# Contextual Memory for Goals: On the Role of Context, Attention, and Intention in Cognitive Control

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**Abstract**

The contextual memory for goals (CMFG) model is presented as a theory of the role of context in cognitive control. CMFG has three components: (1) *contextual chunking*, (2) *perceptual priming*, and (3) *goal setting*. CMFG proposes that the contents of the cognitive buffers (perceptual, motor, intentional, etc.) become bound in declarative memory based on their co-occurrence during each cognitive cycle. The re-occurrence of buffer contents that have previously co-occurred spreads activation to associated chunks of memory. Goals are conceived of as declarative structures representing desired perceptual states that compete for control of cognition, are activated by perceptual priming, and are selected on the basis of activation. CMFG represents an integration of principles from Memory for Goals (MFG) model of cognitive control, Adaptive Control of Thought Rational (ACT-R), a unified theory of cognition, Perceptual Symbol Systems (PSS), and the Theory of Event Coding (TEC). CMFG will be examined in a series of experiments, implemented in the ACT-R cognitive architecture, and used to model experimental results.

**Keywords:** cognitive control; contextual memory; cognitive modeling; cognitive architecture; goals; feature integration.

## Introduction

Goals are a central concept in cognitive control, representing the intentions of the cognitive system. Theories of the cognitive control of attention seek to explain how human behavior balances the need to be both (a) reactive; changing goals due to critical changes in the environment, and (b) proactive; maintaining goals over extended time periods, ignoring changes in the environment. Cognitive science needs good theories about the role of context, attention, and intention in the control of cognition.

Memory for Goals (MFG; Altmann & Trafton, 2002) is a theory of cognitive control that explains goal memory in terms of general declarative memory constructs, such as activation and associative priming, rather than using a special goal memory or control structure, such as a goal stack. Goals in memory compete for control of cognition. The goal with the highest instantaneous activation value becomes the active goal. MFG consists of three components: (1) *the interference level,* (2) *the strengthening constraint*, and (3) *the priming constraint*. Although MFG emphasizes the role of cues in cognitive control, it does not yet specify how cues become associated with goals. MFG has been implemented in cognitive models using the ACT-R cognitive architecture.

ACT-R is a cognitive theory and a production-rule based computational cognitive architecture that is used to model psychological processes (Anderson & Lebiere, 1998; Anderson et al, 2004). ACT-R lacks automatic, general-purpose mechanisms for associative memory, episodic memory, or contextual memory. Associations between modalities require specifically programmed declarative and procedural knowledge.

Goals in ACT-R are abstract symbols that can represent intentions at various levels of behavioral and temporal analysis. Goals are set by production rules and maintained in the goal buffer without cost. ACT-R needs a less ambiguous representation of intention so that goals can be created, suspended, and achieved by cognitive models, rather than by cognitive modelers.

Perceptual Symbol Systems theory (PSS) proposes that all mental representation, including abstract concepts and plans for action are inherently modal (Barsalou, 1999).

The Theory of Event Coding (TEC) proposes that perceptual and action symbols are bound into event files in memory based on their co-occurrence (Hommel, 2009; Hommel, Musseler, Aschersleben, & Prinz, 2001). TEC proposes that perception and action are representationally and functionally equivalent.

In this dissertation, I propose a computational mechanism for the role of contextual associative memory in cognitive control. This model integrates principles from MFG, TEC, and PSS into the ACT-R architecture.

## Theoretical Framework

The Contextual Memory for Goals (CMFG) theory proposes that the attended features of perception are bound into contextual chunks based on there co-occurrence, prime the activation of actions and goals, with the highest activation goal driving cognition. CMFG consists of 3 components: (1) *contextual chunking*, (2) *perceptual priming*, and (3) *goal setting*.

*Contextual chunking* is a form of associative memory. It is the binding of features of the current context into a representation in declarative memory. The current context is conceived as being the contents of the cognitive buffers from ACT-R, and the contextual representations are similar to the event files proposed by TEC. The contextual chunk is limited in its representation of the context based on attention.

*Perceptual priming* is a form of spreading activation. The re-occurrence of a percept, that has been associated with a goal in a contextual chunk, increases the activation of that goal. MFG, TEC and ACT-R, all propose priming by context.

*Goal setting* concerns both the focus and the form of intentions. The assignment of the active goal is based on instantaneous activation. The representation of intentions is based on the principle of common coding of perception and action. Goals are to-be-produced perceptual states.

## Computational Implementation

CMFG will be computationally implemented in the ACT-R cognitive architecture in two forms: (1) using the standard architecture, and (2) using a modified architecture.

**Standard ACT-R implementation**

CMFG will be implemented in the ACT-R architecture using new and modified modules and buffers, relying on productions rules and Lisp functions calls to achieve CMFG's three theoretical principles.

**Modified ACT-R implementation**

CMFG will be implemented in the ACT-R architecture using new and modified modules and buffers to achieve CMFG's three theoretical principles (Figure 1).

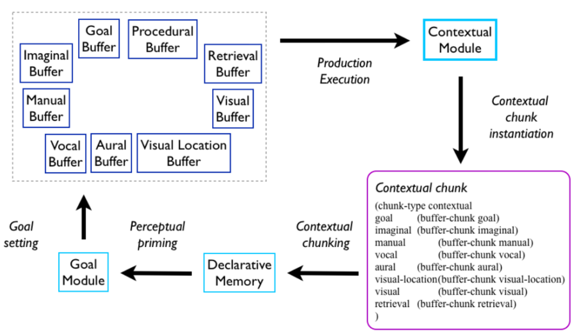


Figure 1: Proposed architectural changes to ACT-R.

*Contextual chunking* occurs within the architecture after the execution of a production rule. The new context module instantiates a contextual chunk with slots for each buffer in ACT-R, sets the value to be the value of the current chunk in each buffer, and harvests the chunk into declarative memory.

*Perceptual priming* occurs within the architecture through ACT-R's standard spreading activation mechanism. The breadth and depth of the pool of declarative chunks involved in spreading activation is massively increased by CMFG.

*Goal setting* occurs within the architecture through change to the operation of the goal module. The active goal is updated, through retrieval, on every production cycle, making the highest activation goal chunk the new goal buffer chunk. Goals are not be abstract concepts, but concrete imaginal buffer chunks.

## Experiments

CMFG will be examined in four experiments, using two experimental paradigms. The first paradigm, Argus Army is an eye-tracked, computer-based environment. Experimental participants will learn associations between icons for military units and goals for action. The strength of these associations will be manipulated in a training phase and its effects will be examined during a testing phase in which participants will select the order of goals to pursue. The purpose of these experiments will be to demonstrate that CMFG can explain the process of learning cross-modal associations and that the activation of goals can predict priorities in goal-directed behavior.

The second paradigm, Coffee Challenge is a table-top, mobile-eye-tracked task. Experimental participants interact with abstract or real-world objects to perform a sequence of coffee-making actions.

## Simulations

The two computational implementations of CMFG will be used in three simulations. Simulation 1 will use data from Hommel (2007), experiment 2, to demonstrate the ability of CMFG to account for response compatibility effects in a binary free-response task. Simulation 2 will model data from the Argus Army experiments. Simulation 3 will model data from the Coffee Challenge experiment. The ACT-R model, using CMFG, will connect to the Tekkotsu robotics framework (Touretzky et al, 2007) to control a custom-built robot consisting of 2 Crustcrawler AX-12 robotic arms, and a pan-and-tilt-capable webcam.

## Conclusions

The Contextual Memory for Goals (CMG) theory includes 3 components: (1) *contextual chunking*, (2) *perceptual priming*, and (3) *goal setting*. The theory will implemented in the ACT-R computational cognitive architecture, supported by experimentation and computer simulation. CMFG represents a new embodied, reactive, distributed, automatic approach to cognitive control.

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