ATTENTIONAL CONTROL AND ASYMMETRIC PRIMING

by

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ABSTRACT

The current research examined the relation between attentional control and strategies used during a lexical decision task. Participants completed a battery of three attentional control tasks and also performed a lexical decision task with symmetrical (e.g., brother, sister) or asymmetrical associated items presented in either the forward (e.g., stork, baby) or backward direction (e.g., baby, stork). Results indicated that individuals higher in attentional control showed greater priming for forward associates, but no priming difference in attentional control for backward associates. Further, equal priming occurred for symmetrical associates regardless of attentional control. Results thus illustrated that both high and low attentional control participants used a retrospective semantic matching strategy, while participants high in attentional control used an expectancy generation strategy. Implications are discussed in terms of existing strategies of attentional control and semantic priming.

INTRODUCTION

While reading, semantic (meaning) context is critical to readers' comprehension. Readers often use semantic clues found in the surrounding written context in to provide insight into the meaning of a difficult or unknown word. Individuals' awareness of the word's semantic context accelerates their reading rate by allowing them to predict upcoming words in advance. Further, reading rate increases when generated predictions match upcoming words.

The semantic priming paradigm is the most common method used to investigate contextual influences during reading. Semantic priming when individuals respond faster to a target word when it is preceded by a semantically related prime word, compared to an unrelated prime. A lexical decision task provides evidence for semantic priming (Neely, 1976), in which individuals must identify whether a target letter string is a word or non-word (see McNamara, 2005, for a review). Various theories have been proposed to explain semantic priming.

Theories of Semantic Priming

Posner and Snyder (1975) developed an influential two-process theory of priming effects on performance in a lexical decision task. This theory involves both automatic spreading activation (ASA) and strategic expectancy generation processes. Keefe and Neely (1990) later modified this to a 3-process theory by adding a third, retrospective semantic matching, process. The first process of the 3-process theory involves ASA (Collins & Loftus, 1975). When seeing or hearing a word, its mental representation becomes activated and this activation spreads across pre-associated lexical pathways (Anderson, 1982, but see Lorch, 1982, for evidence against the "spread" of activation explanation). Activation spreads more quickly or strongly, the stronger the association between two words. For example, when the prime *cat* activates a "cat" representation in memory, activation then spreads to "prime" other related representations (e.g., *dog, pet, claws*, etc.). When a target such as *dog* is later presented, lexical access will occur more quickly than if the target was preceded by an unrelated prime. This is attributed to the fact that the "dog" representation was pre-activated in memory.

The second, expectancy generation process occurs when participants presumably become aware of the frequent pairings of related prime-target pairs in an experiment and use the prime word on a given trial (e.g., *cat*) to develop a conscious expectancy for related targets (e.g., *dog, claws, pet,* etc.). In addition, the visual presentation of the target word activates a set of visually similar words in memory. During conditions of expectancy generation, an exhaustive search of the expectancy set occurs before attention is allotted to the visual set. Facilitation of the speed of lexical access for the target occurs if the target corresponds with an item in the generated expectancy set. However, if the prime and target are unrelated to one another, the time participants spend searching through the generated expectancy set will delay search of the visual set, hindering the speed of recognition (Neely, Keefe & Ross, 1989, Becker, 1980).

Keefe and Neely (1990) suggested that a third process, retrospective semantic matching, occurs for lexical decision tasks in which most of the prime-target word pairs are related. This process is considered retrospective because it takes place after target lexical access. Specifically, participants check back after target lexical access to determine whether or not the prime and target are related (Balota & Lorch, 1986). Given a semantic match can only occur for word trials, the existence of a relation leads to a bias to respond “word,” whereas the absence of a relation leads to a bias to respond “non-word.” If the prime and target are related, the “word” bias will speed responses. However, if the prime and target are unrelated, the “non-word” bias will speed responses to non-words but slow “word” responses to unrelated words, while also increasing errors.

The two prospective processes (ASA and expectancy generation) imply that prime presentation has a forward-acting influence on target processing for related targets, giving them an advantage (e.g., faster response time) when compared to unrelated targets (Thomas, Neely, & O’Connor, 2011). In contrast, retrospective processes imply that target presentation has a backward-acting influence on target processing, such that the participant checks back after target presentation in order to determine if the prime and target are related to one another. These prospective and retrospective priming processes can presumably be observed by measuring priming from prime and target pairs that are directionally associated (e.g., stork- baby). Asymmetric associates are pairs in which one word (e.g., stork) elicits the other (e.g., baby) as a word association response, but not vice-versa. In contrast, symmetric associates are pairs in which both words equally elicit one another as a word association response (e.g., brother-sister). Forward associated pairs are used to test for prospective priming mechanisms because the prime (*stork)* elicits the target *(baby)*, but not vice-versa. After prime presentation, participants must generate and maintain expected targets (only for expectancy generation, but not ASA).

In contrast, retrospective semantic matching does not require participants to maintain expected targets in memory, but rather, involves a memory search following target onset. Thus, participants may rely on a semantic matching strategy because it does not require continual effort and is less demanding than expectancy generation. The absence of semantic matching in a pronunciation task is evidenced by no priming for backward associated pairs (e.g., baby-stork) (Keefe & Neely, 1990, but see Kahan, Neely & Forsythe, 1999, for evidence of backward priming in pronunciation). This makes sense because simply knowing that the prime and target are related does not help participants to pronounce the target. Instead, priming for backward associated pairs should only arise from a post-lexical semantic matching.

Neely, Keefe, & Ross (1989) provided evidence for both prospective and retrospective priming mechanisms using a lexical decision task in which category name primes (e.g., furniture) preceded targets that were either high dominance (e.g., chair) or low dominance exemplars (e.g., stool) of the category. They argued that semantic priming should increase in magnitude as the proportion of related word-prime/word-target trials increases (RP- proportion of related trials). This is expected because generating an expectancy set is more beneficial the higher the probability that a related target will follow the prime. In contrast, an increase in nonword ratio (NR- proportion of unrelated trials with word targets, .08 to .75) should increase the use of strategic, semantic-matching mechanisms, due to an increase in the probability that unrelated pairs involve non-word targets. In their experiment, Neely et al. orthogonally manipulated the RP (.20 to .89) and NR (.08 to .75) in a lexical decision task. Traditionally RP and NR had been confounded with each other whenever RP is manipulated, because researchers typically keep the overall proportion of non-words constant.

Neely et al. (1989) predicted that if the prime is used to generate an expectancy, then lexical access is facilitated for high dominance exemplars because the expectancy set is more likely to include these exemplars. Therefore, the greater the proportion of related pairs, the greater should be the effect on priming for high dominance exemplars. When unconfounded with effects of NR, increases in RP increased priming for high dominance targets, but had little effect on priming for low dominance targets. These results are consistent with the view that RP effects can be attributed to the use of an expectancy generation strategy. In contrast, when unconfounded with effects of RP, increases in NR (equally) increased priming effects for both high and low dominance targets. This result is consistent with Hutchison's (2003) argument that the backward association from target to prime is at least as strong among low dominance targets as for high dominance targets.

Given that both prospective and retrospective strategies influence semantic priming in the lexical decision task, an interesting question concerns the extent to which either strategy requires controlled processing and whether there may be individual differences in strategy use. It is not clear whether these two strategies differently require cognitive control. Individual differences in the ability to engage in the generation and maintenance of expectancies, may reflect differences in the ability to engage in complex mental processes. Therefore, the aim of the current experiment is to determine whether individual differences in the ability to control attention will influence the type of strategies participants may employ.

Attentional Control and Strategy Use

Kane, Bleckley, Conway, and Engle (2001) argued that attentional control (AC) is a crucial component of working memory capacity (WMC). AC is a person's ability to maintain information in a highly accessible state despite environmental or habitual distractions (Kane & Engle, 2002). WMC is an individual's ability to maintain information in an active state. This maintenance is particularly important when interference (e.g., ongoing tasks) is present. Typical WMC tasks require participants' to maintain information in memory, while also ignoring interference from other ongoing tasks or distractions. Individual differences found in WMC tasks reflect both short term memory and restrictions in the allocation of attention for the current task at hand, especially when interference or distractions are present (Engle, Kane & Tuholski, 1999). This account predicts that WMC differences will become evident in tasks that demand controlled processing. Kane, et al. (2001) used an Antisaccade task to establish that individual differences in WMC predict differences in visual attention. In the Antisaccade task a cue is presented on one side of a computer screen and participants are instructed to look on the opposite side in order to detect a target. This task requires participants to act contrary to habit (looking towards the cue). If the participant acts in accordance with habit, they will not have adequate time to direct their attention to the target. High WMC participants made less incorrect saccades than low WMC participants. These results are consistent with the idea that WMC partially involves the ability to control interference over habitual responses in order to maintain and execute task goals.

Kane and Engle (2003) suggested that memory processes alone could not explain the co-variation found in WMC in regards to higher order cognition tasks such as reading comprehension (Conway & Engle, 1996), therefore, they argued that WM = short term memory + AC. Research illustrates that WMC correlates with higher order cognition, but simple short term memory tasks (e.g., recalling a string of presented digits) do not (Cantor, Engle & Hamilton, 1991). Kane and Engle (2002) also contended that the predictive utility of WMC was driven by the controlled attention component of the system. They also concluded that individuals differ in their prefrontal cortex functioning and this variation presumably drives differences found in AC. Similarly, Norman and Shallice (1986) described controlled attention as a "supervisory attention system" that is occupied during conflict (e.g., acting contrary to habit) among various actions. If the goal in a task is not maintained or is momentarily lost, then the individual can be distracted by other stimuli and perform poorly on the task. Research has investigated whether these individual differences in AC influence the ability to engage in expectancy generation.

Hutchison (2007) examined how AC can moderate the use of an expectancy strategy in a pronunciation task, arguing that individuals should differ in their ability to engage in this presumably effortful strategy. Hutchison modified a semantic priming task such that the color of each prime word indicated whether it would likely be followed by a related (high- RP) or an unrelated (low-RP) target. By varying the degree of RP (22.2, 77.8) and the time between the display of the prime and target (or stimulus onset asynchrony [SOA], 267 ms, 1,240 ms), Hutchison found that RP effects (i.e., more priming from high vs. low RP items) increased as AC increased. The pattern of RP effects differed in Experiments 1 and 2. However, in both cases, only high AC individuals showed significant RP effects at both SOAs. This indicated that high AC individuals were able to develop an expectancy quickly, but also maintain the generated expectancy after prime presentation. These findings supported the assumption that RP effects reflect controlled expectancy generation rather than an automatic process, and that the use of expectancy generation occurs more frequently for high AC individuals than low AC individuals. Hutchison also established a battery of tasks (OSPAN, Stroop, & Antisaccade) that effectively measure AC and account for more variance in RP effects than any one task independently. The current task demands specifically set out to test between expectancy generation and semantic matching, while also replicating and extending Hutchison's results in a lexical decision task.

Experiment Overview and Hypotheses

The current experiment used Hutchison's (2007) AC battery to predict priming in a lexical decision task. Priming in lexical decision tasks presumably reflects both prospective and retrospective strategic processes. Given higher AC is associated with the ability to maintain information in an accessible state, it is possible that high AC individuals will use an expectancy generation strategy, whereas AC individuals will use a semantic matching strategy, and this may be evident from the priming effects observed in

LDTs. Recently, such forward-acting versus backward-acting control strategies, as reflected by expectancy generation and semantic matching, have been termed “proactive” and “reactive” forms of control by Braver, Gray and Burgess (2007). Braver et al. (2007) argued that proactive control requires effort, is metabolically taxing, maintains contextual information in memory prior to target onset, and therefore requires predictive cues from the environment. For example, a person needing to stop at the grocery store on their way home from work might use a proactive strategy by continuously reminding themselves throughout the day that they must stop at the store. This type of control is very effective, but also demands energy and interferes with other ongoing activity. Proactive control is also a prospective, or forward-acting and future-oriented, process. In contrast, reactive control is automatically-triggered by target onset and involves retrieving prior context information from long term memory. It is a retrospective process (backward- acting), in which control is only engaged when needed. The use of reactive control does not require continual effort or monitoring of the environment. For instance, the individual may be reminded to stop at the grocery store as s(he) crosses the intersection where the store is located. Reactive control is less demanding than proactive control, but is also vulnerable to interference (i.e., not noticing the intersection, being distracted by the radio, or accidentally taking a different route). Braver et al. suggested that, in many situations, individuals higher in WMC have the AC necessary to use proactive control strategies. Moreover, high WMC individuals are more likely to use proactive strategies only when the task benefits from it. In contrast, low WMC individuals are unable to use proactive control under most circumstances.

In the current study, I predict that AC will be needed for the proactive process of expectancy generation because one must generate and maintain possible target items in working memory during the blank interval between prime and target. It is hypothesized that those high in AC will be better able to engage in expectancy generation than those low in AC. As a result, forward priming should increase with increasing AC, especially at the long SOA in which generated targets must be maintained across a longer interval. In contrast, retrospective semantic matching should reflect a reactive (backward-acting) control process. As a result, both high and low AC individuals should make use of semantic matching. Thus, whereas high AC individuals should show both forward and backward priming, low AC individuals should show backward priming, but impaired forward priming.

METHOD

Participants

A total of 201 native-English speaking men and women participated from Montana State University (N=150) and the State University of New York at Albany (N=51). Participants completed the study for partial completion of a requirement for an introductory psychology course.

Design

The experiment was a mixed design with SOA (250 ms and 1250 ms), Relatedness (related and unrelated) and Type of Associate (Forward, Backward, and Symmetrical) manipulated within-subjects and AC measured continuously between-subjects. The dependent variables were reaction time (RT) and error rates in the priming task.

Priming Task

For the lexical decision task, participants were told that a word in all capital letters would appear on the computer screen and they should read this silently to themselves. They were then told that a string of lowercase letters would appear and they were to respond “word” or “non-word” using the designated keys on the keyboard. Participants were exposed to primes that were either related or unrelated to the target. Moreover, these pairs were either asymmetrically (e.g., stork-baby) or symmetrically (e.g., brother-sister) associated according to word association norms (Nelson, McEvoy, & Schreiber, 1999). In such norms, association strength is defined as the relative frequency of the two words being generated together. Asymmetric pairs were presented in either the forward (e.g., stork-baby) or backward (e.g., baby-stork) direction.

The overall RP (.70) and NR (.67) were constant between subjects. The mean forward prime-to-target association strengths were .55 for forward associates (FA), .00 for backward associates (BA), and .56 for symmetrical associates (SYM). The mean backward prime-to-target association strengths were .00 for FA, .59 for BA, and .60 for SYM. The average length of all words was 5.37 letters, average lexical decision reaction time taken from the English Lexicon Project database (Balota, et al., 2007) was 643.08, and average printed word frequency (according to the HAL database) was 31363.23. Within each of the BA, FA and SYM pairs, related pairs were scrambled to create unrelated pairs. All non-words were pronounceable and created by changing one letter of a target word for SYM pairs (Thomas, Neely & Connor, 2011).

The fixation (+) was displayed on the screen for 600 ms, followed by the prime display for 150 ms. A blank screen was then presented for either 100 ms or 1100 ms, creating an SOA of either 250 ms or 1,250 ms. This SOA was blocked such that participants received either the short or long SOA first, followed by the opposite SOA, with blocks counterbalanced across participants. The target was then displayed for 6000 ms or until a response was given. The length of time between trials was 2000 ms. Each participant was randomly presented with 40 trials of each type of associate (BA, FA, &

SYM). One hundred-twenty non-words and 80 SYM related filler trials were also included.

Attentional Control Battery

The OSPAN task used was taken from Hutchison (2007). In this task, participants first saw a mathematical equation, or operation string, question followed by a noun (e.g., “is (12/3) + 6 = 9? bird”), and indicated the correctness of the equation while maintaining the word in memory for later recall. After responding to a set of operation strings (from two to six, with each set size appearing 2-3 times during the task), participants recalled the words, in order. WMC was determined by the number of words recalled in the correct presentation order from sets in which all words were correctly recalled. The dependent variable of the OSPAN task was accuracy. Higher scores on the OSPAN task indicate better AC, with individuals higher in AC better able to maintain the words in working memory despite distraction from the math task.

The Stroop task included both color words (*green, blue, yellow, and red)* and neutral words (*bad, deep, poor, and legal).* When a word was shown on the screen, participants were told to say the color in which the word was displayed instead of saying the word itself. One third of the trials were incongruent (e.g. the word *green* written in blue ink), one third were congruent (e.g. the word *red* written in red ink), and one third were neutral (e.g. *dog* written in blue ink). Higher RT (time it takes participants to say the color after word presentation) and error scores on the Stroop task indicated worse AC. The dependent variables for the Stroop task were RT and percent errors (i.e., saying the word rather than the ink color). The Stroop task measures participants' ability to maintain and utilize task goals to inhibit the natural response of word reading.

In the Antisaccade task, participants were told that they would see a fixation (+) in the center of the screen and then a star (*) would appear on either the left or right side of the screen for 300 ms (Kane, Bleckley, Conway, & Engle, 2001). After the fixation disappeared, star delay (1,000, 2,000 or 3,000) was varied randomly for each trial. Either an *O* or a *Q* immediately emerged for 100 ms on the opposite side of where the star appeared and was quickly covered by a mask (###) for 5,000 ms. Participants' scores indicated the percentage of targets (Q or O) properly recognized (as indicated by pressing designated keys on keyboard). The dependent variable for the Antisaccade task was accuracy. The Antisaccade measures AC by examining the ability of participants to maintain and utilize the task goals to inhibit the natural response to look toward the star.

Procedure

Participants read and signed a consent form indicating that they were willing to participate in the experiment. The order in which participants received the lexical decision task and AC battery was counterbalanced across participants. Therefore, participants either completed the AC battery of tasks or the priming tasks first. After completing all the tasks, participants were debriefed and thanked for their participation.

RESULTS

Preliminary Data Analysis

Only correct responses were considered for the RT analysis from all AC tasks and the LDT. Because RT distributions tend to be positively skewed, outliers in the lexical decision and Stroop task were removed with the non recursive modified criterion procedure recommended by Van Selst and Jolicoeur (1994). This procedure also corrects for bias introduced by participants with low number of observations (i.e., correct responses) in any condition. This procedure removed 2.3% of the correct RTs in the priming task and 2.5% of the correct RTs in the Stroop task. Semantic priming was measured as the difference in RT and error rates between unrelated and related trials. Stroop interference effects were computed by subtracting the mean RT or error rate for congruent words from the mean RT for incongruent color words.

AC Battery

With the use of a Principle Components Analysis (PCA), the intercorrelations across all dependent variables in the AC battery were assessed. Each of the tasks in the battery presumably contained both common variance due to AC and unique variance due to task-specific abilities (e.g., math ability in OSPAN, color vision in Stroop). The PCA was conducted in order to extract out common variance among the tasks and discard task-specific variance. This common variance serves as a better indicator of AC than each of the tasks alone (Conway, Kane, & Engle, 2003). Higher Stroop interference indicates worse AC and therefore load negatively in the analysis. Higher values in Antisaccade and OSPAN indicate better AC and therefore should have positive loadings.

Intercorrelations between each task in the AC battery were examined. The mean, range and standard deviation for each of the AC tasks are show in Table 1. Table 2 shows the intercorrelations among the AC battery tasks. Stroop RT and errors were converted to z-scores for a single composite Stroop measure. This was done to give each task equal weighting in the PCA. As can be seen in Table 2, significant correlations between all three tasks were found. Results from the PCA revealed one significant component, which accounted for 48% of variance in performance across tasks (see Table 3). As predicted, this pattern of loadings suggests that this component reflects AC, with OSPAN and Antisaccade loading positively and Stroop interference loading negatively. Individual scores on this component ranged from -3.74 to 2.66. Results from the AC battery replicated Hutchison (2007), adding confidence that the three tasks employed did in fact measure AC.

Table 1. Descriptive Statistics for AC Battery Tasks

Task	M	SD	Range
OSPAN	8.14	6.05	0, 30
Antisaccade	71.41	13.1	.39, 1.00
Stroop RT	116.64	62.78	-16.54, 341.15
Stroop Error	4.49	3.98	0, 39.48

Note. M= mean; SD= standard deviation.

Table 2. Component Matrices

Tasks	1	2	3
1. OSPAN	____		
2. Antisaccade	.212*	____	
3. Stroop	-.228*	-.208*	____

* p < .01

Table 3. Component Matrix

	Component 1
Ospan	.699
Antisaccade	.678
Stroop	-.695

Overall Priming Effects

Mauchly's test statistic was significant (W = .842, p < .05), indicating that the assumption of sphericity was violated. Therefore results are reported using the Greenhouse-Geisser correction. RTs were analyzed with the use of an ANCOVA, which allows for the continuous variable AC to be tested alongside the categorical within-subject variables SOA, type, and relatedness (Hutchison, 2007). Allowing AC to remain as a continuous variable is preferable to grouping RT data into extreme groups, such as in a quartile split. Such categorical grouping reduces the power to detect the relationships between variables and can produce spurious effects when using the entirety of the data (Field, 2009). Trim scores are reported, but data were also analyzed with z-scores. The use of z-scores helps account for group differences in variability and overall RT, which may generate false interactions (Faust, Balota, Spieler, & Ferraro,1999; Hutchison, Balota, Cortese, & Watson, 2008). Unless otherwise noted, all reported RT effects were confirmed by the z-score analysis. All reported significant effects are associated with a *p* < . 05.

Overall, there was a significant main effect of relatedness, *F*(1, 200) = 128.746, *MSE* = 1055606.60, □$_{□}^{2}$ = 3.93, such that participants were faster to respond to related than unrelated targets (i.e., a semantic priming effect). There was also a Type x Relatedness interaction, *F*(2,199) = 5.58, *MSE* = 36509.90, □$_{□}^{2}$ = .03, with magnitude of priming depending on direction of associates. No significant interaction was found between overall Relatedness x AC, *F*(1,200) = .011, *p* = .92, *MSE* = 86.20, □$_{□}^{2}$ = .00, illustrating that high and low AC participants did not differ in overall semantic priming. As predicted, and of most importance, a significant AC x Type x Relatedness crossover interaction was present, *F*(2,199) = 3.12, *MSE* = 20367.36, □$_{□}^{2}$ = .02, indicating that the patterns of priming for FA, BA and SYM depended on AC. Figure 1 illustrates the relation between AC and priming for FA, BA, and SYM. This graph was conducted using z-scores to avoid noise due to differences with baseline RTs. As can be seen from Figure 1, as AC increased, priming for FAs numerically increased, whereas priming for BA decreased. Post-hoc correlations reflected that the increase in priming for FA across AC was significant (*r* = .20, *p* = .005), whereas the decrease in priming for BA was not (*r* = -.075, *p* = .289). Priming for SYM was also relatively stable across AC (*r* = .074, *p* =

.295). No other significant effects and no significant interactions involving SOA were found.

For errors, a significant main effect of relatedness was found, *F*(1,200) = 48.416, *MSE* = .209, η_p^2 = .04, indicating the standard priming effect. There was also a Type x Relatedness interaction, *F*(2,199) = 11.870, *MSE* = .038, η_p^2 = .01. Priming was greater for BA and SYM than FA. No other effects were significant.

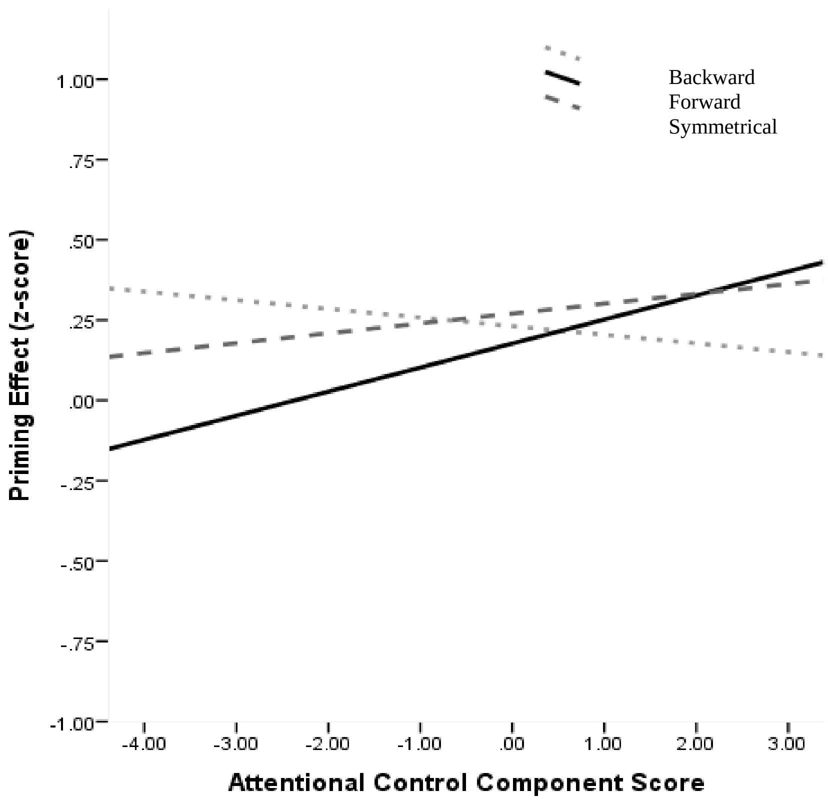
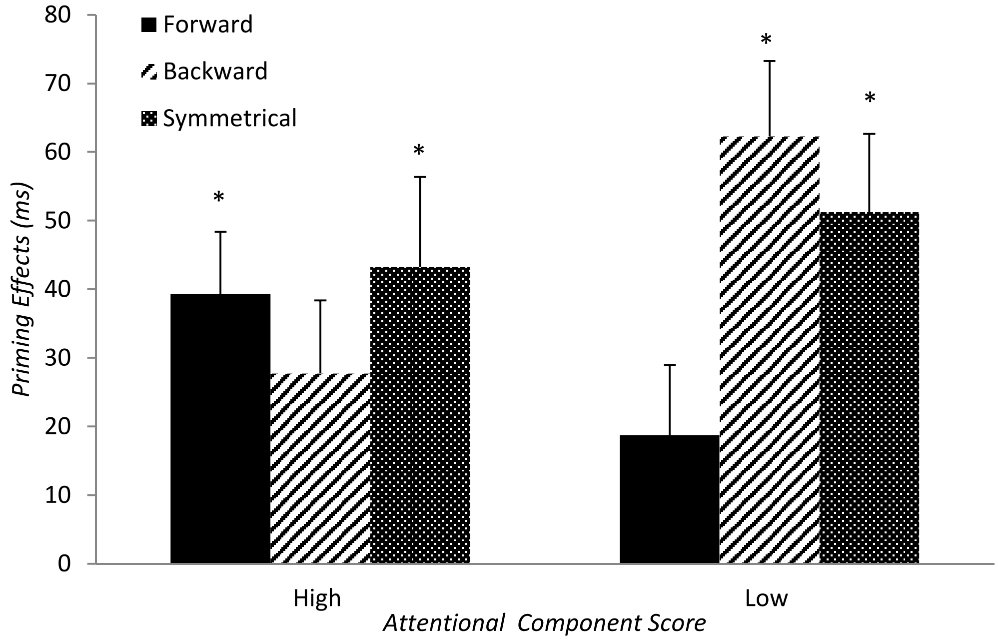


Figure 1. Overall priming effects (z-score) as a function of attentional control component score. As attentional control component score increased, priming for forward associated also increased. Priming for backward and SYM was not statistically correlated with AC component score.

Extreme Groups Analyses

For illustrative purposes, the data are also reported in Figure 2 with AC broken down by high and low quartile groups (post hoc *lsd* tests were conducted to examine the relationship between the variables and AC), and priming shown for each type of associate. A Mixed-model ANOVA was conducted to examine effects of Groups, Type, Relatedness, and SOA. A significant Group x Type x Relatedness interaction was found, $F(2,199) = 3.267$, $MSE = .446$, $\eta_p^2 = .03$. To explain this, simple Type x Relatedness interactions were separately examined for high and low AC groups. For high AC groups, there was numerically greater priming for forward ($M = 39$ ms) and symmetrical ($M = 43$ ms) than BA ($M = 28$ ms). However, priming effects from all three types of associates were significant and the Type x Relatedness interaction was not significant [$F = .72$, $MSE = 4617$, $\eta_p^2 = .01$]. In contrast, low AC individuals had a significant Type x Relatedness interaction [$F = (2,100) = 3.87$, $MSE = 6749$, $\eta_p^2 = .07$] with significant priming only for backward ($M = 62$ ms) and symmetrical ($M = 51$ ms) associates, but not the FA ($M = 19$ ms; $p = .074$). For errors, no significant Group x Type x Relatedness interaction was found, $F(2,199) = .378$, $p = .686$, $MSE = .001$, $\eta_p^2 = .004$.



$p<.05$

Figure 2. Overall priming effects in milliseconds as a function of attentional control group (AC). High AC individuals show greater priming for FA, while low AC individuals show greater priming for BA. No differences due to AC were found in priming for SYM. Standard errors are represented in the figure by the error bars attached to each column.

DISCUSSION

This research helps distinguish the mechanisms/strategies underlying semantic priming and individual differences. Findings from the present experiment support the dual mechanisms of control model of Braver, Gray and Burgess (2007). Proactive control relies on individuals' ability to generate and maintain possible targets in working memory, after prime presentation. This process is demonstrated by enhanced forward priming. Reactive control is a more automatic process and does not require continual effort or monitoring of the environment. This process is evidenced in backward priming. Results from the current priming research support the prediction that low AC individuals are more likely to engage in a reactive strategy after target onset (e.g., semantic matching), whereas high AC individuals can also engage in proactive control, as long as there are predictive cues in the environment (e.g., a high RP, as used in the current experiment) that can benefit performance.

Such proactive and reactive strategies are also evident while reading. Proactive control is evident when individuals use the context to anticipate upcoming words or sentences. Reactive control is evident when individuals check back to the previous sentence or paragraph in order to make sense of the current word or phrases. Sole reliance on a semantic matching strategy could impair overall comprehension because such frequent "backtracking" can impair one's global comprehension. Indeed, lower reading comprehension is present in individuals who are more prone to mind wandering (those low in AC) (McVay & Kane, 2011).

This research increased our understanding of the mechanisms underlying semantic priming. High AC individuals have the attentional capacity required to quickly generate and maintain expected targets in working memory. This produces priming for symmetrical and forward-associated pairs, in which the target would be contained within the generated expectancy set. It is speculated that low AC individuals do not have the attentional capacity necessary to generate or maintain an expectancy, so must instead rely on semantic matching. Indeed, priming for FA was shown to rely on AC. In this experiment, priming effects were greater for FA as AC increased. This supports the prediction that higher AC individuals relied more on an expectancy generation strategy, whereas low AC individuals relied on a semantic matching strategy. In contrast, AC was not related to priming for symmetrically or backward associated items, presumably because the use of semantic matching increases priming for these pairs.

Although it was predicted that forward priming should increase with increasing AC, especially at the long SOA, null effects regarding SOA were found in the current experiment. This may perhaps be due to the ability of high AC individuals to generate associates within 250 ms, demonstrating greater priming for FA at the short SOA. This increase in priming for FA may also be due to strong associates being easier to generate than weak associates. Consistent with both these points, Hutchison (2007) found that high AC individuals showed significant RP effects of comparable size at SOAS of 267 and 1200 ms. Also, if low AC individuals try to use semantic matching on FA items, the lack of backward association could counteract any facilitation caused by spreading activation. Low AC individuals may also be more susceptible to confusion from short prime-target intervals (Bodner & Masson, 2003). These various explanations may help to account for the null effects of SOA.

The various priming effects found for high AC and low AC participants is supported by past research. Expectancy generation within lexical decision tasks requires controlled processing, and this is likely why AC positively correlated with priming effects in this task. Through the use of a naming task (which does not involve semantic matching), Hutchison (2007) showed that high AC participants used the color of the prime to determine whether or not to engage in expectancy generation. Further, the dependence of RP effects on varying levels of AC validates that this process is attentionally demanding. High AC individuals were presumably faster to generate semantic associates and better able to maintain them in working memory. Because such expectancy generation requires AC, low AC individuals in the current lexical decision task instead recruited a retrospective strategy, which involved checking back to determine if the prime and target were related in order to aid the lexical decision response.

Although different control strategies relate to expectancy generation and semantic matching, many questions still remain unanswered. Future studies could use a naming task to further examine priming differences depending on AC. During a naming task, forward, but not backward, priming is predicted to be present. Based on the current findings and those of Hutchison (2007), high AC are expected to show greater priming for FA than low AC individuals. Such results would support the current findings and interpretation. These findings would show that those high and low in AC use differing strategies (replicate current results using a different paradigm).

Future studies could also use a blocking experiment to examine the pattern of strategy use depending on AC. It is expected that in the early blocks of the experiment, those high in AC would use both expectancy generation and semantic matching strategies, whereas those low in AC would only use semantic matching (Koriat, 1981). In the later blocks of the experiment, when given more practice with the task, high AC individuals would shift their strategy and rely on expectancy generation. These findings would show that those high in AC are able to switch between strategies, and eventually only use expectancy generation. Low AC individuals are expected to only use semantic matching, therefore replicating the results from the current experiment.

In the current study, differences in AC affected the way in which individuals responded during the lexical decision task. The present research found that priming for BA did not vary depending on AC, illustrating equivalent retrospective semantic matching across AC. In contrast, High AC individuals had greater priming for FA, illustrating the use of prospective expectancy generation. These findings fit well with Braver et al.'s (2007) dual mechanisms of control model and highlight the utility of examining priming from asymmetric associates in dissociating retrospective semantic matching and prospective expectancy strategies.

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