Prospective Memory and Working Memory: A Hierarchical Modeling Approach

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Prospective Memory and Working Memory

Prospective memory (PM), remembering to perform an action in the future, is an important ability in everyday life. It involves a prospective component, remembering *that* you have to do something, and a retrospective component, remembering *what* action to perform and *when* to perform it. Researchers have pointed to a role of cognitive factors, such as individual differences in working memory (WM), in determining PM performance. Previous studies have found a positive relationship between WM span and PM (e.g., R.E. Smith, Persyn, & Butler, 2011). The goal of the present study is to apply a hierarchical modeling approach to investigate how WM is related to the prospective and retrospective components of PM.

The Multinomial Model of Event-Based PM

PM tasks often involve interrupting an ongoing activity. Therefore, laboratory PM tasks are often embedded in an ongoing task. Smith and Bayen (2004) introduced a multinomial model of event-based PM that can be applied to PM tasks that are embedded in an ongoing task with two response options, such as a lexical decision task. While participants are engaged in the ongoing task, they are supposed to execute a specific action when a PM target occurs. The model (Figure 1) includes parameter P which measures the prospective component and parameter M which measures retrospective recognition memory processes for discriminating PM targets and nontargets. Parameter g defines the probability of guessing that a PM target is present. C_1 and C_2 measure processes related to the ongoing task. For example, in a lexical decision task, C_1 is the probability of correctly detecting that a letter string is a word and C_2 is the probability of correctly detecting that a letter string is a non-word. If a participant does not detect that a string is a word or a non-word, he or she guesses with probability c that it is a word. It is assumed that participants adjust their responses to the perceived ratio of items in a task, that is c = the ratio of word trials to total trials and g = the ratio of PM target trials to total trials. The resulting model has four free parameters P, M, C_1, and C_2, and is identifiable.

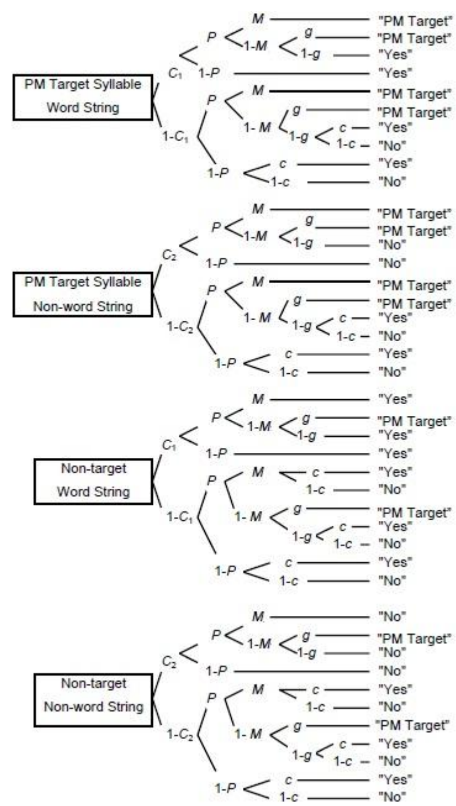

Figure 1: The Multinomial Model of Event-Based PM. Adapted from "A multinomial model of event-based prospective memory" by R.E. Smith and U.J. Bayen, 2004, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, p. 758.

Beta Multinomial Processing Tree Models

Since multinomial models are often applied to data that have been aggregated over participants and items, they assume that all observations are independent and identically distributed and ignore differences between participants and items (Riefer & Batchelder, 1988). However, J.B. Smith and Batchelder (2008) showed that this assumption is often violated even for a carefully constructed item pool and relatively homogeneous groups of participants. This can result in biased parameter estimates.

The beta MPT (J. B. Smith & Batchelder, 2010) assumes that each participant´s parameters are drawn independently from a multivariate distribution consisting of independent marginal beta-distributions. The advantage of the beta distribution is that it lies in the interval [0,1] and thus in the natural parameter space of the model parameters because they represent probabilities. Beta-MPT models are computed using Markov Chain Monte Carlo (MCMC) methods. This analysis is possible without having to solve the integrals which can be computationally very expensive. It can be easily applied using software like WinBUGS (Spiegelhalter, Best, & Lunn, 2003).

Study by R. E. Smith, Persyn, & Butler (2011)

413 participants took part in this experiment. The ongoing task was a lexical decision task. The PM task was to press the F1 key when syllables "low" and "per" appeared. Participants completed a symmetry span task as a measure of WM span. Participants whose WM score fell within the lowest 25% were placed into the lower WM group and those whose WM score was in the top 25% were placed in the higher WM group. In R. E. Smith et al.'s (2011) analysis, participants in the higher WM group had a higher probability of remembering that something needed to be done (the prospective component measured by model parameter *P*), but the two WM groups did not differ on the retrospective component as measured by parameter *M*.

Reanalysis

The extreme-group analysis is limited in that half of the data were omitted. By using the beta-MPT approach we are able to incorporate data from all participants to address the question whether and how individual differences in working memory span contribute to successful PM.

For each Beta-MPT we used a uniform distribution between 1 and 5000 as prior for α and β. This is a very vague prior because of its wide range, but because α and β are greater than 1, it ensures that the beta-distribution is bell-shaped. We used 100,000 iterations and discarded the first half of the iterations as burn-in period.

With the resulting individual parameter estimates, we computed correlations and a regression analysis. The correlation of WM span and the prospective component *P* was significant, $r = .15$, $p < .01$, but WM span and the retrospective-memory component *M* were not associated with one another, $r = .01$, despite sufficient power to detect even a small effect. In the regression analyses, when only WM span was entered as predictor variable for PM performance it was a significant predictor. When *P* was entered as an additional predictor variable, WM span was not a significant predictor. The inclusion of *M* as predictor had no influence on the predictive value of WM span.

Table 1: Results of regression analyses for criterion variable PM performance.

Parameter	*b*	*SE*	β	*t*	*p*	R^2
Constant*	0.41	0.07		6.24	<.01	.01
WM*	0.01	<0.01	.11	2.32	.02	
Constant*	-0.24	0.03		-8.10	<.01	.85
WM	<0.01	<0.01	-.02	-1.15	.25	
*P**	1.22	0.03	.92	47.24	<.01	
Constant*	-0.63	0.01		-53.93	<.01	.98
WM	<0.01	<0.01	.01	0.79	.43	
*P**	0.93	0.01	.70	94.78	<.01	
*M**	0.72	0.01	.43	58.43	<.01	
Constant*	-0.59	0.06		-10.56	<.01	.62
WM*	0.01	<0.01	.11	3.45	<.01	
*M**	1.31	0.05	.78	25.80	<.01	

Thus, the results match previous findings. WM span is related to the prospective component of PM, but not to the retrospective-memory component. Beta-MPT models enabled us to incorporate data from all participants, to look at the data on an individual basis, and to avoid biased parameter estimates. They provide information about the relationship between individual differences in WM span and cognitive processes underlying PM. Regression analyses showed that the relationship between WM span and PM performance was fully accounted for by the prospective component *P*.

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