The Limited Capacity Model of Motivated Mediated Message Processing (LC4MP)

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Abstract
The limited capacity model of motivated mediated message processing (LC4MP) is a model for understanding the dynamic interactions between mediated messages and the human information processing system. At the time of its original writing, the LC4MP was unique in the landscape of media psychology research in that it eschewed rote investigation of message effects and instead focused on investigating how message structure and content interact with and influence various biological systems of the brain and body. In the last twenty years, the LC4MP has catalyzed much progress in our understanding of the biological dimensions of message processing. In this entry, we review the assumptions of the LC4MP, along with key concepts and methods used in the LC4MP literature. In addition, we discuss the core propositions of the model, highlighting ways in which they have evolved as the model has developed. Finally, we introduce a few areas in which the model is still under active development, pointing out promising areas for future research.

1. Introduction

The limited capacity model of motivated mediated message processing (LC4MP) is a model for understanding the dynamic interactions between mediated messages and the human information processing system (Fisher, Keene, Huskey, & Weber, 2018; Lang, 2000, 2009, 2017). The model was originally conceptualized in the late 1990's and early 2000's as the "LC3MP." The fourth "M" (motivation) was not incorporated until several years later. At the time of its original conceptualization, the LC4MP was unique in the theoretical landscape of media psychology. At the time, most other approaches sought to explain and predict the relationship(s) between various forms of media exposure and their effects, treating the human processing system as a "black box" impenetrable to empirical research efforts. The LC4MP in many ways inaugurated a turn to an information processing approach to media psychology. This approach pries open the "black box" of the human processing system to investigate how dynamic activation and interaction of the cognitive, emotional, physiological, and behavioral systems guide message processes and effects. In the last 20 years, the model has been employed in a broad selection of academic and practical contexts, contributing to the empirical understanding of message processing but also to the development of guidelines for message design in view of improving memory, affective evaluations, persuasion, and learning.

For much of its history, the LC4MP could be described as "data-driven" (Lang, 2009). Changes in the model frequently were frequently spurred by new methodological developments (such as the refinement of new psychophysiological measures) or by advancements in theoretical understanding of the human information processing system imported from biology, cognitive science, and other fields. This data-driven approach has allowed LC4MP researchers to make marked progress toward isolating and untangling the biological systems that drive message processing. This approach has also, though, led to a proliferation of findings, tools, best-practices, assumptions, and propositions within the LC4MP literature that can be difficult to integrate into a coherent theoretical whole. Recent efforts to solidify and simplify the conceptual foundations of the LC4MP (see e.g., Clayton, Lang, Leshner, & Quick, 2018; Fisher, Huskey, Keene, & Weber, 2018) have made the model more amenable to additive theoretical predictions regarding how humans process messages.

With these things in mind, this entry provides an introduction to the current state of the LC4MP and its associated literature. First, this entry highlights the core assumptions of the LC4MP. Second, this entry discusses key concepts, theoretical propositions, and methods used to help LC4MP researchers understand cognitive resources, motivated processing, and memory (for an overview of the main propositions of the

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LC4MP, see Table 1). Finally, this entry highlights a few of the most active areas of current LC4MP research, reviewing some of the more salient unanswered questions in the literature and pointing out ways in which the model may continue to be refined in the future.

2. Assumptions of the LC4MP

Although the LC4MP has traditionally been considered a model of media processing rather than a theory in the strictest sense, it is based on a set of theoretical assumptions that guide its propositions and predictions. The first of these assumptions is that humans are limited-capacity information processors. Humans have evolved numerous systems to gather information about their world, integrate this information into their current understanding, and use it to guide their behavior. The biological systems that humans use to carry out these tasks are characterized by various constraints that circumscribe both the quality and the quantity of information that can be processed at any given time. For this reason, individuals must prioritize (either consciously or unconsciously) certain information streams over other ones during message processing in order to manage their limited resources while still achieving their goals. The LC4MP discusses this prioritization process using the language of resource allocation.

The second assumption of the model is that human information processing is by nature motivated. Humans gather and process information in large part as a means to increase their ability to survive and thrive in an uncertain world. The LC4MP assumes that information processing decisions are driven by two evolutionarily-old motivational systems—the appetitive system and the defensive (aversive) system. This assumption is based in an extensive body of literature investigating the neural, hormonal, and other biological signals that guide information processing and behavior in response to stimuli associated with reward or threat (Bradley, 2000). This work shows that the motivational systems are activated in one of three patterns: reciprocal (one system reduces its activation while the other increases its activation), coactive (both systems are concurrently active), and uncoupled (activation in one system is unmoored from activation in the other). The signals provided by the appetitive and defensive systems provide an individual with a suite of adaptive responses that allow them to avoid negative outcomes (like pain, disease, loss, or social ostracism) and pursue positive ones (like nutrition, reproduction, or social affirmation).

The third assumption of the LC4MP is that many of the signs of cognitive resource allocation and motivated processing can be observed through neural and psychophysiological responses of the brain and body. With this assumption, the model takes a strong stance against the idea that operations of the mind are somehow separate from or incommensurable with responses observed in the brain/body. In view of this assumption, the LC4MP treats neural and physiological processes as indicators of mental processes, enabling them to be used to test predictions regarding how specific message content may influence information processing and how this influence may drive certain message effects. This assumption, though, comes with the key caveat that most physiological measures are “monstrosities” resulting from activation and interaction of any number of mental or bodily processes. As such, one cannot assume a clear 1-to-1 relationship between a neural or physiological measure and an associated mental process without accounting for (either statistically or through experimental design) the influence of other factors that may be at play in the relationship. For this reason, much LC4MP work painstakingly seeks to determine two primary things: a) what sorts of neural and physiological responses are necessary or sufficient to be reasonably certain that a given mental process has taken place, and b) how to triangulate these responses with other measures in order to isolate spurious sources of variance.

The model’s fourth assumption is that all communication is mediated. As such, the model assumes that what is traditionally discussed as “mediated” communication (such as television, video games, and other digital media) should be processed in much the same way as “non-mediated” communication. This assumption is largely based on the work of Nass and Reeves in the 1980’s and 1990’s (Reeves & Nass, 1996), finding that in many ways humans process digitally-mediated stimuli using similar heuristics as they use to process “real world” stimuli. In the LC4MP, messages of all forms (both digital and non-digital) are conceptualized as dynamic, multisensory information streams. In interpersonal communication, the media of information transmission could be mechanical or electromagnetic waves (sound and light), or could be

Core Question	Propositions
What drives resource allocation?	Resource allocation is driven by the orienting response. Resource allocation is driven by activation in the motivational systems.
What drives activation in the motivational systems?	Pleasant content drives activation in the appetitive system Unpleasant content drives activation in the defensive system Activation in these systems can also be driven by stimulus characteristics (speed, size, intensity, etc) The pleasantness or unpleasantness of content is defined by flexible and/or rigid associations with reward or threat
How does motivation relate to resource allocation?	At baseline activation pleasant message content will elicit more resource allocation than unpleasant content As activation increases unpleasant content will elicit more resource allocation than pleasant content As activation further increases, unpleasant content will induce a defensive cascade, leading to resource allocation away from the message If appetitive and defensive systems are active at the same time (coactivation), resource allocation to the message will increase Risk takers (high ASA, low DSA) will preferentially engage in a confrontational strategy during the defensive cascade (fight). Risk avoiders (low ASA, high DSA) will preferentially engage in an avoidance strategy during the defensive cascade (flight)
What sorts of things require (consume) resources?	More information dense messages require more resources. If information density increases to the point that there are insufficient resources available to process the message, an individual will enter a state of cognitive overload
How does resource allocation relate to memory?	When available resources are plentiful, memory for the message should be high.When available resources are lower, memory for the message should be reduced, but still good. When available resources are negative, memory for the message should be low.

Table 1: Core questions and propositions of the LC4MP

based on chemical (olfaction, taste) or direct sensory (touch) information transmission. Of course, salient differences may exist between information streams (e.g. proximity, screen size, motivational/survival relevance) and between individuals (e.g. experience, goals, cognitive processing differences) that influence message processing dynamics.

The final assumption of the LC4MP is that the temporal dynamics of information processing are critical for understanding message processes and effects. All human information processing unfolds over time as a dynamic interaction between a message, the sensorimotor systems of the body, and the encoding, storage, and retrieval systems of the brain. In view of this, the model assumes that approaches that collapse measures of interest across an entire message or group of messages (e.g. considering the average valence of a message) are likely to miss or mischaracterize factors that are critical for determining message evaluations, memory, and other outcomes. This assumption informs the operationalization of variables in the LC4MP, as well as how data are collected and analyzed.

3. Critical Concepts, Tools, and Propositions in the LC4MP

The LC4MP comes with a formidable collection of methods, concepts, and approaches that have developed over time as research questions have changed or new data have emerged. This section briefly highlights the main terms and concepts used in each of the three main LC4MP research domains: cognitive resources, motivated processing, and memory. Within each domain, we review the core propositions of the LC4MP and discuss the methods that have most frequently been employed to test these propositions. As space does not permit a comprehensive review of the methods used in the model, interested readers are encouraged to consult Potter and Bolls (2012) or the cross-references at the end of this entry for more in-depth treatments.

3.1. Cognitive Resources

Individuals allocate resources to message processing through a suite of both phasic (short-term) and tonic (longer-term) processes. Phasic changes in resource allocation are driven primarily by the orienting response—a collection of attentional, physiological, and motor processes aimed at quickly acquiring information concerning a novel stimulus. Physically salient (e.g. loud, approaching, or unexpected) stimuli drive orienting responses in almost all individuals with intact sensory and cognitive functions. In the LC4MP, the most widely investigated drivers of the orienting response are structural features of messages (like camera cuts, edits, voice changes, and sound effects). These are called orienting eliciting structural features (OESFs). The LC4MP also suggests that the orienting response can be elicited by content features that an individual has learned signal the presence of important or relevant information (such as their name; Lang, 2000; 2009). The relationship between an OESF and the presence and intensity of orienting response is also influenced by habituation. The orienting response habituates rather quickly if similar OESFs are presented in quick succession. This results in diminishing orienting as similar OESFs are repeated.

For most of its history the LC4MP did not make any assumptions or propositions as to the nature of resources in the human processing system. In the most recent iteration of the model, though, resource limitations are conceptually defined as chemical, temporal, and/or spatial constraints in the human brain (Fisher, Huskey, et al., 2018). This provides a clear physical link for what had previously been a purely abstract concept, allowing for more precise theorizing regarding which sorts of processes may rely on the same resource pool and which may proceed in parallel. In light of this updated assumption, research within the model has reopened the proposition that the resource pool may be able to be meaningfully separated into “cognitive” and “perceptual” pools. In this approach, perceptual resources are required to identify unique items in the audio/visual sensory field and that cognitive resources are required for sense-making, narrative processing, and other higher-order operations.

Resource allocation is an individual response to a message. As such, to measure resource allocation, one must use participant-level measures, not message-level measures. In the LC4MP, the primary methods that have been used to investigate the resource allocation process are secondary task reaction times (STRTs), recognition memory, and heart rate. STRTs are thought to be an indicator of resource availability at encoding (Lang, Bradley, Park, Shin, & Chung, 2006). When a large amount of resources are available, STRTs are fast, but when there are fewer resources available, STRTs are slower. Interestingly, the observed relationship between message complexity and STRTs is curvilinear—both high and low complexity messages are associated with fast STRTs. This is likely due to the fact that individuals allocate resources away from processing the message when it is highly complex, thus leaving more available resources to respond to the STRT. This process of allocating resources away from a message is often referred to as cognitive overload. As such, knowing resource availability alone does not always provide enough information to know where it is that an individual is allocating their resources. This limits the researcher's ability to draw conclusions regarding how STRTs alone should predict outcomes of interest. For this reason, encoding measures such as recognition memory are often used to triangulate STRTs. If STRTs are fast and recognition is high, it is likely that the message is simple and the participant is able to concurrently manage both tasks. If STRTs are fast and recognition memory is low, it is likely that the participant has allocated resources away from processing the message and is simply monitoring for the STRT probe.

Another measure of resource allocation frequently used in the LC4MP is heart rate. A particular phasic cardiac response called the cardiac response curve can be used as an indicator that an orienting response has taken place. This response is characterized by a quick deceleration in heart rate following a particular event (such as a camera change) that then leads to an acceleration back to baseline. Other measures have also been used to indicate an orienting response (e.g. skin conductance responses or ERPs) but these have not been as widely validated. Heart rate can also be used as an indicator of tonic resource allocation. In general, a reduction in heart rate compared to baseline is a sign of increased resource allocation whereas an increase in heart rate from baseline (or reduced deceleration compared to other stimuli) is a sign of decreased allocation. Heart rate can also be triangulated with recognition memory in much the same way as discussed with STRTs. Other measures have also been used to index resource allocation processes, including EEG, eye tracking, and skin conductance levels.

Resource requirements are a message characteristic. As such, to measure the resource requirements of a message, one must measure the message itself, not merely a participant's response to the message. Resource requirements are typically indexed using a measure called information introduced (II or I2). Information is conceptualized in this measure as any of seven changes that can be introduced by a camera change (CC) in a message. These seven dimensions are: object change, novelty, relatedness, distance, perspective change, emotion, and form change. This number is often divided by the number of seconds in the message (II/sec) to gauge the overall information density of the message. II/sec is also frequently divided by the number of CCs in the message in order to account for the influence of pacing on information density. For auditory information, a related measure has been developed (called Aii). A number between 1 and 7 is assigned to each camera change in a message, resulting in an index of the total amount of information contained in the message.

The model proposes that resource allocation is driven by: a) the orienting response, and b) activation in the motivational systems. Thus, messages that frequently elicit an orienting response or that contain more motivationally-relevant information should be expected to elicit more resource allocation. All other things equal, more resource allocation to a message should be associated with: a) reduced heart rate, b) faster STRTs (given that resource requirements are held constant), c) high memory sensitivity for content contained within it. Resource allocation to a specific stimulus feature should result in: a) observation of the cardiac response curve (CRC), and b) greater memory for information immediately following the feature (given that information density is not too high).

The LC4MP also proposes that resources are required to process information contained in messages. This means that increased information density (typically measured using II, II/sec, or II/cc/sec) should reduce the amount of resources available. A reduction in resources available should be associated with: a) slower STRTs, b) reduced memory sensitivity, c) greater criterion bias. If resources required exceeds resources available, the model proposes that, an individual will enter a state of cognitive overload. In this state, resources are allocated away from the primary task and toward other tasks (e.g. mind wandering or responding to the STRT probe). Cognitive overload should be associated with: a) low memory sensitivity, b) very liberal criterion bias, c) fast STRTs.

3.2. Motivated Processing

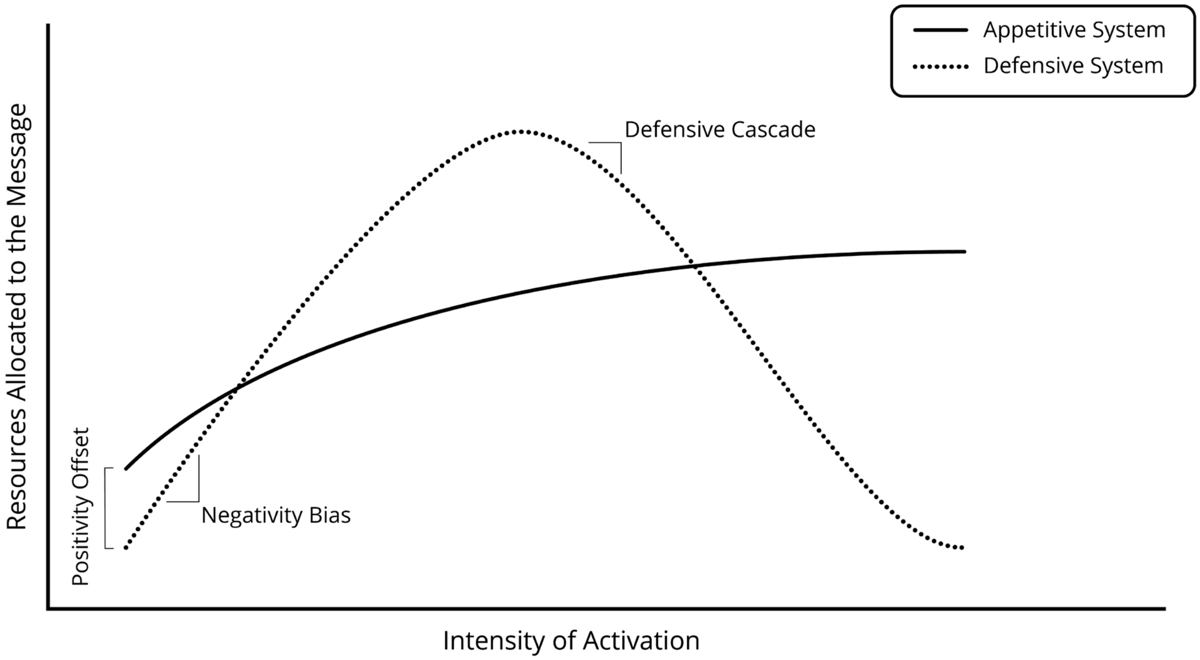

Figure 1. Graphical depiction of resource allocation patterns predicted by the LC4MP, including the positivity offset, negativity bias, and defensive cascade. At baseline levels of activation, resource allocation to positive stimuli is higher than to negative stimuli. As activation increases, resource allocation to negative stimuli increases at a rate greater than that observed for positive stimuli. As activation continues to increase, resource allocation to negative stimuli will collapse, whereas resource allocation to positive stimuli will level off or continue to increase.

A large part of LC4MP research is aimed at understanding how message content motivates individuals to allocate resources toward or away from a stimulus. This approach to motivation is rooted in a rich history of research by P.J. Lang, Caccioppo, Bradley, and others (see e.g., Bradley, 2000). The LC4MP imports much of the terminology that it uses to discuss motivation and emotion from this body of work, modifying them as needed to apply to dynamic, multisensory stimuli. A primary contribution of this body of literature is the finding that physiological and self-reported activation in the motivational systems robustly predicts affective evaluations of and memory for images, events, and other stimuli. Stimuli that reliably elicit activation in these systems are said to be motivationally relevant. This work shows that certain stimuli (e.g. predators, pathogens, sexual images, food) seem to be motivationally relevant for almost all individuals and in almost all contexts. In the LC4MP it is assumed that the positivity or negativity of a stimulus can best be described as the extent to which it activates the appetitive or defensive motivational system. Arousal, then, refers to the intensity of activation that the stimulus elicits in the motivational systems.

At baseline, the appetitive system is slightly more active than the defensive system. This is called the positivity offset. The positivity offset is theorized to guide human processing toward exploring and considering novel options whenever threat levels are low. The defensive system, though, is much more responsive to threatening stimuli than the appetitive system is to rewarding stimuli. This differential response between the systems is known as the negativity bias. The negativity bias is theorized to improve the efficacy of fight or flight responses in the presence of potentially threatening stimuli. This negativity bias also precipitates a defensive cascade in response to highly arousing, highly negative stimuli. During the defensive cascade, an individual is highly motivated to escape or confront the aversive stimulus, shutting down encoding, storage, and retrieval mechanisms in favor of fighting or fleeing from the potential threat (for a graphical depiction of these response patterns, see Figure 1). LC4MP work has shown that robust individual differences exist in baseline levels of appetitive system activation (ASA) and defensive system activation (DSA), and these differences predict message processes and effects.

Recent LC4MP work has refined the model's approach to motivation in three primary ways. First, the incorporation of a new model of memory based on neural processes (discussed in detail below) allows for theoretical advancements in the model regarding how certain message features may come to acquire motivational relevance over short or long spans of time. This enables the LC4MP to explain and predict how individuals may learn the motivational relevance of message features and how these learned associations bias message processing. A second advancement is found in emerging work elucidating how the human processing system operates in a state of coactivation (when the appetitive and defensive systems are active at the same time, see e.g., Keene & Lang, 2016). Finally, a recent integration of the LC4MP with psychological reactance theory has enabled the model to more precisely predict individual reactions to and memory for highly threatening and arousing messages (Clayton et al., 2018).

The LC4MP leverages self-report, continuous response, and psychophysiological measures to indicate activation in the motivational systems during message processing. The most widely used self-report scale is the self-assessment manikin (SAM). In this measure, participants fill out a pictorial scale indicating the extent to which they feel negative/positive, how intense the feeling is, and how dominant they perceive themselves to be over the feeling. Continuous response measurement (CRM) is also widely used. This method has the advantage that it is able to capture the dynamics of a message, but it is limited in that only one dimension of motivational system activation can be measured at a time. Finally, the LC4MP employs a whole suite of psychophysiological measures, including heart rate, skin conductance, facial electromyography, the startle response, the post-auricular response and other psychophysiological measures. As with resource measurements, new measures have been added to the toolbox over time—most notably functional magnetic resonance imaging (fMRI) measures.

To measure individual differences in baseline motivational system activation, the LC4MP uses the Motivation Activation Measure (MAM). The MAM is used to classify individuals into four motivational categories: risk takers (high ASA, low DSA), risk avoiders (low ASA, high DSA), coactives (high ASA, high, DSA), and inactives (low ASA, low DSA). A shorter version of the MAM (mini-MAM) has also been developed to more quickly gauge individual differences in motivational system activation. In addition, resting heart rate variability (rHRV) has been used to investigate individual differences in motivational system activation. Individuals with low rHRV are theorized to have lower ASA and higher DSA than those with higher rHRV.

The LC4MP proposes that activation in the appetitive system is driven by pleasant stimuli and that activation in the aversive system is driven by unpleasant stimuli. Activation in each of these systems should be associated with psychophysiological and self-reported measures of arousal and valence. In addition, the LC4MP proposes that stimuli acquire their pleasantness or unpleasantness as a result of learned associations with the likelihood, magnitude, and proximity of reward and punishment. Some of these associations are rigid, having been acquired over long periods of time or in highly salient events. Some rigid associations (e.g. predators, pests, pathogens, food, sex) may even be evolutionarily-imbued into the processing system. Other associations are more flexible, formed and reformed over time as individual goals change. This means that stimuli that are associated with reward or threat within an experimental design (e.g. a particular symbol in a video game associated with monetary gains or losses) should elicit activation in these systems in much the same way as do stimuli that have traditionally been conceptualized as motivationally relevant (food, sex, predators, etc). This activation should be more flexible and context-dependent than is observed for stimuli that are more rigidly encoded as motivationally relevant. In addition, some of these associations are likely to be fairly consistent across individuals whereas other associations are likely to be more idiosyncratic---a product of individual differences in culture, environment, and experiences.

At baseline, the LC4MP proposes that pleasant message content will elicit more resource allocation than unpleasant content. As activation increases, though, the LC4MP proposes that unpleasant content will elicit more resource allocation than pleasant content. This pattern should continue until the point that an individual enters a the defensive cascade. In the defensive cascade, resources should be allocated away from encoding, storing, and retrieving message content and toward either counterarguing or avoiding the message. Recent work has aided in the development of propositions regarding how individual differences in ASA/DSA may relate to differences in propensity to employ confrontational or avoidance strategies during the defensive cascade (Clayton et al., 2018). Individuals high in ASA and low in DSA should preferentially engage in confrontational strategies during the defensive cascade whereas those high in DSA and low in ASA should preferentially employ avoidance strategies. Finally, the model proposes that if appetitive and defensive systems are active at the same time (coactivation), resource allocation to the message will increase.

3.3. Memory

By far the most frequently investigated message processing outcome in the LC4MP is memory. The LC4MP assumes that when resources are allocated to processing a message, they are allocated to encoding the content contained within the information stream, storing it in short-term and/or long-term memory, and retrieving information that may be relevant for understanding. In the LC4MP, encoding is most often referred to as an attentional selection and representation-formation process (Lang, 2000, 2009). Information from the environment is transduced by sensory receptors into temporal and spatial patterns of neural firing. These patterns are communicated to the brain through various sensory processing pathways. Upon arrival in the brain, these patterns are further processed to produce representations of identifiable objects, entities and events. This process is extremely fast (< 40 msec), and is largely outside of conscious control.

Storage in the LC4MP is conceptualized as a process through which encoded information is nested in an associative structure that allows it to remain in memory for a longer period of time. Retrieval, then, is the process through which this information is reactivated and used to inform concurrent information processing. The model does not clearly delineate between shorter-term and longer-term storage, instead proposing that shorter-term memory is likely just the subset of memories that happen to be active (retrieved) at any given time (Lang, 2000). Earlier versions of the model also do not assume any particular neural model of memory, instead proposing that items are stored in memory in an associative network and that concurrent activation strengthens the associations between items.

The most recent iteration of the model augments this conceptualization of memory with a neural model based on processing functions of the brain (Fisher, Huskey, et al., 2018). In this framework, the definition of encoding as traditionally employed in the LC4MP is refined to mean rapid encoding of single or unitized items. This neural process takes place primarily in sensory processing regions of the neocortex (the outermost layer of the brain) and is supported by a subset of regions surrounding the hippocampus (traditionally thought to be a core player in the brain's memory network). This process is conceptualized as contingent on largely modality-specific resource pools and is thought to undergird performance in recognition memory tasks.

The definition of storage is refined to refer to two separate neural processes: rapid encoding of flexible associations, and slow encoding of rigid associations. Rapid encoding of flexible associations is dependent on the neocortex, but also on the hippocampus. In this process, the hippocampus is thought to integrate activation patterns from disparate regions of the cortex and knit them together into a coherent whole. In the LC4MP, this process is proposed to enable the initial formation of flexible associations between stimuli in a message and reward/threat likelihood, magnitude, and proximity. These associations are then reinforced or weakened through a slower set of operations involving the neocortex, basal ganglia (responsible for encoding reward/threat signals), and cerebellum. This slow encoding of rigid associations is proposed to be the mechanism that allows memories to remain "knit together" without the active influence of the hippocampus (Henke, 2010). The extent to which a memory is rigidly encoded is contingent on how much or how often it is reinforced by signals of reward/threat emanating from the basal ganglia. This neural model of memory formation provides a scaffold for more precise predictions regarding how memories are formed, strengthened, and used to guide behavior during message processing.

In the LC4MP, three primary methods have been used to investigate memory for messages: recognition, cued recall, and free recall. Recognition tests are used as an indicator of encoding, cued recall tests are used to indicate storage, and free recall tests are used to indicate a participant's ability to retrieve information about the message from their memory. Each of these measures provide a different angle from which to investigate the influence of resource allocation and resource requirements in guiding memory formation for messages.In the LC4MP literature, recognition tests are often analyzed using a signal-detection analysis. This analysis technique results in two measures: sensitivity and criterion bias. Sensitivity is a measure of the participant's ability to accurately distinguish targets from foils whereas criterion bias is an indicator of the participant's tendency to identify foils as targets. A high (conservative) criterion bias indicates that a participant is less willing to identify foils as targets and suggests that they are not as confident in their responses or that they are less willing to guess. A low (liberal) criterion bias indicates a higher willingness to identify foils as targets and suggests that a participant is more confident in their responses or more willing to guess. Some recent LC4MP work has also investigated response speed as an indicator of the accessibility of a given item in memory. This measure, although promising, is still in need of further conceptual and operational development.

The model proposes that when available resources are plentiful, memory for the message should be high. When available resources are more limited, memory for the message should be lower, but still fairly good. When available resources are negative, memory for the message should be quite low. Negative available resources (more resources required than were allocated) can result from a few primary factors. First, it can result from extremely high message complexity—even when a participant is allocating as many resources as they can, message content may be difficult to encode, store, and retrieve. Negative available resources can also result from reduced resource allocation to the message, either due to cognitive overload, a defensive cascade, or failure of the message to activate motivational systems. Some work in the LC4MP has extended these propositions into more granular questions of interest, including how resource allocation may differ between encoding and storage processes at varying levels of motivational system activation, how resource allocation relates to more specific measures of recognition memory (like sensitivity and criterion bias), or how resource allocation is related to the formation of explicit and implicit memory processes.

4. Conclusion & Future Directions

The introduction of the LC4MP in many ways catalyzed a shift in media psychology research from looking for the effects of media exposure to investigating the processes that mediate the relationships between media messages and their effects. The model has grown and developed over the past 20 years, resulting in new methods, updated propositions, and best practices for message design in a wide variety of contexts. Although the propositions of the model have become more solidified over the years, there are a few areas in which the model is still under active development. These areas point to promising future directions for the model in regard to refining its current concepts and measures and pushing into new areas of empirical and practical interest.

First, although theoretical developments within the model have led to another look at the process- and modality-specificity of the resource pool, there does not yet exist a validated measure that is able to index the perceptual and cognitive resource requirements of a given message. Extant work has gotten around this constraint by directly manipulating perceptual and cognitive load or by creating custom stimuli of varying levels of load. The development of a content-analytic measure is critical for understanding multimedia stimuli that are commonly the provenance of LC4MP research like news, movies, and PSAs. Emerging work from computer science and other fields suggests that approaches combining computational and traditional content analysis methods may be promising on this front.

Second, recent work suggests that the defensive cascade and cognitive overload may be more conceptually similar than originally thought. When message processing is considered as an effortful, motivated process, one could suspect that the resource reallocation process observed during cognitive overload may be driven by the same sort of motivational process that drives the defensive cascade. Strong evidence indicates that individuals seek to optimize the balance between effort and reward, and that a suboptimal balance between the two drives the human processing system to seek alternatives that are more rewarding and/or less effortful. Furthermore, these imbalances are seen as negative and most individuals seek to avoid them. In this way, cognitive overload can be seen as a motivated process similar to the defensive cascade. Future work should address the interacting roles of message complexity, motivation, and resource allocation to tease out the similarities and possible differences between the resource reallocation observed during the defensive cascade and that observed during cognitive overload.

Third, although the model has traditionally eschewed in-depth examination of individual differences in message processing (Lang, 2017), recent work has opened new research areas seeking to understand how individual differences in baseline motivational activation, age, substance use, and cognitive processing differences such as ADHD guide message processes and effects. This work has produced new propositions regarding how these individual differences could be expected to lead to resource allocation differences during message processing, and how they may predict memory, learning, and persuasion. This is especially promising in relation to recent progress in understanding how individual differences in substance use influence the processing of anti-drug messages (see e.g. Clayton et al., 2018).

Finally, the methodological toolkit of the LC4MP has recently expanded into the area of brain imaging methods, providing insight as to how the resource allocation process can be explained and predicted by activation in relevant brain regions and networks. Although this work is still in its infancy, it has resulted in promising advancements in our understanding of how resource allocation varies in response to both motivation and task difficulty/message complexity (see e.g., Huskey, Craighead, Miller, & Weber, 2018). The increasing accessibility of brain imaging methods will undoubtedly lead to more frequent investigations of LC4MP-related questions using these paradigms. This comes at a time when cognitive and social neuroscience researchers are more frequently turning to investigations of naturalistic, multisensory stimuli like movies and video games. As such, the model stands to inform future work that spans media psychology, communication, and neuroscience research.

Now almost 20 years since its original introduction, the LC4MP still stands as one of the most influential and highly-cited models in media psychology. In describing human communication (in all of its variously mediated forms) as a dynamic, biological process, the LC4MP allows for unique insight into complex message processes and effects. This understanding has informed the design of numerous academic and pragmatic inquiries into the relationships between structural and content features of messages and their interaction within the biological systems of the brain and body. Future LC4MP work will likely contribute to increase the understanding regarding the unique influence of cognitive and perceptual load, the conceptual similarities and differences between cognitive overload and the defensive cascade, how individual differences guide message processing, and how to best integrate media psychology and neuroscience to address unsolved questions.

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