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Distractor filtering in media multitaskers

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Abstract. A growing amount of modern media is consumed simultaneously, a phenomenon known as 'media multitasking'. Individuals who regularly engage in this activity, heavy media multitaskers (HMMs), are more affected by irrelevant information that can intrude into a primary task than are light media multitaskers (LMMs—Ophir et al, 2009 *Proceedings of the National Academy of Sciences of the USA* **106** 15583). However, the locus of this deficit is unknown, as previous research is consistent with both memory and attentional explanations. Here, we isolated attentional processes by employing a singleton distractor task with low working-memory demands. In this task, LMMs used top – down information to improve their performance, yet HMMs did not. This difference in performance in an established attentional capture task argues for the presence of attentional differences in HMMs and is consistent with the idea that HMMs maintain a wider attentional scope than LMMs, even when instructed otherwise.

1 Introduction

The modern media landscape has changed dramatically in the last few decades and there are more media consumption options available than ever before. With these increasing options there has been a rise in media multitasking—consuming multiple forms of media at the same time (eg watching TV while reading)—and this rise has been especially apparent amongst teenagers (Foehr 2006; Roberts and Foehr 2008). The average American 8 – 18-year-old spends 29% of their media consumption time multitasking, up from just 16% a decade ago (Rideout et al 2010). While it has been shown repeatedly that comprehension and effective processing of one medium are reduced while simultaneously consuming a second one (eg Craik et al 1996; Mulligan et al 2007; Wickens 1980), effects of long-term media multitasking are not fully understood. A recent study found that those who routinely consume multiple media simultaneously perform more poorly on a variety of cognitive laboratory tasks (Ophir et al 2009). This finding has profound implications, as it is important to understand how differences in media-consumption habits in daily life are related to differences in basic cognitive abilities.

Ophir et al (2009) demonstrated that heavy media multitaskers (HMMs) are not as able as light media multitaskers (LMMs) to ignore task-irrelevant information. For example, in a visual short-term working-memory task participants were asked to remember red shapes and ignore blue shapes. LMMs were unaffected by the number of irrelevant blue distractors (suggesting they successfully filtered out the irrelevant information), but HMMs were negatively affected by increasing numbers of irrelevant distractors. The HMMs showed a clear deficit, but it is unclear if the deficit arose at encoding, maintenance, or retrieval (ie Mitroff et al 2004; Simons and Rensink 2005). In another task, Ophir et al (2009) found poorer performance for HMMs on a modified AX – CPT paradigm. In such a paradigm, participants view a steady stream of letters and must respond to a contingent temporal combination of the cue and target (eg respond to the target 'X' only if it follows the cue 'A', but not any other cue).

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This modification included distractor stimuli between the cue and the target that were similar to the task-relevant stimuli, except that their color indicated that they were to be ignored. This irrelevant information interfered with performance for HMMs but not for LMMs. Again, the relatively greater impact of irrelevant information on HMMs is clear, but the locus of this deficit is unclear. For example, this could stem from an encoding problem (attending to the irrelevant information rather than ignoring/suppressing it), or it could be due to something further on in the processing stream (eg retroactive interference).

Ophir et al (2009) nicely demonstrated that HMMs processed task-irrelevant information to a greater degree than did LMMs, but a key open question remains about the locus of HMMs' deficits: Are there differences in attention, working-memory encoding, memory retrieval, or some combination of these processes? These processes are often difficult to disentangle, and individual differences in working-memory capacity and resistance to attentional capture have been shown to correlate (Fukuda and Vogel 2009). The goal of the current paper is to begin to answer this question by minimizing working-memory demands in order to examine whether the remaining attention-based demands continue to reveal HMM deficits. To do so, we employ a task well-suited to this purpose, the additional singleton paradigm (Costello et al 2010; Leber and Egeth 2006; Theeuwes 1991). In this task, participants search for a shape singleton in the possible presence of an irrelevant color singleton (see figure 1) and there are limited, if any, demands on short-term memory, as all stimuli remain visible and unchanging for the duration of each trial. Top – down attentional instructions vary across conditions to reveal whether HMMs continue to be negatively influenced by irrelevant distractions in the presence of strong attentional demands but minimal working-memory demands.

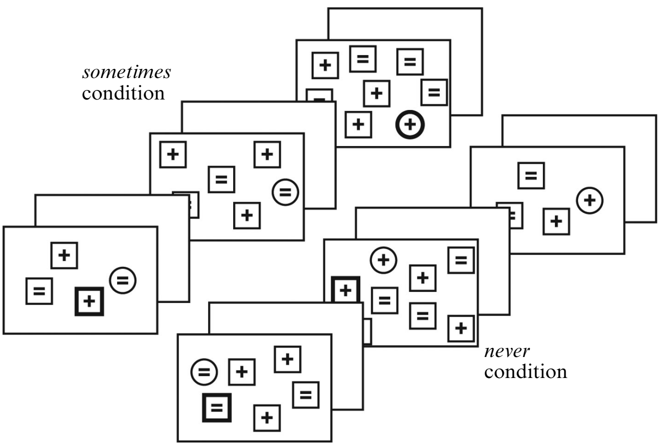

Figure 1. Example trials in both the *sometimes* and *never* conditions (not to scale, display size 12 not pictured) in experiment 1. Participants reported which symbol (+ or =) was within the shape singleton (circle). Stimuli were green outline shapes against a black background, except for a red color singleton (shown here in bold) that was present on half the trials. Stimuli were visible until a response was made or until 3 s had elapsed. The screen was blank in the intertrial interval for correct responses, but presented the word 'Incorrect' after error trials.

2 Methods

2.1 *Participants*

Eighty-five members of the Duke University community participated for course credit or $10. Participants were categorized based on their media multitasking index (MMI) score (calculated via the Media Use Questionnaire; Ophir et al 2009, described below).

The HMMs represented the upper quartile of the MMI scores and the LMMs represented the lower quartile. The twenty-one HMMs (twelve females) all had an MMI > 5.36. The twenty-one LMMs (eleven females) all had an MMI < 3.18. The forty-three participants (twenty-three females) with MMIs in the middle two quartiles were not included in the main analysis, but are included in auxiliary analyses. No HMMs or LMMs reported being color blind.

2.2 *Media use questionnaire*

Participants were given the Media Use Questionnaire (Ophir et al 2009), which asses-ses use of twelve different media: print media, television, computer video, music, non-musical audio, video games, telephone, instant messaging, text messaging (SMS), e-mail, web surfing, and other computer applications. Participants reported the number of hours per week they use each medium and how often ("Most of the time", "Some of the time", "A little of the time", or "Never") they simultaneously use each other's second medium at the same time. MMI scores were calculated as the weighted sum of the number of media consumed simultaneously, normalized by the total hours of consumption of each medium. Thus, the MMI reflects the relative level of media multitasking during time spent consuming media. Some participants completed the MMI in a separate testing session prior to the experiment, but the majority completed it in the testing session, with half completing it before the experiment and half after.

2.3 *Stimuli and procedure*

The program and procedure were identical to those used by Costello et al (2010). Stimuli were generated with E-Prime software (Psychology Software Tools, Sharpsburg, PA) and presented on a 20 inch CRT monitor with participants seated approximately 60 cm from the screen. Each display consisted of a black background with a single target circle (1.2 deg in diameter) and either 3, 5, 7, or 11 square distractors (1.2 deg $\times$ 1.2 deg; see figure 1). On half the trials, all shapes were green. On the other half of the trials, there was a red colored singleton amongst the green shapes. Each shape contained either a + or a = that was the same color as the shape, with each display containing an equal number of both symbols. Participants were to report the symbol inside the circle with a keypress (the 'z' and '/' keys, with the key–to–symbol mapping counter-balanced across participants). Each display was on the screen for 3000 ms or until a response was made. The intertrial interval varied between 1200 and 1800 ms. The screen was black during this interval, except for the 1000 ms immediately following incorrect trials which displayed the word 'Incorrect' in the center of the screen.

There were two task conditions, presented in separate blocks. In the *never* condition, participants were validly instructed that the color singleton would never be the target circle. In the *sometimes* condition, participants were validly instructed that the color singleton would sometimes be the target circle; the color singleton was just as likely to be the target as to be any other shape (eg for set size 8, the target was the color singleton 1/8 of the time). Participants completed 12 experimental blocks of 64 trials each with 6 *never* blocks alternating with 6 *sometimes* blocks (order counterbalanced across participants). An instruction screen informed participants of the identity of each block at the beginning of the block and again halfway through. Participants began with 64 practice trials divided into a 32-item *never* block and a 32-item *sometimes* block.

3 Results and discussion

3.1 *Main analysis*

The variable of primary interest was response time (RT), as accuracy was designed to be near ceiling [mean errors: 3.63% of trials (SD = 2.5%) in the *never* condition and 3.55% (SD = 2.3%) in the *sometimes* condition]. Following Costello et al (2010), trials with incorrect responses (3.60% of all trials) and trials with RTs < 200 ms or

>1600 ms (an additional 1.93% of all trials) were excluded, as were trials where the color singleton was the target circle (3.67%), and the trials following color singleton target trials (3.30%). The trials where the color singleton was the target circle were excluded so that the trials compared between the *sometimes* and *never* conditions would be physically identical (as done in Costello et al 2010). Trials following such trials showed notable trial-history effects, being noticeably slower than other trials, perhaps due to color priming effects (eg Maljkovic and Nakayama 1994; Pinto et al 2005). As these trials were only present in the *sometimes* condition, they were removed from the main analyses to make the two conditions maximally comparable. In additional analyses provided after our primary analyses of interest, we discuss those trials where the color singleton was the target and surrounding trials in more detail.

RTs for included trials were submitted to a $4 \times 2 \times 2 \times 2$ repeated-measures ANOVA with display size (4, 6, 8, or 12 items), condition (*never* or *sometimes*), and color distractor presence (present or not present) as within-subject variables and group (HMM or LMM) as a between-subjects variable. The data are summarized in figure 2.

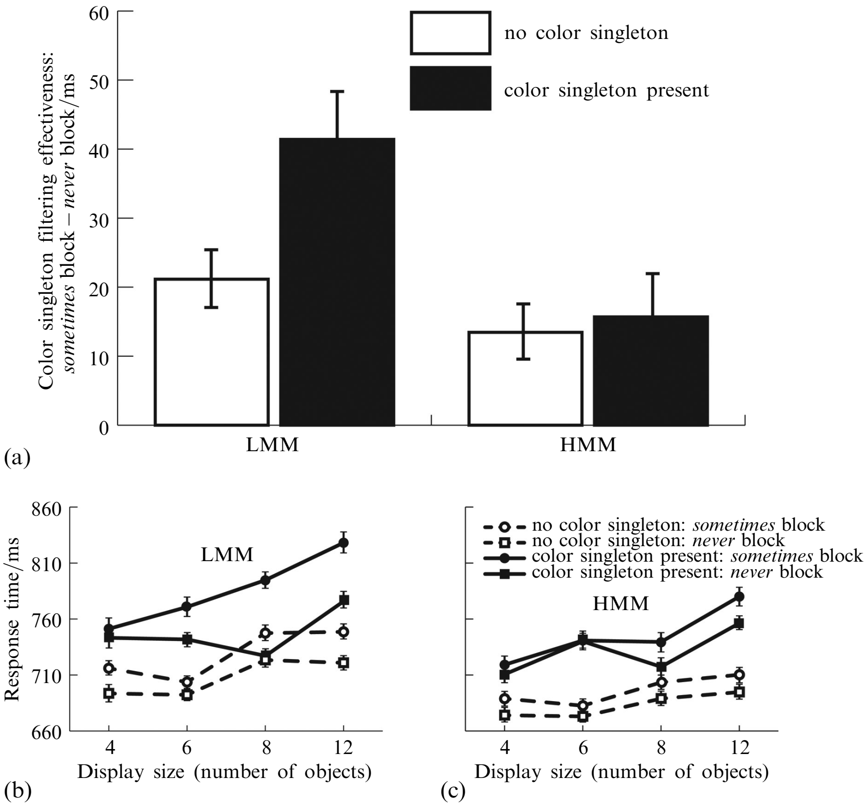

Figure 2. (a) Differences in response times between the *sometimes* and *never* conditions. The ordinate represents the degree to which participants performed more quickly in the *never* condition when they had information about the color singleton than in the *sometimes* condition when they did not have such information. When a color singleton was present in the *never* condition, light media multitaskers effectively used instruction information to improve performance relative to the *sometimes* condition. Heavy media multitaskers did not modulate their performance between the *sometimes* and *never* conditions. Error bars represent standard error of the mean. (b) and (c) Response times for correct trials at each display size and condition for light media multitaskers (LMMs) (b) and heavy media multitaskers (HMMs) (c) when there was no color singleton distractor in the display (dashed lines) and when a color singleton distractor was present (solid lines). Error bars represent within-subjects error (Cousineau 2005; Morey 2008).

There was a significant main effect of display size ($F_{3,120} = 54.97$, $p < 0.001$), with larger display sizes leading to longer RTs; a significant main effect of condition ($F_{1,40} = 57.66$, $p < 0.001$), with RTs in the *never* condition ($M = 712$ ms) being faster overall than in the *sometimes* condition ($M = 738$ ms); and a significant main effect of distractor presence ($F_{1,40} = 127.61$, $p < 0.001$), with trials with a color singleton distractor present ($M = 750$ ms) being slower overall than trials without a color singleton distractor ($M = 699$ ms). While there was a numerical difference in overall RTs between HMMs ($M = 707$ ms) and LMMs ($M = 742$ ms), this difference did not produce a significant main effect of group ($F_{1,40} = 2.00$, $p = 0.165$). There was a significant interaction between display size and condition ($F_{3,120} = 5.49$, $p = 0.001$), with a larger impact of increased display size in the *sometimes* condition than in the *never* condition; a significant interaction between display size and distractor presence ($F_{3,120} = 21.08$, $p < 0.001$), with larger effects of increased display size when a distractor was present than when no distractor was present; and a significant interaction between condition and distractor presence ($F_{1,40} = 7.38$, $p = 0.010$), with a larger RT cost for having a distractor present in the *sometimes* condition than in the *never* condition.

Most relevant for the current questions, there was a significant interaction between condition and group ($F_{1,40} = 8.01$, $p = 0.007$), reflecting that the difference in RT between the *sometimes* condition and the *never* condition was greater for LMMs than for HMMs. This suggests that LMMs were applying top–down distraction filtering more effectively than HMMs. This effect was amplified in the three-way interaction between condition, distractor presence, and group ($F_{1,40} = 6.16$, $p = 0.017$): for LMMs there was a larger RT cost for having a distractor present in the *sometimes* condition when the distractor could be the target than in the *never* condition when it could safely be ignored. This pattern did not hold for HMMs, who showed no difference in distractor presence cost between conditions, indicating that HMMs did not treat distractors differently between conditions. No other interactions approached significance (all ps > 0.1).[(1)]

Examination of figures 2b and 2c suggests an alternative explanation of the group difference: given the overall good performance of HMMs, perhaps LMMs actually have more attentional capture by color singleton distractors in the *sometimes* condition and this deficit drives the primary interaction, rather than lack of filtering by HMMs in the *never* condition. In order to address this, we removed the overall group differences in response speed by converting raw RTs to z-scores. z-Scores were computed for each trial using the RT distribution of all correct trials for each participant, thus allowing for more exact relative comparisons between conditions (Faust et al 1999). In this framework, it becomes clear that the group difference observed when a color singleton distractor was present was because LMMs were both relatively faster than HMMs in the *never* block (−0.069 versus −0.027, respectively) and relatively slower than HMMs in the *sometimes* block (0.126 versus 0.064). While neither of these pairwise comparisons was significant ($p = 0.150$ for both), the overall interaction remained significant ($F_{1,40} = 5.69$, $p = 0.022$). This suggests that LMMs modulated their performance between conditions more so than HMMs and were thus more captured by color singletons in the *sometimes* condition and less captured by them in the *never* condition.

[(1)] To ensure our effects were not an artifact of inclusion criteria for HMM and LMM groups (upper and lower quartiles, respectively) the same ANOVA on RTs was re-run using groups defined by the numeric MMI cutoffs used in Ophir et al (2009), based on ±1 SD within their sample. This was a more conservative threshold than the quartile cutoffs in the present sample, and thus all participants in these groups were also part of the respective quartile-defined groups. This more selective HMM group ($N = 17$; 10 females) had MMI scores above 5.90 and the new LMM group ($N = 17$; 8 females) had MMI scores below 2.26. Despite reduced statistical power with smaller group sizes, all significant effects in the main analysis remained significant (all ps < 0.05).

3.2 *Additional analyses: Color singleton targets*

The main analysis excluded trials where the target was a color singleton and the subsequent trial, as they were only present in the *sometimes* condition and were previously shown to produce somewhat different behavior than other trials (Costello et al 2010). Nevertheless, these trials revealed interesting group differences between HMMs and LMMs. Overall, HMMs responded more quickly than LMMs, so to better analyze the relative patterns of responses in the trials surrounding color singleton targets we examined z-transformed RTs, as described above. z-Transformed RTs for color singleton target trials and the two subsequent trials were submitted to a 3×2 repeated-measures ANOVA with trial position relative to the color singleton target as a within-subject variable and group (HMM or LMM) as a between-subjects variable. There was a significant main effect of trial position ($F_{2,80} = 8.99$, $p < 0.001$) and a significant interaction between trial position and group ($F_{2,80} = 3.81$, $p = 0.026$). Due to the z-transforming procedure, there was not a significant main effect of group ($F_{1,40} = 0.08$, $p = -0.784$).

As can be seen in figure 3, while both groups were slowed on trials with color singleton targets and the subsequent trial compared to baseline, the interaction between trial position and group is clear. LMMs were slower to respond when the target happened to be the color singleton and this slowing carried over to the subsequent trial. In general, if the color singleton status of an object is not task-relevant, it should be inspected no earlier or later than any other object in a search array (Prinzmetal and Taylor 2006); however, this slowed response to color singleton targets (also observed previously in both younger and older adults—Costello et al 2010) may reflect LMMs carrying task information over from the *never* condition and filtering out the color singleton unnecessarily. HMMs showed a very different pattern wherein they were relatively less affected when the target was also a color singleton and were slowest on the subsequent trial. This suggests that HMMs were not ignoring color singletons and were processing them as they would any other stimulus. While not ignoring color singletons was detrimental to performance in the *never* condition, it preserved performance in the *sometimes* condition when a color singleton was the target. For both HMMs and LMMs, slowing on the subsequent trial was driven by slowing on distractor-present trials, with distractor-absent trials returning to baseline (HMMs: 0.539 versus −0.055, $t_{20} = 6.50$, $p < 0.001$; LMMs: 0.372 versus −0.113, $t_{20} = 4.89$, $p < 0.001$). This suggests that both groups—but perhaps especially HMMs—are likely primed by the color singleton target and are therefore strongly captured by the singleton distractor on the subsequent trial (eg Maljkovic and Nakayama 1994; Pinto et al 2005).

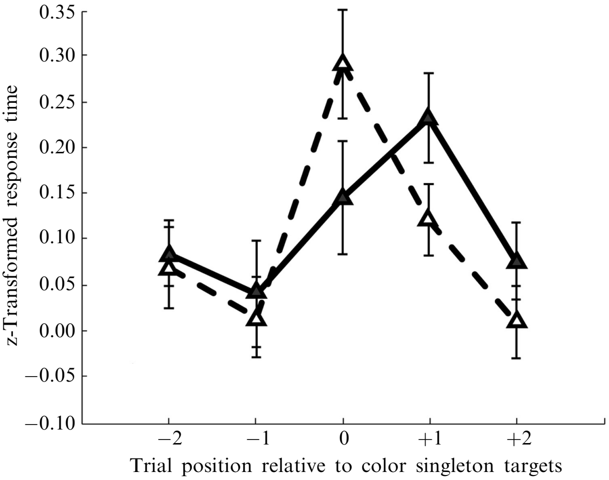

Figure 3. Response times for trials centered around those trials in which the color singleton was also the target-shape singleton. Position zero is when the target is also the color singleton; negatively numbered trials preceded these trials and positively numbered trials followed.

3.3 *Additional analyses: Video game players*

Our main focus in the current study is on the effects of media multitasking, but we wanted to ascertain whether the above effects are unique to HMMs or if other groups with extreme media consumption patterns might be similarly affected. One group with extensive experience in an immersive audiovisual medium is action-video game players. Recent research has revealed that action-video game players may have improved perceptual and attentional abilities (eg Donohue et al 2010; Dye et al 2009; Green and Bavelier 2003), including being less prone to exogenous attention capture by an irrelevant color singleton (Chisholm et al 2010). Further, video game players may also outperform non-players through enhanced top–down strategy choices (Clark et al 2011). It is thus possible that variability in action-video game playing could also predict differences in the current singleton-detection task. We divided our original sample of eighty-five participants into new groups based on their video game expertise and experience. Video game players (VGPs; $N = 11$; 4 females) were defined as those who played first-person shooter and/or action-video games at least six hours per week for the prior six months. This group contained one member of the HMM group and five members of the LMM group from the main analysis. Non-video game players (nVGPs; $N = 33$; 24 females) were categorized as those who played less than one hour per week of first-person shooter and action-video games for the prior six months. This group contained eleven members of the HMM group and seven members of the LMM group. Group membership was lopsided, as groups were selected from the sample of participants who had already completed the experiment and no special recruiting efforts were made to enroll VGPs. While HMMs were slightly more likely to be nVGPs than VGPs, this tendency was not statistically significant ($\chi^2_4 = 1.08$, $p = 0.103$).

Response times for these participants were submitted to a $2 \times 2 \times 2 \times 2$ repeated-measures ANOVA with condition (*sometimes* or *never*) and color distractor presence (present or absent) as within-subject variables, and group (VGP or nVGP) and gender (male or female) as between-subjects variables (display size was not included as a factor because it did not interact with group in the main analysis). In line with the main analysis comparing HMMs and LMMs, there was a significant main effect of condition ($F_{1,40} = 18.12$, $p < 0.001$), with the *never* condition being faster than the *sometimes* condition; a significant main effect of distractor presence ($F_{1,40} = 87.46$, $p < 0.001$); and a marginal interaction between condition and distractor presence ($F_{1,40} = 4.00$, $p = 0.052$). No other effects or interactions approached significance (all ps > 0.1). Importantly, there was not a significant main effect of group, nor did group interact with any other factors, suggesting that both VGPs and nVGPs modulated their performance based on condition instructions and distractor presence to the same degree, unlike HMMs and LMMs.

Despite the lack of a main effect of gender, we performed an additional analysis with only male VGPs and nVGPs since many video game studies have focused solely on male participants (eg Donohue et al 2010; Green and Bavelier 2003), and since this produced more equivalent group sizes (seven VGP and nine nVGP). RTs were submitted to the above ANOVA, excluding the gender variable. There was a significant main effect of condition ($F_{1,14} = 7.13$, $p = 0.018$), a significant main effect of distractor presence ($F_{1,14} = 53.97$, $p < 0.001$), and a marginal main effect of group ($F_{1,14} = 3.37$, $p = 0.088$), suggesting that male VGPs were slightly faster overall than male nVGPs. However, no interactions with group were significant (all ps > 0.3), suggesting that male VGPs and nVGPs do not differ in any meaningful way on this task.

4 General discussion

An increasing amount of modern media consumption is performed simultaneously, and the long-term effects of such habitual engagement in media multitasking are only just starting to be explored. The current findings build upon the pioneering work of Ophir et al (2009), who showed that HMMs performed more poorly on tasks involving the filtering of irrelevant information. To add to this new literature, here we sought to focus on the role of attention by using a task that minimizes the reliance upon memory. We found that, whereas LMMs were able to use top–down instructions to improve their performance, HMMs attended to and processed the color singleton to the same degree whether or not it could have been the target. Previous differences were consistent with influences on either attention or memory processes, but the present experiment demonstrated that variations in attentional mechanisms are likely a strong contributor to HMMs' differential performance. Specifically, these results suggest that HMMs may have broader attentional filters than LMMs—a bias toward taking in more of the available visual information—which could impact both their laboratory performance and their daily lives.

4.1 *Implications beyond the laboratory*

4.1.1 *Causality.* One fundamental question that emerges in investigations of behaviorally defined groups such as media multitaskers, video game players, or athletes is that of causality: do underlying differences in cognitive abilities encourage participation in certain activities, or does repeated engagement in these behaviors lead to cognitive changes? The current data do not speak to causality, but it is intriguing to consider two contrasting causal explanations. One possibility is that those who have more difficulty filtering out irrelevant information may find themselves distracted more easily, often attending to information unrelated to their goals. As a somewhat counterintuitive result, those who are easily distracted may choose to surround themselves with media. The logic is that those with broader attentional filters may assume that they will be distracted from their primary task regardless of the circumstances (eg by the conversation and background music at a café or the incidental noises of appliances, neighbors, and outside traffic in an otherwise quiet apartment), and thus may ensure that the distractions they fall prey to are ones that they enjoy (eg listening to familiar music on headphones or putting on a favorite TV show). Thus, rather than being unintentionally distracted, they become intentional media multitaskers.

A converse causal possibility is that consistent practice with consuming multiple media has led to a broadening of HMMs' attentional filters (Lin 2009). That is, HMMs and LMMs may have started out with similar attentional profiles, but HMMs began consuming multiple media simultaneously for unrelated reasons. HMMs then might have learned to juggle these media more effectively by processing each of them in turn and not automatically filtering any one medium, thus leading to unnecessary distractor processing in laboratory experiments. This sort of learning could lead to a feedback loop in which HMMs are even more inclined to consume multiple media simultaneously as they become more facile at doing so.

4.1.2 *Employee selection and assessment.* Many jobs, and duties within jobs, require extreme focus and resistance to distraction, such as airport baggage screening. Conversely, other job duties may require monitoring multiple information sources, such as video surveillance. Assessing media multitasking behaviors may be a cost-effective and time-effective way to evaluate such job-related attentional abilities. Of course, media multitasking as measured by the MMI cannot serve as a solitary predictor of performance, but it could potentially be highly beneficial when used in combination with other measures. The MMI is a relatively new assessment tool, but it already serves as a compelling example of how the laboratory study of real-world behaviors can provide insight for both academia and for broad societal issues.

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