Interference due to shared features between action plans is influenced by working memory span

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BRIEF REPORT

Interference due to shared features between action plans is influenced by working memory span

Lisa R. Fournier · Lawrence P. Behmer Jr. · Alexandra M. Stubblefield

Abstract In this study, we examined the interactions between the action plans that we hold in memory and the actions that we carry out, asking whether the interference due to shared features between action plans is due to selection demands imposed on working memory. Individuals with low and high working memory spans learned arbitrary motor actions in response to two different visual events (A and B), presented in a serial order. They planned a response to the first event (A) and while maintaining this action plan in memory they then executed a speeded response to the second event (B). Afterward, they executed the action plan for the first event (A) maintained in memory. Speeded responses to the second event (B) were delayed when it shared an action feature (feature overlap) with the first event (A), relative to when it did not (no feature overlap). The size of the feature-overlap delay was greater for low-span than for high-span participants. This indicates that interference due to overlapping action plans is greater when fewer working memory resources are available, suggesting that this interference is due to selection demands imposed on working memory. Thus, working memory plays an important role in managing current and upcoming action plans, at least for newly learned tasks. Also, managing multiple action plans is compromised in individuals who have low versus high working memory spans.

Keywords Action planning · Working memory · Action feature overlap · Partial repetition costs · Management of action plans

Everyday actions like cooking dinner require action planning. We must decide what to do and when to do it (Keele, 1968; Lashley, 1951; Miller, Galanter, & Pribram, 1960). Sometimes we need to momentarily suspend the execution of one action plan in order to execute another. For example, when cooking, we may plan to turn the heat down over sauce that is burning, but before executing this action the need to remove the pot of pasta (boiling over!) takes precedence. Research shows that executing the action that takes precedence can be delayed when another action plan is maintained in working memory, particularly if the ongoing action shares an action feature with the action plan maintained in working memory (Hommel, 2004; Mattson & Fournier, 2008; Stoet & Hommel, 1999). This article is concerned with interactions between the action plans that we hold in memory ("turn down the heat") and the actions that we carry out ("remove the pot"; Logan, 2007), to investigate whether the interference due to shared features between action plans is due to selection demands imposed on working memory (WM). Some evidence suggests that interference due to feature overlap between the action plans does not occur if the *current* action does not impose a demand on WM (i.e., can be executed automatically; Fournier et al., 2010; Wiediger & Fournier, 2008; see also Mattson & Fournier, 2008). However, if interference due to feature overlap depends on WM, this interference should be greater when the demands on WM are increased, and hence should be greater for individuals who have a low versus high WM span. We tested this prediction in an experiment in which we examined the effects of WM span on the interaction between ongoing actions and action plans held in WM.

Research has shown that executing an action plan can be delayed if it partly overlaps with an action plan maintained in WM. For example, executing a left-hand action is delayed if it shares a feature code ("left") with an action plan maintained in WM ("left hand move up"), as compared to when it does not ("right hand move up"; Mattson & Fournier, 2008; Stoet & Hommel, 1999; Wiediger & Fournier, 2008; see also Fournier, Gallimore, Feiszli, & Logan, 2014). This delay is referred to

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as a *partial-repetition cost*. Partial repetition costs are assumed to occur when a feature code from the current action plan reactivates (*primes*) the action plan maintained in WM (Fournier & Gallimore, 2013; Hommel, 2004). The action features are integrated in the action plan, so reactivating (priming) one feature should activate other features with which it is integrated (Hommel, 2004; Hommel & Colzato, 2004; Mattson, Fournier, & Behmer, 2012). This leads to temporary confusion as to which action plan is relevant for the current task: the current plan or the one maintained in WM (Fournier & Gallimore, 2013; Hommel, 2004, 2005; Mattson & Fournier, 2008). The irrelevant feature code or action plan must be inhibited, and the time required to inhibit it delays selection of the correct action plan for the current task. Fournier and colleagues have argued that WM plays a central role in partial repetition costs, and that delays are due to increased time to select the correct action plan from WM that is relevant to the current event (Fournier & Gallimore, 2013; Fournier et al., 2010; Mattson, Fournier, & Behmer, 2012; Wiediger & Fournier, 2008).

To date, relatively little research has focused on the role of WM in the interference between action plans (but see Klapp, 1976, 1980). Evidence indicating that partial repetition costs are restricted to actions that impose a demand on WM is based on two studies showing that partial repetition costs are not observed when the current action can be executed automatically (Fournier et al., 2010; Wiediger & Fournier, 2008). However, if partial-repetition costs are indeed contingent on actions requiring WM, and if WM plays a role in selecting the current action from those that are active in WM, the magnitude of partial-repetition costs should increase when the WM resources available to select the correct action and inhibit the others are reduced.

We assessed individual differences to test this hypothesis, using a partial-repetition paradigm (Stoet & Hommel, 1999) to examine whether partial-repetition costs are greater for participants identified as having a low WM span, relative to those identified as having a high WM span. We examined the contribution of WM to partial-repetition costs by comparing individuals with low and high WM span, as opposed to adding yet another task, to avoid having the added task interfere with the planning and maintenance of the first action event in WM. Participants were assigned to low- or high-span WM groups on the basis of their Automated Operation Span (AOSPAN) scores (Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2003; Unsworth, Heitz, Schrock, & Engle, 2005). In the subsequent action-planning task, participants learned to execute different left- and right-hand motor actions in response to two different abstract stimuli, presented in a serial order. Participants planned a motor response (e.g., "move right hand to upper key") to the first stimulus event, and maintained this action plan in WM while waiting for the presentation of a second stimulus event that required an immediate, speeded response (e.g., "right hand press center key"). After executing a response to the second event, participants executed the action plan maintained in WM, corresponding to the first event. For all participants, the actions for the first and second events required either the same action hand (feature overlap) or a different action hand (no feature overlap). Also, the stimulus–response associations for both events were arbitrary, and hence action planning for both events should impose a demand on WM (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Jeannerod, 1997; Lavie, Hirst, de Fockert, & Viding, 2004; Logan, 1979; Ungerleider & Mishkin, 1982; Wiediger & Fournier, 2008). If partial-repetition costs are due to increased demands on WM, the size of the partial-repetition cost obtained (response time [RT] for feature-overlap condition – RT for no-feature-overlap condition) should be greater for low-span than for high-span participants.

Method

Participants

Undergraduate students from Washington State University volunteered for optional credit in their psychology courses. This study was approved by the Institutional Review Board, and informed consent was obtained. Participants had at least 20/40 visual acuity, as assessed using a Snellen chart. The AOSPAN task (Unsworth et al., 2005) was completed by 168 participants, of whom 81 (the top and bottom 25 %) were invited to participate in the action-planning task due to their AOSPAN scores. A total of 60 of the 81 invited participants completed the action-planning task.

Apparatus, stimuli, and procedure

AOSPAN task

We used the AOSPAN task (Unsworth et al., 2005) to obtain a memory span score for each participant, as is described by Behmer and Fournier (2014). The overall AOSPAN score (ranging from 0 to 75) was used to classify participants as high span (upper 25 %) and low span (bottom 25 %) for the action-planning session (Watson & Strayer, 2010).

Action-planning task

Prior to the task, participants were fitted with an EEG cap and electrodes to investigate differences in cortical motor activity based on WM span during action planning and the maintenance interval for Event A (the EEG data are reported in Behmer & Fournier, 2014). All instructions and stimuli appeared on a 17-in. CRT monitor ~50 cm from the participant.

E-Prime software (Version 2.1) was used to present the stimuli and collect the data. Two keypads were located on a table in front of the participant, with one keypad 11 cm to the left and the other 11 cm to the right of the participant's body midline. The keypads recorded responses made with the index fingers: Left-hand responses were executed on the left keypad, and right-hand responses were executed on the right keypad. Each keypad had three vertically oriented keys (the keys were 1 cm × 1 cm in size and separated by 0.2 cm). Participants rested their index fingers on the center keys before and during each trial. All visual stimuli appeared on a black background. The stimuli and responses for the two visual events (A and B) in the action-planning task were as follows.

Event A Event A was an arrowhead (0.63° visual angle) pointing to the left or right and an asterisk (0.53° of visual angle) located 0.74° of visual angle above or below the arrowhead. The arrowhead was centered (2° of visual angle) above the central fixation cross (cross). The arrowhead direction (left or right) indicated the response hand (left or right, respectively), and the asterisk (above or below the arrowhead) indicated the initial movement direction of the index finger (upper keypress, toward the CRT, or lower keypress, toward the participants body, respectively) relative to the center key on the keypad. Thus, four different action plans (left hand–move up, left hand–move down, right hand–move up, and right hand–move down) were mapped to the four different arrowhead–asterisk stimulus combinations. All responses began and ended by pressing the appropriate left or right center key (home key) with the index finger.

Event B Event B was a red or green number symbol (#, 0.67° of visual angle) centered 2° of visual angle below the cross. Event B required a speeded keypress dependent on color. Half of the participants pressed the left center key twice with their left hand to the green number symbol and pressed the right center key twice with their right hand to the red number symbol; the other half had the opposite stimulus–response assignment.

Figure 1 shows the trial events. Each trial began with a message that read "Press the home [center] keys to begin trial." When the center keys were pressed simultaneously the trial started, and a cross appeared in the center of the screen for 1,250 ms. Afterward, Event A appeared above the cross for 500 ms, followed by the cross alone for 1,250 ms. During this time, participants planned their response to Event A. Then, Event B appeared below the cross for 50 ms, followed by a blank screen for 4,750 ms or until a response was detected for Event B. Participants were instructed to respond to Event B quickly and accurately. After responding to Event B, they had 5,000 ms to execute the planned response to Event A.

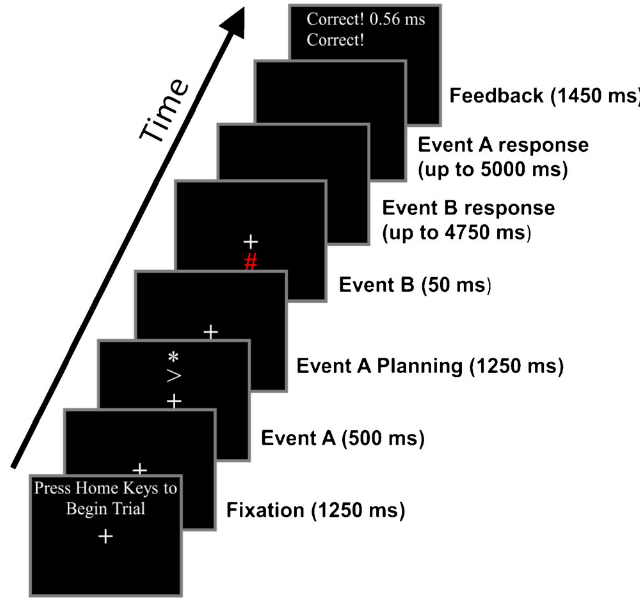

Fig. 1 Sequence of events in a trial

Feedback indicating the Event B RT, Event B accuracy, and Event A accuracy was presented together for 1,450 ms. Then the initiation screen for the next trial appeared. Participants initiated the next trial when ready.

Participants were instructed not to execute any part of the planned response to Event A until after responding to Event B. Also, they were not to move their fingers or use external cues to help them remember the planned response to Event A—they were told to maintain the action to Event A in memory.

Two factors varied. The first, Feature Overlap, was manipulated within participants: The actions for Event B and Event A required either the same hand (overlap) or different hands (no overlap). The second, WM Span, was contrasted between participants: Half of the participants were classified as low WM span, and the other half as high WM span. All possible Event A and Event B stimuli were paired together equally often within a block of trials, in random order. Eighteen participants completed 18 blocks of 18 trials, 15 completed 18 blocks of 24 trials, and 30 completed 14 blocks of 16 trials.[1] Mandatory 30-s breaks were imposed every three blocks. The experiment required 90–100 min to complete.

Results

AOSPAN task

AOSPAN scores were calculated for 168 participants. The mean score was 42.3, with a standard deviation of 15.9. Participants with a score of 39 or lower (bottom 25 %) were

[1] The latter participants were from a pilot study using identical procedures, except for block size.

categorized as "low WM span," and those with a score of 51 or higher (upper 25 %) were categorized as "high WM span." Sixty participants completed the action-planning task: 30 (16 female, 14 male) were high WM span (M = 59.8, SD = 5.4) and 30 (21 female, 9 male) were low WM span (M = 24.8, SD = 8.6).

Action-planning task

Mixed design analyses of variance (ANOVAs), with the within-subjects factor Feature Overlap (overlap, no overlap) and the between-subjects factor WM Span (low, high), were conducted separately on the means for correct Event B RTs, Event B accuracy, and Event A accuracy. The RT and accuracy analyses for Event B were restricted to trials in which responses to Event A were accurate. Figure 2 shows that partial-repetition costs occurred for both low- and high-span participants and that these costs were greater for low-span than for high-span participants.

Event B As is evident in Fig. 2, RTs were significantly longer for low-span than for high-span participants [$F(1, 58) = 4.09$, $p < .05$, $\eta_p^2 = .07$], indicating that the task was more difficult for low-span than for high-span participants. Also, RTs were significantly longer in the feature-overlap than in the no-overlap condition [$F(1, 58) = 37.31$, $p < .0001$, $\eta_p^2 = .39$], indicating that a partial-repetition cost occurred. Figure 2 shows that the RT difference between feature-overlap and no-overlap conditions was significantly greater for the low-span (M = 38 ms) than for the high-span (M = 19 ms) participants [$F(1, 58) = 4.09$, $p < .05$, $\eta_p^2 = .07$], and the 19-ms difference found for high-span participants was significantly different from zero, $p = .001$. This indicates that partial-repetition costs were larger for low-span than for high-span participants. The accuracy data indicate that these RT effects were not due to a speed–accuracy trade-off. The error rate was slightly higher for the feature-overlap than for the no-overlap case [$F(1, 58) = 10.62$, $p < .01$, $\eta_p^2 = .16$], and no other effects on accuracy were significant, Fs < 1.

Event A Error rates in recalling Event A were significantly greater for low-span (M = 12.1 %, SE = 1.0) than for high-span (M = 8.4 %; SE = 1.0) participants [$F(1, 58) = 6.96$, $p = .01$, $\eta_p^2 = .11$], indicating that low-span participants had more difficulty planning, maintaining, or recalling Event A than did high-spans. Also, the error rate was slightly greater for the feature-overlap (M = 10.9 %, SE = 0.9) than for the no-overlap (M = 9.6 %, SE = 0.6) case [$F(1, 58) = 4.28$, $p < .05$, $\eta_p^2 = .07$], suggesting that feature overlap between Event B and Event A might have interfered with the recall of Event A. The interaction was not significant, F < 1.

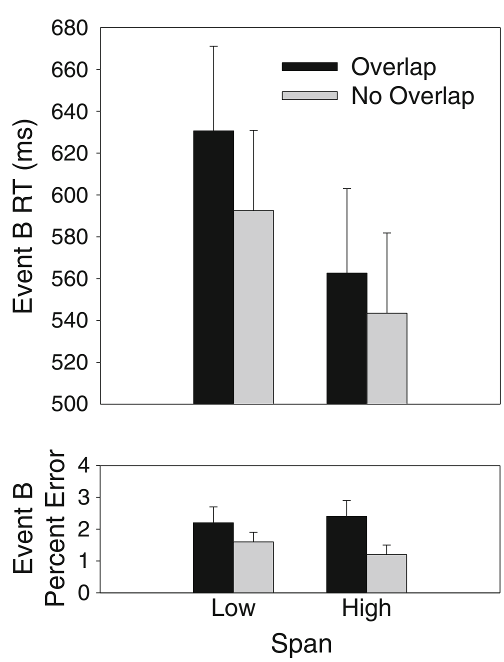

Fig. 2 Event B mean correct response times (RTs) and percent errors in the feature-overlap and no-feature-overlap conditions for low-span and high-span participants. The error bars represent one standard error of the mean

Discussion

This study showed that the degree of interference due to feature overlap between a current action and an action plan maintained in WM depends on WM. Partial-repetition costs were greater for participants with low WM spans than for those with high WM spans. This suggests that low-span participants had fewer WM resources available and required more time to inhibit the incorrect action plan and to select the correct action plan. Low-span participants were slower to respond to the second stimulus (Event B) than were high-span participants, and low-span participants were less accurate in recalling the action plan to the first stimulus (Event A) than were high-span participants, which provides converging evidence that low-span participants had fewer WM resources. Taken together, our results suggest that interference due to shared features between action plans is due to selection demands imposed on WM. This is consistent with research showing that partial-repetition costs may be limited to action plans that require WM (Fournier et al., 2010; Wiediger & Fournier, 2008).

Although WM has not traditionally been thought of as a system for motor planning (cf. Rosenbaum, Chapman, Weigelt, Weiss, & van der Wel, 2012; but see the work by Klapp, 1976, 1980), evidence from the present study and others suggests that action planning requires cognitive resources (Klapp, 1976, 1980; Lawrence, Myerson, Oonk, & Abrams, 2001; Weigelt et al., 2009; see also Behmer & Fournier, 2014) and that WM plays an important role in the management and selection of action plans (Fournier et al., 2010; Mattson & Fournier, 2008; Wiediger & Fournier, 2008). Engle and colleagues have argued that WM span tasks, such as the AOSPAN used in the present study, reflect the ability to keep information online and the ability to inhibit incorrect activation in order to resolve information competition (Engle, Kane, & Tuholski, 1999; Kane & Engle, 2003; Lustig, May, & Hasher, 2001; May, Hasher, & Kane, 1999; see also Roberts, Hager, & Heron, 1994). This idea fits well with our interpretation that individuals with low WM spans in the present study took longer (due to reduced resources) to resolve competition between the current action plan and the action plan maintained in WM (in cases of feature overlap) than did individuals with high WM spans. Thus, our findings are consistent with previous research suggesting that high-span individuals are better at suppressing irrelevant information than are low-span individuals (Chiappe, Hasher, & Siegel, 2000; Gernsbacher & Faust, 1991), and that greater resistance to interference may be a signature of individuals high in WM span capacity (e.g., Burgess, Gray, Conway, & Braver, 2011; Jonides & Nee, 2006; Rosen & Engle, 1998).

Research suggests that WM capacity is related to performance in situations in which some form of interference must be overcome, such as proactive interference (Anderson & Neely, 1996; Jonides & Nee, 2006; Lustig et al., 2001), response competition (Conway & Engle, 1994), or habitual, inappropriate responses (see Conway et al., 2003), with high-span individuals showing more resistance to interference. Similar conclusions have been drawn in attention tasks such as Stroop tasks (Long & Pratt, 2002), visual orienting (Kane et al., 2001), and negative priming (Conway, Tuholski, Shisler, & Engle, 1999). We have shown that these same conclusions about WM capacity can be generalized to action planning in which one must decide what to do and when to do it. Taken together, it appears that WM span differences are reflected in the control processes required to select the correct response from among highly accessible incorrect responses.

In summary, the present study shows that the degree of interference between overlapping action plans depends on WM span. Fewer WM resources (i.e., low span scores) are associated with greater interference. More generally, this study has shown that WM plays an important role in managing current and upcoming action plans, at least for newly learned tasks. The time required to select and execute an action plan, while maintaining another action plan in WM, is compromised more in individuals with low WM spans than in individuals with high WM spans. These findings suggest that WM span can predict one's ability to suppress goal-irrelevant actions in order to select goal-relevant ones.

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References

Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Memory (Handbook of Perception and Cognition)* (2nd ed., pp. 237–313). San Diego, CA: Academic Press.

Behmer, L. P., & Fournier, L. R. (2014). Working memory modulates neural efficiency over motor components during a novel action planning task: An EEG study. *Behavioural Brain Research, 260,* 1–7. doi:10.1016/j.bbr.2013.11.031

Burgess, G. C., Gray, J. R., Conway, A. R. A., & Braver, T. S. (2011). Neural mechanisms of interference control underlie the relationship between fluid intelligence and working memory span. *Journal of Experimental Psychology: General, 140,* 674.

Chiappe, P., Hasher, L., & Siegel, L. S. (2000). Working memory, inhibitory control, and reading disability. *Memory & Cognition, 28,* 8–17. doi:10.3758/BF03211570

Conway, A. R. A., & Engle, R. W. (1994). Working memory and retrieval: a resource-dependent inhibition model. *Journal of Experimental Psychology: General, 123,* 354–373. doi:10.1037/0096-3445.123.4.354

Conway, A. R. A., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences, 7,* 547–552. doi:10.1016/j.tics.2003.10.005

Conway, A. R. A., Tuholski, S. W., Shisler, R. J., & Engle, R. W. (1999). The effect of memory load on negative priming: An individual differences investigation. *Memory & Cognition, 2,* 1042–1050.

Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102–134). Cambridge, UK: Cambridge University Press.

Fournier, L. R., & Gallimore, J. M. (2013). What makes an event: Temporal integration of stimuli or actions? *Attention, Perception, & Psychophysics, 75,* 1293–1305. doi:10.3758/s13414-013-0461-x

Fournier, L. R., Gallimore, J. M., Feiszli, K. R., & Logan, G. D. (2014). On the importance of being first: Serial order effects in the interaction between action plans and ongoing actions. *Psychonomic Bulletin & Review, 21,* 163–169. doi:10.3758/s13423-013-0486-0

Fournier, L. R., Wiediger, M. D., McMeans, R., Mattson, P. S., Kirkwood, J., & Herzog, T. (2010). Holding a manual response sequence in memory can disrupt vocal responses that share semantic features with the manual response. *Psychological Research, 74,* 359–369.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 245–262. doi:10.1037/0278-7393.17.2.245

Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences, 8,* 494–500. doi:10.1016/j.tics.2004.08.007

Hommel, B. (2005). How much attention does an event file need? *Journal of Experimental Psychology: Human Perception and Performance, 31,* 1067–1082. doi:10.1037/0096-1523.31.5.1067

Hommel, B., & Colzato, L. (2004). Visual attention and the temporal dynamics of feature integration. *Visual Cognition, 11,* 483–521.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioural Brain Science, 24,* 849–878. doi:10.1017/S0140525X01000103

Jeannerod, M. (1997). *The cognitive neuroscience of action*. Cambridge, MA: Blackwell.

Jonides, J., & Nee, D. E. (2006). Brain mechanisms of proactive interference in working memory. *Neuroscience, 139,* 181–193.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130,* 169–183. doi:10.1037/0096-3445.130.2.169

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47–70. doi:10.1037/0096-3445.132.1.47

Keele, S. W. (1968). Motor control in skilled motor performance. *Psychological Bulletin, 70,* 387–403.

Klapp, S. T. (1976). Short-term memory as a response preparation state. *Memory & Cognition, 4,* 721–729.

Klapp, S. T. (1980). The memory drum theory after twenty years: Comments on Henry's note. *Journal of Motor Behavior, 12,* 169–171.

Lashley, K. S. (1951). The problem of serial order in behavior. In L. A. Jeffress (Ed.), *Cerebral mechanisms in behavior* (pp. 112–146). New York, NY: Wiley.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133,* 339–354. doi:10.1037/0096-3445.133.3.339

Lawrence, B. M., Myerson, J., Oonk, H. M., & Abrams, R. A. (2001). The effects of eye and limb movements on working memory. *Memory, 9,* 433–444.

Logan, G. D. (1979). On the use of a concurrent memory load to measure attention and automaticity. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 189–207. doi:10.1037/0096-1523.5.2.189

Logan, G. D. (2007). What it costs to implement a plan: Plan-level and task-level contributions to switch costs. *Memory & Cognition, 35,* 591–602.

Long, D. L., & Prat, C. S. (2002). Working memory and Stroop interference: An individual differences investigation. *Memory & Cognition, 30,* 294–301.

Lustig, C., May, C. P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General, 130,* 199–207. doi:10.1037/0096-3445.130.2.199

Mattson, P. S., & Fournier, L. R. (2008). An action sequence held in memory can interfere with response selection of a target stimulus, but does not interfere with response activation of noise stimuli. *Memory & Cognition, 36,* 1236–1247. doi:10.3758/MC.36.7.1236

Mattson, P. S., Fournier, L. R., & Behmer, L. P., Jr. (2012). Frequency of the first feature in action sequences influences feature binding. *Attention, Perception, & Psychophysics, 74,* 1446–1460. doi:10.3758/s13414-012-0335-7

May, C. P., Hasher, L., & Kane, M. J. (1999). The role of interference in memory span. *Memory & Cognition, 27,* 759–767.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior*. New York, NY: Holt, Rinehart & Winston.

Roberts, R. J., Hager, L. D., & Heron, C. (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology: General, 123,* 374–393. doi:10.1037/0096-3445.123.4.374

Rosen, V. M., & Engle, R. W. (1998). Working memory capacity and suppression. *Journal of Memory and Language, 39,* 418–436.

Rosenbaum, D. A., Chapman, K. M., Weigelt, M., Weiss, D. J., & van der Wel, R. (2012). Cognition, action, and object manipulation. *Psychological Bulletin, 138,* 924–946.

Stoet, G., & Hommel, B. (1999). Action planning and the temporal binding of response codes. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1625–1640. doi:10.1037/0096-1523.25.6.1625

Ungerleider, L. G., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 549–586). Cambridge, MA: MIT Press.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavioral Research Methods, 37,* 498–505. doi:10.3758/BF03192720

Watson, J. M., & Strayer, D. L. (2010). Supertaskers: Profiles in extraordinary multitasking ability. *Psychonomic Bulletin & Review, 17,* 479–485. doi:10.3758/PBR.17.4.479

Weigelt, M., Rosenbaum, D. A., Huelshorst, S., & Schack, T. (2009). Moving and memorizing: Motor planning modulates the recency effect in serial and free recall. *Acta Psychologica, 132,* 68–79. doi:10.1016/j.actpsy.2009.06.005

Wiediger, M. D., & Fournier, L. R. (2008). An action sequence withheld in memory can delay execution of visually guided actions: The generalization of response compatibility interference. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 1136–1149. doi:10.1037/0096-1523.34.5.1136