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Appendix E from Fernbach, Kan, and Lynch, “Squeezed: Coping with Constraint through Efficiency and Prioritization”

(JCR, vol. 41, no. 5, p. 000)

DETAILS OF STUDY 2

Study 2 tested the general proposition that as constraint increases, the relative likelihood of priority plans compared to efficiency plans increases, as does the relative speed of generating priority plans compared to efficiency plans. “Planning mix” refers to the difference (Priority planning – Efficiency planning). Study 2 tested hypotheses 2a and 2b in the main article. We hypothesize that at higher constraint levels, priority plans will be more accessible in memory (see Spiller 2011) and will come to be a larger proportion of the mix of planning strategies that are retrieved and enacted.

H2a—The “planning mix,” or the amount of priority planning relative to efficiency planning, increases with constraint.

H2b—The accessibility of priority plans relative to efficiency plans increases with constraint, leading to faster reaction times to generate plans.

Below we provide additional details on analyses reported in the main article. We also report additional analyses not discussed in the main article. We claim that efficiency planning and priority planning constitute distinct categories in thought. The literature on memory retrieval shows that people tend to enter a category and retrieve instances in clusters (Gruenwald and Lockhead 1980; Hutchinson, Raman, and Mantrala 1994). People continue to retrieve items from one category until output interference slows production of that category (Alba and Chattopadhyay 1985). The result is that members of the same category as the item generated on trial t tend to be more accessible in memory at $t+1$ than members of another category. This can either be construed as facilitation of members of the same category or as inhibition of members of other categories. Consequently, we predicted that after generating a plan of one type, the next plan would more likely be one of the same type, and would be generated faster if it were of the same type. Below we provide analyses testing this conjecture.

Change in Planning Mix as a Function of Constraint: Analytical Details

This section provides additional detail for the analysis reported in the main article regarding how the number of each plan type (planning mix) changed as a function of constraint. For the analysis of how the planning mix changed with constraint, we ran an ANOVA with plan type as a within subject factor (priority vs. efficiency) and constraint level as a between subject factor (low vs. medium vs. high). For the plan type factor, we summed the total number of efficiency plans, and the total number of priority plans generated for each participant. The 2 *df* effect of constraint level was broken down into two orthogonal contrasts for the linear and quadratic effect of constraint. Low-, medium-, and high-constraint levels were coded as -1, 0, 1 for the linear effect, and -1, 2, -1 for the quadratic effect respectively.

The analysis confirmed that constraint level had a significant effect on the mix of plans generated, as there was an interaction between plan type and constraint condition ($F(2, 99) = 3.84$, $p = .025$). The interaction was concentrated in the interaction of plan type with the linear effect of constraint ($F(1, 99) = 7.54$, $p = .007$); the prevalence of priority planning relative to efficiency planning increased as constraint increased, as predicted. There was no interaction of plan type with the quadratic effect of constraint ($F(1, 99) = .005$, NS). There was also a main effect of plan type; participants generated more priority plans than efficiency plans on average ($M_{\text{priority}} = 1.64$, $M_{\text{efficiency}} = 1.12$; $F(1, 9) = 6.76$, $p = .01$). The main effect of constraint condition was not significant ($p > .25$).

We next conducted simple effect tests on the difference in number of efficiency versus priority plans at each constraint level. People generated about the same number of efficiency and priority plans under low constraint ($M_{\text{priority}} = 1.09$, $M_{\text{efficiency}} = 1.31$; $F(1, 99) = .36$, $p = .552$), marginally more priority plans under medium constraint ($M_{\text{priority}} = 1.76$, $M_{\text{efficiency}} = 1.14$; $F(1, 99) = 3.14$, $p = .08$), and significantly more priority plans under high constraint ($M_{\text{priority}} = 2.2$, $M_{\text{efficiency}} = .80$; $F(1, 99) = 9.55$, $p = .003$).

Change in Planning Mix as a Function of Constraint: Additional Analyses

This section provides additional analyses (not reported in the main article) investigating how the planning mix changes as a function of constraint.

Coding for Uneven Spacing of Constraint

Results were virtually identical if we coded in terms of the linear and quadratic effect of objective constraint as reflected in bills of \$100, \$500, or \$1,000. In that case, the linear trend coefficients are −1, 0.0769, 1.0769 and the quadratic trend coefficients are 0.4815, −1, 0.5185 for the low-, medium-, and high-constraint conditions, respectively.

Analyzing for Average Ordinal Position

We also ran an ANOVA using average ordinal position for efficiency plans and for priority plans as the within-subject plan type factor. If a subject did not generate any plans of a particular type, we substituted seven as the average ordinal position for that plan to reflect the relative inaccessibility of that plan type. The average ordinal position for each plan type varied by constraint level ($F(2, 99) = 5.08$, $p = .008$). That interaction was concentrated in the interaction of plan type with the linear effect of constraint ($F(1, 99) = 9.96$, $p = .002$). There was no interaction of plan type with the quadratic effect of constraint. Efficiency plans were generated marginally sooner than priority plans under low constraint ($F(1, 99) = 3.08$, $p = .082$). There was no difference in how soon the efficiency and priority plans were generated under medium constraint, $F(1, 99) = .79$, $p = .377$. Priority plans were generated sooner than efficiency plans under high constraint ($F(1, 99) = 7.01$, $p = .009$).

Response Times for Priority and Efficiency Plans: Analytical Details

This section provides additional detail for the analysis reported in the main article regarding how the response times for priority and efficiency plans changed as a function of constraint. It also explores how response times for priority and efficiency plans change as a function of which plan type immediately preceded it (this analysis is not reported in the main article). To explore the relative accessibility of priority and efficiency plans, we specified the following random intercept model:

$$\textit{Log response time}_{ts} = \beta_0 + \beta_1 \times (\textit{Other vs. Planning})_{ts} + \beta_2 \times (\textit{Efficiency vs. Priority planning})_{ts} + \beta_3 \times (\textit{Linear effect of constraint})_{s} + \beta_4 \times (\textit{Other v. Planning} \times \textit{Linear effect of constraint})_{ts} + \beta_5 \times (\textit{Efficiency vs. Priority planning} \times \textit{Linear effect of constraint})_{ts} + \beta_6 \times (\textit{Transition})_{ts} + \beta_7 \times (\textit{Trial})_{t} + \zeta_s + e_{ts}.$$

Other vs. Planning$_{ts}$ is coded as −1 if plan type is efficiency or priority and 2 if "other." *Efficiency vs. Priority planning*$_{ts}$ is coded −1 if plan type is efficiency, 1 if priority, and 0 if "other." The *Linear effect of constraint*$_s$ is coded −1, 0, +1 for low, medium, and high constraint, respectively. *Transition*$_{ts}$ is −1 if the previous plan is the same as the current plan and 1 if the previous plan is different from the current plan. It is worth emphasizing that the *Transition*$_{ts}$ variable reflects transitions between any type of response and not between priority and efficiency planning alone. For example, a participant who provided an efficiency plan and an "other" plan (e.g., working more hours) in subsequent responses would also be coded as transitioning between different plans. The use of the transition variable for the six responses implies that we have a maximum of 5 data points per respondent. *Trial*$_t$ is the trial number minus 1, such that 0 is trial number 1, 1 is trial number 2, etc.

Fixed effects are represented by β's, and random effects are represented by ζ_s and e_{ts}. The e random effect is the deviation of the t'th response from the subject s's mean and represents the residual in response times not accounted for by plan type, transition type, or trial number. It has variance θ. The ζ random effect is the deviation of each subject's mean from the overall mean and represents the combined effects of any omitted subject characteristics or unobserved heterogeneity at the subject level. It has variance ψ.

As predicted by hypothesis 2b, there was an *Efficiency vs. Priority Planning* × *Linear effect of constraint* interaction ($\beta_5 = -.13$, $z = -2.03$, $p = .042$), such that the relative speed of generating priority plans relative to efficiency plans increased with constraint. We next tested for the simple effect of plan type on response times at each constraint level. Compared to efficiency planning, priority plans were directionally slower under low constraint ($\beta = .07$, $z = 0.87$, $p = .383$), directionally faster under medium constraint ($\beta_2 = -.07$, $z = -1.30$, $p = .193$), and significantly faster under high constraint ($\beta = -.20$, $z = -2.27$, $p = .023$).

In addition, there was a significant effect of *Transition*$_{ts}$, such that participants were faster at generating plans when their previous plan was of the same type than when their previous plan was of a different type ($\beta_6 = -.16$, $z = -4.51$, $p < .001$). This result provides support for the notion that efficiency planning and priority planning are distinct cognitive categories, in that retrieval of members of one category facilitates retrieval of members of the same category or inhibit retrieval of members of a different category. Note that the $Transition_{ts}$ variable captures interference of any state with any other state and not only interference between efficiency and priority planning.

Response Times for Priority and Efficiency Plans: Additional Analyses

This section provides additional analyses (not reported in the main article) investigating how the response times for priority and efficiency plans change as a function of constraint, and also how the response times for priority and efficiency plans change as a function of which plan type immediately preceded it.

Including the quadratic effect of constraint

We also analyzed these data including the quadratic effect of constraint. The transition term remained significant and the interaction of the linear effect of constraint by efficiency vs. priority planning dropped to marginal significance ($p = .054$). The quadratic term and its interactions were nonsignificant at all $p > .40$, so we dropped them from the main model.

Coding for the Uneven Spacing of Constraint

We also ran this analysis coded in terms of the linear and quadratic effect of objective constraint as reflected in bills of $100, $500, or $1,000 (using linear trend coefficients −1, 0.0769, 1.0769 and quadratic trend coefficients 0.4815, −1, 0.5185 for the low-, medium-, and high-constraint conditions, respectively). Results were virtually identical.

Including Response Time for the First Plan in the Model

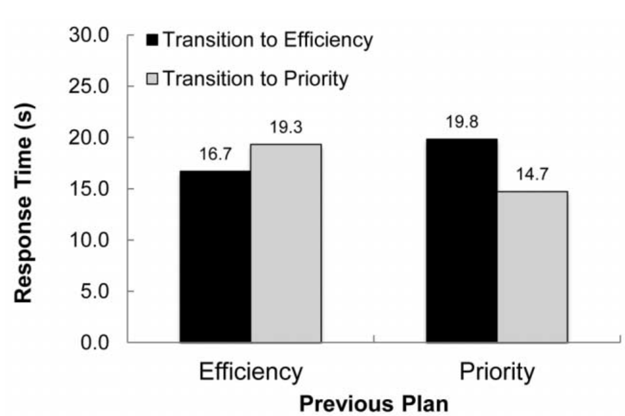
We also included response time for the first plan in the model as a covariate. This term was significant and positive ($\beta = .01$, $z = 5.01$, $p < .001$), interpretable as capturing individual differences in speed. The Transition term remained significant, as did the interaction of the linear effect of constraint by efficiency vs. priority planning. However, we note that the response time for the first plan in the model did vary as a function of constraint level (all $p < .01$), suggesting that using this as a covariate would partial out treatment effects in addition to individual differences in speed.

Testing for the Interference between Efficiency and Priority Plans Specifically

We also ran this analysis testing for the effect of interference between efficiency and priority plans specifically. Participants are faster at generating responses when transitioning from efficiency to efficiency plans or from priority to priority plans, than when transitioning from efficiency to priority plans or from priority plans to efficiency plans, $z = 2.30$, $p = .022$. This can be seen from the pattern of means in figure E1.

FIGURE E1

STUDY 2 RESPONSE TIME BY TRANSITION TYPE, COLLAPSING ACROSS TRIALS AND PARTICIPANTS



Probability of Generating Each Type of Plan: Analytical Details and Additional Analyses

This section provides additional analyses investigating how the likelihood of generating one plan type changes as a function of the plan type that immediately preceded it.

A similar interference effect can be seen in an analysis of the likelihood of generating an efficiency plan or priority plan on trial $t + 1$, conditional on the type of plan generated at time t, as can be seen in figure E2. To test for a within-participant interference effect (wherein a plan of one type at time t inhibits generation of a plan of a different type at $t + 1$), we ran two separate random intercept logistic regressions with the previous plan choice, the linear effect of constraint, and the first plan choice as predictor variables. The first plan choice was included as a covariate to account for the initial conditions problem of separating heterogeneity from state-dependence (Wooldridge 2005).

In the first analysis, the dependent variable was coded 1 if the plan was a priority plan and 0 if the plan was anything else (efficiency or other). Consistent with the interference effect, people were more likely to produce a priority plan if the previous plan was also a priority plan ($\beta_{\text{previous plan}} = .879$, $z = 2.46$, $p = .014$). We also found that people were more likely to engage in priority planning as the level of constraint increased ($\beta_{\text{linear contrast}} = .509$, $z = 2.64$, $p = .008$), consistent with hypothesis 2a. There was a significant effect of the first plan choice ($\beta_{\text{first plan}} = 1.123$, $z = 2.92$, $p = .004$), suggesting that there was substantial correlation between the unobserved heterogeneity and the initial plan choice.

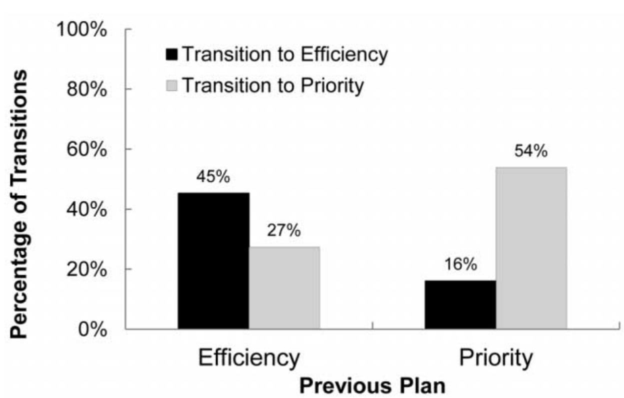
In the second analysis, the dependent variable was coded 1 if the plan was an efficiency plan and 0 if the plan was anything else (priority or other). Consistent with the interference effect, people were more likely to produce an efficiency plan if the previous plan was also an efficiency plan ($\beta_{\text{previous plan}} = 1.196$, $z = 3.00$, $p = .003$). The linear term was not significant, suggesting that the probability of producing an efficiency plan did not differ as a function of constraint level ($\beta_{\text{linear contrast}} = -.157$, $z = -0.85$, $p = .396$). We would expect, however, in an environment where there is not an opportunity to prioritize, constraint would lead to efficiency planning, consistent with our interpretation of Shah et al. (2012). We also found a significant effect of the first plan choice ($\beta_{\text{first plan}} = 1.034$, $z = 2.67$, $p = .008$).

Including the Quadratic Effect of Constraint

We also ran the random intercept logistic regressions with the quadratic term included in the model. The quadratic terms for both models were not significant (all $p > .46$), and results for the other terms in the models were virtually identical.

FIGURE E2

STUDY 2 PERCENTAGE OF TRANSITIONS OF EACH TYPE, COLLAPSING ACROSS TRIAL AND PARTICIPANT



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Wooldridge, Jeffrey M. (2005), "Simple Solutions to the Initial Conditions Problem in Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity," *Journal of Applied Econometrics*, 20 (1), 39–54.