FAMILIARITY AND ORGANIZATION

OF ACTION MEMORY IN ADULTS AND YOUNG CHILDREN

by

JEFFERY THOMAS LOUCKS

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Confirmation of Approval and Acceptance of Dissertation prepared by:

Jeffery Loucks

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This dissertation has been accepted and approved in partial fulfillment of the requirements for the degree in the Department of Psychology by:

Dare Baldwin, Chairperson, Psychology
Marjorie Taylor, Member, Psychology
Ulrich Mayr, Member, Psychology
Eric Pederson, Outside Member, Linguistics

and Richard Linton, Vice President for Research and Graduate Studies/Dean of the Graduate School for the University of Oregon.

June 13, 2009

Original approval signatures are on file with the Graduate School and the University of Oregon Libraries.

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Jeffery Thomas Loucks   for the degree of   Doctor of Philosophy

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Title: FAMILIARITY AND ORGANIZATION OF ACTION MEMORY IN ADULTS

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Approved: _____

Dr. Dare Baldwin

Although research on action processing indicates people segment action
according to a partonomic goal hierarchy, no previous research has investigated whether
memory for complex human action is actually organized in the mind with respect to
goals. This dissertation explored the primary organization of action memory in adults and
young children and explored the role of familiarity in young children's organization of
action in memory. Borrowing from the text memory literature, a priming experiment was
designed to investigate the degree to which action memory is organized with respect to
goals versus veridical temporal structure. In all studies, participants viewed videos in
which goals were carried out in an interleaved fashion, such that the execution of a goal
was at times interrupted by action related to the other goal. In a first experiment with
adults, the results indicated that adults reorganize action information in memory in order
to emphasize goal structure relative to verbatim temporal structure. A second control

experiment with adults clarified that the goal priming effect observed in the first experiment arose as a result of viewing the action scenario and was not simply due to the stimuli cuing pre-existing semantic memory. The results of a third experiment with adults revealed this process of goal organization is unlikely to be a by-product of goal-based linguistic encoding, but instead reflects encoding of human action itself. Young children's action memory was examined in a fourth experiment, and the role of children's familiarity with the action scenarios in action memory organization was also explored. Children did not display a significant tendency to organize action according to goal inferences (or temporal structure, either, for that matter). As well, children's prior familiarity with action did not modulate their memory organization to any significant degree. Overall, the results of this dissertation suggest that adult memory for action emphasizes goal inferences but cannot speak to how or when this process in achieved developmentally. These findings have implications for contemporary theories of action processing, point to commonalities in the processing of language and human action, and open the door to future research into the development of action memory organization.

CURRICULUM VITAE

NAME OF AUTHOR: Jeffery Thomas Loucks

PLACE OF BIRTH: Kingston, Ontario, Canada

DATE OF BIRTH: October 27, 1979

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

>   University of Oregon
>   Queen's University

DEGREES AWARDED:

>   Doctor of Philosophy in Psychology, 2009, University of Oregon
>   Master of Science in Psychology, 2003, University of Oregon
>   Bachelor of Arts in Psychology, 2002, Queen's University

AREAS OF SPECIAL INTEREST:

>   Developmental Psychology
>   Cognitive Development

PROFESSIONAL EXPERIENCE:

>   Instructor, Department of Psychology, University of Oregon, Eugene, 2003-2009

>   Teaching Assistant, Department of Psychology, University of Oregon, Eugene, 2002-2009

>   Human Subjects Coordinator, Department of Psychology, University of Oregon, Eugene, 2006-2008

>   Lab Coordinator, Dr. Baldwin's Developmental Lab, Department of Psychology, University of Oregon, Eugene, 2003-2004

GRANTS, AWARDS AND HONORS:

Cognitive Science Society Student Travel Award, 2008

Clarence and Lucille Dunbar Scholarship, 2007-2008

Passed Preliminary Exams with Distinction, 2005

PUBLICATIONS:

Loucks, J. & Pederson, E. (in press). Linguistic and non-linguistic categorization of complex motion events. To appear in J. Bohnemeyer & E. Pederson (Eds.), *Event Representations in Language and Cognition*. New York: Cambridge University Press.

Loucks, J. & Baldwin, D. (2009). Sources of information for discriminating dynamic human actions. *Cognition, 111*, 84-97.

Loucks, J., & Baldwin, D. (2008). Sources of information in human action. In B. C. Love, K. McRae, & V. M. Sloutsky (Eds.), *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp. 121-126). Washington, DC: Cognitive Science Society.

Baldwin, D., Loucks, J. & Sabbagh, M. A. (2008). Pragmatics of Human Action. In T. F. Shipley & J. M. Zacks (Eds.), *Understanding events: From perception to action* (pp. 96-129). New York: Oxford University Press.

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CHAPTER I

INTRODUCTION

Imagine yourself at the airport, preparing to fly across the country to visit relatives for the winter holidays. As you step through the sequence of events that will get you from the entrance to your gate, your senses are assailed by a barrage of complex information in the form of other people's behavior. Success lies in accurate processing of others' action within each step – from navigating through fast-moving, unpredictable crowds, interacting with the check-in clerk, and passing through the security gate. The action in each of these scenarios can be broken down into smaller and smaller units, until at the level of small actions: body parts moving here and there, objects being grasped and released, motion being carried out in the blink of an eye. Your mind must process a significant portion of this very large set of small action chunks. Although it is remarkable that we can do this at all with seemingly little effort, it is also remarkable how much is processed that will not be properly encoded in memory. While you could later recall some action sequences in a coherent fashion, you would be unlikely to remember much of the small action detail. What, then, determines what will be remembered and what will be forgotten? An answer to this question lies partly in understanding how action information tends to be encoded and organized in memory.

The processing of other people's action is central to everyday social functioning, and thus understanding the organization of action memory has important implications for the study of social cognition, language and social cognitive development, and artificial intelligence. Investigating memory for action allows us to infer the elements of higher-level cognition that underlie the processing of human action. In addition, understanding the nature of action memory representations provides a window into how people might make use of memories for action in further social-cognitive processing.

In adults, memory encoding and storage is aided significantly by the use of top-down knowledge: information stored in memory that guides processing. For example, if you are technologically savvy then you know how a metal detector works, and this will aid your processing of others' action that surrounds the metal-detector. Although many of the actions that other people engage in around the metal-detector might differ substantially, there is still a sequence of events that must occur in the proper operation of the metal detector: all metal must be removed and placed in the tray before you may pass. Knowledge of this higher-level sequence of actions likely speeds information processing, and probably also aids in highlighting portions of the action stream most relevant to one's current goals.

But what if you have never been to the airport, and know absolutely nothing about how metal-detectors function? Would the processes that underlie your encoding and storage of other people's action in memory differ? This is the typical situation for young children. Since they often lack the relevant top-down information, their processing might be focused on the details of each and every action, rendering processing much more

cumbersome. Or, as active knowledge seekers, they may try to apply top-down knowledge from some other domain they know about (e.g., going to the movies) in order to help organize their processing. In either case, their memory for such events might be substantially different from that of adults.

This dissertation explores the relationship between top-down knowledge and memory organization for human action, in both adults and young children. Despite a surge of recent research on action processing, a great deal remains unknown about the cognitive system that processes action. In particular, relatively little is known about how action information is organized in memory. In addition, much remains to be learned about children's memory for action. Young children are at a point in their life when they are gathering large amounts of top-down knowledge on a daily basis, thus it is likely that they are particularly sensitive to such information when inferring other people's goals and intentions through their behavior. For this reason, studying young children may provide an especially sensitive window for exploring the use of top-down information in memory for action.

This introduction will first begin by outlining two sources of information that action memory could plausibly be organized with respect to: information regarding goal inferences and temporal order information. I will argue that these two sources of information are often in conflict with one another in the ongoing flow of other's action, which has implications for how memory is organized. I will then review the literature on action segmentation, the literature on memory for text in adults, and the literature on

memory for event sequences in young children, all of which helped give rise to the current hypotheses. I will end by outlining the specific research questions addressed in this dissertation.

Goals and Temporal Information

Any account of how memory for action is encoded and organized needs to incorporate the processing of goals and intentions. Goals and intentions are an essential aspect of people's processing of other's behavior (Baldwin, 2005; Heider, 1958; Malle, Moses, & Baldwin, 2001; Schult & Wellman, 1997). In the majority of cases, observers seem less concerned about how an action is carried out (e.g., that the salt be lifted or pushed across the table) and more concerned about the goal of the action (e.g., the passing of the salt). Most theorists believe intentions are not contained in the action stimulus itself, but are inferred using a number of bottom-up and top-down cues. This process of intention/goal inference is a central component of current theoretical perspectives on action processing (Baldwin, 2005; Zacks, Speer, Swallow, Braver, & Reynolds, 2007) and the development of the action processing system (Baldwin, Baird, Saylor, & Clark, 2001; Meltzoff, 2007; Woodward, Sommerville, & Guajardo, 2001).

When considering how dynamic human action might be encoded and organized in memory, we might thus expect representations of action events to reflect the process of goal inference. One possibility is that individual actions (e.g., grasping a mug, grasping a tea kettle, pouring hot water into the mug) might be organized in such a way as to reflect their relations vis à vis an inferred higher level intention (e.g., preparing a cup of tea). In

such a scenario, information about individual actions would be stored in a meaningful way that relates actions to one another while also representing the goal of the actor. Moreover, information about the surface details of actions low on the goal hierarchy might frequently be dispensed with altogether to the extent that such detail seems irrelevant to the inferred goal structure of the scenario.

Because human action unfolds dynamically over time, processing of the inherent temporal or sequential structure of action is an additional component that should also be characterized in an account of action memory organization. When learning a new task, for instance, capturing the precise temporal order of observed action events can be essential to understanding the new task well enough to perform it later (e.g., learning to tie a difficult knot). It is known that adults indeed register at least some kinds of temporal information within the stream of human behavior. For example, recent research has documented that adults track sequential information within novel intentional action sequences and utilize the information to discover segmental structure within the sequence (e.g., Baldwin, Andersson, Saffran, & Meyer, 2008; Swallow & Zacks, 2008).

We might thus also expect action memory to be organized with respect to the inherent temporal structure of an action sequence. In this scenario, actions might be associated with one another in a chain-like sequence that specifies which actions came before and after a given action. Unlike organization according to goal structure, in some ways organization according to temporal structure seems to be achievable without

effortful inference, as the information is readily available from the surface flow of events. The current event being encountered only needs to be associated with the previously encountered event, as the perception of that event unfolds over time.

Of course, in many action scenarios, goal structure and temporal structure coincide, with memory organization thus potentially being redundantly specified for both. Consider for example, a person who grasps a mug, puts a tea bag into the mug, grasps a tea kettle, pours hot water into the mug, grasps a book, and flips through the book, and begins reading a particular page. In this scenario the temporal sequence of events matches the grouping of actions that are associated with each of the two goals – making tea and reading a book – and thus both types of information can be unified under one organizational scheme. On the other hand, however, the goal structure underlying human action frequently violates simple sequential linearity. Distinct actions serving different goals can overlap in time, disruptions can occur, and actions serving one goal are often purposefully interrupted by those serving a quite different goal, and subsequently resumed. Consider for example, a person picking up a nail, picking up a hammer, hammering the nail into wood, grasping a mug of coffee, taking a sip, and then picking up another nail. In this sequence of action, organization via goal inferences and organization via temporal structure diverge. Although the relative frequency of such types of action sequences is not currently known, they may occur quite often. These non-linearity issues beset attempts to model action computationally (e.g., Flieschman, Decamp, & Roy, 2006), and pose an intriguing question regarding how humans organize memory for action.

When goal and temporal information do not coincide, which source of information takes precedence in memory? Although both types of information could certainly be processed to some degree, it seems plausible that one type of information may be more primary in the memory representation compared to the other. If action memory is organized primarily with respect to the goal structure of the action sequence, then memory for temporal relations may be attenuated or even distorted in memory. Alternatively, temporal relations could be emphasized over goal relations, yielding a similar cost to storing goal-related information. My hypothesis, consonant with broader theoretical perspectives on action processing, was that goal structure would be emphasized over temporal structure in memory organization.

Structuring action memory primarily with respect to goals and less with respect to temporal information is likely beneficial in a number of ways. For one, it would likely aid in the recall of action information, especially for action sequences in which goals are disrupted or otherwise disfluent in some way. As many theorists believe that ascertaining goals from action is an inferential process (e.g., Baldwin, 2005; Schult & Wellman, 1997; Zacks et al., 2007), structuring memory with respect to goals requires relatively more processing than structuring memory with respect to temporal information. In general, memory is improved when people engage with information at a deeper level compared to a more shallow level (e.g., Craik & Tulving, 1975), and thus memory for action may be enhanced through goal organization. In addition, to the extent that goals are indeed the most central aspect of people's processing of human action events, structuring the action

information with respect to goals helps preserve this most central aspect in memory. Over time, as the memory for the event decays, memory for the small action units may be lost, while the overall goals of the actor remain.

Although I hypothesize that goal organization generally takes precedence over temporal organization in memory, it is important to note that this can only be the case when goal inferences are possible. Whenever one is not able to infer a goal from another's activity, goal information is not available as a source of information according to which action memory can be organized, while temporal information remains readily available for this purpose. Novel action poses this particular challenge. Without top-down knowledge that allows one to infer the goal of the novel action, one cannot know whether a particular action embedded in the action sequence is causally related to the unknown goal or not. Thus, a full account of memory organization for dynamic human action should detail how action memory is organized according to the types of actions that are observed. I hypothesize that action information is primarily organized with respect to goal structure, but that temporal structure may be more primary in situations when goal inference is challenging or impossible.

Recent work on action segmentation helped to fuel the current hypothesis. Although memory organization is not the primary focus of such action segmentation research, this body of work has nevertheless illuminated several aspects of how action is processed that may be important for action memory.

<p style="text-align:center">Segmentation and Memory</p>

A crucial component of processing other people's action involves segmenting the continuous stream of behavior into units (Baldwin & Baird, 2001; Newtson, 1973; Newtson & Engquist, 1976; Sharon & Wynn, 1998; Zacks, Tversky, & Iyer, 2001). Despite the fact that action events are largely continuous, research indicates that people can explicitly segment action into meaningful, discrete units (Baird & Baldwin, 2001; Newtson, 1973; Zacks, Tversky, et al., 2001). In these tasks, participants typically are asked to identify boundaries or "breakpoints" of action – meaningful junctures within the continuous flow of motion. Participants' responding in these tasks reveals a high degree of agreement and consistency. Furthermore, breakpoints appear to hold special status in memory, as action at breakpoints is remembered more accurately than action at non-breakpoints (Newtson & Engquist, 1976; Schwan & Garsoffky, 2004), and action sequences that are interrupted at breakpoints are remembered more accurately than sequences interrupted at non-breakpoints (Boltz, 1992). Effective segmentation also leads to better memory for action (Zacks, Speer, Vettel, & Jacoby, 2006). Segmentation is likely influenced by a variety of cues, one of which is inferences about the actor's goals and intentions (Zacks, 2004).

In contrast to these explicit segmentation tasks, recent evidence also indicates people spontaneously segment action online while they view other people's behavior (Baldwin, 2005; Zacks, Braver, et al., 2001). In one study, Baldwin, Pederson, Craven, Andersson, and Bjork (in prep.) had participants detect frame deletions in video action sequences that were either deleted at breakpoints or non-breakpoints. Participants were

significantly faster at detecting deletions at breakpoints, indicating that online attention is modulated at breakpoints. This modulation of attention is thought to reflect online segmentation. Thus explicit segmentation tasks appear to be tapping into a psychologically real phenomenon of online processing (see also Zacks, Braver, et al., 2001).

Furthermore, the effects of segmentation also influence memory. Baird and colleagues (Baird, Baldwin, & Malle, 2009) asked participants to remember the location of tones inserted into a sequence of everyday, intentional action. Tones either occurred at breakpoints (e.g. just as the grasping of a pen was completed and before writing began), or at points within a segment in the action stream (e.g., in the midst of a reach to grasp a pen). People were more likely to accurately remember the placement of breakpoint tones than mid-segment tones. Furthermore, mid-segment tones were misremembered as having occurred closer to the nearest segment boundary of the segment interrupted, suggesting the psychological salience of segment boundaries. A similar effect has been found in segmentation of speech (Fodor & Bever, 1965), highlighting a commonality in processing between these two domains.

Importantly, this study indicates that segmentation influences memory for action, and suggests action memory is organized with respect to the segmental structure of the action sequence. Breakpoints provide an anchor in memory with respect to which observers can organize information contained in the action sequence. It is important to note that as yet it is unknown whether segmentation influences memory at the encoding

phase, storage phase, or recall phase. However, the evidence from Baldwin et al. (in prep.) noted above suggests that encoding – as the action information is being taken in – is at least one phase during which segmentation influences memory.

Action segmentation may also be important for memory organization with respect to hierarchical representation. Research on explicit segmentation of action has shown that people typically represent action in a partonomic hierarchy – that is, observers parse action into coarse units (e.g., cleaning the kitchen), finer units from which each coarse unit is composed (e.g., washing dishes and throwing out the trash), and into even finer nested units still (e.g., grabbing a dish, running it under water, putting it in the tray, Zacks, Tversky, et al., 2001). This kind of structure provides the viewer a way of chunking information at differing levels of granularity for differing purposes (e.g., inferring the actor's immediate goals versus broader or longer term goals).

Recent work by Hard (2006) goes further to suggest that hierarchical processing of action plays a role in action memory and understanding. Prior studies from the text comprehension literature have demonstrated that reading time is slowed at boundary points in the text (e.g., clauses, sentences) relative to non-boundary points, and that the amount of slowing is directly related to the size of the boundary point in the hierarchical structure of the text (i.e., slower reading near sentence boundaries than clause boundaries, Haberlandt & Graesser, 1989; Haberlandt, Graesser, Schneider, & Kiely, 1986). Hard created an action analogue to these text studies, in which participants viewed slide-shows of everyday actions, with action still frames presented one at a time in a self-paced format. Looking time to each slide was recorded. Results showed that looking time

increased at boundaries relative to points mid-segment, and also as a function of hierarchical level: that is, longer looking occurred at boundaries of larger action units relative to nested sub-action units, similar to the slower reading at major, relative to minor, clause boundaries in text. Hard also found that looking time at boundary points was significantly correlated with participants' later recall of the action sequences. These results are consistent with the hypothesis that cognitive processing increases closer to segment boundaries (Baldwin et al., in prep.). In addition, they suggest that hierarchical encoding of action positively enhances memory for action. Finally, they also point to an additional commonality in the online processing of language and human action.

To summarize, people can explicitly and spontaneously segment action according to the hierarchical structure of the actor's goals, and some evidence indicates this pattern of segmentation influences memory for action. I hypothesize that action memory is organized hierarchically and primarily emphasizes the inferred goal structure of the action sequence. However, although previous research suggests that hierarchical structure is important for action memory, surprisingly no direct evidence as yet demonstrates that action memory is in fact structured with respect to goals. In developing ways in which to test this idea, I took inspiration from past research on memory for text. Studies on text memory have demonstrated that memory for information in text emphasizes hierarchical representation of propositions, even when this conflicts with the sequential structure occurring in the text presentation itself.

<u>Studies of Memory for Text</u>

Language and action, though dissimilar in a number of ways, share some important similarities. In both domains a complex, dynamic stimulus must be analyzed on multiple levels in parallel on-the-fly. Regarding language, it has been shown that these processing challenges result in poor memory for the precise wording of a sentence; the surface form of a sentence decays rapidly from memory over time (Fillenbaum, 1966; Sachs, 1967). It is widely believed that once the listener has encoded enough of the relevant surface information in order to decode its meaning, the meaning components of sentences are stored as propositions (Kintsch & Keenan, 1973). Propositions are concepts that predicate a relation with respect to its arguments (e.g., in 'Scott ate a pizza', 'eating' specifies a particular kind of gustatory relation between 'Scott' and 'pizza').

If sentences are stored propositionally, then what of whole sections of discourse or passages of text? McKoon and Ratcliff (1980) provided evidence that propositions are organized in memory in a hierarchical fashion with little reference to the surface structure of the text. The logic behind this study will form the basis behind the design of the proposed research concerning human action, so I will review it in detail here. Participants in their study read passages of text and were asked afterwards to verify whether particular propositions had been encountered in the text they had just read. Each text was analyzed in terms of its underlying propositional hierarchy, meaning that the relationship between propositions in the text could be described in terms of both surface distance (proximity in terms of the number of intervening propositions in the original verbatim text) and meaning distance (proximity in terms of the number of intervening propositions in the

hierarchy). Importantly, propositions at different levels in the meaning hierarchy were intermingled in the surface structure of the text, which allowed McKoon and Ratcliff to select pairs of propositions as primes which were maximally contrasted in terms of surface distance and meaning distance. Participants were significantly faster at verifying target propositions if they were preceded by propositions close to the target in meaning structure but far from the target in surface structure than if they were preceded by propositions close in surface structure but far in meaning structure. This meaning priming advantage clarified that memory for text emphasizes hierarchical representation of component propositions, rather than the sequential surface structure of the text.

A control experiment indicated this priming effect manifested only after reading the text passages, and thus was not due to extraneous differences between the two prime types or pre-existing semantic memory. In this experiment, instead of reading the actual passages, participants studied a randomly organized set of sentences from the passages. Participants were tested in the identical manner (i.e., asked to verify whether they had seen propositions before), with the same targets, meaning primes, and surface primes. If inherent extraneous differences or pre-existing semantic associations produced the priming effect in the first experiment, then they should have been evident in this experiment as well. In fact, the results of this control revealed no difference in priming between surface and meaning primes, suggesting the results of the first experiment were due to the organization in memory of the newly encountered text material.

Thus, the information encountered in text is initially processed in terms of surface detail but ultimately encoded as propositions, organized hierarchically in memory

primarily in terms of meaning relations. Interestingly, at least some parts of this process do not appear to be limited to comprehending text. For example, Gernsbacher (1985) provided evidence that loss of surface information occurs in picture narratives – stories told only with sequences of pictures – as well. It is entirely possible that this pattern of surface information loss and organizational restructuring is a domain-general processing tendency, utilized whenever people are faced with analyzing and comprehending complex, structured sequences of information. If so, it is highly plausible that similar effects of surface information loss and memory reorganization could exist for the processing and storage of dynamic human action.

Although this review of the research on text memory supports the general notion that the primary organization of action memory could reflect hierarchical inferences about goals, I was also interested in the developmental pathways to this form of memory organization. To this end, I also looked to the rich literature on children's event memory and imitation for clues about whether goal and temporal information are processed by young children, and how action memory might be organized in this younger population.

Studies of Event Memory and Imitation in Children

One methodological tool which has been invaluable in exploration of memory development is imitation. Research using imitation has demonstrated that important aspects of children's memory systems are present from fairly early in infancy, and that a great deal of maturation over the course of memory development is quantitative in nature rather than qualitative.

Bauer and colleagues, elaborating on ideas from Piaget (1962) and Meltzoff and Moore (1977), have used imitation to extensively explore young children's memory for events (Bauer, 1992; Bauer & Mandler, 1989, 1992; Bauer & Shore, 1987). The standard procedure used in these studies is to expose children to three- or four-step action sequences in which the experimenter manipulates some toys, and then give the toys to the children and asks them to reenact the sequence through imitation. This research has demonstrated that very young children – starting as young as 9 months – are sensitive to the temporal information contained in action sequences, and are often able to recall the steps involved in the sequence in the correct order they occurred. The amount of temporal information that children can store and maintain in memory increases with age.

Very early on this line of research indicated the causal structure of the action sequences has a major impact on children's ability to recall the events. Bauer has dubbed these causal features "enabling relations" (Bauer & Shore, 1987). An enabling relationship between actions is one in which one action must be executed before another action can be executed. An example enabling relation used in Bauer and Mandler (1989) was the Frog-jump, which involved placing a wooden board on a block, placing the frog on the lowered end of the board, and then hitting the elevated end of the board to catapult the frog into the air. In this instance, placing the frog on the board is a necessary condition before the catapulting can occur, and thus there is an enabling relation between these two events. Other sequences of action – arbitrary relations – have no such necessary causal relation, in which any event can be preceded or followed by any other event in the

sequence. Bauer has found that children can recall the order of steps involved in action sequences significantly better if they involve enabling relations over arbitrary relations (Bauer, 1992; Bauer & Mandler, 1989, 1992; Bauer & Shore, 1987).

Memory for sequences of action involving arbitrary relations does improve with age. Improvements occur between 16 months and 28 months, and significant improvements can still be seen between 3 and 4 years (Bauer, 2006). However, memory for sequences involving enabling relations always has a significant advantage over memory for sequences involving arbitrary relations. Even when children are given repeated exposure to sequences of arbitrary relations, the temporal order of sequences involving enabling relations is still recalled significantly more accurately.

What is it about enabling relations that make them more memorable? Bauer has argued that enabling relations are grouped and represented as a chunk or unit of information in memory, thus reducing the processing load for memory storage. Evidence to support this claim comes from experimental demonstrations that these units are resistant to interruption (Bauer, 1992), similar to the demonstrations of unit resistance that have been shown in language processing described earlier (Fodor & Bever, 1965). In these studies, children are presented with a sequence of actions in which an action unrelated to an enabling relation is inserted between the two parts of the enabling relation (e.g., between the placing of the frog on the board and the launching of the frog). In their reproduction of the sequence, children display systematic errors in ordering that suggest the unitization in memory. In particular, they are most likely to reproduce the enabling

relations sequentially adjacent and the interrupting action either before or after the enabling relation. This effect is also stronger after a delay is imposed between exposure and test.

Although Bauer has argued that this effect reflects chunking of steps together in memory, a number of alternatives have not yet been ruled out. For instance, children might find the enabling relations inherently more interesting, and thus they are better attended to and encoded more reliably in memory. Relatedly, children may accurately remember that another step intervened in the enabling relation, but poor inhibitory control skills render children unable to stop themselves from executing the inherently more interesting step in the enabling sequence.

However, assuming that children do chunk these units together in memory, this may in fact be evidence of children's hierarchical representation of action based upon top-down, goal-related causal knowledge. Infants and young children may be representing these two-step small-action sequences as a goal unit based upon the fact that they are causally related in a transparent fashion. Research indicates that even very young infants understand basic physical principles such as solidity, gravity, and support (Baillargeon, 2004; Spelke, Breinlinger, Macomber, & Jacobson, 1992). These basic physical principles might act as a form of top-down knowledge that children bring to these situations which enables them to infer a higher-level goal unit (e.g, make the frog jump). When an arbitrary action is enacted that interrupts an enabling relation, children may reorganize the action information in memory according to its goal structure, and recall the goal-related enabling relations as having occurred adjacent in time. In the

situations Bauer and colleagues have used so far, only basic physical knowledge is needed in order to infer the goal of the actor. However, with more complex novel stimuli, one could assess the role of top-down knowledge in this process of goal inference – and possibly unitization of action in memory – by manipulating the level of knowledge children receive regarding the novel stimuli. To my knowledge, this research question has not been addressed directly.

Related work has demonstrated that goal information can indeed modulate children's imitation of other's action. Williamson and Markman (2006) experimentally manipulated the degree to which 3- to 4-year-old children understood the overall goal of the action sequence. Somewhat counter-intuitively, at least on the face of it, when children were not aware of the actor's goal they were actually more faithful imitators compared to when they did know the goal of the actor. That is, they were more likely to imitate the exact temporal sequence of actions if they did not know the goal. The authors suggest that children selectively attend and encode only those actions that are relevant to the goal when they are aware of the goal, and that without knowing what the goal of the action is children attend and encode more action detail, including veridical temporal sequencing.

Interestingly, however, similar work by Horner and Whiten (2005) as well as Lyons, Young, and Keil (2007) appears to contradict the results of Williamson and Markman (2006), and suggests 3- to 4-year-old children are faithful imitators even when causal knowledge is readily available. In their tasks children are presented with a novel causal object, and the experimenter provides a demonstration using both causally relevant

and causally irrelevant actions. When children are asked to imitate, they imitate all actions, causally irrelevant or not. This is the case even when children can directly observe the causal irrelevance of the actions (Horner & Whiten), and also when they are given direct instructions not to imitate causally irrelevant action (Lyons). This phenomenon has been dubbed "overimitation."

How can these two seemingly opposing sets of results be unified? Lyons et al. (2007) offer the plausible suggestion that the key difference between selectively imitating and overimitating is likely due to different cognitive strategies children utilize in the face of relative novelty. In the stimuli and the action sequences used by Williamson and Markman (2006), relatively familiar stimuli were used, and thus the goal and the relevant top-down knowledge were likely very clear to children. Thus, they were able to selectively process or reorganize their representation according to the inferred goal structure. Contrast that with the stimuli used by Horner and Whiten (2005) and Lyons et al., which were much more novel relative to those used by Williamson and Markman. This novelty likely caused children to adopted a different cognitive strategy in which children focused on all aspects of the actor's action as potentially causally relevant and goal-related. Their imitation was thus modulated according to these adjustments. As both Lyons and Williamson and Markman suggest, children are "flexible imitators", and are able to vary their imitation according to the task demands (see also Williamson, Meltzoff, and Markman (2008), for a similar point).

To sum up, the research on event memory and imitation with infants and young children suggests that children are sensitive to sequential temporal information starting

early on in infancy, but that the causal features of the events play a role in the organization of event memory. It is possible that the causal features of the event may allow children to infer goal units and structure memory according to those inferred goals. Research on imitation also suggests that by 3 to 4 years of age children become sensitive to contextual factors which alter their memory for goal and temporal information contained in events; In particular, novelty seems to increase children's adherence in memory to the temporal structure of events.

The Current Experiments

The goal of the current experiments was to identify the primary form of organization for action memory, to assess whether developmental differences exist between adults and young children in this regard, and explore the contribution of familiarity in possible developmental differences.

Action sequences in which two goals are carried out in an interleaved fashion contain goal information diverges from the surface-level temporal structure of the sequence. These types of action sequences provide a vehicle to test the hypothesis that action memory may be organized primarily according to goals, as these sequences can be organized in memory in more than one possible way, each way leading to a testable prediction. Such sequences could be organized according to the veridical temporal sequence, in which actions that occur adjacent to one another in the temporal sequence – irrespective of their goal relatedness – are more closely related in memory. Alternatively,

they could be organized according to the goal structure, in which actions that are related to the same over-arching goal – irrespective of their temporal distance from one another – are related more closely in memory.

The research on action segmentation suggests that goals are prominent in people's online processing of action, as well as in their recall of action events. Hierarchical encoding of action goals also appears to be a fundamental aspect of how action is segmented and processed online. Thus, although organization via goals and organization via temporal structure are both possible, I hypothesized that organization according to inferred goal structure would be the primary organizational strategy in memory. As discussed previously, this form of organization likely has advantages over temporal organization, as it involves relatively deeper processing and helps to preserve the overall goals of the actor in memory.

Note that organization according to goals for events in which goals are carried out in an interleaved fashion requires that action events be *reorganized* in memory. For such events, temporal organization does not require reorganization – it simply reflects the order in which action information was encountered. However, if goal organization is more primary, then the action information must be reorganized to keep disparate goal-related actions together in memory. The literature on text memory suggests that a comparable process of reorganization does indeed occur when people read relatively complex passages of text. If reorganization according to meaning can occur, then it seemed plausible that reorganization for action meaning – i.e., goals – could also occur.

In Experiment 1 the hypothesis that goal organization is more primary than temporal organization in action memory was tested by constructing a task very similar to the one used by McKoon and Ratcliff (1980), but adopted for human action. In this task, participants viewed sequences of action in which two goals were carried out in an interleaved fashion, instead of one after the other. Participants' memory for the videos was tested using still frames, and within the test particular target frames were primed by goal relevant frames versus temporally relevant frames. Both types of prime frames were maximally separated on their respective dimensions – that is, goal primes shared the goal of the target but occurred far in time from the target, while temporal primes occurred very near in time to the target but did not share the goal of the target. I predicted that priming participants' memory for such actions sequences with goal-relevant information would lead to improved recall performance relative to priming with temporally relevant information.

The goal of Experiment 2 was to fine-tune the results of Experiment 1. This experiment was a control experiment, similar to the one used by McKoon and Ratcliff (1980), which examined the extent to which any priming differences observed in Experiment 1 were the result of newly formed memory structure as opposed to preexisting semantic structure. Because my stimuli involved activities that would be highly familiar to adults, there existed a risk that any priming differences I observed in Experiment 1 could be due to semantic and/or episodic memory associations that participants had formed prior to watching the videos. In Experiment 2 participants viewed randomly organized still frames instead of the actual videos, so that their memory

for the images could be tested with the same priming structure as in Experiment 1. Any priming differences observed in this context would reflect pre-existing memory associations, and would suggest that the results of Experiment 1 were confounded with this phenomenon. I hypothesized that priming differences would only emerge after viewing the actual action sequences.

Experiment 3 was aimed at elucidating the role of language in action memory organization. It is possible that action organization is mediated by linguistic coding of the action events. Action sequences that are coded linguistically essentially represent a narrative of the actor's activities. It is possible that people generate goal inferences as a result of this narrative construction process. Thus, any goal-priming advantage relative to temporal priming could arise as a result of a narrative-based reorganization, rather than as a product of action processing per se. Experiment 3 explored this intriguing possibility by having participants engage in the same memory priming task used in Experiment 1, but while they watched the videos participants simultaneously shadowed linguistic material. I hypothesized that shadowing would engage participants' linguistic systems to such a degree as to make linguistic recoding of the action sequences difficult. If linguistic recoding is the source of priming differences observed in Experiment 1, then priming differences should be significantly reduced by the shadowing manipulation.

Although I hypothesized that adults reorganize action information in memory according to inferred goals, there was reason to believe that children may show a different pattern. The research on imitation and event memory suggests that developmental differences may exist between adults and children in the degree to which

temporal information is processed and stored in memory, and also suggests that familiarity with the action sequences may play a role in this process. Children appear to be sensitive to temporal information, and when actions and situations are relatively novel, their sensitivity to temporal information appears to be increased. In situations that are relatively familiar however, children appear to pay little attention to temporal information. Furthermore, in situations where the novelty is low and the causal principles of the actions allow children to infer a goal, there is evidence to suggest that goal information takes precedence over temporal information.

Thus, in Experiment 4 I assessed the degree to which 6-year-old children organize action memory according to inferred goals or temporal structure. The motivation for selecting this age group was largely atheoretical; This age group was chosen because it was the minimum age that could appropriately complete the memory task that adults performed in Experiment 1. I modified the task that was used with adults only such that it would be engaging and enjoyable for young children. Otherwise, the stimuli and the priming structure of the memory test were identical to those used with adults. Because this priming task only required visual recognition of the information contained in the action sequences, it was not heavily confounded with elements of executive function. In studies of action memory that use imitation as the main dependent measure, the child's imitative response is confounded with inhibitory control: children may be unable to inhibit the motor response for carrying out a salient sequence of actions, despite the fact that they correctly remember that another action interrupted the salient sequence. The task I used thus allowed for a more sensitive test of action memory organization in young

children than those that have been employed previously. I also developed a questionnaire for parents to complete (the Activity Survey) which asked them to rate their child's familiarity with each of the activities depicted in the videos, in order to assess the role of familiarity with children's memory performance and priming differences. I hypothesized that, for children, goal organization would be more primary for videos that involved highly familiar activities, but that for relatively novel activities temporal organization would be more primary.

CHAPTER II

EXPERIMENT 1

The purpose of Experiment 1 was to determine whether the organization of

memory for human action emphasizes inferred underlying goal structures relative to

temporal surface structure. To this end, I conducted an experiment analogous to that of

McKoon and Ratcliff (1980) on organization of text in memory, modified for use with

videos of human action. Participants watched videos of human action involving two

commonly associated high-level goals (e.g., ironing and folding laundry). The actions

related to the two distinct goals were carried out such that they were to some degree

intermingled. Although behavior was continuous, actions related to goal A were

interrupted in order to carry out actions related to goal B, then goal A interrupted goal B,

then goal B interrupted goal A for a final time. Thus, for observers, the videos could be

represented in memory in terms of goal structure (e.g., each goal represented, with sub-

goals nested underneath) and/or in terms of temporal structure (e.g., the temporal

sequence within the actual motion stream). After watching each video, participants were

shown a series of still frames. For each still frame they were asked to verify whether the

frame was from the video they had just watched. The still frame series included target

frames, goal primes, and temporal primes, selected from each video. Goal primes were

frames of action from the same goal as the target, but relatively distant with respect to the

temporal structure of the video. Temporal primes were the opposite: they were frames relatively close to the target in terms of temporal structure, but from a different goal than the target. For a given target, either a goal prime or a temporal prime immediately preceded the target frame during the test. If organization of action memory emphasizes goal structure, then participants should be faster at verifying the target frame when it is preceded by a goal prime compared to a temporal prime. In other words, inferred goal relations should serve as more effective primes than surface temporal relations.

Method

Participants

Participants were 78 adults, all students enrolled at the University of Oregon (39 female). Participants received partial course credit for their participation in the experiment.

Stimuli

The digital video stimuli consisted of 16 videos of everyday human action. Each video involved two commonly associated but causally independent high-level goals. As described earlier, actions related to each of the goals were enacted in an intermingled fashion (e.g., two goal A actions, followed by three goal B actions, followed by two goal A actions, etc.). The purpose of this intermingling was to ensure that observers could potentially represent each video in at least two different ways: in terms of temporal structure and/or in terms of goal structure. The videos ranged in length from 51 to 116

seconds ($M = 77.63$, $SD = 18.40$), and the frame rate was 30 frames per second. Each video measured 720 (w) x 528 (h) pixels. A short description of each video can be found in Table 1, while a detailed script of the activities can be found in Appendix A. Half of the videos were specifically designed to involve activities that would be highly familiar to young children, for use in Experiment 4.

Five types of still frames were selected from each video: target frames, goal and temporal primes, and true and false fillers. Two target frames were selected from each video, one from each high-level goal. Two goal primes and two temporal primes were also selected from each video, one of each type for each target frame. Goal primes were frames of action from the same goal as the target; in addition, these frames were specifically selected to have occurred relatively distant from the target in terms of the temporal structure of the action sequence ($M = 31.13$ s, $SD = 12.04$). Temporal primes were frames of action relatively close in actual time to the target ($M = 7.96$ s, $SD = 3.46$), but involving actions from the other goal. The aim in selecting goal primes relatively far from the target in time was to maximally contrast the two types of primes in their relevant goal and temporal properties. Due to the length and nature of the videos, primes from the first target in a video always had goal and temporal primes that occurred after the target frame in the video, while primes associated with the second target frame in the video always preceded that target frame in the video. Thus the directionality of temporal vs. goal primes with respect to target frames was balanced for a given target and fully counterbalanced across the videos.

Table 1. *The 16 video scenarios.*

Scenario	Description
Coloring and blocks	In a play room, the actor creates a block figure while drawing a picture with crayons
Cooking and cleaning	In a kitchen, the actor puts away cooking items while making a sandwich
Combing and teeth	In a bathroom, the actor brushes her teeth while combing her hair and arranging it in a ponytail
Computer and cleaning	In an office, the actor cleans up a messy desk while unpacking and setting up a laptop computer
Filing and microwave	In an office, the actor files away stacks of papers while microwaving some food
Food and cooking	In a kitchen, the actor gets food items out of the fridge while boiling water and cooking a meal
Frying and calling	In a kitchen, the actor fries eggs while getting out the phonebook and making a call
Ironing and folding	In a living room, the actor sets up a shirt for ironing while folding towels
Reading and eating	In a reading room, the actor selects and reads a book while eating a banana
Running and books	In a bedroom, the actor puts on running shoes while putting away books on a shelf
Socks and toys	In a play room, the actor puts on socks while selecting and playing with some toys
Sweeping and dishes	In a kitchen, the actor sweeps the floor while putting away clean dishes
Tea and recipes	In a kitchen, the actor makes tea while selecting a recipe book and reading it
Train and toys	In a play room, the actor sets up a toy train track while cleaning up a mess of toys
Video game and drink	In a living room, the actor sets up a video game system while pouring a soda
Windows and trunk	In a driveway, the actor washes the windows of the car while packing luggage into the trunk

Two true fillers and four false fillers were also selected for each video. The purpose of the false fillers was to ensure the test was an actual test of memory. That is, if participants' responses genuinely reflected memory for having viewed the actions in each sequence, then they should be able to accurately answer "no" to the question regarding whether they had previously viewed false fillers.

False fillers were frames from extended footage of unrelated action sequences with the same actor in the same setting that participants did not actually view. For example, in the video in which the actor washes the windows of his car and packs the trunk, one of the false fillers was a still frame of the actor checking the tire pressure. The purpose of the true fillers was to increase the length of the test, thereby providing more data for computing each participant's mean reaction time for correct positive identification (i.e., a correct "yes" response). True fillers were additional frames taken from the video sequence – one from each goal – that were not relevant as primes (i.e., they never immediately preceded a target frame in the test).

Figure 1 displays the script for one video, represented in terms of both the veridical temporal structure and the goal structure, as well as both target frames and their corresponding goal and temporal primes.

Video creation and frame selection were carried out with a number of constraints in mind. First, care was taken to ensure that extraneous differences between the primes and their respective targets were not systematically biased in favor of one type of prime over the other. For example, I ensured that whatever differences were manifest in actor location, body posture or eye gaze with respect to the target were not systematically

associated with one prime type compared to the other. Second, in all cases, targets and prime frames were only taken from breakpoints of the action stream within a particular goal. In order to test the hypothesis that action is organized according to goals in memory, it was essential that the goal of the frame was readily identifiable by participants to ensure the high-level goal was appropriately activated, if such structure existed. Given that breakpoints are more informative than non-breakpoints at depicting goal-related information (e.g., Newtson & Engquist, 1976), only breakpoints were selected.

Similarity Ratings

Although the stimuli were carefully designed in order to minimize systematic perceptual differences between goal primes and temporal primes relative to the target, it was still possible that goal primes were more similar to the targets overall. Since goal primes, by their very definition, involve actions and objects that are typically associated with the action depicted in target frames, they might have been more similar to targets in some surface sense compared to temporal primes simply because they involved related activities and objects. If this were the case, participants might have been primed to respond faster due to overall similarity rather than goal-relatedness per se.

In order to examine this possibility in greater detail, a separate group of 50 participants (28 female) were asked to rate the similarity of goal primes and temporal primes relative to the targets. Ratings were completed online. Participants viewed two still frames – a prime and its target – side by side, and were asked to rate how similar the pictures were on a seven point scale, where 1 was *not at all similar* and 7 was *extremely*

Example video: Sweeping and Dishes

a) Temporal Representation:

| Get broom | → | Sweep floor | → | Get utensils | → | Put utensils in drawer | → | Get dustpan | → |
| Sweep dirt into dustpan | → | Throw away dirt | → | Lean broom on door | → | Open cupboard | → | Get cups | → | Put cups in cupboard |

b) Goal Representation:

Goal: Sweep Floor

| Get broom | Sweep floor | Get dustpan | Sweep dirt into dustpan | Throw away dirt | Lean broom on door |

Goal: Put away dishes

| Get utensils | Put utensils in drawer | Open cupboard | Get cups | Put cups in cupboard |
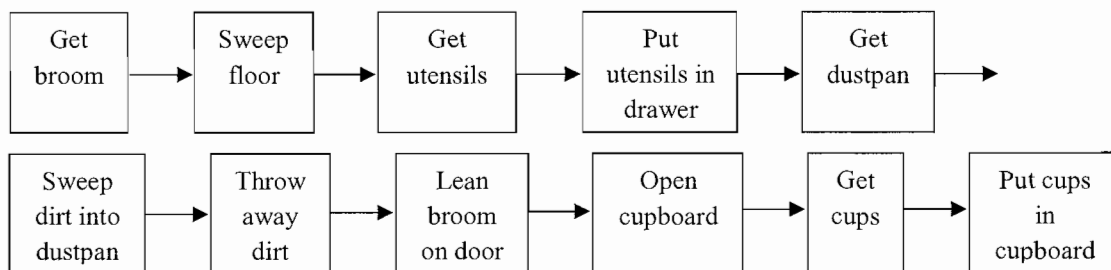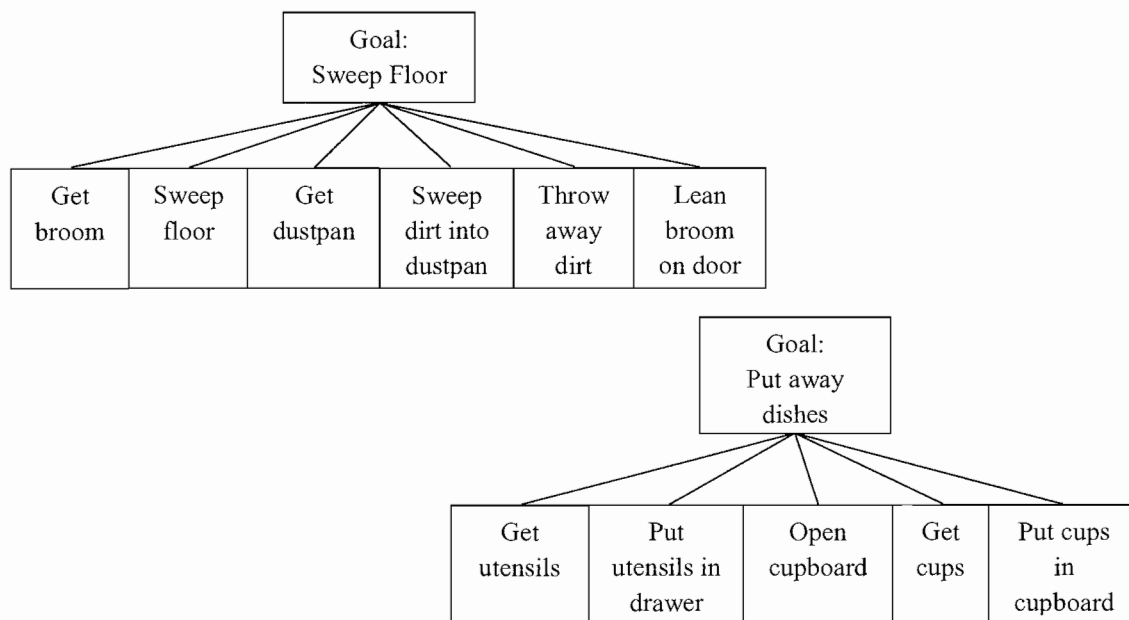
c) Prime and target information:

Prime type	Prime frame	Target frame
Goal	Get dustpan	Sweep floor
Temporal	Get utensils	
Goal	Put utensils in drawer	Open cupboard
Temporal	Throw away dirt	

Figure 1. Example video according to a) veridical temporal organization and b) goal organization, and c) the two targets and respective prime frames.

similar. Participants were told the pictures were very similar to start with, as all involved the same person in the same location at the same camera angle, and were asked to provide similarity judgments after already taking these factors into account.

Perceptual Similarity

In order to examine the possibility that goal primes were more similar to temporal primes in greater detail, I also compared the objective amount of physical difference between each of the prime types and their respective targets. The pixel values of each prime frame and its target were compared using the following algorithm:

$$\sum_{i=1}^{h}\sum_{j=1}^{w}\sqrt{(R_{Pij}-R_{Tij})^2+(G_{Pij}-G_{Tij})^2+(B_{Pij}-B_{Tij})^2}$$

where R, G and B represent the red, green, and blue color values of a pixel, P and T denote the prime frame and target frame, i and j represent the coordinate value of the pixel, and h and w represent the height and width of the frames in pixels. The average amount of pixel change for the goal primes and temporal primes was computed. If goal primes were more similar to the target frames in an objective sense (e.g., similar body and object positions), then the magnitude of pixel change for the goal primes should be significantly smaller than the magnitude of pixel change for the temporal primes. However, goal primes ($M = 12368106.12$, $SD = 4740638.33$) actually displayed larger physical changes on average compared to temporal primes ($M = 11045212.32$, $SD =$

4890126.73), though this difference was not significant, $t(62) = 1.10, p = .28$. Thus, this analysis assured that the two prime types were statistically equated in their objective perceptual similarity to the targets.

Design and Procedure

The 16 stimulus videos and 16 associated test trials were separated into four blocks. Each block involved a study phase containing four videos and a test phase containing the four associated tests. In the study phase, participants viewed the four videos. After watching each video, participants were asked to write down a prediction about what the actor was about to do next on a sheet of paper. This was done to ensure that participants accurately processed the actions performed by the actor in the video.[1] After watching all four videos in the study phase, the test phase began. Tests for each video were conducted serially, in the order that the videos were presented in the study phase. On each trial of a video test, a still frame was presented and remained on the screen until the participant responded. A 150 millisecond blank screen separated each trial following the participant's response (this inter-stimulus interval was adopted from McKoon & Ratcliff, 1980). A total of 10 trials comprised each video test: two for each of the target frames, two for each of the prime frames, one for each target (one goal prime, one temporal prime), and six filler trials (two true fillers and two false fillers). The order of trials within a particular video test was determined pseudo-randomly to ensure variability across tests while also maintaining adequate spacing between each of the

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[1] After each participant completed the experiment, the experimenter looked over their response to the prediction question for each video. While no formal qualitative analysis was completed, all participants offered predictions which were reasonable given the activities they saw in the contexts in which they occurred.

target-prime pairs in the list. Specifically, targets were never presented first or second, primes immediately preceded targets, and targets were never immediately followed by the other target's prime. The order of targets in the test and the type of prime preceding each target was also fully counterbalanced between-subjects. The order of video presentation across the four blocks was entirely random.

A Macintosh G5 computer was used to present stimuli and record participant responses on a 19.5" x 12" cinema display. From where participants were seated, videos subtended approximately 9.29 degrees of visual angle. Psychtoolbox (Brainard, 1997) was used to conduct the experiment and record responses.

Following provision of informed consent, participants were told that they would be presented videos of everyday, human action, and their memory for the videos would be tested. After the experimenter explained the task generally, participants completed a short practice study phase and test phase, consisting of only two videos and two video tests. These two videos were unrelated to the 16 videos used in the experimental procedure, were a similar length and involved a similar number of actions. During the practice study phase, participants watched each video, and after viewing each video were prompted to make a prediction about what the actor would do next. The practice test phase immediately followed the practice study phase. Participants were asked to judge whether or not a still frame was from the video they saw. Similar to the experimental tests, the practice tests involved 10 still frames, four which were false and six which were true. There were no target or prime still frames during the practice phase. Participants made their judgments using specially marked "Yes" and "No" keys (location

counterbalanced across participants). They were instructed to make their judgments as quickly and accurately as possible. Following the first practice video test, the experimenter informed the participant that all of the "No" trials would involve the actor performing entirely different activities than they performed in the video, and would not involve minor changes such as the location of the objects. This was done to ensure that participants were only focusing on the actions of the actor, and not surface details (as pilot work demonstrated participants tend to assume minor surface changes, which leads to very long reaction times). Following the practice phase, the experimenter left the room and the real trials began. Each of the four blocks comprising the real trials involved all of the same steps as the practice trials, but with four videos and video tests each block instead of two.

Results

Trials in which a participant correctly identified both the target and the prime that preceded it were used to calculate mean target reaction times. Only data from participants who correctly identified 75% or more of the targets ($N = 74$) were used in the analysis, in order to ensure that mean target reaction times were reliable. The mean proportion correct was .91 ($SD = .04$). Reaction times longer than 2.5 standard deviations above a participant's mean reaction times were also omitted. All means reported below are raw reaction time means. However, in order to reduce positive skew that is typical with

reaction time data, all within-subject statistical tests and effect sizes were calculated based on natural log transforms of the reaction time data.

Recall that I predicted goal priming would facilitate memory recognition for the target in comparison to temporal priming. This was indeed the case, as participants identified targets primed by goal information ($M = 1127.27$ ms, $SD = 274.05$) significantly faster than targets primed by temporal information ($M = 1166.45$ ms, $SD = 262.49$), $t(73) = 2.22$, $p = .03$, Cohen's $d = 0.26$. This priming difference did not emerge as a function of accuracy, however, as there were no significant differences in the proportion of goal-primed targets missed ($M = .08$, $SD = .08$) compared to temporal-primed targets ($M = .09$, $SD = .07$), $t(73) = 0.42$, $p = .67$.

I also compared goal and temporal priming in an analysis treating target frames, rather than participants, as the random variable. In this case, targets primed by goal information ($M = 1126.40$ ms, $SD = 199.07$) tended to elicit faster identification than targets primed by temporal information ($M = 1188.82$ ms, $SD = 201.50$), and this difference approached significance, $t(31) = 1.85$, $p = .074$, Cohen's $d = 0.33$. Again, this priming difference was not observed when comparing the proportion of misses for targets primed by goal information ($M = .09$, $SD = .12$) and temporal information ($M = .09$, $SD = .10$), $t(31) = 0.35$, $p = .73$.

Similarity Analyses

Similarity ratings between each type of prime and its respective target were compared using a paired t-test. The purpose of this analysis was to determine whether goal and temporal primes systematically differed in their overall similarity to the targets.

This analysis revealed that, despite concerted efforts in the design phase to avoid this, goal primes (M = 4.22, SD = 0.62) were perceived as significantly more similar to the target than temporal primes (M = 3.91, SD = 0.55), $t(31)$ = 2.25, p = .032, Cohen's d = 0.40. Although the earlier pixel-change analysis suggested that goal primes were not more similar to targets in an objective physical sense, this finding nonetheless raised the concern that the advantage for goal primes over temporal primes might have been due to similarity and not memory organization per se.

In order to assess the degree to which the goal priming advantage could be explained by differences in similarity, I correlated each target's goal priming advantage (mean goal primed RT – mean temporal primed RT) with each target's goal similarity advantage (mean goal similarity rating – mean temporal similarity rating). If the goal priming advantage varied according to similarity differences between the two prime types, then there should be a negative correlation between these variables. However, this correlation was not significant, $r(30)$ = -.037, p = .84. I also correlated the difference in pixel change between the goal primes and the temporal primes (mean goal prime pixel change – mean temporal prime pixel change) and correlated this with each target's goal priming advantage (as above). If the goal priming advantage was driven by the degree of pixel change (with more similar primes having displaying less pixel change), then there should be a positive correlation between these variables. However, this correlation was also not significant, $r(30)$ = .269, p = .14. Taken together these findings argue against a strong role for similarity in influencing participants' reaction times.

Despite this reassurance, I also conducted an analysis in which certain targets were removed from the analysis in order to equate the similarity of goal primes and temporal primes. In order to achieve this effect with as little disruption to the estimation of participants' mean reaction times as possible, I iteratively removed targets, in order of their similarity difference (beginning with those ranked highest in similarity difference), until the difference was no longer significant. Thus three targets were removed: one each from the videos *Cooking and Cleaning*, *Socks and Toys*, and *Tea and Recipes*. With their removal the similarity difference between goal primes and temporal primes was no longer statistically significant, $t(28) = 1.36, p = .186$. If the goal priming advantage found in the initial analyses was due to increased similarity between prime and target, then the advantage should be diminished when using a set of targets for which there was no longer a statistically significant similarity difference. However, when these targets were removed from participants' mean target reaction times, the reaction time advantage for verifying targets primed by goal information ($M = 1113.30$ ms, $SD = 258.47$) relative to temporal information ($M = 1153.21$ ms, $SD = 241.94$) remained statistically significant, $t(73) = 2.49, p = .015$, Cohen's $d = 0.29$. In addition, when these three targets were removed from the analysis treating targets, rather than participants, as the random factor, the priming advantage for goal information ($M = 1104.55$ ms, $SD = 194.61$) compared to temporal information ($M = 1184.00$ ms, $SD = 209.74$) achieved significance, $t(28) = 2.23$, $p = .034$, Cohen's $d = 0.41$. In sum, the convergence between this analysis and the

correlational analyses suggests the observed differences in similarity ratings between goal primes and temporal primes were not the source of the goal priming advantage in this task.

Discussion

The results of Experiment 1 confirmed the predictions. People appear to readily extract the goal structure of complex action sequences, and the organization of memory for these sequences emphasizes that goal structure. Although it would be entirely plausible for action memory organization to emphasize the order in which action information is encountered, this does not appear to be the case, at least for sequences of the kind that were presented, in which goal information is readily inferred. Rather than centering on a veridical representation of the flow of actions presented, action memory instead more strongly reflects encoding of inferences regarding the goals and intentions of the actor, and the causal relationships linked to those goals and intentions. This type of memory organization is similar to the organizational strategy that has been proposed for encoding propositions in memory (McKoon & Ratcliff, 1980). Importantly, however, these results should not be taken to indicate that no temporal information is stored in memory for action, but simply that goal organization is emphasized relative to temporal information.

At the outset, I was concerned that goal primes might be more similar to the target frames compared to temporal primes because they involve highly related actions and objects. Although I took considerable care in stimulus design to overcome this concern, and although I confirmed that goal primes were not more perceptually similar to targets in an objective sense, I nevertheless felt it important to empirically assess whether precautions in this regard were psychologically effective. To this end, I collected similarity ratings from a different group of participants, and conducted a series of statistical analyses to address the extent to which objective and perceived differences might have influenced the findings. These analyses indicated clearly that the similarity advantage for goal primes exerted little influence on the presence or the magnitude of the observed goal priming advantage.

Although I felt assured that the results of Experiment 1 did not arise merely as a result of a similarity confound, there remained an alternative explanation for the results. Specifically, it was possible that the goal priming advantage was the result of the test still frames triggering pre-existing memory organization, rather than the result of memory encoding during the viewing of the action sequences within the experimental session. Put another way, the priming advantage seen at test could simply have had its source in the test still frames activating pre-existing mental networks, instead of arising from activation of newly formed memory networks for the action sequences themselves.

Recall that McKoon and Ratcliff (1980) considered this possible explanation for the meaning priming advantage they discovered in their experiments on memory for text, and designed a control experiment to assess this possibility. In their control experiment,

participants viewed the identical sentences that had appeared in the passages in their

original experiment, but in a randomly organized fashion instead of in the original,

narratively coherent passage. Control study participants were then tested in the identical

manner as the original experiment with the same targets and primes. The results revealed

no advantage for meaning primes over surface primes in this context, clarifying that the

priming advantage observed in the original experiment was a reflection of newly formed

memories derived in the context of reading sentences within a coherent narrative. Thus,

in Experiment 2 I designed an analogous version of McKoon and Ratcliff's control

experiment to address the parallel question regarding organization in action memory.

CHAPTER III

EXPERIMENT 2

Experiment 2 was aimed at clarifying the results of Experiment 1. The goal priming advantage observed in Experiment 1 could have been due to accessing newly established memories of the action sequences, or could have been due to viewing of the test still frames simply directly triggering access to pre-existing semantic knowledge. In order to test between these possibilities, in Experiment 2 participants viewed a randomly organized set of still frames taken from each of the videos rather than the actual videos themselves. This allowed for use of the same test stimuli from Experiment 1, with the same targets and primes structured in an identical fashion. If activation of pre-existing mental structures during the test phase can account for the goal priming advantage, then this advantage should again be present when these frames were viewed in the absence of a coherent action context. However, if the results of Experiment 1 were due to memory organization for newly encoded action, as I have hypothesized, then the results of this experiment should yield no significant advantage for goal primes over temporal primes.

Method

Participants

Participants were 94 adults, all students enrolled at the University of Oregon (46 female). Participants received partial course credit for their participation in the experiment. One participant was excluded due to experimental error.

Stimuli

There were no video stimuli in this experiment. Instead, sets of still frames from each of the videos were used in place of actual videos. These sets of still frames consisted of the same targets, goal and temporal primes, and true and false fillers as in Experiment 1. In addition, four extra frames were taken from each video (two from each goal). These additional frames were used only in the study phase for each set of still frames, in order to make the study phases between Experiment 1 and 2 approximately equal in duration.

Design and Procedure

The design and procedure of Experiment 2 was identical to Experiment 1, except for two key differences. First, sets of still frames were used in place of actual videos during the study phase. These still frames were displayed one at a time for five seconds, and the next still frame in the set was displayed immediately after. Importantly, the order of still frame presentation within a set was entirely random. The second difference was that participants no longer were asked to predict what the actor would do next, as there was no temporal coherence during the still frame presentation to support such a prediction. Other than these two differences all aspects of the procedure were the same.

Results

As in Experiment 1, only trials in which a participant correctly identified both the target and the prime that preceded it were used to calculate mean target reaction times. In addition, only data from participants who correctly identified 75% or more of the targets ($N = 75$) was used in the analysis. This experiment was more challenging for participants than Experiment 1, as the mean proportion correct was .86 ($SD = .07$), and this differed significantly from Experiment 1 ($M = .91, SD = .04$), $t(168) = 6.12, p < .001$. However, participants in this experiment were also, on average, significantly faster at correctly verifying previously seen still frames ($M = 1094.86, SD = 291.18$) compared to the participants in Experiment 1 ($M = 1290.82, SD = 315.64$), $t(168) = 4.21, p < .001$. Reaction times longer than 2.5 standard deviations above a participant's mean reaction times were also omitted. Finally, as in Experiment 1, all means reported below are raw reaction time means, while all within-subject statistical tests and effect sizes were calculated using natural log transformed reaction time data.

In this experiment, no statistically significant difference emerged in participants' target identification for goal primes ($M = 964.82$ ms, $SD = 232.34$) relative to temporal primes ($M = 989.49$ ms, $SD = 282.54$), $t(74) = 1.28, p = .20$. In addition, there was no statistically significant priming difference when comparing the proportion of misses for targets primed by goal structure ($M = .12, SD = .10$) and temporal structure ($M = .12, SD = .10$), $t(74) = 0.48, p = .63$.

I also compared goal and temporal priming in an analysis treating targets as the random factor. Mirroring the within-subjects analyses, there was no statistically significant difference in reaction time for targets primed by goal information ($M = 969.10$ ms, $SD = 113.64$) compared to temporal information ($M = 1002.09$ ms, $SD = 138.29$), $t(31) = 1.37, p = .18$. As well, no significant priming difference was observed in the proportion of misses for goal-primed targets ($M = .12, SD = .09$) and temporal-primed targets ($M = .13, SD = .11$), $t(31) = 0.22, p = .83$.

Discussion

The results of Experiment 2 provide further support for the hypothesis that the goal priming advantage seen in Experiment 1 was due to memory organization that participants established as a result of viewing the action sequences. In this second experiment, participants encountered action information regarding small action goals (e.g., picking up shoes, opening the fridge) in a disorganized, pictorial fashion. This was done so that I could test participants in the identical manner as in Experiment 1 (i.e., asking them to verify whether they had seen a given still frame previously), to examine any priming effects on verification of target frames during the test in the absence of having viewed the action sequences. At test, participants displayed no differences in target detection based on the two prime types. Thus, goal primes functioned no

differently than temporal primes in the absence of seeing the action, suggesting the priming advantage for goal primes observed in Experiment 1 was not due to these primes merely triggering pre-existing semantic memory.

Because participants were significantly faster at correctly identifying still frames in this experiment compared to Experiment 1, one could argue that the absence of a goal-priming effect in this experiment is due to a floor effect. However, since participants' mean correct identification reaction time was approximately one second, this argument holds little weight. Priming effects in a whole host of other cognitive domains can be seen with reaction times that are much faster than the reaction times observed in this experiment. It is unclear why participants were slower in Experiment 1 compared to this experiment. One possibility is that in this experiment, participants were matching the observed still frame in test to an exact physical still frame match in memory, while in Experiment 1 they were matching an observed still frame to an actual event in memory. Thus, the recognition test for participants in Experiment 1 involved determining whether or not the current still frame described an event that *could* have occurred in the movie, which would require additional processing time compared to simply matching the current still frame to a previously seen still frame.

These results also provide additional evidence ruling out the idea that the goal priming advantage observed in Experiment 1 was due to greater similarity between targets and goal primes than targets and temporal primes. If similarity were the sole source of this effect, it should have differentiated goal primes and temporal primes in the same fashion in Experiment 2.

Taken together, the results of Experiment 1 and 2 demonstrate that people organize newly acquired action information in memory according to goals when they view other people's behavior. However, the results of these experiments do not speak to how this organization is actually accomplished. I hypothesize that visual action information is directly translated into a form of semantic representation that highlights the goals of the small action events and groups them together according to these goals (potentially hierarchically). However, it is also possible that this process is achieved linguistically. Perhaps as observers view complex action, they represent the action sequence in the form of a narrative. Given that people are known to emphasize propositional meaning over temporal structure in their organization of linguistic information (text), then the narrative representation may be organized according to the primary meaning of the action sequence – that is, the two goals. If the memory representation is indeed a narrative, organized according to meaning, then the goal priming advantage seen at test might be the same propositional priming advantage already demonstrated by McKoon and Ratcliff (1980) in the text processing literature. That is, the findings reported thus far might reflect memory representation derived from narrative encoding, rather than organization of memory for action per se. Experiment 3 was designed to address this issue, investigating whether a goal priming advantage occurs even when linguistic encoding – and hence narrative construction in the linguistic sense – is disrupted.

CHAPTER IV

EXPERIMENT 3

The purpose of Experiment 3 was to explore the possibility that the memory organization effects observed in Experiment 1 indicating an emphasis on goal encoding might have been mediated by language. In this experiment, participants engaged in a task very similar to Experiment 1, except while they were watching the videos they were required to shadow spoken language. Shadowing is a technique in which participants repeat aloud as quickly as possible language that is simultaneously being spoken over headphones (Cherry, 1953). Shadowing has been shown to disrupt the ability to use language to verbally recode visual information in simultaneous visual tasks (Besner, Davies, & Daniels, 1981; W. K. Estes, 1973; Levy, 1971; Murray, 1967). In addition, shadowing demands a large share of attention. If language is required to generate the goal priming advantage seen in Experiment 1, then disrupting participants' ability to use language during their viewing of the action sequences should seriously undercut this effect. At test, participants should show no goal priming advantage if linguistic recoding was prevented during encoding. If, on the other hand, the goal priming advantage in Experiment 1 arose directly from encoding of action information then the shadowing task, disrupting linguistic recoding should not interfere with the emergence of this goal priming advantage.

Method

Participants

Participants were 86 adults, all students enrolled at University of Oregon (46 female). Participants received partial course credit for their participation in the experiment.

Stimuli

The video and still frame stimuli were identical to Experiment 1. The shadowing material was an audio recording of the children's story *The Adventures of Paddy the Beaver* (Burgess, 1917), narrated by a male voice. The story was 60 minutes and 56 seconds long (though participants did not hear the story in its entirety), and had a mean sentence length of 16.49 words. The audio recording was played through a personal digital audio player and headphones.

Design and Procedure

The procedure was identical to Experiment 1, save for two key differences. First, participants shadowed the children's story during the study phases of the experiment. Participants controlled the playback of the story from the audio player. At the end of each study phase, they were instructed to pause the audio player before starting the test phase, and after each test phase, they were instructed to resume playback and shadowing. The experimenter was in an adjoining room, and monitored whether or not participants were shadowing the story appropriately (all participants were able to do so). The second difference was that participants did not predict what the actor would do next, as I felt this

would additionally increase the complexity of the task unnecessarily (given that it would require participants to carry out two linguistic tasks simultaneously: shadowing and predicting). Other than these two differences all other aspects were identical.

Results

Trials in which a participant correctly identified both the target and the prime that preceded it were used to calculate mean target reaction times. Only data from participants who correctly identified 75% or more of the targets ($N = 77$) was used in the analysis, in order to ensure that mean target reaction times were reliable. This experiment was more difficult than Experiment 1 in terms of the mean proportion correct ($M = .84$, $SD = .06$), $t(162) = 8.54$, $p < .001$, but did not differ from Experiment 2 in this regard, $t(177) = 1.42$, $p = .15$. As in the previous experiments, reaction times longer than 2.5 standard deviations above a participant's mean reaction times were also omitted. As before, all reported means are raw reaction time means, while all within-subject statistical tests and effect sizes were calculated using natural log transformed reaction time data.

As predicted, even when shadowing rendered it difficult or impossible for participants to linguistically recode the events, they identified targets primed by goal information ($M = 1113.17$ ms, $SD = 279.51$) significantly faster than targets primed by temporal information ($M = 1147.59$ ms, $SD = 259.03$), $t(76) = 2.03$, $p = .046$, Cohen's $d = 0.23$. As in Experiment 1, this priming difference did not emerge when comparing the

proportion of misses for goal-primed targets ($M = .12$, $SD = .09$) and temporal-primed targets ($M = .12$, $SD = .09$), $t(76) = 0.06$, $p = .95$.

I again compared goal and temporal priming in an analysis treating targets as the random factor. Complementing the above results, when a target was primed by goal information ($M = 1127.27$ ms, $SD = 173.29$) it was identified faster than if primed by temporal information ($M = 1172.85$ ms, $SD = 188.12$), and this difference approached significance, $t(31) = 1.94$, $p = .062$, Cohen's $d = 0.34$. This priming difference was once again not observed when comparing the proportion of misses for targets primed by goal information ($M = .12$, $SD = .14$) versus temporal information ($M = .12$, $SD = .11$), $t(31) = 0.14$, $p = .89$.

Similarity Analyses

As in Experiment 1, I wanted to ensure that the goal priming advantage was not due to goal primes being perceived as significantly more similar to targets compared to temporal primes. Because this experiment differed from Experiment 1 due to the shadowing procedure, it was possible that similarity could have played a more meaningful role in any goal priming advantage that might have been observed. I thus conducted the same correlation and similarity equivalence analyses for this experiment that I conducted in Experiment 1. As in Experiment 1, the correlation between each target's goal priming advantage (mean goal primed RT – mean temporal primed RT) and each target's goal similarity advantage (mean goal similarity rating – mean temporal similarity rating) was not significant, $r(30) = .022$, $p = .90$. I also correlated the difference in pixel change (mean goal prime pixel change – mean temporal prime pixel change) with

each target's goal priming advantage. Surprisingly this correlation was significant and negative, $r(30) = -.606, p < .001$. In this analysis a positive correlation would have indicated that perceptual similarity – in particular, goal primes being more similar to targets – could have played a role in the goal priming advantage. The negative correlation instead suggests that the bigger the goal prime changes were compared to temporal prime changes the faster the target was verified. Although I cannot provide a sensible explanation for this negative correlation, of greatest note is that the correlation was not positive. Taken together these findings again argue against a strong role for similarity in influencing participants' reaction times.

Following the analysis strategy of Experiment 1 further, I also conducted an analysis in which certain targets were removed in order to equate the similarity of goal primes and temporal primes (i.e., making the mean similarity difference statistically equal). As in Experiment 1, when these targets were removed from participants' mean target reaction times, the difference between targets primed by goal information ($M = 1109.70$ ms, $SD = 281.98$) and temporal information ($M = 1145.75$ ms, $SD = 244.24$) remained significant, $t(76) = 2.39, p = .019$, Cohen's $d = 0.27$. In addition, when these three targets were removed from the analysis treating targets as the random factor, the priming advantage for goal information ($M = 1118.00$ ms, $SD = 177.60$) compared to temporal information ($M = 1163.62$ ms, $SD = 193.78$) still approached significance, $t(28) = 1.76, p = .089$, Cohen's $d = 0.33$. As before, the convergence between this analysis and the correlational analyses indicates the observed differences in similarity between the two prime types were unlikely to have been the sole source of the goal priming advantage.

Discussion

The results of Experiment 3 shed light on the possible mechanisms involved in action memory organization. When participants shadow speech while they encode complex action information, their memory for action nonetheless appears to emphasize the goal structure of the action sequence. Thus, it appears that linguistic recoding is not necessary for extracting goal information from human intentional action sequences and highlighting it in memory.

Recall that in Experiment 1, participants were asked to predict what the actor would do next after viewing each action sequence. This was done to ensure that participants processed the actions of the actors accurately. In this experiment, participants were not asked to make this prediction, as I felt it would place too much additional demand on the participant and interrupt the flow of shadowing during the study phase. However, the results of this experiment suggest that making such predictions are not the source of the goal organization effect. It is possible that making the predictions did enhance participants overall memory for the events, as participants in this experiment were significantly less accurate overall compared to the participants in Experiment 1. However, most importantly, targets primed by goal information were still verified significantly faster than targets primed by temporal information, suggesting that it is goal inferences that primarily structure action memory.

The results of Experiment 3 are also especially striking given the large attentional demands placed on participants in order to simultaneously shadow and watch the videos.

It is impressive that participants were able to process the action in meaningful, goal-related terms while under this dual task demand. Taken together with the fact that participants in this experiment did not predict the actor's next action, this suggests goal organization in memory for action is robust and likely an important aspect of people's memory for action. As well, these findings suggest that memory organization in goal-related terms may well occur fairly automatically.

CHAPTER V

EXPERIMENT 4

Experiment 4 was designed to explore the organization of young children's memory for human action. As I have demonstrated in the first three experiments, adults primarily organize action memory according to inferred goals, even when goals are not aligned temporally in the original event, and achieve this form of organization sufficiently without the use of language. Thus, Experiment 4 had three primary goals: 1) to design a task that could assess memory organization in young children, 2) to explore potential developmental differences in goal versus temporal organization between adults and young children, and 3) to explore mechanisms that could potentially support the development of goal organization.

With respect to the first goal, the basic memory priming task used with adults in the previous three studies was modified to be more engaging for children. This involved turning the task into something akin to a game, with prizes children could earn at certain intervals throughout the game, a specially designed colorful response pad, and colorful game titles and game music. My goal was to make the task interesting enough for children so that they could complete as many trials as adults (in order to obtain stable reaction times). Pilot testing with this modified task indicated that it was appropriate for children of a minimum age of approximately six years. If this task were successful for

observing reaction time differences in this population then it could be used to address a variety of other developmental research questions in action processing that use priming as the basic dependent measure. Priming studies have an advantage over studies that require children to imitate previously seen action, as responses are not confounded with inhibitory control. Though relatively rare, there have been a number of previous studies that have successfully used priming tasks with children of this age (for recent examples see Hashimoto, McGregor, & Graham, 2007; Mecklenbräuker, Hupbach, & Wippich, 2003). In the majority of these studies accuracy is used as the main dependent measure of priming effects with young children, and priming effects manifested in reaction time are rarer still.

Regarding the second goal, it was unknown how young children might organize their action memory in comparison to adults. Previous research suggests two opposing possibilities. The first is that children, like adults, will organize action memory primarily according to inferred goals. This hypothesis is supported by Bauer's research on imitation and enabling relations (Bauer, 1992; Bauer & Shore, 1987). Recall that enabling relations denote a relationship between two or more actions in which one action must occur before a second action can be performed. Bauer's research has demonstrated that when two actions are linked by an enabling relation, children will recall these activities as having occurred adjacent in time, even when an unrelated action intervened between these two actions. To the degree that enabling relations provide a cue to goal inference, which seems highly plausible, these results suggest that children reorganize action information

in memory according to inferred goals, even when this process conflicts with the veridical temporal structure of the sequence. If this is the correct interpretation, then priming patterns in Experiment 4 should reflect goal over temporal organization.

On the other hand, a similar body of research suggests that temporal organization might be the primary memory organization format in young children. The research of Lyons et al. (2007) and Horner and Whiten (2005), and to a lesser extent Williamson and Markman (2006), indicate that 3- to 4-year-old children are indeed sensitive to the temporal structure of events for novel actions, at least when tested using imitation. When children are presented relatively novel action events with novel objects, they are most likely to imitate all steps in the sequence, regardless of enabling relations that may structure the ultimate goal of the actor. Thus, if these results using explicit recall are indicative of children's underlying memory organization, then the priming patterns in this experiment should reflect the primacy of temporal over goal organization.

This discrepancy in which organizational format will be more primary in children can be addressed with the third goal of this experiment, exploring potential mechanisms that support the development of goal organization. I hypothesize that goal organization is at times more primary than temporal organization in young children, and at times the reverse is true, and that familiarity with the action events in question is one factor that modulates which organizational format is more primary in memory. The effects of familiarity likely interact with memory organization To the extent that young children are familiar with an action scenario and thus readily able to infer the goals of the actor, then memory for action should primarily be organized with respect to goal structure. However,

when children cannot infer the goal of the actor, then memory cannot be structured with respect to goals, and temporal organization should be more primary. This hypothesis is similar to the explanation Williamson and Markman (2006) provided for their imitation findings (though imitation of temporal order was not a central focus of their research).

In order to probe the role of familiarity in young children's memory organization, I created a questionnaire – the Activity Survey – for parents to fill out which was designed to assess how familiar each child was with the events depicted in the videos. My aim was to correlate parental report of action familiarity with children's tendency to show the goal priming effect. The video stimuli used in Experiment 4 were identical to the stimuli used in Experiments 1 and 3. Although all of the events depicted in the videos would have been highly familiar to adults, recall that half of the videos I designed to be highly familiar to children and the other half to be relatively unfamiliar to children. I hypothesized that priming patterns would reveal goal organization to a greater degree for highly familiar events than for relatively unfamiliar events.

Method

Participants

Participants were 45 six-year-old children ($M = 72.38$ months, $SD = 3.03$, *range* = 66-77 months). There were 23 boys and 22 girls. Parents and their children were recruited from the Eugene-Springfield area via phone, from a database of families maintained by the University of Oregon Department of Psychology. Demographic characteristics of the

families largely reflected those of the community from which they were recruited, which is predominantly white and middle-class. A total of three participants were excluded from the final analysis: one for only completing three blocks, one for misunderstanding the task, and one due to experimental error. Families were compensated with a 10 dollar gift certificate for a local toy store for their participation.

<div align="center">Materials and Stimuli</div>

The video stimuli and still frame stimuli were identical to those used in Experiments 1 and 3. For the practice phase of the experiment, eight animal illustrations were also selected via an internet image search. These images included a cat, a butterfly, a dog, an elephant, a goldfish, a horse, a ladybug, and a lion.

A special child response box was also created for this experiment. This box was a cardboard computer keyboard box that housed a computer keyboard. The entire box was painted yellow. Two holes, 6 cm in diameter, were cut out of the top of the box, centered evenly along the surface of the box. Large wooden buttons, painted green and red, 4.7 cm in diameter, were affixed to keys on the keyboard with poster tack. The buttons were raised above the surface of the box with plastic cubes, and the gap between the hole in the box and the buttons was filled in by red and green construction paper. Below each of the buttons on the box Velcro signs were affixed that read 'Yes' and 'No'. The green button was always paired with the Yes sign, and the red button with the No sign. The signs and the buttons were removable so that the green Yes button would always be on the side of the child's dominant hand (as determined from parent report).

Activity Survey

An Activity Survey was created in order to assess children's familiarity with each of the actions depicted in the video, through parent report. A copy of the entire survey can be found in Appendix B. Each section of the Activity Survey was reserved for each of the 31 actions depicted in the videos.[2] Each section gave a short description of the activity and asked questions within three different sub-sections: understanding, frequency, and performance. In the understanding subsection, parents were asked to rate how much they felt their child understood the steps involved in the activity on a 7-point Likert scale, where 1 was *Does not understand at all* and 7 was *Understands all steps very well*. In the instructions for the Activity survey, parents were informed to answer this question specifically with regard to understanding the steps involved, and not with regard to whether their child understood the overall purpose of the activity. Parents were also given the opportunity to describe what aspects of the activity they thought their child understood in this subsection as well. In the frequency subsection, parents were asked to rate how often their child saw someone perform the activity on a 5-point Likert scale, where 1 was *Has never seen* and 5 was *Sees it nearly every day*. Parents were also given the opportunity to clarify this response below. Finally, in the performance subsection, parents were asked whether their child could perform this activity themselves or with help from someone else. They were also asked to rate how often their child performed this activity.

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[2] Although each of the 16 videos contained two different activities, the activity *Getting a book from the bookshelf and reading/looking at it* was used in two different videos, thus parents only reported on that activity once in the survey.

Design and Procedure

The design of Experiment 4 was identical to Experiment 1, with the same study phases and test phases, separated into four blocks of four videos at a time. The experimental procedure, however, differed in a number of respects. A script of the experimental procedure can be found in Appendix C.

After parents gave consent, they were instructed to fill out the Activity Survey while the child participated in the experiment. Children were then introduced to four stuffed animals, and were told that each of the stuffed animals wanted to play The Movie Game with the child. Children were then seated at a small table in front of the response box and a small computer screen. They were then given a sticker sheet, which contained four large boxes, each labeled with one of the four animal's names. Children were told that every time they played The Movie Game with one of the animals, they would receive a sticker from the animal at the end of the game. Children were told if they collected all four stickers they would receive the prize, which was the ten dollar gift certificate for the toy store.

Children were then introduced to the response box. They were told that the green button was the Yes button, and the red button was the No button. In order to ensure that the children understood the basic purpose of the response box, they practiced using the response box to answer a set of yes and no questions asked by the experimenter. They were then told they would practice using the box for a short memory game. Children were first shown a series of four animal images on the computer screen, and were asked to remember them all. Each image was displayed on the screen for a total of 5 seconds.

Following familiarization, children were told that the screen would now show some pictures, and that some of them would be pictures that they had just seen, and others would be pictures they had not yet seen. Children were instructed to press the green Yes key for old pictures and the red No key for new pictures. If children ever made a mistake during this practice phase, the experimenter reminded them what the buttons were. A total of four old and four new pictures were shown. Very few children made errors during this phase, and those who did never made more than two errors.

Following the practice phase, children selected an animal to play The Movie Game with. Once selected, The Movie Game title screen loaded and the title music played, and children were told that the stuffed animal had 4 movies of its friends that it wanted the child to watch. They were told that after they had watched all of the movies (i.e., the study phase), they would play a memory game for the movies using the response box (i.e., the test phase). With the exception of the test phase, the experimenter advanced through the various portions of the game by clicking the mouse. Children were introduced to the actor's name before each movie, and after watching each movie they were asked to predict what they thought the actor would do next (verbally). Just as in Experiment 1, this was done in order to ensure that children attended to the actions of the actor during the video. Children also checked one of four boxes each time that they viewed a movie in order to track their progress through the game.

At the end of the study phase, children began the memory game (test phase). Children were told they would play the memory game for each movie they had seen. They were told that for each movie pictures would show up on the screen, and some

would be pictures of something the actor did in the movie, and that some would be pictures of things that the actor did not do during the movie. They were instructed to press the green Yes key if it was something the actor had done, and the red No key if it was something the actor had not done. Just as in Experiment 1, still frames were displayed one at a time and remained on the screen until the child responded, and a 150 millisecond blank screen separated each still frame presentation. If children made a significant number of errors during the first memory game they were reminded how to use the buttons, but most children did not need this reminder.

At the end of The Movie Game children selected a sticker for their sticker sheet, and selected a new animal to play The Movie Game with. At the end of the entire study they were given the ten dollar gift certificate. Parents were given an opportunity to ask the experimenter clarification questions about the survey, and were then debriefed.

Results

Activity Survey

Mean ratings for the understanding subsection and the frequency subsection were calculated directly from the Likert ratings provided by parents. Responses in the performance subsection were coded numerically: responses indicating that a child could not perform the activity were coded as 0, and responses indicating that the child could perform the activity, with or without someone's help, were coded as a 1. Mean performance scores for each activity were then calculated from these numerical ratings.

Table 2. *Correlations among subsections of the Activity Survey*

Subsections	1	2	3
1. Understanding	--	.737*	.887*
2. Frequency		--	.695*
3. Performance			--

* $p < .001$

As can be seen in the correlation matrix shown in Table 2, correlational analyses indicated that all three subsections were significantly positively correlated with one another. This suggested that the subsections were all measuring the same underlying construct of familiarity. Thus, a composite familiarity score was created by calculating the standardized average of each of these subsections (scores ranged from 0 to 1).

Mean composite familiarity ratings were calculated for each activity, and the mean familiarity of each of the 16 videos was calculated from these mean activity composite familiarity ratings. The resulting set of familiarity scores can be found in Table 3. Recall that I designed half of the videos to be highly familiar to children, and the other half less familiar. The top eight familiar videos strongly matched my intuition, with the exception of the *Sweeping and Dishes* and *Running and Books* videos, which I had expected to be less familiar, and the *Food and Cooking* and *Video Game and Drink* videos, which I had expected to be more familiar. Importantly, the group of unfamiliar videos ($M = .64$, $SD = .09$) were significantly less familiar to children than the group of familiar videos ($M = .89$, $SD = .05$), $t(14) = 6.61$, $p < .001$.

Table 3. *Mean familiarity scores for the 16 video scenarios, grouped as familiar and unfamiliar.*

Familiar		Unfamiliar	
Scenario	Mean Familiarity	Scenario	Mean Familiarity
Socks and toys	.97	Food and cooking	.79
Reading and eating	.93	Video game and drink	.76
Coloring and blocks	.91	Tea and recipes	.69
Combing and teeth	.90	Ironing and folding	.61
Running and books	.87	Computer and cleaning	.60
Cooking and cleaning	.85	Filing and microwave	.59
Sweeping and dishes	.84	Windows and trunk	.58
Train and toys	.84	Frying and calling	.52

Main Analyses

As in the first three experiments, only trials in which a participant correctly identified both the target and the prime that preceded it were used to calculate mean target reaction times. In addition, reaction times longer than 2.5 standard deviations above a participant's mean reaction times were also omitted. Although I sought to exclude participants who did not correctly identify 75% or more of the targets, as I did in the first three experiments, the lower overall accuracy in this experiment would not permit this, as it would have removed over half of the sample ($N = 23$). In fact, children

($M = .80$, $SD = .07$) were significantly less accurate than the adults in Experiment1 ($M =$ .91, $SD = .04$), $t(118) = 10.53$, $p < .001$. Children's accuracy scores were normally distributed, however, and ranged from .65 to .95. Thus, reaction time data from all participants was included in the analyses. It should also be noted that children's mean reaction time for correct positive responses ($M = 2589.10$, $SD = 427.87$) was significantly slower than the mean reaction time of adults in Experiment 1 ($M = 1290.82$, $SD =$ 315.64), $t(118) = 18.61$, $p < .001$. As in the previous experiments, all means reported below are raw reaction time means, while all within-subject statistical tests and effect sizes were calculated using natural log transformed reaction time data.

Recall that, unlike with adults, I had no specific predictions regarding overall priming differences for children. This is because I predicted that children might not be familiar enough with at least half of the action scenarios to be able to emphasize goal structure in their memory organization for the action content. Nevertheless, I explored the reaction time data with respect to this overall difference. Although the mean difference was in the same direction as the adults in Experiments 1 and 3, as predicted, no statistically significant difference emerged in children's target identification for goal primes ($M = 2461.03$ ms, $SD = 462.97$) relative to temporal primes ($M = 2516.26$ ms, $SD = 556.77$), $t(41) = 0.61$, $p = .54$. In addition, there was no statistically significant priming difference when the proportion of misses for targets primed by goal structure ($M = .27$, $SD = .13$) and temporal structure ($M = .27$, $SD = .17$) were compared, $t(41) = 0.12$, $p = .91$.

I again also compared goal and temporal priming in an analysis treating targets as the random factor. Consonant with the within-subjects analyses, and as predicted there was no statistically significant difference in reaction time for targets primed by goal information (M = 2509.28 ms, SD = 441.79) compared to temporal information (M = 2521.21 ms, SD = 425.24), $t(31)$ = 0.13, p = .90. As well, no significant priming difference was observed in the proportion of misses for goal-primed targets (M = .26, SD = .20) and temporal-primed targets (M = .27, SD = .20) either, $t(31)$ = 0.17, p = .87.

Familiarity Analyses

I predicted that familiarity with the videos would interact with children's priming differences in this experiment, and that priming patterns would indicate relatively more goal organization for highly familiar videos than for relatively unfamiliar videos. From the composite familiarity scores, videos were divided into the top eight familiar videos versus the bottom eight unfamiliar videos (this grouping is represented in Table 3). I then analyzed children's reaction times with a 2 (familiar vs. unfamiliar) x 2 (goal primed vs. temporal primed) repeated-measures ANOVA.[3] Mean reaction times for each of the four conditions in this analysis can be found in Figure 2. This analysis indicated no significant main effects for either the type of prime, $F(1,39)$ = 1.36, p = .25, or the level of familiarity, $F(1,39)$ = 0.17, p = .69. Most importantly, there was also no significant interaction between the type of prime and the level of familiarity, $F(1,39)$ = 1.07, p = .31. Planned comparisons revealed there were no significant differences

[3] Two children were excluded from this analysis as they missed all of the targets in one of the four conditions, and thus there was no mean reaction time for that condition for these children.
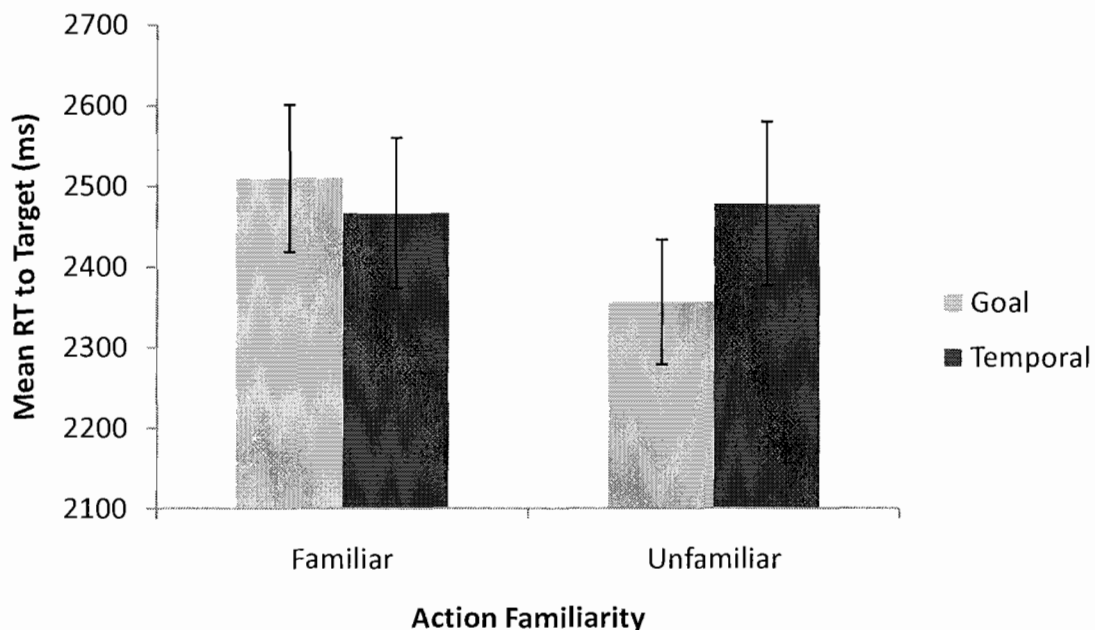
Figure 2. Mean reaction time to the target as a function of prime type (goal vs. temporal) and action familiarity (familiar vs. unfamiliar) when the familiarity grouping was based upon average familiarity levels. Error bars represent the standard error of the mean.

between targets primed by goal information and temporal information for familiar videos, $t(39) = 0.52$, $p = .61$, or for unfamiliar videos, $t(39) = 1.00$, $p = .32$. Interestingly, though non-significant, the mean differences for familiar and unfamiliar activities were actually the reverse of what I predicted. At least for unfamiliar videos, if there is anything to be gained from comparing mean differences alone, it looks as though goal organization is more primary.

Results differed somewhat when accuracy served as the dependent variable in this 2 x 2 ANOVA. The mean error rates for each condition are displayed in Figure 3. In this case, the main effect of familiarity was significant, $F(1,39) = 5.18$, $p = .03$, $\eta^2 = .12$.
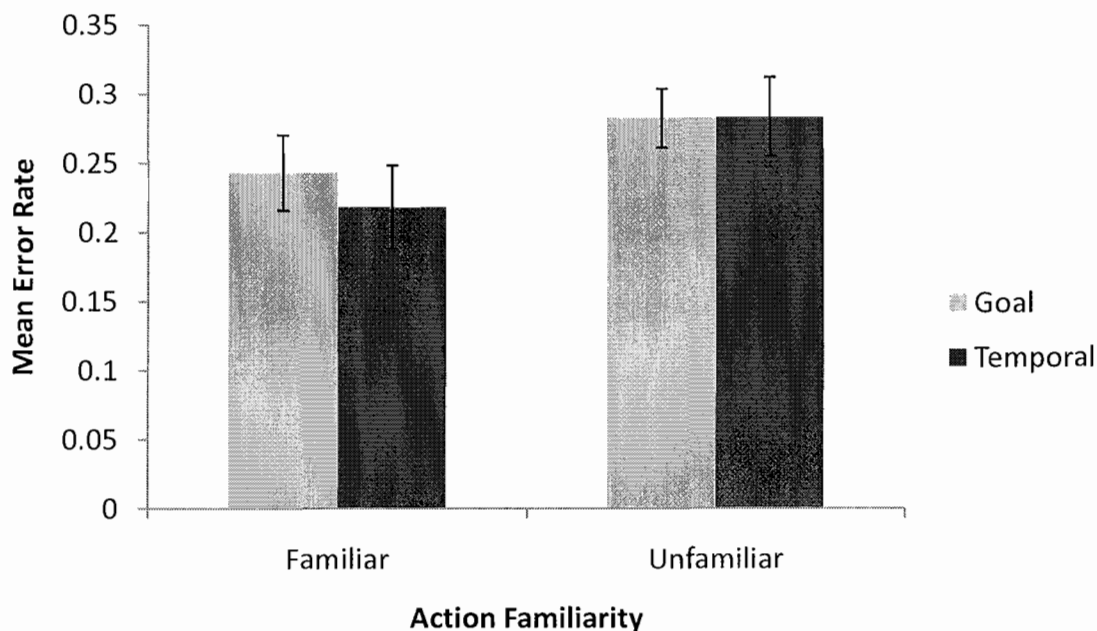
Figure 3. Mean target error rates as a function of prime type (goal vs. temporal) and action familiarity (familiar vs. unfamiliar) when the familiarity grouping was based upon average familiarity levels. Error bars represent the standard error of the mean.

Children missed significantly fewer targets for familiar videos ($M = .24$, $SD = .19$) compared to unfamiliar videos ($M = .30$, $SD = .18$). However, this analysis did not reveal a significant main effect of prime type, $F(1,39) = 0.21$, $p = .65$, nor any significant interaction between familiarity and prime type, $F(1,39) = 0.30$, $p = .58$. As with the reaction time data, planned comparisons revealed there were no significant differences in accuracy between targets primed by goal information and temporal information for familiar videos, $t(39) = 0.68$, $p = .50$, or for unfamiliar videos, $t(39) = 0.03$, $p = .98$.

I also ran analyses with targets as the random factor according to the average familiarity level. The results of these analyses were identical to the previous analyses with subjects as the random factor. For the reaction time data, there were no main effects of familiarity, $F(1,30) = 1.03$, $p = .32$, or prime type, $F(1,30) = 0.02$, $p = .90$, and there was no significant interaction between these two factors, $F(1,30) = 0.88$, $p = .36$. For the accuracy data, there were also no main effects of familiarity, $F(1,30) = 0.83$, $p = .37$, or prime type, $F(1,30) = 0.03$, $p = .87$, and there was no significant interaction between these two factors, $F(1,30) = 0.57$, $p = .46$.

Because data collected on the Activity Survey was for each individual activity, I was also able to correlate data from the Activity Survey with the reaction time and accuracy data of each individual target frame. A measure of the goal priming effect for reaction time was created by subtracting the mean reaction time for each target in the goal priming condition with the mean reaction time for each target in the temporal priming condition. The same calculation was applied to the mean error rates for each target in each priming condition, creating a measure of the goal priming effect for error rates. For both of these variables, higher scores indicate a stronger goal priming effect. These two measures of the goal priming effect for each target activity were then correlated with the mean values of each of the subsections of the Activity Survey for each activity, as well as the mean composite familiarity score for each activity.

The correlation matrix for this analysis can be found in Table 4. As can be seen, most of the correlations between these measures were non-significant. Surprisingly,

Table 4. *Correlations among measures of goal priming and measures of familiarity*

Measure	Understanding	Frequency	Performance	Familiarity
Goal Priming: Reaction time	-.182	-.348*	-.235	-.271
Goal Priming: Error rate	.103	-.076	.016	.014

* $p = .051$

however, yet consistent with the directionality of the effect with unfamiliar videos

reported above, the correlations between the goal priming effect in reaction time and the

measures of familiarity were all negative, and one correlation approached significance:

the correlation between the average goal priming effect in reaction time and average

frequency that children saw the activity. Since this was a negative correlation, it indicated

that as children saw the activity more frequently they were less likely to show the goal

priming effect. This ran counter to my general hypothesis that as children became more

familiar with the activities they would be more likely to show the goal priming effect.

Again, however, this was only a marginally significant effect, and it was only with one of

the subsections of the Activity Survey. Nonetheless, it does match the mean difference

for unfamiliar videos primed by goal and temporal information observed in the previous

analysis with participants as the random factor.

Overall, at this point the data suggest that the predicted interaction between

familiarity and priming patterns was not present in this experiment. However, it was

possible that the familiarity grouping used in the above two analyses glossed over

individual differences in relative familiarity across children. Perhaps the interaction between familiarity and memory organization is present within an individual child, but children's individual familiarity levels are so variable they wash out the interaction when the familiarity grouping is created from average familiarity scores. In order to create a more sensitive grouping of familiar and unfamiliar videos, I calculated a ranking of the top eight familiar and lower eight unfamiliar videos for each individual child based on parental report of familiarity for that child. Using this ranking, I calculated mean reaction times and error rates for each type of prime at each level of familiarity.

Mean reaction times from this individual grouping were submitted to a 2 (familiar vs. unfamiliar) x 2 (goal primed vs. temporal primed) repeated-measures ANOVA.[4] Mean reaction times for each of the four conditions in this analysis can be found in Figure 4. In this analysis there was no significant main effect of the type of prime, $F(1,36) = 0.03$, $p = .87$, but the main effect of familiarity approached significance, $F(1,36) = 3.36$, $p = .075$, $\eta^2 = .09$. Somewhat surprisingly, targets from familiar videos ($M = 2590.74$ ms, $SD = 746.46$) were verified significantly more slowly than targets from unfamiliar videos ($M = 2438.74$ ms, $SD = 805.15$). However, there was again no significant interaction between the type of prime and the level of familiarity, $F(1,36) = 1.37$, $p = .25$. There was no significant difference between targets primed by goal information and temporal information for familiar videos, $t(36) = 1.05$, $p = .30$, or for unfamiliar videos, $t(36) = 0.73$, $p = .47$.

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[4] Five children were excluded from this analysis as they missed all of the targets in one of the four conditions, and thus there was no mean reaction time for that condition for these children.
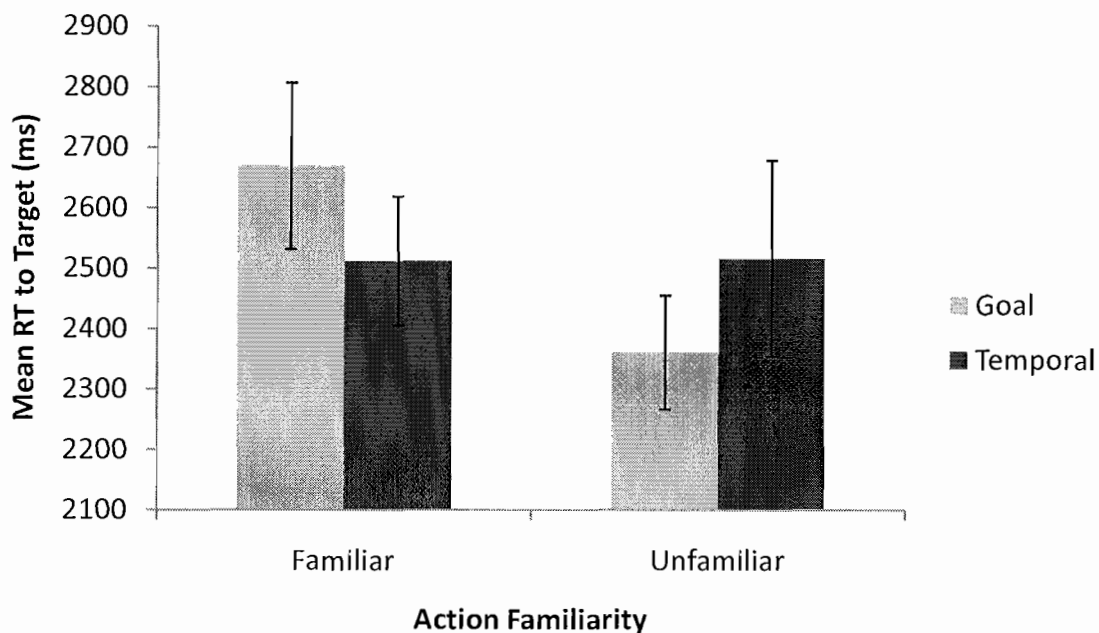
Figure 4. Mean reaction time to the target as a function of prime type (goal vs. temporal) and action familiarity (familiar vs. unfamiliar) when the familiarity grouping was based on individual familiarity levels. Error bars represent the standard error of the mean.

When accuracy served as the dependent variable in this 2 x 2 ANOVA, the results mirrored the results of the average grouping analysis. The mean error rates for each condition are displayed in Figure 5. The main effect of familiarity was again significant, $F(1,36) = 5.95, p = .02, \eta^2 = .14$. Children missed significantly fewer targets for familiar videos ($M = .20, SD = .16$) compared to unfamiliar videos ($M = .28, SD = .21$). Similarly, this analysis did not reveal a significant main effect of prime type, $F(1,36) = 0.18, p = .68$, nor any significant interaction between familiarity and prime type, $F(1,36) = 0.003, p$
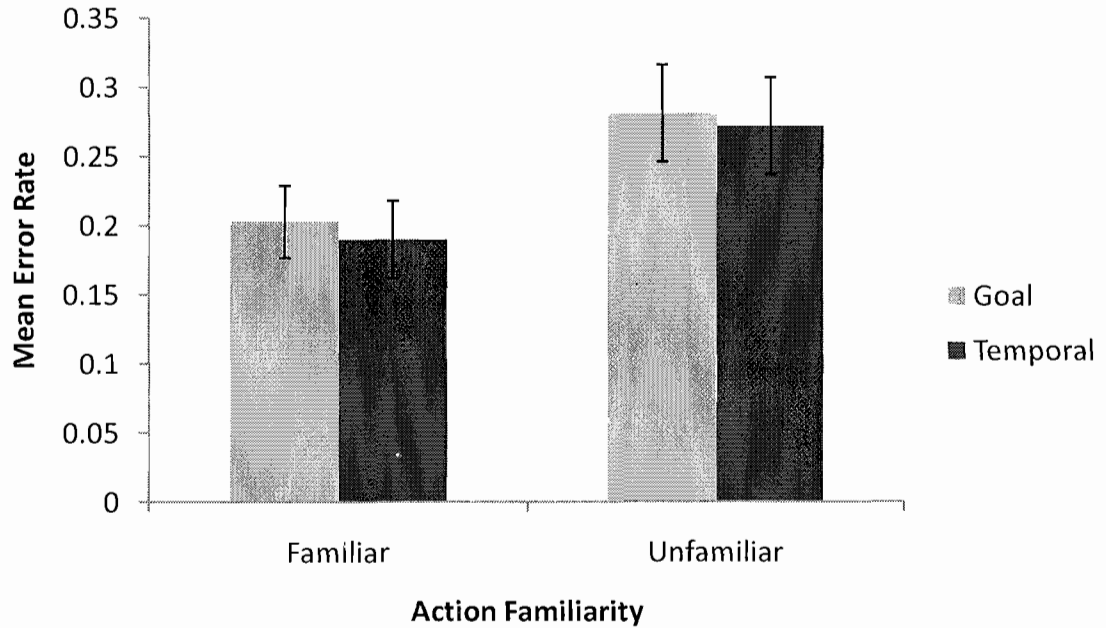
Figure 5. Mean target error rates as a function of prime type (goal vs. temporal) and action familiarity (familiar vs. unfamiliar) when the familiarity grouping was based upon individual familiarity levels. Error bars represent the standard error of the mean.

= .95. There was no significant difference in accuracy between targets primed by goal information and temporal information for familiar videos, $t(36) = 0.40, p = .69$, or for unfamiliar videos, $t(36) = 0.22, p = .83$.

Discussion

Experiment 4 failed to reveal strong evidence that young children organize their memory primarily in terms of either goal inferences or temporal structure. Although children's mean reaction times to identifying the target were faster when primed by goal

information compared to temporal information, this difference was not statistically reliable. This failure to find a significant difference in overall priming patterns across the 16 videos is perhaps not surprising, given that the videos varied in the relative familiarity of the actions depicted, and I hypothesized that familiarity would influence priming patterns. Nonetheless, these results may indicate that by six years of age children show a slight tendency to organize memory according to goal inferences, but this tendency is far from the organizational preference that the previous experiments demonstrated in adults.

Although the adults in Experiments 1 and 3 showed no differences in accuracy at correctly identifying the target across the two priming conditions, children might plausibly nonetheless have displayed evidence of organizational preferences based on accuracy rates. However, the overall accuracy rates for target detection did not differ across the two priming conditions either.

The main predictions of this experiment concerned the role of familiarity in memory organization. I predicted that goal organization would occur to a greater degree for videos depicting actions that were highly familiar to children relative to videos depicting less familiar actions. However, these predictions were also not borne out by the data: there was no significant difference in reaction times based on the type of prime used for familiar and unfamiliar videos in reaction time or in accuracy. It is worthwhile to note, however, that the main effect of familiarity was significant in this experiment: children were more accurate at detecting the target when it was a familiar video. This provides evidence that the familiarity division I used – to split videos either into familiar on unfamiliar – had some psychological reality in children's processing of the action

scenarios. At the very least this demonstrates that the non-significant interaction between familiarity and prime type was not the result of homogeneity in familiarity across the two familiarity categories.

Interestingly, however, across both types of familiarity analyses – average video familiarity and individual level familiarity – the pattern of mean reaction times actually demonstrated tendencies opposite to those predicted. For *familiar* videos, targets primed by goal information were detected about as quickly as those primed by temporal information, but for *unfamiliar* videos targets primed by goal information were generally detected *more quickly* than those primed by temporal information. Very little can be gained in the way of evidence from this observation alone, since this mean difference was not statistically significant; It is thus unknown whether these tendency simply reflects variation around a general mean reaction time or whether it instead reflects a tendency for young children to organize memory according to goals for unfamiliar activities. However, there was some additional evidence to corroborate this latter possibility: when measures of familiarity were correlated with measures of the goal priming effect, there was a trend for less frequently seen activities to show stronger goal priming effects (at least in terms of reaction time). This was only a marginally significant correlation, and the sample size of the correlation is low. Nonetheless, taken together with the mean difference in the reaction time analysis with participants, this may indicate that children are more likely to organize memory according to goals for activities that are relatively unfamiliar.

In sum, the results of Experiment 4 failed to support predictions, but also generated some puzzling unpredicted results. There are a number of reasons why this may have been the case, but I will save discussion of these for the next chapter, the general discussion.

CHAPTER VI

GENERAL DISCUSSION

Despite the ubiquity of action processing in our daily lives, relatively little is known about the cognitive system that supports such processing. The present studies are among the first to investigate how memory for human intentional action is organized in the mind, both in adults and young children. When we observe complex action in which two goals are interwoven, we can plausibly represent the action in at least two contrastive ways: with respect to the veridical temporal structure of the sequence, or with respect to the goal structure of the sequence. The results from the current studies indicate that adults emphasize goal information over temporal information in memory for human action. When adult participants were required to remember whether a particular action was carried out by the actor, priming on the preceding trial with goal-relevant information significantly facilitated detection relative to priming with sequence-relevant temporal information. Somewhat surprisingly, no evidence emerged that indicated 6-year-old children emphasize goal information over temporal information in memory. Further, familiarity with the actions involved did not influence young children's memory organization.

Because the results in adults and children differ, I will discuss the experimental findings involving adults separately from those involving children. Following this, I will end with some suggestions for future directions for this research.

<div align="center">Results with Adults</div>

The results across the first three experiments with adults are consonant with larger theoretical perspectives on how we process other people's behavior and social cognition more broadly (Baldwin, 2005; Tomasello, 1999). When we observe other people move about, our visual system is presented with a barrage of complex information from which we need to extract meaning. A central aspect of this process is thought to involve identifying the goals and intentions of the actor from movement patterns. In the majority of cases goals are what observers seem to be interested in discerning, not specifics about movement characteristics and trajectories. The present research has demonstrated that goals are not only inferred from movement patterns, but also that such goal inferences play an influential role in the way that action information is organized in the memory of adults.

Interestingly, memory organization that emphasizes goal structure implies the use of cognitive resources to infer and encode goals, which seems to require significant processing in comparison to organization that emphasizes temporal structure. Organization with respect to temporal relations comes for "free": participants only need to store the information according to the order in which they receive it. Organization via

goal structure requires making an inference about the actor's goals and intentions, and –
at least for the stimuli used in these experiments – also requires some form of
reorganization in memory. What is more, these results suggest that adult participants
expend this additional cognitive effort to achieve goal organization spontaneously,
without explicit instruction to do so. At this point I can only speculate as to why this
process occurs spontaneously. These findings are reminiscent of research demonstrating
that attending to meaning during encoding promotes subsequent recall (Craik & Tulving,
1975; Elias & Perfetti, 1973). Thus one possibility is that goal-related information is
advantaged over temporal information simply for reasons of meaningfulness more
generally. Another possibility, however, is that this organizational tendency might be
especially beneficial, cognitively speaking, when disfluencies occur within the motion
stream – that is, when goal-related action is interrupted by incidental behavior or action
that serves unrelated goals. The frequency with which such disfluency occurs in everyday
action is unknown, but it seems likely to be common. Thus, later recall of such action
may be improved with goal organization.

Although some of the conceptual inspiration for this research came from prior
work on memory for text, these results do not simply reflect the identical priming effects
that have been reported in the text processing literature. First, the results of Experiment 3
suggest that language is not the medium by which goal information is extracted from the
action scenarios. Second, the current task differed in a number of ways from the research
of McKoon and Ratcliff (1980). For one, the verification task was visual as opposed to
linguistic. Relatedly, in the test phase of McKoon and Ratcliff's study, participants were

verifying whether the ideas expressed in propositions were true or false given the text they had previously read, but none of the propositions were word-for-word veridical sentences that were read in the original text. Thus, it is possible that McKoon and Ratcliff's test biased participants toward a meaning-based strategy in their recognition of the text material. In these experiments participants were all tested with images that they actually had seen in the videos they had just watched. It is thus striking that goal primes facilitated target frame recognition relative to temporal primes, given that the temporal primes indeed occurred in closer proximity to target frames in participants' prior perceptual experience.

Language and Action

While acknowledging the differences just discussed, at the same time the results with adults are strikingly similar to the findings of McKoon and Ratcliff (1980) on memory for text, from which I adapted my basic research methodology. In both domains, memory for complex information is organized in a fashion which differs from how it was originally structured. It is important to note, however, that the analogy is not perfect. The meaning hierarchy that McKoon and Ratcliff proposed for memory for text is not a partonomic hierarchy, as seems to be the case for action processing (Zacks, Tversky, et al., 2001). Moreover, the propositions contained in the passages McKoon and Ratcliff used were likely more complex in their arguments and connectedness than the semantic information extracted from the action sequences in the present research. Nonetheless, the present findings point to intriguing commonalities in the encoding of meaningful

structure across language and action. The extent to which such commonalities arise as a direct result of domain general mechanisms guiding processing across domains will be an interesting topic for future research.

Although memory for language and action seem to share important commonalities, these findings also indicate that the process of goal organization in memory need not be mediated by language. When adult participants were required to shadow speech while watching the videos, their memory for action nonetheless emphasized goal structure. The resulting memory is likely some kind of semantic representation, but a form of semantic representation that is non-linguistic. It is yet unknown how this process is achieved, which is yet another issue ripe for investigation.

Temporal Information

Again, it should be emphasized that these findings in no way point to temporal information being left out of adult's memory representations of action. These results clarify that adult memory for action emphasizes goal relations relative to temporal relations, at least for action sequences like those that were sampled. Information about the veridical sequential structure of the events could well be stored, but simply not as strongly. In fact, recent research on statistical learning of action sequences suggests that observers exploit sequential temporal information for the purposes of discovering higher-level units within continuous novel action that they can already segment at a small-scale level (e.g., Baldwin et al., 2008; Swallow & Zacks, 2008). Thus, for the purposes of segmentation, processing temporal information is key. Temporal relations among actions could also potentially be a cue to goal inference. For example, if you observe someone

sniff the contents of a cup and then take a sip from it, you might assume they found the contents agreeable and took a drink. However, if they took a sip from the cup and then sniffed the contents afterward, you might assume they found the contents disagreeable and may not drink it again.

Indeed, temporal information may play a relatively important role in memory when action is strikingly novel, even for adults. In the present research, extracting the goal structure was likely relatively easy, as the videos depicted goals that adult participants were, on the whole, very familiar with. However, when extracting goal information is difficult, as may be the case when action is quite novel, people may register temporal information more heavily and emphasize it in the organization of action memory. In such cases, temporal information may become more prominent in online processing, and consequently gain ascendance in memory organization.

While novelty may challenge the action processing system and alter processing and/or memory tendencies, individual differences might also play a role in the organization of action information in memory. For instance, individuals with autism, who have been shown to have difficulty inferring the mental states of others (Baron-Cohen, 1995; Gernsbacher, Stevensen, Khandaka, & Goldsmith, 2008), may have difficulty extracting the goals from action and organizing their memory with respect to such goals. Their action memory may emphasize temporal relations to a higher degree than normal individuals. In a similar vein, individuals with schizophrenia may also emphasize temporal relations, as their ability to detect intentions in theory of mind tasks has been shown to be disrupted (Frith & Corcoran, 1996).

Broader Implications

While the results of the present experiments have direct implications for the field of action processing and event cognition, they also have implications for a variety of other domains.

Recall that participants in these studies viewed videos in which actions related to different goals were intermingled in the actual motion stream. Their reaction times to verify target still frames revealed that they had gleaned a goal structure that abstracted beyond the temporal flow of events. Accounting for human action processing will thus need to include a characterization of the mechanisms by which such inferential redescription occurs. This is one criterion by which to evaluate the success of theoretical accounts and computational models of human action processing (Flieschman et al., 2006). Interestingly, one influential account of a mechanism enabling people to extract intentions and goals from others' action – the Motor Cognition Hypothesis (MCH), which points to the involvement of the mirror neuron system (Gallese, Rochat, Cossu, & Sinigaglia, 2009) – falls short of explaining such redescription. The crux of the MCH is that mirror neurons directly represent the abstract intention of all simple motor behaviors that observers can execute themselves, which is thought to result in direct understanding of action events without requiring sophisticated metarepresentational capabilities such as inferences about mental states. On this account, intentions are apprehended directly from the flow of behavior as small actions sequentially unfold across time. Yet the current findings clarify that observers achieve, and encode, an analysis of the goal structure that

goes beyond direct apprehension of small-scale action intentions from the surface flow of motion. At present, the MCH provides no way of accounting for this higher-level analysis of goal structure.

Another perspective on the present research is that it showcases a new methodology for indexing inferences about intentions and goals that observers have made upon viewing dynamic action. Such a methodology is potentially valuable for exploring the presence of intentional inferences. This possibility is of particular interest in relation to populations such as infants and non-human primates, as there is debate regarding whether, and when, genuine intentional inferences are executed (Gergely, Nádasdy, Csibra, & Bíró, 1995; Povinelli, 2001; Tomasello, Call, & Hare, 2003; Woodward et al., 2001). Interestingly, infants and non-human primates unable to infer goal structure might display better memory for surface temporal properties of action than those who are able to achieve the higher-level analysis of goal structure. A shift in priming patterns away from surface temporal advantage to goal-structure advantage would thus provide an additional index complementing existing techniques for probing such understanding in these populations.

Results with Children

The results of Experiment 4 with children were not as clear cut as the set of results with adults. When looking at the overall priming patterns, children's mean reaction times to target detection in the two priming conditions were in the same direction

as adults. However, because of the large variability in children's reaction times, this difference was not statistically significant, and thus the directionality of this difference cannot be relied upon as systematic. More critical to the predictions of Experiment 4 were children's reaction times to unfamiliar and familiar videos in the two priming conditions. Variability again overshadowed mean differences in this analysis, and similarly no significant differences in priming patterns between the two levels of familiarity were found.

The remaining discussion is split into three sections. The first two will focus on two potential reasons children may have failed to show any reaction time differences in this task, namely 1) that young children do not yet have any organizational preference in memory for human action, and 2) that the task used was problematic. I will then discuss the role of familiarity in children's memory organization.

The Lack of an Organizational Preference in Young Children

Recall that the main hypothesis for the experiment with children was that familiarity would increase the degree of goal organization in memory. Note that this hypothesis is not specific to children. It is entirely possible that familiarity with the activities that comprise the achievement of a goal could influence memory organization at any age. Children were assessed in order to test the effect of familiarity simply because they are less familiar with activities in comparison with adults. Using children allowed me to generate a set of video stimuli that I could be reasonably assured adults would be familiar with, but that would vary in familiarity for children. If familiarity with the activities modulates children's response times to detecting the target, then analyzing

responses based solely upon goal versus temporal priming could lead to a null result. According to this view, children may at times organize primarily according to inferred goals, but at other times organize primarily according to temporal structure, and it is children's relative familiarity with the activities that can, at least in part, explain this variation. Since I designed the videos in order for there to be differences in the relative familiarity to children of the activities depicted, I effectively reduced the number of videos that could demonstrate an overall effect of goal over temporal priming. Thus, this aspect of the design may have reduced power for observing any overall organizational differences in young children.

Assuming, however, that familiarity does not contribute to children's memory organization, a second possibility is that the overall null results for goal and temporal priming indicates a genuine difference between adults and young children in the organization of action memory. Although somewhat puzzling, it is possible that young children do not yet organize memory preferentially according to goals, as adults appear to. I say puzzling because there is now a great deal of research suggesting that many aspects of action and goal understanding are present very early in infancy (Baldwin et al., 2001; Gergely et al., 1995; Sommerville & Woodward, 2005; Woodward, 2009). This body of developmental research suggests a great deal of continuity in the action processing system from infancy to adulthood. Thus, to some extent the possibility that young children differ from adults in their action memory organization would be surprising, given the early emergence of many action processing skills. However, the issue of how memory for action is represented and organized in the mind has received a

great deal less attention to date. In particular, this dissertation reports the first research that specifically addresses how action memory is organized for sequences of action in which goal and temporal information do not coincide perfectly. Thus, the difference between adults and young children may in fact be the result of a relatively late-emerging component of the action processing system.

An intriguing possibility is that these results may be showcasing some kind of organizational equivalence in young children's memory representations of human action. This organizational equivalence could be due to the fact that children do not yet organize *primarily* according to one type of information over the other. According to this view, children extract goal information and temporal structure, and both types of information influence the organization of the memory structure to such a degree that neither type is primary over the other. Thus, in this experiment, goal information would have primed the target just as well as temporal information, and the difference that was obtained in reaction time according to the two prime types was simply an estimate of zero difference.

While the possibility that young children differ in their memory organization from adults is intriguing, it is impossible to argue from a single set of null results. If further research confirms that the type of prime has no effect on children's response times and that familiarity does not interact with the type of prime on children's response times, then this would provide support for the hypothesis that children genuinely differ from adults in their memory organization for human action.

Problems with the Methodology

Even if further research can replicate these null results, there would remain the possibility that the priming methodology itself is deficient in accurately revealing young children's memory organization. According to this view, these results simply reflect a failure to find a significant difference in children that was found with adults.

There are at least two ways in which the task itself may have been problematic. First, it may simply be that reaction times are too variable in 6-year-old children, and thus reaction time was not an ideal choice for the main dependent measure with this age group. To be sure, some researchers have successfully utilized reaction time as a dependent measure to explore cognitive processing in young children. Estes (1998), for instance, has shown differences in reaction time in mental rotation tasks with 5-year-old children (see also Kosslyn, Margolis, Barrett, & Goldknopf, 1990). Although children's reaction times are much slower than adults, studies like these indicate that systematic variation in response times do exist for certain types of cognitive processing. However, the effects Estes showed for mental rotation in 5-year-olds were on the order of one second. Recall that the priming effect in adults observed in Experiments 1 and 3, while statistically reliable, was nonetheless small. Children may indeed organize memory for action according to goal or temporal information, but the small reaction time difference that would provide evidence of organizational preferences from priming patterns would be washed out amidst their highly variable reaction times.

The second problem with the task is the large attentional demand it placed on children. Although children enjoyed the task generally, they may not have been as

attentive as adults while watching the videos. Children appeared to enjoy the overall structure of the task, and almost all children seemed to really enjoy the test phases; some children even verbally volunteered their liking of that phase of the experiment. However, for all of the children it was at times difficult to maintain attention on the videos during the study phase. Some children would talk through the videos, while others would simply let their eyes wander around the room. Although the experimenters vigilantly monitored children's attention to the screen during the study phases, and consistently brought children's attention back to the screen if it wandered, the attentional demands of the task were high, and may have been too high for children at this age. This may have had a great impact on their memory for the studies.

Indeed, children's overall accuracy was significantly lower than adults' in Experiment 1. Children had more trouble correctly identifying true still frames and correctly rejecting false still frames, which led to a decrease in the number of correctly identified targets. Recall that in the experiments with adults I set a strict criterion that 75% of the targets be correctly identified in order for a participant's data to be included. Because the data with children was not held to this criterion, this may have had a negative impact on the reliability of the mean reaction time estimates.

The Role of Familiarity

Although I predicted that familiarity would increase the likelihood that memory for action would be organized according to goals, the interaction between familiarity and the type of prime was not significant, and the mean differences according to familiarity were actually opposite to predictions. As I have already discussed, there are a number of

reasons why this null effect does not necessarily imply a lack of association between familiarity and memory organization. For one, the methodological problems outlined in the previous section also apply to this analysis as well: children's variable reaction times may have clouded any small differences. Furthermore, inattention to the videos may have decreased children's memory, and this may have introduced error into the data.

It may also be that the familiarity contrast somehow missed the mark. Perhaps the parent report measure I designed – the Activity Survey – was not valid, and thus was not sensitive enough to children's actual familiarity levels with the activities in the videos. A careful examination of this possibility would require correlating the Activity Survey with some other measure of children's familiarity levels. In some ways, however, the present dissertation has already done this. Recall that children were less accurate at correctly identifying the target for unfamiliar videos than for familiar videos. Thus, at least at a very global level, the results of the Activity Survey do correlate with children's memory abilities.

Nonetheless the contrast may not have been as sharp as it could have been. Although I split videos into those that were highly familiar and those that were less familiar, the majority of children were familiar with the nature of the activities to some extent (at least in terms of the overall purpose of many of the activities). Especially since all videos were split into familiar or unfamiliar, there was a high degree of similarity in familiarity scores from videos at the bottom end of the familiar group and the top half of the unfamiliar group. One possible analysis that would have alleviated this concern to some extent would have been to create a group of the top five familiar and the bottom

five unfamiliar videos, and so removing videos the six videos that were of 'medium' familiarity. However, this analysis was not possible with the current sample, as mean reaction time estimates would, in many cases, have been based on too few reaction times. In order to avoid this issue in a future study, ideally one would create videos that would be novel for all children, and compare memory organization for those videos to videos that are highly familiar to the majority of children.

While I can conclude very little about the role of familiarity in action memory organization from the results with children, speculating about possible differences according to the pattern of findings may be relevant to future research in this domain. In particular, I believe the fact that unfamiliar videos showed a mean advantage for goal priming over temporal priming is potentially of interest. One speculation is that when young children view unfamiliar activities, their inferential system may actually be hard at work attempting to infer the goals of the actor from his or her behavior. The activation of the inferential system while inferring goals for relatively unfamiliar activities may be increased relative to the activation required to infer goals for familiar activities. This increased activation may help to promote goals in memory, and thus goal information is more readily available to serve as the primary means of organization in the memory trace for relatively unfamiliar activities. Perhaps the familiar videos used in this experiment were too familiar to children, and strong goal organization only occurs in young children when goal inferences require more cognitive processing.

In any case, the key difference between the organization of memory for familiar activities and unfamiliar activities may have been modulated by some difference in the

amount of cognitive processing that children were engaging in while watching the videos. Children may have been paying attention more globally to the unfamiliar videos, or engaging more heavily in inferential processes for unfamiliar videos because they were at the right level of unfamiliarity. Unfortunately, this dissertation cannot address the veracity of these speculations. At this phase I am offering what is simply speculation based on a set of null results. Future research can explore what actually influences young children's action memory organization.

Limitations and Future Directions

This dissertation has uncovered a heretofore unknown property of action processing: at least in adults, action memory appears to be structured according to inferred goals, and is even reorganized to conform to inferred goals when the goal structure of the action sequence does not map perfectly on to the temporal flow of observed events. This discovery, however, is only the tip of the iceberg in understanding the cognitive system that processes other people's behavior and generates memory representations of human action events.

One limitation of the current research was the use of familiar activities. When familiar activities with familiar objects are used, there exists a risk that any effects of goal priming could be due to similarities between the goal prime and the target in the objects used, or could be the result of pre-existing associations in memory for the actions involved in the activities. I anticipated this result, and took several measures to alleviate

this concern: 1) I collected data on the subjective similarity between primes and targets, and investigated possible relations between those similarity ratings and the effect of goal priming in Experiments 1 and 3, 2) I collected data on the objective perceptual similarity between primes and targets, and explored possible relations between those similarity ratings and the effect of goal priming in Experiments 1 and 3, and 3) I ran a control experiment (Experiment 2) in which the effect of goal priming was observed when participants viewed frames that had been extracted from the action videos but in random order during the familiarization phase (yielding exposure to the test frames without coherent structure). Findings that emerged from all three of these countermeasures pointed to the same conclusion, suggesting that the effect of goal priming was the result of newly created associations in memory for the action events, and was not due to similarity or pre-existing memory associations.

Nonetheless, one could still dispute the adequacy of these countermeasures for laying this concern to rest. Since goal primes were rated as subjectively more similar to targets compared to temporal primes, one could argue that the effect of similarity still exerted influence over the reaction time data in a more global fashion, without necessarily being revealed in a correlational analysis across items. In addition, one could argue that the results of the control experiment were simply a result of a Type II error. Since the direction of the means in that experiment showed that targets were identified more quickly if primed by a goal prime, it could be that the effect really was there, and was simply not observed due to statistical variation in the size of the mean difference. After all, the goal priming effect observed in Experiments 1 and 3 was also small.

In order to alleviate these concerns completely, one would need to create action events that were novel in some way. This could be achieved by filming events involving novel objects with novel functions, or by filming events in which familiar objects are used in novel ways. In the former case, the events would have no basis for previous memory associations, and one could more carefully design the objects and events such that perceptual similarity was reduced between the goal primes and the targets. In the latter case, previous memory associations could not be a systematic confound, as the way in which the objects and events manifested in the videos would differ from previous associations. Designing a study that utilizes one of these two principles will be an important direction for future research in this domain, in order to be certain that the observed goal priming effect in adults is due solely to the organization of newly formed action memories.

Another direction for future research in this domain is the degree to which goal and temporal information are maintained in memory over time. In the text processing literature, it has been shown that memory for the surface features of text decays over time while memory for the meaning of propositions in the text does not show this same decay (Fillenbaum, 1966; Sachs, 1967). Depending on the degree of similarity in memory processing between text and action, there might be a similar process of surface decay over time. Temporal information in action is one form of surface memory, and thus one might expect the advantage of goal priming relative to temporal priming to increase over time. This would be a relatively easy study to carry out, as one would only need to

introduce a delay between study and test for one group of participants, and compare these findings to the results from a separate group who had no delay between study and test, as was done in the experiments described.

With children, the direction of future research should be focused on determining whether or not this effect of goal organization over temporal organization can be observed. The first three experiments of this dissertation identified this principle of action memory organization in adults, so it must emerge at some point in development.

Since it is unclear whether priming effects in reaction time can even be observed in young children, designing a task that does not involve reaction times as the main dependent measure would be ideal. One possibility – that would require the same type of video stimuli used in the current research – would be to design a task in which children explicitly judge the order of events in the action sequences. For example, children could be shown a target event, and then shown two other action events, one that is from the same goal as the target but occurred farther away in time (goal event), and another that is from a different goal that occurred closer in time to the target (temporal event). Children could be asked to judge which event occurred before/after the target event. If children organize action according to inferred goals, then they may be more likely to incorrectly judge that the goal event occurred closer in time to the target instead of the temporal event. It is possible that in a context such as this, the effects of goal organization could be observed in young children.

The future directions previously outlined with adults could also apply to future research with children. Since the effect of familiarity on memory organization is as yet

unclear from the results of this dissertation, comparing children's memory organization for familiar versus novel actions could be of great interest. Introducing a delay between study and test for children could also be valuable, as one could compare whether children differ in the degree to which goal and temporal information is maintained in memory over time, compared with adults.

Conclusion

This dissertation deepens our understanding of action processing. Organization in memory for action in adults emphasizes the goal structure that is extracted from the action events, and this is undertaken spontaneously, without explicit instruction, and without mediation from language. Young children did not reveal any tendency to organize action memory according to goal or temporal structure, whether the videos were highly familiar or relatively less familiar. Thus, the organization of action memory in young children and the process by which children's memory for action transforms into the mature adult memory system remain topics for future research. Nonetheless, this dissertation has uncovered a heretofore unknown aspect of the cognitive system that processes action, and opens the door to future research on action memory and its development.

APPENDIX A

DETAILED DESCRIPTIONS OF THE VIDEO STIMULI

1. **Coloring and blocks**
   Setting: In a room with a small desk
   Actor gender: Female
   Events:
   - Open block container
   - Take out some blocks
   - Close lid of box and push aside
   - Attach blocks together   **Target 1**
   - Move block figure aside
   - Get sheet of paper from the shelf   **Temporal prime 1**
   - Grab crayon box from shelf   Goal prime 2
   - Get out crayon A from box
   - Draw with crayon A on paper
   - Put crayon down
   - Move paper aside
   - Get block figure
   - Get more blocks out of container   **Goal prime 1**
   - Attach more blocks on to figure   Temporal prime 2
   - Move container and figure aside
   - Put back crayon A
   - Get out crayon B
   - Draw with crayon on paper B   Target 2

2. Cooking and cleaning

Setting: In a kitchen
Actor gender: Male
Events:

- Grab colander		
- Open cupboard A		
- Put colander in cupboard A		
- Grab vinegar		
- Put vinegar in cupboard A	**Target 1**	
- Grab bag of bread		
- Take out two slices of bread		Goal prime 2
- Open mustard container	**Temporal prime 1**	
- Grab butter knife		
- Get mustard out with knife		
- Spread mustard on bread with knife		
- Close cupboard A		
- Grab rice		
- Open cupboard B		
- Put rice in cupboard B	**Goal prime 1**	
- Grab flour		
- Put flour in cupboard B		
- Close cupboard B		Temporal prime 2
- Grab sliced cheese		
- Unwrap sliced cheese		Target 2
- Put cheese slices on sandwich		
- Grab slice of meat		
- Put meat on sandwich		
- Put sandwich together		

3. Combing and teeth

<u>Setting</u>: In a bathroom
<u>Actor gender</u>: Female
<u>Events</u>:
- Open cabinet
- Grab toothpaste
- Close cabinet
- Unscrew toothpaste cap   **Target 1**
- Put toothpaste down
- Grab comb   **Temporal prime 1**
- Comb hair   <u>Goal prime 2</u>
- Put comb down
- Grab toothpaste
- Grab toothbrush
- Turn away from sink
- Put toothpaste on brush   **Goal prime 1**
- Put toothpaste down   <u>Temporal prime 2</u>
- Put toothbrush in mouth
- Open cupboard
- Grab hair elastic   <u>Target 2</u>
- Close cupboard
- Put hair in ponytail
- Brush teeth

4. **Computer and cleaning**
   <u>Setting</u>: In a home office
   <u>Actor gender</u>: Male
   <u>Events</u>:
   - Grab and stack paper
   - Put papers on floor
   - Open desk drawer
   - Grab calculator
   - Put calculator in drawer
   - Close desk drawer   **Target 1**
   - Unzip backpack   **Temporal prime 1**
   - Pull computer out of backpack
   - Place on computer stand   <u>Goal prime 2</u>
   - Grab pens
   - Put pen into pen holder
   - Grab glass and bowl   **Goal prime 1**
   - Move glass and bowl to one side of desk
   - Wipe table with hand   <u>Temporal prime 2</u>
   - Get out and unwrap power cord   <u>Target 2</u>
   - Plug in power cord to computer
   - Plug in power cord to power outlet
   - Plug in cables to computer
   - Open up laptop

5. Filing and microwave
Setting: In an office with a filing cabinet
Actor gender: Female
Events:
- Grab and stack papers
- Open drawer of filing cabinet
- Take folder 1 out of drawer
- Open folder and place on desk
- Put papers into folder 1   **Target 1**
- Close folder 1 and move aside
- Grab plastic bag   **Temporal prime 1**
- Get box of food out of bag
- Open box of food   Goal prime 2
- Remove food package
- Place food package near microwave
- Grab folder 1
- Put folder 1 back in drawer
- Get folder 2 out of drawer   **Goal prime 1**
- Open folder 2
- Grab and stack more papers
- Put papers in folder 2   Temporal prime 2
- Close folder 2
- Open microwave door   Target 2
- Put food package into microwave
- Close microwave door
- Press buttons on microwave

6. **Food and cooking**
   Setting: In a kitchen
   Actor gender: Male
   Events:
   - Open fridge
   - Grab pasta sauce
   - Put pasta sauce on counter
   - Grab cheese
   - Put cheese on counter   **Target 1**
   - Close fridge
   - Open cabinet A
   - Get out pot and close cabinet A   **Temporal prime 1**
   - Fill pot with water
   - Place pot on stove   Goal prime 2
   - Turn on stove
   - Open fridge
   - Grab juice
   - Put juice on counter
   - Grab salad dressing
   - Inspect label of salad dressing   **Goal prime 1**
   - Put salad dressing on counter
   - Close fridge   Temporal prime 2
   - Open cabinet B
   - Get noodle container out and close cabinet B   Target 2
   - Open lid to noodle container
   - Put noodles into pot
   - Close lid to noodle container and put on counter
   - Grab spoon
   - Stir contents of pot

7. Frying and calling

<u>Setting</u>: In a kitchen

<u>Actor gender</u>: Female

<u>Events</u>:

- Open cabinet
- Get out frying pan from cabinet
- Place frying pan on counter
- Open fridge
- Grab egg container   **Target 1**
- Place egg container on counter
- Open drawer
- Get phone book out of drawer   **Temporal prime 1**
- Place phone book on table
- Open phone book
- Look up number
- Pick up phone   <u>Goal prime 2</u>
- Dial number and listen
- Hang up phone and put down
- Get out egg from container
- Put pan on stove   **Goal prime 1**
- Crack egg on pan
- Empty egg into pan   <u>Temporal prime 2</u>
- Place egg shell in container
- Look up number again   <u>Target 2</u>
- Dial number and listen again

8. Ironing and folding

<u>Setting</u>: In a living room with a laundry basket
<u>Actor gender</u>: Female
<u>Events</u>:

- Open closet door	
- Get out ironing board	
- Close closet door	
- Set up ironing board	**Target 1**
- Grab laundry basket	
- Take lid off of laundry basket	
- Pick up towel A	**Temporal prime 1**
- Fold towel A	
- Put towel A on couch	
- Pick up towel B	
- Fold towel B	
- Put towel B on top of towel A	<u>Goal prime 2</u>
- Get out shirt	
- Put shirt on ironing board	
- Open closet door	**Goal prime 1**
- Get out iron	
- Close closet door	
- Put iron on ironing board	<u>Temporal prime 2</u>
- Pick up towel C	
- Fold towel C	<u>Target 2</u>
- Put towel C on top of towel B	
- Pick up towels and walk out of room	

9. **Reading and eating**

   <u>Setting</u>: In a room with a table and bookshelves
   <u>Actor gender</u>: Female
   <u>Events</u>:
   - Scan bookshelf
   - Select book
   - Put book on table   **Target 1**
   - Pull out chair
   - Sit down in chair
   - Open plastic bag
   - Get banana bunch out of bag   **Temporal prime 1**
   - Take banana from bunch
   - Put banana bunch back in bag   <u>Goal prime 2</u>
   - Peel part of banana
   - Open book and place on knee
   - Flip through pages   **Goal prime 1**
   - Put book back on table
   - Read pages from book   <u>Temporal prime 2</u>
   - Take bite from banana
   - Peel banana again   <u>Target 2</u>
   - Take second bite from banana
   - Look around room
   - Take third bite from banana

10. Running and books

Setting: In a room with a bookshelf
Actor gender: Female
Events:
- Grab shoes
- Untie shoes
- Put shoes down on floor   **Target 1**
- Pick up book A   **Temporal prime 1**
- Take book A to shelf
- Shelve book A   Goal prime 2
- Sit down on chair
- Pick up shoe 1
- Put on shoe 1   **Goal prime 1**
- Tie shoe 1
- Pick up shoe 2
- Put on shoe 2
- Tie shoe 2   Temporal prime 2
- Pick up books B and C   Target 2
- Take books to shelf
- Shelve books B and C

11. Socks and toys

Setting: In a room with a dollhouse
Actor gender: Male
Events:
- Grab doll box
- Take off lid of doll box
- Get out doll A
- Get out doll B
- Put doll box on shelf
- Grab lid
- Put lid on doll box
- Sit on couch
- Grab folded socks
- Unfold socks
- Put socks down
- Open doll box again
- Get out doll C
- Put back doll B
- Put lid back on doll box
- Grab dolls
- Put dolls in dollhouse
- Grab socks
- Put on sock 1
- Grab sock 2
- Put on sock 2

Target 1

Temporal prime 1
      Goal prime 2

Goal prime 1

      Temporal prime 2
      Target 2

12. Sweeping and dishes

Setting: In a kitchen
Actor gender: Male
Events:
- Open closet door
- Get broom
- Close closet door
- Sweep floor   **Target 1**
- Lay broom against counter
- Get cutlery   **Temporal prime 1**
- Open drawer
- Put cutlery into drawer   Goal prime 2
- Close drawer
- Open closet door   **Goal prime 1**
- Grab dustpan
- Close door
- Sweep dirt into dustpan
- Open garbage cabinet door
- Throw away dirt into garbage   Temporal prime 2
- Close garbage cabinet door
- Attach dustpan to broom and lean against door
- Open cupboard   Target 2
- Get cups
- Put cups into cupboard
- Close cupboard

13. Tea and recipes

<u>Setting</u>: In a kitchen with a bookshelf

<u>Actor gender</u>: Male

<u>Events</u>:

- Grab kettle
- Place kettle on burner
- Open cupboard
- Get out tea cup   **Target 1**
- Close cupboard
- Grab recipe book   **Temporal prime 1**
- Open book
- Place book on counter
- Flip to a page
- Scan page   <u>Goal prime 2</u>
- Turn on burner   **Goal prime 1**
- Open cupboard
- Get tea packet from cupboard
- Close cupboard
- Open tea packet
- Put tea bag into tea cup   <u>Temporal prime 2</u>
- Pick up book
- Flip to new page   <u>Target 2</u>
- Read new page

14. Train and toys

Setting: In a room with a toy cabinet
Actor gender: Female
Events:
- Pick up toy box
- Open cupboard A
- Put toy box in cupboard A
- Close cupboard A
- Pick up toy car and puppet
- Open cupboard B
- Put toy car and puppet in cupboard B **Target 1**
- Close cupboard B
- Get train set box **Temporal prime 1**
- Get train tracks out of box
- Set up train tracks on floor Goal prime 2
- Put blocks in box **Goal prime 1**
- Put block box on top of cupboard Temporal prime 2
- Get out trains from train set box
- Put trains on to train tracks Target 2
- Set up more tracks on floor
- Push trains along track

15. Video game and drink

Setting: In a living room with a TV cabinet
Actor gender: Male
Events:
- Get video game system
- Put game system on floor
- Open cabinet
- Get out game controller
- Close cabinet
- Plug controller into game system
- Get game box   **Target 1**
- Put game box on floor
- Grab soda can   **Temporal prime 1**
- Grab glass   Goal prime 2
- Put glass on floor
- Open soda can
- Open game box
- Take out disc
- Put in disc in game system   **Goal prime 1**
- Close game box
- Put away game box   Temporal prime 2
- Pour soda into glass   Target 2
- Put can down
- Take sip of drink

16. Windows and trunk

Setting: In a driveway with a parked car
Actor gender: Male
Events:
- Get spray bottle and rag
- Open driver side door
- Spray inside window
- Wipe inside window
- Spray outside window
- Wipe outside window
- Close driver side door
- Put bottle and rag on roof of car   **Target 1**
- Open trunk   **Temporal prime 1**
- Shuffle items in trunk
- Grab bag A
- Put bag A in trunk   Goal prime 2
- Open rear side door
- Grab bottle and rag from roof
- Spray inside window   **Goal prime 1**
- Wipe inside window
- Spray outside window
- Wipe outside window   Temporal prime 2
- Put rag and bottle on roof
- Grab bag B and bag C   Target 2
- Close rear side door
- Shuffle items in trunk
- Put in bag B
- Put in bag C
- Close trunk

APPENDIX B

ACTIVITY SURVEY

Activity Survey

We are interested in finding out how much your child knows about different activities. A very short description of an activity will be provided and a number of questions about that activity will follow. Please answer the questions using the scales as well as with written comments. Please do not feel obligated to comment using the written portions if there is no clarification needed.

The first question for each activity asks how well you think your child understands the steps involved in this activity. This question is not directly asking about your child's understanding of the purpose of the activity – e.g., that containers are for storage, or that microwaves heat up food. A child could know the purpose behind the activity but still not know the steps involved in carrying out that activity. Please do your best to just indicate your child's understanding of the steps involved in the activity.

If you have questions or need clarification about a particular activity, please note the page, and then move on to another question. The researcher will be happy to provide help on that question once you have completed the rest of the survey. Our goal is to help you provide the best information you can about your child's level of understanding about these activities.

Thank you for filling out this survey!

1. Using crayons to draw a picture

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

2. Building something with duplos/legos

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

3. Getting toys out of a container to play with

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

4. Unfolding and putting on socks

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

5. Brushing teeth (from getting the toothbrush to brushing)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

6. Combing/brushing hair and putting it in a ponytail

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

7. Peeling and eating a banana

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

8. Getting a book from the bookshelf and reading/looking at it

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

9. Setting up toy train tracks and playing with a train on them

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

10. Cleaning up toys (putting them in containers and putting containers on shelf/in cupboard)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

11. Playing a video game (getting out a video game and system, and setting up game and controllers)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

12. Opening up a canned drink, pouring it into a cup, and drinking it

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

13. Cooking pasta (or something similar that requires boiling water)
    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

14. Getting food out of the fridge
    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

15. Cleaning up the kitchen (putting food and utensils into cupboards/drawers)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

16. Making a sandwich

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

17. Putting on and tying up shoes

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

18. Putting books away on a bookshelf

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

19. Heating food in a microwave

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

20. Putting papers in a folder and filing them in a filing cabinet

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

21. Ironing clothes (setting up the ironing board and ironing a shirt)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

22. Folding laundry

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

23. Sweeping the floor

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

24. Putting away dishes (from a dish strainer to the cupboard)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

25. Making tea (putting a kettle on and putting a tea bag in a cup)

   a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all				understands all steps very well		

Please specify what aspects of this activity you think your child understands:

_____

   b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

   c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

26. Using a frying pan to fry eggs

   a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all				understands all steps very well		

Please specify what aspects of this activity you think your child understands:

_____

   b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

   c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

27. Getting out the phonebook and making a phone call

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

28. Tidying up a desk (clearing off junk and putting things in drawers)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

29. Setting up a laptop computer (opening it up and plugging in cords)

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

30. Cleaning car windows

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all						understands all steps very well

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

31. Packing luggage in a car trunk

    a. How much do you think your child understands the steps involved in this activity?

1	2	3	4	5	6	7
does not understand at all					understands all steps very well	

Please specify what aspects of this activity you think your child understands:

_____

    b. How often does your child see you or someone else do this activity?

1	2	3	4	5
has never seen	has seen once or twice	sees it every now and then	sees it nearly every week	sees it nearly every day

Please comment about this if you feel you need to clarify:

_____

    c. Does your child ever do this activity? If they do this with your or someone else's help, please specify. Also specify how often they do this activity.

_____

APPENDIX C

SCRIPT USED WITH CHILDREN IN EXPERIMENT 4

Introduction

- Introduce animals:
    - o "This is Busy Beaver, Diggity Dog, Tiny Turtle and Funky Monkey. They all heard you were coming in to play today, and are really excited to play the Movie Game with you. Do you want to play the game with them?"
- Introduce sticker sheet:
    - o "OK, so we'll play the game with each of them one at a time. And here is your sticker sheet! Each time you play the movie game with one of them, they'll give you a sticker for your sticker sheet. When you have filled up all 4 stickers on your sheet, you'll get the prize. And do you know what the prize is? 10 dollars for the toy store!"
- Familiarize children with answer box:
    - o "OK, this is the answer box. This GREEN button is the YES button, and this RED button is the NO button. We're going to use the answer box in our game, but first we need to practice using it. I'm going to ask you some questions, and I want you to answer them using the answer box. You press the green button for YES, and the red button for NO. Are you ready?"
    - o Questions: "Do fish swim?" (YES), "Do dogs meow?" (NO), "Do you wear socks on your ears?" (NO), "Do you wear shoes on your feet?" (YES)
    - o "OK! Now let's practice using the screen. I'm going to show you some pictures up on the screen, and I just want you to try to remember them."
    - o <do practice study phase with animal pictures>
    - o "Now for the memory game. Some pictures are going to show up on the screen, and some are going to be pictures you just saw, and some are going to be pictures you didn't see. If it's a picture you saw, you press the green button for YES. If it's a picture you didn't see, you press the red button for NO. OK?"
    - o <do practice test trial>
    - o "OK, are you ready to play? Who do you want to play with first?"

Structure of each block (four total)

- Introduce the study phase:
  - o "[Animal] wants to play the Movie Game with you. [Animal] has four movies of his friends that he wants to show you. After you watch each movie, we'll check the box here to say we've watched it. After we watch all of the movies, there will be a fun memory game to play using the answer box. And after the memory game, he'll give you a sticker for your sheet!"
  - o "OK - let's start with [actor]'s movie. Watch it carefully, because you'll need to remember what happened to play the memory game at the end."
  - o After watching a movie:
    - ▪ "OK! Great job! It's all done. Hey [child's name], what do you think [actor] was going to do after that?"
    - ▪ "Alright, let's check the box for that movie on your sheet."
- After all four movies in the study phase:
  - o "OK, now for the memory game. We're going to play the memory game for [actor]'s movie first. Some pictures will come up on the screen. Some of the pictures are things [actor] *did* in the movie, and some are things [actor] *didn't do* in the movie. If the picture is something she *did* in the movie, you press the green button for YES. If it's something she *didn't do*, press the red button for NO. OK? Are you ready to play?"
  - o After first test (and remind as necessary after later tests):
    - ▪ "Good job! Now we'll play the memory game for [actor]'s movie. Remember, press the green button if it's something [actor] did do, and the red button if it's something [actor] didn't do. OK, you ready?"
  - o After all four tests:
    - ▪ "OK! You did *so good*! You got through all of the movies! For helping him play, [animal] wants to give you a sticker. Let's bring your sheet over to the sticker table to get a sticker."
    - ▪ "Now another friend wants to play the movie game with you. Who do you want to play with next?"

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