Aging, circadian arousal patterns, and cognition 9

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In the past few decades, human chronobiology research has documented circadian rhythms in a variety of biological and physiological functions, including body temperature, heart rate, and hormone secretions, reflecting regular peaks and declines across the day (Horne & Ostberg, 1976, 1977; Hrushesky, 1994). Circadian rhythms exhibit pronounced effects on important aspects of everyday life, including health and medical treatment (e.g., Hrushesky, 1989, 1994; Smolensky & D'Alonzo, 1993), as well as the ability to adapt to shift work (e.g., Monk, 1986; Moore-Ede & McIntosh, 1993). While extensive research addressing general circadian patterns exists, a far smaller literature concerns the extent to which there are individual differences in these patterns and, in turn, differences in performance at different times of day (e.g., Bodenhausen, 1990; Colquhoun, 1971; Folkard, Knauth, Monk, & Rutenfranz, 1976; Folkard, Weaver, & Wildgruber, 1983). This work has shown that individual patterns of circadian arousal are indeed correlated with performance on a variety of tasks (e.g., efficiency in reacting to stimuli, performing simple arithmetic, engaging in cognitive activity) such that performance peaks at a certain level of circadian arousal, a peak that occurs more or less regularly at a specific point in the day.

Within the field of cognition, awareness of the individual variation in circadian arousal patterns has been quite limited until recently. A few studies have demonstrated that this individual difference variable can significantly alter cognitive performance across the day (e.g., Bodenhausen, 1990; Horne, Brass, & Pettitt, 1980; Petros, Beckwith, & Anderson, 1990). A study by May, Hasher, and Stoltzfus (1993) further found clear age-group differ-

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ences in circadian arousal patterns, with older adults tending strongly toward a morningness pattern and with college students tending strongly away from this pattern of arousal. They also reported dramatic differences in memory performance across the day (from early morning to late afternoon) for both younger and older adults. However, the patterns of performance differences across the day were quite different for younger and older adults. Here, we report findings that differences in cognitive performance across the day are associated with age-related differences in circadian arousal, and that younger adults get better as the day progresses while older adults get worse. This pattern obtains across a number of tasks, although, as will be seen, there also are some very intriguing exceptions.

Age differences in morningness-eveningness tendencies

Measure

To assess individual and group differences in circadian patterns, we and others have used the Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976). The MEQ is a simple paper-and-pencil test consisting of 19 questions that address such issues as sleep-wake habits, subjective assessment of intellectual and physical peak times, and appetite and alertness over the day. Scores on the questionnaire delineate three main types of individuals: morning types, evening types, and neither types. This delineation has been validated by demonstrations of reliable differences between morning and evening types on both physiological (e.g., body temperature, heart rate, skin conductance, amplitude of evoked brain potentials; e.g., Adan, 1991; Horne, Brass, & Pettitt, 1980; Horne & Ostberg, 1976; Kerkhof, van der Geest, Korving, & Rietveld, 1981) and psychological measures of behavior (e.g., personality traits, sleep-wake behaviors, perceived alertness; Buela-Casal, Caballo, & Cueto, 1990; Horne & Ostberg, 1976; Mecacci, Zani, Rocchetti, & Lucioli, 1986; Webb & Bonnet, 1978; Wilson, 1990). In addition, the MEQ has high test retest reliability (e.g., Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991; Kerkhof, 1984), and psychometric tests have indicated that it is a valid index of circadian rhythmicity (e.g., Smith, Reilly, & Midkiff, 1989).

Recent work on individual and group differences in morningness-eveningness tendencies has indicated a significant shift toward morningness with age (e.g., Adan & Almirall, 1990; Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; Kerkhof, 1985; May et al., 1993; Mecacci & Zani, 1983; Vitiello, Smallwood, Avery, & Pascualy, 1986). The shift appears to begin around age 50 (Ishihara, Miyake, Miyasita, & Miyata, 1991), and occurs cross-culturally, as similar patterns have been obtained in Italy (Mecacci et al., 1986), Spain (Adan & Almirall, 1990), England (Wilson, 1990), Japan (Ishihara et al., 1991), Canada (Yoon & Lee, 1998), and the

United States (May & Hasher, 1998). We have now administered the MEQ to over 1,500 college students (age 18 to 23) and over 600 older adults (age 60 to 75) in different regions of North America and, as can be seen in Figure 9.1, the norms show clear age differences in the pattern of peak times across the day. Roughly 40% of younger adults (all of whom were college students) showed eveningness tendencies, with a large proportion of neither types and less than 10% morning-types. By contrast, less than 3% of older adults showed eveningness tendencies, and the majority (~75%) were morning types. These findings indicate that younger and older adults differ markedly in their circadian peaks over the day and suggest that, for those cognitive functions influenced by circadian arousal patterns, performance of many younger adults will improve across the day, while that of most older adults will deteriorate as the day progresses.

Differences in intellectual and physical behavior

Accounting for individual differences in circadian arousal thus is critical in aging studies involving intellectual and physical behavior that varies across the day. One set of findings which suggests real differences in behavior across the day comes from a study that addressed media and shopping patterns of older adults, compared with those of younger adults, and found them to be different across time of day (Yoon, 1997). In this study, a questionnaire was administered to younger and older adults regarding when they tended to read newspapers and magazines, watch television, and go shopping. More than 80% of the older subjects indicated that they read newspapers early in the morning, while only 14% of younger subjects reported doing so early in the morning. Magazines, on the other hand, were

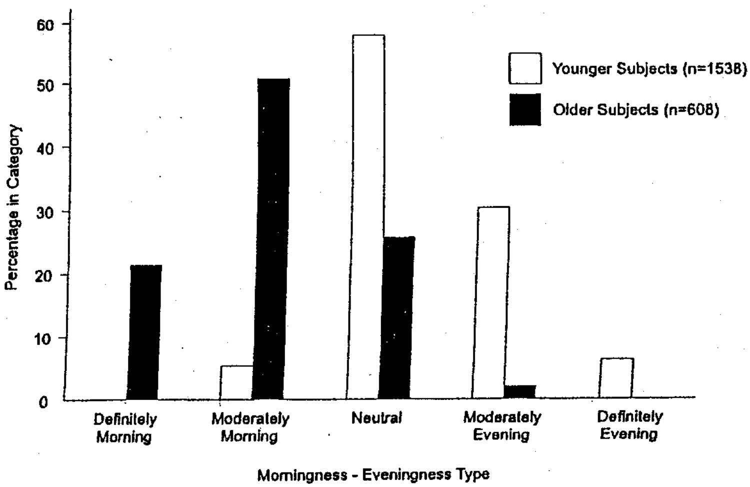

FIG. 9.1.
Time of day categories for older and younger adults.

read in the afternoon or evening by more than two thirds of both younger and older adults. About half of the older people indicated a clear preference for shopping in the morning or early afternoon, whereas younger people tended to do so in the late afternoon or evening. Older people's distinct preference to shop in the morning is consistent with their tendency to be mentally alert and energetic in the morning. They may reserve those hours to engage in tasks that pose a relatively greater cognitive or physical challenge.

Other studies have found intellectual and physical behavior to vary across age and time of day. One study found that prospective memory involving older adults' medication and appointment adherence was significantly greater in the morning than in the afternoon or evening (Leirer, Tanke, & Morrow, 1994). Another study conducted by Skinner (1985) with college students examined the relationship between grades and time of day when classes are held. The study involved a simple test comparing mean grades across morning, afternoon, and evening classes and found that grades in morning classes were significantly lower than those in afternoon and evening classes. Although these studies did not collect MEQ-type measures, they suggest real intellectual and behavioral differences across time of day that are quite consistent with circadian patterns reported elsewhere for these age groups (May et al., 1993; Yoon, 1997).

Changes in cognitive performance across the day

We have begun to explore the types of cognitive processes that are likely to be affected by the match between an individual's peak circadian arousal period and the time at which testing occurs, an influence referred to as the "synchrony effect" (May et al., 1993). Our goal is to identify those cognitive functions that demonstrate a synchrony effect as well as those that may be invariant over the day. To this end, our investigations have been guided by an inhibitory framework of attention and memory, positing that successful processing of information depends both on excitatory attentional mechanisms (Allport, 1989; Navon, 1989), which are responsible for the activation of relevant, goal oriented material, as well as on inhibitory mechanisms, which are responsible for the suppression of irrelevant, off-task information (Allport, 1989; Hasher, Zacks, & May, 1999; Navon, 1989). As discussed below, the bulk of data indicates that excitatory processing remains intact across optimal and nonoptimal times, but that inhibitory processing is impaired at individuals' off-peak times. The data also are consistent in confirming age-related impairments in inhibitory processes. We consider first the role of inhibition in information processing and then turn to the consequences of such inhibitory impairments for cognitive performance.

Inhibition

In taking an inhibitory view of attention and memory, we assume that, once familiar stimuli in the environment have established representations in memory, their reoccurrence will activate all linkages and associations to the existing representations, even though not all of them are necessarily relevant to the task at hand (Hasher & Zacks, 1988; Hasher et al., 1999). We further assume that among those representations that have received some degree of activation, conscious awareness is restricted to the most highly activated subset (cf., Cowan, 1988, 1993). This subset of representations is what we hereafter refer to as the *contents of working memory*. *Working memory* thus is assumed to be the contents of consciousness or ongoing mental workspace.

Inhibitory mechanisms are thought to be critical for three general functions, each of which is directed at controlling the contents of working memory so as to enable the efficient on-line processing and subsequent successful retrieval of target information (e.g., Hasher et al., 1999). First, inhibitory mechanisms prevent irrelevant, off-task information from entering working memory, thus limiting access to purely goal-relevant information. Inhibition also serves to delete or suppress from working memory information that is marginally relevant or that once was relevant but is no longer appropriate for current goals. Taken together, the access and deletion functions act to minimize competition from distracting material during both encoding and retrieval, thus increasing the likelihood that items activated concurrently in working memory are relevant to one another, and that target information will be successfully processed and retrieved. Finally, inhibition operates to restrain strong responses from being emitted before their appropriateness can be evaluated. The restraint function of inhibition thus allows for the appraisal and rejection of dominant responses when they are undesirable, so that a less probable, but more suitable, response can be produced.

There are both direct and indirect consequences of diminished inhibition. For example, individuals with impaired inhibitory functioning may be more susceptible to distracting, irrelevant information, whether that distraction is generated from external sources (e.g., speech from a radio or television that has been left on in the background) or internal sources (e.g., distracting thoughts about personal concerns or issues). In addition, the inability to clear away previously relevant, but currently inappropriate, information may lead to heightened interference between relevant and irrelevant information for poor inhibitors, resulting in difficulties in acquiring new material, comprehending questions, and retrieving stored memories. Poor inhibitors also may have difficulty disengaging from one line of thought or activity and switching to another, in addition to preventing the production of well-learned responses when those responses are inappropriate.

These direct impairments, produced by deficient inhibitory functioning, may lead to other, indirect cognitive consequences. Since control over working memory also ultimately reduces the efficiency of retrieval, diminished inhibition efficiency can further lead to an increased reliance on stereotypes, heuristics, or schemas in decision making, even in situations where detailed, analytical processing is clearly more appropriate (Bodenhausen, 1990; Yoon, 1997). For example, in social cognition studies involving perceptions of outgroup members' traits and behaviors, individuals are more likely to rely on stereotypic-based information, which often is negative, when responding at their nonoptimal compared to optimal time of day. This, in turn, may have implications for identifying important situations in which stereotyped groups may experience systematic disadvantages (e.g., personnel selection, law enforcement). Related to this is the possibility that inefficient inhibitors may be more susceptible to persuasion by weak arguments, particularly if those arguments contain material related to, but inconsequential for, the current topic (Rahhal, Abendroth, & Hasher, 1996; Yoon & Lee, 1998).

In the following sections, we first present direct evidence for on-line (i.e., current) failures of access, deletion, and restraint at off-peak times, failures that are attributed to deficient inhibition at nonoptimal times. We next discuss those tasks in which synchrony plays little or no role for either age group. We then present evidence for the subsequent downstream consequences of deficient inhibition at nonoptimal times. In each of the studies to be discussed, younger and older adults were tested at peak and off-peak times of day. All younger adults were evening types and all older adults were morning types, as assessed by the MEQ.[1]

Diminished inhibition at off-peak times

Access function of inhibition costs of distraction in problem solving. If individuals suffer inhibitory deficits at off-peak times, then distracting information should have a greater effect on their performance relative to participants tested at peak times. To test this prediction, we examined the impact of distraction on younger and older adults' ability to solve word problems at optimal and nonoptimal times of day (May, 1999). We used a modified version of the Remote Associates Test ([RAT]; Mednick, 1962), in which each problem consisted of three cue words (e.g., rat, blue, cottage) that all are remotely related to the same target word (e.g., cheese). The participants' task was to produce the target word that connected the three cue words. Our interest was in the effect of different types of distractors on individuals' ability to produce the targets by presenting distraction that led away from a solution versus distraction that led toward a solution.

Previous findings with this task indicated that target identification is impaired on the RAT when misleading distractors are placed next to each of the cue words (e.g., rat [cat], blue [red], cottage [cabin] = cheese; Smith & Blankenship, 1991). We expected that the cost of distraction would be greater for participants tested at off-peak relative to peak times, as they might be less able to suppress the irrelevant, misleading information. In addition, we explored the possibility that there might be situations in which the failure to suppress irrelevant information would be beneficial. To do so, we included a small proportion of test items in which the distractors presented with the cue trios were not misleading, but instead were "leading"; that is, they related the cues to the target (e.g., rat [eat], blue [dressing], cottage [diet] = cheese). Any benefits of distraction should be greater at nonoptimal times than at optimal times, when people have more control over distraction.

With all participants instructed to ignore distraction on all trials, we expected that, relative to individuals tested at optimal times, those tested at nonoptimal times would show greater deficits in solution production when misleading distractors were present, and greater benefit when leading distractors were present. The cost of misleading distractors and the benefit of leading distractors were calculated by subtracting the target identification rates for control trials (where no distraction was present) from the rates for misleading and leading trials, respectively. Table 9.1 shows the impact of distraction on problem solving for younger and older adults tested at peak and off-peak times of day. As expected, synchrony affected performance for both age groups, with those participants tested at off-peak times (i.e., younger adults tested in the morning and older adults tested in the evening) showing both greater costs of misleading distraction and greater benefits of leading distraction relative to age-mates tested at peak times. In addition, older adults generally showed a larger influence of distraction than younger adults, a finding consistent with an inhibitory-deficit model of aging (Hasher & Zacks, 1988).

Deletion function of inhibition: Sustained activation of no-longer-relevant material. In dynamic experiences, such as conversations, topics and locales change, and these shifts most often require that thought content also shifts. To simulate the need to stop thinking about one topic or idea and to start thinking about another, we assessed individuals' ability to suppress information that once was relevant, but is no longer suitable for current goals. To do this, May and Hasher (1998) used a garden path sentence completion task (Hartman & Hasher, 1991). In the first phase of this task, participants were presented with sentence frames that were missing highly predictable final words (e.g., "Before you go to bed, turn off the _____"), and

TABLE 9.1. Effect of distraction on problem solving for younger and older adults

Age and time	*Cost*	*Benefit*
Younger adults		
AM (nonpeak)	−11	17
PM (peak)	−2	1
Older adults		
AM (peak)	−10	8
PM (nonpeak)	−18	23

were asked to generate an ending for each frame (high-cloze sentences). Once participants generated an ending for a given frame (e.g., "lights" for the present example), a target word appeared, which participants were instructed to remember for a later, unspecified memory test. For half of the sentence frames (filler items), the participant-generated ending appeared; for the remaining sentence frames (critical items), the participant-generated ending was disconfirmed by the presence of a new, less probable, but nonetheless plausible, ending for the sentence (e.g., "stove"). Thus, for critical items, there was an implicit instruction to forget the generated ending (e.g., "lights"), as participants were informed that only the target endings (the ones presented by the experiment; e.g., "stove") would appear on the subsequent memory test.

Our aim was to determine, after a brief interval of 5 to 6 minutes, the accessibility of the target (e.g., "stove") and disconfirmed or no-longer-relevant (e.g., "lights") items from the critical sentence frames for younger and older participants who were tested at peak and off-peak times. On the premise that inhibition acts to delete from working memory those items that are no longer relevant for current goals, we expected efficient inhibitors (i.e., younger adults tested at peak times) to have access to target items only; disconfirmed items should be no more accessible than control items as a result of an active suppression operating to delete these items from working memory. By contrast, we expected inefficient inhibitors (i.e., older adults and those tested at asynchronous times) to have access to both target and disconfirmed items.

To assess these predictions, we used an indirect memory test, which enabled a comparison of production rates for target, disconfirmed, and control (i.e., words not presented in Phase 1) items. For this task, participants generated endings to sentence frames that had moderately predictable endings (medium cloze sentences) under the guise that they were helping create materials for a new experiment. Three types of frames were included: (a) frames that were moderately predictive of the target endings (e.g., "She remodeled her kitchen and replaced the old _____", for "stove"); (b) frames that were moderately predictive of the disconfirmed endings (e.g., "The baby was fascinated by the bright _____", for "lights"); and (c) frames that were moderately predictive of new, never-seen control endings (e.g., "The kitten slept peacefully on her owner's _____", for "lap"). We calculated priming scores for the target and disconfirmed endings by comparing completion rates for those items to the completion rate for control items[2]; positive priming indicates that the critical items were produced more often than control items, while negative priming indicates that the critical items were produced less often than control items. The priming data can be seen in Figure 9.2.

Consider first the pattern of priming for younger adults: at peak times, younger adults showed reliable priming of target endings and actually showed significant, below-baseline priming for the disconfirmed endings. These findings suggest that for younger adults at optimal times, the dele-

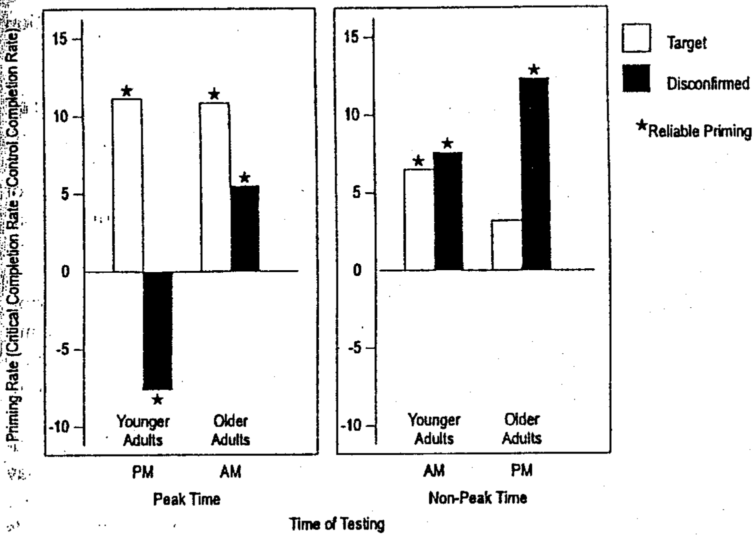

FIG. 9.2.
Priming for target and disconfirmed items for younger and older adults by time of testing.

tion function of inhibition is so efficient that the disconfirmed items actually are less accessible than items that were never presented. By contrast, younger adults tested at nonoptimal times showed positive priming for both target and disconfirmed items, indicating that they are impaired in their ability to delete from working memory no-longer-relevant information at down times of day.

Older adults also demonstrated strong synchrony effects on performance, but their overall pattern of priming was different from that of younger adults due to age-related inhibitory deficits. At their peak time, older adults closely resembled younger adults tested at nonoptimal times: they showed reliable positive priming for both target and disconfirmed items, suggesting that even at their best time of day, older adults are not efficient at deleting currently irrelevant information from working memory. At nonoptimal times, older adults were severely impaired in suppressing the self-generated but disconfirmed items, so much so that they showed marginally enhanced priming for those items relative to older adults tested at peak times, and actually failed to show any priming for experimenter-provided target items. It seems that inhibitory processing for older adults at nonoptimal times is so deficient that they are incapable of abandoning their self-generated, highly probable response, and as a consequence fail to show any priming at all for new target items. The patterns of priming for younger and older adults tested across the day are consistent with the suggestion that inhibitory functioning is diminished at off-peak relative to peak times, resulting in an inability to suppress or delete information that once was relevant, but is no longer appropriate for current goals. Note that the apparent inability of older adults to abandon their self-generated response in favor of a new response suggests that acquisition of new information will be difficult at nonoptimal times.

Failing to prevent strong responses at nonoptimal times: Stop signal. Inhibitory mechanisms are believed to enable control over behavior by restraining production of strong, dominant, or highly practiced responses, thus enabling the evaluation of and, if necessary, the rejection of those responses if they are deemed inappropriate for the present context. This function of inhibition allows for variation of behavior and retrieval of nondominating thoughts.

To investigate the possibility that the restraining function of inhibition is impaired at nonoptimal times, we used the stop signal task (e.g., Logan, 1983, 1985, 1994), in which participants had to withhold a very likely response whenever a stopping cue (which was relatively infrequent) occurred. The ability to prevent a response in the presence of the stopping cue provided a measure of restraint. In this study (May & Hasher, 1998), participants were trained to make category membership judgments (e.g., to say correctly that "yes, a chair is a piece of furniture" and "no, a stove is not a piece of furniture") as quickly as possible. On a small proportion of trials (stop-signal trials), participants heard a tone, which indicated that they were to stop or prevent their category judgment response. The proportion of stop-signal trials on which participants were successful at stopping their category response is displayed in Figure 9.3. Synchrony did affect stopping performance, such that both age groups were better able to stop when sig-

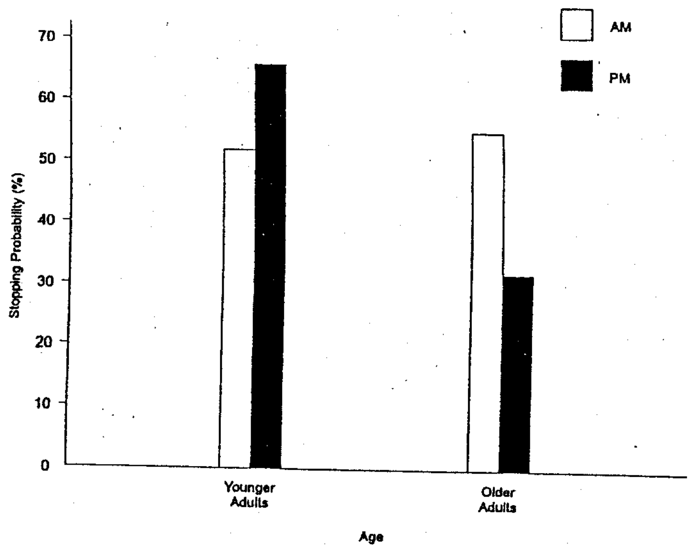

FIG. 9.3. Mean stopping bilities for younger older adults tested he morning and in the evening.

naled to do so at peak relative to off-peak times. Thus, as with the access and deletion functions of inhibition, the restraint function of inhibition seems to be susceptible to synchrony effects for both younger and older adults. In addition, younger adults were generally better than older adults at withholding responses on stop-signal trials, again consistent with the suggestion that there are age-related declines in inhibitory efficiency.

Further evidence that individuals tested at off-peak times have difficulty controlling strong, well-practiced responses has come from a study examining general knowledge (May, Hasher, & Bhatt, 1994). In this study, participants were to answer simple trivia questions as quickly and accurately as possible (e.g., "What hero does Clark Kent become when he changes in a phone booth?"). Included in the list of questions however, were some "illusion" questions which, if taken literally, could not be answered (e.g., "How many animals of each kind did Moses take on the ark?" [Note that Noah, not Moses, built the ark.]). Participants were warned in advance of the presence of these illusion questions and were instructed not to produce the likely answer (e.g., two), but rather to respond "can't say." Thus, participants were asked to suppress the well-learned, highly probable verbal responses to the illusion questions and instead to answer with an alternative response. As illustrated in Figure 9.4, both younger and older adults showed an effect of synchrony on their ability to prevent strong, probable verbal responses: for illusion questions, participants tested at off-peak times were more likely to generate an inappropriate response (e.g., two) than age-mates tested at peak times.

When synchrony does not matter

Though the evidence we have reported thus far is consistent with the premise that inhibitory functioning is impaired at individuals' nonoptimal relative to optimal times, a number of findings also suggest that excitatory functioning does not vary across the day (see Table 9.2). First, scores on

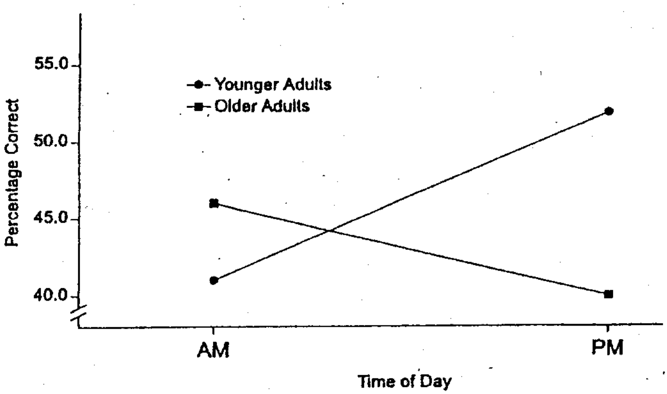

FIG. 9.4. Percentage of correct answers on Moses illusion questions for younger and older adults by time of day.

TABLE 9.2. Tasks with no effect on synchrony on age

	Younger adults		Older adults	
	AM (Nonpeak)	PM (Peak)	AM (Nonpeak)	PM (Peak)
Vocabulary[a] (lap/bowl)	22	23	26	29
Vocabulary[b] (stop signal)	18	17	28	24
Moses trivia[c]	78%	78%	79%	81%
High-cloze rates[d]	89%	89%	88%	87%
Medium-cloze rates	52%	53%	49%	51%
Stop-signal categorization[c]	91%	92%	89%	91%
RAT control completion	36%	32%	33%	32%

Note. [a]ervt v4; max 48; [b]ervt v3; max 36; [c]percentage correct; [d]percentage of sentences completed with expected.

vocabulary tests (taken from several studies) did not change for either younger or older adults across the day, suggesting that retrieval of information from semantic or long-term memory is spared at nonoptimal times. Second, access to well-learned, familiar, or highly practiced responses was consistently preserved at nonoptimal times. We found spared performance on the trivia-type questions, into which illusion statements (e.g., Moses and the ark) were embedded. In the deletion experiment reported above (May & Hasher, 1998), both younger and older adults generated the expected ending for high-cloze sentence frames equally often at optimal and nonoptimal times. In addition, they were as fast and accurate in making category judgments about familiar categories across the day in the stop signal experiment. Finally, no effect of either synchrony or age on target production for control items was obtained for the RAT task in the May (1999) study, a finding which further supports the suggestion that activation processes are not impaired at nonoptimal times.

Thus, there is a growing number of findings that show that production of familiar, highly probable, or well-learned responses are not affected by the synchrony between peak circadian periods and testing times. Taken together, these findings are consistent with predictions of an inhibitory framework of synchrony effects, which suggest that suppression, but not activation, processes are affected by circadian arousal. The findings of no age differences in activation processes also are consistent with the original assumption made by Hasher and Zacks (1988) that attention-based age differences are due largely to differences in inhibition, not excitatory processes.

Indirect consequences of diminished inhibition

In addition to the patterns of impairment and sparing that are directly predicted from an inhibitory framework, there also are indirect or downstream consequences of inhibitory failures that are evident at asynchronous times of day. These deficits may be manifested in a number of ways, including memory impairments, particularly when tasks involve multiple trials and require the deletion of information from a previous trial in order to remember information from only the current trial. Other downstream consequences of diminished inhibition at nonpeak times of day include reliance on simple heuristic-based judgments, rather than more careful and effortful evaluations, and increased likelihood of being persuaded by weak arguments. Evidence of indirect consequences is provided in the sections that follow.

Heightened susceptibility to interference. As inhibitory control over no longer relevant information declines both at nonoptimal times of day and with age, it might be expected that all tasks that are performed best with no input from prior tasks will show circadian and age effects. One such family of tasks are multiple recall tasks in which the target items for each recall are at least partially different from preceding to-be-recalled sets. A classic example is the memory span task in which participants typically are given units of information to recall on multiple consecutive trials. Although the type of information tested in span experiments varies greatly from numbers to words to sentences, one common aspect of nearly all span experiments is that participants first receive small units of information (e.g., one or two words) and progressively advance to larger units (e.g., six or seven words). Span is determined by the largest unit size for which participants successfully recall all of the information; thus, those who recall the largest units have the highest span score. Note, however, that the largest units are also those that are most likely to be disrupted by unsuccessfully suppressed items from previous lists or trials and involve the greatest amount of proactive interference (disruption of performance on currently relevant target items brought about by material presented before these target items), as they are preceded by a number of trials with very similar information. For those such as older adults who cannot efficiently use inhibition to cut off access to previous information, the large units should be especially problematic; hence, span scores should be reduced. In addition, since inhibitory efficiency declines at nonoptimal times, span scores also should be reduced then, relative to optimal times.

Recent work by May, Hasher, and Kane (in press) has indicated that, indeed, span tasks do involve proactive interference, and that individuals who are particularly interference-prone are differentially disadvantaged by the standard administration of span tasks. To explore the possibility that synchrony impairs inhibitory functioning, thereby diminishing span performance, younger and older adults were administered a simple word span task, in which they read words on a computer screen and then had to repeat them aloud from memory. The words were presented in sets, beginning with set size 2 and progressing to set size 6. Each participant completed three trials at each set size, and span was calculated as the largest set size at which an individual was correct on two of the three trials. As can be seen in Figure 9.5, synchrony did affect span performance, with both age groups demonstrating higher span scores at peak relative to off-peak times.

Use of heuristics. Since research findings have seemed to suggest that both aging and performance at nonoptimal times can reduce access to details of information that are stored in memory, what is retrieved at nonoptimal times? Along with the evidence we have reviewed suggesting that strong responses are easily accessible, the work of Bodenhausen (1990) has suggested that heuristics (e.g., simple rules of thumb, shortcuts) and schemas, which Alba and Hasher (1983) argued are highly accessible relative to details of complex events, are also highly accessible at nonoptimal times and so are very likely to be used in evaluation situations. Below, we first discuss findings related to the role of synchrony in people's differential use of heuristics, and then consider further downstream consequences for persuasion in the following section.

During nonoptimal times of day, individuals appear to rely more on heuristics to process information than they do during optimal times of day. Bodenhausen (1990) found that people used stereotypes in making social judgments of individuals at nonoptimal times. Those who reached their mental peak early in the day were more likely to generate stereotypic responses in the afternoon and the evening, while those who reached their peak in the evening exhibited a greater tendency to generate stereotypic responses in the morning.

A study by Yoon (1997) provided further evidence that people rely more on heuristic or schema-based processing rather than detailed processing at nonoptimal times of day, and that this tendency is more pronounced in older than younger adults. In this study, participants were given a recognition task containing target and foil items. Consistent with a pattern of results suggestive of schema-based processing, older people at their nonoptimal time had relatively high hit rates and high false alarm rates for foils that were congruent and mildly incongruent (and, thus, likely to be mistakenly processed as a congruent item), but low false alarm rates for

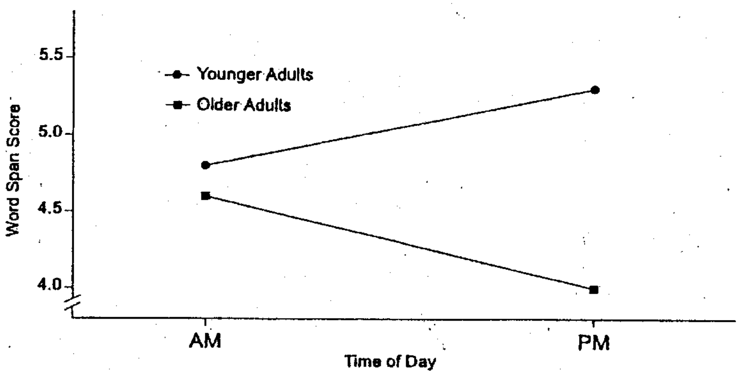

FIG. 9.5.
Word span scores for younger and older adults by time of day.

highly incongruent foils. However, at optimal times of day, older adults were as detailed in their processing as younger adults, evidenced by high hit rates and low false alarm rates (see Table 9.3).

The results of these two studies suggest the potential importance of considering the role of synchrony when investigating people's use of different types of processing strategies. For example, in social cognition studies involving perceptions of outgroup members' traits and behaviors, individuals may be more likely to rely on stereotype-based information, which often is negative, when responding at their nonoptimal compared to optimal time of day. This, in turn, may have implications for identifying important situations in which stereotyped groups may experience systematic disadvantages (e.g., personnel selection, law enforcement).

Persuasion. The notion that diminished inhibitory efficiency at nonpeak times can lead to an increased reliance on heuristic or schema-based, rather than more analytic, processing suggests further downstream consequences for persuasion. The elaboration likelihood model (Petty & Cacioppo, 1986) posits that there can be different routes to persuasion depending on an individual's ability and motivation to process information. In cases where the likelihood of elaboration is high (i.e., where ability and motivation to process are high), the attitude change process involves thoughtful scrutiny and detailed processing of persuasive communication (e.g., argument strength). This process is referred to as the "central route" to persuasion. On the other hand, when the individual lacks either the ability or the motivation to process information, a different process of attitude change occurs. This process, referred to as the "peripheral route" to persuasion, involves the use of simple rules of thumb, or heuristics, for evaluating the content of a persuasive message (e.g., peripheral cues). We thus might expect people who have neither the ability (e.g., at their nonoptimal time of day) nor the motivation to process incoming messages to be persuaded by cues that are not particularly diagnostic or informative, but nonetheless are appealing or relatively effortless to process.

TABLE 9.3. Effects of synchrony and age on recognition accuracy

		False alarm rates (FOILS)		
			Incongruent	
Age and time	*Message items (Hit rates)*	*Congruent*	*Low*	*High*
Younger adults				
AM (nonpeak)	.81	.20	.06	.02
PM (peak)	.83	.08	.03	.06
Older adults				
AM (peak)	.93	.19	.04	.04
PM (nonpeak)	.77	.43	.37	.09

Adapted with permission from Yoon, 1997.

A study by Yoon and Lee (1998) found empirical support for such tendencies. The study examined how synchrony, age, and level of motivation might affect the extent to which people are persuaded by argument strength versus peripheral cues in an advertising setting. Persuasion was assessed by averaging four 9-point postmessage attitude ratings (semantic differential scales anchored by *bad/good, unsatisfactory/satisfactory, unfavorable/favorable, not worthwhile/worthwhile*). The results suggest that older adults, as well as younger adults, were persuaded by relatively strong arguments (i.e., a "central route"), as opposed to weak arguments, when highly motivated to process advertising messages during their respective peak times (see Table 9.4A). However, older adults also seemed to be persuaded by strong arguments, even when their motivation to process was low, as long as they were exposed to the information during their peak time of day. At the nonpeak time of day, the older adults appeared to be persuaded via a "peripheral route" (i.e., a peripheral cue operationalized as relevance of the picture to the product featured in the advertisement) under both low- and high-involvement conditions (see Table 9.4B). Thus, these results suggest that the ability to process incoming information depending on the time of day, not the level of motivation, is the critical determinant in the persuasibility of older adults. By contrast, younger adults who were highly motivated to process appeared to be persuaded by strong arguments even at their nonoptimal time of day (see Table 9.4A); they were persuaded by relevance of the picture (i.e., the peripheral cue) only when their motivation to process was low (see Table 9.4B).

Previous research involving younger adults has found that the degree to which people will agree with or be persuaded by the substance of an argument also may hinge on the degree to which people are distracted during the presentation of a message. In particular, Petty, Wells, and Brock (1976) demonstrated that weak arguments are particularly persuasive when people are distracted. In a study by Rahhal et al. (1996), the concern was with the degree to which distraction and persuasion effects are heightened at nonoptimal times. They conducted a study in which they created and normed two weak arguments (about abolishing home schooling and police

TABLE 9.4A. Persuasion of argument strength by age, time of day, and motivation

	Low motivation		*High motivation*	
Argument strength	*Weak*	*Strong*	*Weak*	*Strong*
Younger adults				
AM (nonpeak)	5.7	5.7	3.4	4.8
PM (peak)	5.6	5.8	3.5	5.2
Older adults				
AM (peak)	4.3	6.2	2.3	5.1
PM (nonpeak)	4.5	5.0	3.7	3.3

Note. Average of four postmessage attitude ratings on 9-point scales (1 = negative, 9 = positive).

TABLE 9.4B. Persuasion of picture relevance by age, time of day, and motivation

Picture relevance	Low motivation		High motivation	
	Weak	*Strong*	*Weak*	*Strong*
Younger adults				
AM (nonpeak)	5.2	6.3	4.1	3.7
PM (peak)	5.2	6.3	3.8	4.2
Older adults				
AM (peak)	4.8	5.4	3.1	3.4
PM (nonpeak)	4.3	5.7	3.0	4.2

Note. Average of four postmessage attitude ratings on 9-point scales (1 = negative, 9 = positive).

reassignment plans) which were presented in the presence versus absence of distraction to older adults who were tested in the morning or afternoon. The distraction task was extremely simple, and required participants to monitor where an *X* appeared on a computer screen. While doing this, participants listened to a message, and immediately afterward, their attitudes toward the message were assessed, using a series of 7-point rating scales. The data (see Figure 9.6) clearly show that distraction in the morning has little impact on attitude scores (how good, wise, favorable, and beneficial the arguments were). But, distraction at nonoptimal times has a major impact on older adults, such that the weak arguments were considerably more persuasive in the afternoon than in the morning.

Conclusion

The synchrony between circadian arousal periods really matters for some cognition- and social cognition–type tasks, but not for others. Moreover, the consequences of synchrony can be greater for older adults than for

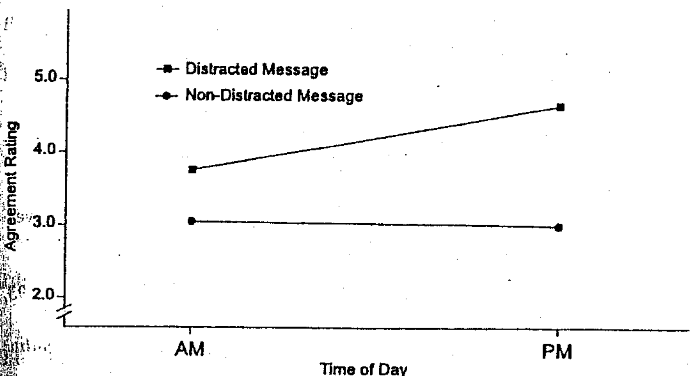

FIG. 9.6. Agreement ratings for messages for older adults by time of day.

younger adults given the age-related deficits in inhibition. To the extent that changes in cognitive functioning at off-peak times do in fact stem from circadian related deficits in inhibition, performance at nonoptimal times reflects deficits such as heightened access to irrelevant information, failure to clear away or suppress information that is no longer useful, and difficulties in restraining or preventing the production of strong, dominant responses that are undesirable or inappropriate. In addition, downstream consequences of diminished inhibition include heightened susceptibility to proactive interference, impaired judgments resulting from retrieval failures, and increased reliance on stereotypes and heuristics.

On the other hand, performance appears to be spared over the day in some instances, such as when tasks simply require access to or production of familiar, well learned, or practiced material (e.g., vocabulary tests, simple trivia questions), or when strong, dominant responses produce correct answers (e.g., word associations, familiar category judgments).

Taken together, the evidence suggests that in investigations of age-related differences in cognitive performance, particularly those involving inhibitory functioning, it is important to guard against any potential biases by controlling for individual and group differences in circadian arousal patterns. Insomuch as we know that older adults tend to reach their mental peak in the morning while younger adults do so in the evening, studies failing to account for such differences in arousal patterns may otherwise produce results that reflect a systematic under- or over-estimation of relationships between age and other variables of interest.

Notes

1. Unfortunately, the fully crossed design of Age × Morningness-Eveningness was not possible because so few of the younger adults were morning types, and virtually none of the older adults was an evening type.

2. The control items for any given participant had served as presented items for another participant, via a counterbalancing scheme.

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