More Time, More Work: How Time Limits Bias Estimates of Task Scope and Project Duration

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Abstract

We propose that externally induced time limits overly affect predictions of other people's task completion times, due to an over-generalized association between the time available and inferred task scope. We find higher estimates of the time needed to complete a given task by another person when the time limit is longer. While such predictions could be normative when time limits are informative, the effect persists even when the decision-maker knows that the limit is arbitrary and is unknown to the other person, and therefore, cannot affect behavior. Perception of task scope mediates the relationship between time limits and completion time estimates, and weakening the association between time limits and task scope attenuates the effect. The over-learned cognitive bias persists even among experienced decision-makers making estimates in a familiar setting. Our findings have implications for people who make decisions that use judgments of others' task completion time as an input.

Keywords: Time Limits; Deadlines; Time Judgments; Estimation Bias; Over-learned Responses

First Version: October 2014

Current Version: October 2020

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Making accurate estimates of how long others will take to complete a task is important for effective decision making across a variety of settings. Consistent with this need, a major focus of the foundational work in organizational behavior and management was to precisely define and time the steps in industrial processes (e.g., Lowry, Maynard, & Stegemerten, 1940). This approach was feasible for the manufacturing assembly line but is difficult to implement in today's workplace, where no two tasks might be the same, and completing each task may require different skills. Thus, prior measurement approaches are often infeasible in modern workplaces, and managers must instead rely on judgment-based estimates of project completion time as the primary inputs for important planning and resource allocation decisions (Halkjelsvik & Jørgensen, 2012).

People making completion time judgments often do so based on limited objective information, and therefore, their estimates are potentially vulnerable to contextual influences. In this paper, we investigate how completion time estimates *for other people*, a crucial input into planning, budgeting, and resource-allocations decisions are influenced by externally imposed time limits. Across our studies, people estimated more time to complete a task when the time limit was longer. While estimating longer completion times for longer deadlines can constitute a normative inference in some settings, we find that judgments of the time that others will take are overly sensitive to time limits, *even when* the time limits are non-informative and irrelevant, contributing to inaccurate estimates. For example, we find that the effect persists even when the time limits are determined at random (i.e., could not provide information) or are not known by the other person completing the task (i.e., could not affect motivation or completion times).

The effect of deadlines that we report in this paper is extremely robust and may be driven by more than one psychological mechanism. We propose and isolate a novel *scope perception* account, which explains the observed behavior and is distinct from other mechanisms. In particular, our scope perception account predicts that longer time limits increase the subjective scope of the work. This cognition-based account makes distinct predictions from a motivation-based account, implied by prior research, in which managers believe that shorter (longer) time limits increase (decrease) workers' pace. We also distinguish the effect of the scope perception account from that of other potential decision heuristics, including anchoring, truncation of estimates by available time, and differences in anticipated work quality. We test the time limit bias and scope perception account in five studies (as well as in an additional seven studies reported in the Online Supplemental Studies Appendix),[1] using lay subjects and experienced managers, familiar and novel tasks, hypothetical scenarios, and consequential settings.

Predictions of task completion time

Making duration judgments of prospective, non-experienced events, such as predicting a task-completion time, is a particularly difficult task. A large body of work has shown that duration judgments of non-experienced events are susceptible to contextual factors and are therefore often biased (see Roy, Christenfeld, & McKenzie, 2005 and Halkjelsvik & Jørgensen, 2012 for reviews). For example, prospective duration judgments of non-experienced events have been found to be affected by many factors,

[1] All data collected is reported, either in the paper or as supplemental studies, along with full stimuli, in the Online Supplemental Materials. All data are available at http://osf.io/zhw4a.

including arousal and vividness (Ahn, Liu, & Soman, 2009; Caruso, Gilbert, & Wilson, 2008), details of task description (Kruger & Evans, 2004), valence of the pending outcome (Bilgin & LeBoeuf, 2010), completion motivation (Buehler, Griffin, & MacDonald, 1997; Byram, 1997), measurement units (LeBoeuf & Shafir, 2009), and perceived contraction of objective duration (Zauberman, Kim, Malkoc, & Bettman, 2009).

Furthermore, even prior experience with the task might not improve duration judgments. Retrospective duration judgments are often biased by contextual factors, including the interval between the occurrence of the event and time of judgment (Neter, 1970), and availability of cognitive cues and resources (Block, 1992; Zauberman, Levav, Diehl, & Bhargave, 2010). These biases result in inaccurate recall and make it difficult for decision-makers to learn from (Meyvis, Ratner, & Levav, 2010) and utilize (Buehler, Griffin, & Ross, 1994; Gruschke & Jørgensen, 2008) prior experience. Consequently, experienced decision-makers might not perform any better compared to novices when making completion time estimates. The inherent subjectivity of time estimation can also make decision-makers overconfident (Klayman, Soll, González-Vallejo, & Barlas, 1999), and perversely bias their estimates even when they are deciding on a familiar task (Jørgensen, Teigen, & Moløkken, 2004).

The malleability of prospective judgments and the difficulty of learning from prior experience makes time estimation susceptible to the use of judgment heuristics and sensitive to salient characteristics of the decision environment. Indeed, research has shown that decision-makers tend to rely on a more heuristic-based approach when they are thinking about expending resources in the form of time (vs. money; Saini & Monga, 2008). Could time limits, which are a salient and pervasive characteristic of many decision environments, trigger heuristic thinking and affect estimates of task completion times?

A decision-maker's estimate of task completion times for the self and the other could be affected by very different psychological processes. In particular, the prior literature has suggested that estimates of *one's own* completion time are often explained by motives and biases specific to reasoning about the self, such as presentation motives (Leary, 1996), attributional motives (Jones & Nisbett, 1971), motivated reasoning (Kunda, 1990), and strategic behavior (König, 2005; Thomas & Handley, 2008; Locke, Latham, Smith, Wood, & Bandura, 1990). The key unanswered question we investigate is whether time limits also influence estimates for *other people,* where these egocentric motives might be weaker or even non-existent.

Predictions of task completion time for others under external time limits

Several factors can influence how a person's prediction of other people's task completion times may vary under different external time limits. First, external time limits can reveal relevant information. When informed people use their knowledge to set a reasonable time limit, taking into account the work needing to be done, the time limit itself can be a valid signal of the scope of the work. For example, the time limit could be either the upper bound on how long the task would be allowed to take or may reflect the limit-setters' knowledge about how long it typically does take. As such, therefore, external time limits might exert a normative influence on people's completion time estimations in some settings.

However, even in settings where time limits are potentially informative, the sources of the time limit and the associated goals in setting the limit may vary. For example, time limits may reflect the needs or requirements of a client or third party. In particular, a manager may face deadlines dictated by a client that either requires the work to be done faster than usual or allows the work to take significantly longer than necessary. As a result, time limits can differ from typical completion times. Therefore, the informativeness of the time limits might be particularly difficult to assess via intuitive judgment in those complex work environments where no two situations are exactly alike and the time limit is typically the result of a complex multi-party negotiation.

Second, people may base their estimates on their beliefs about the effects of time limits on others' motivation. For example, people may believe that others will work more slowly when more time is available to them (e.g., "Parkinson's Law," Parkinson, 1955). Some lab studies have found evidence that people may, in fact, spend more time to complete a task when the time limit is experimentally manipulated to be longer (Aronson & Landy, 1967; Brannon, Hershberger, & Brock, 1999; Bryan & Locke, 1967; Jørgensen & Sjøberg, 2001 as reported in Halkjelsvik & Jørgensen, 2012), though the necessary conditions for this effect are not well understood. Although not tested in this literature, beliefs about others taking more time than needed might be stronger when wages are paid based on the time taken. In such settings, decision-makers might expect that others will "slack," i.e., strategically taking longer so as to earn higher total wages, particularly when the external deadlines are longer (Goswami & Urminsky, 2020).

Relatedly, people also could incorporate into their estimates a variety of other lay beliefs about how they think time limits affect others' motivation. For example, the goal-gradient tendency for people to work more slowly earlier in the process when task completion goals are farther away (Gjesme, 1975; Hull, 1932; Kivetz, Urminsky, & Zheng, 2006) may be exacerbated by longer deadlines. Conversely, a shorter deadline might prompt people to work at a faster pace. Working under a longer deadline can also lead to more procrastination, rather than spending more time on the task (Ariely & Wertenbroch, 2002), leading to higher overall completion times.

Third, people could also be inadvertently influenced by time limits and anchor on the deadlines, even when the deadlines are not informative (e.g., when they are told that the deadlines are random). Alternatively, people could deliberately truncate or censor their beliefs about the distribution of completion times when generating estimates.

Fourth, it is possible that external time limits will not affect people's estimates at all, beyond providing an upper bound on the possible time others could take. This would be consistent with prior research in other domains which has demonstrated insensitivity to important cues, particularly when evaluated in isolation, without a frame of reference (Hsee, Loewenstein, Blount, & Bazerman, 1999; Hsee, 1996).

Next, we introduce a novel additional possibility – the scope perception bias – based on an overgeneralized inference, which makes unique predictions about the effect of external time limits on judgments of others' performance.

Scope Perception Bias

We hypothesize that people may judge the time taken to complete a task based on their perceived scope of work, and their judgments of scope may, in turn, be influenced by time limits. A longer external time limit might lead people to infer a task that is larger in scope, and accordingly, estimate it to have a longer completion time.

We propose that this "Scope Perception" effect of deadlines could be an overlearned response. People learn from their experience that "bigger" tasks often have "longer" deadlines. This directional relationship between time limits and task scope is so prevalent that people might then over-generalize it to a bidirectional association. When this happens, longer external time limits might spontaneously make beliefs about bigger task-scope salient. Longer time limits could also bring to mind aspects of task scope such as greater complexity, difficulty, number of intermediate steps required to complete the task, effort-required, thoroughness, and so on. Such inferences, in turn, could result in a higher estimate of task completion time when time limits are longer.

Extant research has suggested that over-learned responses are indeed quite common in everyday judgments. For example, decision-makers have been found to infer physical distance from clarity (Brunswik 1943), frequency of occurrence from valuation (Dai, Wertenbroch, & Brendl, 2008), and perceived value of a service from the time it took to provide that service (Yeung & Soman, 2007). When judging an attribute that is less accessible and for which they have less information (e.g., physical distance, frequency of occurrence, value of a service, task-completion time), decision-makers might automatically substitute the less-accessible attribute with an attribute that is more salient to them (Kahneman & Frederick, 2002).

Thus, irrespective of whether the time limit is normatively informative, people may more readily imagine a scope of work consistent with the time limit, based on an over-learned association between time limit and amount of work. To test this, in some studies, we construct experimental situations in which the decision-maker knows that the time limit is uninformative (e.g., because it is determined by coin-flip or by other non-informative external factors). We take this approach in order to theoretically identify and study any potential bias in predicting others' task completion times on account of longer or shorter time limits. However, we expect the psychological process we discuss here to also occur, along with more straightforward inferential processes, in situations where time limits are clearly either diagnostic or where the diagnosticity of the time limit is difficult to ascertain.

In order to provide a strong test of the scope perception hypothesis, we investigate whether time limits affect estimates even in the extreme case when workers are themselves unaware of the time limit while completing the task, and the time limits are only known to the decision-maker. According to our proposed account, time limits would activate an over-learned association in the decision-maker's mind, even in this special case when the decision-maker is aware that such time limits cannot have a causal effect on workers' motivation. We predict that decision-makers would still be influenced by the time limits, even when the time limit could not affect the workers' motivation or pace of work. In contrast, an alternative account based on beliefs about how external time limits affect workers' motivation would predict no effect of unknown time limits on judgments about task completion time.

We also distinguish scope perception from a standard anchoring and adjustment process. Standard anchoring involves anchor-consistent information coming to mind more readily (Chapman & Johnson, 1994; Strack & Mussweiler, 1997), along with subsequent adjustment (Simmons, LeBoeuf, & Nelson, 2010). Therefore, if decision-makers indeed anchor on the external time limits and insufficiently adjust from these limits in generating their estimates, the estimates should be clustered around the anchors (Sussman & Bartels 2018). Our proposed scope perception account, in contrast, is based on general inferences about task length, and does not predict that responses will be clustered around the time limit. We will use this approach, directly comparing the effect of time limits to the effect of anchors in Study 1, to test whether people' estimates are better described by the scope perception account or a standard anchoring process. Finally, we will directly test the scope perception account by both measuring the perceived scope of work, and by manipulating people's beliefs about the strength of the underlying association between time limits and scope.

The rest of the paper is organized as follows. We first measure the accuracy of judges' estimates by comparing consequential judgments to actual time taken by real workers to complete a task under a time limit, and contrast the results with predictions of alternative accounts, including anchoring (Study 1). In pre-registered Study 2, we use a hypothetical scenario to test the robustness of the scope perception effect to workers' awareness of the time limit and test a competing motivational-belief account. In pre-registered Study 3, we generalize the findings to situations when managers make multiple estimates and we provide evidence that perceived scope mediates the effect of deadlines on completion time judgments. Next, we further test the proposed scope perception mechanism by manipulating the underlying association between time limits and scope (Study 4). We examine the generalizability of our findings in a field survey with experienced managers (Study 5).

Study 1: The joint effect of time limits on workers' times and judges' estimates

Method

In Phase 1, participants in a research laboratory (n=116) were assigned the role of workers and were all asked to solve the same digital jigsaw puzzle. Each worker was randomly assigned to one of three between-subject time limit conditions: either having unlimited time, 5 minutes (shorter time limit), or 15 minutes (longer time limit) to complete the puzzle. The times were chosen based on pre-testing, which indicated that nearly all workers were able to solve the puzzle in 5 minutes.

The workers were paid a flat fee of $3 in all three conditions, regardless of how long they took to solve the puzzle. They were informed about their compensation and time limit before starting the timed puzzle. To make sure that participants did not think that they might have to continue waiting until any time limit assigned to them was up even after solving the puzzle, they were explicitly told that they could either move on to participate in another study or leave the lab after they completed the puzzle. Therefore, the design precluded any perverse incentives worker might have to delay task completion (e.g., in order to earn more from the jigsaw puzzle task).

The jigsaw puzzle was administered using a computer interface from the online puzzle site *jigzone.com*.[2] The interface showed a timer which started counting immediately after the first piece was moved, and which stopped and continued displaying the final time once all the pieces were in place. All participants solved the same puzzle, but each participant started off with a different random arrangement of the puzzle pieces. As participants moved the puzzle pieces on the screen, the pieces snapped together whenever two pieces fit. As a result, it was not possible to solve the puzzle incorrectly, and quality of outcome was held constant across workers. After each worker finished the puzzle, the completion time was recorded from the digital interface by a research assistant.

In Phase 2, a separate sample of online participants (n=602[3]) was assigned the role of *judges* and were provided with detailed information about Phase 1, including two pictures of the puzzle which the workers had solved. The first picture showed a typical initial layout with the pieces randomly spread out, and the second showed the way the puzzle looked when it had been solved. All judges were told that each worker was *randomly assigned* to either have no restriction on the maximum time they could take, or a maximum time of 5 minutes (the shorter time limit), or a maximum time of 15 minutes (the longer time limit) to solve the puzzle. Judges were further informed that all of the workers were paid a flat fee of $3 for their work, and the materials emphasized that workers could not choose or influence their time limit. Given that workers' wages were

[2] See Online Appendix A for detailed stimuli and instructions used in the experiments.

[3] In all online studies, the reported sample size is after dropping participants with duplicate IPs and who failed a simple attention check (see Online Appendix B). The exclusion criterion was decided *apriori* without looking at the data and was applied consistently to all studies.

fixed and the same under all the time limits, the possibility that workers would intentionally work slower to earn more was not a relevant factor in the judges' decisions.

Judges were told that they would be answering a few questions about estimating the time it took people to finish solving the puzzle, and were randomly assigned to a 2 (shorter vs. longer) x 2 (time limit vs. anchor) design. In the time limit conditions, judges were asked to predict the task completion time for an average worker either under the 5-minute time limit (shorter time-limit condition) or under the 15-minute time limit (longer time-limit condition). After making their estimate, judges in the time-limit conditions were asked to also make an estimate based on the other time limit, on a separate screen. Judges also estimated what percentage of workers in each condition solved the puzzle in 3 minutes or less, to examine the distributional beliefs about task completion times.

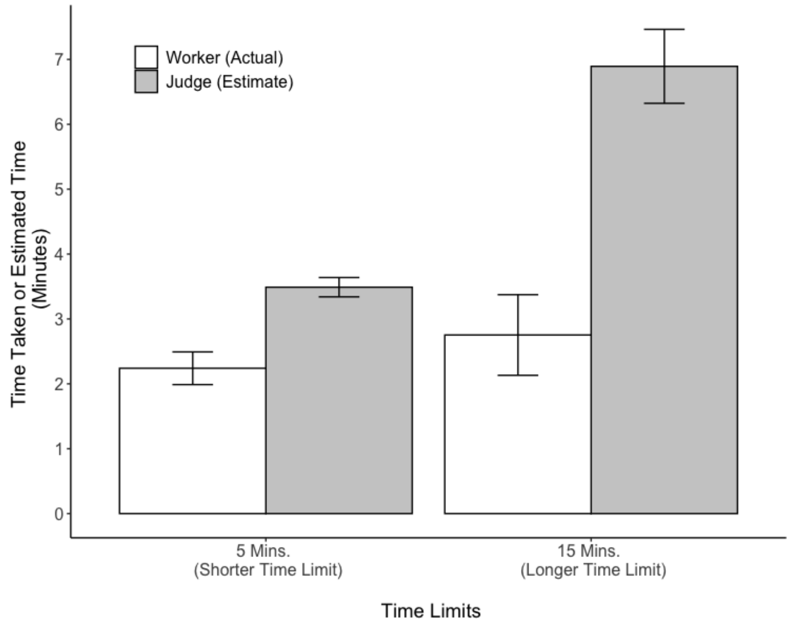
Judges in the anchoring conditions were instead asked to consider a typical worker for whom there was no maximum time and answered whether they believed the worker would spend more or less than either 5 minutes (low anchor condition) or 15 minutes (high anchor condition) working on the puzzle. The same judges were then asked to predict the task completion time of an average worker with no restriction on the maximum time.

Judges in all conditions were told that they could earn a bonus of up to $1 based on how accurately they predicted the task completion time. Specifically, for every minute their estimate deviated from the actual average time in their time limit condition, 10 cents were deducted from the maximum bonus amount (i.e., a linear incentive for accuracy). After judges made their estimates, they were asked a few follow-up questions about their beliefs about the completion time, their assessment about workers' feelings while they were solving the puzzle, and their familiarity with jigsaw puzzles.

Results

Workers' Completion Times. All workers solved the puzzle within the allotted time. On average, workers took a similar length of time to solve the puzzle in all three conditions ($M_{Shorter}$= 2.24; M_{Longer} = 2.75; $M_{Unlimited\ Time}$=2.23; $F(2,113)=1.92$, p=.153). Post-hoc tests indicated that workers completed the task directionally faster under the shorter and unlimited time limits than the longer time limit ($M_{Shorter}$ vs. M_{Longer}: p= .118; $M_{Shorter}$ vs. $M_{Unlimited}$: p= .988; M_{Longer} vs. $M_{Unlimited}$: p= .148). Therefore, even when time limits were three times longer (compared to the 5-minute limit) or absent altogether, the actual time taken by the workers was not greatly affected by the time limit. Given that workers in all conditions earned a flat fee of $3 irrespective of how much time it took them to solve the puzzle, they arguably did not face meaningfully different incentives for working at different speeds across the conditions.

Judges' Time Estimates. Judges' first estimates in the time limit conditions did not accurately predict the workers' times. Judges' average estimates were significantly higher than the actual workers' times in each of the two time limit conditions (Shorter Time: M_{Judges} = 3.49 vs. $M_{Workers}$ = 2.24, $t(187) = 7.86$, $p<.001$; Longer Time: M_{Judges} = 6.89 vs. $M_{Workers}$ = 2.75, $t(191) = 6.86$, $p<.001$). More importantly, the over-prediction increased with longer time limits (interaction $F(1, 378) = 21.61$, $p<.001$; see Figure 1).



Note: Vertical lines are +/- 2SE

Figure 1: Time taken by workers and time estimated by judges as a function of time limits (Study 1)

Could these observed results be explained by the judges anchoring on the time limits and insufficiently adjusting? In the anchoring conditions, judges' estimated task completion times were not only lower but also higher than the anchor value (35% and 7% estimated higher values in the 5-minute and in the 15-minute conditions, respectively) suggesting that the anchoring manipulation was successful. In contrast with estimates in the time limit conditions, estimates in the anchoring conditions were clustered closer to the anchor value (consistent with insufficient adjustment), and were, therefore, higher, on average, than the estimates in the time limit conditions ($M_{Anchoring}$=8.49 vs. $M_{TimeLimit}$ = 5.22, $t(600)$=2.42, p=.016). Specifically, estimates in the shorter anchor condition were significantly higher than in the equivalent shorter time limit condition ($M_{Shorter, Anchoring}$ = 9.07 vs. $M_{Shorter}$ = 3.49, $t(300)$=2.12, p=.035). A similar marginally significant difference was observed comparing the longer anchoring condition and the corresponding time limit condition ($M_{Longer,\ Anchoring}$ = 7.87 vs. M_{Longer} = 6.89, $t(298)$=1.84, p=.066).[4] These results suggest that the way time limits impact people's estimates is distinct from a standard anchoring and adjustment process, and suggests that a different psychological mechanism accounts for the observed findings in the time limit conditions.

Discussion

The results of Study 1 provide an initial demonstration of a time limit bias: people estimate more time for others to complete a task when there is a longer time limit, compared to a shorter time limit, even when actual completion times do not substantially differ. We find similar but directionally weaker results within-subjects (see Online Appendix C), suggesting that judges updated their beliefs based on a new time limit. This basic effect of external time limits on completion time estimates is highly robust, and we have consistently replicated it (e.g., see also studies S1 and S2 in Online Appendix D). Furthermore, the evidence suggests standard anchoring on the numerical amounts used in the time limits yields different estimates and, therefore, cannot fully explain the observed time limit bias. We further rule out the role of incidental anchors in Study S3 in Online Appendix D.

Other Alternative Accounts

Estimating more time based on a longer time limit can sometimes be a valid inference because, in practice, a time limit may often convey diagnostic information that

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[4] The substantive conclusions remain unchanged if use log-transformed values of time estimates. The same is true if we identify and replace outliers and/or truncate the anchoring estimates to maximum time limit. See Online Appendix C for details.

was used to determine the time limit. This is not the case in Study 1, however, where judges were informed that the workers' time limits were assigned at random. A follow-up question confirmed that nearly all the judges (96%) correctly recalled that workers were randomly assigned to the different time limits (rather than on the basis of matching workers to time limits based on their proficiency or skill, for example) in all the conditions. The difference in the judges' estimates between the two time-limit conditions remains even after excluding the judges who failed the comprehension test.

This bias does not seem to be attributable to judges' lack of attention, or lack of relevant experience with jigsaw puzzles or beliefs about workers' motivation. In Phase 2, the amount of time judges took to read the instructions did not moderate the effect of time limits on judges' estimates. The results did not differ based on judges' self-reported experience with jigsaw puzzles, although in this study, judges with higher self-reported knowledge of jigsaw puzzles showed lower sensitivity to time limits (p=.068). Judges' beliefs about differences in either how accountable workers felt to finish the puzzle as soon as possible or about workers' task goals (to finish quickly or to take longer and enjoy it) in the different time limit conditions likewise could not explain the difference in estimates.

An important alternative explanation of the observed results is that judges hold a belief that people work slower when they have more time (a tendency sometimes known as "Parkinson's Law"). Although this might be a reasonable heuristic in some situations, Study 1 suggests that, at a minimum, judges in this situation were over-applying the heuristic in this situation, since the time limit did not substantially affect the actual time spent by the workers. Furthermore, if judges based their estimates on a lay theory about different rates of work under different time limits, it would have to be a lay theory that did not fully account for the workers' incentive to complete the puzzle quickly, regardless of the time limit, given the fixed payment and outside option of completing other studies.

To further test this possibility, we asked the judges for their general beliefs about whether people would work slower, faster or at the same pace when more time is available. The majority (63%) of judges stated that people take more time when more time is available. However, whether or not a judge expressed this belief in Parkinson's law made no difference for the effect of time limits on their completion time estimates (interaction of time limit condition and measured beliefs, p =.710). This suggests that beliefs about differences in rates of work due to time limits do not explain the results.

Another potential explanation of our results is that judges in both shorter and longer time limit conditions had the same underlying distribution of completion times in mind, but simply truncated all the higher estimates to the deadline when the time limit was shorter. To test this "truncation account" (Huttenlocher, Hedges, & Bradburn, 1990), we compared the proportion of workers that judges expected to finish in up to 3 minutes in the longer vs. shorter time limit conditions. Under the truncation account, these two proportions should be the same. However, judges estimated that significantly fewer workers would complete the puzzle in up to 3 minutes in the longer time limit condition than within the same duration in the shorter time limit condition ($M_{Shorter}$ = 51% vs. M_{Longer} = 34%, $t(301)=5.28$, $p<.001$)[5], suggesting they had very different distributions of task completion times in mind for the two different time limit conditions.

[5] We use a t-test as judges' estimates were captured as continuous numbers.

A separate distributional-heuristic account is that judges may have started with the same believed distribution of unlimited times in all conditions, but eliminated from consideration all times greater than the time limit, possibly coding them as failing in the task and therefore not qualifying for inclusion. In Study S4 (see Online Appendix D), we investigate this "censoring account" by having judges explicitly indicate the proportion of workers in each of a set of time ranges, including the proportion they believed did not complete the task in the assigned time limit. Computing the estimated completion time by using a weighted average of the mid-point of each time-bins and the reported proportions as weights, we replicate the results of Study 1. This suggests that censoring accounts cannot explain our findings.

Why did the time limits bias judges' estimates? Most judges understood the instructions and knew that workers were randomly assigned to different time limits, and therefore that time limits did not have any informational value. However, it is still possible that judges, acting as amateur psychologists, were trying to predict the impact of the time limits on workers' behavior. When workers had more time to complete the job, workers could have procrastinated by engaging in daydreaming or could have simply worked at a slower pace (although doing so would be non-optimal based on the wage scheme). This might result in workers taking more time under longer deadlines. In the next study, we directly test this account by testing judges' estimates in a hypothetical scenario using the extreme case of a non-influential time limit – one that workers are actually unaware of and which therefore could not affect their motivation.

Study 2: Estimating completion times with irrelevant time limits

Method

We ran a pre-registered study (http://aspredicted.org/blind.php?x=kv2g7m) in which online participants (n=358) played the role of judges and estimated the time to complete a hypothetical jigsaw puzzle. Judges were assigned to one of three between-subjects conditions: unlimited time, shorter (30 minutes) time limit or longer (45 minutes) time limit. Judges read a hypothetical scenario, in which a 100-piece jigsaw puzzle was administered to an initial group of people, and that every person took less than 28 minutes to solve the puzzle (see Online Appendix A), with no time limit mentioned.

In the scenario used in the study, judges were told that the *same* puzzle was administered to a new worker, from the same population. The worker in the scenario either had unlimited time, or had been randomly assigned to one of two timed conditions based on a coin flip – a maximum time of 30 minutes (shorter time), or a maximum time of 45 minutes (longer time). By telling the judges that similar workers had all completed the task within both the time limits used in the study, we controlled for accounts based on beliefs about workers having difficulty completing the puzzles in time used (such as truncation or censoring). However, because we only informed judges about the *maximum time* used by prior workers, the judges still needed to make inferences about project scope to estimate the *average* time workers took.

In this study, the scenario was designed so that time limits logically could not affect worker's behavior. Specifically, judges in the time limit conditions read that the worker *did not know* about the time limit and had simply been instructed to complete the work at his or her own pace. Judges were then asked to estimate the average task completion time. If the time limit bias persists in this scenario, the finding could not be explained by judges taking into account the effect of providing time limits to workers (e.g., by revealing private information to workers or shifting their motivation).

Of course, the ability of this study to potentially rule out these alternative explanations is predicated on the assumption that the judges read and understood these key details in the instructions. To address whether the observed results could be explained by judges failing to understand that the deadlines in the study were arbitrary and irrelevant, we asked the judges a battery of six comprehension check questions at the end of the survey (see Online Appendix A). In particular, judges were asked to recall *both* the external times limits used in the study, whether workers in both these time limits worked on the *same* jigsaw puzzle, whether workers were *randomly* assigned to one of these two time limits, the *number of pieces* in the jigsaw puzzle, the *maximum time taken by a similar group* of workers who had attempted to solve the same jigsaw puzzle in the past, and finally whether the current group of workers believed that they had unlimited time to work on the puzzle. We will test the robustness of the results to restricting the analysis to only those judges who passed this comprehensive set of checks.

Results

An omnibus test revealed that the estimates differed significantly across the three conditions ($F(2,355)=9.40$, $p<.001$).[6] In the unlimited time (control) condition, judges

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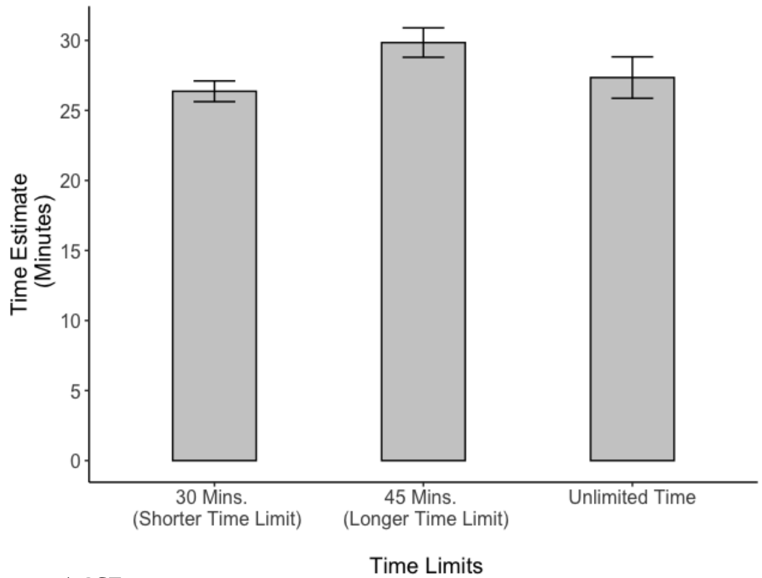
[6] The results do not change if we use log transformed estimates to handle potential extreme values, particularly in the unlimited time condition ($F(2,355)=7.29$, $p<.001$)

estimated an average completion time of 27.35 minutes. In the irrelevant time limit conditions, judges estimated a significantly higher task completion time when the time limit was longer ($M_{Shorter}$ = 26.36 minutes vs. M_{Longer} = 29.84, $t(232)=5.28$, $p < .001$; see Figure 2).



Note: Vertical lines are +/- 2SE

Figure 2: Estimated time for task completion in different irrelevant time limit conditions (Study 2)

We checked whether the observed results could be explained by judges failing to register the details of the situation, particularly the fact that the workers did not have any time limits. We redid the analysis using only those judges who passed *all* six of the comprehension checks asked at the end of the survey (n=198). This subset of judges with perfect recall also estimated a longer task completion time under a longer deadline ($M_{Shorter}$ = 27.05 minutes vs. M_{Longer} = 28.66, $t(131)=3.74$, $p < .001$)[7]. This confirms that

[7] The results do not change if we use log transformed estimates ($t(131)=3.72$, $p < .001$)

the results cannot be interpreted as normative on account of judges failing to understand the instructions in the study.

Discussion

We once again replicated the effect of time limits on estimates, this time using an extreme case in which the time limits are completely irrelevant. We have also replicated these results of irrelevant time limits on planning using a completely different, consequential budgeting game conducted in a classroom setting (Study S5, Online Appendix D). Overestimation of task completion times, even in these contexts where judges understood that workers cannot be affected by external time limits (e.g., because the effect holds among those who passed comprehension checks), suggests that the effect of time limits on estimates cannot be explained by beliefs about differences in worker's rate of work, quality of work, the distribution of task completion times, or information signaling. In other words, the observed results cannot be interpreted as an artifact of judges misunderstanding or failing to recall that the deadlines in the study were normatively uninformative.

Furthermore, given that all judges in Study 2, regardless of condition, were exposed to the same timing information (both the shorter and longer time limits were known, along with the maximum time of 28 minutes taken by a prior group to solve the same puzzle), this study provides further evidence that the effect of deadlines cannot be explained by even incidental anchoring.

Why do even randomly determined time limits unknown to workers lead to differences in judgments about workers' task completion times? In people's experience, more effortful tasks often have longer time limits, and people may overgeneralize this relationship, such that they perceive a task with a longer time limit to have a larger scope of work even when longer time limits are irrelevant. Over-learned associations can then become a decision heuristic that is triggered by the presence of relevant stimuli in the decision environment, such as time limits triggering an associated sense of the scope of work. According to this s*cope perception* account, the effect of time limits on estimated completion time is driven by this subjective perception of the work to be done, rather than by beliefs about how rapidly workers are trying to work.

In the next study, we further replicate the effect of time limits on perceived scope even when judges are told that workers do not know about time limits. We also include a confirmatory test of the proposed causal role of perceived scope on completion time estimates by measuring the perceived scope and using mediation analysis. Finally, we examine the generalizability of our findings by extending our test to a situation in which decision-makers make multiple estimates for different tasks of the same kind.

Study 3: Role of perceived task scope on completion time estimates

Method

Online participants (n=347) acting as judges participated in a pre-registered scenario study (https://aspredicted.org/blind.php?x=5u3fi9) where they were required to predict the task completion times for a few jigsaw puzzles. Judges were briefed about jigsaw puzzles, the online interface used to administer the puzzles, and the details of a sample of participants who had worked on puzzles in the past. Specifically, judges were told that every participant worked on only one puzzle and no participant took more than 30 minutes to solve any puzzle. Unlike in Study 2, where judges were not told anything about how the participants were paid, in this study, we also explicitly told the judges that all participants were paid a fixed fee for their work.

In the new scenario, a sample of participants drawn from the same population was asked to solve a jigsaw puzzle. Further, based on a coin toss, workers in the scenario were randomly assigned to one of two time-limit conditions: 35 minutes (shorter time limit) and 50 minutes (longer time limit). Judges were then assigned to the only between-subjects condition in the experiment. Half the judges were told that the participants knew about their assigned time limit before they started working. The other half were told that participants were not informed about the time limits and that the time limits were for administrative convenience such that a worker, instructed to work as his/her own pace, who could not finish solving the puzzle before the "assigned" time limit expired, was asked to stop working any further.

Participants answered a series of nine comprehension questions on the experimental setup before they could proceed to make their estimates (see Online Appendix A). The comprehension questions were presented on the same page as the instructions, so every participant could answer them correctly if they attended to the information provided. Judges then estimated the task completion time, in minutes, for two different jigsaw puzzles, one described in terms of the shorter time limit and the other with the longer time limit. The specific puzzles and the order of time limits were counterbalanced.

After judges made their completion time estimates, they answered two different questions that captured their beliefs about the relative scope of work for the two puzzle tasks that had been associated with different time limits. Specifically, they rated which puzzle had more pieces, on a bipolar scale anchored on the tasks and with a neutral mid-point. They also reported how much work they thought it would take to solve each of the two puzzles using two separate slider scales (ends marked as 1= a little work and 100=a lot of work). Finally, judges reported how interesting and enjoyable they thought participants might have found the two puzzles (answered using a bipolar scale described earlier). Judges answered a few questions on their knowledge about jigsaw puzzles, demographics, and an attention check question.

Results

Given the repeated-measures design, we used hierarchical regression to analyze the results of this study. When time limits were known to the participants, as in Study 1, we replicated the effect even when the judges made multiple estimates and were told that the time limits were arbitrary. In particular, judges estimated longer completion time when the externally assigned time limit was longer ($M_{Shorter}$ = 21.85 minutes vs. M_{Longer} = 24.59; β= 2.75, t=5.21, p<.001).

In the experiment, although the tasks were similar, judges encountered different jigsaw puzzles. This mimics real-world situations where managers often manage projects that are of a similar type but different in terms of intrinsic details. The robustness of the time limit bias to the within-subjects design suggests that the bias can persist even in contexts where evaluability of time limits is high (e.g., where managers make estimates for different tasks under different deadlines).

Furthermore, replicating the results of Study 2, the effect persisted even when judges were told that workers did not know about the time limits ($M_{Shorter}$ = 20.74

minutes vs. M_{Longer} = 22.91; β= 2.17, t=4.29, p<.001). In fact, the magnitude of the time limit bias did not significantly differ depending on whether or not the workers knew about the time limits (interaction β= 0.58, t=0.79, p=.428), further confirming that judges' beliefs about how deadlines affect workers' behavior were not responsible for our findings[8]. Given that there was no difference, the remaining analyses use the combined data.

Consistent with our hypothesis that longer deadlines increase the perceived scope of work, judges estimated that a task with a longer deadline would have significantly more pieces (M = +0.15; mid-point test vs. M = 0: t(346)=2.46, p=.014). Furthermore, judges' ratings of the number of pieces significantly mediated the effect of time limit on completion time estimates (bootstrapped 95% CI = [0.06, 0.38]; see online Appendix C). Judges also believed that a task with a longer time limit would entail marginally more work to solve when they responded using the slider scales (M_{Longer} = 60.89 vs. $M_{Shorter}$ = 59.13; β= 1.77, t=1.83, p=.067), and these elicited beliefs about task scope significantly mediated the effect of time limit on completion time estimates (bootstrapped 95% CI = [0.06, 0.57]). Taken together, a composite z-score index measuring the overall perceived scope of work (computed from these two measures of task scope), partially mediated the effect of time limit on completion time estimates (bootstrapped 95% CI = [0.18, 0.69]). By contrast, time limits did not affect judges' ratings of whether workers found a task more interesting and enjoyable (M = -0.009; mid-point test vs. M=0: t(346)=0.10, p=.920).

[8] The results hold if we use log transformed time estimates.

Discussion

Although judges were told that the time limits were arbitrarily determined by a coin toss, they were influenced by time limits when making repeated judgments for similar tasks. In particular, they estimated a significantly longer completion time for a task that was associated with a longer deadline.

As in Study 2, this study also required judges to answered a battery of nine questions to indicate their comprehension (see Online Appendix A), but in this study, the questions were asked before the judges made their estimates. All the results held if we looked at only the judges who passed *all* the comprehension questions (n=203; see Online Appendix C)[9]. This strongly confirms that the results are not on account of a subset of judges who misunderstood the actual irrelevance of the time limits and then made reasonable inferences from the time limits.

Instead, the results are consistent with the scope perception account. In particular, a longer deadline resulted in a larger scope of work perceptions, which in turn mediated the causal relationship between time limits and completion time estimations. This provides evidence for the scope perception account of the time limit bias. We replicated the effect of time limits on scope perception in Study S6 by having judges estimate the number of puzzle pieces as a measure of task scope. Furthermore, in Study S7 (both Studies S6 and S7 are reported in Online Appendix D), we demonstrate that the effect of time limits on both task scope (as measured by puzzle pieces) and estimated completion

[9] Our pre-registration specified testing robustness among judges who passed the two key comprehension check questions: that the assigned time limit was randomly determined and that workers did not know about time limits. The results hold if we looked at this larger subset (n=268).

time is debiased when participants are provided with sufficiently detailed scope-relevant information: the full distribution of completion times in the absence of a time limit.

Despite the robustness of the findings, the scope perception account does point to a testable moderator of the time limit effect. If relatively longer time limits prompt perception of a higher scope of work because of an overgeneralized association between available time and scope, a weaker belief in the association may reduce the effect. In the next study, we test this prediction by either confirming (e.g., suggesting that tasks' scope and time limits are related) or questioning (e.g., suggesting that task scope and time limits need not be related) judges overlearned beliefs about the association between available time and task scope, before they made their estimations. This kind of belief manipulation has been previously used to investigate psychological mechanisms that rely on subjective beliefs and confidence (Briñol, Petty, & Tormala, 2006; Ülkümen, Thomas, & Morwitz, 2008).

Study 4: Time estimation with belief manipulation

Method

Online participants (n=317) played the role of judges in a 2 (time limit: shorter vs. longer) x 2 (lay belief: confirming vs. questioning) between-subjects experiment. As in Study 1, judges read about real workers who had completed a 20-piece jigsaw puzzle under a randomly-assigned 5-minute or 15-minute time limit and saw pictures of the actual puzzle. They were also told that all workers, across time limits, were paid a $3.00 fixed payment for their work.

Judges were then informed that they would be asked to estimate the time it took workers to finish solving the puzzle. Before making their estimates, judges were presented with additional information, manipulated between-subjects. In the confirming-lay-belief condition, judges read:

> *"Recent studies in industrial and organizational psychology indicate that tasks that are larger in scope usually have longer time limits. Tasks smaller in scope, on the other hand, usually have shorter time limits."*

In the questioning-lay-belief condition, they read:

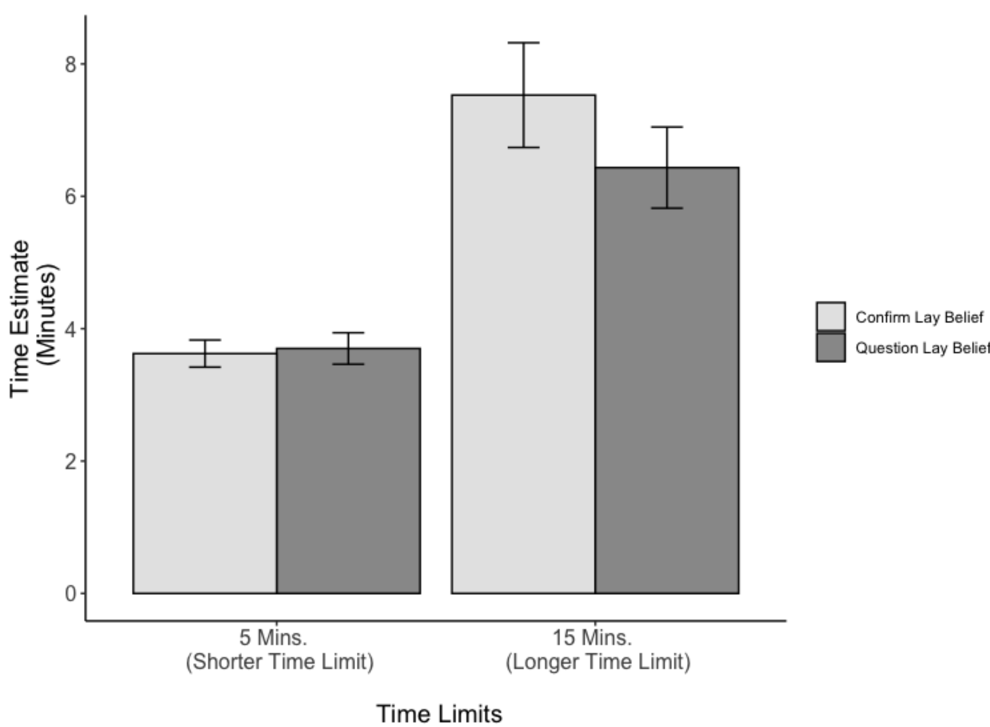
> *"Recent studies in industrial and organizational psychology indicate that task scope might be unrelated to time limits. Therefore, tasks that are larger in scope need not have longer time limits, and vice-versa."*

Judges then proceeded to make their estimates for a typical worker who had completed the puzzle with a maximum time of either 5 minutes or 15 minutes, manipulated between-subjects.

After participants indicated their estimates, they answered a series of five comprehension questions on the two different time limits, how the workers were assigned to one of the time limits, whether the workers were paid differently based on the assigned time limit, and whether workers could potentially earn more money by working longer (see Online Appendix A). Finally, they answered a few questions on their knowledge about jigsaw puzzles, demographics, and an attention check question.

Results

The experimental conditions affected judges' estimates of task completion time ($F(3, 313)=55.45$, $p<.001$). The manipulation of lay beliefs had no discernible effect on judges' estimates in the shorter time limit conditions ($M_{Shorter,\ Question} = 3.70$ vs. $M_{Shorter,\ Confirm} = 3.62$, $t(155)<1$, $p=.624$). However, judges' estimates in the longer time limit condition were significantly lower in the questioning lay belief condition than the confirming lay belief condition ($M_{Longer,\ Question} = 6.43$ vs. $M_{Longer,\ Confirm} = 7.53$, $t(158)=2.21$, $p=.028$). As a result, the sensitivity of time estimates to the time limit was weaker in the questioning condition ($\Delta=2.73$, $t(156)=7.38$, $p<.001$), than in the confirming condition ($\Delta=3.90$, $t(157)=10.55$, p<.001). The 2-way interaction was significant ($F(1, 313)=5.02$, $p=.025$; see Figure 3), demonstrating that prompting judges to question the over-generalized belief significantly reduced (but did not eliminate) the time limit bias.



Note: Vertical lines are +/- 2SE

Figure 3: Estimated time for task completion under different time limits when beliefs are manipulated (Study 4)

Discussion

The results of Study 4 provide further support for the scope perception account, demonstrating a role of beliefs about the association between time limits and task scope in the effects of time limits on completion time estimates. When judges read information casting doubt on the association between time limit and task scope, the effect of time limits on estimates was significantly reduced, specifically in the longer time limit condition. It should be noted that the manipulation we used in this study was subtle, in that, it prompted participants to doubt a potential link between task deadline and task scope (e.g., “might be unrelated”, “need not have”). Presumably, the manipulation weakened judges’ lay beliefs but did not necessarily eliminate them, particularly among participants who held strong beliefs prior to the manipulation. The observed results suggest that weakening the underlying association reduces the overgeneralized response and reduces the bias in estimation due to time limits. Therefore, this study provides additional evidence that scope perception beliefs underlie the observed time limit bias in this paper.

Furthermore, the moderation by believed associations demonstrated in this study is incompatible with other alternative accounts. The results cannot be explained by anchoring and adjustment, which should persist in both conditions. The observed difference across conditions is also inconsistent with the effect occurring because of participants not reading instructions carefully. As an additional test, as in Studies 2 and 3, we examined the robustness of the results by looking at the subset judges who currently answered a battery of five questions to indicate their comprehension. The substantive conclusions remained unchanged among this subset of judges (n=257; see Online Appendix C), further confirming that the observed results are not on account of judges misunderstanding the instructions regarding the situation facing the workers.

Thus far, we have investigated the effect of time limits on estimates using a single setting (jigsaw puzzles) that provides strong experimental control and using a population that generally has limited experience in making completion time estimates for workers. In the final study, we generalize our findings to a population of experienced managers making estimates about a relatively familiar task in a more naturalistic setting.

Study 5: Scope Perception Bias among experienced managers

Method

In a field survey, 203 actual managers of small-to-medium businesses (under 100 employees), who were responsible for deciding printing needs for their companies, were recruited from a paid online panel to answer questions in a vignette study that was included in a larger marketing research survey. After completing survey questions about their use of office printing services, participants read a scenario in which they were asked to imagine that they had hired a third-party vendor to send out customized mailers as part of a direct-marketing campaign. The vendor would use its own list of potential customers, customizing the mailers based on other information they had about the individuals. The scenario specified that after the vendor finalized the list of people to target from their database, it usually took four weeks to customize the mailers before sending them out.

The study employed a 2 (longer vs. shorter time limit) x 2 (time estimate vs. scope estimate) design. Participants were randomly assigned to either the shorter (4 weeks) or longer (6 weeks) time limit conditions. In the longer time limit condition, the scenario further elaborated that they had just come across an industry report which suggested that direct mail was less effective during late summer, and they had therefore informed the vendor about delaying the mailing by two weeks so that the mailers instead went out in early fall. We reiterated that this was a last-minute decision, made after the list of potential target customers had already been finalized and that, because of this change, the vendor now had six weeks to customize the mailers before sending them out. This manipulation introduces a difference in deadlines between the two conditions while holding constant the project's scope.

The managers participating in the survey were randomly assigned to either estimate the number of weeks it would take the vendor to prepare the customized mailers (time-estimate condition) or the number of mailers that would be prepared (scope-estimate condition; between-subjects). All participants then estimated the typical worker's rate (the number of mailers prepared by a worker in a day). The estimates were elicited using an ordinal measure with six different numerical ranges (see online Appendix A for the instructions used in the study). The judges also indicated the number of prospective customers they thought was within the mailing area of the direct-marketing campaign, whether they had any prior experience with direct-marketing campaigns and their zip code. We merged in an estimate of population density based on census data for each participant's zip code.

Results

Using ordinal regression (since the responses were elicited using an ordered scale), participants in the time-estimate condition (n=101) thought the vendor would take longer when the time limit in the scenario was longer (interpolated means in weeks: $M_{Shorter}$= 1.62 vs. M_{Longer}= 2.73; β=2.07, z=5.21, p <.001). This generalizes our prior finding of an effect of time limits on time estimates to a different setting and to experienced decision-makers. In particular, this demonstrates that a non-informative longer time limit leads experienced judges to expect that the same project, in a setting familiar to them, will take longer to complete.

We elicited beliefs about the rate of work in all the conditions by asking participants to estimate the number of mailers prepared per worker per day (unlike Study 3 where the rate was imputed). Participants' estimated rate of work did not differ significantly between the two time limit conditions ($M_{Shorter}$ = 398.00 vs. M_{Longer} = 313.72; β=0.36, z = 1.01, p=.311). Furthermore, in a multivariate ordinal regression predicting project completion time, we find that longer time limits yielded significantly higher completion time estimates (β=2.11, z=5.26, p <.001) controlling for the effect of estimated rate (β=0.0004, z=0.859, p=.390).[10] This suggests that the differences in the managers' time estimates under different deadline conditions cannot be explained by their belief that workers would work slower when more time was available.

To more directly test the scope of work account, the participants in the scope-estimate conditions (n=102) rated the total number of mailers they thought would be

[10] We find the same effects when also controlling for their zip code's population density, which was not a significant predictor.

prepared by the vendor, which was not specified in the scenario. Interpolating within the ordered levels representing ranges, the average estimated number of mailers was approximately 12,000 when the time limit was shorter, compared with 17,000 when two additional weeks were available. In an ordinal regression, we find that the estimated amount of work (i.e., number of mailers) in the longer time limit condition was marginally higher than in the shorter time limit condition (β=0.69, z=1.82, p=.069).

As in the time-estimate condition, the reported rate of work did not significantly differ based on the time limit ($M_{Shorter}$ = 464 vs. M_{Longer} = 356, z = 0.99, p=.322). A multivariate ordinal regression reveals that the managers estimated a larger scope for the completed project (more mailers sent) when the time limit was longer (β=1.06, z=2.57, p=.010) controlling for the effect of estimated rate (β=0.002, z=4.53, p<.001) suggesting that the scope perception effect is distinct from the effect of beliefs that workers would adjust their pace depending on the available time. In addition, as expected, the reported rate of work did not differ in the time-estimate and scope-estimate conditions, as a function of external time limits (interaction: β=0.025, z=0.051, p=.959).

Thirty-five percent of the participants reported that they had prior personal experience running direct-marketing campaigns, just like the one we had described in the experimental scenario. Personal experience with direct mail did not moderate any of the results (see Online Appendix C).

Discussion

In Study 5, using a field survey with experienced managers, we first replicated our previous finding that judges predict a longer task completion time when the deadline is longer, even when the change in deadline is due to completely incidental reasons. Furthermore, we find that a direct measure of the scope of work (i.e., the number of mailers sent) did vary with the time limit. Importantly, this effect was distinct from the effect of beliefs about how time limits affect the rate of work. Controlling for the measured rate of work, participants estimated a significantly larger amount of work when the deadline was longer, consistent with the scope perception account.

General Discussion

Across five studies in this paper (along with another seven studies in the appendix), we consistently find that people systematically estimate longer task completion time for others when more time is available to complete a task (meta-analytic $d = 1.25$, see Online Appendix E), even when the available time limits are irrelevant, contributing to over-estimation. Judges' estimates were overly influenced by time limits, relative to actual workers' time, even when they were paid for the accuracy of their estimates (Study 1). The effect of time limits persisted when judges were told that time limits were not known to the workers (Study 2, pre-registered). This finding is inconsistent with a lay motivational theory, in which time estimates are based on beliefs about how time limits affect workers' pace. Indeed, we found that the bias in time estimation cannot be explained by either imputed or directly-elicited beliefs about the rate of work (Study 5). Our studies also rule out alternative accounts such as direct inferences from time limits, truncation, or censoring of the completion time distribution.

In everyday life, time limits are often associated with task scope because time limits are endogenous, i.e., the deadlines are set after, at least in part, based on estimating the scope. Therefore, when judgments are impacted by time limits in practice, we typically cannot tell whether that is because of a scope perception bias or a reasonable inference. Our experiments, by contrast, are designed to distinguish between the two and isolate any bias in estimation. Specifically, we informed judges that the time limits were randomly assigned (and therefore exogenous; Studies 1-4). Even when time limits are exogenous, judges could have a reasonable belief that workers will pace themselves to finish the work in the assigned time limit. To address this normative inference, we told judges that workers did not know about the time limit (e.g., the time limit was the time after which they would have been stopped in their work, without their prior knowledge; Studies 2 and 3). The time-limit bias replicated among only the subset of judges who passed a comprehensive set of checks (Studies 2-4). Therefore, the findings cannot be attributed to judges' lack of understanding of the instructions in our experiments.

Instead, we find direct evidence for a scope-of-work explanation of the time-limit bias, in which longer time limits affect people's perceptions of task scope (meta-analytic $d = 0.327$, see Online Appendix E), even when there is no effect on rate of work. We find that judges estimate a task to be objectively larger (e.g., more puzzle pieces, more difficult) with longer time limits, even when the time limit is chosen at random and participants make judgments for multiple similar tasks (Study 3, pre-registered). Furthermore, in Study 3, we find that the larger perceived scope of work mediates the relationship between time limits and estimated completion time, consistent with the proposed scope perception mechanism. We also find that weakening beliefs about an association between time limits and task scope reduces the time limit bias (Study 4), providing further evidence that believed associations underlie the observed misestimation. Furthermore, experienced managers estimate that a direct mail campaign involves sending more items of mail when the deadline is exogenously extended and, therefore longer (Study 5).

Our results are consistent with recent research showing incidental externally imposed deadlines can affect perceptions of task difficulty for one's own self, with downstream consequences (Zhu et al., 2018). In our conceptualization, task difficulty is another aspect of task scope that can be affected by external deadlines. It is important to note that some of our tests of time-limit bias (e.g., Studies 1 and 4) were particularly conservative because the judges were provided with information relevant to the scope of the task (e.g., they saw a picture of the puzzle and knew the number of pieces). In these studies, the effect of scope perception on time estimation is limited to a subjective judgment of task difficulty, potentially incorporating factors such as the similarity of the puzzle pieces, the difficulty of sorting through them to find matching pieces, etc. This is analogous to a manager who has information about the objective, quantifiable parameters of a deliverable, but whose time estimates may still depend on a subjective assessment, shaped by the time limit, of the difficulty workers will have in completing the task. When objective measures of a task scope are absent, as is often the case with work tasks becoming more complex, we expect an even greater sensitivity to time limits on estimates via the scope perception bias.

Given the robustness of the effects described in the paper, it is likely that the time-limit bias is multiply determined. In particular, while anchoring and adjustment (Epley & Gilovich, 2001) alone is not sufficient to explain our findings (e.g., tested directly in Study 1, and excluded by showing all participants the same time limits in Studies 2-4), anchoring could contribute to the phenomenon we document in practice. Some prior research has suggested that anchors can influence judgments across modalities by priming a general sense of magnitude (Oppenheimer, LeBouef and Brewer 2008; Critcher & Gilovich, 2008; Wilson et al., 1996), such that when people encounter a large number, they make higher unrelated magnitude estimates. It is noteworthy that in Study 5, we found that the larger time limits increased only those judgments predicted by the scope account, but did not increase judgments indiscriminately (e.g., that of the rate of work), inconsistent with the cross-modal anchoring account.

In most of our studies (Study 1, 3 and 4) we used scenarios in which all workers were paid a fixed fee. This provides a conservative test of the effect of time limits on completion time estimates. If managers know that workers have no incentive to delay task completion, their estimates are likely to be less affected by time limits. However, in the real world, workers are sometimes paid using time-metered fees (e.g., dollar per minute, dollar per hour, etc.). Such payment schemes might perversely motivate workers to work for a longer duration to earn more money, and judges anticipating such behavior might predict longer completion times when time limits are longer. The extent to which judges are well-calibrated about workers' behavior would determine the accuracy of their estimates, and therefore the time-limit bias reported in this paper could also manifest in the real world for this completely different reason. In this paper, our aim was to identify and isolate a particular psychological route, scope perception, which could lead to biased completion time estimates in response to time limits facing a task.

Limitations and future research

The current paper focuses on examining a theoretical account of how deadlines might affect completion time judgments for others. In order to do this, we used stylized settings and vignette scenarios that included relatively short deadlines and small incentives among participants inexperienced in making such judgments. We deliberately used the controlled jigsaw puzzle setting in most of our studies because it helped rule out important confounds (e.g., quality of final output), but it raises questions about generalizability. Study 5 provides initial evidence that the time-limit bias can generalize to a setting outside the lab among experienced managers. The scope perception bias may help explain why managers may over-value flat fee contracts (versus per-unit-time contracts) to hire temporary employees when the available time limit is longer (Goswami & Urminsky, 2020). Similarly, managers might be overly impressed by workers' completion times when an exogenously determined time limit (e.g., set by a client) is longer, and then judge the same performance as poor when the time limit is shorter, potentially even impacting promotion, compensation, and performance appraisal decisions (Levy & Williams, 2004).

Our findings on how deadlines affect estimates of *other people's* task completion times also raise questions about whether deadlines will similarly affect predictions of one's own completion times. Indeed, recent research has shown that incidental longer deadlines affect resource allocation decisions for personal goals when the means and the outcomes are not well defined (Zhu et al., 2018). Our results also suggest that deadlines may affect procrastination, planning, and goal pursuit via the scope perception bias and resulting beliefs about one's own completion times. Interestingly, Zhu et al. (2018) find that experience with the task attenuates the effect of deadlines, whereas we do not find any moderating influence of measured experience or task knowledge (Studies 1-4), or of repeated choices (Study 3). This highlights the importance of systematically studying the role of experience on the effect of deadlines for decisions pertaining to self vs. others.

Future research could also examine what kind of scope information might be sufficient to eliminate the estimation bias induced by time limits. Studies 2 and 3 suggested that merely providing people information about the maximum time to complete a task is not sufficient to eliminate the bias. Likewise, in Study 4, calling into question the association between time limits and task scope significantly reduces but does not eliminate the bias. We believe that more detailed scope-relevant information is likely to be necessary to counter people's pre-existing beliefs about the relationship between time limits and scope that drive the observed bias. We find preliminary support for this in Study S7 (Online Appendix), in which we provided judges with a complete distribution of hypothetical task completion, which eliminated the scope perception effect. Given the pervasiveness of deadlines in the real world and the evidence that scope-relevant judgments are biased by deadlines, further investigation of interventions in consequential settings that reduce time-limit bias would be a useful research endeavor.

"Parkinson's Law," the idea that work expands such that people take more time when more time is available (Parkinson, 1955), has been highly influential, despite limited empirical evidence. In this paper, we suggest and provide evidence for a parallel Parkinson's Law of the Mind: people's conceptualization of a task expands with the time available, such that beliefs about the project scope and the time required expand with longer time limits, even when both the actual work done and time taken are not affected.

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Online Supplemental Materials

More Time, More Work: How Time Limits Bias Estimates of Project Duration and Task Scope

Contents

Appendix A: Study Materials (including Stimuli and Instructions)

Study 1

Jigzone.com interface which was integrated in a Qualtrics Survey in Study 1. Both workers and judges saw this picture. The same picture was used in Study 4.

Additional picture of the completed 20-piece jigsaw puzzle shown to workers and judges in Study 1. The same picture was used in Study 4.

Please read the following information SLOWLY AND CAREFULLY. This will be important to the choice you will be asked to make as well as for a bonus you can earn (details are provided later), and we will confirm your understanding at the end of the survey.

We conducted an actual study earlier this year, in which the workers were primarily students at commuter colleges participating in a research lab in downtown Chicago.

Workers were given the puzzle shown above, and were asked to solve the puzzle **either with no restriction on the maximum time** they could take, or a **maximum time of 5 minutes**, or a **maximum time of 15 minutes** to solve the puzzle. The time limit each person got was assigned completely at random, and workers did not get to choose the time limit.

Regardless of the time limit they had or how long it took, as soon as a worker finished the puzzle, that worker was

paid $3 and, after answering a few follow-up questions, could either leave or participate in other unrelated paid studies in that lab.

Next, we will ask you a few questions in which you will estimate the time it took people to finish solving the puzzle.

You can earn up to an additional $1 bonus payment, based on your accuracy. We will pick one of your estimates below at random and compare your response to the average actual time in the study we ran, described on the previous pages.

If your estimate matches the average time exactly, you will get an extra $1. For every minute of difference between your estimated time and the actual average time, we will deduct ten cents from the bonus. Any bonus you earn will be paid as a bonus payment via mechanical turk.

So, you will earn a larger bonus if you are as accurate as you can be in making your estimate on the next page.

Common instructions in Study 1.

Consider a typical worker for whom there was **no restriction on the maximum time** that could be taken to solve the 20 piece puzzle shown earlier.

Do you think that the typical worker spent **more or less than 5 minutes** working on the puzzle?

- ○ The typical worker spent LESS than five minutes
- ○ The typical worker spent five minutes
- ○ The typical worker spent MORE than five minutes

How much time do you think the average worker with no time limit took to solve the puzzle?

Remember you can earn an additional reward of up to $1.00 for making an accurate prediction.

Please enter the time in MINUTES in the box below:

Questions asked to investigate potential anchoring and adjustment account of time limits in Study 1. The figure shows the 5 minutes (short time limit) condition as an illustrative example.

Consider a typical worker for whom there was a **maximum time of 5 minutes** to solve the 20 piece puzzle shown earlier.

How much time do you think the average worker with a maximum time limit of 5 minutes took to solve the puzzle?

Remember you can earn an additional reward of up to $1.00 for making an accurate prediction.

Please enter the time in MINUTES in the box below:

The five-minutes condition in Study 1

Consider a typical worker for whom there was a **maximum time of 15 minutes** to solve the 20 piece puzzle shown earlier.

How much time do you think the average worker with a maximum time limit of 15 minutes took to solve the puzzle?

Remember you can earn an additional reward of up to $1.00 for making an accurate prediction.

Please enter the time in MINUTES in the box below:

The fifteen-minutes condition in Study 1

How do you think workers were assigned to get the unrestricted time condition, or the 5 minute maximum time condition, or the 15 minute maximum time condition?

- They were assigned completely at random
- They were assigned based on how fast and proficient they were in solving jigsaw puzzles, or some other factor

End-of-survey comprehension check questions in Study 1

Study 2

Assume, that we have a 100 piece jigsaw puzzle. It need not be of the same picture which was earlier shown to you as an example.

We administered this puzzle to a group of individuals in a mid-western university and each person took less than 28 minutes to solve it.

As part of this study, we would like to administer the same puzzle to another group of people who are similar to those in our previous group.

To confirm the number of pieces in the puzzle which we are going to use in this experiment, please enter the number below to proceed further.

Common instructions to all judges in Study 2

Assume that there is no limit on the amount of time individuals in the group have to solve the puzzle.

This means that an individual can take as much time as they need to solve the jigsaw puzzle.

Instructions in the control (unlimited time) condition in Study 2

Assume, that our study has two conditions based on the total amount of time each individual is given to solve the puzzle.

Condition 1: Total time available to solve the puzzle is 30 minutes.
Condition 2: Total time available to solve the puzzle is 45 minutes.

A fair coin is tossed and if the result is HEADS, the person is assigned to Condition 1. Otherwise, if the coin comes up TAILS, the individual is assigned to Condition 2.

Therefore, every individual in the new group will have an equal chance of getting assigned to either of the two conditions.

Once assigned to a condition, individuals will work until they solve the problem or the time limit is over, whichever occurs earlier.

Instructions in the treatment (i.e., deadline) conditions in Study 2

However, here is an IMPORTANT point (please read carefully).

A person assigned to either of the above mentioned conditions is not told that there is a time limit.
So, participants in the 30 minutes condition and in the 45 minutes condition do not know about these time limits.

The experimenter who has assigned them to either of the two conditions is just going to stop a participant from proceeding any further in case he or she is not done with solving the puzzle in the allotted experimental time.

The participant is only told to solve the puzzle at his or her own pace.

Additional instructions in the treatment (i.e., deadline) conditions in Study 2

What were the maximum time available to a person to solve the jigsaw puzzle in the two conditions described in the study?

Please enter the values in MINUTES below.

Condition 1 (Max. time in MINUTES)

Condition 2 (Max. time in MINUTES)

Did people working under 30 minutes time limit and those working under 45 minutes time limit solve the same puzzle?

- Yes, both solved the same jigsaw puzzle
- No, they solved different jigsaw puzzles
- Don't Know/Can't Say

How do you think people were assigned to one of the two time limit conditions?

- They were assigned at random
- They were assigned based on how fast and proficient they were in solving jigsaw puzzles

How many pieces were there in the jigsaw puzzle? Please enter the value in the box below.

When we had tested the 100 piece jigsaw puzzle with the first group of individuals in a mid-western university, what was the maximum time people took to solve the puzzle?

Please enter the value in MINUTES below.

Time in MINUTES

Regardless of how much time they actually had, how much time do you think participants in the study **thought** they had to solve the puzzle?

Participants thought they had _______ Minutes:

- Unlimited time
- No more than _____ minutes:

Condition: No more than _____ minutes: Is Selected. Skip To: How many minutes did they think they ....

How many minutes did they think they had?

End-of-survey comprehension check questions in Study 2

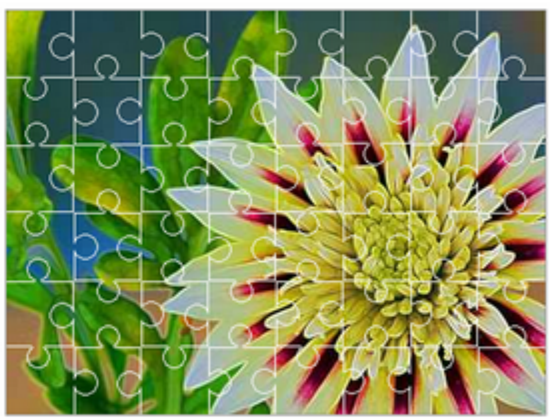
Study 3

As you might know, **a jigsaw puzzle requires the assembly of numerous small, often oddly shaped, interlocking pieces to produce a complete picture**.

The pictures below show an example jigsaw puzzle (with the pieces shuffled, Fig. 1), and how it looks when it is solved (Fig. 2)

Fig. 1: Jigsaw puzzle

Fig. 2: Solved puzzle



Online jigsaw puzzles (like the ones used in this survey) are played using software that initially shuffles the puzzle pieces, and allows the player to drag them together. The software also gives feedback (via an audible snap sound) when two valid pieces are brought together. This ensures that a particular puzzle has only one solution, i.e., the correct solution.

The online software also automatically (and accurately) records the time taken to solve a jigsaw puzzle.

Imagine that we ask actual participants to solve an online jigsaw puzzle and the software accurately records the time taken. In this survey, your task is to predict these completion times for a few jigsaw puzzles. We will then ask you a few followup questions about your thinking process. That's all.

In the next few pages, we will provide you with information about the participants who work on the puzzles, the situation they face including details of the jigsaw puzzles they attempt to solve.

Common instructions in Study 3

We plan to recruit several **students from commuter colleges** in a large Midwestern city in the United States.

So, **our typical participant is not a jigsaw-puzzle expert**, but an ordinary person like you and me. Also, **participants solve only one puzzle** so they do not get an opportunity to practice and hone their skills.

We plan to pay every participant a fixed flat fee for the work. After they are done working, they collect their payment and leave the venue.

IMPORTANT NOTE: In the past, we have done some preliminary tests asking such participants to solve similar jigsaw puzzles. In those tests, **every individual participant was able to solve the puzzle that he/she was assigned. Also, NONE of the participants took more than 30 minutes to solve any puzzle.**

About the situation facing the participants

There is an assigned time limit within which every participant is expected to solve the puzzle. **The time limit is random**: chosen between one of two time limits BASED ON A COIN TOSS.


If the coin turns up HEADS, the participant will have a maximum time limit of **35 minutes** to solve the assigned puzzle.


If the coin turns up TAILS, the participant will have a maximum time limit of **50 minutes** to solve the assigned puzzle.

As you would realize, **every participant has an equal chance of getting one of the two time limits**.

NOTE CAREFULLY:

Participants are told about their time limit before they start working on the puzzle. In particular, they are informed that they would work until they are done or the assigned time limit expires, whichever occurs earlier.

However, the way the time limit is set (i.e., using a coin toss) is for administrative convenience and **participants are NOT told that the assigned time limit was randomly determined**.

Additional instructions in the condition where workers knew about the time limits in Study 3. In the condition where workers *did not know* the time limit, the last block was changed.

Before you proceed to the next page, please answer a few yes/no questions to indicate your comprehension. All the information required for answering these questions is there in the instructions you have read so far.

	No	Yes
The jigsaw puzzles are administered to participants using an online software	○	○
Only experts are recruited as participants for solving the jigsaw puzzles	○	○
Some participants are asked to solve more than one jigsaw puzzles	○	○
Participants are paid a fixed flat fee to work on a jigsaw puzzle	○	○
There is an assigned time limit for every participant within which he/she is expected to finish solving the puzzle	○	○
The assigned time limit for any participant is randomly determined	○	○
Participants know about their assigned time limit before starting to work	○	○
In the past, some participants took more than 30 minutes to solve the assigned puzzle	○	○
In the past, every participant was able to successfully solve the assigned puzzle	○	○

Comprehension questions about the experimental setup in Study 3

The following is one puzzle that participants solve, and **we want you to predict the completion time for a typical participant.**

Fig.1: Jigsaw puzzle

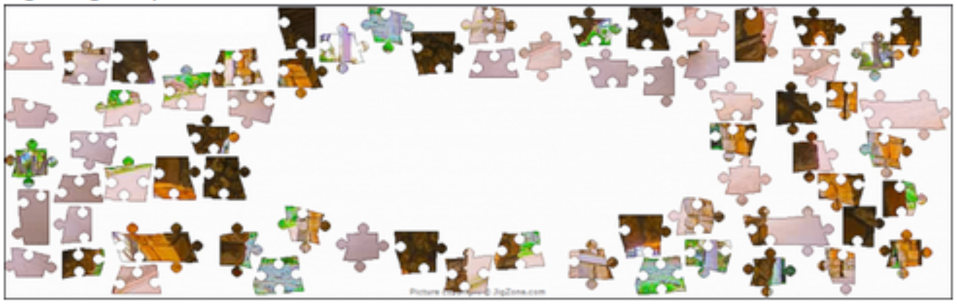


Fig. 2: Solved puzzle

IMPORTANT NOTE: The particular individual for which you are predicting is assigned a time limit of 35 minutes, based on a coin toss, to solve the puzzle.

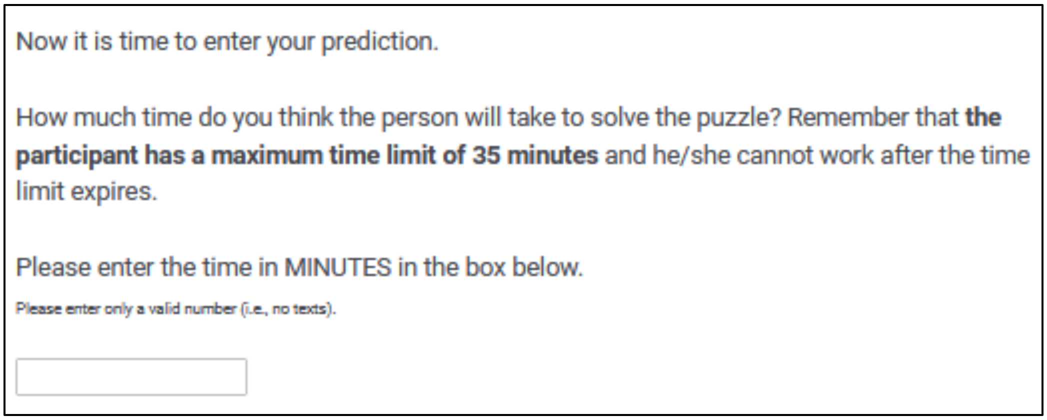
Also, **the participant knows that he/she has a time limit of 35 minutes** before starting to work on the puzzle.

Please spend some time on this page carefully thinking about the jigsaw puzzle. How might the participant approach this task? How much work do you think solving this puzzle would entail given the situation the participant is facing?

You will be asked to enter your prediction (time in minutes, the participant took to solve the puzzle) on the next page.

Click Next only when you are ready to enter your prediction.

The first decision scenario in Study 3 (here the first decision was for a task that had a 35 minutes time limit; the task and the time limit was counterbalanced in the experiment)



Now it is time to enter your prediction.

How much time do you think the person will take to solve the puzzle? Remember that **the participant has a maximum time limit of 35 minutes** and he/she cannot work after the time limit expires.

Please enter the time in MINUTES in the box below.

Please enter only a valid number (i.e., no texts).

Eliciting judges' estimation in Study 3. A similar question followed after judges were introduced to the second decision scenario shown below.

The following is **another puzzle that a separate group of participants solves.** We now want you to predict the completion time for this puzzle for a typical participant.

Please read carefully as the situation might have changed.

Fig.1: Jigsaw puzzle

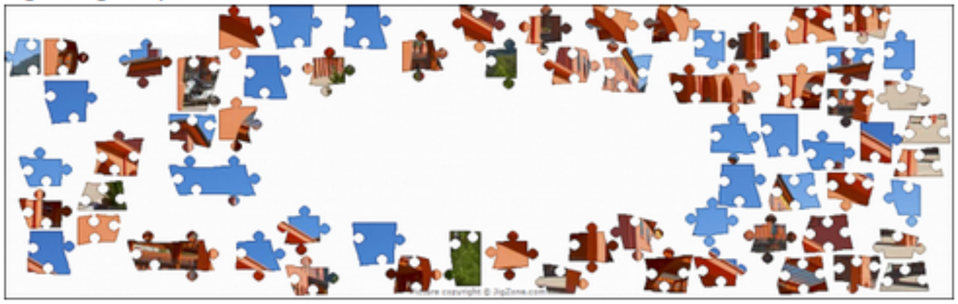


Fig. 2: Solved puzzle

IMPORTANT NOTE: The particular individual for which you are predicting is assigned a time limit of 50 minutes, based on a coin toss, to solve the puzzle.

Also, **the participant knows that he/she has a time limit of 50 minutes** before starting to work on the puzzle.

Please spend some time on this page carefully thinking about the jigsaw puzzle. How might the participant approach this task? How much work do you think solving this puzzle would entail given the situation the participant is facing?

You will be asked to enter your prediction (time in minutes, the participant took to solve the puzzle) on the next page.

The second decision scenario in Study 3

Recall that you were asked to make prediction decisions about these two jigsaw puzzles.

	
Puzzle 1 (maximum time limit = 35 mins) The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.	**Puzzle 2 (maximum time limit = 50 mins)** The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.

Which puzzle, according to you, did a typical participant find more interesting and enjoyable?

1. Puzzle 1 was more interesting and enjoyable	2	3	4. Equally interesting and enjoyable	5	6	7. Puzzle 2 was more interesting and enjoyable

Post-decision follow-up question in Study 3. Each of the follow-up questions was asked on a separate page with back navigation disabled.

Recall that you were asked to make prediction decisions about these two jigsaw puzzles.

	
Puzzle 1 (maximum time limit = 35 mins) The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.	**Puzzle 2 (maximum time limit = 50 mins)** The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.

According to you, "how much work" is there in solving **Puzzle 1**? Please drag the bar below to indicate your answer (1=A Little Work; 100= A Lot of Work).

1 11 21 31 41 51 60 70 80 90 100

Puzzle 1

According to you, "how much work" is there in solving **Puzzle 2**? Please drag the bar below to indicate your answer (1=A Little Work; 100= A Lot of Work).

1 11 21 31 41 51 60 70 80 90 100

Puzzle 2

Post-decision follow-up question in Study 3. Each of the follow-up questions was asked on a separate page with back navigation disabled.

Recall that you were asked to make prediction decisions about these two jigsaw puzzles.

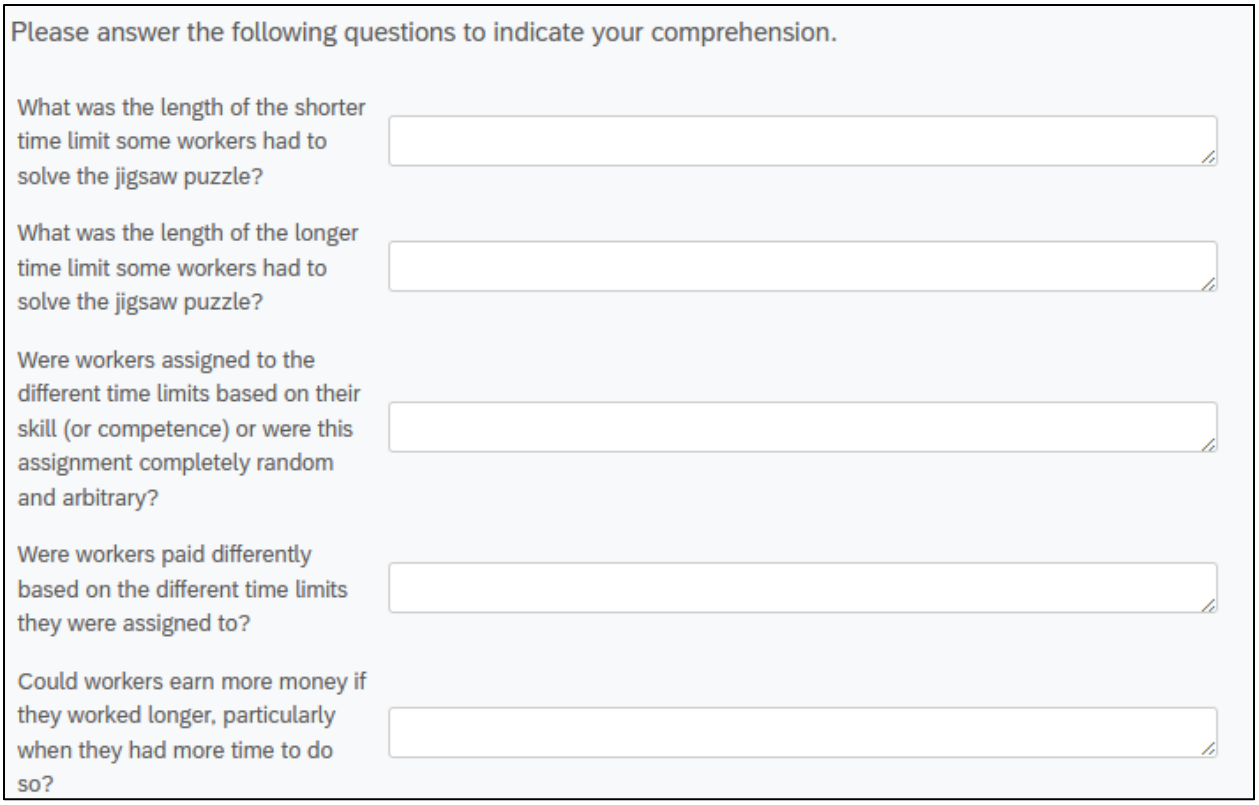
	
Puzzle 1 (maximum time limit = 35 mins) The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.	**Puzzle 2 (maximum time limit = 50 mins)** The survey is administered using an online interface that accurately records the time taken. Participants are commuter college students who are randomly assigned to one of two time-limits. The time limit is known to the participants.

Which jigsaw puzzle do you think had more number of pieces?

1. More pieces in Puzzle 1	2	3	4. Same number of pieces	5	6	7. More pieces in Puzzle 2

Post-decision follow-up question in Study 3. Each of the follow-up questions was asked on a separate page with back navigation disabled.

Study 4



Please answer the following questions to indicate your comprehension.

What was the length of the shorter time limit some workers had to solve the jigsaw puzzle?

What was the length of the longer time limit some workers had to solve the jigsaw puzzle?

Were workers assigned to the different time limits based on their skill (or competence) or were this assignment completely random and arbitrary?

Were workers paid differently based on the different time limits they were assigned to?

Could workers earn more money if they worked longer, particularly when they had more time to do so?

End-of-survey comprehension check questions in Study 4

Study 5

Imagine that you have hired a third party vendor which sends out customized mailers to promote your business to prospective customers. The vendor will use their own list and they specialize in customizing the mailers based on other information they have about the individuals.

Once the deal is finalized, the vendor calculates how many mailers can be sent depending on how many prospects they find in their database. The vendor then spends 4 weeks customizing the mailers and then sends them out.

Common instructions in Study 5

However, you just came across an industry report which says that direct mail is least effective in late summer. Based on this information, you tell the vendor to delay the mailing by two weeks so that it goes out in the early Fall.

This was a last minute decision after the list of prospective customers was already finalized. But, because of this change, the vendors will instead get 6 weeks for customizing the mailers before sending them out.

Additional instructions in the long time limit condition (6 weeks) in Study 5

As mentioned earlier, the vendor has **4 weeks** to prepare the mailers.

Also as mentioned earlier, the vendor prepares the master list of prospective customers first and then does the customization for each. The vendor sends a customized mailer to each person in this list.

How many mailers do you think the vendor would **actually** send out? Just give us your best guess.

- Less than 5000
- 5000 to 10000
- 10000 to 30000
- 30000 to 50000
- 50000 to 80000
- 80000 to 100000
- More than 100000

Eliciting scope of work in the short time limit condition in Study 5

How many customized mailers do you think an average employee of the vendor who is working only on this project is preparing per day? Just give us your best guess.

- ○ Less than 100
- ○ 100 to 200
- ○ 200 to 500
- ○ 500 to 800
- ○ 800 to 1000
- ○ Greater than 1000

Eliciting rate of work in both the short and the long time limit condition in Study 5

As mentioned earlier, the vendor has **4 weeks** to prepare the mailers.

How much time do you think the vendor would **actually** take to prepare the customized mailers? Please indicate which of these comes closest to your best guess.

- ○ 25% of the available time (1 week)
- ○ 37.5% of the available time (1.5 weeks)
- ○ 50% of the available time (2 weeks)
- ○ 62.5% of the available time (2.5 weeks)
- ○ 75% of the available time (3 weeks)
- ○ 87.5% of the available time (3.5 weeks)
- ○ 100% of the available time (4 weeks)

Elicitation procedure for time estimation in the short time limit condition in Study 5. In the long time limit condition (6 weeks) the percentages of available time were the same (25%, 37.5%, etc.), and the absolute numbers were calculated accordingly (1.5 weeks, 2.25 weeks, etc.)

Appendix B: Data Handling and Comprehension Dropouts

Data Exclusion: All online participants with duplicate IP addresses were excluded from analysis (in all studies) before looking at the data. In addition, judges in Studies 1-4 answered the following attention check question towards the end of the survey, and those who failed this check were excluded from analysis (in all studies) before looking at the data.

People vary in the amount they pay attention to these kinds of surveys. Some take them seriously and read each question, whereas others go very quickly and barely read the questions at all. If you have read this question carefully, please write the word yes in the blank Other box below.

1 Not at all
2
3
4
5 A great deal
6 Other ________________________________

Following are the drop rates in the online studies. We also examine if these rates are different by the experimental conditions. Please note the following:

1. In order to be consistent, we compute the drop rates on the base of all Ps from whom some responses were captured when the survey ended. Some of these responses were incomplete. As a result, dropout rates might look high. For example, in the pre-registered study 3, we requested for 350 respondents and had 347 usable responses at the end (< 1% drop rate). But, based on the number of respondents in our data set (i.e., 392), the drop rate looks larger.
2. Phase 1 of Study 1 (i.e., the workers' phase) used lab participants, and there were no dropouts. Study 5 used a paid online panel, and there were no dropouts.
3. In Study 3, the time limit was a within-subjects factor. The only between-subjects factor was whether the workers knew their time limits (yes, no), which we use below.

The results confirm that the initial dropouts did not vary by experimental conditions.

Study #	Overall drop rate	Experimental Conditions (between/subjects)	Chi-Square results
1	8.2%	5, 15, 5-Anchor, 15-Anchor	$\chi 2(3)= 1.44, p= .694$
2	15.7%	Untimed, 30, 45	$\chi 2(2)= 3.04, p= .219$
3	11.5%	Deadline known, not known	$\chi 2(1)<1$
4	10%	5, 15	$\chi 2(1)<1$
4	10%	2(Time Limit: 5,15) x 2(Beliefs: C, Q)	$\chi 2(3)<1$

Dropouts because of comprehension failure: In all studies reported in the manuscript, we included everyone who passed the initial exclusion criteria reported above. However, we examined the robustness of our reported findings, in the online appendix, by looking at the subset of participants who correctly answered the comprehension check questions. Here we examine whether the dropout on account of comprehension check failures varies by experimental conditions.

Two points to note:

1. Study 5 used real managers and did not have any comprehension checks
2. In Study 3, time limit was a within-subjects factor. The only between-subjects factor was whether the workers knew their time limits (yes, no).

The results confirm that these dropouts did not vary by experimental conditions. The results of Study 4 show a marginal difference when we consider all the four cells in the 2x2 design. We do not think this small difference is systematic.

Study #	Number of comprehension check questions	Experimental Conditions (between/subjects)	Chi-Square results
1	1	5, 15, 5-Anchor, 15-Anchor	$\chi 2(3)<1$
2	6	Untimed, 30, 45	$\chi 2(2)<1$
3	2 (pre-registered analysis)	Deadline known, not known	$\chi 2(1)<1$
3	9	Deadline known, not known	$\chi 2(1)<1$
4	5	5,15	$\chi 2(1)<1$
4	4	2(Time Limit: 5,15) x 2(Beliefs: C, Q)	$\chi 2(3)=7.23$, $p=.065$

Appendix C: Additional Analysis

Study 1

Handling Extreme Values: While the time estimates (under deadlines) were bounded to the maximum available time limit, Study 1 also employed an anchoring manipulation where judges could enter a numerical estimate that was not bounded. We examined the robustness of our conclusions after replacing extreme estimate values in the anchoring conditions with minimum or maximum non-outlier values.

Outlier Handling Strategy	1-way ANOVA	Anchoring vs. Time Limit Estimation
Log transformation	$F(3,598)=40.64$, $p<.001$	5 mins: $t(300)=+5.78$, $p<.001$ 15 mins: $t(298)=+1.32$, $p=.186$
Truncation to maximum available time limit	$F(3,598)=80.51$, $p<.001$	5 mins: $t(300)=+4.79$, $p<.001$ 15 mins: $t(298)=+1.09$, $p=.275$
Iterative Grubbs test	$F(3,598)=50.09$, $p<.001$	5 mins: $t(300)=+7.35$, $p<.001$ 15 mins: $t(298)=+1.59$, $p=.111$
Winsorizing 90%	$F(3,598)=53.17$, $p<.001$	5 mins: $t(300)=+7.49$, $p<.001$ 15 mins: $t(298)=+1.64$, $p=.101$
Winsorizing 95%	$F(3,598)=48.39$, $p<.001$	5 mins: $t(300)=+7.23$, $p<.001$ 15 mins: $t(298)=+1.58$, $p=.113$

Within-Estimates: After estimating task completion time for a particular time limit, judges were asked to do a similar (but unanticipated) estimation for workers working under the other time limit (within-subject estimates) for the exact same task. Judges revised their estimates when the time limit changed. After estimating task completion time for the 5 minute time limit ($M_{Shorter}$ = 3.49), judges estimated that workers would take an average of M_{Longer} = 6.36 when time limits are longer ($t(148)=13.54$, $p<.001$). Likewise, when judges first estimated the completion time for longer time limit (M_{Longer} = 6.89), they then estimated a shorter time for the shorter time limit ($M_{Shorter}$ = 3.63; $t(154)=13.10$, $p<.001$). The order of the time limits did not affect the estimates significantly in this study (β=0.38, t=1.16, p=.244). However, the absolute differences in the within-subject estimates were directionally smaller (Δs = 2.87 and 3.25) than the between-subject estimates (Δ=3.40). These results suggest that judges updated their subjective perception of the scope of the task when time limits changed, and accordingly revised their estimates of others' completion times.

Potential Moderating Variables: The tables below examine potential moderation of the effect of time limits (short vs. long) on judges' time estimates by various variables. Some of these variables were measured (e.g., time to read instructions), whereas others were asked as follow-up questions.

Table 1: Log of time to read instructions

	β	SE	*t*	*p*
(Intercept)	4.105	0.966	4.249	<.001
Long Time	4.214	1.194	3.527	<.001
Log of Time To Read Instructions	-0.151	0.232	-0.654	.513
Long Time x Log of Time To Read Instructions	-0.216	0.289	-0.747	.455

Table 2: Judges' self-rated knowledge about jigsaw puzzles

	β	SE	*t*	*p*
(Intercept)	3.88	0.69	5.621	<.001
Long Time	5.106	0.992	5.148	<.001
Judges' Self-Rated Knowledge About Jigsaws	-0.130	0.218	-0.595	.552
Long Time x Judges' Self-Rated Knowledge	-0.584	0.319	-1.833	.068

Interpretation: As self-rated knowledge increased, the difference in judges' estimates in the short vs. long time limit condition reduced marginally (see figure below). We do not replicate this effect systematically in other studies.

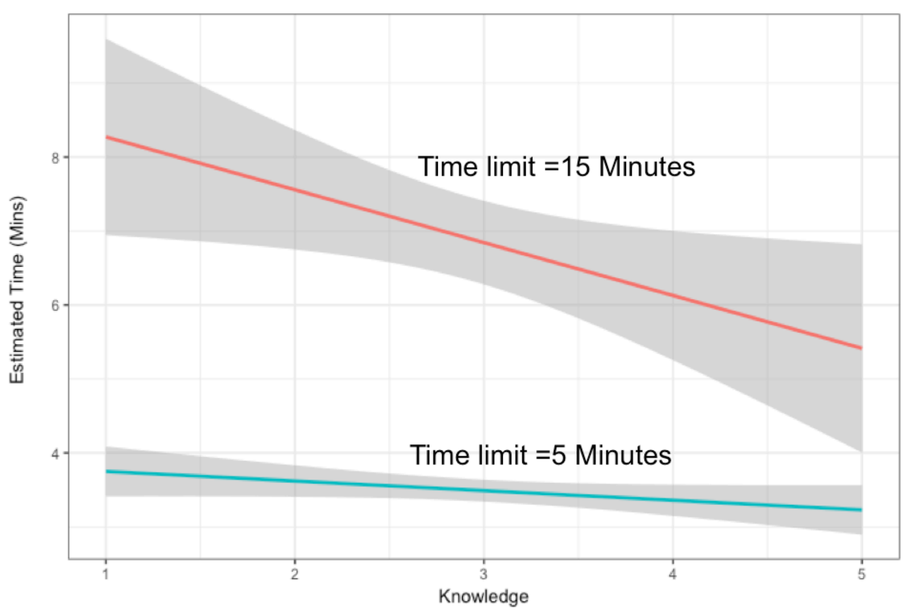


Table 3: Judges' self-rated frequency of solving jigsaw puzzles

	β	SE	*t*	*p*
(Intercept)	3.913	0.728	5.377	<.001
Long Time	3.727	1.099	3.392	<.001
Judges' Self-Rated Frequency of Solving Jigsaws	-0.181	0.297	-0.610	.542
Long Time x Judges' Self-Rated Frequency	-0.135	0.449	-0.300	.764

Table 4: Judges' belief that workers felt accountable to finish ASAP

	β	SE	*t*	*p*
(Intercept)	4.142	1.105	3.747	<.001
Long Time	3.234	1.502	2.153	.032
Workers Felt Accountable to Finish ASAP	-0.17	0.282	-0.602	.548
Long Time x Accountable to Finish ASAP	0.045	0.382	0.118	.906

Table 5: Judges' belief that workers wanted to take longer to enjoy more

	β	SE	*t*	*p*
(Intercept)	3.105	0.503	6.195	<.001
Long Time	2.575	0.714	3.604	<.001
Workers wanted to take longer to enjoy more	0.244	0.288	0.848	.397
Long Time x Workers wanted to take longer to enjoy more	0.558	0.421	1.325	.186

Table 6: Judges' belief that workers found the jigsaw puzzle interesting

	β	SE	*t*	*p*
(Intercept)	3.573	0.89	4.014	<.001
Long Time	3.842	1.206	3.185	.002
Workers Found Puzzle Interesting	-0.024	0.243	-0.097	.923
Long Time x Workers Found Puzzle Interesting	-0.128	0.334	-0.384	.701

Table 7: Judges' belief that people will work slower when more time is available

	β	SE	t	p
(Intercept)	3.524	0.375	9.397	<.001
Long Time	3.245	0.525	6.177	<.001
Beliefs Consistent with Parkinson's Law (PL)	-0.053	0.460	-0.114	.909
Long Time x Beliefs Consistent with PL	0.240	0.644	0.372	.710

Study 2

Potential Moderating Variables: The tables below examine potential moderation of the effect of time limits (short vs. long) on judges' time estimates by various variables.

Table 8: Judges' Self-Rated Knowledge About Jigsaw Puzzles

	β	SE	*t*	*p*
(Intercept)	27.691	1.658	16.696	<.001
Long Time	0.004	2.225	0.002	.998
Judges' Self-Rated Knowledge About Jigsaws	-0.427	0.512	-0.834	.405
Long Time x Judges' Self-Rated Knowledge	1.132	0.691	1.639	.103

Table 9: Judges' Self-Rated Frequency of Solving Jigsaw Puzzles

	β	SE	*t*	*p*
(Intercept)	26.814	1.499	17.877	<.001
Long Time	0.081	2.182	0.037	.970
Judges' Self-Rated Frequency of Solving Jigsaws	-0.196	0.622	-0.315	.753
Long Time x Judges' Self-Rated Frequency	1.485	0.910	1.632	.104

Study 3

Potential Moderating Variable: The table below examines the potential moderation of the relationship between workers' knowledge of time limits (known vs. not-known) and deadlines on estimates.

Table 10: Judges' Self-Rated Knowledge About Jigsaws

	β	SE	*t*	*p*
(Intercept)	20.69	1.91	10.85	<.001
Long Time	1.25	1.40	0.90	.371
Time Limit Known = True	-2.31	2.85	-0.81	.418
Judges' Self-Rated Knowledge About Jigsaws	0.02	0.70	0.03	.975
Long Time x Time Limit Known	1.25	2.09	0.60	.552
Long Time x Judges' Self-Rated Knowledge	0.36	0.51	0.71	.482
Time Limit Known x Judges' Self-Rated Knowledge	1.36	1.06	1.29	.199
Long Time x Time Limit Known x Knowledge	-0.26	0.78	-0.34	.737

Table 11: Judges' Self-Rated Frequency of Solving Jigsaw Puzzles

	β	SE	*t*	*p*
(Intercept)	19.39	2.19	8.87	<.001
Long Time	3.37	1.61	2.10	.037
Time Limit Known = True	-0.85	3.14	-0.27	.786
Judges' Self-Rated Frequency of Solving Jigsaw Puzzles	0.60	0.91	0.65	.513
Long Time x Time Limit Known	-2.18	2.31	-0.95	.345
Long Time x Judges' Self-Rated Frequency	-0.53	0.67	-0.79	.430
Time Limit Known x Judges' Self-Rated Frequency	0.87	1.32	0.66	.508
Long Time x Time Limit Known x Frequency	1.22	0.97	1.26	.207

Table 12: Judges' Age

	β	SE	t	p
(Intercept)	18.02	2.21	8.17	<.001
Long Time	4.62	1.61	2.87	.004
Time Limit Known = True	2.49	3.30	0.76	.450
Judges' Age	0.07	0.05	1.30	.193
Long Time x Time Limit Known	-1.72	2.41	-0.71	.476
Long Time x Judges' Age	-0.06	0.04	-1.61	.108
Time Limit Known x Judges' Age	-0.03	0.09	-0.40	.691
Long Time x Time Limit Known x Age	0.06	0.06	0.96	.338

Table 13: Judges' Gender (Female vs. Male)

	β	SE	t	p
(Intercept)	21.28	0.97	22.04	< .001
Long Time	2.48	0.71	3.49	.001
Time Limit Known = True	0.10	1.33	0.08	.940
Judges' Age	-1.17	1.42	-0.82	.411
Long Time x Time Limit Known	-0.59	0.98	-0.60	.550
Long Time x Judges' Age	-0.67	1.04	-0.64	.523
Time Limit Known x Judges' Age	2.61	2.01	1.29	.196
Long Time x Time Limit Known x Age	2.69	1.48	1.82	.069

Examining mediation using bootstrapping:

Approach: The bootstrapping code runs the following models for 500 times and computes $(\mathrm{b} - \mathrm{b}')$ in each iteration. This difference in coefficients is saved and sorted to calculate the 95% CI. Hierarchical regressions are used in all cases, and X denotes the covariate whose mediating effect is being studied.

Base model: $compensation\ scheme\ choice = a_0 + b * Time\ Limit$
Mediation model: $compensation\ scheme\ choice = a_1 + b' * Time\ Limit + c * X$

The table shows the 95% CI for each of the mediating covariates. All the above mediations were partial.

Mediating Covariate	**Indirect Effect (bootstrapped 95% CI)**
beliefs about whether jigsaw puzzle with 50-mins had more number of pieces	[0.0598, 0.3769]
beliefs about task scope	[0.0636, 0.5759]
Composite index of the two above variables (after standardizing using z-scores)	[0.1852, 0.69271

Proportion of judges whose estimates were higher than the time limit as a function of whether time limits were known or not

35 Minutes		**50 Minutes**	
Time Limit known	Time Limit not known	Time Limit known	Time Limit not known
0.57%	1.1%	0.56%	0%
$\chi^2(1)$= 0.0006, *p*= .98		NS	

The above results further suggest (as in Studies 1, S2, S4) that it is unlikely that judges censored or truncated their distributional beliefs about workers' completion times in the shorter time limit (vs. the longer time limit).

Effect of order of time limits on completion time estimates

In Study 3, judges saw two different (but very similar) puzzles that were counterbalanced and randomly assigned to one of two time limits. As expected, there was no effect of puzzle order (i.e., which jigsaw puzzle was seen first) on how time limits affected completion time estimates (interaction β= 0.59, t=0.81, p=.418). However, the order of time limits (i.e., whether judges estimated completion times for the shorter or the longer time limit first) moderated the effect of time limits on completion time estimates (β= 3.29, t=4.64, p<.001). In particular, longer deadlines exerted a stronger effect on judges' estimation. After estimating completion time for a shorter time limit, judges revised their estimations significantly when they faced a decision involving a longer time limit ($M_{Shorter}$ = 20.45 minutes vs. M_{Longer} = 24.60; β= 4.15, t=8.94, p<.001). However, after having estimated time completion for a task with a longer deadline, judges did not revise their estimates significantly when they subsequently encountered a task with a shorter deadline (M_{Longer} = 22.97 vs. $M_{Shorter}$ = 22.11; β = 0.86, t=1.61, p=.109).

Robustness Check using Judges who passed all the nine comprehension check questions before answering any questions in the survey:

In this analysis, we used only those judges who passed all the nine comprehension check questions before answering any questions in the survey (N=203).

Judges estimated longer completion time when the externally assigned time limit was longer ($M_{Shorter}$ = 20.42 minutes vs. M_{Longer} = 22.15; β= 1.72, t=2.73, p=.007). Furthermore, the effect persisted even when judges were told that workers did not know about the time limits ($M_{Shorter}$ = 18.74 minutes vs. M_{Longer} = 19.91; β= 1.17, t=2.35, p=.021). In fact, the increase in estimation as a result of longer time limits was identical irrespective of whether the workers knew about the time limits or not (interaction β= 0.56, t=0.69, p=.488), further confirming that judges' beliefs about how deadlines affect workers' behavior were not responsible for our findings. Given that there was no difference in estimates because of this experimental manipulation, the rest of the analysis uses the combined data.

Consistent with our hypothesis that longer deadlines increase the perceived scope of work, a composite z-score index computed from these two measures of task scope, partially mediated the effect of time limit on completion time estimates (bootstrapped 95% CI = [0.18, 0.81]). Therefore, using only a subset of judges who passed a rigorous set of nine comprehensive checks, we successfully replicated the important findings and found substantive evidence in favor of our hypothesized process mechanism.

The results also replicate if we look at the judges who correctly answered the two questions included in our pre-registered analysis: time limits were random and workers either were aware or were not aware of the time limits, depending on the conditions (N=268).

Study 4

Potential Moderating Variables: The table below examines the potential moderation of the relationship between belief-manipulation and deadlines on estimates.

Table 14: Judges' Self-Rated Knowledge About Jigsaws

	β	SE	t	p
(Intercept)	3.63	0.82	4.43	<.001
Judges' Self-Rated Knowledge About Jigsaws	0.00	0.24	-0.01	.996
Long Time	3.52	1.36	2.59	.010
Belief Manipulation = Question	0.32	1.26	0.26	.799
Judges' Self-Rated Knowledge x Long Time	0.12	0.42	0.30	.767
Judges' Self-Rated Knowledge x Question	-0.08	0.40	-0.21	.833
Time Limit Known x Question	-0.07	1.88	-0.04	.969
Long Time x Question x Knowledge	-0.35	0.59	-0.60	.551

Table 15: Judges' Self-Rated Frequency of Solving Jigsaw Puzzles

	β	SE	t	p
(Intercept)	3.31	0.81	4.09	<.001
Judges' Self-Rated Frequency of Solving Jigsaw Puzzles	0.13	0.32	0.40	.687
Long Time	5.88	1.29	4.57	<.001
Belief Manipulation = Question	0.16	1.27	0.13	.900
Judges' Self-Rated Frequency x Long Time	-0.83	0.52	-1.61	.109
Judges' Self-Rated Frequency x Question	-0.03	0.51	-0.07	.947
Time Limit Known x Question	-2.11	1.84	-1.15	.251
Long Time x Question x Frequency	0.41	0.74	0.56	.578

Table 16: Judges' Age

	β	SE	t	p
(Intercept)	3.51	0.76	4.64	<.001
Judges' Age	0.03	0.19	0.16	.870
Long Time	6.17	1.21	5.08	<.001
Belief Manipulation = Question	-0.01	1.21	-0.01	.993
Judges' Age x Long Time	-0.59	0.30	-1.95	.052
Judges' Age x Question	0.02	0.30	0.07	.943
Long Time x Question	-4.08	1.71	-2.39	.017
Long Time x Question x Age	0.77	0.42	1.81	.071

Table 17: Judges' Education

	β	SE	t	p
(Intercept)	3.46	0.83	4.19	<.001
Judges' Education	0.04	0.18	0.20	.839
Long Time	4.71	1.31	3.60	<.001
Belief Manipulation = Question	0.16	1.29	0.13	.899
Judges' Education x Long Time	-0.19	0.29	-0.64	.524
Judges' Education x Question	-0.02	0.29	-0.07	.943
Long Time x Question	-1.02	1.83	-0.56	.576
Long Time x Question x Education	-0.04	0.41	-0.10	.917

Robustness Check using Judges correctly answered all the five comprehension check questions:

After judges indicated their completion time estimates, they answered five questions to recall details of the instructions provided to them earlier. Specifically, they recalled the two different time limits, how the workers were assigned to one of the time limits, whether the workers were paid differently based on the assigned time limit, and whether workers could potentially earn more money by working longer. Judges who passed *all* these checks (N=257) were affected by the experimental conditions ($F(3, 253)=45.16$, $p<.001$). The manipulation of lay beliefs had no discernible effect on judges' estimates in the shorter time limit conditions ($M_{Shorter, Question} = 3.61$ vs. $M_{Shorter, Confirm} = 3.51$, $t(125)<1$, $p=.549$). However, judges' estimates in the longer time limit condition were marginally lower in the questioning lay belief condition compared to the confirming lay belief condition ($M_{Longer, Question} = 6.43$ vs. $M_{Longer, Confirm} = 7.41$, $t(128)=1.77$, $p=.078$). The 2-way interaction was also marginally significant ($F(1, 253)=3.48$, $p=.063$), demonstrating that prompting judges to question the over-generalized belief reduced the time limit bias, as we saw with the entire sample of judges used in the study.

Study 5

Potential Moderating Variable: The tables below examine the potential moderating effect of prior experience in running Direct Marketing campaigns on the effect of time limits on judges' estimates of work scope and completion time. All the results are from ordinal regressions.

Table 18: Judges' Self-Rated Experience (Yes, No) in running Direct Marketing Campaigns on Time Estimate

	β	SE	z	p
Long Time	2.187	0.487	4.487	<.001
Have Experience with running Direct Marketing campaigns	0.313	0.571	0.548	0.584
Long Time x Had Experience Running such campaigns	-0.323	0.758	-0.426	0.670

Table 19: Judges' Self-Rated Experience (Yes, No) with running Direct Marketing Campaigns on Scope of Work

	β	SE	z	p
Long Time	0.722	0.473	1.526	0.127
Have Experience with running Direct Marketing campaigns	0.478	0.661	0.723	0.470
Long Time x Had Experience Running such campaigns	-0.326	0.836	-0.390	0.696

Table 20: Judges' Self-Rated Experience (Yes, No) with running Direct Marketing Campaigns on Rate of Work. This regression uses the entire data since all judges in the study estimated the rate of work.

	β	SE	z	p
Long Time	-0.583	0.313	-1.861	0.062
Have Experience with running Direct Marketing campaigns	0.169	0.407	0.415	0.678
Long Time x Had Experience Running such campaigns	0.467	0.537	0.869	0.384

Examining rate of work by conditions: Did judges' estimates of the rate of work vary based on whether they estimated completion time or scope of work?

Table 21: Effect of time limits on the rate of work estimates as a function on the task assigned

	β	SE	z	p
Long Time	-0.364	0.355	-1.026	0.305
Estimated Scope of Work	0.309	0.358	0.863	0.388
Long Time x Estimated Scope of Work	0.025	0.499	0.051	0.959

Robustness check: Effect of time limits on scope/completion time estimates after controlling for covariates

Table 22: Effect of time limits on completion time estimates controlling for estimates rate of work

	β	SE	z	p
Long Time	2.110	0.400	5.265	<.001
Estimated Rate of Work	0.0004	0.0005	0.859	0.390

Table 23: Effect of time limits on completion time estimates controlling for estimates rate of work and population density (based on zip code)

	β	SE	z	p
Long Time	2.129	0.402	5.290	<.001
Estimated Rate of Work	0.0004	0.0005	0.881	0.378
Population Density	-0.00001	0.00002	-0.597	0.550

Table 24: Effect of time limits on scope of work estimates controlling for estimates rate of work

	β	SE	z	p
Long Time	1.062	0.413	2.570	0.010
Estimated Rate of Work	0.002	0.0005	4.536	<.001

Table 25: Effect of time limits on scope of work estimates controlling for estimates rate of work and population density (based on zip code)

	β	SE	z	p
Long Time	1.109	0.417	2.657	0.007
Estimated Rate of Work	0.002	0.0005	4.343	<.001
Population Density	0.00004	0.00001	2.660	0.007

Appendix D: Additional Studies

Study S1: Effect of deadlines on completion time estimates for everyday activities

Method

We tested for the prevalence of the proposed association between time limits and estimated task completion times for common everyday activities (N=29 adult online participants). We asked participants to list five household chores and the average time they take to complete each one. The five most frequently mentioned chores were house cleaning (30%), washing dishes (9%), laundry (8%), vacuuming (8%), and cooking (7%). Participants were then asked, for each chore they had listed, to estimate how long another typical person would take to do the same work in two different conditions: first for a short and then longer available time limit, within-subjects. The short time limit presented was 1.5 times the participants' own self-reported completion time, while the long time limit was three times the participants' own self-reported completion time.

Results

We divided the estimated completion time for others by the time that participants reported for themselves for each of the five tasks. We then compared the average of these five standardized time estimates for each participant across the two (short vs. long) time limit conditions. Averaging across five tasks, participants estimated an average standardized time of 1.07 (SD=0.19) in the shorter time limit condition, and 1.64 (SD=0.57) in the longer time limit condition, a statistically significant 53 percentage point increase in estimated time ($t(28)=5.86$, $p<.001$). We get the same results when we use a regression model with standard errors clustered at the person level. The majority of participants (79%) gave a longer estimated completion time when more time was available for at least one of the five chores they listed.

The results provide evidence that, across a range of participant-chosen tasks, people tend to estimate that others will take longer to complete a task when there is a longer time limit. Therefore, the effect described in the paper is very robust and happens even with everyday activities.

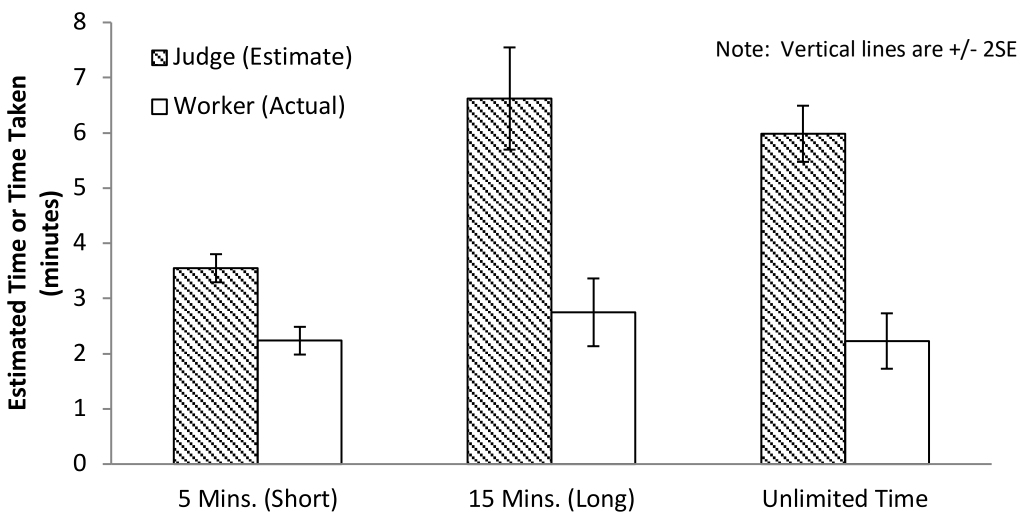
Study S2: Replication of Judges' results in Study 1 (using the workers of Phase 1)

Method

In Phase 2, a sample of online participants (N=103) was assigned the role of *judges* and was provided with detailed information about the Phase 1 Study, including two pictures of the puzzle which the workers had solved (like Study 1). The other instructions, likewise, were exactly similar to Study 1. Judges were asked to predict the task completion time for an average worker under one of the three different time limits (short, long, untimed; order counter-balanced). Similar to Study 1, judges could earn a bonus of up to $1 based on how accurately they predicted the task completion time: for every 1 minute of deviation from the actual average time in a particular time limit condition, 10 cents were deducted from the maximum bonus amount (i.e., a linear incentive for accuracy). The only difference with Study 1 was that this study did not have additional conditions to examine the standard anchoring account.

Results

We strongly replicated the basic results of Study 1. The judges' first estimates did not accurately predict the workers' times. Judges' estimates were significantly higher than the actual workers' times in each of the three time limit conditions (Short Time: $M_{Judges} = 3.55$ vs. $M_{Workers} = 2.24$, $t(68) = 7.21$, $p<.001$; Long Time: $M_{Judges} = 6.62$ vs. $M_{Workers} = 2.75$, $t(77) = 6.86$, $p<.001$; Unlimited Time: $M_{Judges} = 5.98$ vs. $M_{Workers} = 2.23$, $t(68) = 6.33$, $p<.001$). More importantly, in the between-subjects comparison of judges' estimates, the over-prediction increased with longer time limits (interaction $F(2,213) = 8.36$, $p<.001$). As shown in the figure below, this differential over-estimation can be seen when comparing the short time limit condition to either the long time limit ($F(1,145) = 16.67$, $p<.001$) or the unlimited condition ($F(1,136) = 15.38$, $p<.001$). There was no significant difference in over-prediction between the long and unlimited time limit conditions.



Like in Study 1, the bias in completion time estimation does not seem to be attributable to judges' lack of attention, lack of relevant experience or beliefs about workers' state of mind. The amount of time judges took to read the instructions, and their self-reported knowledge or experience with puzzles did not affect estimates or moderate the effect of time limits. Judges' beliefs about differences in either how accountable workers felt to finish the puzzle as soon as possible or about workers' task goals (to finish quickly or to take longer and enjoy it) in the different time limit conditions could not explain the findings. Furthermore, judges were well-calibrated for a diagnostic cue, correctly predicting that workers with low self-rated knowledge of puzzles would take longer to complete under each of time limits.

A majority (70%) of judges stated that people take more time when more time is available. However, this belief in "Parkinson's law" (Parkinson, 1955) did not moderate the effect of time limits on completion time estimates, suggesting that beliefs about differences in rates of work cannot fully explain the results, like in Study 1. Furthermore, if judges simply recoded all completion times above five minutes to five, the estimates in the short time limit condition should be similar to the bounded estimates in the unlimited time condition. To test this, we truncated those estimates from the unlimited time condition which were greater than 5 minutes to 5 minutes. However, judges' estimates were significantly higher in the unlimited time limit condition, even after truncating to five minutes, than in the short time limit condition (M_{5Mins} = 3.55 vs. $M_{Unlimited}$ = 4.37, $t(60)=4.35$, $p<.01$). We find the same result comparing data in the 15 minute time condition after bounding at 5 minutes (M_{15Mins} = 4.50) to the short time limit condition ($t(69)=4.95$, $p<.01$).

As an additional test, we analyzed the second type of estimate the judges made. After their time estimates, judges also estimated what proportion of workers they thought would have completed the work in less than 4 minutes in each of the different deadline conditions (within-subjects). If the observed effect of time limits on time estimates was due to truncation, the findings should be driven by differences in the predictions for those taking more than four minutes, and the estimated proportion of workers who finished in less than 4 minutes should be the same in all conditions. However, we find instead that judges estimated a significantly higher proportion of workers completing the work in less than 4 minutes under the short time limit condition than in the long time limit condition (58% versus 46%; $t(102)=6.34$, $p<.001$), incompatible with a truncation account.

Study S3: Further examination of the role of incidental anchors

Method

Online participants acting as judges (N=120) participated in an estimation game where they were required to estimate the time taken by an imaginary worker to 'solve' a jigsaw puzzle of a known number of pieces. Judges were told that in an untimed pre-test, a 67-piece jigsaw puzzle was solved by a group of workers and no one took more than 31 minutes to solve it. Judges were required to re-enter the maximum time taken by the workers in a text box to proceed. This was done to make sure that the judges registered the information. Subsequently, judges were told that the *same* puzzle was being administered to a new worker. Half the judges were told that based on a coin-flip the worker was assigned to either a short time limit (35 minutes) or a long time limit (60 minutes) condition. These judges were first asked to estimate the task completion time for the worker in a particular time limit condition (between-subjects). The other half were either told that the worker had no time limit (control), or that the worker had no time limit *and* the worker spends 60 minutes every day commuting to work (control with an *incidental* anchor). Judges estimated the task completion time for one of the two control conditions. Before making their estimate, judges were told that they could earn an additional incentive of up to $1 (50% of their base pay) if their estimate was accurate. After the study, the imaginary worker's time was drawn from a uniform distribution of [1, 31] minutes and judges were paid their base pay along with additional bonus based on a linear payoff rule (5 cent deduction for every minute of deviation from the time drawn).

Results

In the between-subject evaluation, judges predicted significantly higher task completion time for workers who had long time limit than those who had short time limit ($M_{Short} = 25.83$ vs. $M_{Long} = 33.96$, $t(61)=4.92$, $p<.001$) replicating prior results. However, the estimates of predicted task completion times in the two control conditions did not differ ($M_{Control} = 28.96$ minutes vs. $M_{Control\ with\ anchor} = 27.42$, $t<1$). Therefore, the introduction of an incidental anchor, which was in the same dimension as the quantity to be estimated, did not influence the predicted task completion time.

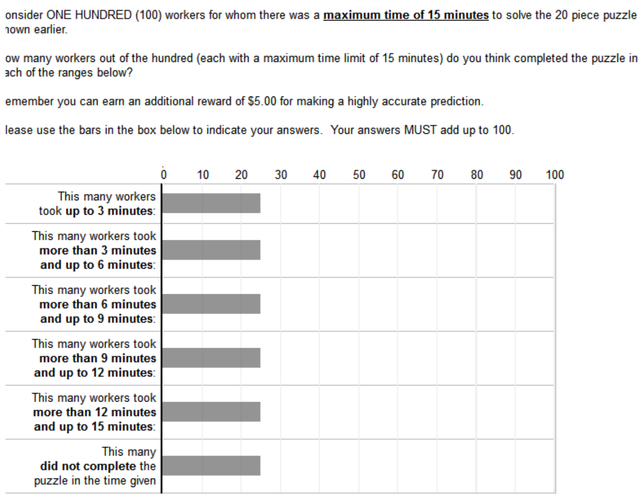
Study S4: Further examination of judges' beliefs about the distribution of worker times

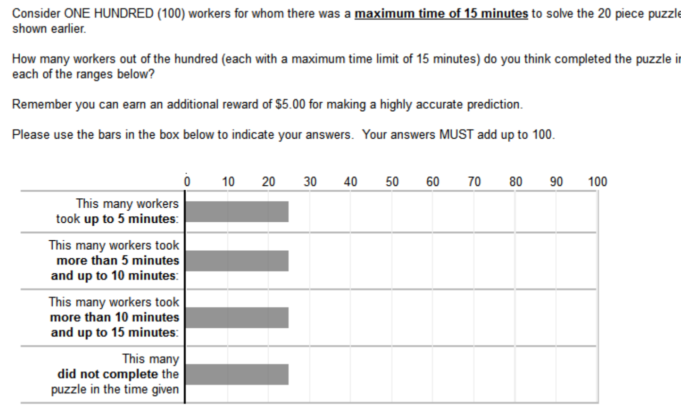
Method

Online participants (N=88) acted as judges and were assigned to two between-subject (time limit: shorter vs. longer) conditions. As in Study 1, judges were told that each worker was randomly assigned to either a maximum time of 5 minutes (the shorter time limit) or a maximum time of 15 minutes (the longer time limit) to solve the puzzle and that workers could not choose or influence their time limit. The judges' task was to estimate the time it took different workers to finish solving the puzzle by indicating the proportion of workers in each of a set of time ranges using an adjustable histogram.

Judges were told that the three participants with the most accurate estimates would receive a bonus payment of $5 (5 times the base payment).

For the shorter time limit condition, judges estimated how many of 100 workers' times would fall into each of five one-minute long intervals (i.e., "This many workers took up to 1 minute," "This many workers took more than 1 minute and up to 2 minutes," etc.), or into the "did not complete" category. For the longer time limit condition, judges estimated either how many of 100 workers' times would fall into each of three five-minute long intervals or into each of five three-minute-long intervals (between subjects; see the figure below). The online interface included a "did not complete" (DNC) category and required the sum of all the allocations to equal 100. In effect, this study used three between-subjects conditions. Therefore, judges allocated workers into six bins in the short time limit condition, and into either four or six bins in the long time limit condition. Lastly, the judges answered a few follow-up questions.





Results

There were no significant differences in the two 15-minute sub-conditions, so we combined them when we computed the average imputed completion time. Based on the elicited distributions, we calculated each judges' estimated average task completion time in the two time-limit conditions. We did this by taking the mid-point of each of the time-bins and computing the weighted average using the proportion of workers allocated to each bin as weights. The imputed means did not differ in the two longer-time sub-conditions ($M_{Longer,\ 3\ bins}$ = 6.69 vs. $M_{Longer,\ 5\ bins}$ = 7.03, $t(40)<1$) and therefore, we combined these two sub-conditions when calculating the completion time estimate for the longer time limit condition. Replicating Study 1, judges estimated a longer mean completion time for workers in the longer time limit condition ($M_{Shorter}$ = 2.85 vs. M_{Longer} = 6.86, $t(86)=11.78$, $p<.001$). As in Study 1, this effect was not moderated by judges' experience or their beliefs about workers' state of mind. This replication of Study 1 using a different elicitation approach also demonstrates that our findings are not an artifact of the measurement method.

To test the censoring account, we compared the number of workers estimated to take 5 minutes or less in the longer vs. the shorter time limit condition (i.e., we compared the 5-minutes condition and the second 15-minutes sub-condition). This meant using the estimated 'completes' in the shorter time limit condition and the proportion of workers assigned to the first time-bin in the four-bin condition in the longer time limit. If the censoring account explains the effect of time limits, these two estimates should not differ. However, judges estimated that, on average, 92% of the workers would complete the puzzle in under 5 minutes in the shorter time limit condition, but only 37% of the workers would complete the puzzle in 5 minutes or less time in the longer time limit condition ($t(65)=11.14$, $p<.001$). This result is not consistent with a censoring account.

We had tested and did not find support for a truncation account in Study 1. To test the truncation account yet again in this study, we compared the proportion of workers estimated to finish in up to 3 minutes in the longer vs. shorter time limit conditions. This meant using the proportion of workers assigned to the first three time-bins in the shorter time limit condition and the proportion of workers assigned to the first time-bin in the 6-bin condition in the longer time limit (i.e., the first 15-minutes sub-condition). Under a truncation process, these two estimates should not differ. However, consistent with our proposed scope perception account, judges estimated that fewer workers would complete the puzzle in up to 3 minutes in the shorter than longer time limit condition ($M_{Shorter}$ = 47% vs. M_{Longer} = 18%, $t(65)=4.50$, $p<.001$).

Study S5: Further examination of the role of irrelevant time limits using an incentive-compatible budgeting game

Method

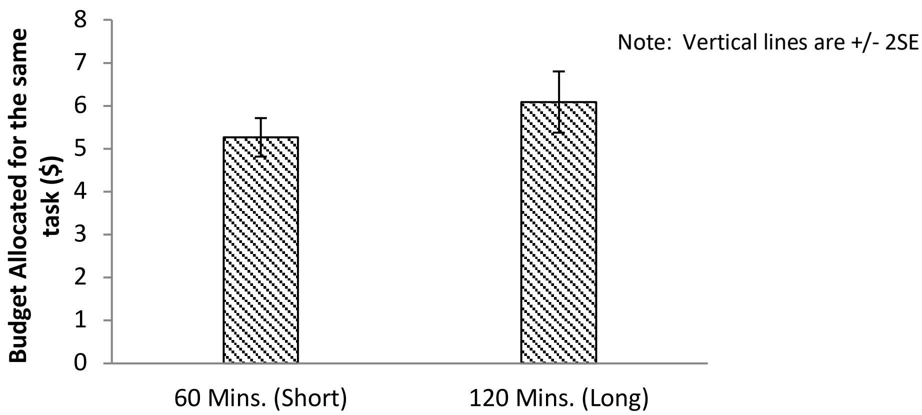
This study was conducted in a classroom setting in two sessions (one for each condition) using both verbal and written instructions. The participants (N=33) were undergraduate students at a large mid-western university who each participated in one session of the Study as part of an Economics course requirement and could earn additional bonus credits based on their performance in the study. Participants played the role of judges (e.g., project managers) in a budget-setting exercise. They needed to budget for a hypothetical worker, who was paid a constant wage rate of 10 cents per minute for the time taken to finish the job, to paint a 20 feet by 10 feet wall. In the scenario, the organization had set a time limit to complete the project – either a short time limit (60 minutes) or a long time limit (120 minutes), varied between subjects – that the hypothetical worker did not know about. The judges were informed that in this game, the worker's time to complete the task would be determined by drawing a number randomly from a uniform distribution between 30 minutes and 90 minutes.

Judges were then asked to budget for the task, by choosing how much money to allocate for the worker's compensation (based on the time to complete the project and the constant wage rate) from the $12.00 available. Judges were incentivized to not over-budget or under-budget. They would earn more if they had budgeted less and the project was still completed. However, if they budgeted less money than turned out to be necessary (based on the randomly drawn task completion time), the participant, having "failed" the budgeting exercise, would not receive any bonus.

Judges, therefore, had an incentive to provide as low a time estimate as possible (i.e., by budgeting as low an amount as possible) without under-guessing (in which case they would not be eligible for any bonus at all). Most importantly, the optimal strategy depended only on the randomly drawn worker time and was independent of the time limit. Thus, there was no incentive for rational judges to incorporate the time limit into their estimate since the optimal bid was determined only by the payoffs and the known distribution of randomly generated worker times. The optimal bid for risk-neutral judges in either time limit condition (60 minutes or 120 minutes) was \$4.63, which corresponds to predicting that the worker would take approximately 46 minutes (see calculations below the Results section). This guess would have earned the judges a bonus of \$0.88 in the game, on average.

Results

Comprehension checks suggested that judges understood that the completion times were drawn from a uniform distribution between 30 minutes to 90 minutes.[1] Despite the fact the optimal bid based on the information known to the judges was the same in both conditions, judges bid significantly more in the longer time limit condition than in the shorter time limit condition, implying a longer time estimate (M_{Short} = \$5.26 vs. M_{Long} = \$6.09, $t(31) = 2.05$, p =.049; see the figure below). Therefore, the longer time limit influenced judges to budget more money for the task, even though they knew that the workers were not aware of the time limit, and the time limit did not even affect the randomly drawn time used to determine the bonus.



This study suggests that the influence of time limits on managers' time estimates can affect their decisions (e.g. budgeting), even when the time limits are irrelevant to the decision. These findings cannot be explained by a motivational lay theory, since judges were told that workers in the scenario did not know about the time limit.

Optimal Strategy for the Budgeting Game

The pay-off structure was as follows:

Offer/Bid = *\$y* Wages Payable = \$w	Wages payable is over-budget If w > y	Wages payable is under-budget If w <= y
Actual Wage Paid in \$	w	y
Bonus Paid in \$	0	0.50 + max(12.00 – 2*y, 0)

[1] In the 60-minute time limit condition there were five judges whose bids represented a completion time of more than 60 minutes. We truncated their bids to the maximum time available for the reported analysis, and we get the same results even if we discard these participants from the analysis.

We know, $t \sim U(30, 90)$, where t is time taken by contractor in minutes to complete the work. This means, $w \sim U(3, 9)$, where w is the wages payable to contractor in Dollars ... (1)

Expected Bonus:

$$E(\mathrm{b}) = \Pr(going\ overbudget) * 0 + \Pr(going\ underbudget) * [0.50 + max(12 - 2y, 0)]$$

$$= \Pr(going\ underbudget) * [0.50 + max(12 - 2y, 0)]$$

$$= \Pr(w \leq y) * [0.50 + max(12 - 2y, 0)]$$

... (2)

Case I: What if $y < 3$. As per (1) this would tantamount to the manager going under-budget in which case he will not earn any bonus. Hence, $y < 3$ is not possible.

Case II: What if $y > 9$. In this case as per (1) $\Pr(going\ underbudget) = 1$. However, knowing (1) the manager would strictly prefer a bid $y \leq 9$ to $y > 9$.

Case III: From the above discussion it is clear that $y \in [3, 9]$ is the feasible range of the manager's bid.

Therefore given an Uniform distribution, $\Pr(w \leq y) = \frac{y-3}{9-3} = \frac{y-3}{6}$. ... (3)

Using (3) in (2), we get

$$E(b) = \frac{y-3}{6} * [0.50 + max(12 - 2y, 0)]$$

$$= \frac{1}{6} * [\frac{y-3}{2} + (\mathrm{y} - 3) * \max(12 - 2y, 0)] \quad \text{... (4)}$$

To solve the maximization problem in (4), we divide y into two ranges $(i)\ 3 \leq y \leq 6$ and $(ii)\ 6 < y \leq 9$

(i) For $3 \leq y \leq 6$: $E(b) = \frac{1}{6} * (y - 3) * [\frac{1}{2} + 12 - 2y]$

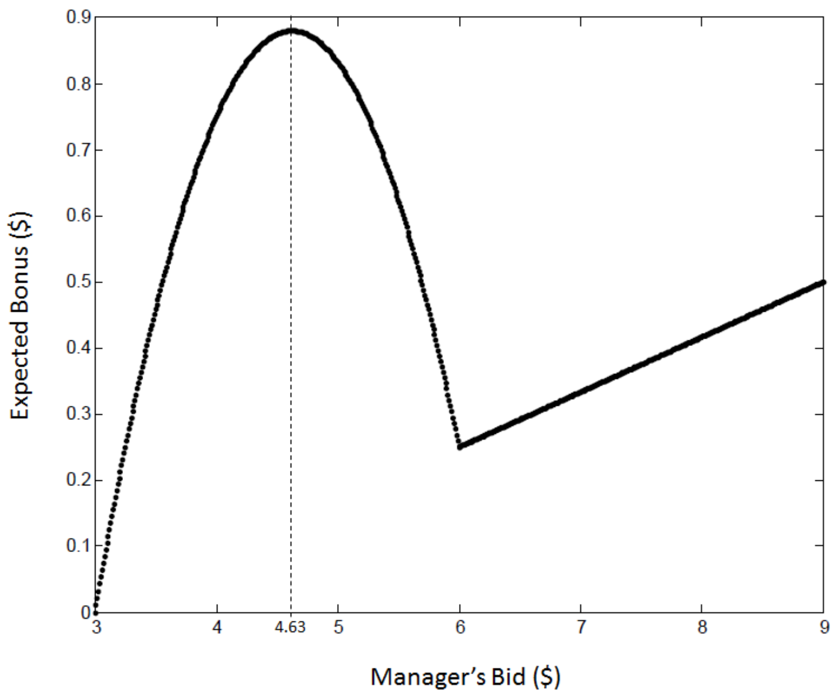
=> $E(b) = \frac{1}{6} * [(y - 3)(12.5 - 2y)]$

This is a concave function in y. Solving the FOC gives us $y = 4.63$. This means $E(b) = 0.88$.

(ii) For $6 < y \leq 9$: $E(b) = \frac{1}{6} * \frac{y-3}{2}$

This is an increasing function of y, hence is maximized at $y = 9$. This means $E(b) = 0.50$.

Therefore, the optimal bid is \$4.63 in which case the expected value of manager's bonus is \$0.88. The figure below depicts expected bonus as a function of the bid.



Complete instructions for the Budgeting Game (conducted in a classroom)

I. Basic Instructions

1. You are a Project Manager in an Organization and you are responsible for budgeting for a task that will be done by a Contractor.

2. The task is very simple – it is painting a 20 ft by 10 ft wall with red color for a promotional activity.

3. The Contractor has already been selected and your job is to set the budget in US Dollars based on your estimate of time which the task will take to complete.

4. If the project goes over-budget (i.e. the project takes longer than you had budgeted for), the contractor will be paid for their time (as per a fixed wage rate), but you will not receive a bonus.

5. If the project comes in under budget, the contractor will receive the budgeted payment, and you will receive a bonus which depends on the difference between the Cap and the budget you set *plus* some fixed amount.

6. The Cap is the maximum money your Organization has set apart for this task.

7. The Organization also has a maximum time which it has set for completing this task.

8. The Contractor does not know anything about either the Cap or the maximum time set by your Organization to complete the task. That information is available only to you as a Project Manager.

9. The Contractor has strong incentive to do it as quickly as they can else they are worried about future consequences (i.e. getting hired for future jobs). So, you can be assured that the contractor will not take any longer than it takes.

II. Contract Details

1. The Cap set by your Organization to complete the task is $12.00.

2. The maximum time set by your Organization to complete the task is 60 minutes (120 minutes).

3. The Contractor's wage rate is 10 cents per minutes and this is fixed.

4. If the Contractor takes ***t*** minutes to complete the work – the total wages payable is **$w= *t*0.10***. If the work remains unfinished till the total time available for its completion – the money payable to the contractor is the time for the entire duration i.e. 60*0.10 = $6.00 (120*0.10 = $12.00).

5. As the Project Manager, you make an offer to the Contractor which is either greater than or equal to the total wages payable. If your offer is ***$y*** and it is not less than the actual wages payable ***$w***, then the Contractor gets ***$y***, as per your offer, and you get a bonus which is detailed in the payoff matrix below.

6. If you make an offer, which is less than the actual wages payable, then the Contractor gets the wages payable ***$w*** and you do not get anything since you did not do a good job in estimating the time.

7. Here is the payoff matrix for you:

	Goes Over Budget	Completed Under Budget
Your Offer = **$y**; Actual wages payable to the Contractor = **$w**	IF w > y	IF w <= y
Contractor gets USD (**as wage**)…	w	y
You get USD (**as bonus**)…	0	$0.50 + max(C-2y,0)

C=Cap i.e. $12.00.

III. Logistics

For the purpose of this exercise, we are going to make a random draw and estimate the Contractor's wages payable at the end of the Study. This will be done in front of you all after you are done answering the questions.

IV. Additional Private Information

You have leant from your reliable sources that in the past other Contractors have taken anywhere between 30 minutes to 90 minutes to complete similar tasks and any duration within this interval were equally likely.

Please ensure that you have understood the above directions completely and let the experimenter know in case you have any doubts before proceeding to answer the questions below.

Study S6: Further examination of the effect of time limits on estimated task scope

Method

Online participants (N=118) acting as judges were told about the range of puzzle sizes (between 6 and 247 pieces) available on *www.jigzone.com* and were also given information about the best and average solving times among visitors to the site. Judges read a hypothetical scenario in which one such puzzle had been selected and administered to a group of students who took an average of 28 minutes to solve it. However, unlike the prior studies, judges did not know which puzzle it was and, more specifically, how many pieces it had. Judges were assigned to one of three between-subject conditions: either an unlimited time condition, a shorter (30 minutes) time limit, or a longer (45 minutes) time limit.

In the scenario used in the study, judges were told that the *same* puzzle was administered to another person (the worker), who was either described as working under no time limit or under a time limit. In the time limit conditions, judges were told that the worker had been randomly assigned (using a coin flip) to either a shorter time limit (30 minutes) or a longer time limit (45 minutes). Each judge then estimated the number of pieces in the puzzle, as a proxy for the scope of the work, and then, on a separate screen, the worker's task completion time. With this information, we could also calculate judges' believed rate of work (the number of puzzle pieces solved per minute) implied by their estimates.

Results

Replicating our results, judges' estimates of task completion time were affected by time limits ($F(2,115)=3.58$, $p=.030$). In particular, judges predicted significantly more time in the longer time limit condition than in the shorter time limit condition ($M_{Shorter} = 24.28$ vs. $M_{Longer} = 36.58$, $t(70)=8.56$, $p<.001$). The estimated task completion time in the unlimited condition ($M_{Unlimited} = 31.97$) was somewhere between the time limit conditions.

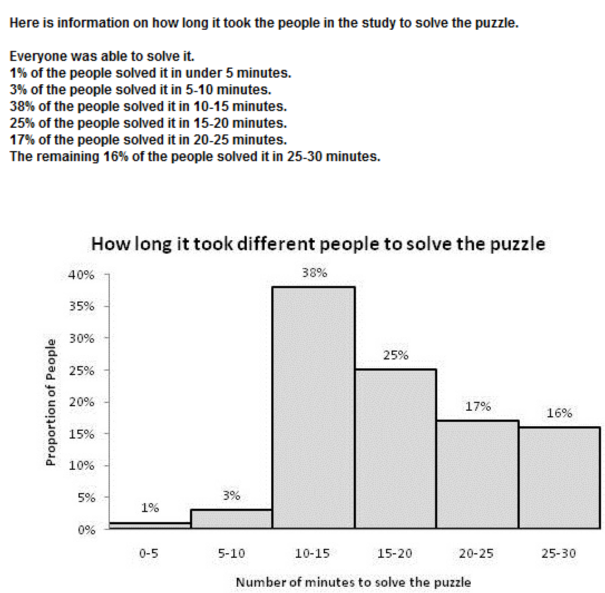
According to our proposed scope perception account, time limits affect completion time estimates because of how the task is perceived. Consistent with this prediction, judges' estimates of the number of pieces in the puzzle varied as a function of the external time limit ($F(2,115)=7.16$, $p=.001$). More specifically, we argue that observing a larger time limit makes the task subjectively seem larger. Indeed, judges estimated that the puzzle had significantly more pieces when the deadline was 45 minutes than when the deadline was 30 minutes ($M_{Shorter} = 130.83$ vs. $M_{Longer} = 177.25$, $t(70)= 2.46$, $p=.016$). The effect of longer time limit on larger estimated puzzle size was confirmed using a non-parametric test (Kruskal-Wallis $\chi 2(1)= 4.56$, $p= .032$). The findings provide direct evidence that people's perception of the scope of work is affected by time limits, such that longer external deadlines cause people to think of the task as larger in scope.

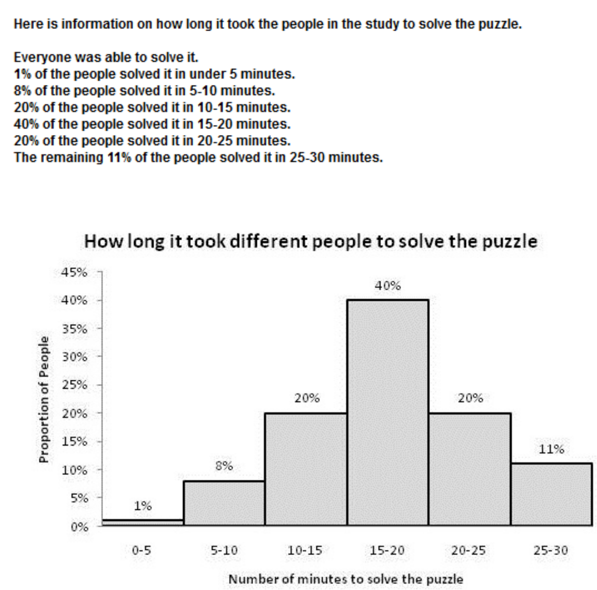
Given that we elicited judges' beliefs about time taken as well as the number of pieces in the jigsaw puzzle, we could compute their implicit beliefs about the rate of work. However, the implied rate of work (estimated puzzle pieces divided by estimated minutes to complete the task) was not statistically different across the different time limit conditions ($F(2,115)=1.37$, $p=.257$), further ruling out beliefs about the effects of time limits on workers' behavior as an alternative explanation behind the observed findings. Ninety-three percent of the judges (N=110) correctly recalled the two time limits used in the study, and that workers were randomly assigned to one of these two time limits. All the reported results hold if we only look at this subset of judges.

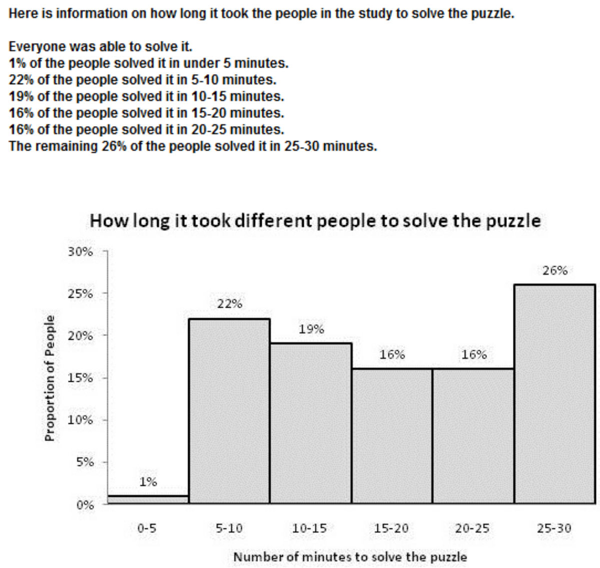
Study S7: Does providing judges with a complete distribution of task completion time debias the effect

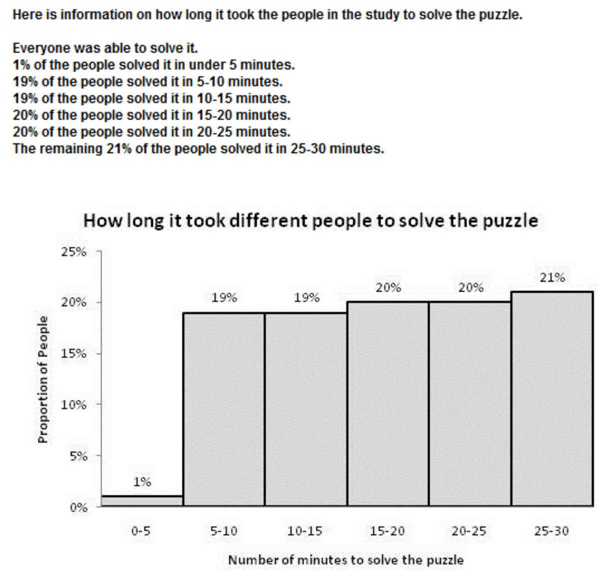
Method

Online participants (N=122) acting as judges were informed about the range of jigsaw puzzle pieces in the website *jigzone.com* along with the best and average time taken to complete puzzles of various sizes.









In the scenario described to the judges, *one* puzzle (unknown to the judge) was taken from the website and was administered to a group of workers. Half the judges were told that, based on a coin flip, workers were either given 30 minutes (short time limit) or 45 minutes (long time limit) to solve the puzzle, and the other half were told that the workers had unlimited time to solve the puzzle.

Judges were first asked to determine the number of pieces there were in the chosen puzzle in one of the time limit conditions (between-subjects). *Before* the judges made their prediction, they were given the distribution of time it took hypothetical workers to complete the task, in the form of a histogram. Four different histograms were used judges saw only one histogram (randomly chosen) with an implied mean of 17.6 minutes (the histograms used are shown above). The same set of histograms was used in both the time limits. After the judges estimated the number of pieces in the puzzle, they were asked to estimate the average time it took the workers to complete the work in a particular condition. Using the reported scope and the task completion time, we could impute judges' beliefs about workers' rate of work.

Results

When judges were given the distribution of task completion times in the various conditions, judges estimated a directionally higher number of puzzle pieces when the time limit was longer, but the difference was no longer statistically significant (M_{Short} = 104.47 vs. M_{Long} = 122.12, $t(78)=1.10$, $p=0.274$). The corresponding estimate in the unlimited condition was 121.81. Likewise, when asked to estimate the average time a worker took to solve the puzzles, judges' estimates were very similar (M_{Short}= 20.19 vs. M_{Long} = 18.81 vs. $T_{Unlimited}$ = 17.89). Therefore, providing exhaustive information, in the form of distribution of past completion times, can help arrest the bias reported in the paper.

Imputing the rate of work from these estimates suggests that the judges' implied rate of work (pieces per minute) was marginally faster for the workers in the longer time limit condition than the shorter time limit condition (M_{Short} = 5.46 vs. M_{Long} = 7.19, $t(78)=1.63$, $p=.106$). These results are further inconsistent with a lay theory account in which judges predict that people work at a slower pace when they have a longer time limit.

Appendix E: Effect Sizes Meta-analysis

The overall effect size for the completion-time estimation effect and the perceived scope of work effect is below. The analysis using only between-subjects data, and therefore excludes Study 4 that uses a within-subjects design.

Time Estimation

	Shorter time limit			Longer time limit						
Study	N	Time	SD Time	N	Time	SD Time	s within	d	Var d	Weight
1	149	3.489	0.918	155	6.894	3.592	2.644	1.287	0.016	62.936
2	112	26.366	3.948	122	29.844	5.856	5.034	0.691	0.018	55.111
3	36	24.278	5.230	36	36.583	6.859	6.099	2.018	0.084	11.930
5	50	1.620	0.805	51	2.735	1.271	1.066	1.046	0.045	22.211
S2	30	3.548	0.697	41	6.622	2.964	2.301	1.336	0.070	14.228
S3	31	25.839	5.466	32	33.969	7.460	6.555	1.240	0.076	13.207
S4	46	2.851	0.726	42	6.861	2.181	1.595	2.514	0.081	12.274
S5	19	52.632	9.771	14	60.857	13.341	11.405	0.721	0.132	7.579
S7 confirm	89	3.624	0.972	70	7.529	3.318	2.317	1.686	0.034	29.022
S7 question	68	3.701	0.983	90	6.433	2.926	2.302	1.187	0.030	33.030

Scope Estimation

	Shorter time limit			Longer time limit						
Study	N	Scope	SD Scope	N	Scope	SD Scope	s within	d	Var d	Weight
3	36	130.833	58.821	36	177.250	96.860	80.131	0.579	0.058	17.275
5	51	12254.900	24100.080	51	17450.980	25497.500	24808.631	0.209	0.039	25.361
S6	40	102.375	62.879	45	120.644	76.227	70.272	0.260	0.048	21.000

Source: Borenstein, Hedges, Higgins and Rothstein (2009) p. 26-27; 65-66

The meta-analytic effect size for the time estimation is: $d = 1.247, z = 20.173, p < .001$
The meta-analytic effect size for the scope estimation is: $d = 0.327, z = 2.605, p = .009$