree of memory load, induced by different presentation frames. Furthermore, research on framing and mental accounting in decision making (e.g., Levin et al., 1998; Thaler, 1999; Tversky & Kahneman, 1981, 1986) and on mental models in reasoning (Johnson-Laird, 2010) has shown that individuals can rely on different mental representations for carrying out the same task, and these representations, affected by the way the problem is framed, influence underlying processes and behavioral responses.

In the next section of this article, we will first present the overall aims and the rationale of the two experiments on intention framing that we have conducted and put forward the hypotheses tested. Then we will present the two studies and illustrate their results. Finally, we will discuss the theoretical and applied implications of our work for research in PM, as well as examine the limitations of our investigation, and outline possible future research directions.

Aims and Hypotheses

The general goal of our research was to appraise whether a variation in the way the intentions of the same time-based PM task were framed (as time rules vs. instances) would affect intention learning, intention mental representations, strategies to establish the upcoming intention, cognitive load, and PM performance. To this aim, we conducted two studies with the same experimental paradigm, while varying the difficulty of the PM task. In Study 1, participants carried out a time-based PM task with two different ways of framing the same intentions as the main manipulation. In the *rule* conditions, participants were asked to learn three PM rules and to apply them while performing an ongoing lexical-decision task (e.g., "green [button] every 10 minutes"). In the *instance* conditions, participants had to learn a series of PM instances (e.g., "green [button] at time 10," "green [button] at time 20," "green [button] at time 30," "green [button] at time 40"), which perfectly matched the PM rules, and to meet the corresponding deadlines while performing an ongoing lexical-decision task (henceforth OT). The two frames of the PM tasks mapped the same objective time deadlines and thus were formally isomorphs in the time dimension. In Study 2, we increased PM task difficulty by adding a fourth rule (and a corresponding additional set of instances). We will now explain the rationale of the hypotheses tested in our study (see also Table 1).

Learning

Our first hypothesis was that learning time rules would be faster than learning corresponding instances, because memorizing three general verbal sentences in the form of meaningful short rules is cognitively simpler than memorizing a series of 12 times in association with the corresponding response buttons (as required in Study 1). Moreover, memory studies have shown that making a sentence or a story with words that have to be learned, and thus giving them a global meaning, leads to a better recall than studying the words as separate items (e.g., Bäuml & Aslan, 2006; Bower & Winzenz, 1970; Sahakyan & Delaney, 2003). This hypothesis was tested by assessing how many study cycles (of fixed time duration)

[1] The focus on relatively simple PM tasks has probably limited also the investigation on the cognitive strategies used to carry out the task, although more recently the issue of strategies in PM has attracted some more interest (e.g., Goedeken et al., 2018; Mäntylä et al., 2009; Reese-Melancon et al., 2019; Rummel & Meiser, 2013). However, even in these cases, the focus is on monitoring strategies (i.e., when to monitor for cues) and not on intention-setting strategies (i.e., when and how to establish the upcoming intention), which are central in the present investigation.

Table 1

Summary of the Hypotheses, Variables Used for Hypothesis Testing, Specific Predictions, and Results of the Studies in Relation to the Hypotheses

Hypothesis name	Hypothesis	Variables	Predictions	Results
H1. Learning	Learning time rules is faster than learning corresponding instances	Number of study cycles needed to reach a 100% recall accuracy criterion	Lower number of study cycles in the rule frame than in the instance frame	Supported in Study 1 (not tested in Study 2)
H2. Representation	Intentions are memorized as rules in the rule frame and as an ordered series of deadline-response pairs in the instance frame	Recall order of the deadlines in an unexpected recall task after the PM task	Deadline recall order following the rules in the rule frame and deadline recall order following the serial order in the instance frame	Supported in Study 1 and in Study 2
H3. Intention-setting strategy	In order to set the next intention, a (more costly) incremental planning strategy is used in the rule frame and a serial recall strategy is used in the instance frame	Retrospective strategy report	Mentioning the rules or rule-related computations to figure out the next deadline in the rule frame and mentioning the mere recall of single deadlines from memory in the instance frame	Supported in Study 1 and in Study 2
		Mean OT RT in the 30 seconds following a PM response	Higher mean OT RT in the 30 seconds following a PM response in the rule frame than in the instance frame	Supported in Study 1 and in Study 2
		RT of the first OT response after a PM response	Higher RT of the first OT response after a PM response in the rule frame than in the instance frame	Supported in Study 2, difference in the expected direction but not reaching statistical significance in Study 1 (p = .08)
H4. Cognitive load	Cognitive load is greater in the rule frame than in the instance frame	Overall OT RT	Higher RT in the OT in the rule frame than in the instance frame	Supported in Study 1, not supported in Study 2
H5. PM performance	Performance is worse in the rule frame than in the instance frame, especially when the task becomes more difficult (Study 2)	PM hits, Number of commission errors, number of omission errors, mean absolute deviation (MAD) of responses from their respective deadlines	Fewer hits, more errors, and higher MAD in the rule frame than in the instance frame	Supported in Study 2 for hits, omission errors, and MAD (difference in commission errors in the expected direction but not reaching statistical significance, p = .08)

Note. OT = ongoing (lexical decision) task.

were needed to learn the time rules versus instances to a 100% criterion (see also the Method section of Study 1).

Representations

Our second hypothesis was that the representation of the intentions would generally match the presentation frame. Thus, a rule frame would induce a representation of the intentions as rules, whereas an instance frame would promote a serial representation of the intentions as a series of deadline-response pairs (with chainlike associations between contiguous items).[2] This hypothesis stems from the literature on problem solving showing that participants typically stick to the representation suggested by problem wording (Hayes & Simon, 1974; Kotovsky et al., 1985; Simon & Hayes, 1976). It is also grounded in the work on framing in decision making, showing that individuals are affected by the way in which the same problem is presented (e.g., Levin et al., 1998; Thaler, 1999; Tversky & Kahneman, 1981, 1986). Additional support comes from studies showing the influence of encoding instructions in multiple-cue judgment tasks (Bröder et al., 2017; Olsson et al., 2006) and, more importantly, from some studies on event-based prospective memory in which, even when a spontaneous conversion of the target representation (i.e., from a general category, e.g., "fruit," to more specific instances of the target, e.g., "orange") seems much easier and motivated than in our studies, only a minority of participants seems to spontaneously apply this transformation (e.g., Scullin et al., 2018). To test the hypothesis on representations, we used an unexpected recall task of the deadlines after the completion of the PM task, with the recall order taken as

[2] Previous work in several areas of cognition showed that rules and instances are employed as cognitive representations. This happened, for instance, in the areas of multiple-cue judgment, categorization, and dynamic system control (e.g., Erickson & Kruschke, 1998; Gonzalez et al., 2003; Juslin et al., 2008; Mata et al., 2012; Nosofsky et al., 1989; von Helversen et al., 2014). Here we propose that these two types of representation can be used also in the case of prospective remembering, in relation to two distinct types of intention frames.

an indicator of the underlying representation (as we will describe in the Method section of Study 1). Namely, we expected that recall order of the deadlines in the rule condition would follow the rules learned (i.e., deadlines remembered by following the rules), whereas in the instance condition the deadlines would be recalled in the sequential time order (deadlines remembered by following the time order).

Intention-Setting Strategies

Usually, strategies in prospective memory are considered mainly in reference to when or how frequently to monitor for the relevant environmental or time cues (e.g., Mäntylä et al., 2009; Smith et al., 2017). However, our main interest was in the strategies that participants would use to set the next prospective intention (after the completion of the previous one) under the two different intention frames (i.e., intention-setting strategies). We hypothesized that the intention-framing manipulation would trigger two distinct intention-setting strategies: incremental planning in the rule frame versus serial recall of intentions in the instance frame. Indeed, given that a rule-based representation (e.g., press the red button every 7 min) does not make explicit what the precise deadlines are, and considering that participants had to handle multiple rules, performing the PM task with a rule-based representation requires planning in order to set the next PM intention. In particular, a simple cognitive task analysis starting from the representation induced by the rule frame (see Figure 1, panel a) suggests that participants would need to (1) project into the future the closest deadlines for each rule and keep these values (and the associated responses) in working memory; (2) select the nearest deadline in time; and (3) memorize the deadline (and the associated response) as the current intention to be met. Considering the strong support for incremental planning strategies and means-ends analysis from studies in problem solving (e.g., Altmann & Trafton, 2002; Ernst & Newell, 1969; Newell & Simon, 1972), we hypothesized that these rule projection and selection processes would take place soon after each deadline was met by the participant's response (and thus when the next intention would need to be set).[3] In the case of the instance-based representation, deadlines are already explicit and participants have simply to recall the next intention after the previous one is met (Figure 1, panel b), using the previous intention as a cue in a chain-like associative recall process (e.g., Altmann, 2000; Bäuml & Aslan, 2006; Kahana, 1996; Murdock, 1983; Nairne, 1983).[4] In order to test the hypothesis on the strategies for intention setting, we relied on strategy reports after the completion of the task (see Table 1 for predictions). Moreover, we relied on two tests on the OT reaction times (RTs). Indeed, given the more cognitively intensive nature of the intention-setting strategy in the rule condition than in the instance condition (requiring cognitive planning vs. cued recall), we hypothesized that intention setting under a rule frame would entail a significantly higher cognitive load on working memory soon after each PM response was given and the next intention needed to be established (see Figure 1). To test this hypothesis, we compared the OT RTs between framing conditions using two measures: the mean OT RT in the 30 s following each PM response and the RT of the first OT response after each PM response. We predicted that intention frames would affect intention-setting strategies as explained, but we did not expect differences between intention framing conditions in monitoring strategies. Indeed, once an intention is set and the next deadline is made explicit, there are no reasons to expect frame-related differences in time monitoring. Thus, we expected, in both framing conditions, a steep increase in the frequency of clock checks as the deadline was approaching, as commonly observed in time-based PM tasks (e.g., Mäntylä et al., 2007; Mioni & Stablum, 2014).

Cognitive Load

Given the postulated more cognitively intensive nature of the intention setting strategies in the rule condition than in the instance condition (as explained above), we expected to observe a higher overall mean OT RT in the rule condition. However, given that the OT RT differences between intention framing conditions are expected mainly in relation to intention-setting strategies (thus soon after each PM deadline was met), this difference should be smaller if appraised over the whole duration of the OT (because diluted). In addition, given the cognitive demands of intention-setting and monitoring strategies, we expected significant differences between both intention framing conditions and the control condition (only OT, no PM task).

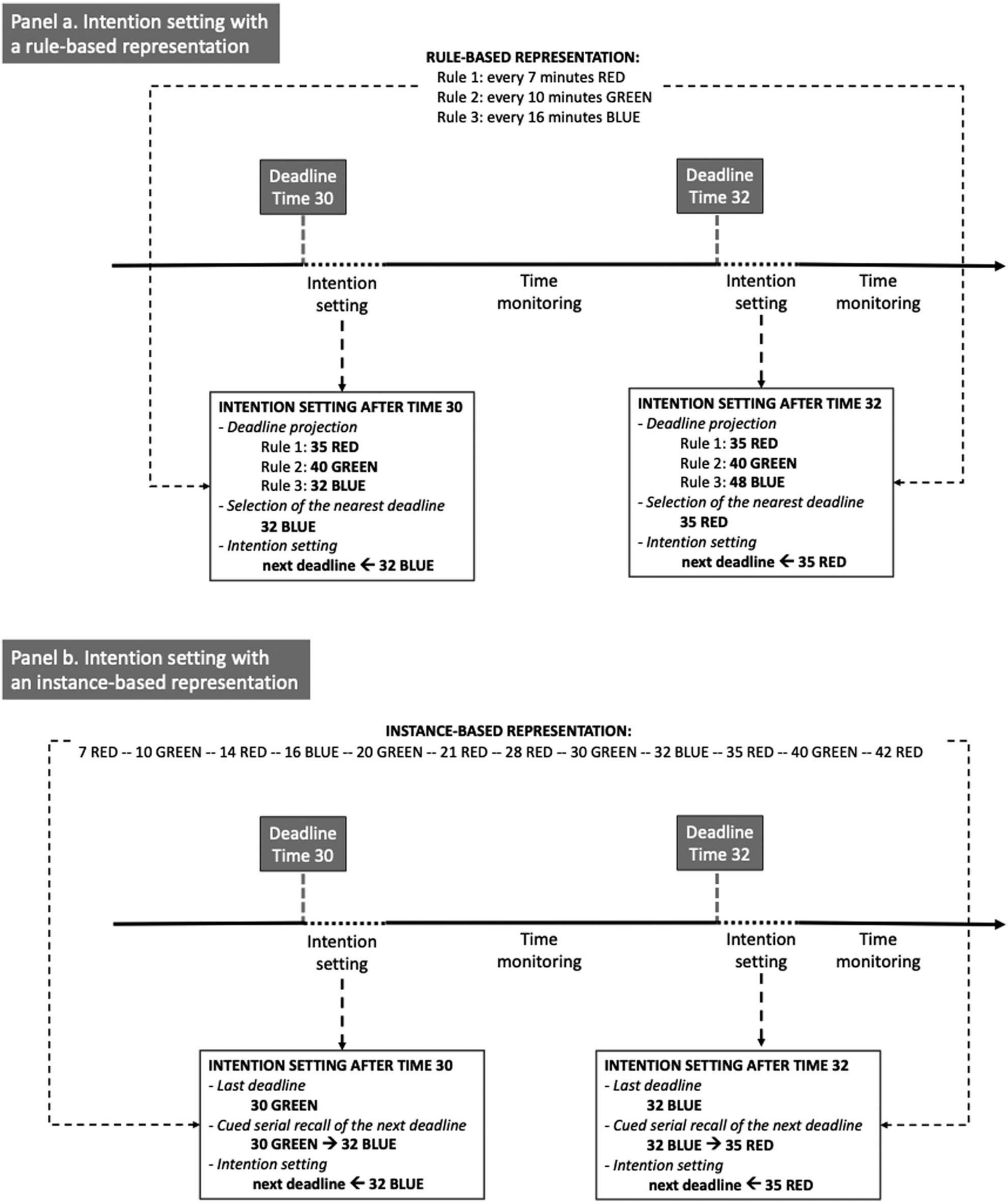
PM Performance

We hypothesized that participants in the rule condition would show worse PM performance than participants in the instance condition, especially with an increased difficulty of the PM task (Study 2). Indeed, a more cognitively demanding intention-setting strategy like the incremental planning one hypothesized in the rule framing condition is potentially more prone to errors than a strategy based on serial recall of a well-learned series of items. In the former case, errors can stem from establishing the wrong deadline during intention setting (and thus missing the right deadline) due to computational mistakes or memory faults, or from interference by the other deadlines projected during the intention setting process (see Figure 1). This hypothesis was tested using several standard measures of PM performance: hits, number of commission and omission errors, and mean absolute deviation (MAD) of responses from their respective deadlines (see also the method section of Study 1).

[3] A complete compilation of the rules into a set of instances soon after the beginning of the PM task was precluded by the cognitive complexity of this process and by the need to carry out the concurrent lexical decision task (OT) together with the PM task.

[4] We cannot exclude the possibility that some participants might be able to plan ahead to set more than one future intention in time (in the rule frame) or to retrieve more than one deadline from memory for future intention setting (in the instance frame), although we think that this would be seriously bounded by the complexity of the task (especially in the rule condition) and by working memory limits. We also cannot exclude that, for the very first PM deadlines, some participants in the rule condition might use the number–color associations included in the text of the rules to set the next intentions without planning (e.g., every 7 min RED → 7 RED, every 10 min GREEN → 10 GREEN). However, participants would need to plan after these few deadlines to set the next intentions. Thus, even taking into consideration these possibilities, our hypotheses and predictions related to the influence of intention frames remain unchanged.

Figure 1
Postulated Cognitive Steps in Intention Setting



Note. Panel a (upper) shows intention setting following an incremental planning strategy in the rule framing condition. Panel b (lower) shows intention setting following a serial recall strategy in the instance framing condition. The example illustrates hypothetical intention setting following the completion of the 30 and 32 deadlines in a PM task with three time rules and corresponding sets of instances. The figure also shows the switches between shorter intention-setting periods and longer time-monitoring periods.

Study 1: Three Rules

In Study 1, we tested our hypotheses (see Table 1) in a time-based PM task with three recurrent time rules and corresponding sets of instances in the context of an OT (lexical decision). Therefore, the main experimental manipulation was the intention frame of the PM task, varied between participants as rule frame versus instance frame. An additional between-participants manipulation, orthogonal to the intention framing one, involved the type of response required by the task, which was either to press a different button for each rule (or the associated set of instances) or to press always the same button for all the rules (and all the instances). This secondary manipulation was motivated by the aim to show that the intention framing effects originate from how the intentions are defined/framed, beyond their specific association with different kinds of responses, and therefore to exclude the possibility that the response type (single vs. multiple) could affect intention formulation and/or performance. Moreover, this manipulation allowed appraising whether the expected effects were robust across different types of responses that could vary in their motor/preparation demands (i.e., multiple response options vs. a single option). As usual in PM studies, we also included in the study a control condition in which participants simply had to carry out the OT (lexical decision), but not the PM task, as a baseline to assess the cognitive load of the dual task conditions.

Method

Participants

One hundred and five undergraduate students took part in the study (81% female, age: $M = 21.07$, $SD = 2.58$) and received course credits for their participation. The sample size was decided with a power analysis assuming a medium effect size in a five-group ANOVA and considering the 12 deadlines as repeated measures (power $> .90$). The study was approved by the Ethical Committee of the University of Trieste, and participants provided their written informed consent.

Design

Participants were asked to complete a time-based PM task while being engaged in an OT (lexical decision). The instructions made explicit that both tasks were equally important. As previously stated, the intention frames and the response type were manipulated according to a 2 (Intention Framing: rules vs. instances) × 2 (Response Type: same vs. different) between-participants factorial design, plus a control condition without the PM task. Twenty-one participants were randomly assigned to each experimental group.

Ongoing Lexical-Decision Task

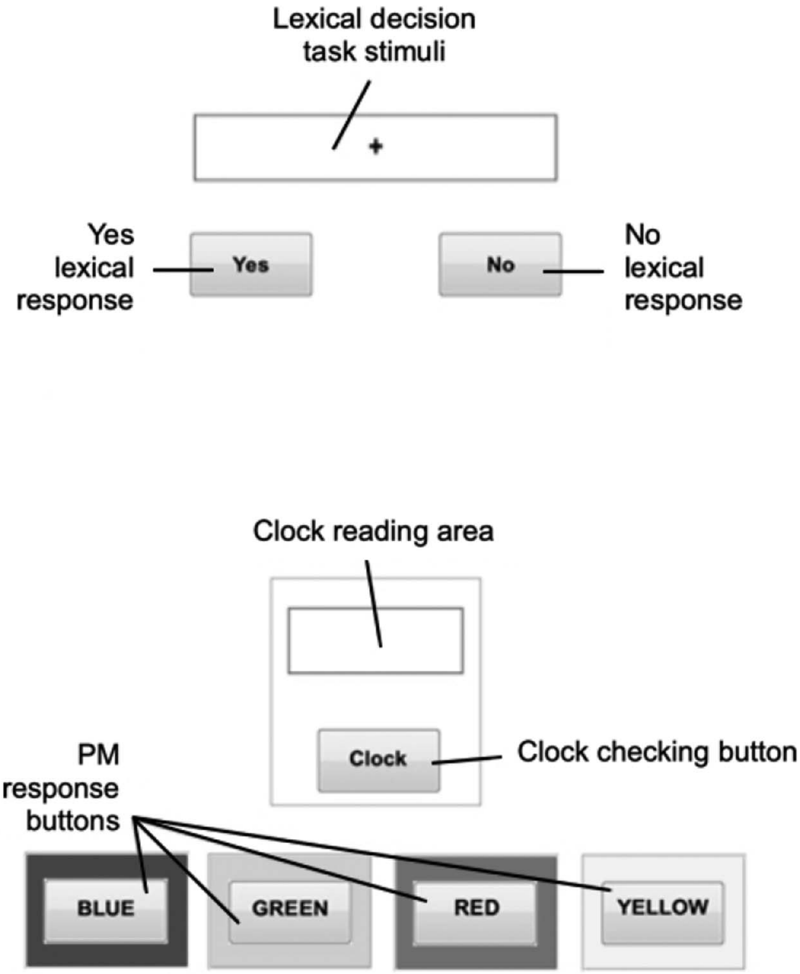
The stimuli for the OT (lexical decision) were 8 blocks of 30 stimuli, derived from a pool of 240 stimuli selected from the LEXVAR database (Barca et al., 2002). Half of the stimuli were words, and the remaining half nonwords generated by changing one or two letters from the words and matched for length in letters and bigram frequency. Stimuli were four-letter, five-letter, six-letter, and seven-letter items (1/4 for each length). Among the words, half of the stimuli were high-frequency words and the other half low-frequency (see Paizi et al., 2013). The stimuli were presented one at a time in the top-center of the screen, using the graphical interface of a custom-made program (see Figure 2). Two response buttons were placed right below the position in which the lexical stimuli appeared, one on the left side (the "yes" response) and one on the right side (the "no" response). Participants were then asked to indicate whether the current stimulus was an Italian word, or not, by clicking with the mouse on the "yes" button or on the "no" button, respectively. Soon after a response was given, the next stimulus appeared on the screen. The task was self-paced, but participants were asked to respond as quickly and accurately as possible. Presentation order of the stimuli within and among blocks was randomized and the procedure repeated until the PM task was completed.

Prospective Memory Task

Depending on the experimental condition, participants were asked to press a specific button or different buttons to meet multiple time deadlines from the beginning of the experiment, using the graphical interface of the program (see Figure 2). The response buttons were placed on the bottom of the screen, on a red, green, and blue background, and labeled accordingly. When a response button was not needed in a specific condition, it was grayed, together with its background, and made inactive. A clock square was placed in the lower part of the screen, and participants had to press a button labeled "clock" in order to check how much time had passed since the beginning of the task, with the time remaining visible for 2 s (in the format min:sec). The entire task lasted 45 min.

According to the condition to which they were assigned, participants received different instructions. In the rule conditions, participants were presented with time rules referring to specific recurrences and colors of the buttons to be pressed (e.g., every X minutes—green). The time recurrences were every 7 min, every 10 min, and every 16 min, while the three response buttons were identified by red, green, and blue color, respectively. The buttons that participants were instructed to press in order to provide their PM responses varied according to the condition to which participants were assigned. Participants in the *same response* condition were asked to press always the same button for all the rules (e.g., every 7 min, red; every 10 min, red; every 16 min, red), whereas participants in the *different responses* condition were asked to click on a different button for each rule (e.g., every 7 min, red; every 10 min, green; every 16 min, blue). Rule-response associations were fully counterbalanced within the groups. In the instance conditions, participants were presented with an ordered series of deadlines, each one paired with a button to be pressed. These deadlines perfectly matched the time rules presented in the rule conditions. Therefore, the rules every 7 min, every 10 min, and every 16 min resulted in the following sequence of deadlines: 7, 10, 14, 16, 20, 21, 28, 30, 32, 35, 40, 42. As in the rule condition, the response buttons were determined by the response condition: Participants in the same response condition responded to all the deadlines with the same button (e.g., 7 red, 10 red, 14 red, 16 red . . .), whereas participants in the different responses condition responded with different buttons, which matched exactly the ones presented in the rule different responses condition (e.g., 7 red, 10 green, 14 red, 16 blue . . .). Participants in the control condition were asked to complete the lexical-decision task only.

Figure 2
Graphical User Interface of the Prospective Memory Paradigm Used in Study 2



Note. The interface used in Study 1 had the same elements, with the exclusion of the yellow response button.

Procedure

Participants in the dual-task conditions were first presented with a learning phase. In the rule conditions, participants were presented with the three rules, written on a sheet, and their corresponding response (e.g., every 7 min, red), according to the conditions to which they were assigned. In the instance conditions, participants were presented with the sequence of deadlines associated with the responses (e.g., 7 red), in agreement with the assigned conditions. All the information was printed in black ink on a white background. Participants were told that the numbers corresponded to time durations in minutes, and they needed to study all the stimuli in view of the following phase of the study.

Participants studied the rule-color or number-color associations in the order in which the stimuli were presented in learning cycles of 2 min each. After each study cycle, participants had to report the rule-color or number-color associations in the correct presentation order on a response sheet. If they were not able to recall all the stimuli, they were asked to complete another study cycle and then they were tested again. This procedure was repeated until participants correctly remembered all the stimuli in the right order. Next, participants completed a 3-min filler task consisting of finding as many differences as possible between two similar pictures. After the filler task, participants were tested again on the learned material. If they failed to recall some of the stimuli, they were given a final chance to study them for 2 min and they were tested again. After the completion of the learning phase, participants were presented with the instructions of the OT and PM tasks. The instructions highlighted that both tasks were equally important and asked participants to carry out both tasks as quickly and accurately as possible. Participants in the control condition were given only the instructions of the OT. Participants then carried out the tasks for 45 min, until the software stopped them automatically.

After completing the tasks, participants were presented with an unexpected recall test. They were asked to report on a blank sheet all the PM deadlines they had to meet “as they come to their minds.”

Next, participants were asked to report how they managed to remember the deadlines with the corresponding responses during the PM task, and then their responses were recorded. If participants did not refer to any strategy, the experimenter asked the following question: "Did you use any method to help you recall the stimuli?"

Two judges, blind to the hypotheses of the study and to the condition assignment, coded the deadline recall answers and the self-reported strategy. The deadline recall answers were coded according to the recall order reported on the sheet: If the deadlines written down were in complete agreement to the rules learned in the first stage (e.g., 7 red, 14 red, 21 red, . . ., 10 green, 20 green, 30 green, . . ., 16 blue, 32, blue, etc.), a "rule" code was given; if they were recalled in complete agreement to the timeline (e.g., 7 red, 10 green, 14 red, 16 blue, 20 green, . . . etc.), a "sequence" code was used; and "other" was employed in the remaining cases.

The reported strategies were classified depending on the participants mentioning the use of the learned rules to figure out the deadlines ("rule"), the use of a serial recall strategy ("sequence"), or the use of other strategies or no strategy ("other"). In particular, the responses were coded as "rules" when participants referred to an ongoing computation of the deadlines during the task using the rules (e.g., "After clicking the [PM response] button, I calculated in my head the number that would come next"), to multiplication tables (e.g., "I recalled multiplication tables, and every time I computed the number that would come next"), or to the rules themselves (e.g., "I followed the rules, thinking about the next numbers"). On the contrary, all the responses that referred to serial recall of single intentions without mentioning computations, rules, or multiple numbers (e.g., "Once a deadline was passed, I tried to remember the next one, one at a time") were coded as "sequence." Ambiguous responses or responses referring to mixed strategies were coded as "other."

Results

We trimmed the OT RT data for each of the variables (see also Table 1) within the intention-framing conditions: RTs that were 3 SDs above or below the variable mean were replaced by the mean $\pm$ 3 SDs. The percentage of RTs substitutions for each variable was always lower than 2.5%.[5] Descriptive statistics for all the measures are presented in Table 2.

Learning

All participants in the rule conditions needed only one study cycle to reach the 100% learning criterion and correctly reported the stimuli after the filler task. In the instance conditions, 9 participants (43%) in the same response condition and 11 in the different responses condition (52%) needed more than one cycle to reach the 100% criterion (two cycles: $n = 16$; three cycles: $n = 4$). All participants, with a single exception, correctly recalled all the stimuli after the filler task. The Fisher's test on the number of participants who needed just one learning cycle versus more than one cycle to reach the 100% learning criterion showed a significant difference between framing conditions ($p < .001$, Cramer's V = .56), with participants in the instance conditions needing significantly more learning cycles than participants in the rule conditions to reach the 100% criterion, in line with our hypothesis. This happened both for participants in the same response conditions ($p = .001$, Cramer's V = .52) and for participants in the different response conditions ($p < .001$, Cramer's V = .60). No significant differences in learning cycles were observed between the response conditions (rule conditions: $p = 1.00$, Cramer's V = *na*; instance conditions: $p = .76$, Cramer's V = .10).

Representations and Intention-Setting Strategies

A significant difference between intention framing conditions was found in the order in which participants recalled the deadlines in the surprise recall test after the PM task, Fisher test $p < .001$, Cramer's V = .57 (see Table 3 for all the frequencies). Indeed, after excluding the small number of "other" responses, a large majority of participants in the instance conditions (92.1%) reported the deadlines in temporal sequence (e.g., 7 red, 10 green, 14 red, 16 blue, etc.), while only a minority of participants in the rule conditions did so (37.5%). On the contrary, more than 60% of participants in the rule conditions (62.5%) recalled the deadlines according to the rules they learned (e.g., 7 red, 14 red, 21 red, 28 red, 35 red, 42 red; 10 green, 20 green, 30 green, 40 green, etc.), whereas only 7.9% of participants in the instance conditions did so. These findings support the hypothesis that participants with different intention frames adopted different representations.

A significant difference between intention framing conditions was found also in relation to the strategy participants reported to have used in order to complete the task, Fisher test $p < .001$, Cramer's V = .95 (see Table 3). In particular, after excluding the small number of "other" responses, all participants in the rule conditions provided evidence of having used the rules to figure out the deadlines. On the contrary, the large majority of participants in the instance conditions reported to have recalled the deadlines one after the other (94.4%).

Moreover, in the rule conditions, all participants who recalled the deadlines according to the rules also reported having used a rule-based strategy during the PM task, while in the instance conditions a large majority of participants who recalled the deadlines in a sequential way also reported having used a serial recall strategy (85.7%, 30 of 35). We then checked whether the participants recalling the deadlines in an order compatible with their intention frame also adopted an intention-setting strategy congruent with the representation (i.e., a rule-based strategy following a rule frame and a rule-based recall of deadlines, and a serial recall strategy following an instance frame and a sequential recall of deadlines). A Fisher test comparing the consistent matches between deadline recall order and reported strategy with the inconsistent matches (rule-based recall + serial recall strategy in the rule conditions, serial recall + rule-based strategy in the instance conditions) highlighted a significant association between recall

[5] Data trimming led to the following substitutions: 1.44% of the OT RTs; 2.17% of the RTs after PM responses; 1.65% of the RTs in the 30-s intervals following PM responses; 1.56% of the RTs between PM responses. The analyses with trimmed data led to similar results as the ones with untrimmed data and the conclusions did not change. Two violations of the homogeneity of variance were found (for OT accuracy and commission errors), but in these cases nonparametric tests provided results similar to the one obtained with the parametric tests reported in the article. Indeed, nonparametric tests confirmed that the intention framing and the control conditions did not differ in the OT accuracy score (Kruskal-Wallis test: $\chi^2(2) = 2.62$, $p = .27$, $\varepsilon^2 = .03$) and that the difference between the rule and the instance conditions in the number of commission errors was not significant (Mann-Whithey $U = 740$, $p = .18$, $d = 0.14$).

Table 2
Descriptive Statistics for Study 1

Variable	Rule condition: Same response *M*	*SE*	Different responses *M*	*SE*	Total *M*	*SE*	Instance condition: Same response *M*	*SE*	Different responses *M*	*SE*	Total *M*	*SE*	Lexical decision only *M*	*SE*
Lexical decision task														
Accuracy (% correct)	.97	.003	.97	.004	.97	.002	.97	.006	.98	.003	.98	.003	.96	.010
RT (ms)	1086	39	1122	34	1104	26	1036	29	1029	28	1032	20	956	29
RT after PM (ms)	3541	342	4011	476	3776	292	2834	221	3449	361	3141	215		
RT 30-sec (ms)	1398	89	1489	74	1444	58	1214	49	1244	56	1229	37		
RT between PM (ms)	1096	63	1089	39	1093	37	1016	29	1009	28	1012	20		
Prospective memory task														
Hits (number of)	9.05	0.59	8.05	0.83	8.55	0.51	8.62	0.82	8.52	0.63	8.57	0.51		
Omissions (number of)	0.43	0.16	0.67	0.20	0.55	0.13	0.67	0.30	0.86	0.30	0.76	0.21		
Errors (number of)	0.57	0.24	1.43	0.46	1.00	0.26	0.81	0.15	1.67	0.47	1.24	0.25		
MAD (ms)	7339	1207	8320	1650	7830	1013	8212	2066	6520	1176	7366	1182		
Clock checks (number of)	58.14	4.90	53.71	7.32	55.93	4.36	55.33	5.45	56.71	5.85	56.02	3.95		

Note. The table reports the means (*M*) and standard errors (*SE*) in the various experimental conditions for the main dependent and control variables. RT = overall RT in the OT; RT after PM = mean RT between each PM response and the successive OT response; RT 30-sec = mean OT RT in the 30-second intervals immediately following each PM response; RT between PM = mean OT RT in the time intervals ranging from 30 seconds after a PM response to 30 seconds before the next PM response; hits = number of correct PM responses within ± 10 seconds from the deadline; omissions = number of missed PM deadlines; errors = wrong PM responses; MAD = mean absolute deviation in time of a PM response from the corresponding PM deadline (within ± 60 seconds).

order and reported strategy, $p < .001$, Cramer's V = .96 (see Table 3, note a for actual frequencies). These results support the hypothesis that the two intention frames are associated with different cognitive strategies for intention setting.

In order to test the hypothesis of a higher cognitive load in the rule condition versus the instance conditions, associated to the different intention-setting strategies (i.e., deadline projection and selection vs. serial cued recall; see Figure 1), we used two RT measures: (1) the mean RT in the OT in the 30-s interval following each PM response, controlling for the mean number of clock checks participants made in the same time interval, and (2) the RT between each PM response and the successive OT response. Both measures considered all the PM responses given by participants, irrespectively of whether the responses corresponded to a deadline correctly met or not. Nevertheless, significance of results and conclusions did not change considering only RTs following hits.

The results of a 2 (Intention Framing: rule vs. instance) × 2 (Response Type: same vs. different) between-subjects ANOVA on the mean RTs in the 30-s intervals following PM responses showed a significant effect of the intention frame, $F(1, 79) = 10.78$, $p = .002$, $\eta_p^2 = .12$, when controlling for the mean number of clock checks in the same interval, $F(1, 79) = 17.85$, $p < .001$, $\eta_p^2 = .18$. Participants in the rule conditions were slower (M = 1444, SE = 58) than participants in the instance conditions (M = 1229, SE = 37). The effect of the response condition, $F(1, 79) = 0.64$, $p = .43$, $\eta_p^2 = .01$, and the interaction, $F(1, 79) = 1.57$, $p = .21$, $\eta_p^2 = .02$, were not significant. The results did not change when we removed from the analysis the first OT responses following the PM responses.

Given that participants in the rule conditions might have been slower than participants in instance conditions in the 30-s intervals following PM responses due to a global slowing in performance, we tested whether the two framing conditions differed also in the average OT RTs in the time intervals ranging from 30 s after a PM response to 30 s before the next PM response. The results of a 2 (Intention Framing: rule vs. instance) × 2 (Response Type: same vs. different) between-subjects ANOVA showed no significant effects of the intention frame, $F(1, 80) = 3.61$, $p = .06$, $\eta_p^2 = .04$, or of the response condition, $F(1, 80) = 0.03$, $p = .87$, $\eta_p^2 = .00$, and no significant interaction, $F(1, 80) = 0.00$, $p = .99$, $\eta_p^2 = .00$.

For what concerns the mean RT time between each PM response and the successive OT response, although RTs were considerably higher in the rule conditions (M = 3776, SE = 292) than in the instance conditions (M = 3141, SD = 215), this difference did not reach significance in a 2 (Intention Framing: rule vs. instance) × 2 (Response Type: same vs. different) between-subjects ANOVA, $F(1, 80) = 3.08$, $p = .08$, $\eta_p^2 = .04$, possibly due to a higher variability of this measure as compared to the previous one. As with the previous measure, neither the main effect of the response condition, $F(1, 80) = 2.25$, $p = .14$, $\eta_p^2 = .03$, nor the interaction, $F(1, 80) = 0.04$, $p = .84$, $\eta_p^2 = .00$, were significant.

Overall, these results provide indications of a higher cognitive load soon after PM responses in the rule conditions versus the instance conditions, in agreement with the hypothesis that participants under the rule frame were engaged in incremental planning to set the next intention soon after each PM response was given.

Table 3
Frequencies of the Strategies Reported According to Deadline Recall Order and Intention Framing Condition

	Deadline recall order							
	Rule condition				Instance condition			
Strategy report	Sequence	Rules	Other	Total	Sequence	Rules	Other	Total
Sequence	0	0[a]	0	0	30[a]	1	3	34
Rules	15	25[a]	2	42	1[a]	1	0	2
Other	0	0	0	0	4	1	1	6
Total	15	25	2	42	35	3	4	42

[a] Frequencies of consistent and inconsistent matches between deadline recall order and strategy report in the rule and instance intention-framing conditions.

Cognitive Load

We carried out 2 (Intention Framing: rule vs. instance) × 2 (Response Type: same vs. different) between-participants ANOVAs on OT accuracy and overall OT RTs. The results showed no significant effects on OT accuracy (intention framing: $F(1, 80) = 0.28$, $p = .60$, $\eta_p^2 = .00$; response type: $F(1, 80) = 0.58$, $p = .45$, $\eta_p^2 = .01$; interaction: $F(1, 80) = 0.43$, $p = .51$, $\eta_p^2 = .01$). However, participants in the rule conditions ($M = 1104$, $SE = 26$) were significantly slower than participants in the instance conditions ($M = 1032$, $SE = 20$), $F(1, 80) = 4.73$, $p = .03$, $\eta_p^2 = .06$. The main effect of the response type, $F(1, 80) = 0.20$, $p = .66$, $\eta_p^2 = .00$, and the interaction, $F(1, 80) = 0.43$, $p = .51$, $\eta_p^2 = .01$, were not significant. The difference in OT RT between the two intention frames remained significant, $F(1, 78) = 4.96$, $p = .03$, $\eta_p^2 = .06$, even after including OT accuracy and the number of clock checks in the PM task as covariates, whereas the main effect of the response type, $F(1, 78) = 0.18$, $p = .67$, $\eta_p^2 = .00$, and the interaction, $F(1, 78) = 0.62$, $p = .43$, $\eta_p^2 = .01$, were still not significant. Given that there was no effect of the response type on accuracy and on overall RTs, we merged the response type conditions in order to compare the two intention framing conditions with the control condition with a one-way ANOVA. No significant differences were found between the intention framing conditions and the control one in the OT accuracy, $F(2, 102) = 3.01$, $p = .054$, $\eta_p^2 = .06$. Regarding overall OT RTs, the effect of the framing condition was significant, $F(2, 102) = 7.46$, $p < .001$, $\eta_p^2 = .13$. Participants in the rule conditions ($M = 1104$, $SE = 26$) were significantly slower than participants in the control condition ($M = 956$, $SE = 29$), $t = 3.79$, $p < .001$, and slower than participants in the instance conditions ($M = 1032$, $SE = 20$), $t = 2.24$, $p = .03$, which did not differ from participants in the control condition, $t = 1.96$, $p = .053$, although the mean RT was higher in the instance conditions than in the control condition. The results did not change when we removed from the analysis the first OT responses after the PM responses. In agreement with our hypothesis, the rule-based frame seems to entail a higher cognitive load than the instance-based frame and to interfere more with the OT performance.

Interestingly, the effect of intention framing on the overall OT RT was no longer significant when controlling for the RTs in the 30 s following each PM response, $F(1, 79) = 0.11$, $p = .74$, $\eta_p^2 = .00$, whereas the main effect of the response, $F(1, 79) = 0.12$, $p = .73$, $\eta_p^2 = .00$, and the interaction, $F(1, 79) = 0.24$, $p = .63$, $\eta_p^2 = .00$, remained not significant. This indicates that the slowdown soon after each PM response in the rule conditions can account for the effect of intention framing on the overall OT RTs.

PM Performance and External Time Monitoring

PM performance was assessed with multiple measures: number of hits, omissions, commission errors, and MAD of the responses from their respective deadlines. A response was scored as a hit when the correct button was pressed within ±10 s from the deadline. Responses that did not match any deadline (i.e., extra responses or responses provided before/after 60 s from the closest deadline) and responses provided with a wrong button press were scored as errors. Missed deadlines were scored as omissions. Moreover, the MAD was computed from the correct responses within ±60 s from the respective deadlines.

We carried out a series of 2 (Intention Framing: rule vs. instance) × 2 (Response Type: same vs. different) between-subjects ANOVAs on these dependent variables. The results on the number of hits showed no significant effects of the frame, $F(1, 80) = 0.001$, $p = .97$, $\eta_p^2 = .00$, and of the response condition, $F(1, 80) = 0.57$, $p = .45$, $\eta_p^2 = .01$, as well as no significant interaction, $F(1, 80) = 0.39$, $p = .53$, $\eta_p^2 = .00$. A significant effect of the response was found on the number of errors, $F(1, 80) = 5.76$, $p = .02$, $\eta_p^2 = .07$, whereas the main effect of the intention frame, $F(1, 80) = 0.44$, $p = .51$, $\eta_p^2 = .01$, and the frame-by-response interaction were not significant, $F(1, 80) = 0.00$, $p = 1.00$, $\eta_p^2 = .00$. A further examination of the errors showed that the effect of the response was mainly due to wrong button presses, which were possible only in the different response conditions. Indeed, after removing wrong button presses from the error scores, the effect of the response was no longer significant (0.69 vs. 0.98), $F(1, 80) = 1.05$, $p = .31$, $\eta_p^2 = .01$. No effects were found in relation to the number of omissions that participants made (framing: $F(1, 80) = 0.76$, $p = .38$, $\eta_p^2 = .01$; response: $F(1, 80) = 0.76$, $p = .38$, $\eta_p^2 = .01$; interaction: $F(1, 80) = 0.01$, $p = .92$, $\eta_p^2 = .00$). Finally, also the results on the MAD showed no significant effects (framing: $F(1, 80) = 0.09$, $p = .77$, $\eta_p^2 = .00$; response: $F(1, 80) = 0.05$, $p = .82$, $\eta_p^2 = .00$; interaction: $F(1, 80) = 0.73$, $p = .40$, $\eta_p^2 = .01$).

We also analyzed the number of clock checks during the task. No significant differences were found (framing: $F(1, 80) = 0.00$, $p = .99$, $\eta_p^2 = .00$; response: $F(1, 80) = 0.07$, $p = .80$, $\eta_p^2 = .00$; interaction: $F(1, 80) = 0.24$, $p = .63$, $\eta_p^2 = .00$). Nevertheless, as is common in PM studies, in both framing conditions the number of clock checks participants made was positively correlated to the number of hits (rule conditions: $r = .49$, $p = .001$; instance conditions: $r = .52$, $p < .001$) and negatively correlated to MAD (rule conditions: $r = -.55$, $p < .001$; instance conditions: $r = -.51$, $p < .001$).

We further investigated clock-checking frequency distributions over time by intention framing conditions. Given that the length of the time intervals between PM responses varied from 1 min to 7 min, we performed separate analyses for different interval lengths, excluding too short ones (≤ 2 min, $n = 5$). As usual in time-based PM studies, we analyzed the number of clock checks that participants made in 1-min periods before a correct PM response (hit), but we did so separately for 3-min intervals ($n = 2$), 4-min intervals ($n = 2$), 5-min intervals ($n = 1$), and 7-min intervals ($n = 2$; see Figure 3).

Mixed ANOVAs with time as a within-participants factor and framing condition as a between-participants factor showed a main effect of the time interval for all the four intervals considered (Fs > 28.30, ps $<.001$), with post hoc tests showing no increase in the number of clock checks with the passage of time until the last minute before the deadline, which showed a significant increase when compared to the preceding minute (ts > 5.60, ps $<$ .001). The framing condition did not affect clock checking (main effect of framing: Fs < 0.67, ps $> .40$; interaction: Fs < 0.99, ps $> .39$).[6] Taken together, these analyses showed that participants accentuated the number of clock checks in the last minute before the deadline regardless of the intention framing condition.

Discussion

Study 1 provided evidence showing the psychological dissimilarity of the same time-based PM task when prospective intentions are framed as time rules versus corresponding time instances. The results showed that the rule frame favored learning but was associated with a higher cognitive load during the PM task execution, increasing the OT RT. A finer-grained analysis of the OT data showed a stronger increase in RT soon after a PM deadline was met in the rule condition (vs. the instance condition), suggesting that setting the next PM intention is more cognitively demanding in this condition, and this explained the overall effect of intention framing on cognitive load in the rule (vs. instance) condition. This interpretation was also supported by participants' retrospective reports on their intention-setting strategies and by the observation that monitoring strategies (after an intention has been set) did not differ between the framing conditions. These findings are consistent with the hypothesis that a rule frame is associated with an incremental planning strategy, requiring deadline projection and intention selection, while an instance frame is associated with a serial recall strategy of the next deadline (see Figure 1). Moreover, the order in which participants retrieved the deadlines in the surprise recall task provided behavioral evidence that the two intention frames trigger two different representations, which were related to the two intention-setting strategies.

The RT results of Study 1 also showed that what matters for intention framing is the presentation/representation of the intentions, and not their association with specific responses or the number of different responses to be produced. Indeed, no significant effects of the response factor or response-related interactions have been detected, with the exception of a main effect on the number of PM errors. Nevertheless, our results also show that the intention framing manipulation did not significantly affect PM performance, possibly because the difficulty of the PM task, in terms of number of rules and corresponding instances, was not sufficient to make differences in PM performance emerge. In order to test this possibility, in Study 2 we increased the PM task difficulty by adding a new rule (and an additional set of corresponding instances).

Study 2: Four Rules

Study 2 followed the same rationale of Study 1, contrasting rule-based and instance-based intention frames with the same paradigm and in a between-participants design, but in this experiment we increased the difficulty of the PM task by adding a fourth time rule (and a corresponding series of instances) to the ones used in Study 1. Indeed, the main aim of Study 2 was to appraise whether, in a PM task more difficult than the one employed in Study 1, differences in PM performance would also emerge in relation to different intention frames, beyond the differences in intention learning, intention representations, intention-setting strategies, and cognitive load already observed in the previous experiment.

In Study 2, we also introduced three minor methodological changes. First, given that the first experiment already assessed the cognitive costs in intention-framing PM conditions compared to a no-PM control condition, and because our interests were primarily in the comparison of the rule and the instance framing conditions, the second experiment did not include the no-PM control condition. However, our analyses included also a cross-experiment comparison with the control condition of Study 1, considering the high similarity between the two studies in participants (recruited from the same population), physical setting (same lab), and temporal context (same year). Second, given that our response manipulation in Study 1 did not have major effects (and showed no interactions with the intention-framing manipulation), participants of Study 2 always had to press a different response button for each rule (or the associated set of instances), as is typical for studies with multiple intentions, in which each intention is usually associated with a different action. Third, we changed the learning procedure for the instance condition (as explained below), because we wanted to maintain the perfect learning criterion of Study 1 and pretesting showed that the procedure used in Study 1 made perfect learning too hard after we increased the number of deadlines.

Method

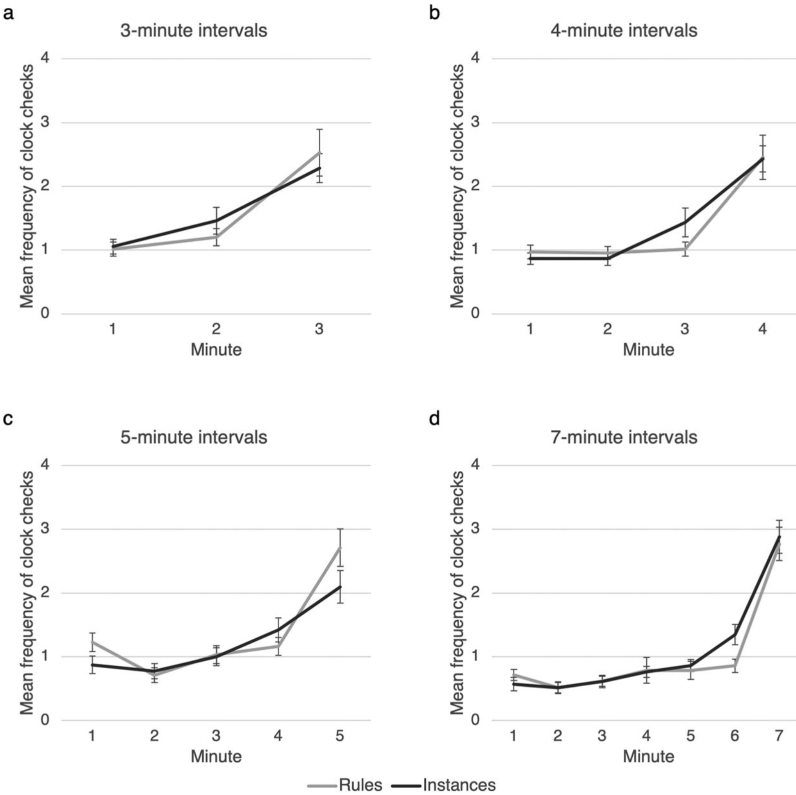
Participants

Forty-eight undergraduates took part in the study (77% female, age: $M = 20.81$, $SD = 3.41$), receiving course credits for their participation. At the recruitment stage, we verified that no participant enrolled for Study 2 had already taken part in Study 1. The sample size was decided after a power analysis assuming a medium effect size in a two-group ANOVA design and considering the 17 deadlines as repeated measures (power $> .90$). All participants provided their written informed consent, and the research

[6] Except for the 5-min intervals, in which a significant interaction was found, $F(4, 236) = 2.50$, $p = .04$, $\eta_p^2 = .04$. Post hoc tests showed that, while both framing conditions displayed the same trend observed in the other intervals (significant difference between the last minute and the previous one, ts > 2.94, ps $< .01$), participants in the instance condition made slightly fewer clock checks in the last minute than participants in the rule condition ($t = 2.40$, $p = .02$).

Figure 3

Mean Frequency of Clock Checks in 1-Min Periods Before a PM Deadline by Time Interval Length (3, 4, 5, and 7 Min) and Framing Condition (Rule vs. Instance)



Note. Error bars represent standard errors.

was approved by the Ethical Committee of the University of Trieste.

Design and Tasks

Participants were randomly assigned to the rule condition or to the instance condition ($n = 24$ for both groups). As in Study 1, participants completed a PM task while being engaged in an OT (lexical decision). However, in the rule condition, we added the rule "every 9 min" to the three already used in Study 1 (i.e., every 7 min, every 10 min, every 16 min). In the instance condition, the addition of the fourth rule generated five extra instances, resulting in 17 instances overall (i.e., 7, 9, 10, 14, 16, 18, 20, 21, 27, 28, 30, 32, 35, 36, 40, 42, 45). The task duration was 46 min. Four response buttons were made available, each of them identified by a color (i.e., red, green, blue, and yellow; see Figure 2). Participants were asked to press a different button for each rule in the rule condition (i.e., every 7 min, blue; every 9 min, yellow; every 10 min, green; every 16 min, red) and to press buttons that matched exactly the abovementioned rules in the instance condition (7 blue, 9 yellow, 10 green, 14 blue, 16 red . . .). All the other aspects of the tasks were as in Study 1.

Procedure

In the rule condition, the learning phase was as in Study 1. Participants were presented with the four rules written on a sheet, associated with corresponding response buttons (e.g., every 7 min, red). They underwent 2-min study + test cycles until they reached the 100% criterion of correct recall, followed by the same filler task of Study 1, a test session, and another study cycle in case they failed the test. In the instance condition, the Study 1 procedure was modified in order to facilitate learning a larger number of instances (17 times paired with 4 response buttons). The instances were divided into three blocks of 6, 6, and 5 instances, respectively. For each block, participants were engaged in 1-min study + test cycles until they reached the 100% criterion of correct recall. After reaching the 100% criterion in every block, they were asked to recall all the 17 instances in the correct presentation order. If they did not reach the 100% criterion of correct recall, participants went through 2-min learning cycles with all the 17 instances presented, until they reached the criterion. Then they were presented with the 3-min filler task (find the differences) and they were tested again. As in Study 1, if they failed the test, they went through another study cycle.

Participants then received the dual-task instructions as in Study 1 and they completed the PM task along with the OT, with the two tasks being assigned the same importance. Following the procedure used in Study 1, after completing the tasks, participants were presented with the unexpected recall test of the deadlines, and they were probed about the strategies used.

Results

We trimmed each RT variable within the intention framing conditions as in Study 1. The percentage of RT substitutions for each variable was always lower than 2.5%.[7] Descriptive statistics for all the measures in Study 2 are shown in Table 4.

Learning

As in Study 1, all participants in the rule condition reached the 100% criterion of correct recall in a single learning cycle and correctly recalled the stimuli after the filler task. In the instance condition, participants needed on average slightly more than one study cycle for learning each block of stimuli (Block 1 $M = 1.21$, $SE = 0.08$; Block 2 $M = 1.21$, $SE = 0.08$; Block 3 $M = 1.17$, $SE = 0.08$), but a mean of 2.25 additional cycles was necessary to correctly recall all the instances together ($SE = 0.21$). Moreover, four participants failed the test after the filler task and needed another learning cycle. Even if the different learning methods used in rule and instance conditions in Study 2 prevent us from directly comparing them on the number of learning cycles, the just-presented descriptive statistics indicate faster learning in the rule condition, in line with Study 1 and our hypothesis on learning.

Representations and Intention-Setting Strategies

Two judges, blind to the hypotheses of the study and condition assignment, coded the deadline recall answers and the self-reported strategy following the coding scheme of Study 1 (see Study 1 method section). The intention framing conditions differed in the order in which participants recalled the deadlines on the surprise final test, Fisher test $p < .001$, Cramer's V = .54 (see Table 5 for all the frequencies). Consistent with Study 1, after excluding the small number of "other" responses, 90.9% of participants in the instance condition recalled the deadlines according to their time sequence. In contrast, 60.9% of participants in the rule condition recalled the deadlines according to the rules they learned (additionally, in this condition, 77.8% of participants who arranged the deadlines according to a time-based sequence verbally computed aloud the deadlines during the recall before writing down the answers, using the rules to reconstruct the serial order). These findings are consistent with the hypothesis that the two intention frames triggered different representations of the deadlines, matching their respective frames.

The two framing conditions also differed in their retrospective report of the strategies used during the task, Fisher test $p < .001$, Cramer's V = .91 (see Table 5). In particular, after excluding the small number of "other" responses, all participants in the rule condition reported using the rules to establish the deadlines during the task. In the instance condition, 90.9% of participants reported to have used a recall strategy following the serial order. These findings agree with Study 1 and with the hypothesis on the intention-setting strategies as related to the framing manipulation.

Moreover, in the rule condition, almost all participants who recalled the deadlines according to the rules reported having used a rule-based intention-setting strategy (92.9%, 13 on 14), similarly to what happened in the instance condition, in which participants who recalled the deadlines in a sequential way reported having used a recall strategy following the serial order in the large majority of cases (85%, 17 on 20). A Fisher test comparing these two conditions with the inconsistent matches (rule-based recall and serial recall strategy in the rule condition, serial recall and rule-based strategy in the instance condition) showed a significant association between recall order and reported intention-setting strategy, $p < .001$, Cramer's V = .94 (see Table 5, note a, for the actual frequencies).

In order to test the hypothesis of different intention-setting strategies under different framing conditions, we examined the cognitive load soon after a deadline was met with between-participants ANOVAs. The results showed that participants in the rule condition ($M = 2062$, $SE = 229$) were significantly slower in the OT during the 30-s intervals following PM responses than participants in the instance condition ($M = 1372$, $SE = 73$), $F(1, 45) = 8.14$, $p = .01$, $\eta_p^2 = .15$, when controlling for the mean number of clock checks participants made in the same time interval, $F(1, 45) = 0.12$, $p = .73$, $\eta_p^2 = .00$. The results did not change when we removed from the analysis the first OT responses following the PM responses. As in Study 1, no difference between the conditions was found on RTs in time intervals more distant from PM responses (i.e., intervals between 30 s after each PM response and 30 s before the next PM responses), $F(1, 46) = 0.00$, $p = 1.00$, $\eta_p^2 = .00$. Additionally, the results showed that participants in the rule condition displayed a significantly higher mean RT in the first OT response soon after a PM response ($M = 5124$, $SE = 680$) than participants in the instance condition ($M = 3328$, $SE = 312$), $F(1, 46) = 5.77$, $p = .02$, $\eta_p^2 = .11$.

Cognitive Load

Between-participants ANOVAs showed no significant differences between the rule and the instance conditions in OT accuracy (0.97 vs. 0.97), $F(1, 46) = 0.07$, $p = .80$, $\eta_p^2 = .00$, or in OT RT (1124 vs. 1105), $F(1, 46) = 0.11$, $p = .74$, $\eta_p^2 = .00$. The intention framing conditions did not differ in OT RT, $F(1, 44) = 0.11$, $p = .74$, $\eta_p^2 = .00$, even when controlling for accuracy in the OT and for the number of clock checks. The results did not change when we removed from the analysis the first OT responses after the PM responses. A cross-experimental comparison showed that both the rule and the instance conditions of Study 2 differed significantly from the control condition of Study 1, $F(2, 66) = 6.13$, $p = .004$,

[7] Data trimming led to the following substitutions: 1.30% of overall OT RTs; 2.04% of the RTs after PM; 1.49% of the RTs in the 30-s intervals following PM responses; 1.44% of the RTs between PM responses. Analyses based on untrimmed data showed results similar to the ones with trimmed data, and the conclusions did not change. In case of homogeneity of variance violations (RTs in the 30-s intervals following PM responses, OT RTs after PM responses, omission errors, OT accuracy score), nonparametric tests provided results similar to the ones obtained with the parametric tests reported in the article. Indeed, nonparametric tests confirmed that participants in the rule condition, compared to participants in the instance condition, were slower in the 30-s intervals following PM responses (Mann-Whithey $U = 183$, $p = .03$, $d = 0.58$), were slower in the OT responses after PM responses (Mann-Whithey $U = 186$, $p = .04$, $d = 0.69$), and made significantly more omissions (Mann-Whithey $U = 142$, $p = .002$, $d = 1.08$). Regarding the OT accuracy score, nonparametric tests confirmed no difference between the two framing conditions and Study 1 control condition (Kruskal-Wallis test: $\chi^2(2) = 0.18$, $p = .92$, $\varepsilon^2 = .00$).

Table 4
Descriptive Statistics for Study 2

Variable	Intention framing			
	Rule condition		Instance condition	
	M	*SE*	*M*	*SE*
Lexical decision task				
Accuracy (% correct)	.97	.003	.97	.005
RT (ms)	1124	35	1105	42
RT after PM (ms)	5124	680	3328	312
RT 30-sec (ms)	2062	229	1373	73
RT between PM (ms)	1086	39	1087	40
Prospective memory				
Hits (number of)	7.87	0.91	12.08	0.73
Omissions (number of)	3.79	0.87	0.50	0.12
Errors (number of)	3.67	0.73	2.04	0.53
MAD (ms)	10634	1323	6008	885
Clock checks (number of)	91.38	23.21	71.92	6.05

Note. The table reports the means (*M*) and standard errors (*SE*) in the two intention-framing conditions (rule and instance) for the main dependent and control variables. RT = overall RT in the OT; RT after PM = mean RT between each PM response and the successive OT response; RT 30-sec = mean OT RT in the 30-second intervals immediately following each PM response; RT between PM = mean OT RT in the time intervals ranging from 30 seconds after a PM response to 30 seconds before the next PM response; hits = number of correct PM responses within ± 10 seconds from the deadline; omissions = number of missed PM deadlines; errors = wrong PM responses; MAD = mean absolute deviation in time of a PM response from the corresponding PM deadline (within ± 60 seconds).

$\eta_p^2 = .16$. In particular, participants in the control group were significantly faster ($M = 956$, $SE = 29$) than both participants in the rule ($M = 1124$, $SE = 35$, $t = 3.23$, $p = .002$) and in the instance conditions ($M = 1105$, $SE = 42$, $t = 2.87$, $p = .01$). Moreover, as in Study 1, no differences were found in OT accuracy among the groups, $F(2, 66) = 1.31$, $p = .28$, $\eta_p^2 = .04$.

PM Performance and External Time Monitoring

We analyzed the number of hits, errors, omissions, and MAD from the deadlines for the PM task with a series of between-participants ANOVAs. The results showed significantly more hits in the instance condition ($M = 12.08$, $SE = 0.73$) than in the rule condition ($M = 7.87$, $SE = 0.91$), $F(1, 46) = 12.99$, $p < .001$, $\eta_p^2 = .22$. There were more commission errors in the rule condition ($M = 3.67$; $SE = 0.73$) than in the instance condition ($M = 2.04$, $SE = 0.53$), although this difference did not reach significance, $F(1, 46) = 3.24$, $p = .08$, $\eta_p^2 = .07$. Moreover, participants in the instance condition made significantly fewer omissions ($M = 0.50$, $SE = 0.12$) than participants in the rule condition ($M = 3.79$, $SE = 0.87$), $F(1, 46) = 14.11$, $p < .001$, $\eta_p^2 = .23$. Finally, the MAD from the deadlines was significantly smaller in the instance condition ($M = 6008$, $SE = 885$) than in the rule condition ($M = 10{,}634$, $SE = 1323$), $F(1, 46) = 8.45$, $p = .01$, $\eta_p^2 = .16$. These results clearly show a better PM performance in the instance condition than in the rule condition.

No difference between the framing conditions was found in the number of clock checks made during the task (instance: $M = 71.92$, $SE = 6.05$; rule: $M = 91.38$, $SE = 23.21$), $F(1, 46) = 0.66$, $p = .42$, $\eta_p^2 = .01$. Monitoring frequency was positively correlated with the number of hits, $r = .45$, $p = .03$ and negatively correlated with MAD, $r = -.62$, $p = .001$, but only in the instance condition.

We performed the same analysis as in Study 1 on clock checks frequency distribution over time (see Figure 4). Overall, we found evidence of the same trend found in Study 1 and in previous research on perspective memory: Participants increased the frequency of clock checks as they approached the deadline, in particular in the last minute before the PM response, although this trend was attenuated in the rule framing condition for two interval lengths (4 and 6 min), possibly signaling a somewhat less effective time monitoring under this intention framing condition for some intervals.[8]

Discussion

In Study 2, we increased PM task difficulty and found consistent effects of intentions framing on multiple measures of PM perfor-

[8] In particular, a significant main effect of time was found for the 3-min intervals, $F(2, 72) = 26.48$, $p < .001$, $\eta_p^2 = .42$, and for the 7-min intervals, $F(6, 174) = 19.56$, $p < .001$, $\eta_p^2 = .40$, whereas the effect of the intention framing condition (Fs < 0.04, ps $> .84$) and the interactions (Fs < 0.78, ps $> .58$) were not significant for these intervals. For the 3-min intervals, post hoc tests highlighted only a significant difference between the last minute and the preceding one ($t = 6.51$, $p < .001$). In the 7-min intervals, there was no increase in the number of clock checks (ts < 1.14, ps $> .25$) until minute 6, in which participants checked the clock more frequently than in the previous period ($t = 2.03$, $p = .04$), but less than in the last minute ($t = 6.22$, $p < .001$). For 4-min and 6-min intervals, a significant time by framing condition interaction was found (4-min: $F(3, 108) = 4.00$, $p = .01$, $\eta_p^2 = .10$; 6-min: $F(5, 90) = 4.00$, $p = .003$, $\eta_p^2 = .18$). For the 4-min intervals, post hoc tests showed the previously-found trend both for rule and instance conditions (increased number of clock checks in the last minute than in the preceding one, $t = 3.15$, $p = .002$, and $t = 7.59$, $p < .001$, respectively), but such an increase was higher in instance condition than in rule condition ($t = 3.34$, $p = .001$). In 6-min intervals, participants in the rule condition made fewer clock checks in the last minute than participants in the instance condition ($t = 4.11$, $p < .001$), and they did not show a significant increase in the number of clock checks in the last minute from the previous minute ($t = 0.34$, $p = .74$), unlike participants in the instance condition ($t = 6.10$, $p < .001$).

Table 5
Frequencies of the Strategies Reported According to Deadline Recall Order and Intention Framing Condition

	Deadline recall order							
	Rule condition				Instance condition			
Strategy report	Sequence	Rules	Other	Total	Sequence	Rules	Other	Total
Sequence	0	0[a]	0	0	17[a]	1	2	20
Rules	7	13[a]	1	21	1[a]	1	0	2
Other	2	1	0	3	2	0	0	2
Total	9	14	1	24	20	2	2	24

[a] Frequencies of consistent and inconsistent matches between deadline recall order and strategy report in the rule and instance intention-framing conditions.

mance. Namely, the instance frame led to a better PM performance than the rule frame in terms of hits, omissions, and MAD, and there was no trade-off with the accuracy in the OT, which was completed accurately in both intention framing conditions.

In Study 2, as in Study 1, significant differences between intention framing conditions were detected in the cognitive load soon after each PM was met. Indeed, the two measures we used showed much higher OT RTs in the rule condition than in the instance condition, with differences larger than the ones observed in Study 1. These findings support the hypothesis of the adoption of an incremental planning strategy with a rule frame versus a serial recall strategy with an instance frame. Moreover, the deadline recall data and the strategy reports in Study 2 provided evidence fully consistent with Study 1, strengthening the idea that the two intention frames of the PM task triggered different mental representations and were associated with different intention-setting strategies.

No significant difference between the intention framing conditions was found in the overall OT RT in Study 2, but the results showed higher cognitive load in the two framing conditions than in the control condition of Study 1. The inspection of RTs on the lexical-decision task shows an unexpected increased load in the instance condition in Study 2 as compared with Study 1 (Table 2 vs. Table 4). This may be explained by the fact that participants had to deal with a greater number of instances in Study 2, potentially generating more interference and requiring more active maintenance of the current intention. This may have increased the overall cognitive load (and OT RT variability) in the instance condition of Study 2 (vs. Study 1), without sacrificing the accuracy of the serial recall strategy needed to complete the PM task.

General Discussion

The studies presented in this article had the goal of appraising the cognitive and behavioral effects of intention framing on time-based PM. We manipulated the framing of intentions (time rules vs. instances) in a well-structured time-based PM task and evaluated the effects of these two frames on intention learning, intention representation, intention-setting strategies, cognitive load, and PM performance. In Study 1, we showed that learning time rules is easier than learning corresponding sets of instances, and that intention representations match the way in which intentions are initially presented. We acquired evidence supporting the use of two different intention-setting strategies, incremental planning in the rule condition and serial recall of intentions in the instance condition, which were each associated with a different cognitive load. In Study 2, with a more difficult PM task, we also observed marked differences in multiple measures of PM performance, favoring the instance framing condition over the rule framing one (see last column in Table 1 for a synthesis of findings).

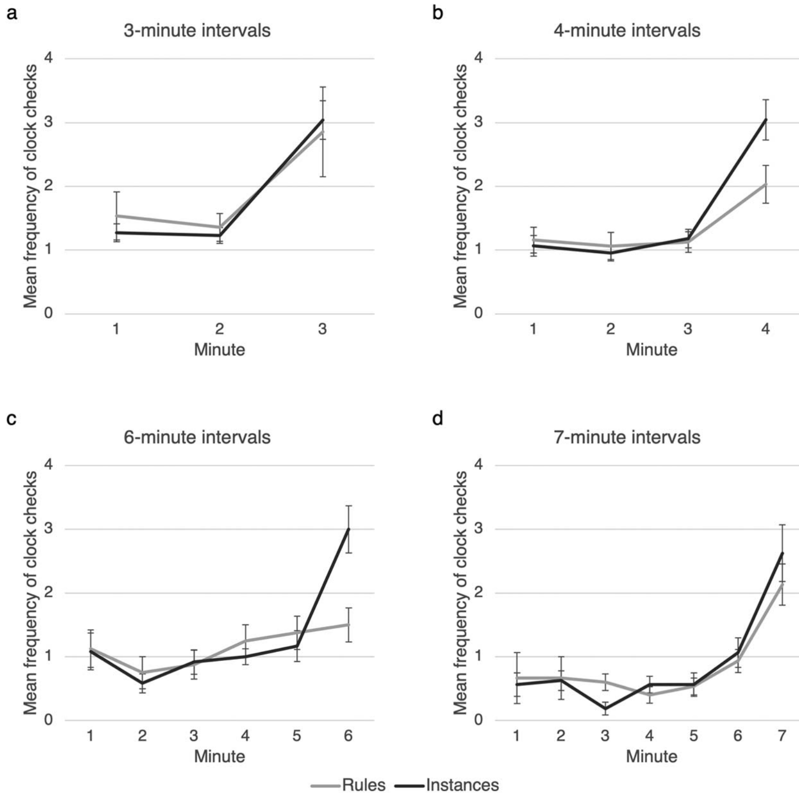
The first theoretical implication of our findings stems from the demonstration of the psychological dissimilarity of a time isomorphic PM task when the intentions are framed as time rules versus time instances. This work extends earlier cognitive studies on the influence of presentation form (e.g., Kotovsky et al., 1985; Simon & Hayes, 1976) and problem framing (e.g., Levin et al., 1998; Thaler, 1999; Tversky & Kahneman, 1981, 1986) to the domain of time-based prospective remembering, a domain in which this issue did not receive attention, possibly due to the almost exclusive focus on single (repeated) intentions and simple tasks in PM paradigms. Thus, even in the time-based PM domain, the way in which one and the same task is framed can make a profound difference in psychological terms, affecting mental representation, cognitive strategies, and performance.

Theoretically speaking, these findings suggest the need to broaden current theories of prospective remembering (e.g., Anderson et al., 2017; Scullin et al., 2018; Shelton & Scullin, 2017; Smith, 2003, 2017), including intention framing as an important factor related to intention representations and intention-setting strategies, at least for what concerns time-based PM tasks with multiple intentions. Interestingly, there is some evidence coming from studies in event-based PM which seems to indicate, in a converging manner, that instance-like representations may be associated with lower cognitive load and better PM performance than more general forms of representation (see, e.g., Scullin et al., 2018). However, there are significant differences between these event-based PM paradigms and our time-based PM paradigm, which involves goal-directed planning and proactive monitoring of multiple deadlines on a predictable time structure and a direct manipulation of the intention frame. Therefore, the degree of convergence between our studies and event-based paradigms still needs to be empirically explored. A promising possibility would be to direct this exploration toward studies in event-based PM with multiple intentions in which contextual hints allow participants to anticipate the next potential deadlines and thus provide room for applying intention-setting strategies beyond cue monitoring ones (e.g., Smith et al., 2017; see also Bowden et al., 2017).

For what concerns the debate on the processes underlying PM performance, we think that our results extend the view that cognitively costly intention-setting and time-monitoring processes are at stake when trying to remember multiple time-based intentions.

Figure 4

Mean Frequency of Clock Checks Before a PM Deadline in 1-Min Periods by Time Interval Length (Intervals of 3, 4, 6, and 7 Min) and Framing Condition (Rules vs. Instances)



Note. Error bars represent standard errors.

The results also agree with the view that these processes can vary in their cognitive demands in relation to the difficulty of the PM task and to the way intentions are framed, thus reconciling and hopefully extending the PAM theory and the MP framework. Furthermore, our studies contribute to the very meager research on how people remember multiple time-based intentions (e.g., Hicks et al., 2005; Kubik et al., 2020; Rendell & Craik, 2000), suggesting that handling multiple intentions in time may require more complex and proactive strategies than the ones based on simpler monitoring or associative processes postulated for simpler PM paradigms. In a broader sense, our findings indicate that current theories of PM need to be extended to more goal-directed (and proactive rather than reactive) tasks with multiple intentions, ones which are rather common in everyday life.

The second theoretical implication of our findings concerns the potential trade-off between intention learning costs and implementation costs suggested by our results. We have shown that learning time rules seem much easier than corresponding time instances, but time rules are associated with higher costs in the implementation stage and, when the task gets more difficult, with worse performance. Thus, the use of one type of representation or the other could entail a trade-off between learning costs and implementation costs, similar to other cognitive trade-offs observed in memory research (Gilbert et al., 2020) and in other areas of cognition (e.g., Christensen-Szalanski, 1978; Payne et al., 1993). This is a theoretical and applied issue that deserves further investigation in the prospective remembering domain. Moreover, an important area of future research may involve the investigation of when and how participants change the representation initially induced by the intention frame, and how these transitions are related to individual differences in cognitive skills. We hypothesize that the experience of high implementation costs and poor PM performance may eventually lead to an adaptive and spontaneous change in representation (e.g., from rules to instances) and in intention-setting strategies, as already observed in other areas of cognition (e.g., Payne et al., 1993; Simon & Hayes, 1976). Thus, an interesting possibility would be to systematically manipulate implementation costs (and OT demands) and appraise via representational/strategy probes whether and when representational/strategic transitions take place.

The third theoretical implication of our work is related to the identification of two different cognitive strategies used for intention setting. Literature on PM has usually not delved deeply into the strategies that participants employ, and this limited our understanding of how prospective remembering is accomplished. Moreover, strategies in prospective memory are considered mainly in reference to when or how frequently to monitor for the relevant environmental or time cues (e.g., Goedeken et al., 2018; Mäntylä et al., 2009; Reese-Melancon et al., 2019; Rummel & Meiser, 2013; Smith et al., 2017) and not in relation to when or how to set the next prospective intention (after the completion of the previous one).

Our findings suggest that, at least when multiple time-based intentions are at stake and a clear (and fixed) deadline sequential order is not defined from the beginning (as might be also the case for several complex real-life environments), the accomplishment of a PM task may not involve only strategic monitoring for time cues, but also strategic intention setting. Therefore, in these cases, the cost and performance profiles may depend on a more complex interplay between representational and strategic elements. More specifically, our studies allowed us to gain some empirical support for the use of incremental planning and serial recall strategies for intention setting, with the adoption of one or the other strategy being contingent on the intention frame of the PM task. At the same time, we generally replicated the results of previous studies for what concerns external time-monitoring strategies (Mäntylä et al., 2007, 2009; Mioni & Stablum, 2014).

Incremental planning is frequently used to handle complex problems and to trim down complexity heuristically, and it usually works reasonably well (e.g., Altmann & Trafton, 2002; Ernst & Newell, 1969; Newell & Simon, 1972). Serial recall strategies based on associative cueing have been postulated in memory research (e.g., Altmann, 2000; Bäuml & Aslan, 2006; Kahana, 1996; Murdock, 1983; Nairne, 1983), but they usually remained confined to retrospective episodic remembering. Here, we showed that these strategies can be used also for prospective remembering. Future research may build on these findings to further investigate and better characterize the strategies people use to set intentions in prospective remembering, and the relations among mental representation of intentions, intention setting strategies, and monitoring strategies.

From the applied perspective, the observation that the intention framing of a PM task is associated with different learning costs and with performance accuracy may inform the development of potential interventions. In the case of a small number of recurrent intentions, the rule-based intention frame may be preferred due to ease of learning, and performance may be improved if recurrent time intentions can be associated with significant events in the daily routine (e.g., taking pills after meals) and strengthened by implementation intentions (Insel et al., 2016). However, when many recurrent intentions have to be remembered, deadline offloading in the form of instances (e.g., on a physical or digital calendar) may produce better results, especially if digital prompts are also available as reminders for the upcoming deadlines (e.g., Ferguson et al., 2015; Jamieson et al., 2014). Thus, the development of applied research related to intention framing in PM tasks may be another promising future direction.

Limitations and Future Research

Although our studies represent a first step forward in the investigation of intention framing in time-based PM, our research has some limitations. First, our study employs an extension of the classical time-based PM paradigm, and as such it allows a good experimental control, but its external and ecological validity may be limited. Thus, future investigations may move toward more realistic tasks and even field studies (e.g., Au et al., 2018; Rendell & Craik, 2000).

A second limitation may concern the way in which we assessed representations and strategies. Surprise final recall and retrospective reports, in addition to RT analysis, can provide a good insight, but this evidence can be strengthened by the use of different methods, like other experimental manipulations selectively affecting representations and strategies, concurrent verbal protocols, and neuroimaging or neurostimulation techniques. Furthermore, with reference to representations, a potentially problematic issue in our studies concerns the possibility that participants may have spontaneously converted the rules into instances (thus compiling them) or vice versa (i.e., induced the rules from the instances), during the learning phase or the main PM task. However, even if this possibility (as well as the use of a "mixed" type of representation) cannot be excluded for some of the participants, there are both (a priori) theoretical considerations and empirical evidence running against the hypothesis that the majority of participants may have changed the representation, initially induced by the framing manipulation, during the study. On the theoretical side, the literature on problem-solving isomorphs (e.g., Kotovsky et al., 1985; Simon & Hayes, 1976) and representations on decision making (e.g., Levin et al., 1998; Thaler, 1999; Tversky & Kahneman, 1981, 1986) shows that participants typically stick to the representation suggested by problem wording, unless the high cognitive cost of using it (or the fact of remaining stuck during the task execution) promotes a representational change. Moreover, representational changes in a task like ours do not come easy nor without a cost, and they are hindered by the need to perform the PM task and the OT at the same time. A similar conclusion can be reached also by examining some studies on event-based prospective memory: Even when a spontaneous conversion of the target representation (e.g., from a general category, e.g., "fruit," to more specific instances of the target, e.g., "orange") seems much easier and motivated than in our studies, only a minority of participants actually seem to apply the transformation (e.g., Scullin et al., 2018). More importantly, we have converging empirical evidence from our two studies (surprise deadline recall, retrospective strategy reports, RT data) indicating that our participants generally did not change the representations initially given/learned. Indeed, if the majority of participants had transformed instances into rules (or rules into instances), we should not have observed the differences in OT RTs and PM performance that were actually obtained, and if both transformations occurred at the same time in the two experimental conditions, we should have observed a pattern of results opposite to the one actually obtained. The same holds for deadline recall data and retrospective strategy reports. However, as we have anticipated, a very interesting future research direction could be to investigate experimentally when and how conversions of intention representations may take place in a time-based PM task with multiple intentions like ours.

A more technical limitation of our studies may have resided in the interface setup we used, with rather salient response and clock-checking buttons. Indeed, this design choice may have highlighted response and clock-checking cues, thus making the PM task potentially easier. However, this design choice also possibly avoided what we considered as a main potential problem. Indeed, had we used a standard keyboard arrangement for responses, the need to employ multiple response keys (three/four for PM responses, two for OT responses, and one for checking the clock) may have created response interference and confusion in participants, while providing all the response options clearly ordered on the screen possibly avoided these problems. Moreover, using labeled buttons removed the cognitive cost and burden of having to remember the response-key mapping, which was not integral to the time-based PM task per se. More importantly, given the findings obtained, we think that the main point our studies are making (i.e., the framing of intentions matters in time-based PM tasks) is not likely to be affected by the interface/responses used.

Another aspect that deserves more investigation is the one related to the difficulty of the PM task. Adding a fourth rule in Study 2 to the three already present in Study 1 may have changed the difficulty of the task for various reasons. Indeed, although four rules may be more difficult to handle than three when it comes to intention setting, the difficulty of the task may also stem from a change in the average distance between pairs of PM deadlines, or from the fact that there are more deadlines to be met overall. However, there are empirical reasons to think that, in our experiments, handling time rules was more relevant as a source of difficulty than the shortened distance between pairs of PM deadlines. Indeed, the main differences between framing conditions in OT RTs were always observed soon after the PM responses (within 30 s), and the minimal distance between a pair of deadlines in Study 2 was 1 min, so participants had enough time to meet the deadline also in this worst-case scenario (and usually they had minutes of time to do so). Moreover, it is unlikely that the increased number of deadlines was the main source of difficulty in Study 2, because PM performance in the instance conditions did not differ much from the one observed in Study 1 (e.g., the proportion of hits was .71 in both studies), while this was not the case for the rule condition (e.g., the proportion of hits dropped from .71 in Study 1 to .46 in Study 2). Thus, the number of deadlines per se does not seem to explain the specific difficulty in the rule condition of Study 2, even if it may have contributed to increasing the overall OT RT in the instance condition via increased interference among deadlines (as explained before). However, we think that future research should expand our investigation by manipulating systematically different potential sources of task difficulty in time-based PM tasks, such as the number and type of time rules (and corresponding instances), the distance between the deadlines, and other aspects potentially relevant, together with intention framing. This will allow us to reach a deeper understanding of the factors affecting the difficulty of a time-based PM task with multiple intentions.

Conclusion

Our studies have started to shed light on the influence of intention framing on time-based prospective remembering, a previously neglected research topic in PM. Additionally, they have offered the first insight on the type of representations and intention-setting strategies people use when they have to remember multiple time deadlines under different intention frames. We hope that our findings may foster further research on these topics and, more generally, on prospective remembering of multiple intentions.

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