Taboo: Working memory and mental control in an interactive task

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Individual differences in working memory (WM) predict principled variation in tasks of reasoning, response time, memory, and other abilities. Theoretically, a central function of WM is keeping task-relevant information easily accessible while suppressing irrelevant information. The present experiment was a novel study of mental control, using performance in the game Taboo as a measure. We tested effects of WM capacity on several indices, including perseveration errors (repeating previous guesses or clues) and taboo errors (saying at least part of a taboo or target word). By most measures, high-span participants were superior to low-span participants: High-spans were better at guessing answers, better at encouraging correct guesses from teammates, and less likely to either repeat themselves or produce taboo clues. Differences in taboo errors occurred only in an easy control condition. The results suggest that WM capacity predicts behavior in tasks requiring mental control, extending this finding to an interactive group setting.

Measures of working memory capacity (WMC) predict myriad cognitive abilities, including reading comprehension, problem solving, and processing speed (Daneman & Carpenter, 1980; Engle, Carullo, & Collins, 1991). Across tasks, it often appears that people with greater WMC have superior executive attention, the ability to focus and sustain attention (Baddeley, 2003; Engle, 2002). Executive attention is especially important in tasks requiring continuous vigilance, as when people must negotiate competing signals or potential responses. For example, Kane, Bleckley, Conway, and Engle (2001; also see Unsworth, Schrock, & Engle, 2004) found that individual differences in WMC predict speed and accuracy in an antisaccade task: High-span participants are better able to resist the natural tendency to shift visual attention toward abrupt-onset stimuli.

A key function of executive attention is to keep task-relevant goals and information active while suppressing task-irrelevant signals or unwanted thoughts. With respect to external signals, Conway, Cowan, and Bunting (2001) examined dichotic listening; participants shadowed words in one ear while ignoring words (including their own names) in the other ear. People with greater WMC were less likely to experience the cocktail party effect, noticing their own names in the unattended ear. In similar fashion, Kane and Engle (2003) found that WMC predicts

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susceptibility to Stroop interference: Lower-span participants were less efficient in suppressing prepotent word reading responses, especially when incongruent trials occurred infrequently. With respect to internal signals, Wegner (1994) reported that people struggle to suppress ideas once they have been introduced. Brewin and Smart (2005; Brewin & Beaton, 2002) found that WMC predicts ability to suppress intrusive thoughts, with greater suppression skill for people with greater WMC.

Although differences between high- and low-spans often arise as main effects, span differences often interact with levels of cognitive load. Rosen and Engle (1997) had people list as many animals as possible, without repetitions, in 15 min. High-spans produced more names and fewer repetitions compared with low-spans. When a secondary digit-monitoring task was added, verbal fluency was selectively reduced among high-spans, but low-spans were unaffected. Similarly, Kane and Engle (2000) found that, given a single short-term memory task, high-spans resisted proactive interference better than low-spans. With divided attention, high-spans were selectively impaired, performing comparably to low-spans, whose performance was unchanged. Engle and colleagues suggested that these interactions reflect differences in resource allocation: High-spans allocate executive attention efficiently in single tasks but fail in dual tasks. Conversely, low-spans are inefficient even in single tasks and are thus unaffected by increased load (see Engle & Kane, 2004, for discussion).

The present research: Taboo

Although many recent studies have focused on individual differences in WMC, the present study focused on a question that has rarely (if ever) been addressed: Does WMC affect performance in a social, cooperative endeavor? This question has clear practical implications and also relates to theories of mental control. In a recent study, Wardlow Lane, Groisman, and Ferreira (2006) described failures of mental control that occurred when people performed a cooperative referential communication task. In their study, pairs of people played a game: A speaker and a guesser each saw an array of objects; one was visible only to the speaker. The speaker's goal was to prompt the guesser into selecting a predetermined target. In critical trials, the hidden object was a larger version of the target (e.g., a large triangle was hidden; a small triangle was the target). In these trials, speakers often "leaked" information about the hidden objects (e.g., "It's the smaller one"). Of particular interest, such leakage occurred more often when people explicitly tried to avoid revealing properties of the hidden objects, an ironic effect of attempted mental control (Wegner & Erskine, 2003).

The study by Wardlow Lane et al. (2006) showed that people may suffer lapses of mental control during speech production, especially when holding conflicting goals in mind. In the present study, we had people engage in a cooperative game. Specifically, low- and high-span volunteers played the game Taboo, in which speakers produce clues, trying to get their teammates (guessers) to identify target words. During each turn of the game, the speaker selects a card with a target word (nouns, adjectives, or verbs), followed by a series of taboo words (Figure 1). The speaker must elicit the target word from teammates while refraining from speaking the taboo words as clues. These are salient associates (i.e., excellent potential clues) for

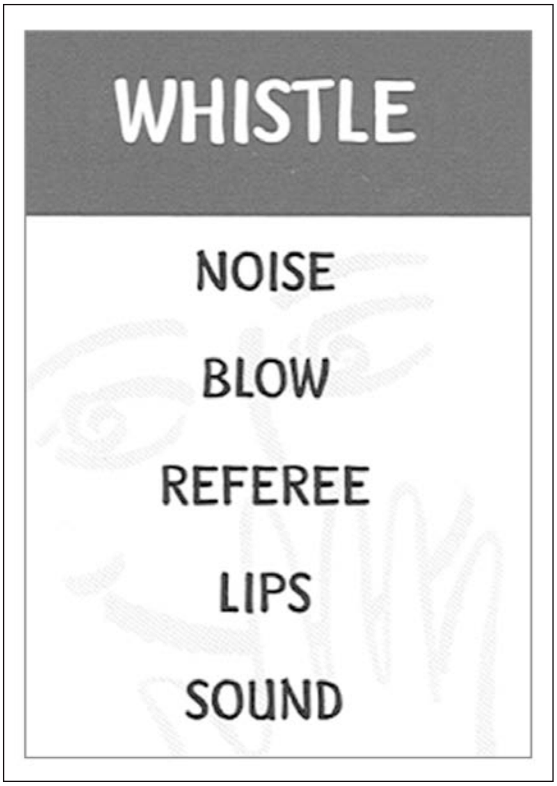

FIGURE 1. A typical game card from Taboo, with the target word *whistle* and its taboo associates

the targets, creating difficulty for both speakers and guessers. Players often benefit from approaching target words in an unorthodox way. For example, instead of trying to describe a whistle (taboo words *noise, blow, sound, lips, referee*), one might use a culturally salient clue: "You do this while you work." Indeed, for both speakers and guessers, playing Taboo is often similar to solving insight problems, an ability that differs according to WMC (Ash & Wiley, 2006).

In addition to asking a novel question, we investigated Taboo because it provides a unique synthesis of cognitive processes that are related to WMC. In Taboo, multiple domains of prior research are combined, including verbal fluency, memory search, creation of ad hoc categories (Barsalou, 1983), and problem solving. Most important, because Taboo is a cooperative task, speakers must divide and control attention: They must resist the temptation to speak taboo words (and should avoid repeating previously unsuccessful clues), and they must monitor the active schemata of teammates. Thus, as an index of mental control, Taboo strikes a unique balance: People interact and respond quite freely, but the game is naturally structured to challenge executive attention.

With respect to mental control, two behaviors in Taboo are especially interesting. First are taboo errors, wherein speakers produce off-limit words (either a taboo or target word). There are unique, dual demands on working memory in Taboo: People must keep taboo words active while resisting the urge to say them aloud. Players must also search memory for other salient clues while suppressing unrelated and off-limit words. We expected high-spans to better negotiate these competing demands, making fewer taboo errors. However, in prior research (Rosen & Engle, 1997; Kane & Engle, 2000), even modest mental workloads selectively impaired high-span participants. In Taboo, cognitive demand is quite high, suggesting that all participants might commit taboo errors at similar rates. To facilitate comparison across groups, we created a control condition by removing taboo words from selected game cards. The workload imposed by these control trials was greatly reduced because the target words were the only off-limit words. Reflecting the demands of the conditions, we call the control condition "simple" and the condition with taboo words "complex." Given the documented interaction of WMC and workload, we expected larger group differences in the simple condition than in the complex condition. This is a counterintuitive prediction—that effects of WMC will be most evident in the easier task—but it is consistent with prior findings (Rosen & Engle, 1997; Kane & Engle, 2000).

A second measure was perseveration rates. In verbal fluency, Rosen and Engle (1997) found that, relative to high-span participants, low-spans generated more repetitions. Other research shows that perseverations increase under cognitive load (Azuma, 2004; Oomen & Postma, 2002). Although repetitions are not forbidden in Taboo, it behooves speakers and guessers to avoid repeating unsuccessful clues or incorrect guesses. Following prior research, we expected high-spans to make fewer perseverations than low-spans. Moreover, given that perseverations increase with cognitive demand, we expected overall perseverations to increase in the complex condition. Finally, because Taboo involves problem solving by teammates, we also analyzed accuracy (for guessers), elicited accuracy (for speakers), and how often the speaker passed, abandoning a target word.

EXPERIMENT

METHOD

The study was conducted in two stages. We first administered WMC screening tests to 375 undergraduates. After identifying low- and high-capacity students, we recruited as many as possible to play Taboo.

WMC Screening

PARTICIPANTS.

Three hundred seventy-five Arizona State University students completed three WMC tests; all received partial course credit.

MATERIALS.

The WMC tasks were variations of operation span (Turner & Engle, 1989), digit reordering (MacDonald, Almor, Henderson, Kempler, & Andersen, 2001), and counting span (Case, Kurland, & Goldberg, 1982). Groups of three to eight people were tested using computers and E-Prime software. Participants recorded answers manually on answer sheets. Data analyses used all-or-nothing scoring (Conway et al., 2005), reflecting the total number of correctly remembered items for each complete series.

In operation span, participants were shown correct or incorrect equations, each followed by a word (e.g., "(8/2) – 3 = 1 dog"). Participants decided whether the equation was correct, then tried to memorize the word. When ready, they pressed "Q" (*correct*) or "P" (*incorrect*), which initiated the next operation–word combination. Trials were separated by a fixation signal ("***") shown for 1 s. This process was repeated two to six times per series. After the last trial per series, a "*recall*" prompt appeared; participants recorded every word they could remember, in presentation order, on their answer sheets. When finished, participants pressed "=" to begin the next series. The memorization and recall stages were both self-paced. After a practice series of 5 items, there were 12 test series with 56 operation–word combinations.

In digit reordering, participants were shown a series of numbers, ranging from 1 to 19, for 2 s each. Participants memorized each number and, at a "*recall*" prompt, tried to recall them in ascending order. Encoding was computer paced, and the recall portion was self-paced. Set sizes ranged from two to eight items, with 20 series comprising 120 digits.

In counting span, participants viewed displays containing dark blue circles, light blue circles, and dark blue squares. Participants counted the dark blue circles, memorizing this number for later recall, then pushed the spacebar to initiate the next display. There were two to six displays per series. Eventually, a "*recall*" prompt appeared; participants tried to recall the numbers of dark blue circles they saw, in order of presentation. Like operation span, this task was entirely self-paced. There were 12 series that contained 55 displays total.

Taboo

PARTICIPANTS.

Participants were selected according to their WMC scores. Standardized scores were derived for participants for all three span tasks; students who scored consistently in the upper or lower quartiles were recruited to play Taboo.[1] In total, 176 people were contacted; 67 eventually participated in exchange for cash (and chocolate bars, used as incentive to compete). Data from 3 participants were not used because they were not native English speakers, leaving 43 high-spans and 21 low-spans. In data analysis, we removed another 22 participants (18 high-span, 4 low-span) who reported having prior experience playing Taboo, leaving final sets of 25 high-span and 17 low-span participants.[2]

MATERIALS.

Materials included the game Taboo (a minute timer, card holder, Taboo cards, and a buzzer). Our only addition to the game was a set of control cards. Twenty-five percent of the Taboo cards were removed from the game; their target words were copied onto similarly shaped cards, without the taboo words.

PROCEDURE.

Groups of three to six participants were scheduled to play Taboo. Participants were assigned to groups based on their availability. Scheduling constraints prevented systematic assignment of high- and low-spans to groups. The majority of groups had a combination of high- and low-span participants, although there were four instances in which a group consisted of only high-span participants or one group that consisted of only low-spans. There were 15 groups total: 4 groups with three players, 3 with four players, 5 groups with five players, and 3 with six players. If only three participants came, they all played as one team; otherwise, they were divided into two teams and randomly rearranged once during play.

The goal of Taboo is to correctly guess as many target words as a team as possible. In each turn, a member of one team (the speaker) gave clues about the target word, and the other team members (guessers) tried to guess the target word. In the complex condition, the speaker tried to avoid using parts of the target word or taboo words. In the simple condition, taboo words were not present on the playing cards, and so only the target word was off limits. Members of the opposing team were in charge of monitoring the speaker for errors and watching the timer, although experimenters also monitored both. If the speaker uttered the target or a taboo word, the opposing team pressed the buzzer, signaling a "taboo error." Speakers were encouraged to give creative clues, but they were forbidden to use rhyming clues, acronyms (e.g., *TV* for the target/taboo word *television*), or hand gestures, although these responses were not counted as "taboo errors" for data analysis. Each time a team correctly guessed the target word or the speaker made an error, the card was placed to the side and the next card was drawn. Each speaker had 1 min to elicit as many correct guesses as possible. Points were given for every correctly guessed target word; points were subtracted for errors. Passing was allowed, but at the cost of 1 point. Participants were encouraged to compete for prizes, although all participants actually received them.

Participants played in a conference room in the student union for 1 hour. Across groups, orders of the simple and complex conditions were counterbalanced. Two experimenters were present during each session. One refereed the game; the other recorded each target word and outcome (correctly identified, passed, taboo error). Each session was recorded using a Sony digital video camera, mounted on a tripod, for later coding purposes.

RESULTS

Data coding

Five judges each viewed a subset of the videotapes, with nearly perfect agreement. Guessing and speaking behaviors were coded separately for each participant. For guessers, we tallied correct, incorrect, and repeated guesses. For speakers, we tallied correct cards, taboo cards, and passed cards, in addition to numbers of clues and repeated clues.

Correct responses

All results were analyzed in 2 × 2 (span × condition) mixed-model analyses of variance (ANOVAS). As shown in Figure 2a, participants were more accurate guessing targets in the simple condition than in the complex condition, $F(1, 40) = 89.6, p < .0001, \eta_p^2 = .69$. Of greater interest, high-spans were more accurate than low-spans, $F(1, 40) = 3.94, p < .05, \eta_p^2 = .09$, an effect that was driven largely by low-span participants generating incorrect guesses. The interaction of condition × span was not reliable, $F(1, 40) = 0.02$, *ns*. As shown in Figure 2b, speakers were more likely to elicit correct guesses (expressed as the percentage of cards) from their teammates in the simple condition than in the complex condition, $F(1, 40) = 55.84, p < .0001, \eta_p^2 = .58$. A main effect of span was again observed, $F(1, 40) = 11.89, p < .001, \eta_p^2 = .23$, as high-spans elicited higher accuracy than low-spans. There was no trend toward an interaction, $F(1, 40) = 0.38$, *ns*.

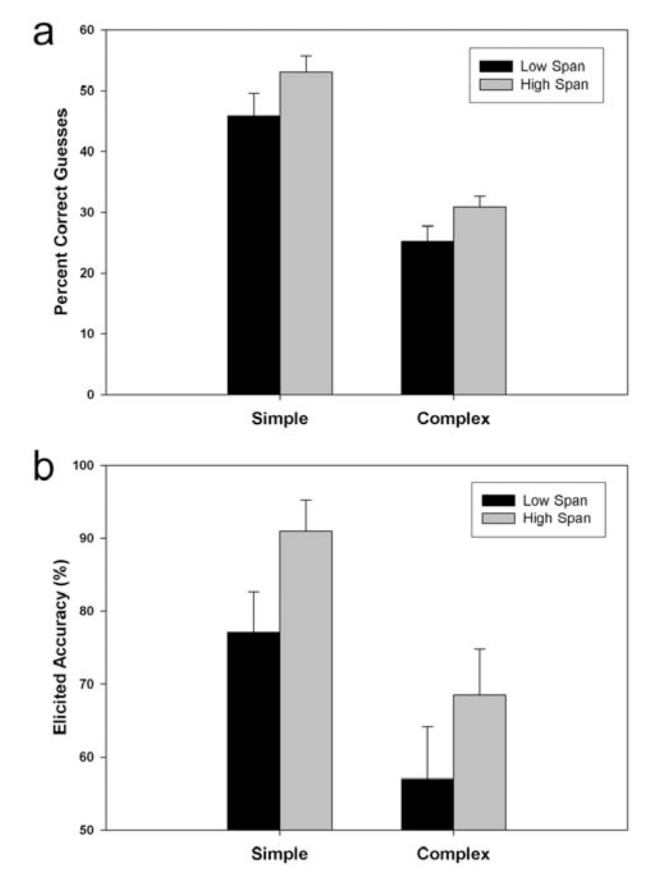

FIGURE 2. Correct responses: (a) Percentages of correct guesses (±*SEM*) for low- and high-span participants in each condition; (b) elicited correct response rates (±*SEM*) for low- and high-span speakers in each condition

Taboo errors

Figure 3a shows Taboo error rates, a key indicator of mental control. As noted earlier, people must hold the Taboo words in mind while resisting the urge to produce them, precisely the situation created in experimental procedures such as the Stroop task. Thus, following prior studies (e.g., Kane & Engle, 2003), we expected Taboo errors to produce an interaction of span and condition. A main effect of condition was observed, $F(1, 40) = 38.52, p < .0001, \eta_p^2 = .46$, with more errors in the complex condition. A marginal main effect of span was observed, $F(1, 40) = 3.55, p < .06, \eta_p^2 = .08$, with fewer Taboo errors by high-span participants. Span and condition also produced a reliable interaction, $F(1, 40) = 15.20, p < .001, \eta_p^2 = .16$. As shown in Figure 3a, the difference between groups was substantial in the simple condition, $F(1, 40) = 21.03, p < .001, \eta_p^2 = .19$, but was absent in the complex condition, $F(1, 40) = 0.16$, *ns*.

Passing rates

As noted earlier, we recorded information on passing rates and perseverations. Neither passing nor perseverating was expressly prohibited, but both behaviors were considered undesirable. Passing resulted in the

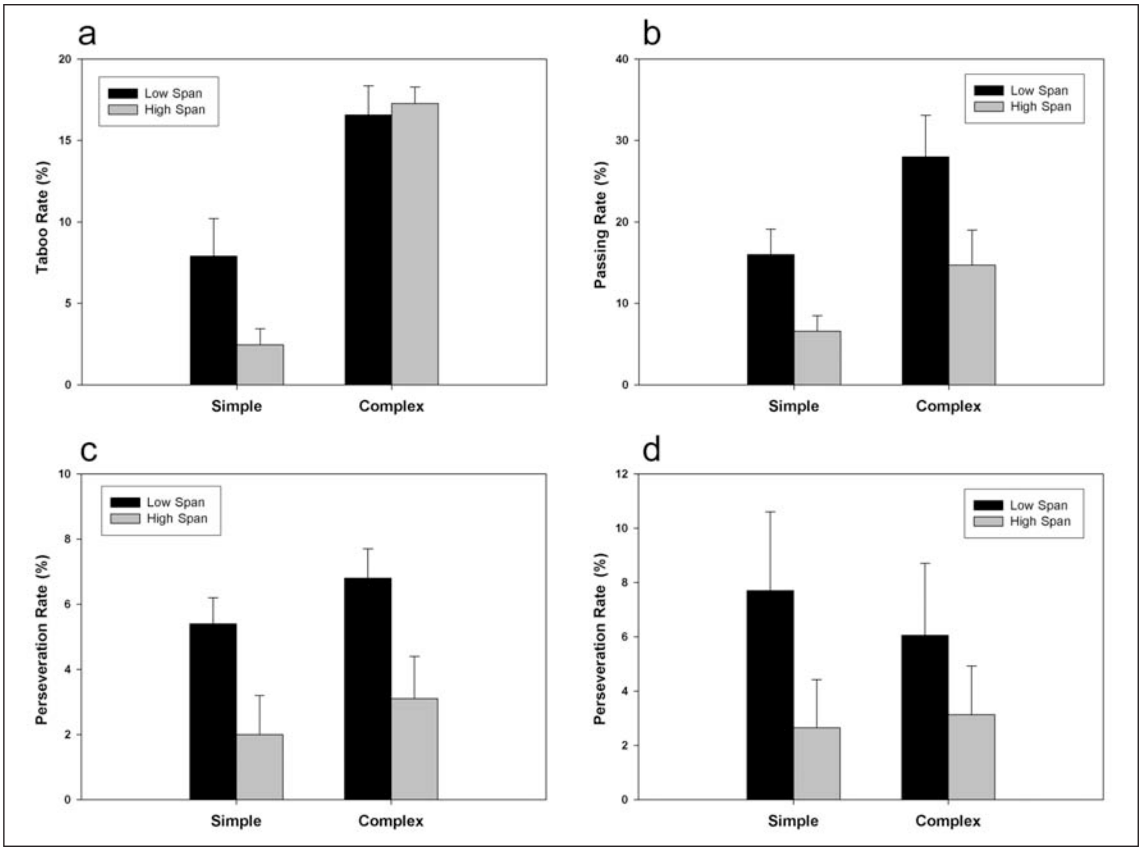

FIGURE 3. Negative behaviors: (a) Taboo rates (±*SEM*) for low- and high-span participants in each condition; (b) passing rates (±*SEM*) for low- and high-span participants in each condition; (c, d) perseveration rates (±*SEM*) for guessers and speakers, respectively

loss of a point, and repeating incorrect responses (as a speaker or guesser) wasted valuable time. Figure 3b shows passing rates (the percentage of cards that speakers chose to skip). A main effect of condition was observed, $F(1, 40) = 21.62$, $p < .001$, $\eta_p^2 = .35$, with more passing in the complex condition. There was also a main effect of span, $F(1, 40) = 8.66$, $p < .01$, $\eta_p^2 = .14$, with high-spans passing less often than low-spans. There was no trend toward an interaction, $F(1, 40) = 0.17$, *ns*.

Perseveration rates

Figure 3c shows perseveration rates as percentages of repeated incorrect guesses. Greater perseveration was observed in the complex condition, $F(1, 40) = 6.24$, $p < .02$, $\eta_p^2 = .13$, than in the simple condition. A marginal main effect of span was observed, $F(1, 40) = 3.44$, $p < .06$, $\eta_p^2 = .07$, with high-spans perseverating less. The span × condition interaction did not approach significance, $F(1, 40) = 0.08$, *ns*. Figure 3d shows perseveration rates for speakers, as percentages of repeated clues. Although no main effect of condition was observed, $F(1, 40) = 0.19$, *ns*, there was a main effect of span, $F(1, 40) = 9.11$, $p < .01$, $\eta_p^2 = .13$, with high-spans perseverating less often than low-spans. There was no trend toward an interaction, $F(1, 62) = 1.06$, *ns*.

DISCUSSION

In prior research (e.g., Kane & Engle, 2002), individual differences in WMC have been related to differences in myriad cognitive processes, including reasoning, verbal fluency, and the ability to perform dual tasks (Engle & Kane, 2004). Although there is debate about the underlying aspects of WMC that produce such differences (Ackerman, Beier, & Boyle, 2005; Oberauer, Schulze, Wilhelm, & Süß, 2005), it is agreed that people with lower WMC spans perform poorly in searching controlled memory, self-monitoring for errors, and suppressing irrelevant information. In this study, we attempted a synthesis, comparing people with low and high WMCs playing Taboo, a game that requires fast reasoning, search of semantic memory, verbal fluency within categories, and the ability to resist speaking high-primed words. By naturally combining so many elements of prior research, Taboo provides an excellent way to evaluate individual differences in WMC in an interactive, social setting, where participants must monitor and update their responses based on the responses of their teammates. If differences emerge between low- and high-spans in Taboo, they will probably arise in other settings wherein teams of people must cooperate under cognitive load.

Our results are easily summarized: First, performance was better for all participants in the simple condition than in the complex condition. This is not surprising given the constraints that the complex condition imposes on players: It presents dual challenges of keeping "forbidden" words active while searching memory for associated words. It also removes the most common clues. The combination of increased mental load and removal of common associates led to an increase in Taboo errors, passing rates, and perseveration rates while decreasing correct guesses.

We also found that, by nearly all measures, high-span participants played Taboo more effectively than low-span participants. High-spans were better guessers and were more likely to elicit correct guesses from teammates. They repeated themselves less often, both when guessing and when giving clues. They also passed difficult cards less often than low-spans. In Taboo errors, we replicated a pattern seen in prior studies (Engle & Kane, 2004): In the simple condition, high-span participants made almost no Taboo errors; low-spans committed significantly more. In the more challenging complex condition, both groups committed Taboo errors at higher, equivalent rates. Thus, the added constraints had a more profound effect on the high-span participants. Similar interactions have been reported in procedures that force simultaneous activation of competing responses (e.g., antisaccade and Stroop tasks). Although our observed pattern runs counter to intuition, it is consistent with the prior literature. Although other measures showed uniformly superior performance by high-span volunteers, Taboo errors most directly estimate competition of overlapping representations.

We failed to find span × condition interactions on other dependent measures, such as perseverations, where it might have been expected. For example, Rosen and Engle (1997) found that high-spans perseverated more when a secondary task was added. There are several possible explanations for this. First, although not ideal, perseverations were not explicitly prohibited in Taboo. Furthermore, subjective reports from participants suggest that perseverations were occasionally intentional: Speakers sometimes repeated clues to emphasize their importance. Finally, no main effect of condition was observed for speaking perseverations, suggesting that perseverations are less sensitive to cognitive load in this task. The differences observed between span groups appear to reflect differences in attentional control. We suggest that high-spans outperformed low-spans because they were better able to negotiate the competing attentional demands that Taboo imposes on players.

Other findings

Although differences in WMC reliably exist in controlled laboratory experiments, few studies have assessed whether WMC might affect natural behavior (see Kane et al., 2007, for one recent example). Beyond differences in game performance, we observed other interesting and unexpected differences in our participant groups. First, it was quite difficult to successfully recruit low-span volunteers. During our WMC screening, students indicated whether they wanted to participate further for payment. High- and low-spans responded "yes," and later scheduled Taboo sessions, in equivalent numbers. We reminded all students via e-mail and telephone the evening before each session. Nevertheless, we ended up with 45 high-spans and 22 low-spans. Relative to low-spans, high-spans were significantly more likely to show up for scheduled sessions, $\chi^2_{(1)} = 7.34$, $p < .01$. In our sample, many low-spans (contacted after missed sessions) indicated that they "simply forgot" about their appointments. Smith and Bayen (2005) reported that WMC predicts performance on prospective memory tasks, wherein participants must remember to respond given a certain cue. They suggest that high-spans use attentional processes to keep goal-related information active more often, relative to low-spans, performing better on prospective memory tasks.

Second, we asked whether participants had prior experience playing Taboo. Interestingly, among the people with Taboo experience, almost all (18 of 22) were high-spans, $p = .0017$, binomial test. Although we are reluctant to overinterpret this isolated observation, it suggests that people with higher WMC are more likely to enjoy (or self-select) leisure activities that present mental challenges.

Finally, one issue regarding the interactive nature of Taboo merits mention. Although we observed differences between low- and high-span participants in nearly all measures, our results probably *underestimated* their true differences. Because Taboo is a cooperative activity, there is natural convergence: High-spans make lower-span teammates "look better" by giving good clues, making good guesses given poor clues, answering before low-span teammates begin perseverating, and so on. The opposite pattern is also likely, with low-spans making high-span teammates "look worse." Only a few behaviors would be unaffected by teammates, such as immediate "pass" decisions or Taboo errors, wherein someone reads a card and promptly says a Taboo word. (Such instant suppression failures were fairly common among low-spans. One participant remarked, "The only reason I said [the taboo word] was because I looked at the card, and there it was.") Cooperative tasks such as Taboo may suggest a social solution to resource limitations in that people can "share" WMC resources to achieve common goals. Research on WMC has focused nearly exclusively on people taking tests in isolation. Taboo deviates from this typical approach toward an interactive method. Future research on interactive activities (whether cooperative or competitive) is likely to provide important new insights into the complex relationship of working memory and mental control.

NOTES

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1. Because we administered three separate WMC tests, we used a conservative approach to classify participants as high- or low-span. We generated *z* scores for all participants in each test and derived averages of those *z* scores. To be counted in the upper or lower quartile, a person had to meet two requirements: First, his or her average *z* score had to fall into that quartile. Second, at least two of the separate component scores also had to fall into that quartile.

2. All reported results were based on the final sample of inexperienced Taboo players, including 25 high-span and 17 low-span volunteers. We also conducted analyses on the original pool of 64 participants, with and without prior Taboo experience (numerically estimated from participants' self-reports) entered as a covariate. In each case, the results were qualitatively and statistically consistent with those reported in this article.

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