AMERICAN PSYCHOLOGICAL ASSOCIATION

Psychology and Aging

ISSN: 0882-7974

2020, Vol. 35, No. 5, 605–613
http://dx.doi.org/10.1037/pag0000564

Aging and Inhibition: Introduction to the Special Issue

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Inhibitory theory suggests that a major determinant of individual differences in cognitive performance (including differences that are typically observed with increasing age) is the ability to dampen down goal-irrelevant stimuli, thoughts, and actions. While this theory has garnered a lot of support over the years, it has also seen several challenges. This special issue of *Psychology and Aging* entitled "Aging and Inhibition: The View Ahead" continues with this theme and includes 14 articles by top researchers in the field of cognitive aging. While most of the articles included here lend support to the theory, some challenge it or provide limiting conditions. We organize our overview of these articles according to the different functions, or stages, of inhibition, which we refer to as *access*, *deletion*, and *restraint*, followed by a discussion of potential moderators, including practice, motivation, and arousal. In our view, these articles contribute to our understanding of how and when age differences in inhibitory control are observed and the wider implications (both positive and negative) for cognition.

Keywords: aging, inhibition, attention, memory, distraction

Research on aging and cognition typically reports differences that favor young adults. This is particularly the case for work on attention (executive function/cognitive control) and most forms of (at least intentional) memory. Given this, findings of spared and even improved cognition by older adults (e.g., in emotion regulation, wisdom, semantic memory, general knowledge, language comprehension, priming, implicit memory) are puzzling. One of the primary questions in cognitive aging research is whether these aspects of mental life are all to be treated individually or whether there is a common mechanism underlying the patterns of impaired and spared cognition. If the latter, is this mechanism unique to aging or does it vary across age and among individuals?

At the time of its introduction, inhibitory theory (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999) was proposed as an alternative to popular capacity and resource-based explanations of individual and group differences in cognition. These latter views suggested that the ability to activate and maintain task-related information was the determining factor for cognitive performance. By contrast, inhibitory theory assumed that familiar stimuli in the environment automatically activate their associated memory representations and that this (automatic) process is relatively invariant between individuals and across the life span (Hasher & Zacks, 1979). Instead, the major limiting factor in cognitive performance was the ability to control and actively suppress excessive activation so that thought and action can be guided toward goal-relevant information and action (Hasher & Zacks, 1988). It is this inhibitory process that is thought to vary across individuals and, on average, to be reduced in older adults, with widely studied consequences that include costs to performance as well as some surprising advantages (Amer, Campbell, & Hasher, 2016; Weeks & Hasher, 2014). These ideas were not tied to any particular task but instead focused on tasks that addressed the flow of information across time from initial exposure to subsequent use whether intentional or unintentional. The theory stimulated research across cognitive domains, across groups of people, and within individuals, using a wide range of tasks, initially behavioral and now including neuroscience methods. It is worth noting that inhibition also plays an important role in other theoretical frameworks, including those focused on child development and disorders such as attention-deficit/hyperactivity disorder (Nigg, 2000), educational psychology (Dempster & Corkill, 1999), episodic memory (M. C. Anderson & Spellman, 1995), and different types of executive function (Friedman & Miyake, 2004). The concept of inhibition has a long history in both physiology and behavior from at least the 19th century on (see Smith, 1992).

Inhibition is thought to be especially important at three points in the flow of information from exposure to use (Hasher et al., 1999; see Kramer, Humphrey, Larish, & Logan, 1994 for an alternative taxonomy). The *access* function serves as a gatekeeper for the

Editor's Note. This is an introduction to the special issue "Aging and Inhibition: The View Ahead." Please see the Table of Contents here: http://psycnet.apa.org/journals/pag/35/5/.—EALS-M

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focus of attention, limiting it to those mental representations that are relevant to current goals. It is this function that enables cognition to be efficient in the face of distraction (e.g., Lustig, Hasher, & Tonev, 2006; May, 1999). The *deletion* function is responsible for clearing the mental workspace to focus only on current concerns by suppressing mental representations that were never relevant in the first instance as well as those that became irrelevant as goals, tasks, and topics changed (e.g., Lustig, May, & Hasher, 2001; Radvansky & Copeland, 2006). Deletion (which has also been referred to as "disengagement" and working memory "updating"; Miyake et al., 2000; Talbot, Ksander, & Gutchess, 2018) also plays a role in successive tasks such as in multiple list recall, in reading comprehension, and in prospective and retrospective memory tasks (Campbell, Trelle, & Hasher, 2014; Hamm & Hasher, 1992; Scullin, Bugg, McDaniel, & Einstein, 2011). Finally, the *restraint* function allows for selection among competing responses by suppressing prepotent (or relatively automatic) responses in both thought and action (e.g., Spieler, Balota, & Faust, 1996; Williams, Ponesse, Schachar, Logan, & Tannock, 1999). Restraint is also engaged at retrieval whenever a cue triggers more than one possible response and selection is required to produce the correct one (e.g., Healey, Campbell, Hasher, & Ossher, 2010; Healey, Ngo, & Hasher, 2014; Ikier, Yang, & Hasher, 2008).

Although not a perfect fit, we use this tripartite framework of inhibitory theory to help organize our overview of the articles in this special issue. We note that inhibitory theory is not without its critics. Some have questioned whether inhibition is a useful explanatory construct at all (e.g., Burke & College, 1997; MacLeod, 2007) and others whether older adults actually show inhibitory deficits or whether such deficits (if they do exist) can explain age differences in performance on a range of measures (e.g., Verhaeghen, 2011). Indeed, the present collection of articles includes some that challenge inhibitory theory as well as its findings (see especially Nicosia & Balota, 2020). Others report moderating factors (e.g., practice, Wilkinson & Yang, 2020; motivation, Swirsky & Spaniol, 2020; arousal, Gallant, Durbin, & Mather, 2020) or extensions to new domains and connections to other theoretical frameworks in contemporary cognition (e.g., proactive vs. reactive control; Braver, 2012; Higgins, Johnson, & Johnson, 2020) as well as to other literatures (especially neuroscience; Allen, Hellerstedt, Sharma, & Bergström, 2020). We believe these articles provide new insights into the functions and mechanisms of inhibition and how (and possibly when) they differ between younger and older adults.

Access

Several articles in this issue relate to the access function of inhibition, or the suppression of information before (or immediately after) it enters the focus of attention. One of the main assertions of the inhibitory framework, based on early work by Rabbitt (1965), among others, was that age differences in performance (e.g., in speed of processing) are caused by a decreased ability to ignore concurrent but irrelevant information. This assertion was based originally on behavioral studies (e.g., Connelly, Hasher, & Zacks, 1991) and is now buttressed by work using neuroimaging techniques. For instance, a number of studies have shown that relative to younger adults, older adults are less able to ignore completely irrelevant distraction in both visual and auditory perceptual brain regions responsible for processing those stimuli (e.g., Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Jost, Bryck, Vogel, & Mayr, 2011; McNab et al., 2015; Stevens, Hasher, Chiew, & Grady, 2008).

Distractor interference is reported in a study by Zanesco, Witkin, Morrison, Denkova, and Jha (2020). Using a very large (N = 505) life span sample, they reported that the ability to overcome distractor interference increases from adolescence to young adulthood, followed by a steady decline with age, an effect that is exacerbated by high memory load. Among other important findings, they reported that the type of distraction matters in that confusable stimuli from the same perceptual category (e.g., faces when the target stimulus is a face) are more disruptive than stimuli from another category (e.g., shoes; Wickens, 1970; see Oberauer & Kliegl, 2006 for an example of a mathematical model describing the idea of interference-causing similarity in terms of feature overlap). They also examined the effects of previous-trial demands on current-trial performance and found that the ability to increase effort in response to prior high demands was relatively maintained throughout the life span, but older adults showed a deficit in dynamically adjusting control in response to high-interference trials. This indicates that deficits in the access-control function of inhibition not only increase the functional memory load for older adults but also impact the discrimination of target and nontarget items at the point of retrieval.

Another study in this issue (Maillet, Yu, Hasher, & Grady, 2020), considered the source of the distraction: the external (visual) or internal (mind-wandering) worlds. Their results confirm that older adults are more prone to visual distraction than younger adults, but they, like others, report fewer instances of internal distraction (i.e., mind wandering). The age-related reduction in mind wandering seems counterintuitive but is a longstanding and frequently replicated finding dating back at least to Giambra (1989). Maillet et al. (2020) discussed potential reasons for the dissociation between age differences in visual distraction and mind wandering, including age differences in affect, motivation, and task-related interference (i.e., worrying about how one is doing on the task instead of just doing the task; Frank, Nara, Zavagnin, Touron, & Kane, 2015; McVay, Meier, Touron, & Kane, 2013). Also, older adults' greater motivation may make them less likely to report instances of mind wandering, which highlights one of the main shortcomings of mind-wandering research in general: heavy reliance on introspection and self-report (Murray, Krasich, Schooler, & Seli, 2020).

Though imperfect, neuroimaging can provide at least some insights into those processes otherwise measured by introspection—though even with such methods, what one sees and what one concludes are heavily dependent on what one measures. As reported here, Allen et al. (2020) used electroencephalography (EEG) and event-related potentials (ERP) to demonstrate converging and diverging neurocognitive pathways for young and older adults in the biasing effects of prior distraction on recognition memory. Although previous work showed that older adults' recognition judgments about a target stimulus are more influenced than are young adults' by the familiarity of concurrently presented distractors (B. A. Anderson, Jacoby, Thomas, & Balota, 2011; Craik & Schloerscheidt, 2011; Gutchess et al., 2007; Lindenberger & Mayr, 2014), they found no age difference in this "memory Stroop effect" and also found age equivalence in EEG oscillatory patterns related to intentional and unintentional recognition. These results appear to contradict the inhibitory deficit hypothesis, though they noted that their use of highly salient distractors compared to prior studies (pictures vs. line drawings) may have been difficult even for young adults to ignore, especially as testing was done under divided attention. In contrast to the behavioral and EEG results, the ERP patterns for young and older adults were quite different, suggesting age differences in the processing of targets and distractors and possibly compensation by the older adult group.

Deletion

While the access function of inhibition controls what enters the focus of attention, the deletion function clears the mental workspace both of information that was never relevant but that escaped access control and of information that has become irrelevant due to a change in context or goals. Five articles here relate to how deletion (or the lack thereof) of previous information influences downstream processing.

Carpenter, Chae, and Yoon (2020) tested the delayed effect of no-longer-relevant information on two creativity tasks (generating ideas for recipes and a classic, alternative uses task). Relative to a control condition, exposure to relevant distraction gave a larger boost to creative responses in older adults than in young adults (see also Kim, Hasher, & Zacks, 2007), despite the relatively brief time allotted for idea generation. Similar differential age-related utilization of nonrelevant information in subsequent tasks has been shown several times, with studies showing both a cost and a benefit from these carryover effects (e.g., Amer, Anderson, & Hasher, 2018; Biss, Campbell, & Hasher, 2013; Campbell, Hasher, & Thomas, 2010; Rowe, Hasher, & Turcotte, 2010). These lab-based scenarios may seem contrived, with the distractors on one task serving as solutions (or interfering items) on the next, but given regularity and redundancy in the environment, such findings are likely to play out in the real world as well as in the lab. Of course, in order to benefit (or suffer interference) from previous distraction, one must also maintain access to that information over time—a failure of the deletion function.

In contrast to this work, Nicosia and Balota (2020) report age-equivalent (and above baseline) memory for previously distracting words on three tasks: recognition, visual priming, and a test of general knowledge. These findings suggest that there are at least some circumstances in which young adults encode distracting words, sustain access to them, and then use them in new circumstances. The differences between these findings and others (e.g., time of testing, number and type of trials on the encoding task) remains to be seen, but as mentioned at the start of this review, all individuals vary in their inhibitory control, and certain conditions have been shown to decrease control even in the young (further discussed in the final section of this overview).

Two other articles reported carryover effects from information in one task to a subsequent task. The first of these (Katsumi et al., 2020) actually showed a cost to young adults of efficient suppression. Katsumi and colleagues used functional MRI to examine age differences in the neural and behavioral consequences of implicitly versus explicitly cued emotion regulation goals in the face of negative and neutral images. Both groups showed similar activation patterns when regulating their emotions, but subsequent memory analyses (contrasting activity for remembered vs. forgotten images) showed that young adults alone exhibited reduced hippocampal activity and decreased hippocampus-PFC functional connectivity when suppressing their emotions. While older adults may have been able to control their emotional response to emotional stimuli in the short term, this did not translate to long-term memory suppression, which was seen in younger adults' reduced recognition of negative compared to neutral images. The imaging data suggest that the neural differences are tied to top-down modulation of encoding-related activity in the medial temporal lobes in younger but not older adults (for a review, see M. C. Anderson, Bunce, & Barbas, 2016).

Another consequence of the failure to delete previously attended information is the buildup of proactive interference (by which old learning interferes with new learning), which are already known to contribute to greater impairments in older than younger adults and have been seen in both working and long-term memory (Ikier et al., 2008; Lustig et al., 2001; May, Hasher, & Kane, 1999). Failed suppression is also thought to contribute to retroactive interference (when new learning interferes with old) because deletion is required to suppress the original task information. Although older adults are typically more vulnerable to both types of interference, their deleterious effects can be minimized by encoding that integrates across lists or events to create a single, more complex memory representation that can be retrieved in its entirety, reducing the need for suppression at retrieval (Myers, O'Brien, Balota, & Toyofuku, 1984; Radvansky & Zacks, 1991). One way to form these integrated representations is by consciously noticing a connection between overlapping stimuli at encoding (Wahlheim & Jacoby, 2013). For instance, during A-B, A-C paired associate learning, one could form an integrated representation by noticing that *house-shoe* in List 2 contains the same stimulus term as *house-rabbit* in List 1 (the overlapping stimulus term *house* serves as a reminder). However, these reminders are likely only useful if one can accurately retrieve the to-be-integrated information.

The study by Garlitch and Wahlheim (2020) used an A-B, A-C paradigm and encouraged integrative encoding by alerting participants that noticing a change in pairs moving from List 1 to List 2 would help on the final memory test. They found that integrative encoding is beneficial to both age groups in that noticing a change during List 2 learning was associated with retroactive facilitation of List 1 recall, whereas failing to notice a change was associated with retroactive interference. Younger adults derived greater benefit from remindings because they were better able to retrieve the List 1 response during List 2 encoding (not just notice the change) and retrieve both responses (B and C) during final recall.

In cases where participants are not explicitly instructed to remember, older adults seem to show greater sustained access to previously attended information (e.g., Kahana, Howard, Zaromb, & Wingfield, 2002; Scullin et al., 2011). This leads to the question of how older adults maintain such high functioning in everyday life (e.g., James, Burke, Austin, & Hulme, 1998) in the face of interference caused by poor suppression. On the flip side (not actually considered here), how do young adults regain access to a suppressed past? The issue for older adults is addressed here in a study that evaluated the time course of engaging suppression (Higgins et al., 2020). This work joins with other findings (e.g., Gazzaley et al., 2008; Jost et al., 2011; Schwarzkopp, Mayr, & Jost, 2016; Weeks, Grady, Hasher, & Buchsbaum, 2020) to suggest that deletion occurs but is delayed in older adults. They presented younger and older adults with two words, followed by a cue to refresh (i.e., think of) one of the words again. After a delay of either 100 or 500 ms, reaction times were recorded as participants read aloud the just-refreshed word, the nonrefreshed word, or a new word. They found that young adults were slower to read refreshed than nonrefreshed words at the short, but not the long, delay (suggesting that refreshing causes a temporary suppression effect), whereas older adults only showed this suppression effect at the long delay. This finding of delayed suppression in the older group is quite similar to work showing that inhibition of return (i.e., slower responding to targets that appear at previously cued locations; Posner, Rafal, Choate, & Vaughan, 1985) is delayed in older adults (Castel, Chasteen, Scialfa, & Pratt, 2003). Thus, older adults may be able to suppress previously attended information or locations but will take longer to do so. We note, on the downside, that delayed suppression leads information to be maintained in the mind for longer and so may well cause greater disruption to ongoing processing (especially on time-sensitive tasks) and allow for greater interference (or facilitation) from that distraction.

Restraint

The restraint function of inhibition serves to control competing responses (both physical and mental) in order to enable selection of a goal-relevant response. Restraint is needed to withhold a response, for example, to infrequent no-go trials on the go/no-go task and to override automatic word reading on the Stroop task. Three articles here speak directly to this phase of inhibition.

In a recent meta-analysis, Rey-Mermet and Gade (2018) found reliable age-related impairments on tasks requiring motor inhibition (i.e., the go/no-go and stop-signal tasks), while age differences were not consistently observed on tasks such as the flanker and color Stroop (but see Nicosia & Balota, 2020). However, even when behavioral differences in motor control are not observed, there may be differences in underlying neural activity, reflecting compensation or the recruitment of alternative systems in older adults to achieve the same level of control (e.g., Tsvetanov et al., 2018). For instance, in the study by Kardos, Kóbor, and Molnár (2020), older adults made fewer commission errors on the go/no-go task than younger adults, but this was coupled with slower responding, suggesting a speed-accuracy trade-off. Using ERPs, Kardos et al. (2020) also reported that at a neural level, younger and older adults' responses were similar at an early time marker (N2, with a higher amplitude for no-go than go trials), but age differences emerged later in the critical P3 window. Only young adults showed modulation of the P3 (a component associated with response evaluation). These findings fit with others showing that older adults prioritize accuracy over speed (Salthouse, 1979; Starns & Ratcliff, 2010) and rely more on late-stage, reactive control (Braver, 2012), which may sometimes allow them to overcome inhibitory deficits when given enough time to enact action (e.g., Higgins et al., 2020).

The Erb, Touron, and Marcovitch (2020) study also suggests that older adults take more time to resolve response conflict. In this study, older and younger adults completed a flanker task that required responding to left and right markers at the top of a touchscreen while movement initiation time and the trajectory of their arm movements to the screen were recorded. They reported that older adults took longer to initiate their arm movements but not to complete arm movements. Slower initiation time might allow for better selection between competing responses, as seen in the context of eye-movement trajectories (Campbell, Al-Aidroos, Fatt, Pratt, & Hasher, 2010; Campbell, Al-Aidroos, Pratt, & Hasher, 2009). In those studies, older and younger adults moved their eyes from a central fixation point toward a peripheral target either in the presence or not of a nearby distractor. Young adults' eye movements tended to curve away from the distractor en route to the target. Older adults, in contrast, showed curvature toward the distractor, an effect that was reduced when they took longer to initiate an eye movement, suggesting that the controlled selection process can be improved if the "brakes" are applied for longer.

Erb et al. (2020) also addressed recent debates about age differences in the congruency sequence effect (CSE), or a decrease in interference from incongruent stimuli (e.g., on a flanker or Stroop task) following an incongruent trial relative to a congruent trial (e.g., Aisenberg, Sapir, d'Avossa, & Henik, 2014; Aschenbrenner & Balota, 2015; Puccioni & Vallesi, 2012; see also Zanesco et al., 2020). They noted—and we agree—that the nature of the CSE itself remains controversial, and it appears to be quite sensitive to differences across tasks, although the exact parameters that matter remain unclear. These issues are highlighted by Rey-Mermet and Gade (2020) in this issue, who found that the presence of the CSE in young adults and/or age differences in the CSE vary widely across tasks. They noted that if the CSE is taken as a measure of dynamic adjustments of control, this challenges the idea of an age-related decline in such control—but on the other hand, their disparate findings across tasks also challenge the validity of the CSE as a measure. One more promising aspect of their results is that there is some consistency in findings with different types of tasks (e.g., flanker vs. Stroop), suggesting that careful consideration of where and how inhibition plays a role may ultimately help clarify these issues both for the CSE itself and age differences (or not) therein.

Moderating Factors

Giving older adults more time to deal with distraction either presented concurrently or from the past can improve their performance, consistent with the suggestion that inhibitory regulation is delayed in older adults (e.g., Higgins et al., 2020). Three articles in this special issue address other potential moderators, including practice, motivation, and arousal. We note an additional one in the next section.

With respect to practice, most experiments only include a short practice block before participants are launched into the experiment proper, typically performing a task they have never seen before. Is it thus perhaps unsurprising that older adults, who often have less experience with computers (much less laboratory settings if they are naïve to experiments), do worse than younger adults. Previous work has shown that practice and training can improve older adults' inhibitory control, at least on the task being trained (e.g., Davidson, Zacks, & Williams, 2003; Sandberg, Rönnlund, Nyberg, & Stigsdotter Neely, 2014), though the long-term maintenance of these effects is rarely tested beyond a few months. This is the question addressed by Wilkinson and Yang (2020) in this issue, who retested participants from their multiple task inhibition practice study (Wilkinson & Yang, 2016) after a 3.5-year interval.

In the original training protocol, participants in the training group completed six 30-min training sessions (three times per week), during which they practiced three tasks (local-global, n-back, and go/no-go). Relative to the no-contact control group, the training group retained their practice benefits on both the n-back and go/no-go tasks, as well as near transfer effects to similar tasks with different materials, suggesting that practice effects can be quite long lasting in older adults.

While durable gains are surely a good thing, this finding should also give pause to those of us who repeatedly test the same pool of older adult volunteers. Experienced participants will undoubtedly behave differently from naïve ones. The Wilkinson and Yang (2020) study shows benefits of practice; other work has shown costs, and these are known to be substantial for explicit memory, as seen in short-term memory, working memory, and long-term memory (e.g., Keppel & Underwood, 1962; Lustig & Hasher, 2002; Underwood, 1957). An earlier study by Ji, Wang, Chen, Du, and Zhan (2016) suggested that of the three functions of inhibition, deletion may be most sensitive to training.

In addition to more practice with a task, greater motivation can also improve inhibitory control. Older adults tend to be more motivated than younger adults overall when it comes to laboratory tasks (e.g., Frank et al., 2015; Jackson & Balota, 2012), but motivation also can be manipulated on a trial-by-trial or item-by-item basis using incentives. Both younger and older adults show improved attention and memory for stimuli presented on trials associated with monetary reward (for a recent review, see Swirsky & Spaniol, 2019), suggesting that motivation, like practice, can improve inhibitory control in older adults. In this issue, Swirsky and Spaniol (2020) address whether this effect extends to hyper-binding (the automatic association formed at least by older adults between simultaneously occurring targets and distractors; Campbell et al., 2010; Davis, Foy, Giovanello, & Campbell, 2020). They provided performance incentives during a one-back task on faces superimposed with distracting names. Memory for the irrelevant face-name pairs was later tested, and older adults in the no-incentive control condition showed the typical hyper-binding pattern of better memory for intact versus rearranged pairs, while those in the motivated condition showed no evidence of hyper-binding. Young adults, on the other hand, did not show either hyper-binding or an effect of motivation. These findings suggest that increased motivation can improve attentional control and eliminate the hyper-binding effect (thought to be a failure of the access function) in older adults.

A final note on motivation is warranted: The goals, values, and social contexts of older adults (e.g., Carstensen, Isaacowitz, & Charles, 1999; Hess, 2014; Mayr & Freund, 2020) differ from those of young adults, as work showing the importance of accuracy rather than speed (Salthouse, 1979; Starns & Ratcliff, 2010) has made clear. Materials that matter to older adults (e.g., the location of safe vs. unsafe food or medicines) result in associative memory performance that is at least as good as that of young adults' (Rahhal, May, & Hasher, 2002). Thus, age differences in inhibitory control may also be minimized when the materials (particularly the target information) matter to older adults—a possibility that warrants further research.

A final study here reported one moderating factor that appears to improve inhibitory control in young, but not older, adults: arousal. Several studies have shown that increased arousal improves selective attention in younger adults (for a review, see Mather, Clewett, Sakaki, & Harley, 2016), but this may not be the case for older adults. For instance, a recent functional MRI study showed that while arousal enhances selectivity in young adults (increasing activation to relevant stimuli and decreasing activation to irrelevant stimuli), it disrupts selectivity in older adults, leading to increased processing of both relevant and irrelevant information (Lee et al., 2018). As reported in this special issue, Gallant et al. (2020) tested the effects of arousing distraction (using taboo words) on concurrent one-back performance, as well as subsequent memory for that distraction in younger and older adults. Older adults' responses on the one-back task were more affected by distracting taboo words relative to younger adults, and older adults also remembered more distracting words on a subsequent recognition memory test (see also Gazzaley et al., 2005). Young adults, by contrast, showed a memory suppression effect for neutral distractors that preceded taboo distractors on the one-back task, suggesting that increased arousal improved inhibition of recently encountered irrelevant information. Unfortunately, arousal does not seem to improve selective attention in older adults—if anything, it does quite the opposite. In this last section, we consider some additional moderating factors that may be critical in understanding when inhibition and associated age differences occur versus when they do not.

Conclusion

The preponderance of behavioral and neuroscience evidence reported here and elsewhere in the literature (e.g., Gazzaley et al., 2005; Healey et al., 2014; Sawaki & Luck, 2013) supports the existence of inhibition. Evidence is also consistent with the existence of age differences in inhibitory regulation. Nonetheless, there is clearly variability in findings, and we suggest the sources are likely located in moderating factors (see also discussion sections in Maillet et al., 2020 and Nicosia & Balota, 2020). Several have already been discussed, including motivation, practice, and arousal. One factor not empirically considered in this group of articles appears to be a critical determinant of inhibitory efficiency in general and in older adults in particular: time of testing (or synchrony).

There are large age differences in circadian arousal patterns across the day, with older adults tending toward being morning-type individuals, a relatively rare state for the young adults to whom they are compared (who tend to be neutral or evening types). The synchrony effect proposes that inhibitory regulation will be best at a time of day that matches one's chronotype (May & Hasher, 1998). An individual and age differences literature reports time of testing differences. With respect to inhibitory control and aging, off-peak testing times (e.g., in the afternoon for the majority of older adults) enable greater disruption from distraction (access), a bigger impact of no-longer-relevant information (deletion), and lesser control over strong responses (restraint; e.g., May, 1999; Ngo & Hasher, 2017; Rothen & Meier, 2016). There are also time-of-day effects seen in memory tasks with heavy inhibitory demands (e.g., Barner, Schmid, & Diekelmann, 2019; Maylor & Badham, 2018). Neural differences are also seen across the day, which are especially notable in older adults (e.g., J. A. E. Anderson et al., 2017; Karch et al., 2019; Song et al., 2018)—differences that include brain volume, connectivity patterns, neurotransmitters, as well as gene expression (e.g., Chen et al., 2016). It is possible that when participants are tested can play a major role in the observation of age effects.

In closing this overview, we note that inhibitory theory continues to be a productive area of research, and we are pleased to present the articles in this issue of *Psychology and Aging*, several of which touch upon next steps or "the view ahead." For instance, it remains unclear whether these cognitively separable inhibitory processes are also separable in the brain, each negatively affected by age, or share a common origin (e.g., Castiglione, Wagner, Anderson, & Aron, 2019) that itself is affected by age. We suspect that it is some combination of the two. Further, even when behavioral differences are minimal, older adults may arrive at equivalent performance via either quantitatively (e.g., greater recruitment of attentional control systems) or qualitatively (e.g., unique strategies) different neural pathways than younger adults, and this issue is touched upon by some of the articles in this special issue and deserves greater attention going forward. A better understanding of the neural underpinnings of inhibitory control may also help resolve another remaining issue, which is how older adults have greater memory for previously irrelevant information (e.g., Amer et al., 2018; Biss et al., 2013; cf. Nicosia & Balota, 2020) if they are simply delayed in the application of inhibition (Higgins et al., 2020). If older adults can suppress irrelevant information but at a delay, then why do they have greater access to that information on subsequent tasks? Is delayed suppression (or reactive control) not as effective as immediate suppression (or proactive control)? Even after a short delay, the "damage" may already be done in that information may already be encoded into long-term stores, but this issue requires further investigation. Finally, much of this special issue and, indeed, the literature is focused on the negative effects of reduced inhibitory control (cf. Carpenter et al., 2020). However, we have argued that reduced inhibitory control is like a double-edged sword (Amer et al., 2016) in that it produces both costs and benefits for those who experience it. We are only starting to understand the benefits, but it is clear from older adults' rich lives outside the lab that age-related declines in inhibitory control cannot be all bad.

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Received June 11, 2020
Revision received June 30, 2020
Accepted July 2, 2020 ■