6

CHAPTER

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Aging, Circadian Arousal Patterns, and Cognition

In the past few decades, human chronobiology research has documented rhythms in a variety of biological and physiological functions (e.g., body temperature, blood pressure, metabolic rate, hormonal and digestive secretions) reflecting circadian cycles of approximately 24 hours. Circadian rhythms exhibit pronounced effects on important aspects of everyday life, health, and medical treatment (e.g., Hrushesky, 1989, 1994; Smolensky & D'Alonzo, 1993), as well as on 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 shows that individual circadian arousal is 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 which 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, until recently, been quite limited. 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 differences in circadian arousal patterns, with older adults tending strongly towards 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, and of special relevance to the present paper, the patterns of performance differences across the day were quite different for younger and older adults. Herein, we report findings that performance differences 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 is now known to obtain across a number of tasks, although, as will be seen, there are some very intriguing exceptions as well.

Since survey researchers pose questions to people across the age range, attention to circadian arousal patterns and to their impact on some but not all cognitive processes may help to improve the accuracy and adequacy of responses, particularly by older adults. To the extent that there are individual and group differences in circadian arousal patterns across time of day, errors in survey data may result when the size and direction of response effects are differentially influenced by when a questionnaire is administered and completed. For example, as will be seen, people of all ages have a tendency to produce a strong or highly likely response at nonoptimal times of day and there are many situations in which the most accessible response is not necessarily the correct one. Investigators who rely on questionnaires and surveys to tap memory processes should in particular be alerted to how the variation in circadian arousal may produce systematically biased response data.

We turn now to consider some of the key findings that are of potential relevance to the ability of people, particularly older adults, to answer questions that survey researchers (and others) might ask of them. We begin with the evidence showing age differences in circadian arousal patterns.

☐ Age Differences in Morningness–Eveningness Tendencies

Measure

To assess individual and group differences in circadian patterns, we and others have used the Horne-Ostberg (1976) Morningness-Eveningness Questionnaire, or MEQ. The MEQ is a simple paper-and-pencil test consisting of 19 questions which address such items 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. These delineations are validated by a number of findings demonstrating 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 & Ostberg, 1976; Horne, Brass, & Pettitt, 1980; 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., Kerkhof, 1984; Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991), and psychometric tests indicate 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 indicates a significant shift towards morningness with age (e.g., Adan & Almirall, 1990; Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; Kerkhof, 1985; May, Hasher, & Stoltzfus, 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 U.S. (May & Hasher, in press). We have now administered the MEQ to over 1,500 college students (aged 18–23) and over 600 older adults (aged 60–75) in different regions of North America and, as can be seen in Figure 1, the norms show clear age differences in the pattern of peak times across the day: roughly 40% of younger adults (all of whom are college students) show eveningness tendencies, with a large proportion of neither-types and less than 10% morning-types. By contrast, less than 3% of older adults show eveningness tendencies, and the majority (~75%) are 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.

Investigators who utilize surveys, particularly those interested in cognitive aging, thus need to consider how response biases might potentially be introduced when age differences in circadian arousal are not

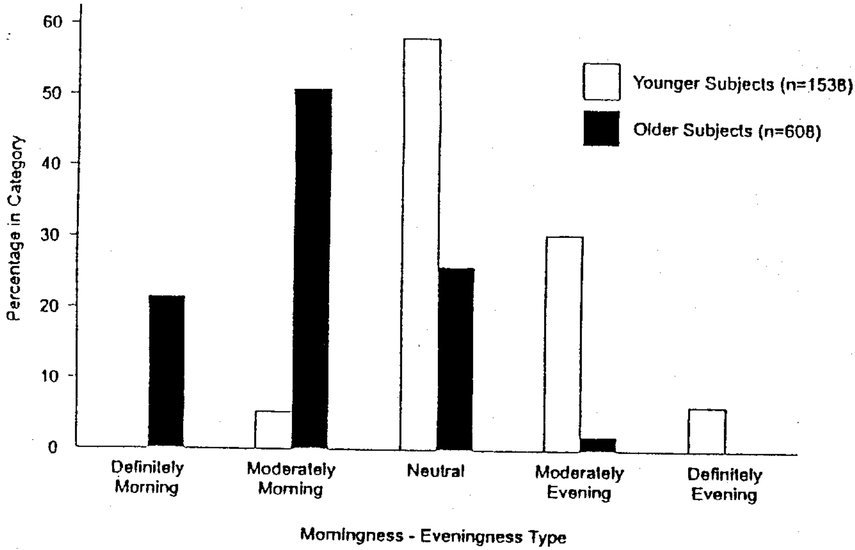

FIGURE 1. Time of day categories for older and younger adults.

accounted for. Biases associated with respondents may act to alter observed relations between the independent and dependent variables in ways that either produce relationships when none really exist or cause systematic under- or overestimation of relationships. For example, given that we know that older adults tend to reach their mental peak in the morning while younger adults do so in the evening, surveys assessing cognitive performance that are administered in the evening may serve to exaggerate any true age differences in abilities. (See May et al., 1993, for a more detailed discussion.) Such surveys may also give an inaccurate picture of the values, attitudes, and behaviors of older adults, who may, for example, seem more prejudiced than they actually are (Bodenhausen, 1990). In conducting research that seeks to uncover relationships between age and other variables of interest, investigators, whenever possible, need to guard against such potential sources of response bias.

Differences in Intellectual and Physical Behavior

Accounting for individual differences in circadian arousal in aging studies is critical in situations where intellectual and physical behavior varies across the day in ways that are relevant for those interested in asking questions of others. One set of findings which suggests real differences in behavior across the day comes from a study that addresses media and shopping patterns of older adults, compared with those of younger adults, finding 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 tend to read newspapers, read 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 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' medical 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) examined the relationship between grades and time of day when classes are held, among college students. 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 synchronous with circadian patterns reported elsewhere for these age groups (May et al., 1993; Yoon, 1997). It is conceivable, for example, that differences in intellectual and physical energy will influence the likelihood of participation in studies involving telephone or personal interviews, in ways that might easily bias both the samples obtained and the kinds of answers given.

☐ 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, in press; 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 are consistent as well in confirming relatively impaired inhibitory processes of older adults. Thus, here we focus on the role of inhibition in information processing, the consequences of inhibitory impairments for cognitive performance, and the implications of such impairments for the administration of surveys.

Inhibition

Inhibitory mechanisms are thought to be critical for three general functions, each of which is directed at controlling the contents of working memory to enable the efficient on-line processing and subsequent successful retrieval of target information (e.g., Hasher et al., in press). 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 was once 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 not been turned off during a questionnaire) 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 for poor inhibitors, resulting in difficulties in acquiring new material, comprehending questions, and retrieving stored memories. Poor inhibitors may also 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 influences the efficiency of retrieval, diminished inhibition efficiency can further lead to an increased reliance on stereotypes, heuristics, or schemas when making decisions or answering questions, even in situations where detailed, analytical processing is clearly more appropriate (Bodenhausen, 1990; Yoon, 1997). 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).

Hence, if changes in cognitive functioning at off-peak times do in fact stem from circadian-related deficits in inhibition, then performance at nonoptimal times can be expected to reflect inaccurate assessment of people's opinions and knowledge in question-asking situations whenever irrelevant or previously relevant information affects responses, or when strong, prepotent responses must be rejected in favor of subordinate ones. If only inhibitory, but not excitatory, processes vary with arousal, time of testing should not matter whenever tasks simply require access to or production of well-learned material (e.g., vocabulary, simple trivia questions, identification of familiar stimuli), or when strong responses produce correct answers (e.g., word associations, highly practiced motor skills, perceptual priming).

Furthermore, given that surveys are commonly employed to estimate the frequency or amount of certain kinds of behaviors (when records for the relevant population are either nonexistent or difficult to obtain), it is clear that inhibitory functions, as related to variation in levels of circadian arousal, can play a large role in determining the accuracy of respondent reporting. For example, individuals, during their peak times of day, may have relatively greater ability to inhibit irrelevant past events and generate accurate responses, whereas during nonpeak times of day, they may have a tendency to overreport irrelevant events.

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, and 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, in press). We used a modified version of the Remote Associates Test (RAT; Mednick, 1962), in which each problem consists of three cue words (e.g., rat, blue, cottage) that are all remotely related to the same target word (e.g., cheese). The participants' task was to identify the target word that connects the three cue words. Of interest was the effect of distractors on individuals' ability to identify the targets. We gauged susceptibility to distraction in two ways: (1) the cost of misleading distraction and (2) the benefit of "leading" distraction.

Previous findings with this task indicate 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). The cost of distraction should be greater for participants tested at off-peak relative to peak times, as they may be less able to suppress the irrelevant, misleading information. In addition, we explored the possibility that there may 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 target identification 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 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., young tested in the morning and old 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).

With respect to people's ability to answer questions, these data suggest patterns of disruptions (with both costs and benefits), with individuals who are queried at nonoptimal times being particularly vulnerable to distraction when questionnaires are administered in relatively noisy environments (as with mail-in questionnaires, telephone interviews, mall intercept interviews, etc.). If questionnaires are given in "noisy" environments, those irrelevant stimuli can lead to answers that come not from a direct response to the query but rather from a response heavily biased by irrelevant information. To whatever degree

TABLE 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

these effects impact on young adults, their impact will be greater on older adults, particularly at their off-peak, evening hours.

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 shift as well. 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 was once relevant, but is no longer suitable for current goals. To do this, May and Hasher (in press) used a garden path sentence completion task (Hartman & Hasher, 1991). In the first phase of this task, participants were presented with high-cloze sentence frames that were missing their final words (e.g., "Before you go to bed, turn off the _____"), and were asked to generate an ending for each frame. 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 (e.g., "stove") would appear on the subsequent memory test.

Our aim was to determine 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 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 both to target and to 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 medium-cloze sentence frames (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 2.

Consider first the pattern of priming for younger adults: At peak times, younger adults show reliable priming of target endings and actually show significant, *below-baseline* priming for the disconfirmed endings. These findings suggest that for younger adults at optimal times, the deletion function of inhibition is so efficient that the disconfirmed items

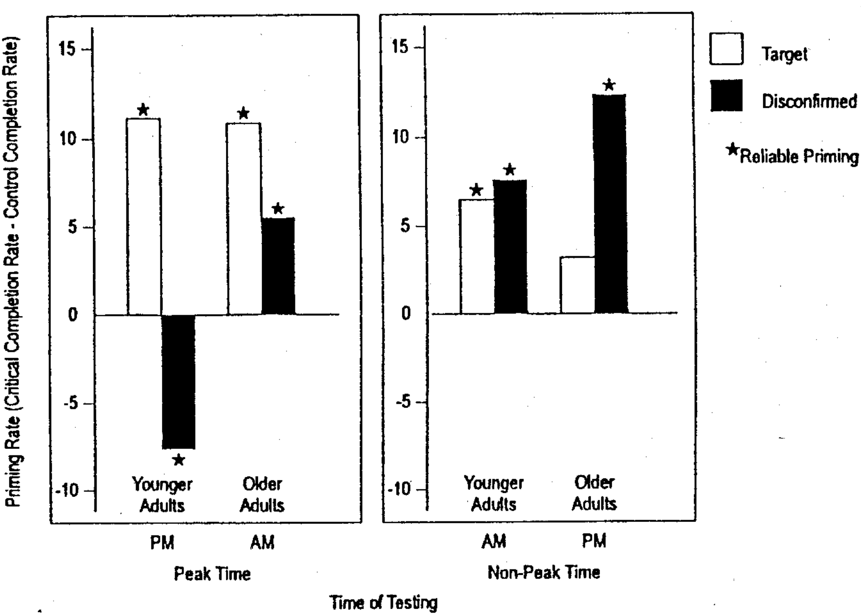

FIGURE 2. Priming for target and disconfirmed items for younger and older adults by time of testing.

are less accessible than items that were never presented. By contrast, younger adults tested at nonoptimal times show 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 demonstrate strong synchrony effects on performance, but their overall pattern of priming is different from that of younger adults due to age-related inhibitory deficits. At their peak time, older adults closely resemble young adults tested at nonoptimal times: They show 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 are severely impaired in suppressing the self-generated but disconfirmed items, so much so that they show marginally enhanced priming for those items relative to older adults tested at peak times, and actually fail 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 was once relevant, but is no longer appropriate for current goals.

What do these findings mean for the ability of younger and older adults to respond to survey questions? Because the deletion function is less effective for older adults and less effective for each group at nonoptimal times, difficulties can be anticipated whenever a topic shifts in a series of questions. For example, one series of questions might elicit preferences for different types of TV shows, followed by a second series of questions that probe individuals' attitudes towards different types of books. The inability to switch to a new topic may heighten carry-over of responses from the initial topic to a new one, giving unstable or inaccurate responses to the new topic.

Is there a way to increase accurate switching to topic changes? A recent finding suggests that the provision of additional information about the new topic, prior to asking any questions, will help older adults to make the switch that they do not make on their own (see Hasher, Quig, & May, 1997). The findings from this study suggest that when inhibition is deficient, as it is for older adults generally and for anyone tested at nonoptimal times, additional interpretive context is required to enable effective mental shifts to actual changes in context.

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, of special interest for question answering, 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, in press), participants were trained to make category judgments (e.g., to say that a chair is a piece of furniture) as quickly as possible. The proportion of stop-signal trials on which participants were successful at stopping their category response is displayed in Figure 3. Synchrony did affect stopping performance, such that both

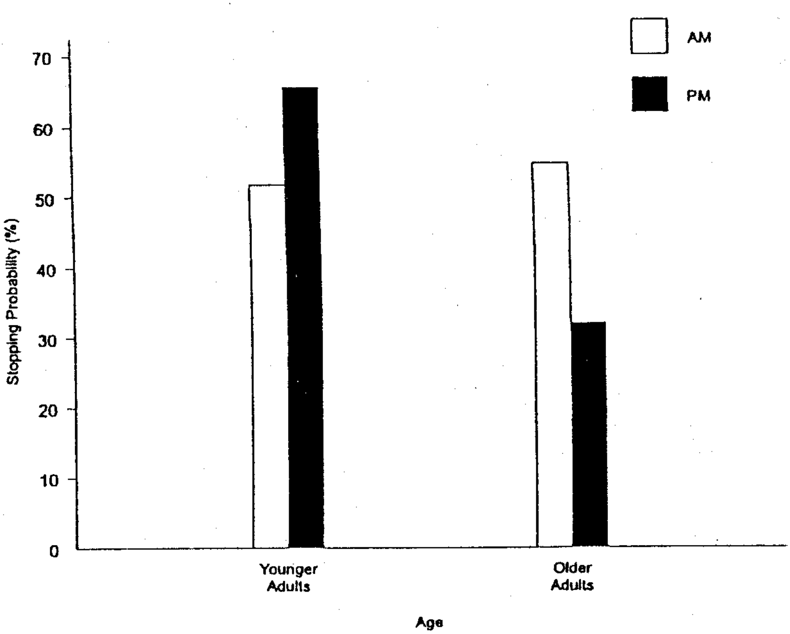

FIGURE 3. Mean stopping probabilities for younger and older adults tested in the morning and in the evening.

age groups were better able to stop when signaled 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 supporting an inhibitory-deficit view of aging.

Further evidence that individuals tested at off-peak times have difficulty controlling strong, well-practiced responses comes 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 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.

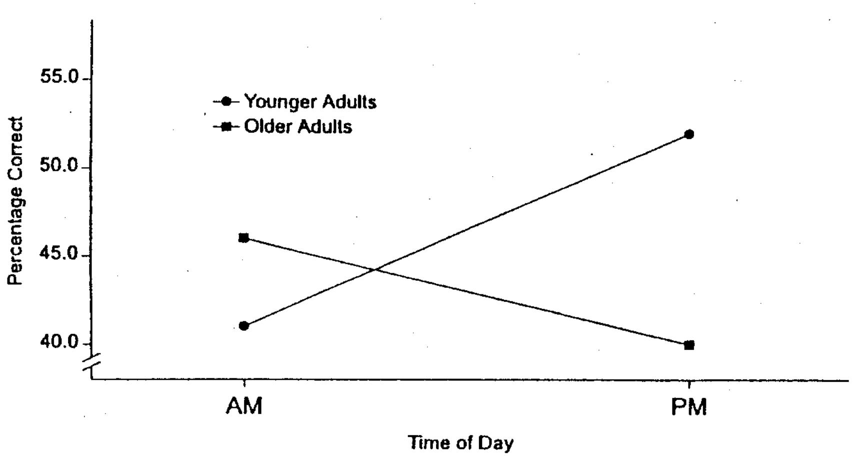

FIGURE 4. Percentage of correct answers on Moses illusion questions for younger and older adults by time of day.

Taken together, these two sets of data suggest that there will be reductions in accuracy in question answering whenever the questions prime a strong response *and* when the respondent is older or is answering at nonoptimal times. Not only can strong responses be based on past knowledge (however inaccurate that might be, e.g., Moses and the Ark) but the responses can also become strong within the context of a series of questions, as when one alternative answer has already been used multiple times or when multiple questions prime similar information.

When Synchrony Does Not Matter

Although the evidence we have reported thus far is consistent with the premise that inhibitory functioning is impaired at individuals' nonoptimal relative to optimal times, several findings also suggest that excitatory functioning does not vary across the day (see Table 2). First, scores on 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. 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

TABLE 2. TASKS WITH NO EFFECT ON SYNCHRONY ON AGE

	Younger Adults		Older Adults	
	AM (Nonpeak)	PM (Peak)	AM (Peak)	PM (Nonpeak)
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.

about familiar categories across the day. Finally, no effect of either synchrony or age on target production for control items was obtained for the RAT task in the May (in press) study, a finding which further supports the suggestion that activation processes are not impaired at nonoptimal times.

Thus there are a growing number of findings showing 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 that suggest that suppression but not activation processes are affected by circadian arousal.

Indirect Consequences of Diminished Inhibition

In addition to the patterns of impairment and sparing that are directly predicted from an inhibitory framework, there are also 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 only from the current trial. Further-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. In research utilizing surveys, one can conceive of conditions in which interviewing at peak versus nonpeak times of day might systematically bias the resulting data, not only in the way questions are interpreted by respondents, but in a manner which may be exacerbated by differences in respondent and interviewer characteristics (e.g., gender, race, social status, education level). Evidence of indirect consequences is provided in the sections that follow.

Heightened Susceptibility to Interference

As inhibitory efficiency declines at nonoptimal times of day and with age, span scores should also be reduced at nonoptimal times and for older adults. In memory span tasks, participants are typically 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 involve the greatest amount of proactive interference, as they are preceded by a number of trials with very similar information. For those who cannot efficiently use inhibition to cut off access to previous information, the large units should be especially problematic, and hence span scores should be reduced. In addition, since inhibitory efficiency declines at nonoptimal times, span scores should also be reduced then, relative to at optimal times.

Recent work by May, Hasher, and Kane (1997) indicates 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 3 trials at each set size, and span was calculated as the largest set size at which an individual was correct on 2 of the 3 trials. As can be seen in Figure 5, synchrony did affect span performance, with both age groups demonstrating higher span scores at peak relative to off-peak times.

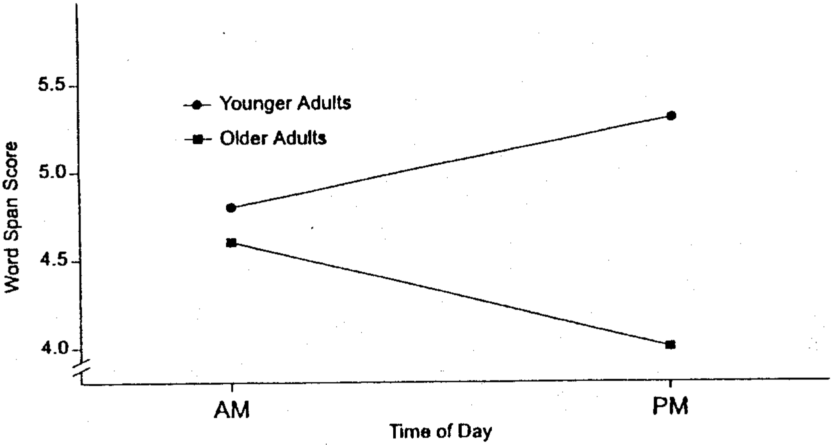

FIGURE 5. Word span scores for younger and older adults by time of day.

Inefficiency at clearing away previously relevant but currently obsolete information thus appears to reduce individuals' ability to store and process information. As a result, older adults and people tested at asynchronous times should have difficulty when questionnaires place heavy demands on working memory (e.g., when they require retrieval of large units of information or when they demand use of a complicated scale), particularly for questions occurring late in a series.

Use of Heuristics

Since research findings seem 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) suggests that heuristics 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 at nonoptimal times. Those who reach their mental peak early in the day were more likely to generate stereotypic responses in the afternoon and the evening, while those who reach their peak in the evening exhibited a greater tendency to generate stereotypic responses in the morning.

A study by Yoon (1997) provides 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 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 3).

TABLE 3. EFFECTS OF SYNCHRONY AND AGE ON RECOGNITION ACCURACY (YOON, 1997)

Age and Time	Message Items (Hit Rates)	FOILS (False Alarm Rates)		
			Incongruent	
		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

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 are more likely to rely on stereotype-based information, which is often negative, when responding at their nonoptimal compared to optimal time of day. This may, in turn, have implications for identifying important situations in which stereotyped groups may experience systematic disadvantages (e.g., personnel selection, law enforcement).

In addition, the fact that synchrony may influence people's use of heuristic versus more analytic processing impacts on question-asking situations, particularly when investigating age differences. In answering questions that call on relatively detailed and systematic processing of complex information, both younger and older people (but particularly older people), at their nonoptimal times, may be differentially disadvantaged. On the other hand, responses to questions that primarily require individuals to rely on schema-based processing would not be susceptible to synchrony effects and could be safely administered throughout the day.

We further speculate that in designing survey questions, certain formats are more likely to promote schema-based processing, as opposed to more systematic processing. For example, in attempting to formulate the optimal attribute mix for a new product, a methodology such as conjoint analysis may be chosen, where the measures of interest are individuals' trade-offs between various available product features. In such a case, it is crucial that participants not overly focus on any particular attribute (e.g., price) as a proxy for their overall satisfaction with a given bundle of features, a schema-based evaluative behavior more likely at their nonoptimal time of day. Question order may also lead to a distribution of responses that are systematically biased. Imagine a questionnaire in which initial responses involve judgments that commit a respondent to a schema-based or stereotype-based view (e.g., in the U.S., that Asians tend to be good at math). A respondent, once committed to a schema-based view, would likely formulate subsequent responses consistent with that view, a tendency which may be exacerbated during nonoptimal times of day and diminished at optimal times of day. Different conclusions might thus be reached depending on the time of day the questions are asked.

Persuasion

The notion that diminished inhibition 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, that is, 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 might thus 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 are nonetheless appealing or relatively effortless to process.

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 postmessage attitude ratings. 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 4A).

TABLE 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 nine-point scales (1 = negative, 9 = positive).

However, the 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 more persuaded via a "peripheral route" (i.e., relevance of the picture to the product featured in the advertisement) under both low- and high-involvement conditions (see Table 4B). These results thus 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 4A); they were

TABLE 4B. PERSUASION OF PICTURE RELEVANCE BY AGE, TIME OF DAY, AND MOTIVATION

	Low Motivation		High Motivation	
Picture Relevance	Irrelevant	Relevant	Irrelevant	Relevant
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 nine-point scales (1 = negative, 9 = positive).

persuaded by relevance of the picture (i.e, the peripheral cue) only when their motivation to process was low (see Table 4B).

This study clearly demonstrates the effects of synchrony and circadian arousal on persuasibility of older adults. Insights gained about how older adults' attitudes are affected by exposure to persuasive communications potentially impact on the issue of questionnaire design. For example, researchers who wish to get an accurate assessment of the strength of an argument relating to a particular topic would need to explicitly account for time of testing, especially if the arguments are complex or responses are to be elicited from older adults.

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 may also 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 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 afterwards, their attitudes towards the message were assessed, using a series of seven-point rating scales. The data (see Figure 6) show clearly that distraction in the morning has

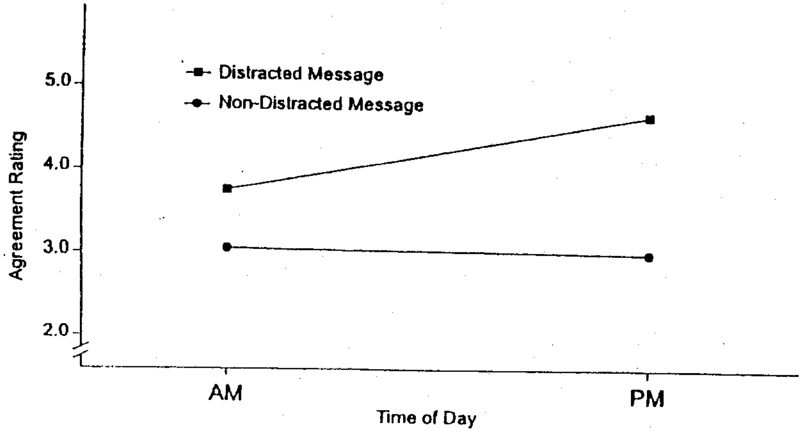

FIGURE 6. Agreement ratings for messages for older adults by time of day.

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.

This study also raises questions about the circumstances under which survey questions are asked. Is there a TV or radio on? Is there someone else in the room while the questioning is occurring? If so, the views of older adults may actually change during the course of an interview if the content of the questions includes any substantive information that might lead to supporting one point of view. Note that it is weak evidence for a particular point that has been found to be compelling under distracting or nonoptimal testing circumstances.

☐ 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 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, failures 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).

What are the potential consequences of inefficient inhibition for questionnaire performance? Formats that place particularly heavy memory demands on individuals (e.g., those with complicated scales for responding, or multiple scales that change from section to section, or those that require participants to base current answers on previous ones) may differentially place poor inhibitors at a disadvantage. In those instances, inefficient suppressors may simply shift to strategic, load-reducing strategies, using only parts of a given scale or relying on strong, easily retrieved responses rather than performing the careful, analytical thinking that may be desired by the investigator.

Reliance on strong, familiar, or stereotypic responses may be particularly problematic when trying to assess "temporary" or "momentary" states of individuals or when searching for the possibility of nondominant or unlikely answers. For example, suppose that an investigator is interested in the influence of a spouse's job loss on marital satisfaction. If, in general, a person's marriage is healthy, she may tend to respond "fine," "good," etc. to questions about marriage, despite any temporary decrease in marital satisfaction. A biased set of responses is particularly likely when people are asked such questions at their nonpeak time of day.

Ultimately, researchers may need not only to keep track of when studies are administered but also to instruct study participants as to when during the day they should complete mail-in questionnaires, or to note the time when the questionnaires are completed. As testing time might influence the types of responses likely to be given, the respondents' answers may need to be interpreted in light of that fact. For researchers investigating group differences in cognition and social cognition that involve inhibitory functioning, the time at which questions are asked probably cannot be safely ignored, particularly if the groups of interest differ markedly in age.

Endnotes

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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References

Adan, A. (1991). Influence of morningness-eveningness preference in the relationship between body temperature and performance: A diurnal study. *Personality and Individual Differences, 12,* 1159–1169.

Adan, A., & Almirall, H. (1990). Adaptation and standardization of a Spanish version of the morningness eveningness questionnaire: Individual differences. *Personality and Individual Differences, 11,* 1123–1130.

Alba, J. W., & Hasher, L. (1983). Is memory schematic? *Psychological Bulletin, 93,* 203–231.

Allport, A. (1989). Visual attention. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp 631–682). Cambridge, MA: MIT Press.

Anderson, M., Petros, T. V., Beckwith, B. E., Mitchell, W. W., & Fritz, S. (1991). Individual differences in the effect of time of day on long-term memory access. *American Journal of Psychology, 104,* 241–255.

Bodenhausen, G. V. (1990). Stereotypes and judgmental heuristics: Evidence of circadian variations in discrimination. *Psychological Science, 1,* 319–322.

Buela-Casal, G., Caballo, V. E., & Cueto, E. (1990). Differences between morning and evening types in performance. *Personality and Individual Differences, 11,* 447–450.

Colquhoun, W. P. (1971). Circadian variations in mental efficiency. In W. P. Colquhoun (Ed.), *Biological rhythms and human performance* (pp. 39–107). London: Academic Press.

Folkard, S., Knauth, P., Monk, T. H., & Rutenfranz, J. (1976). The effect of memory load on the circadian variation in performance efficiency under rapidly rotating shift system. *Ergonomics, 10,* 479–488.

Folkard, S., Weaver, R., & Wildgruber, C. (1983). Multi-oscillatory control of circadian rhythms in human performance. *Nature, 305,* 223–226.

Hartman, M., & Hasher, L. (1991). Aging and suppression: Memory for previously relevant information. *Psychology and Aging, 6,* 587–594.

Hasher, L., Quig, M. B., & May, C. P. (1997). Inhibitory control over no-longer-relevant information: Adult age differences. *Memory & Cognition, 25,* 286–295.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). New York: Academic Press.

Hasher, L., Zacks, R. T., & May, C. P. (in press). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention and performance, XVII, Cognitive regulation of performance: Interaction of theory and application.* Cambridge, MA: MIT Press.

Horne, J., Brass, C., & Pettitt, S. (1980). Circadian performance differences between morning and evening types. *Ergonomics, 23,* 29–36.

Horne, J., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology, 4,* 97–110.

Hrushesky, W. (1989). Circadian chronotherapy: From animal experiments to human cancer chemotherapy. In B. Lemmer (Ed.), *Chronopharmacology: Cellular and biochemical interactions* (pp. 439–473). New York: Marcel Dekker.

Hrushesky, W. (1994). Timing is everything. *The Sciences, 34(July/Aug.)*, 32–37.

Intons-Peterson, M. J., Rocchi, P., West, T., McLellan, K., & Hackney, A. (1998). Aging, optimal testing times, and negative priming. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24*, 362–376.

Ishihara, K, Miyake, S., Miyasita, A., & Miyata, Y. (1991). Morningness-eveningness preference and sleep habits in Japanese office workers of different ages. *Chronobiologia, 18*, 9–16.

Kerkhof, G. A. (1984). A Dutch-language questionnaire for the selection of morning and evening type individuals. *Nederlands Tijdschrift voor de Psychologie, 39*, 281–294.

Kerkhof, G. A. (1985). Inter-individual differences in the human circadian system: A review. *Biological Psychology, 20*, 83–112.

Kerkhof, G. A., van der Geest, W., Korving, H. J., & Rietveld W. J. (1981). Diurnal differences between morning-type and evening-type subjects in some indices of central and autonomous nervous activity. In A. Reinberg, N. Vieux, & P. Andlauer (Eds.), *Night and shift work: Biological and social aspects* (pp. 457–464). Oxford, England: Pergamon Press.

Leirer, V. O., Tanke, E. D., & Morrow, D. G. (1994). Time of day and naturalistic prospective memory. *Experimental Aging Research, 20*, 127–134.

Logan, G. D. (1983). On the ability to inhibit simple thoughts and actions: 1. Stop signal studies of decision and memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 585–606.

Logan, G. D. (1985). On the ability to inhibit simple thoughts and actions: 2. Stop signal studies of repetition priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 675–691.

Logan, G. D. (1994). On the ability to inhibit thought and action: A users' guide to the stop signal paradigm. In D. Dagenbach and T. Carr (Eds.), *Inhibitory mechanisms in attention, memory, and language* (pp. 189–239). New York: Academic Press.

May, C. P. (in press). Synchrony effects in cognition: The costs and a benefit. *Psychological Bulletin and Review.*

May, C. P., & Hasher, L. (in press). Synchrony effects in inhibitory control over thought and action. *Journal of Experimental Psychology: Human Perception and Performance.*

May, C. P., Hasher, L., & Bhatt, A. (1994, April). *Time of day affects susceptibility to misinformation in younger and older adults.* Presented at the Cognitive Aging Conference, Atlanta, GA.

May, C. P., Hasher, L., & Kane, M. J. (1997). *The role of interference in memory span measures.* Manuscript submitted for publication.

May, C. P., Hasher, L., & Stoltzfus, E. R. (1993). Optimal time of day and the magnitude of age differences in memory. *Psychological Science, 4*, 326–330.

Mecacci, L., & Zani, A. (1983). Morningness-eveningness preferences and sleep-waking diary data of morning and evening types in student and workers samples. *Ergonomics, 26*, 1147–1153.

Mecacci, L., Zani, A., Rocchetti, G., & Lucioli, R. (1986). The relationships between morningness-eveningness, ageing and personality. *Personality and Individual Differences, 7*, 911–913.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220–232.

Monk, T. H. (1986). Advantages and disadvantages of rapidly rotating shift schedules: A circadian viewpoint. *Human Factors, 28*, 553–557.

Moore-Ede, M., & McIntosh, J. (1993, October 1). Alert at the switch. *Technology Review, 96*, 52–65.

Navon, D. (1989). The importance of being visible: On the role of attention in a mind viewed as an anarchic intelligence system: 1. Basic tenets. *European Journal of Cognitive Psychology, 1,* 191–213.

Petros, T. V., Beckwith, B. E., & Anderson, M. (1990). Individual differences in the effects of time of day and passage difficulty on prose memory in adults. *British Journal of Psychology, 81,* 63–72.

Petty, R. E., & Cacioppo, J. T. (1986). *Communication and persuasion: Central and peripheral routes to persuasion.* New York: Springer-Verlag.

Petty, R. E., Wells, G. L., & Brock, T. L. (1976). Distraction can enhance or reduce yielding to propaganda: Thought disruption versus effort justification. *Journal of Personality and Social Psychology, 34,* 874–884.

Rahhal, T. A., Abendroth, L. J., & Hasher, L. (April, 1996). *Can older adults resist persuasion? The effects of distraction and time of day on attitude change.* Poster presented at the Cognitive Aging Conference, Atlanta, GA.

Skinner, N. F. (1985). University grades and time of day of instruction. *Bulletin of the Psychonomic Society, 23,* 67.

Smith, C. S., Reilly, C., & Midkiff, K. (1989). Evaluation of the circadian rhythm questionnaires with suggestions for an improved measure of morningness. *Journal of Applied Psychology, 74,* 728–738.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *American Journal of Psychology, 104,* 61–87.

Smolensky, M., & D'Alonzo G. (1993). Medical chronobiology: Concepts and applications. *American Review of Respiratory Disease, 147,* S2–S19.

Vitiello, M. V., Smallwood, R. G., Avery, D. H., & Pascualy, R. A. (1986). Circadian temperature rhythms in young adult and aged men. *Neurobiology of Aging, 7,* 97–100.

Webb, W. B., & Bonnet, M. H. (1978). The sleep of 'morning' and 'evening' types. *Biological Psychology, 7,* 29–35.

Wilson, G. D. (1990). Personality, time of day, and arousal. *Personality and Individual Differences, 11,* 153–168.

Yoon, C. (1997). Age differences in consumers' processing strategies: An investigation of moderating influences. *Journal of Consumer Research, 24,* 329–342.

Yoon, C., & Lee, M. (1998). *Age differences in processing of pictorial and verbal information across time of day: Implications for persuasion.* Manuscript submitted for publication.

Zacks, R. T., & Hasher, L. (1994). Directed ignoring: Inhibitory regulation of working memory. In D. Dagenbach and T. Carr (Eds.), *Inhibitory mechanisms in attention, memory, and language* (pp. 241–264). New York: Academic Press.

SOURCE: In N. Schwarz, D.C. Park, B. Knauper, & S. Sudman (Eds.) (1999). Cognition, aging, and self-reports (pp. 117-143). Hove, England: Psychology Press.