# EXPECTANCY GENERATION AND UTILIZATION:

# AN ATTENTIONAL CONTROL PERSPECTIVE

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Applied Psychology

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2007

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April 2007

# ACKNOWLEDGEMENTS

Special thanks to Dr. Keith A. Hutchison, Dr. Jason Watson, Dr. Michelle L. Meade, Dr. Richard A. Block, Ann E. Lambert, Karyn Lewis and Katya Numbers.

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# ABSTRACT

Although the research of Balota, Black and Cheney (1992) has shown attentional deficits in older adults to be detrimental to performance in semantic priming tasks which require a shift of attention away from a presented category, no attempt has been made to link performance to measures of attentional control. The current study utilizes the same paradigm as Balota, Black and Cheney with participants' attentional control measured using the battery of Hutchison (in press). Results show ability not only to generate expectancy for the target category, but to override automatic processes initiated by the prime word is tied to attentional control. Unfortunately, the attempt of Balota, Black and Cheney to estimate expectancy generation when no shift of attention is required may require revision.

# INTRODUCTION

Among the basic insights of modern psychology is an understanding that automatic responding to the most powerful stimulus offered by the environment is not always conducive to the achievement of goals. Environmental stimulation can be a powerful cue for directing attention and behavior; however, external stimuli can also serve as distraction, directing mental activity away from the current objective. Importantly, otherwise normally functioning humans can show broad variation in the ability to enact the cognitive control needed to override environmental cues that conflict with current intentions.

According to Posner and Snyder's (1975) dual process model of behavior, certain generalized characteristics of exogenously and endogenously activated information make these forms of processing both separable and observable. Specifically, automated processes are fast acting (< 50 ms), unintentional, free from conscious expectations and do not produce inhibitory effects on other processes. Conversely, attentionally-based control processes are relatively slow to engage (generally > 300 ms, but see Hutchison, Johnson & Neely, 2001; Hutchison, in press), depend on conscious expectancies and produce both priming of context relevant input and inhibition of context-irrelevant information. According to Engle, Kane and Tuholski (1999), these properties make limited capacity attention, for all intents and purposes, interchangeable with Baddeley's (Baddeley & Hitch, 1974; Baddeley & Logie, 1999) working memory central executive. In this way, controlled attention acts in the face of distraction to maintain connections with long-term memory and avoid environmentally activated distraction.

One of the earliest and most cited examinations of Posner and Snyder's (1975) predictions was Neely's (1977) study of conscious expectations within the lexical decision task (LDT). In the LDT, participants are shown a *prime* word, then expected to judge the status of a second string of letters as either a word or nonword, via key press. Although it had already been established that recognition of a *target* word is often facilitated if it is preceded by a related prime word relative to an unrelated word (Meyer & Schvandveldt, 1971), it was not clear to whether this *priming effect* could be at least partially attributed to attentionally controlled processes or was purely a product of automatically-activated associations between related words (i.e. spreading activation; Collins & Loftus, 1975). As one possible version of attentional priming, Becker (1980) proposed that attentionally controlled processes produce priming by using the prime word to generate and maintain possible targets during the time period separating the first and second word. Once the target is presented, it activates an additional set of visually similar words. The already generated candidates are compared against the visually similar set until a match is found. In this way, attention speeds word recognition by giving weight to mental representations of likely targets, but depending on the size of the generated list (as all words are compared), can also cause significant inhibition for non-generated words. In contrast to these attentionally controlled processes, an automatic process, such as spreading activation (Collins & Loftus, 1975), is proposed to activate words associated to the prime quickly and below the level of conscious awareness.

In order to clearly separate these automatic and attentionally controlled processes, Neely (1977) used category names as primes and category members as targets. Critically, on some trials Neely required participants to direct attention to a pre-specified category each time a specific prime was displayed (e.g., each time the prime BUILDING is presented, focus attention on *parts of the BODY*). In order to reinforce expectancies, primes were followed by targets from the pre-specified category on two-thirds of all trials, with the remaining third consisting of targets that were unexpectedly related to the prime category (on attention shift trials) or completely unrelated to the prime category (both shift and no-shift trials). On shift trials, priming occurred for target words in the specified category (e.g., BODY parts) relative to when the words were preceded with a neutral prime of *XXXX*. Consistent with the predictions of Posner and Snyder (1975), this expectancy-based priming only occurred if ample time was provided between presentation of the prime and target words (in this case, more than 400 ms). Additionally, at these relatively long delays, responding to words in the related category (e.g., *door*) was inhibited, relative to the neutral condition, despite environmental support for the prime. However, this was not the case when a mere 250 ms of preparation time was provided. In these instances, priming occurred only for words from the related category (e.g. *door*), but not for the unrelated but more likely targets (e.g., *arm*). Thus, attention produced both a benefit for expected information and cost for unexpected information, but only when enough time was given for mobilization.

While Neely's (1977) data provides evidence that attention can be redirected to information not available within the immediate environment, the research of Kane, Engle and colleagues (Engle, 2002; Kane & Engle, 2002) suggests this ability is subject to individual differences. To date, individual differences in working memory capacity (classically measured by way of ospan; Turner & Engle, 1989) have been linked to disparity in the ability to suppress proactive interference while retaining relevant information (Unsworth & Engle, 2007; Rosen & Engle 1997), override reflexive responses (Kane, Bleckley, Conway & Engle, 2001) and are associated with general fluid intelligence (i.e. reasoning and novel problem solving; Engle, Tuholski, Laughlin & Conway, 1999).

The possibility that such processing disparity could occur within Neely's (1977) study is not without precedent. Balota, Black, and Cheney (1992) used a paradigm similar to that of Neely[1] to explore the possibility that attention-based priming is impaired in older adults. The results indicated that priming based on expectations is deficient for older participants. In particular, older adults seem to have difficulty maintaining expectancy for a coming target word (Experiment 1) over longer delays (1750 ms) as well as occasionally failing to suppress associated information when they are required to switch categories (seen across all three experiments). Similar to the younger adults, older participants showed priming for unassociated word pairs at stimulus onset asynchronies (SOAs; the time from presentation of prime to presentation of the target) of up to 1000 ms, but unlike the younger group priming disappeared at 1750 ms. Support for the conclusion that older participants experienced difficulty maintaining target expectancies was provided by Experiment 2, in which the prime word remained on

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[1] The primary difference between Balota, Black and Cheney (1992) and Neely (1977) was the substitution of a pronunciation task, which simply requires participants to speak the target word into a microphone, in place of a LDT. Such a task removes processes involved in judging the status of a string of letters as a word or non-word. The main issue being that, since a non-word target cannot be related to the prime, the relationship between prime and target can be utilized to speed responding to associated words. If this process is enacted, response times to unrelated prime/target pairs will be slowed, as participants will favor responding "non-word" to unassociated pairs (Neely & Keefe, 1989). For this reason, pronunciation is considered to be a cleaner measure of expectancy and association and is utilized in the current study.

the computer screen throughout the entire SOA. In this experiment, older participants were capable of maintaining unassociated expectancies regardless of the time from the onset of the prime to presentation of the target. However, the older adults additionally showed greater priming for targets from which attention had been diverted, relative to Experiment 1.

A second finding of Balota et al. (1992) was that of a significant expectancy × relatedness × SOA interaction for young adults. Balota et al. interpreted this to mean that as use of expectancy for possible targets increases, an equivalent decrease of relatedness based processing occurs. An important implication of a relationship between expectancy and relatedness which lacks independence is that inhibition of automaticity need not be invoked as a process, but can be explained as interference of automatically generated information caused by attention being focused on consciously generated categories. Curiously, this interaction was absent for the older participants.

As has been previously mentioned, the work of Kane and Engle (Engle, 2002; Kane & Engle, 2002) suggests that the ability to engage attention for controlled processing varies within the general population. Recently, Hutchison (in press) examined expectancy-based priming as a product of attentional control (AC; measurement described in methods) through manipulating participants' knowledge of the likelihood that a given prime would be related to the upcoming target word. The manipulation was achieved though color coding prime words such that when they appeared in green there was an 80% chance the prime would be related; however, when the prime was printed in red the likelihood of relatedness dropped to 20%. Counter to the assertion attributed to Posner and Snyder (1975) and Neely (1977) that attention required more than 300 ms to engage, participants who had measured high in AC were able to utilize the prime information to facilitate responding for primes in the high-relatedness-probability condition (relative to the low-relatedness-probability condition) at an SOA of 267 ms. For moderate AC participants, no evidence of expectancy was seen at this SOA, while low AC participants showed less priming in the high-relatedness-probability condition, suggesting the attempt to utilize expectancies interfered with responding.

From the studies described above, it can be concluded that the results of an experiment utilizing a paradigm such as Neely (1977) or Balota et al. (1992) will be subject to participants ability to successfully control attentional processes. Because these studies were respectively conducted at Yale and Washington University, both of which are highly selective institutions, the possibility exists that participants may have been ideally suited for the paradigm, especially since a link between AC and general fluid intelligence has been established (Engle, Tuholski, Laughlin & Conway, 1999). If this assumption is valid, a study that takes into account individual differences in AC may reveal fresh insight into the processes at play. Particularly, one might assume that participants with high AC will show greater ability to direct attention to unrelated target categories, while also avoiding associative information activated by prime words. These abilities should diminish with low AC, if attention is truly driving priming for unrelated prime/target pairs. The results of Hutchison (in press) suggest that for low AC participants, expectancy generation should not be seen and the additional demand of inhibiting environmentally activated information should create further difficulty.

As the main task in the current study will conceptually replicate Balota et al. (1992), an interpretation of their categories as well as an interpretation of their data is necessary.

## Interpretation of Balota, Black, and Cheney (1992)

In the Balota et al. (1992) paradigm, four categories are used to create the major conditions of Neely's experiment (1977). An example of how the categories might be set up within an experimental block is given in Table 1, with two category names appearing

Table 1

*Critical Conditions of Balota, Black and Cheney (1992)*

| Relatedness | Expected | Unexpected |
|---|---|---|
| Related | BIRD-robin | BUILDING-door |
| Unrelated | BUILDING-arm | BIRD-pistol |

*Note.* When participants are presented with the category BIRD they are instructed to focus attention on the category of BIRD. When BUILDING is presented they are instructed to focus attention of the category of BODY.

as primes in the shift-attention condition and in the no shift condition. One difficulty in interpreting the results of Balota et al. as well as the results of the current study is that Neely's *XXXX* baseline has been removed, and instead expectancy and relatedness are calculated through different combinations of the conditions presented in Table 1 (citing Jonides & Mack, 1984, Balota et al. called into question the legitimacy of such a baseline). Since some categories are assumed to take advantage of processes that others cannot, it was reasoned that one could serve as a baseline for another (in place of Neely's, *XXXX-as-a-prime* baseline) and the total difference in reaction time (RT) could be attributed to specific processes. For instance, neither unexpected/unrelated nor expected/unrelated conditions (see Table 1) contain an association between the prime and target words. Therefore, facilitated responding to expected/unrelated targets when compared to unexpected/unrelated targets can be attributed solely to attentional processes activated by the participant.

Expectancy in the Unrelated Condition

Regarding the two types of expectancy reported by Balota et al. (1992) and shown in Table 2, the reader will note the *Related* column reports an attempt to estimate expectancy generation under conditions in which participants are not required to make a shift of attention to an unassociated category, whereas expectancy in the *Unrelated* column applies to times when the participant needs to make such a shift to facilitate responding. While the Unrelated column provides a reasonable measure of expectancy generation, uncontaminated by preexisting association, a clear line has not been drawn between expectancies and relatedness under conditions where the prime and target are both expected and related. For this reason, serious concerns surround some of the conclusions of Balota et al. and discussion of expectancy and relatedness in the expected/related condition will be postponed until situations involving shifts of attention have been explained. Of all types of prime/target trials (see Table 1) the unexpected/unrelated condition (prime: BIRD; think: BIRD; see: pistol) is the only category for which neither expectancy nor association will facilitate responding. In calculating expectancy in the unrelated situation, Balota et al. (1992) subtracted RTs to targets in the expected/unrelated condition (prime: BUILDING; think: BODY; target: arm) from RTs for targets in the unexpected/unrelated condition. As both categories

Table 2

*Expectancy and Relatedness Effects (in ms) as Reported by Balota, Black and Cheney (1992), Experiment 1- Younger Adults*

| | Expectancy (attentional) effects | | |
|---|---|---|---|
| SOA | Related (non-shift) | Unrelated (shift) | Mean |
| 250 ms | 15 | 0 | 8 |
| 1000 ms | 26 | 11 | 18 |
| 1750 ms | 23 | 27 | 25 |
| Mean | 21 | 19 | 17 |
| | Relatedness (automatic) effects | | |
| SOA | Expected (non-shift) | Unexpected (shift) | Mean |
| 250 ms | 13 | -2 | 6 |
| 1000 ms | 12 | -3 | 5 |
| 1750 ms | -2 | 2 | 0 |
| Mean | 8 | 0 | 4 |
| | Standard Priming Effects | | |
| SOA | Expected/Related | Unexpected/Unrelated | Priming Effect |
| 250 ms | 519 | 532 | 13 |
| 1000 ms | 470 | 493 | 23 |
| 1750 ms | 471 | 496 | 25 |

*Note.* Standard priming effects were calculated by subtracting mean reaction times for targets that were both expected and related from mean response times that were neither expected nor related. This information was not reported within Balota et al. (1992).

effectively contain the same prime and target (once counterbalancing occurs), any priming that is seen can be attributed to the shift of attention to the appropriate unrelated category required in the expected/unrelated condition. This method of extraction is quite similar to that of Neely (1977) in which he compared RT in the unrelated/expected condition (prime: BUILDING; think: BODY; target: arm) to his neutral condition (prime: XXXX; target: arm) with the exception that the baseline is now primed with a word.

Relatedness in the Unexpected Condition

Similar to the estimation of expectancy described above, relatedness in the Unexpected column resembles the extraction method of Neely (1977). However, in this case it is RTs for prime/target pairs that are pre-associated, but for which expectancy generation has been directed to another category (unexpected/related; prime: BUILDING, think: BODY, target: door) which are subtracted from the unexpected/unrelated RTs. Any priming seen here should be due to failed suppression of pre-associated targets when one shifts attention to an unrelated category. This would appear as a positive number in the Unexpected column of Table 2. On the other hand, when attentional focus successfully inhibits targets in the associated category, the column will either be 0 or a negative number (meaning it takes less time to respond when the target is from the unexpected and unassociated "baseline"). In conjunction with expectancy generation as described above, this column recreates Neely's situations where participants are required to shift attention away from the prime category.

Expectancy and Relatedness within the Expected/Related Condition

The unfortunate issue which plagues the estimation of expectancy and relatedness under conditions where the prime and target are both *related and expected* is that, unlike shift conditions, subtracting expected/related targets from unexpected/unrelated targets yields the overall priming effect which is a mixture of expectancy and relatedness. Therefore Balota et al. (1992) subtracted RTs in the expected/related condition from the conditions in which priming could only be attributed to preexisting association (unexpected/related) or attention (expected/unrelated), but not to both. Although seemingly reasonable, close examination of this method raises serious concerns.

Note on Table 2 that the Relatedness-shift column can be added to the Expectancy-non-shift column to yield the overall priming effect. Similarly the Relatedness-non-shift column can be added to the Expectancy-shift column to reach the same end. The reason for this is simple. The *overall priming effect*, the *Expectancy-shift* and the *Relatedness-shift* columns are respectively equal to the *expected/related*, *unexpected/related* and *expected/unrelated* conditions of Table 1, with the exception that on Table 2 they are seen after having been subtracted from the unexpected/unrelated condition. Therefore, regardless of when subtraction occurs, estimates of expectancy and relatedness on non-shift trials are effectively each shift condition individually subtracted from the *total* priming effect. Why this should be predictive of processing under non-shift conditions was not adequately explained and runs into serious difficulty once one considers that Balota et al. (1992) argued attention is directed at different rates along previously associated and non-associated pathways. These concerns can be further reflected in the observation that expectancy and relatedness in the non-shift conditions are never predictive of the overall priming effect (note that for the non-shift condition at 1750 ms the expectancy and relatedness estimates sum to less than the priming effect).

In effect, the reason the expectancy × relatedness × SOA interaction was found may be a product of the manner of estimate. The priming effect grew at each SOA while relatedness in the shift condition revealed successful “inhibition” of associative information at each SOA. By the subtractive methods listed above, the non-shift expectancy can only grow at each SOA. Expectancy in the shift condition was slow to form at first, but eventually was as large as the priming effect. Therefore, relatedness estimates in the non-shift condition were bound to an inverted pattern; large at first, but shrinking with SOA.

This should not, however, be assumed to be an argument for the independence of expectancy and relatedness, instead it points at the methods for extracting expectancy and relatedness from the expected/related condition. If expectancy and relatedness were independent, the estimates of Balota et al. (1992) would actually work, as the natural decay of spreading activation over time could in fact be subtracted from the priming effect to produce a clean estimate of expectancy. It seems, however, these measurements were created with the notion of independence in mind, but not corrected once the contrary evidence was obtained.

### Current Study

Although concerns have been expressed regarding certain aspects of Balota et al. (1992), the overall setup provides a feasible method for replicating Neely (1977) in the absence of a *XXXX-prime* baseline. Regardless of whether estimates of expectancy and relatedness in the non-shift condition prove viable, an overall priming effect can be calculated, which is consistent with the nature of the non-shift condition reported by Neely. As Hutchison (in press) has already demonstrated a link between AC and expectancy generated for related prime-target pairs, the primary focus of the current study will be exploring situations in which attention must be directed from automatically activated categories. Extending the findings which have been discussed, it is expected that high AC individuals will show the strongest ability to engage such processes, reflected in the expected/unrelated condition. Conversely low AC individuals are expected to show priming for prime-target pairs that possess a preexisting association, regardless of whether attention was shifted.

Additionally, as noted in the introduction, the older adults of Balota et al. (1992) occasionally showed priming for related targets from which attention had been shifted. This occurred despite priming for the shifted-to category. It seems that with diminished attention comes decreased ability to inhibit environmental stimulation, despite the generation of expectancies. As such it is expected this pattern will become evident with lower AC.

As with Neely (1977) and Balota et al. (1992), within each block of trials all participants are exposed to both primes that require attention to be focused on the presented category and primes that signal a need to shift attention to another category. Thus a target can also be expectedly or unexpectedly associated to the prime category. Once again, variable SOAs will be implemented to allow for examination of responses at 250 ms, 1000 ms and 1750 ms. The specific extension of the current study will be, of course, the ability to examine AC as a between subjects variable.

# EXPERIMENT

## Method

### Participants

One hundred two male and female students from Montana State University and twenty one male and female students from the University of Utah participated toward partial completion of an introductory psychology research requirement. All participants were native English speakers with normal or corrected-to-normal, color vision. The data from two participants from Montana State was excluded due to experimenter error. One Utah participant was not analyzed due to failure to meet the requirement that all participants be native English speakers. During analysis, one additional MSU student and two Utah participants were excluded due to below chance performance (accuracy < .4) on the antisaccade task.

### Materials/Procedure

Participants completed one semantic priming pronunciation task and three tasks intended to measure AC (detailed below). The order of presentation was changed every twenty four subjects to account for possible influence of tasks. An examination of pronunciation task results using task order as a between subjects variable, revealed no interactions with task order. All stimuli were created using e-prime software (Schneider, Eschman & Zuccolotto, 2002). Participants were run in individual rooms and seated approximately 60 cm from a VGA monitor on which all tasks were presented. Response times for word naming and Stroop tasks were recorded via microphone attached to a 300 PST serial response box. Each session lasted approximately 50 minutes.

Pronunciation Task Design

Expectancies and relatedness were measured via naming latency using a procedure based upon the pronunciation task utilized by Balota, Black and Cheney (1992). Four categories were presented within each testing block. Two as both primes and targets and two as targets only (see Table 1). Three possible time intervals (50 ms, 800 ms, or 1550 ms) separated presentation of the prime and target words. Categories were rotated between subjects such that words would eventually appear in each relationship shown on Table 1. Additionally, prime and target pairs were separated by each of the previously mentioned time intervals. Therefore a total of 12 versions of the procedure were needed to ensure that each critical target word would appear at each SOA × Relatedness × Expectancy condition.

Categories were selected using Battig and Monague's (1969) norms. In order to accommodate for one practice and three experimental blocks, 16 categories were used. For each category the four most dominant responses served as critical trials. The fifth and sixth words were always preceded by the word READY in place of a category prime. In order to reinforce prime-target contingencies, twenty four additional prime target pairs for the expected-related (12 pairs) and expected-unrelated (12 pairs) conditions were created to serve as buffer trials. Two READY buffer trials were created for each of these categories as well. Presentation was random with the exception that one buffer trial from each of the expected-related and expected-unrelated categories was first presented.

Instructions provided to the participant were taken directly from Balota, Black and Cheney (1992). The instructions were presented via computer monitor as follows:

> For the following block of trials, when you receive the category name [expected-related category name], it is crucial that you think of items from the category [expected-related category name]. However, when you receive the category name [expected-unrelated category name], it is crucial that you switch your attention and think of items from the different category [expected-unrelated category name]. REMEMBER, this is important. Type the digit 1 when you are sure you have the above category instructions completely understood.

Subjects were given an opportunity to ask relevant questions and the experimenter remained in the room until the practice trials were complete.

The sequence of each trial was also an exact replication of Balota, Black and Cheney (1992) and consisted of the following: (a) three centered asterisks separated by spaces for 300 ms; (b) a blank screen for 300 ms; (c) a 150 ms warning tone; (d) another blank screen for 300 ms; (e) an upper case category name [the prime] presented for 200 ms; (f) the variable interstimulus interval; (g) the target word which the participant was required to speak into the microphone. At the conclusion of each trial, participants were required to categorize the sequence, via keyboard, as (1) Correct Pronunciation, (2) Mispronounced, (3) Unsure, or (4) Microphone Error. This coding procedure is an expanded version of the one used by Balota et al. (1992) and was taken from Hutchison (in press). Self coding error by participants has been successfully utilized by Speiler and

Balota (1997) and Balota et. al (2004). The coding response initiated a 2400 ms intertrial interval.

<u>Attentional Control Battery</u>

Attentional control measures were the same used by Hutchison (in press), Experiment 2. The battery consists of ospan (Turner & Engle, 1997), an antisaccade task and a Stroop task. Each task is thought to require unique aspects of controlled attention (detailed below) and therefore when combined will create a more complete picture of AC. Because performance on each AC measure requires additional task-specific abilities (e.g. experience with mathematics should lead to less interference on ospan while visual abilities play a part in Stroop and antisaccade performance), principal components analysis was utilized as the method of extracting common variance underlying performance in all three tasks. As will be shown, the loading pattern matched Hutchison (in press) with ospan and antisaccade loading positively (accuracy should be indicative of AC) and with Stoop RT and error loading negatively (long RT and high errors should be indicative of low AC). The generated component score was utilized as the measure of AC. Attentional control for each participant was therefore measured relative to the results of all other participants.

The ospan measure used in the present experiment is a shortened version (50 items vs. 60 items) of the task originally reported in Turner and Engle (1989). Within this task participants are presented with a series of operation strings (e.g. “is (8/2) + 3 = 7 ? fence) which must be read aloud. After 2–6 such strings, the participants are presented with “?????” at which point they are required to report, in order of presentation, all words which appeared in the set. The experimenter remained in the room throughout this task and manually recorded all responses. If the participant was able to correctly repeat these words, a score equal to the length of the set was added to his or her total. Sets of sizes 2, 3 or 5 items were presented twice while sets of 4 or 6 items were presented three times for a total possible score of 50.

Critical to the current study, solving the mathematical operations disrupts attempts by the participant to rehearse target words. It is therefore imperative that participants utilize attention to maintain targets in a highly accessible state (Engle, 2002).

In the antisaccade task participants are shown a centered fixation point ("+" for either 1000 or 2000 ms) which was followed by an asterisk, presented for 300 ms, 3 degrees to the right or left. Participants were told to look to the side of the screen opposite the asterisk for the presentation of either an "O" or a "Q" (3 degrees from fixation) which is masked with "##" after 100 ms. Due to the rapid presentation, when participants accidentally look toward the asterisk, the target is masked by the time the inappropriate eye movement is overcome. This task can therefore be interpreted as a measure of ability to override reflexive responses initiated by the environment and instead enact goal relevant behavior (Kane et al., 2001). Participants completed 8 practice trials with the experimenter and 48 experimental trials alone.

The Stroop task required participants to read aloud the ink color a word has been printed in while ignoring any information provided by the word itself. Interference can occur if a color word is presented in an incongruent ink (e.g. word: BLUE; ink color: RED) resulting in longer response times and increased errors (i.e. saying the word or response correction [e.g. "blu…green"]). Within this version of the Stroop, participants saw 36 incongruently colored words, 36 congruently colored words and 45 neutral (e.g.

non-color) words. Participants were therefore given minimal environmental assistance in goal maintenance (only 36 of 117 trials required the color-words be ignored). Per Kane and Engle (2003), these conditions should greatly reduce the performance of participants who are relatively low in attentional control.

Preliminary Data Analysis

Performance in the pronunciation and Stroop tasks was measured through reaction time and errors. Only error-free responses which fell between 100 ms and 1500 ms (1450 ms for Stroop) were considered valid reaction times. Of all non-error responses, 0.5% were removed from each task by these time restrictions. Further outliers were removed using the nonrecursive procedure of Van Selst and Jolicoeur (1994). This resulted in removal of 2.3% of all Stroop trials and 3.2% of all pronunciation trials.

For the pronunciation task, expectancy and relatedness estimates were generated using the procedure of Balota et al. (1992) outlined in Table 1. Put simply, the effect of expectancy for a target can be calculated by subtracting response times for situations in which the word is part of an expected category from situations in which it is from an unexpected category. Relatedness is judged similarly, except expectation is held constant and instances involving prime-target relatedness are subtracted from instances which lack such a relationship. Stroop RTs and errors were calculated by subtracting response time and accuracy in the congruent condition from the incongruent condition.

As has been previously stated, ospan score was created by summing the total number of words recalled in sets which were recalled with complete accuracy. Saccade accuracy was the total number of correct responses divided by the number of trials with both short and long fixation periods. These two numbers were averaged to create an overall percentage of correct responses.

## Results and Discussion

### Attentional Control Battery

The correlations between attentional control measures are presented in Table 3 (descriptive statistics provided in Appendix B). Unlike the previous findings of Hutchison (Experiment 2; in press), Stroop RT does not correlate with any other component, while Stroop error correlates with antisaccade performance. This inconsistency is acceptable once one considers that Stroop error is indicative of failure to maintain the goal of responding to ink color (Kane & Engle, 2003). In these instances, participants are unlikely to engage in conflict resolution when incongruent stimuli are

Table 3

*Correlations among Attentional Control Battery Tasks*

| | Ospan | Antisaccade | Stroop RT | Stroop Error |
|---|---|---|---|---|
| Ospan | 1.00 | .19* | -.03 | -.03 |
| Antisaccade | | 1.00 | -.08 | -.23** |
| Stroop RT | | | 1.00 | .08 |
| Stroop Error | | | | 1.00 |

*Note.*

*p < .05 **p < .001

encountered, thus leading to inconsistent response times. The end result is that attentional control within the Stroop is largely expressed in the number of errors made.

As can be seen in Table 4, the relationship between attentional control measures is comparable to that of Hutchison (in press), Experiment 2. The main exception is that Stroop error and RT have changed positions for reasons explained above. This was the only significant component extracted from the measures and accounted for 33.7% of the variance in performance across tasks.

Table 4

*Factor Loadings of Attentional Control Tasks within Principal Components Analysis*

| Task | Current | Hutchison (in press) |
|---|---|---|
| Ospan | .49 | .69 |
| Antisaccade | .76 | .71 |
| Stroop RT | -.32 | -.68 |
| Stroop Error | -.63 | -.38 |

Pronunciation Task

Reaction times from the pronunciation task were entered into a 2 (expectancy) × 2 (relatedness) × 3 (SOA) repeated measures ANOVA with attentional control as a covariate in order to utilize the full scale of attentional control component scores. Additionally, the attentional control factor was divided into tertile segments for purposes of illustration where appropriate.

Mean RTs and error means are shown in Table 5, both overall and separated by their attentional control groups. In addition, Figure 1 shows estimated priming effects separated by Balota et al.'s (1992) expectancy and relatedness measures, respectively.

Table 5

*Mean Response Times (in milliseconds) to Target Words within each Priming Condition*

| | Related | | | | Unrelated | | | |
|---|---|---|---|---|---|---|---|---|
| SOA | Expected | E | Unexpected | E | Expected | E | Unexpected | E |
| | | | | Overall | | | | |
| 250 ms | 564.36 | 0.8 | 560.00 | 1.9 | 562.99 | 0.5 | 564.61 | 1.1 |
| 1000 ms | 528.71 | 1.2 | 532.94 | 1.7 | 522.75 | 0.4 | 545.74 | 0.9 |
| 1750 ms | 523.48 | 0.7 | 528.25 | 1.9 | 519.08 | 0.8 | 539.99 | 1.5 |
| | | | | High AC | | | | |
| 250 ms | 560.96 | 2.0 | 559.45 | 2.4 | 554.97 | 0.8 | 562.45 | 0.0 |
| 1000 ms | 505.81 | 0.8 | 528.22 | 0.8 | 500.10 | 0.8 | 530.48 | 0.0 |
| 1750 ms | 508.60 | 0.0 | 515.30 | 0.0 | 495.02 | 0.8 | 517.04 | 1.6 |
| | | | | Moderate AC | | | | |
| 250 ms | 571.61 | 0.0 | 561.71 | 2.0 | 567.02 | 0.8 | 569.04 | 2.8 |
| 1000 ms | 534.41 | 1.2 | 527.50 | 2.4 | 540.14 | 0.0 | 563.46 | 2.4 |
| 1750 ms | 539.14 | 2.0 | 527.93 | 0.0 | 512.49 | 0.0 | 563.21 | 2.4 |
| | | | | Low AC | | | | |
| 250 ms | 560.51 | 0.4 | 558.84 | 1.2 | 566.99 | 0.0 | 562.33 | 0.4 |
| 1000 ms | 545.90 | 1.6 | 543.11 | 2.0 | 528.00 | 0.4 | 543.29 | 0.4 |
| 1750 ms | 522.71 | 0.0 | 541.52 | 5.6 | 549.73 | 1.6 | 539.71 | 0.4 |

*Note.* E = mean percent errors within condition.

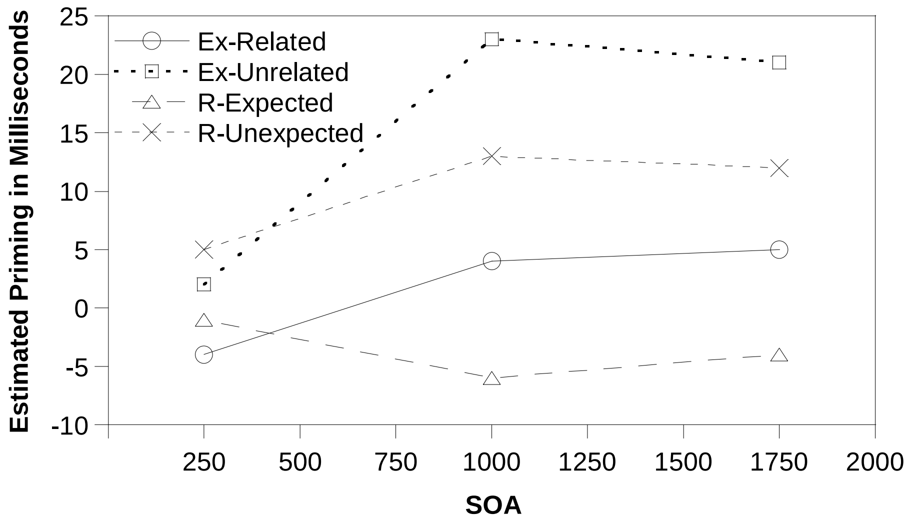


*Figure 1.* Overall expectancy and relatedness by condition as estimated using the methods of Balota et al. (1992). *Ex*- denotes priming attributed to expectancy generation. *R*- denotes priming due to prime-target relatedness.

As can be seen in Table 5, the main effect of SOA was significant, $F$ (1, 122) = 86.63, MSE = 308,364, $p < .001$, $\eta_p^2 = .42$, as well as an interaction between SOA and attentional control, $F$ (1, 122) = 11.18, MSE = 39,804, $p = .001$, $\eta_p^2 = .08$, indicating that differences between attentional control groups became more apparent at longer SOAs. The main effect of expectancy was significant, $F$ (1, 122) = 6.19, MSE = 25,988, $p$ = .014, $\eta_p^2 = .05$, with subjects showing greater priming for expected categories. It should be noted that, although the expectancy × AC interaction was not significant, $F$ (1, 122) = .95, MSE = 3,990, $p = .32$, $\eta_p^2 = .01$, the high attentional control group were the only participants to show this effect as an individual group, $F$ (1, 40) = 8.95, MSE = 26,149, $p$ = .005, $\eta_p^2 = .18$. Additionally, there was a significant interaction of expectancy and relatedness, $F$ (1, 122) = 5.39, MSE = 17,689, $p = .022$, $\eta_p^2 = .04$. As can be seen in

Figure 1, this interaction could be explained by participants typically generating expectancy only for unassociated prime-target pairs in combination with an almost complete lack of relatedness based priming for targets in the expected/related condition, however for reasons given in the introduction, caution should be taken in the interpretation of this observation. Consistent with both Neely (1977) and Balota et al. (1992), significant interaction of expectancy by SOA, $F(1, 122) = 4.39$, MSE = 12,646, $p = .038$, $\eta_p^2 = .04$, was seen, with expectancy effects markedly higher at both 1000 and 1750 ms SOAs than at 250 ms.

Furthermore a four way interaction of expectancy, relatedness, SOA and attentional control was obtained, $F(1, 122) = 4.76$, MSE = 16,543, $p = .031$, $\eta_p^2 = .04$. It has already been pointed out that the raw data in Figure 1 can be somewhat difficult to interpret, so in order to more clearly scrutinize the interaction, several aspects will be explained individually.

Expectancy within AC Groups

As can be seen in Figures 2-5, although expectancy was significantly ($p < .001$) generated for unrelated targets, this effect only seen for High and moderate AC groups. When taken in conjunction with the previously discussed results of Hutchison (in press), it was an unsurprising finding that high AC participants generated expectancy more

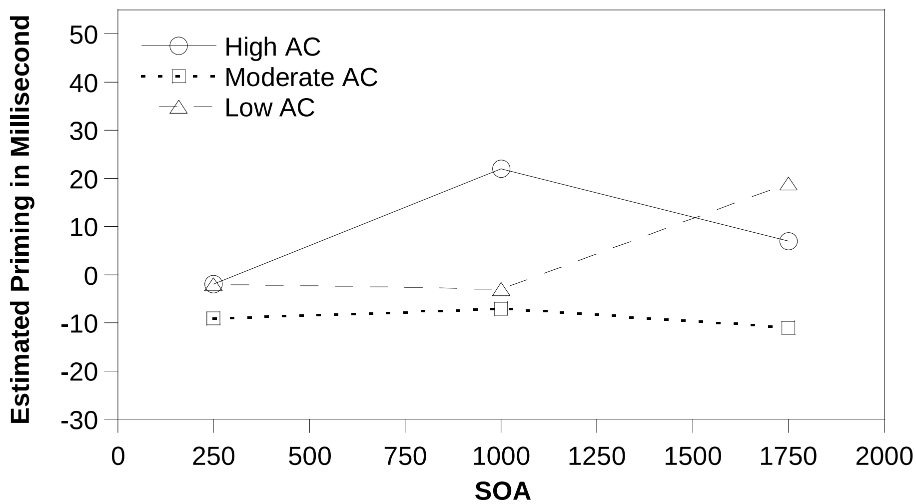


*Figure 2.* Estimated priming due to expectancy when prime and target are related.

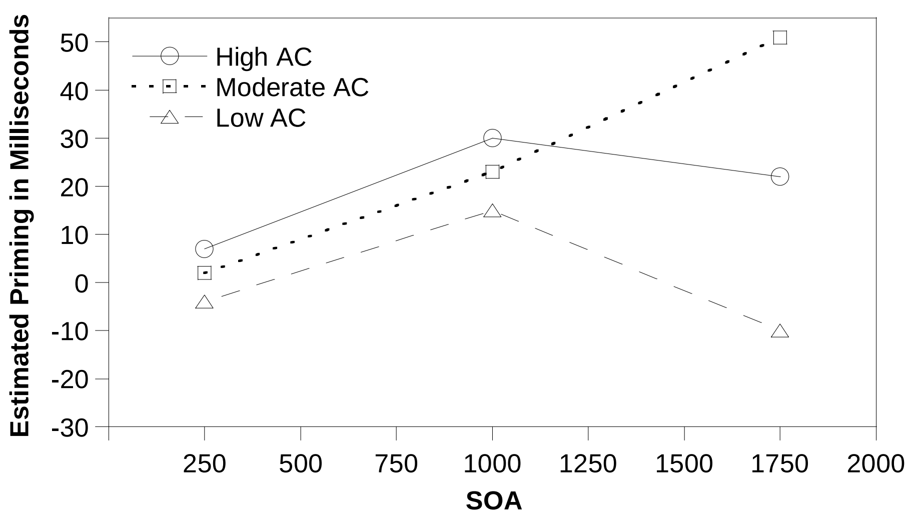


*Figure 3.* Estimated priming due to expectancy when prime and target are unrelated.

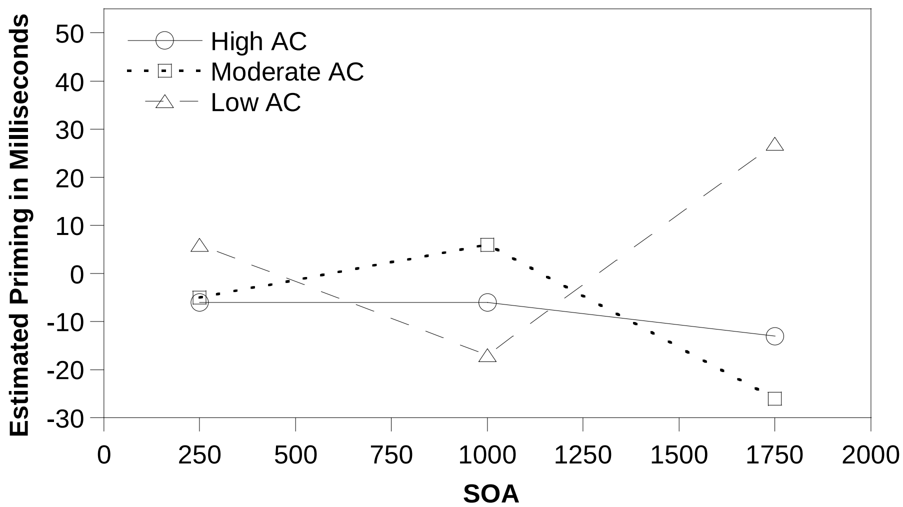


*Figure 4.* Estimated priming due to prime-target association when relatedness is expected.

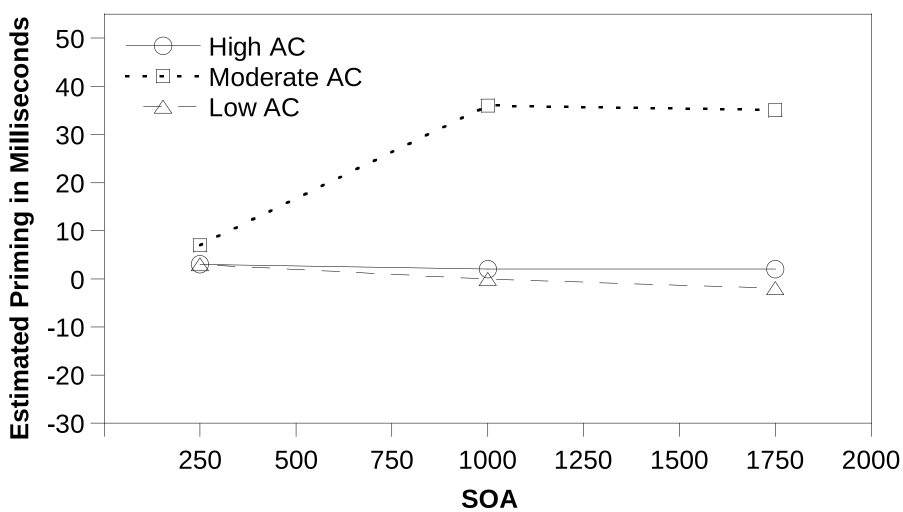


*Figure 5.* Estimated priming due to prime-target association when relatedness is unexpected.

quickly than those in the moderate AC group, however what was rather shocking was that overall, moderate AC participants were actually generating expectancy for unrelated targets which was equivalent to their high AC counterparts. This was reflected in a lack of correlation between expectancy generation for unrelated targets with AC, which only reached marginal significance ($r = +.173$, $p = .055$) by the long SOA. Low AC participants failed to generate significant expectancy at any SOA.

Relatedness within AC Groups

Surprisingly, relatedness played a significant ($p = .03$) role in RT for unexpected targets. The implication of this finding is that many subjects failed to inhibit associative information, even as they were showing a large buildup of expectancy. An examination of Figure 5 shows this trend to be particularly pronounced in the moderate AC group. At the same time, by the standards of Balota et al. (1992), automatic and attentional processes for target words which are expected and related look to be inhibited in general (Figure 4). For further elucidation of this interesting pattern, we turn now to the current data, presented from the perspective of traditional semantic priming experiments.

Traditional Priming Effects

Balota et al. (1992) never reported the more traditional interpretations of their findings, possibly because in their case this would have added little to the discussion. However while examining participants within the realm of individual differences, particularly for results which do not cleanly match previous studies, such information has proven particularly telling.

In order to examine classic priming effects, a 2 (Expected/Related condition vs. Unexpected/Unrelated condition) × 3 (SOA) repeated measures ANOVA was conducted. Table 6 provides the results comparing RTs in the expected/related condition against the unexpected/unrelated condition. This is a more traditional view of priming data where expectancy and association should work together to predict the eventual target relative to a situation where neither expectancy nor association have a predictive influence (due to counterbalancing the same set of target words appear in both situations). An overall significant priming effect was found, $F$ (1, 122) = 5.49, MSE = 23,788, $p$ = .02 , $\eta_p^2$ = .04, and a main effect of SOA, $F$ (1, 122) = 37.65, MSE = 132,102, $p$ < .001, $\eta_p^2$ = .24, indicating overall faster responding over time and for targets which were expected and

Table 6

*Traditional Priming Effects (in ms)*

| SOA | Overall | High AC | Moderate AC | Low AC |
|---|---|---|---|---|
| 250 | 0.25 | 1.49 | -2.57 | 1.83 |
| 1000 | 17.04* | 24.67* | 29.05† | -2.61 |
| 1750 | 16.51* | 8.45 | 24.08 | 16.99 |
| Mean | 15.17* | 19.96* | 25.35* | 5.40 |

*Note.* Priming effects generated by subtraction of expected/related category from unexpected/unrelated.
†p < .10 *p < .05

related. Additionally a marginal interaction of priming and SOA $F$ (1, 122) = 2.95, MSE = 8,277, $p$ < .09, $\eta_p^2$ = .02, suggested priming increased at the longer SOAs. Here it can be seen that participants are indeed showing standard priming effects, despite the lack of evidence provided by viewing the data from the perspective of Balota et al. (1992; e.g. Figures 1 and 2-5). The main exception is the 250 ms SOA where facilitated responding is not apparent for any participants. This point will be returned to in the general discussion.

## Expectancy in Opposition to Relatedness

Figures 1 and 2-5 provide a fairly clear estimate of expectancy and association in situations where a shift of attention is made, since relatedness and expectancy have each been calculated against the same relatively neutral baseline (in fact the same one used to calculate traditional priming). This is the point where conceptualizations of expectancy generation and expectancy utilization as the same process begin to break down. Although not an issue in Balota et al. (1992) where the younger adults showed high performance in expectancy utilization, the current study reveals a confound as moderate AC participants are generating expectancy during attention shifts while still utilizing the automatic processing of associations between unexpectedly related prime/target pairs. The problem is that by subtracting RTs of expected/unrelated targets from unexpected/unrelated targets, the influence of the environment, which should work in opposition to the attention shift, was neutralized. In order to reinstate this influence, RTs for expected/unrelated targets (prime: BUIDING; think: BODY; target: arm) and unexpected/related targets (prime: BUIDING; think: BODY; target: door) were directly compared.

As can be seen in Table 7, the results reveal a situation which closely resembles traditional interpretations of interplay between expectancy, relatedness and attentional control. Across groups, the high AC participants were the only group to show any expectancy utilization ($p < .04$) relative to contradictory environmental associations. For moderate AC participants, utilization of generated expectancies seems to have been

Table 7

*Expectancy versus Relatedness Effects (in ms)*

| SOA | Overall | High AC | Moderate AC | Low AC |
|---|---|---|---|---|
| 250 | -2.99 | 4.49 | -5.30 | -8.14 |
| 1000 | 10.19 | 28.16* | -12.64 | 15.11 |
| 1750 | 9.17 | 20.28 | 15.44 | -8.21 |
| Mean | 5.46 | 17.63* | -0.84 | -0.42 |

*Note.* Values calculated by subtracting expected/unrelated from unexpected/related. Negative numbers indicate faster responding for associations, positive numbers indicated faster responding for expectancies. *p < .05

disrupted by environmentally opposed information. Overall the only significant main effect was for SOAs, $F$ (1, 122) = 50.43, MSE = 177,967, $p < .001$, $\eta_p^2 = .29$, and the only interaction was SOA by AC, $F$ (1, 122) = 15.25, MSE = 53,836, $p < .001$, $\eta_p^2 = .11$, with the implication that participants were better at suppressing automatic associations at long SOAs. This was most pronounced in the high AC group.

Errors

Errors, which are reported in Table 5, are the percentage of trials in which participants reported mispronunciation or unsure pronunciation of words. A main effect of expectancy was significant, $F$ (1, 122) = 5.64, MSE = .021, $p = .019$, $\eta_p^2 < .05$ with most errors occurring when the target word was not in the expected category. Relatedness effect in errors only reached marginal significance, $F$ (1, 122) = 2.77, MSE = .009, $p = .097$, $\eta_p^2 = .02$, and was, somewhat surprisingly, more due to errors when words were associated. These errors became more prominent across SOA and with lower attentional control as revealed by a significant interaction of relatedness, SOA and attentional control, $F$ (1, 122) = 5.56, MSE = .018, $p$ = .018, $\eta_p^2 < .05$, as well as a marginal interaction of SOA and attentional control, $F$ (1, 122) = 3.63, MSE = .011, $p$ = .059, $\eta_p^2 = .03$. Additionally, a significant four way interaction of expectancy by relatedness by SOA by AC, $F$ (1, 122) = 7.23, MSE = .024, $p$ = .008, $\eta_p^2 < .06$ arises from a combination of the previously described interactions and the tendency of low and moderate AC participants to commit significant errors in categorically opposite directions.

# GENERAL DISCUSSION

The current results (best represented by viewing Figure 1 and Table 6) show overall patterns of responding consistent with previous results obtained by Neely and Balota et al. (1992) in that participants showed the ability to engage in standard semantic priming while occasionally using attention to facilitate responding to categories which were unrelated to the prime. However, looking at the Expected/Unrelated condition on Figures 2-5 it is clear that this ability was the domain of high and middle AC groups. Significant priming effects never materialized for the low AC participants, likely due to a combination of a task which poses ever changing demands and a general inability to break from environmental stimulation,.

Additionally, as predicted in the introduction, the expectancy and relatedness estimates of Balota et al. (1992) did not provide reliable estimates of priming when participants focused attention on the visually presented category. Across Figures 2-5 few signs of priming were seen for non-shift conditions. As indicated by Table 6, this did not translate to an absence of overall priming effects. It would seem that expectancy generation does indeed grow at different rates depending upon whether attention is being shifted, making estimates of non-shift conditions, which are based on responding in shift conditions, unworkable.

## Expectancy Generation vs. Expectancy Utilization

Although two of the three groups in the present experiment were capable of generating expectancies relative to a *neutral* baseline, only the high AC group showed priming relative to environmental inconsistencies. This opens the door to the possible clarification that generation of expectancies and utilization of expectancies can be seen as separable. In other words, some people have more difficulty overriding the environment than others, despite an equally strong ability to generate possible targets in a non-associated category. The young adults in Balota et al.'s (1992) study did not show such a dissociation; however, one will note that at several points over the course of three experiments, older adults did show a relationship between expectancy and relatedness in unsupportive environments which is similar to that displayed by the moderate AC group in the current experiment. At any rate, the current data serve as a warning that measuring expectancy against a neutral baseline is not the same as measuring the ability to utilize expectancy within an unsupportive environment.

Balota et al. (1992; see page 497) noted a situation similar to that of the moderate AC group. After collapsing across several studies which utilized a similar paradigm (Balota et al., 1992; Neely, 1977; Burke, White, & Diaz, 1987; Favereau & Segalowitz, 1983), it was found that, at long SOAs, automatic processing in expectedly related pairs combined to -7 ms while in unexpectedly related pairs it reached 48 ms. As an explanation, Balota et al. offered that for expected categories participants received an expected target and therefore associative information was not needed, while in unexpected situations, expectations were not met, leaving participants to fall back on the most readily available information. As a counter explanation, the current data support the possibility that some participants have difficulty inhibiting automatically generated information, even as expectancies are being generated. Whether or not this is observed depends on the overall attentional capacity of the sampled group of participants.

## Absent Priming at 250 Milliseconds

One notable issue with the current findings is a lack of priming effects at the 250 ms SOA. This is possibly due to the paradigm being, in essence, a task switching environment (Allport, 1994; Monsell & Driver; 1995) in which the presented stimuli cue appropriate behavior. De Jong (2000) as well as Nieuwenhuis and Monsell (2002) have argued that among other factors, successful reorganization of task set requires preparation time and may be subject to the abilities of the individual. The current results seem to provide evidence in support of such a position as each AC group requires more time to display signs of utilization of expectancy and automaticity (it should be noted, however, that the low AC group never actually reached significant effects of either process). Recall that in a paradigm that required participants to simply decide whether or not to generate expectancy for already associated categories, Hutchison (in press) found that such instructions were disruptive to responding for low AC participants, neutral for moderate AC participants and helpful for high AC participants, particularly at short SOAs. It is not unreasonable to assume that further instruction to randomly switch attention to an unassociated category which must be held in (or quickly recalled to) active memory would increase disruption. This however is speculative and will require further experimentation, such as an attempt to add participants with higher AC which, it is assumed, will be similar to the participants of Neely (1977) and Balota et al. (1992). What is important to the current study is that traditional priming was found overall, indicating participants were taking advantage of either associative or internally generated information.

## Implications of Estimates of Expected/Related Condition

As can be seen in Figures 2-5 along with Table 6, the subtractive methods of Balota et al. (1992) do not reflect the actual priming effect in the current study. Certainly, the current reasoning that generation and utilization of expectancies are not conceptually equal must be made to conform to the assumption that relatedness and expectancy are not independent. The very fact that Balota et al.'s methods of dividing the expected/related category fail to predict the priming effect demonstrates that what happens in a shift condition cannot be used to estimate processing in the non-shift condition. Overall the main conclusion of Balota et al. is supported with the clarification that in truth expectancy *utilization,* not generation, is what interacts with relatedness.

## Conclusions

The major advance Balota et al. (1992) attempted to provide over Neely (1977) was the ability to estimate the roles of expectancy and relatedness in the expected/related condition across SOAs. Unfortunately, there is reason to call into question the validity of these methods of extraction. However, at the very least, Balota et al. (1992) still serves as a replication of the results of Neely (1977) with the added benefit of showing that the attentional capabilities of the participant (in this case older adults) can have an effect on the results. When one accounts for the priming effect shown on Table 6 in conjunction with the unrelated expectancy generation and utilization results of Figures 2-5, the current study replicates Neely (1977), with the addition of demonstrating that performance within this paradigm is subject to attentional capabilities beyond age-related decline as well as a pointing out that seemingly equal expectancy generation between individuals can have vastly different outcomes when placed in opposition to the environment.

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# APPENDIX A

## DESCRIPTIVE STATISTICS FOR THE

## ATTENTIONAL CONTROL BATTERY

DESCRIPTIVE STATISTICS FOR THE ATTENTIONAL CONTROL BATTERY

| Task | Mean | SD | Range |
|---|---|---|---|
| Ospan | 10.44 | 7.33 | 0, 39 |
| Antisaccade | 74.83 | 12.63 | .44, 1.0 |
| Stroop RT | 136.13 | 60.04 | -16.54, 344.85 |
| Stroop Error | 5.41 | 4.50 | 0.0, 36.00 |