Cognition and Emotion in TV Message Processing: How Valence, Arousing Content, Structural Complexity, and Information Density Affect the Availability of Cognitive Resources

ANNIE LANG
Indiana University

BYUNGHO PARK
National University of Singapore

ASHLEY N. SANDERS-JACKSON
University of Pennsylvania

BRIAN D. WILSON
Indiana University

ZHENG WANG
Ohio State University

This paper examines whether emotional message content alters the effects of structural complexity and information density on available resources, measured by secondary task reaction times (STRTs), and message encoding, measured by audio recognition. In addition, hypotheses relating motivational activation and resource availability based on the motivational activation concepts of positivity offset (greater appetitive activation in a neutral environment) and negativity bias (faster aversive activation) influence are tested. Results replicate previous research supporting the contention that STRTs measure available resources. In addition, they show that the basic pattern of STRTs and recognition as a function of allocated and required resources is relatively consistent

Address correspondence to Annie Lang, Department of Telecommunication, Indiana University, 1229 E. 7th St., Bloomington, IN 47405-5501. E-mail: anlang@indiana.edu

regardless of emotional content of the message. Emotion appears to function as a constant, increasing both resource allocation and resources required. Finally, these data provide some initial support for predicted relationships between motivational activation and resource allocation based on the constructs of positivity offset and negativity bias.

Measuring online attention in a media laboratory is an ongoing challenge for communication researchers attempting to understand how mediated messages are processed. Many measures have been introduced and have found committed followings including continuous response self-report measures (Biocca, David, & West, 1994), physiological measures (Ravaja, 2004), and secondary task reaction times (STRTs) (Alwitt, Anderson, & Lorch, 1980; Chaffee & Schleuder, 1986; Deutsch & Deutsch, 1963; Grimes & Meadowcroft, 1995; A. Lang, 1990; P. J. Lang, M. M. Bradley, & Cuthbert, 1997; Meadowcroft & Watt, 1990; Reeves, Thorson, & Schleuder, 1986; Thorson, Reeves, & Schleuder, 1986). This paper continues a line of theoretical development begun by A. Lang and Basil (1998) and initially tested by A. Lang, S. D. Bradley, Park, Shin, and Chung (2006) which conceptualizes the STRT as a measure of available resources (equal to resources allocated minus resources required). In this paper we examine the independent effects of a structural complexity variable (number of camera changes per second) used to manipulate automatic resource allocation and an information density variable (information introduced per second) used to manipulate resources required on available resources (measured by STRTs) and task performance (measured by audio recognition). Previous work is extended by also investigating whether emotion alters the effects of structure and information on available resources and task performance.

This paper tries to reconcile two lines of research on STRTs. One examines how a variety of independent variables which fall under the rubric of structural and/or information complexity impact STRTs (Anderson, Levin, & Lorch, 1977; Bolls, Muehling, & Yoon, 2003; A. Lang, Schwartz, Chung, & Lee, 2004) and the other investigates how STRTs vary with the primary dimensions of emotion (i.e., valence and arousal) (A. Lang, Bolls, Potter, & Kawahara, 1999; A. Lang, Dhillon, & Dong, 1995; A. Lang, Newhagen, & Reeves, 1996; Newhagen & Reeves, 1992; Potter & A. Lang, 1996). The primary question this paper sets out to answer is whether STRTs can be used as a reliable measure of available resources during mediated message processing even when the messages are emotional. In other words, do the effects of message emotion on available resources (and therefore on STRTs) add to or interact with the effects of resources allocated and resources required?

STRUCTURAL COMPLEXITY, INFORMATION DENSITY, AND STRTS

The basic STRT paradigm conceptualizes humans as information processors with a limited pool of cognitive resources which are allocated independently to the tasks involved in processing messages (encoding, storage, retrieval, etc.) (Basil, 1994; A. Lang & Basil, 1998). People perform a primary task—in a media laboratory, the primary task usually is watching a mediated message. They are instructed to pay close attention to the message as they will be tested on their memory for the information contained in the messages. At the same time, they are told to be alert for a signal (e.g., a tone or a flash) and, when they perceive it, to push a button as fast as they can. This is the secondary task. The speed with which they perform the secondary task or the STRT has traditionally been interpreted as an indicator of the amount of resources not being used to perform the primary task (see A. Lang & Basil, 1998 for a review). When the primary task is difficult and requires many resources, STRTs should be slow, reflecting few remaining resources. When the primary task is easy and requires few resources, STRTs should be fast.

When this paradigm was initially imported into the media laboratory as a measure of resource allocation, problems appeared. In multiple media contexts (e.g., text and TV), more complex messages resulted in faster STRTs compared to less complex messages (Britton & Tesser, 1982; Britton, Westbrook, & Holgredge, 1978; Grimes, 1990, 1991; Grimes & Meadowcroft, 1995). Applying the standard theoretical interpretations yields the counterintuitive conclusion that complex messages use fewer resources than simple ones. Media researchers offered several explanations for why this might be the case, such as that complex messages were more arousing (Thorson et al., 1986) or that less complex messages used more capacity (Reeves et al., 1986). However, none of these explanations was able to account for the finding that, despite the fast STRTs indicative of plenty of resources, primary task performance (that is memory for the messages) was poor, suggesting that there were not sufficient resources to perform the task.

In a review of this literature, A. Lang and Basil (1998) suggested that the problem lay in the theoretical conceptualization of which resources were being measured by the STRT. They argued that there are four primary pieces of the resource pie: resources allocated, resources required, resources remaining, and resources available. The traditional STRT paradigm conceives of STRTs as measuring the remaining resources (i.e., resources that have not been allocated to the primary task). Instead, A. Lang and Basil suggested that it made more sense to think of STRTs as available resources (i.e., resources allocated to the primary task but not required to do the task) in other words, resources allocated to the primary task minus the resources required by it. When more resources are allocated to a task than the task requires, this results in a surplus of allocated resources; therefore, there are available resources. When the right level of resources is allocated to a task, there are

zero available resources. When too few resources are allocated to the task, there are, at least theoretically, negative available resources. Thus, available resources can be positive (resulting in fast STRTs), near zero (resulting in slow STRTs), or negative. Negative available resources correspond to a state of cognitive overload in the primary processing task meaning that there are insufficient resources available to perform the primary task and, as a result, primary task performance suffers. This means that if the primary processing task is encoding the message—then encoding performance (measured by recognition) should decrease. Indeed, in general a decrease in encoding has been the primary indicator that the encoding process is overloaded.

It is not intuitively clear what should happen to STRTs when available resources are negative. Two recent studies, however, have provided empirical data suggesting that when the encoding process is overloaded, indicated by a sudden statistically significant drop in recognition performance, STRTs also become significantly faster—generally becoming as fast as they are at the point when there is an abundance of available resources (A. Lang et al., 2006; Fox, Park, & A. Lang, in press). The authors suggested that at the point of overload, that is at the point when encoding performance drops significantly, resources are automatically shifted to encoding the STRT probe resulting in improved secondary task performance and faster STRTs. The authors suggest one reason this might occur is that, in a multi-tasking situation, once the primary task begins to fail—resources might be allocated to the secondary task—to ensure its completion—because there are no longer resources available to take care of it. There are several reasons why the authors argue that this shift is automatic and not controlled. First, overload is defined very narrowly as a statistically detectable decrease in recognition performance. This does not mean that participants "feel" overloaded, that they notice that they are processing the message poorly, or that they stop trying to process the message because it is too hard. Indeed, previous research shows that structurally complex messages which elicit this very specific type of overload also elicit the slowest heart rates (indicative of the most attention), the greatest skin conductance (indicative of the most arousal), and are rated as more enjoyable and positive than messages which do not elicit recognition performance decrements. Second, if the shift were controlled then all or most users would have to be continuously deciding in concert, from one message to the next, whether to follow the instructions (e.g., to pay close attention to the message) or whether, instead, to pay attention to the STRT probe. There is no sign that they are doing this and it seems highly unlikely that all subjects would consistently make the same controlled decisions at the same point in the messages—especially given that the messages are presented, generally, in random order.

However, regardless of whether the resources are shifted automatically or through controlled processes, it does seem to be clear that messages which are designed to elicit both *high* levels of available resources and *negative*

available resources lead to similarly fast STRTs, but that the former state is accompanied by excellent primary task performance (i.e., recognition) and the latter is accompanied by poor primary task performance. This finding is also consistent with the pattern of fast STRTs and poor recognition historically seen during complex message viewing and provides support for the interpretation that this pattern of results was caused by cognitive overload (or negative available resources).

The experimental paradigm used to test these hypotheses in the previous studies and replicated here (A. Lang et al., 2006; Fox et al., 2006; Fox et al., 2007) had viewers watch television messages which varied in terms of the number of camera changes per second (cc/sec) and the amount of information introduced by those camera changes per second (ii/sec). The number of camera changes is used to manipulate resources allocated based on the theoretical premise from the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP, A. Lang, 2000, 2006a, 2006b) that camera changes elicit orienting responses which results in an automatic allocation of resources to encoding the message (A. Lang, 1990; A. Lang, Geiger, Strickwerda, & Sumner, 1993; A. Lang et al., 1999). Therefore, the more camera changes in a message the more resources are allocated to encoding the message. Resources required are manipulated by the level of information introduced by the camera change. At a given level of resource allocation (or cc/sec), the more information introduced by a camera change, the more resources will be required to encode it, and the fewer resources will be available—up to the point where available resources become negative. In the study by A. Lang et al. (in press), it was found that, at a given level of cc/sec, STRTs became slower as ii/sec increased until the point at which recognition performance (used as an indicator of cognitive overload) got significantly worse at which point STRTs got significantly faster. In the study reported here, the same two variables cc/sec and ii/sec were used to manipulate resources allocated and resources required respectively and the same hypotheses are proposed for replication:

H1: STRTs should get slower as resources required (ii/sec) increase until the point of cognitive overload at which point they should get significantly faster.

H2: Recognition should stay the same or decrease slightly as resources required (ii/sec) increase until the point of cognitive overload at which point it should drop significantly.

EMOTION AND STRTS

In addition, this study extends the previous work by asking if emotional message content alters the effects of resources automatically allocated to the

message (cc/sec) and resources required by the message (ii/sec) on available resources (STRTs) and task performance (recognition). Research examining the effects of arousing content and valence has shown that increasing arousing content results in both better recognition and slower STRTs. Early versions of the limited capacity model theorized that arousing content increased both the resources allocated to and the resources required by the encoding subprocess. Motivational relevance (e.g., threats and opportunities) were thought to compel attention, which was achieved through the mechanism of automatic allocation of resources to encoding. At the same time, a survival advantage might be gained by encoding more information about motivationally relevant stimuli, hence resources required was also thought to increase. This resulted in the prediction that recognition would be better for arousing compared to calm content, because the overall level of resource allocation was higher, but, at the same time STRTs would get slower because the level of resources required also increased. A fair number of studies have indeed shown this pattern of results when measuring STRTs and recognition in response to emotional messages (A. Lang, Dhillon, & Dong, 1995; A. Lang, Newhagen, & Reeves, 1996; Newhagen & Reeves, 1992; Potter & Lang, 1996). Hence, to replicate that work, this paper predicts that:

H3: STRTs will be slower and recognition will be better during arousing compared to calm messages.

VALENCE, AROUSAL, AND MOTIVATIONAL ACTIVATION

A limitation, however, of the earlier work and theoretical model was that only arousing content was considered. The effects of valence and message complexity were largely ignored and unexplored. To fully predict how emotional content impacts available resources requires a theory of emotional processing. In general, there are two main theoretical approaches to emotion, the dimensional approach and the categorical approach. This paper takes the LC4MP theoretical perspective which incorporates within it a dimensional theory and a dual system theory of emotion. Dimensional theories of emotion generally explain emotional experience as a function of two major underlying dimensions, valence and arousal. Valence is whether a message is positive or negative and arousal is the level of excitement or activation associated with the emotion (A. Lang, 2006a, 2006b).

Most dimensional theories argue that emotional stimuli are motivationally relevant and as a result engage the underlying appetitive (approach) and aversive (avoid) motivational systems and that the level of activation in these systems results in the experience of emotion (Cacioppo & Berntson, 1999; Cacioppo & Gardner, 1999). Valence primarily affects which motivational system activates, with negative messages activating the aversive and
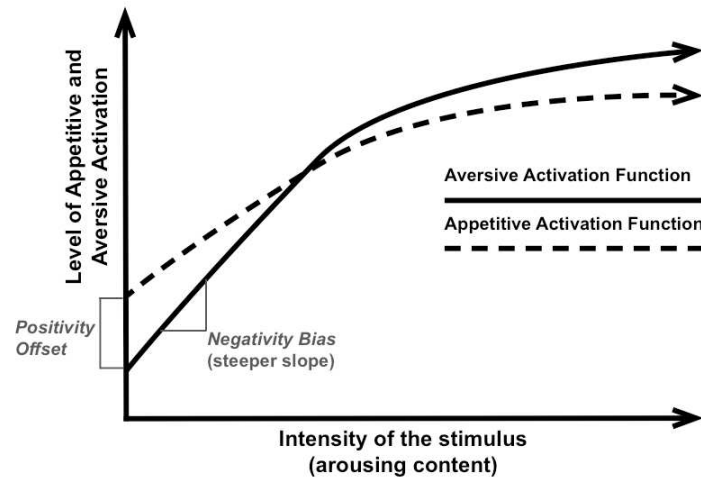
FIGURE 1 The motivational activation functions.

positive messages activating the appetitive system. Arousing content influences the level of activation in the relevant motivational system. A great deal of research using video, still images, audio, and text has demonstrated that viewing negative media increases aversive system activation, that viewing positive media increases appetitive activation and, that increasingly arousing content results in increasing levels of motivational activation (e.g., Bolls, Potter, & A. Lang, 2001; A. Lang, Shin, & Lee, 2005).

In addition, the dual system theory also conceptualizes two primary characteristics of the appetitive and aversive motivational activation functions (Cacioppo & Berntson, 1999; Cacioppo & Gardner, 1999; Cacioppo, Gardner, & Berntson, 1999; Ito, Larsen, Smith, & Cacioppo, 1998). The motivational activation functions (see Figure 1) plot the degree of activation in the motivational systems (y axis) elicited by an increase in arousing content in the stimulus (x axis). The two primary characteristics of these functions are the positivity offset and negativity bias. Positivity offset describes the finding that in a neutral environment the appetitive system is more active than the aversive system in order to facilitate exploratory behavior; negativity bias describes the finding that the aversive system activates more quickly and more sharply than the appetitive system in response to increases in arousing content so as to facilitate quick response to aversive stimuli in environment.

RESOURCES ALLOCATED AND REQUIRED IN EMOTIONAL MESSAGE PROCESSING

LC4MP argues that the level of resources allocated to a positive message follows the shape of the appetitive activation function whereas resources

allocated to negative messages follow the shape of the aversive function up to a moderately high level of arousing content. At high levels of arousing negative content (e.g., a level at which fight or flight becomes imperative), resources allocated to encoding are theorized to drop off quickly since further encoding of the stimulus is no longer useful but instead action should be taken (A. Lang, 2006a, 2006b). This means that during calm messages, as a result of the positivity offset, more resources are allocated to positive than to negative messages; during moderate and moderately high levels of arousing content, as a result of negativity bias, more resources are allocated to negative than to positive messages, and; at very high levels of arousing content, more resources are allocated to encoding positive than negative messages.

Overall, however, as long as you stay below the fight or flight level, for both systems, the more arousing the message the more activated the motivational system will be and the more resources should be allocated to encoding which is in line with previous research and theory. Given positivity offset and negativity bias, it may also make sense to argue that at very low levels of arousing content, as a result of positivity offset, slightly more resources may be allocated to positive compared to negative messages and that at moderately high levels of arousing content, due to negativity bias, slightly more resources may be allocated to negative compared to positive messages. It also makes sense to continue to argue, as did previous researchers, that the presence of increasingly arousing content also results in more resources being required in order to more thoroughly encode the motivationally relevant stimulus, meaning that resources required should also rise as a function of arousing content.

What we don't know is whether resources allocated and resources required, as a function of arousing content, increase at the same or different rates for appetitive compared to aversive activation. Research arguing that negative messages compel attention (Newhagen & Reeves, 1991, 1992) might imply that resources required would increase faster for negative compared to positive messages, or that it is always higher (regardless of arousing content). On the other hand, theoretical arguments that information intake is the primary goal of appetitive activation might imply that resources required would be higher for positive messages. Given that there is no data on this topic and no real reason to choose between them, no specific prediction will be made here about how valence may modify the relationships between arousing content and resources allocated and required.

The next step is to combine the predictions about how arousing content and valence impact resource allocation with our earlier predictions about how available resources vary as a function of camera changes and information introduced. First, it is argued that the allocation of resources elicited by a camera change should not be affected by arousing content or valence since it is a phasic, reflexive response. Similarly, the resources required as

a function of information introduced by camera changes should remain the same regardless of emotional content. However, arousing content and valence should combine to affect resources allocated and required as described earlier. So, although the phasic variations in available resources brought about by cc/sec and ii/sec should not be affected, the overall level of available resources will be. If there is only an overall level change, this would suggest that there should not be an interaction of the complexity measures with the emotional measures. That is, the interactions seen as a result of Hypotheses 1 and 2 should not vary across emotional message types.

On the other hand, it is also possible that increasing the overall allocation of resources to encoding the message will push the entire system into cognitive overload more quickly since more resources need to be allocated out of a fixed capacity pool, as a result, there may be insufficient resources in the system to answer all the automatic calls for resources (e.g., the pool may run dry). If this is the case then overload should occur sooner (i.e., at lower levels of ii/sec controlling for cc/sec) in some conditions compared to others which will result in a four way interaction. Based on the above theoretical predictions about resource allocation, overload should occur sooner: (1) for arousing compared to calm messages because the system lacks sufficient resources to completely fulfill the automatic calls for resources; (2) for calm positive messages compared to calm negative messages (as a result of positivity offset) because more resources are allocated to positive messages when the messages are calm, and therefore they should exceed the system's capacity sooner, and; (3) for moderately arousing negative compared to moderately arousing positive messages (as a result of negativity bias) because more resources are allocated to negative messages when the messages are moderately arousing, and therefore they should exceed the system capacity sooner. If this is the case, there should be a four way interaction such that:

> H4: Overload (indicated by fast STRTs and poor recognition) will occur at an earlier level of ii/sec for arousing compared to calm messages within a valence category, for calm positive compared to calm negative messages, and for arousing negative compared to arousing positive messages.

METHOD

This study used a 2 (Valence) × 2 (Arousing Content) × 2 (cc/sec) × 3 (ii/sec) × 3 (Messages) × 2 (Half) mixed design. One hundred and forty four messages were selected from a pool of television messages and feature films. Messages were either 30 or 60 seconds in duration. There were six messages in each Valence × Arousing Content × cc/sec × ii/sec category. Then the

144 messages were separated into two balanced groups of 72 messages, with three messages in each category. Half is the only between-subjects variable. Each participant was randomly assigned to view one set of 72 messages presented in a random order.

Stimuli and Independent Variables

Initially messages were recorded (primarily) from the local cable television system for possible inclusion in the study based on valence and arousing content. All of these messages were then coded for cc/sec and ii/sec.

cc/sec. To manipulate resources allocated, messages were chosen based on the number of camera changes per second (cc/sec). Research shows and theory suggests that the size of the orienting response, and therefore the size of the resource allocation, does not vary with the complexity of the camera change (A. Lang et al., 1993). Thus, the more camera changes in a message the more resources are automatically allocated to the task of encoding the message. Cc/sec was measured by counting the number of camera changes in each message and dividing it by the number of seconds in each message.

ii/sec. Resources required were manipulated by selecting messages which differed on the amount of information introduced by the camera changes. The measure ii/sec was developed by A. Lang et al. (2006). It is coded by comparing the information which immediately precedes and follows a camera change on seven dimensions of information which are theoretically and empirically related to resource requirements. To code ii/sec, a determination is made for each camera change whether the information following the camera change is: 1) Emotionally different; 2) A new focal object; 3) New to this message; 4) Expected or related; 5) Closer to the camera; 6) Seen from a new perspective, or; 7) Presented in a different form (e.g., video to text, animation to live action) compared to the information before the camera change. A given camera change can have an ii score ranging from 1 to 7. For each message, these scores are summed across camera changes and divided by message length to produce the measure of Information Introduced per Second (ii/sec). Two trained coders coded 25% of the messages and arrived at an inter-coder correlation of 0.97 during independent coding sessions. One coder then coded each of the remaining messages.

Valence and Arousing Content. Message emotion was conceptualized as a message characteristic. Messages were selected as being positive if they contained positive events (parties, weddings, graduations, births, eating, romantic sex, etc.), locations (beautiful surroundings, restaurants, etc.), or people having fun and displaying positive emotions (smiling, laughing, etc.). Messages were negative if they contained negative events (fighting, yelling/arguing, funerals, natural disasters, etc.), locations (cemeteries, hospitals, etc.), or people portraying negative emotions (crying, screaming, shaking in terror, etc.). Messages were considered to be arousing when there

was a strong sense of excitement in the message and the positive or negative events were momentous and imminent. Messages were considered to be calm when the message lacked excitement and the positive or negative events were not momentous and not imminent. Groups of graduate students (ranging in size from 3-6) along with one of the primary researchers watched independent subsets of the messages and achieved consensus on the emotional content of each message.

Next, the ii/sec values for each message were examined and the 12 messages with the lowest, highest and middle most ii/sec values were chosen in each Valence × Arousing Content group. At each level of ii/sec for each emotional message group, the messages were rank ordered by cc/sec. The top six were designated as the high cc/sec group and the bottom six were the low cc/sec group. Values of ii/sec are significantly different across levels ($F(1, 141) = 63.40$, $p < .001$) with means in the manipulated direction ($M_{low} = .30$, $SE_{low} = .08$; $M_{med} = .62$, $SE_{med} = .08$; $M_{high} = .1.45$, $SE_{high} = .08$), and pairwise comparisons show each level is significantly different from the other two. Manipulation of cc/sec was also successful ($F(1, 142) = 5.17$, $p < .005$; $M_{low} = .22$, $SE_{low} = .07$; $M_{high} = .45$, $SE_{high} = .08$). There were no significant effects of Valence or Arousing Content on ii/sec or cc/sec (all $F < 1$).

Dependent Variables

STRTs. An audio STRT probe (250 milliseconds, 1,000 Hz) was inserted at three randomly selected points in each message with one probe occurring in each third of the messages. Three STRT probes were inserted per message in order to measure the viewer's responses over an entire message without overly disrupting the viewer's information processing. Randomness of the probe locations makes the probes unpredictable for the viewer which is important to ensure the validity of the STRT measure. In addition, to avoid the confounding effects of message onset, offset, and camera change, the first probe was inserted at least 5 seconds after the message onset, and the last probe was inserted no less than 2 seconds before the end of the message, and no probe occurred sooner than 500 milliseconds after a camera change.

Recognition. A forced choice (yes-no) audio-recognition test was developed by choosing three target sentences in each message. These sentences were chosen to be central to the ongoing action in the message. For each sentence a foil was developed by changing three words in the sentence. This resulted in 3 pairs of sentences (3 targets and 3 foils) for each message. There were four messages which did not contain three sentences. For these, two target sentences were used and two target foil pairs were created. One speaker recorded all the sentences. During the recognition test, participants listened to the recordings and responded "yes" or "no" to the question of

whether they had heard the exact statement earlier in the experiment. For analysis, percent correct is averaged for each message.

Participants

Ninety-four undergraduate students from a large Midwestern university were recruited from communications courses and given partial credit for their participation in the study. There were 45 females, 48 males, and 1 unidentified participant.

Procedure

Participants signed an informed consent and were given instructions about the experiment. They were told to pay close attention to the messages as their memory would be tested. They were also told that from time to time they would hear a beep, and when that happened, they should push a button as quickly as possible. Participants completed a practice test and were given the option to ask questions before beginning the experiment. Participants viewed the messages on a laptop computer with the audio (including the STRT probes) delivered through headphones. After viewing the messages, participants filled out a non-related questionnaire which served as a distraction task to clear their short term memory. Participants then completed the auditory recognition task. Due to computer technical problems, 14 participants' STRT data and two participants' recognition data were corrupted and excluded from the analysis.

Analysis

The STRT and recognition data were averaged across the 3 (messages) × 2 (Half) trials at each of the 2 (Valence) × 2 (Arousing Content) × 2 (cc/sec) × 3 (ii/sec) manipulation level, and then submitted to a repeated ANOVA of 2 (Valence) × 2 (Arousing Content) × 2 (cc/sec) × 3 (ii/sec) post-hoc comparisons were done using t-tests. Means are reported as significantly different at $p < .05$.

RESULTS

Hypothesis 1

This hypothesis predicted that STRTs would get slower as resources required (ii/sec) increased up to the point of cognitive overload at which point they should get significantly faster. The main effect of ii/sec on the STRT data was significant, $F(2, 158) = 12.55$, $p < .01$, partial $\eta^2 = .14$.
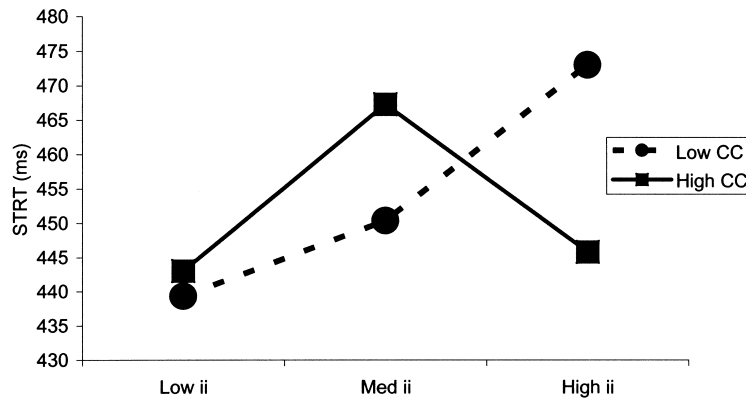
FIGURE 2 Interaction of cc/sec × ii /sec on STRTs (ms).

STRTs did get slower as ii/sec increased ($M_{\text{low ii/sec}} = 441.21$, $SE_{\text{low ii/sec}} = 11.23$; $M_{\text{medium ii/sec}} = 458.86$, $SE_{\text{medium ii/sec}} = 12.13$; $M_{\text{high ii/sec}} = 459.41$, $SE_{\text{high ii/sec}} = 10.88$) though none of the means differ significantly from one another, probably because of the significant cc/sec × ii/sec interaction, $F(2, 158) = 19.36$, $p < .001$, partial $\eta^2 = .20$, shown in Figure 2. At low levels of cc/sec, STRTs get slower as ii/sec gets higher and the mean STRT at high ii/sec is significantly slower than at medium or low. However, at high cc/sec, STRTs get significantly slower from low to medium ii/sec but then get significantly faster from medium to high ii/sec. These results suggest that at low levels of cc/sec, no cognitive overload occurred although available resources did decline as ii/sec increased. However, at high levels of cc/sec, cognitive overload may have occurred at high levels of ii/sec, indicated by the significant speeding up of the STRTs. If this is the case, there should be a corresponding significant decline in the recognition measure at high levels of cc/sec and ii/sec.

Hypothesis 2

This hypothesis predicted that as ii/sec increased, audio recognition would stay the same or increase until the point of cognitive overload at which point it would decrease. There is a significant main effect of ii/sec on the recognition data, $F(2, 182) = 3.99$, $p < .05$, partial $\eta^2 = .04$. Audio recognition did not differ significantly from low ($M = 57.5$, $SE = .01$) to medium ii/sec ($M = 58.2$, $SE = .06$) but did drop significantly from medium to high ii/sec ($M = 56.7$, $SE = .01$). In addition, there is a marginally significant cc/sec × ii/sec interaction, $F(2, 182) = 2.58$, $p = .08$, partial $\eta^2 = .03$, shown in Figure 3. For low levels of cc/sec recognition improved significantly from low to medium ii/sec but then declined slightly, though not significantly, from medium to high ii/sec. For the high cc/sec messages, recognition declined
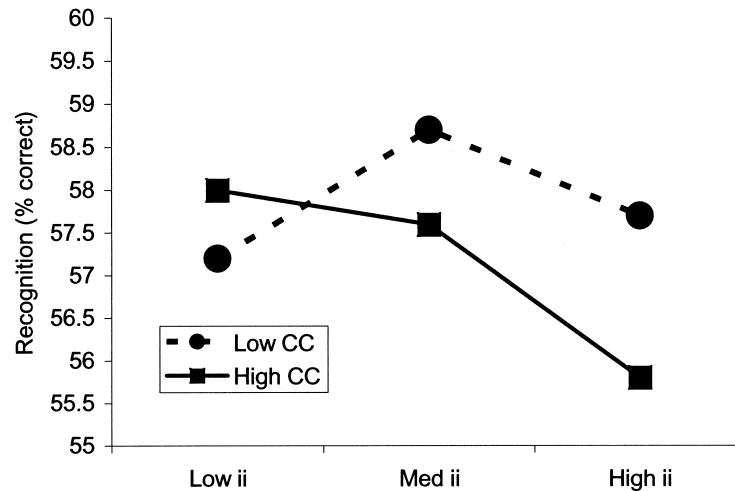
FIGURE 3 Interaction of cc/sec × ii/sec on recognition (percent correct).

slightly but not significantly from low to medium ii/sec, and then declined significantly from medium to high ii/sec.

Thus, examining the results of these two hypotheses together we see that at low levels of cc/sec, there is no cognitive overload, resulting in slower STRTs and little change in recognition as available resources decline but remain sufficient for encoding information with increasing ii/sec. For the high cc/sec conditions, however, cognitive overload does occur at the high ii/sec level evidenced by the concurrent appearance of significantly *faster* STRTs and significantly *worse* recognition.

Hypothesis 3

This hypothesis predicted that STRTs would be slower and recognition would be better during arousing compared to calm messages. As predicted, the main effect of Arousing Content was significant on the STRT data, $F(1, 79) = 9.33$, $p < .01$, partial $\eta^2 = .11$, with slower STRTs during arousing messages ($M = 458.32$, $SE = 11.04$) than during calm messages ($M = 448.00$, $SE = 11.54$). The main effect of Arousing Content was also significant on the recognition data, $F(1, 90) = 8.24$, $p < .01$, with slightly better recognition during arousing messages ($M = .58$, $SE = .01$) than during calm messages ($M = .57$, $SE = .01$).

Hypothesis 4

This hypothesis predicts that overload (indicated by fast STRTs and poor recognition) will occur sooner (e.g., at a lower level of ii/sec controlling for cc/sec) in the following situations: (1) within a valence category, for arousing

compared to calm messages because of the overall increased resource allocation associated with arousing messages; (2) within calm messages, for positive compared to negative messages, because of positivity offset, and; (3) within moderately arousing messages, for negative compared to positive messages because of negativity bias. When there is no overload, increased ii/sec (controlling for cc/sec) should result in slower STRTs and stable or improving recognition scores.

The four-way Valence × Arousing Content × cc/sec × ii/sec interaction was significant for both the STRT, $F(2, 158) = 3.18$, $p < .05$, partial $\eta^2 = .04$, and the recognition data, $F(2, 182) = 13.53$, $p < .001$, partial $\eta^2 = .13$. Both interactions are shown in Figure 4, with the recognition data in the left column and the STRT data in the right column. The first two rows of Figure 4 show the positive messages and the second two rows show the negative messages, with calm preceding arousing messages in each case. To unpack this interaction, we will first determine at what level of cc/sec and ii/sec, overload occurred for each emotional message type, keeping in mind that STRT and recognition must both decrease significantly for us to be sure that overload has occurred.

For the calm positive messages, planned comparisons show that both recognition scores and STRTs decreased significantly (indicative of overload) only during high cc/sec messages going from medium to high ii/sec. Therefore, for calm positive messages, there was no overload for low cc/sec messages, and for high cc/sec messages, overload occurred at the high ii/sec level.

For arousing positive messages, recognition scores but not STRTs decreased significantly from medium to high ii/sec. For high cc/sec messages, recognition performance decreased significantly from low to medium ii/sec whereas STRTs got significantly faster from medium to high ii/sec. Thus, both STRTs and recognition decreased significantly for high cc/sec messages at high levels of ii/sec. Recognition, but not STRTs, decreased significantly for low cc/sec high ii/sec and high cc/sec medium ii/sec messages. If we contemplate that having one but not the other significant decrease of the recognition or STRTs as a sign of impending overload (but not yet a state of overload), it would make sense to say that arousing positive low cc/sec messages did not achieve a state of overload but show some signs of impending overload at high ii/sec condition, whereas high cc/sec messages showed signs of overload at medium ii/sec and reached overload at high ii/sec.

For calm negative messages, there were no significant drops in STRT or recognition at either level of cc/sec, thus calm negative messages did not appear to reach overload.

For arousing negative messages, there were no significant drops in recognition or STRT for low cc/sec messages; but during high cc/sec messages, recognition and STRT both dropped significantly from medium to high ii/sec.
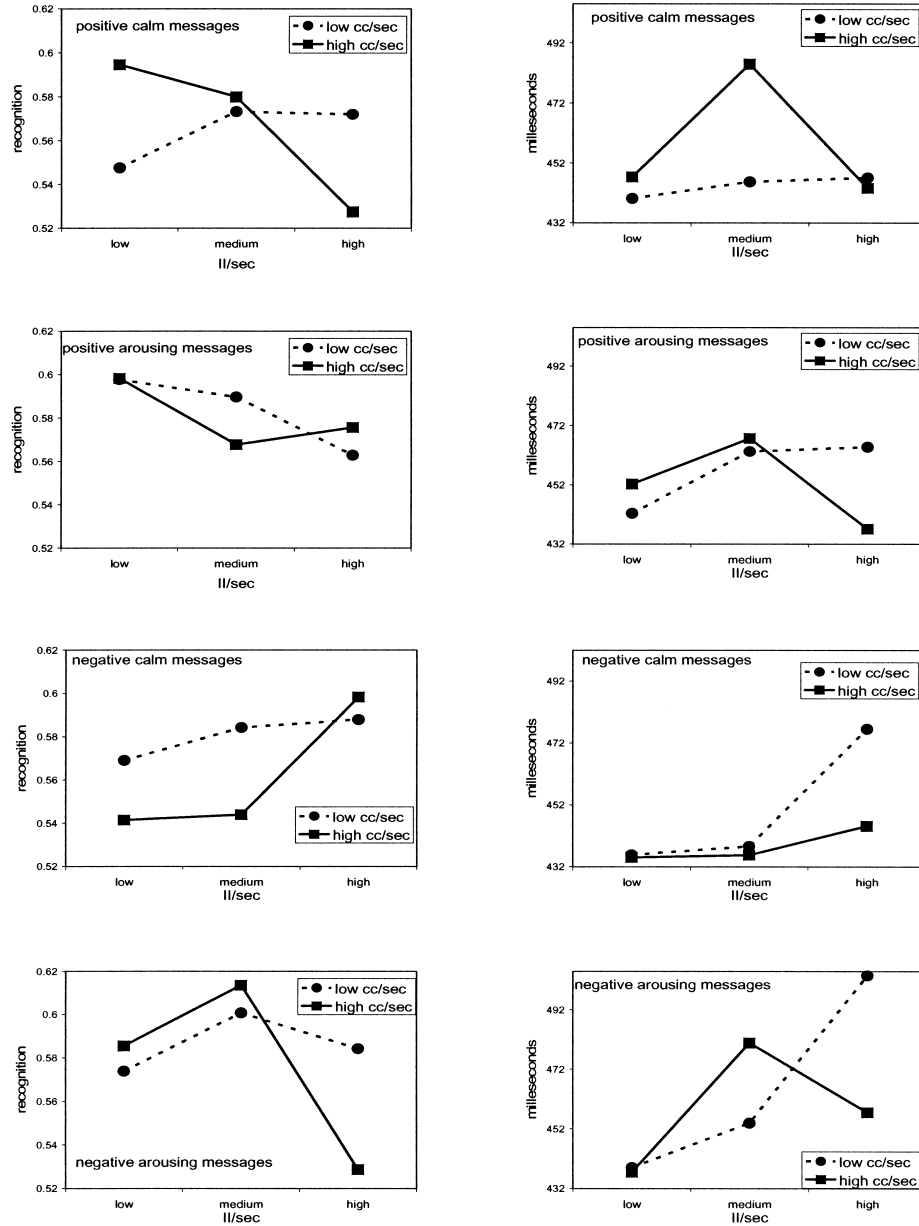
FIGURE 4 Valence × arousing content × cc/sec × ii/sec on STRTs (ms) and recognition (percent correct).

Thus, low cc/sec messages did not cause overload and high cc/sec messages caused overload at the high level of ii/sec.

Now that we know when each type of messages reached overload, we can examine the three predictions made by this hypothesis with ease. First, it was predicted that within a valence category, arousing messages would cause overload before calm messages. During positive messages, both low and high cc/sec arousing messages showed signs of overload (a drop in recognition with no accompanying drop in STRT) sooner than calm messages, though they actually reached overload at the same level of ii/sec. During low cc negative messages neither calm nor arousing messages reached overload. During high cc/sec messages arousing messages overloaded sooner than calm messages.

Next, it was predicted that within calm messages, positive messages would overload before negative messages. Neither positive nor negative calm messages overloaded at the low cc/sec level. However, at the high cc/sec level overload occurred sooner for calm positive messages (at the high ii/sec level) compared to calm negative messages (which did not overload).

Third, it was predicted that within arousing messages, negative messages would reach overload earlier than positive messages because of negativity bias. Here, positive messages showed signs of impending overload but never reached the state of overload; however, negative messages reached overload at the high ii/sec level for high cc/sec messages.

CONCLUSION

This paper asked three main questions. First, could we replicate the findings of A. Lang et al. (in press), that STRTs measured during TV viewing seem to be measuring available resources? Second, would resource availability vary as a function of positivity offset and negativity bias as predicted by the LC4MP? Third, would the effects of structural complexity and information density on STRTs and recognition remain predictable when the messages were emotional? To which we can answer yes, partially, and yes respectively.

In general, this paper suggests that the experimental paradigm which uses cc/sec as a measure of resources allocated and ii/sec as a measure of resources required can be used to manipulate available resources and that STRTs appear to be measuring the level of available resources such that as the level of available resources gets lower, STRTs get slower until cognitive overload has occurred, at which point they will become significantly faster. Further, recognition is stable as long as there are available resources but then drops significantly when overload is reached. This is good because it provides a sound theoretical explanation for previous findings showing fast STRTs in response to complex television messages. These results tell us that indeed messages that are structurally complex and messages that have high

information density both stress the cognitive system—one by demanding increasingly large allocations of resources and the other by consuming large amounts of the resources allocated. How well a message is encoded (the first step in processing) is the result of both the structural complexity of the message and its information density. Thus, message producers who want to create memorable messages need to balance these two variables to optimize ease of processing.

Second, these results suggest that STRT and recognition measures need to be used in concert to identify the point of cognitive overload. If a study measures STRT without recognition measures then one cannot determine if fast STRTs are the result of available or of negative resources. In this study, in most instances, STRTs got faster and recognition got lower at the same level of available resources, which was then identified as the point of cognitive overload. In two instances, however, (both with positive arousing messages) the significant drop in recognition occurred before the significant drop in STRTs. Future research should employ more fine grained manipulations of available resources in order to determine if recognition performance regularly shows signs of overload before STRTs do. Recent research by Fox and her colleagues (Fox et al., in press) using the same experimental paradigm used here but assessing encoding using signal detection methods rather than simple % correct measures may shed some light on this question. In that work, it was shown that criterion bias, which is the level of familiarity at which participants are willing to say "yes (I saw that before)," became significantly more liberal (e.g., more willing to say yes at a lower level of familiarity) at a level of available resources that preceded the significant drop in recognition sensitivity (which is an indicator for the respondent's ability to distinguish old versus new information). This suggests that the strategy being employed to perform the recognition task changes as a result of the proficiency with which the encoding task was originally performed. During viewing, when available resources become scarce (but not negative), a similar amount of information continues to be encoded, but is encoded less well. As a result, later, when the recognition test is taken, the information encoded during scarce compared to ample resource messages feels less familiar. This leads to a shift in the criterion bias, reflecting the general drop in familiarity of the entire distribution of encoded items as a result of the scarcity of resources but there is no change in recognition sensitivity until resources actually become negative.

The second set of results provided solid evidence that there are fewer available resources when messages are arousing (i.e., STRTs were slower for arousing compared to calm messages); and as a result, cognitive overload occurs at lower combinations of structural complexity and information density. In addition, the positivity offset prediction that there would be fewer available resources during calm positive compared to calm negative messages was partially supported and the negativity bias prediction that moderately

arousing messages would be allocated more resources if they were negative than if they were positive was also supported. Taken together these findings provide additional evidence that motivational activation fundamentally impacts resource allocation and the subsequent cognitive processing of mediated messages. This finding is important because it suggests that emotional content in messages does much more than simply elicit emotion in viewers. Instead emotional content elicits motivational activation which fine tunes cognitive processing to maximize evolutionarily positive outcomes. Thus, negative things receive quick and thorough processing in order to protect the organism and positive things receive slower more deliberative processing to ensure that the best choices are made.

Finally, this study provides good news for those interested in using STRTs as a measure of cognitive load during media viewing. These data strongly suggest that STRTs and recognition used together measure available resources during television viewing no matter what the emotional content of the message. For all four emotional types in this study, increases in ii/sec and cc/sec produced the expected pattern of STRTs. The more information introduced (e.g., the harder the message) at a given level of resource allocation, the slower the STRTs became until the point of cognitive overload. These results also continue to suggest that when using STRTs to measure cognitive load, it is important that researchers recognize that they are likely tracking available, rather than remaining, resources.

Finally, these results should be useful to all producers of mediated messages because they continue to increase our understanding of which aspects of messages elicit automatic responses of the cognitive, experiential, or motivational systems which, in turn, predictably impact which parts of messages people will attend to and the extent to which that attention will increase or decrease their ability to encode the message. These results continue to caution media producers that media structural complexity is a two edged sword. Although it clearly increases resource allocation, liking, and attention, it also contributes to cognitive overload. Its injudicious use can easily lead to messages which are engaging, even engrossing, but cannot be remembered in any detail. Further, these results tell us that this double edged sword is even sharper if the messages are emotional. Arousing content does increase attention by increasing both the resources allocated and the resources required by messages. However, these increased demands push the system to capacity more quickly.

Finally, it is worth noting that both emotional content and structural complexity are compelling because they play on the automatic, unconscious resource allocation mechanisms. As a result, messages containing this type of content are easier to watch, listen to, or read because they do the work of maintaining attention. These automatic orienting and motivational responses are undoubtedly some of the mechanisms underlying phenomenon like attentional inertia and flow. In addition, when combined with measures of

individual difference variables (like levels of motivational activation, personality type, etc.) they have the potential to begin to explain why different people find different types of media and different types of content more or less entertaining.

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