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A Motivationally Based Computational Interpretation of Social Anxiety Induced Stereotype Bias

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Abstract

Lambert et al. (2003) suggested that stereotyping could be thought of as automatic (implicit) responses that may become magnified in certain social settings through a loss of cognitive control. This type of explanation seems reasonable; however, to date, no attempts have been made to provide a more thorough, mechanistic (computational) explanation of the exact processes underlying the phenomenon. This paper proposes just such a detailed explanation using the CLARION cognitive architecture. Our CLARION-based theory takes into account motivational factors as well as the interaction between explicit and implicit processes and is used to provide a plausible interpretation of data from an identification task in Lambert et al. (2003).

Keywords: CLARION; cognitive architecture; cognitive modeling; motivation; social anxiety; stereotype.

Introduction

In line with existing studies of the effects of social anxiety on stereotype bias (e.g., Lambert et al., 2003; Payne, 2001), an explanation of such a phenomenon can be made within a computational framework, specifically the CLARION cognitive architecture (Sun, 2002, 2003). According to our interpretation, increases in anxiety related motivational drives (Sun, 2007, 2009) have a causal effect on the ability to make controlled (explicit) responses. The reduced capability can lead an individual to revert to a reliance on more “automatic” (implicit) systems.

In the remainder of this paper, we develop a motivationally based, mechanistic theory within the CLARION framework. This CLARION-based theory will then be used to simulate the Lambert et al. (2003) stereotype-inducing identification task and the simulation results will be matched to their human data. The next two sections will examine the task as well as the empirical findings from Lambert et al. (2003). The section following these will present the CLARION-based theory for capturing the phenomenon. The section after that will examine the simulation results and compare them to the human data. The final section will discuss how our theory relates broadly to the phenomenon of cognitive distracters and their impact on cognitive control.

Lambert et al.’s (2003) Experiment

Participants were instructed that they were to identify target objects being presented on a screen as belonging to either the “tool” category or the “gun” category. They were also told that the task required both speed and accuracy. Participants then completed a 48-trial “practice” phase allowing them to become familiar with the requirements of the experiment as well as the target objects (i.e., the tools and guns). After completing the practice trials, participants were told either that all of their responses would be kept confidential (i.e., they were in the private group) or that they would be asked to share and discuss their responses with the other participants in the testing room (i.e., they belonged to the anticipated public group).

For the test phase, an additional element was added to the identification task: the prime, a picture of a person’s face, was presented briefly (for 200 ms.) before being replaced by the target object (which was presented for 100 ms.). Participants were given a total of 550 ms. to make a response (by pressing a button associated with the target’s category).

Participants completed a total of three blocks of trials. In each block, each of the eight primes (4 black, 4 white) was randomly paired with each of the eight targets (4 tools, 4 guns) twice. This yielded 128 trials per block, and a total of 384 trials overall.

After completing the identification task, participants also completed a measure of social anxiety and the Dunton and Fazio (1997) Motivation to Control Prejudicial Reactions Scale. These scales attempted to measure the individual differences in social anxiety and motivations to control prejudicial reactions.

Experimental Results and Discussion

The results from Lambert et al. (2003) showed that participants tended to make stereotypic errors (i.e. misclassifying a tool as a gun when primed with a black face or a gun as a tool when primed with a white face) on tool trials regardless of context ($F = 20.03$, $p < .001$ for the anticipated public group, $F = 3.74$, $p = .058$ for the private group). In other words, when the results were collapsed over context, people who were presented with a tool were significantly more likely to mistake it for a gun when it was coupled with a black prime ($M = .24$) than a white prime ($M = .22$). In

addition, people who were presented with a gun were significantly less likely to mistake it for a tool if it was coupled with a black ($M = .19$) rather than a white ($M = .21$) face. This finding was evidenced by a significant Prime X Object interaction ($F = 22.13, p < .001$).

The results further indicated that people in anxiety-inducing situations (e.g. the anticipated public group) made significantly more stereotypic errors than those people who were not distracted by an anxiety-inducing context (e.g., the private group). This was confirmed by a significantly stronger Prime X Object interaction in the anticipated public condition compared to the private condition ($F = 20.03, p < .001$ vs. $F = 3.74, p = .058$, as mentioned before).

Further, the presence of the black prime had an enhanced effect on participants' responses than the white prime. In other words, on black prime trials, participants were significantly more inclined to make stereotypic errors ($F = 11.52, p < .001$ for the main effect of object). This tendency was not evidenced when primed with a white face ($p > .20$).

Based on the process dissociation procedure (Jacoby, 1991), it was found that participants in the private group had higher estimates of cognitive control (.60) than participants in the anticipated public group (.53). These numbers were essentially the same regardless of prime as confirmed by a Prime x Context ANOVA, which revealed a significant main effect for context ($F = 4.54, p < .05$), no significant effect of prime ($F = .67, p > .05$), and no evidence of a significant Prime x Context interaction ($F = .01, p > .05$).

Additionally, Lambert et al. (2003) hypothesized that accessibility bias (i.e., the likelihood of making a stereotyped response when control failed) was a separate (dissociated) process from cognitive control. The results on accessibility bias estimates showed that when participants were primed with a black face, estimates were significantly higher (.56) than when they were primed with a white face ($\approx .50$). To confirm this, a Prime x Context ANOVA was performed revealing a significant interaction ($F = 20.39, p < .001$). Beyond this, no other significant effects emerged from these analyses. Of particular importance, accessibility bias was not affected by manipulating context ($F < 1.00, p > .05$).

Lambert et al. (2003) also posited that accessibility bias estimates could be used to roughly capture individual variation in stereotypic associations about blacks (i.e., how strongly a person associates guns with this group). Taking into account that control is particularly low for high-anxiety participants in the anticipated public group, Lambert et al. (2003) predicted that, for the aforementioned group, a correlation exists between estimates of accessibility bias and performance. To test this, they constructed an overall index of stereotypic errors: Higher error indices indicated a greater propensity toward making stereotypic errors over counter-stereotypic errors when presented with a black prime.

A few important points resulted from that analysis. First, in the private group context, the relationship between accessibility bias and gun responses was moderate and about the same regardless of anxiety. However, the relationship was especially strong in the anticipated public group, but this

was only among participants who were high in state anxiety. Those participants with higher accessibility bias scores and high anxiety made more stereotyped errors on black primed trials, whereas participants with lower accessibility bias scores made less stereotyped errors on those same trials.

Of additional pertinence to the present work is the effect that context had on reported levels of state anxiety. Recall that at the end of the experiment, participants completed a questionnaire aimed at measuring a person's reported level of anxiety. Analysis of the anxiety measure indicated that, consistent with expectations, participants reported significantly higher levels of (task-specific, i.e., state) anxiety in the anticipated public ($M = 1.89$) compared with the private condition ($M = 1.32$) [$F = 10.03, p < .01$].

A CLARION-based Theory

CLARION is a well-established cognitive architecture (Sun, 2002, 2003; Sun et al., 2005). It consists of a number of subsystems. The following three subsystems were used for simulating the task in Lambert et al. (2003): the action-centered subsystem (ACS), the motivational subsystem (MS), and the meta-cognitive subsystem (MCS). Each subsystem is divided into two levels of representation: the explicit (top) and implicit (bottom) levels (see Reber, 1989; Sun, 2002 for justifications).

One of the fundamental theoretical assumptions in CLARION is the distinction between implicit and explicit processing. What we term explicit processing is also known as "controlled" processing (Lambert et al., 2003). Explicit processes are often rule-based, require more time to obtain results, and sometimes require more than one step to reach a conclusion (Sun, 2002). Similarly, implicit processes are often referred to as "automatic" processes. Further, when researchers refer to "a loss in cognitive control", what they are referring to, in CLARION terms, is an inability to adequately rely on explicit processes over (or in addition to) implicit processes. A loss of cognitive control, therefore, is equivalent to using more implicit processes.

Moving now to the representations within the two levels, in the bottom level, CLARION takes note of the fact that the inaccessible nature of implicit knowledge is best captured by subsymbolic, distributed representations (such as in a backpropagation network). It has been extensively argued that the characteristics of distributed representations accord well with the relative inaccessibility of implicit knowledge (Sun, 2002). In contrast, explicit knowledge can be best captured in computational modeling by symbolic or localist representations (Sun, 2002; Sun et al., 2005), in which each unit is more easily interpretable and has a clearer conceptual meaning. This characteristic of symbolic or localist representations captures the characteristic of explicit knowledge being more accessible (Sun, 2002). Accessibility here refers to the direct and immediate availability of mental content for the major operations that are responsible for, or concomitant with, consciousness, such as introspection, forming higher-order thoughts, and verbal reporting, as well as meta-level control and manipulation.

The dichotomous difference in the representations of the two different types of knowledge led to a two-level architecture, whereby each level uses one kind of representation and captures one corresponding type of process (this paper focuses specifically on the interaction between implicit and explicit processing within the action-centered subsystem).

The Action-Centered Subsystem (ACS)

The Action-Centered Subsystem (ACS) consists of implicit processing (in the bottom level of the two-level structure, in the form of a backpropagation network) and explicit processing (in the top level, through explicit action rules; Sun, 2002). When both implicit and explicit knowledge is available in the ACS for determining appropriate actions, the two types of knowledge are “integrated”, for example, through stochastic selection of one type or the other. For further details related to the ACS, see Sun (2002, 2003).

For our simulation, the ACS was responsible for generating responses to a set of featurized inputs (created based on the actual pictures from Payne, 2001, to make the inputs as accurate as possible; see table 1).

The bottom level of the ACS took the featurized descriptions of a prime and target as inputs and output the specification of whether the target item was a tool or gun. The backpropagation network had 25 input nodes (13 describing a person in 6 dimensions, 12 describing an object in 5 dimensions; see table 1), 10 hidden nodes, 2 output nodes (the classification of tool or gun), and the default parameter settings (Sun, 2003). Also, since this task required quick responding, it should be especially prone to noise. We captured this effect by setting the temperature (to .4) involved in stochastic selection of the output.

The bottom level was trained to focus on skin color, because it represents the stereotyping in its simplest form. According to Payne (2001), the primes were designed to filter the characteristics of the faces until race was the only distinguishing feature. We also chose to exclude specific target characteristics during training, because we felt that the link between race and guns was likely a connection between skin color and the concept of a gun (which is the output of the ACS), not any particular gun or tool feature.

Furthermore, we posit that stereotype bias is developed slowly through subtle, cumulative experiences within a society. These biases have evolved from a fundamental need to easily “classify” other members of society for the purpose of ensuring survival. It has been argued that, in general, people have developed “classification” systems to provide help in making reasonable responses quickly to unexpected or unclear circumstances (Sun, 2002). People are not necessarily cognizant of these response mechanisms. In fact, research suggests that tasks requiring quick reactions are often performed implicitly (Reber, 1989; Sun, 2002; Sun et al., 2005). Taking these arguments together, we feel that it is reasonable to think of stereotyping as a form of “classification” that is often best explained as an implicit process.¹

The bottom level was given 500,000 training trials presenting the black and white characteristic in such a fashion that was consistent with the accessibility bias estimates from Lambert et al. (2003). The accessibility bias estimate is the probability that a stereotyped response will be made if control fails, and in our simulation control failing means that only the bottom level of the ACS is used. Hence, it seemed appropriate to use this measure to help guide the training. On about 56% (plus or minus 3.5% for individual differences) of trials where a black face was presented to the network, it was coupled with a gun (on about 44% it was coupled with a tool). Tools and guns were paired at an equal rate (plus or minus 3.5%) when coupled with a white face.

The top level of the ACS learned appropriate response rules mapping inputs concerning specific tool/gun characteristics to the proper tool/gun classification output. The assumption is that these rules represent explicit knowledge learned during the 48 practice trials as well as prior experiences by the human participants.

The Motivational Subsystem (MS)

In addition to the ACS, the motivational subsystem (MS) is another major component in CLARION. The MS is responsible for motivational states (comprised of “drives” and “goals”; Sun, 2007, 2009). In CLARION, drives are fundamental motivational forces behind decision-making (as well as other processes). Anxiety can be thought of as the biological/physiological consequence of heightened (avoidance-oriented) drive strengths (see the discussion of drives in Sun, 2009). Thus, in the simulation, an agent’s drive strengths are set in the MS based on the experimental contexts (e.g., the existence of an anxiety-inducing situation).

Considering the specific aspects of this task, it was determined that a single drive, “honor” (i.e., obeying social norms and codes), best encapsulated the motivating factors involved with the contexts (groups). Based on an agent’s context, its “honor” drive strength level was set in the MS.

The drive strength was obtained using a backpropagation network with 2 input nodes, 4 hidden nodes, 1 output node, and the default parameter settings (Sun, 2003). The first input specified the context (group) to which the agent be-

Table 1. Featurized inputs as dimension/value pairs.

Primes (people)		Targets (guns/tools)	
Dim.	Val.	Dim.	Val.
Skin Color	Black, White, Gray	Handle Color	Black, White, Gray
Nose Shape	Thin, Wide	Shape	Bent, Straight
Nose Length	Short, Long	Handle Length	Long, Short
Eyebrow Shape	Thick, Thin	Head Length	Long, Short
Eye Size	Big, Small	Head Color	Black, White, Gray
Sex	Male, Female		

¹ Note that our interpretation is in line with the arguments made by Lambert et al. (2003).

longed. The second input represented the agent’s predisposition toward anxiety in social settings. While more generalized drive-strength equations exist, for the purposes of this simulation, it was determined that a hyperbolic tangent function provided a reasonable approximation for translating “stimulus” (i.e. context) and “deficit” (i.e. the individual predisposition toward anxiety) into a drive strength.

Making the drive sensitive to both the context as well as the predisposition to anxiety is justified by analysis performed by Lambert et al (2003), which found the existence of a significant Context x Anxiety interaction using a hierarchical regression analysis.

Further analysis of the data of Lambert et al. showed that, among participants above the group median in state anxiety, there was a significant effect of context on estimates of control ($\beta = .25, p < .05$), reflecting lower control in the anticipated public context compared with the private context ($M_s = .51$ vs. $.60$, respectively). However, context had no significant effect on control for the participants reporting low levels of anxiety ($\beta = .08, p = .52$), reflecting the fact that control was relatively high and about equal across the anticipated public and private contexts ($M_s = .57$ vs. $.60$). This effect led to the two different values used for the parameter of the hyperbolic tangent curve for the drive strength in the MS. As a result of the two different parameter values, an agent’s drive strength increased more rapidly and reached a higher level in the public group than in the private group. Figure 1 gives a graphical representation of the drive.

The Meta-Cognitive Subsystem (MCS)

Finally, in conjunction with the MS, the meta-cognitive subsystem (MCS) may be used for setting parameters in the ACS. The MCS performs a number of backend actions (including the setting of parameters for action selection, reasoning, and learning, etc.) based on drive states and so on (see Sun, 2007, 2009). In the simulation, (avoidance-oriented) drive strengths (levels of anxiety) from the MS are used as the basis by the MCS to determine the likelihood of making decisions in a more or less explicit (i.e., controlled) way by the ACS.

The MCS contains a module for determining the mode of action decision making (i.e., the proportion of implicit vs. explicit processing in the ACS). A backpropagation network

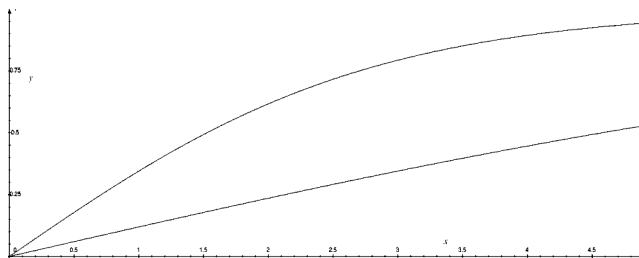


Figure 1. Graphical representation of the “honor” drive. The x-axis represents the predisposition toward anxiety ($0 \leq x \leq 5$); the y-axis represents drive strength ($0 \leq y \leq 1$). The bottom curve represents the private group [$y = \tanh(.12x)$]; the top curve represents the anticipated public group [$y = \tanh(.36x)$].

with 1 input node, 4 hidden nodes, 1 output node, and the default parameter settings (Sun, 2003) was used. The network was used to produce outputs based on an inverted U curve (see Yerkes & Dobson, 1908) that mapped drive strengths (the input) to the probability of being explicit (i.e., using the top level of the ACS) during action decision making (see figure 2). The working hypothesis in this regard is that when anxiety is at a relatively low level, it has little (or possibly even a positive) effect on the ability to be controlled (explicit) in making action decisions. However, when anxiety reaches a certain higher level, it can begin impairing control, creating a need to revert to faster, more automatic, implicit processes (Sun, 2007, 2009; Wilson et al., 2009; Yerkes & Dobson, 1908)

Simulation Results

In exact correspondence with experiment 2 of Lambert et al. (2003), simulated agents were placed in either a simulated private group or a simulated anticipated public group. Like the human experiment, the test phase was run using 384 trials where each face/tool pairing was observed six times at intervals of 2 times per 128 trials. A total of 128 agents were used (as opposed to 127 human participants in Lambert et al., 2003) and 64 agents were placed into each group.

The results of the simulation were recorded as error rates for the four different possible pairings of prime and target. Consistent with the findings from Lambert et al. (2003), agents in the simulated private group made significantly fewer errors on gun trials than on tool trials when paired with a black prime (.174 vs. .224) [$F = 42.62, p < .001$]. Additionally, on trials containing a white prime, in the simulated private group, error rates on gun and tool trials were essentially the same (.202 vs. .199) [$F = .17, p > .05$]. In the simulated public group, when a black prime was paired with a gun, error rates were significantly lower than when paired with a tool (.214 vs. .27) [$F = 45.37, p < .001$]. Also, when a white prime was paired with either a gun or a tool, error rates were not significantly different (.244 vs. .238) [$F = .491, p > .05$] for the simulated public group. These findings were consistent with Lambert et al. (2003).

Further analysis of the simulation data revealed a signifi-

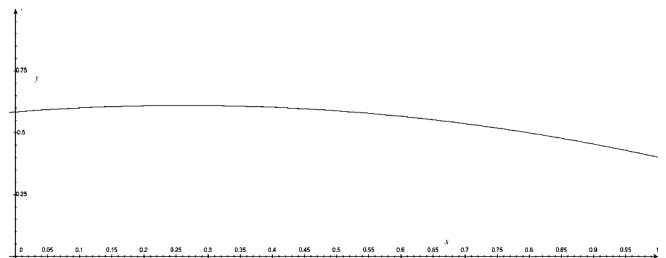


Figure 2. Inverted U-Curve. The x-axis represents the drive strength ($0 \leq x \leq 1$); the y-axis represents the level of cognitive control ($0 \leq y \leq 1$) [$y = -.38x^2 + .2x + .58$].

cant Prime X Object interaction ($F = 48.4, p < .001$). Collapsed over situational context, agents were significantly more likely to mistakenly identify a tool as a gun if they were primed with a black face ($M = .247$) than a white face ($M = .219$) [$F = 30.991, p < .001$]. Conversely, agents were significantly less likely to mistakenly identify a gun as a tool if they were primed with a black face ($M = .194$) than a white face ($M = .223$) [$F = 26.546, p < .001$]. Looking at it another way, agents showed a significantly stronger tendency toward mistaking a tool for a gun when primed with a black face, as opposed to mistaking a gun for a tool, when primed with a black face ($F = 88.42, p < .001$ for the main effect of object). When agents were primed with white faces, error rates did not vary significantly across object types ($F = .649, p > .05$). These findings were, again, consistent with Lambert et al. (2003).

Moreover, agents in the simulated public group made significantly more errors in general than agents in the simulated private group. This was confirmed statistically by comparing the mean error rates between the simulated public group ($M = .24$) and the simulated private group ($M = .20$) [$F = 56.64, p < .001$ for the main effect of context]. In a related statistic, the Object X Prime interaction was stronger in the simulated public group ($F = 28.01, p < .001$) compared with the simulated private group ($F = 22.26, p < .001$). Figure 3 graphically illustrates the above pattern of data and gives a comparison to Lambert et al. (2003).

Turning to analyses based on process dissociation, inferences into some of the mechanisms within CLARION can be made. First, the cognitive control estimate (Lambert et al., 2003) can be thought of as the probability that a person will be able to use their explicit processes (the top level of the ACS) when making a response (Sun et al., 2005). Second, the accessibility bias estimate (Lambert et al., 2003) can be thought of as the probability of making a gun response when cognitive control fails. According to our interpretation, a failure of control is tantamount to using implicit processing (see Sun, 2002; Sun et al., 2005).

Given this interpretation, there were two methods to report the cognitive control estimate from the simulation: by looking at the probability of using the top level of the ACS (as determined by the MCS), and by the process dissociation procedure (Jacoby, 1991; Lambert et al., 2003). Table 2 shows the MCS determined levels of cognitive control, the cognitive control estimates calculated using process dissociation, as well as the cognitive control estimates reported by Lambert et al. (2003). The cognitive control estimates from the simulation clearly correspond to Lambert et al.'s findings. A Prime X Context ANOVA on cognitive control

Table 2. Cognitive control estimates.

Lambert et al. (2003)			Simulation			
Group	Black Prime	White Prime	Group	MCS	Black Prime	White Prime
Private	.61	.60	Private	.599	.602	.598
Public	.53	.53	Public	.528	.518	.517

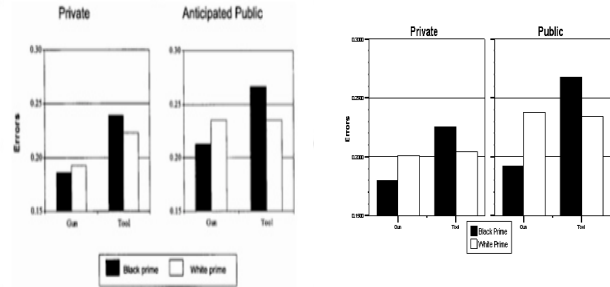


Figure 3. The graph on the left shows the human data from Lambert et al. (2003). The graph on the right is the simulation results.

estimates, calculated using the process dissociation equation (Lambert et al., 2003), from the simulation data revealed the expected significant main effect for context ($F = 56.635, p < .001$), no significant effect for prime ($F = .861, p > .05$), and no significant Prime X Context interaction ($F = .683, p > .05$). This analysis provides support to the notion that cognitive control estimates are affected by context but not by prime.

Additionally, as per our interpretation, two methods for reporting accessibility bias estimates from simulation existed as well: process dissociation and actual levels of accessibility bias that were calculated by simply keeping track of the number of times the bottom level chose a gun classification when the bottom level was used. Table 3 shows the actual accessibility bias, the accessibility bias estimates calculated using process dissociation, as well as the accessibility bias estimates from Lambert et al. (2003). As expected, the accessibility bias estimates from the simulation, calculated using the process dissociation equation (Lambert et al., 2003), were significantly higher for a black prime than a white prime and did not vary significantly by context. A Prime X Context ANOVA on accessibility bias estimates confirmed a significant main effect of prime ($F = 37.92, p < .001$), no significant effect of context ($F = .039, p > .05$), and no significant interaction ($F = .179, p > .05$).

Finally, a comparison between a standardized error index, which measured the agent's tendency toward making stereotypic vs. counter-stereotypic errors and the accessibility bias estimates, was calculated. Consistent with the findings from Lambert et al. (2003), the relationship between accessibility bias estimates and gun responses, as specified by the standardized error index, was moderate in the simulated private group, regardless of anxiety. However, this relationship became stronger in the simulated public group, but only when anxiety was high. A graphical representation of this analy-

Table 3. Accessibility Bias Estimates.

Lambert et al. (2003)			Simulation				
Group	Black Prime	White Prime	Group	ACS Black	ACS White	Black Prime	White Prime
Private	.56	.53	Private	.57	.508	.565	.504
Public	.56	.49	Public	.562	.505	.559	.506

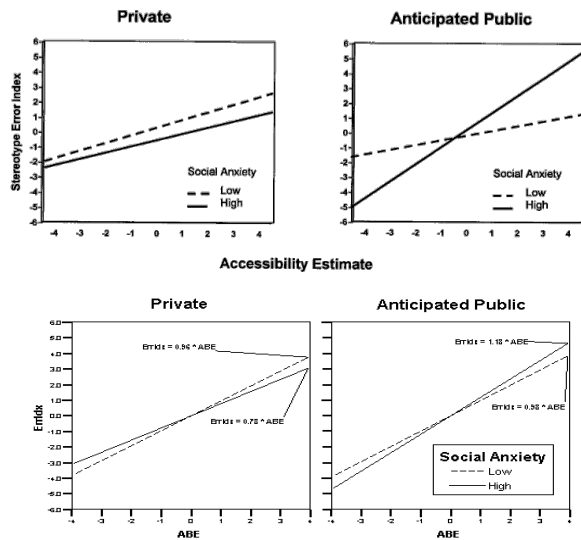


Figure 4. The top graph is the human data from Lambert et al. (2003). The bottom graph is the simulation results.

sis, along with a comparison to the findings from Lambert et al. (2003), can be seen in figure 4. Our finding of the correlation between accessibility bias estimates and error rates, as specified by the standardized error index, lend further support to the implicit nature of stereotyping. In addition, similar to the findings by Lambert et al. (2003), the connection between state anxiety and an agent's ability to make controlled (i.e., explicit) responses is characterized by the lack of a strong correlation between accessibility bias estimates and gun responses in both groups when agents were not highly effected by the anxiety-inducing cues. In other words, agents with lower levels of anxiety made more controlled responses and therefore had less chances of making stereotyped (implicit) responses.

General Discussion and Conclusion

Our CLARION-based theory appears to be capable of modeling the cognitive processes associated with the induction of stereotype biases in a social anxiety context, as illustrated by the successful simulation of Lambert et al. (2003). Moreover, our model captures the essence of the analysis of the empirical data by Lambert et al. (2003) (in a manner consistent with their interpretations).

Of related interest, our simulation supports the argument that stereotyping can be seen as mostly being an automatic (i.e., implicit) response that likely manifests itself as a result of a lessening in the ability to use more controlled (i.e., explicit) processes, as opposed to a strengthening of stereotyping habits (see Lambert et al., 2003 for further details related to this argument).

In conclusion, this article has laid out preliminary foundations that can later be applied to developing a more detailed theory of the mechanistic processes underlying the effects that anxiety and other cognitive distracters, in general, have on the control of cognition. Our theory suggests that the

broader phenomenon (i.e., the effects that cognitive distracters have on performance in a variety of contexts) is explainable in a quantitative, process-based way. In this regard, CLARION provides a useful framework, which has been derived from our prior studies and simulations of human experimental data (e.g., Sun et al., 2005; Sun, 2002; Wilson et al., 2009). Our ability to explore such tasks in a more detailed, more unified fashion should be useful in better understanding the interaction between motivation, meta-cognition, and implicit and explicit performance.

Acknowledgments

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