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The development of objective time: The integration of logical and cultural conceptual systems

Carbery, Maureen, Ph.D.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

THE DEVELOPMENT OF OBJECTIVE TIME:
THE INTEGRATION OF LOGICAL AND CULTURAL CONCEPTUAL SYSTEMS

by

MAUREEN CARBERY

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Katherine Nelson — Chair of Examining Committee

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Herbert D. Saltzstein — Executive Officer

Joe Glick

David Bearison

Katherine Nelson

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

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by

Maureen Carbery

Adviser: Professor Katherine Nelson

Objective duration, a "unique and homogenous time scale" has been considered within a system of Newtonian relationships: a Piagetian construction achieved through the integrations of concrete operational logic. But objective duration is also a cultural construction: a conventional reference system created through socio-historical patterns of cultural evolution. Cultural duration can be represented, functionally defined, and developmentally mediated by psychological tools, such as clocks. Psychological tools extend social interaction in concept development beyond the interpersonal to the sociocultural level. The impact of a psychological tool of a clock on the demonstration of a concept of objective duration was investigated in an extension of the standard duration comparison paradigm. The judgement and justification of relative duration by 5-, 6- and 7-year-old children was compared with the clock and without the clock across 3 types of duration tasksets: successive, activity and linear. The results indicated that overall, performance with the clock significantly improved over performance without the clock across the 3 types of duration, for both the judgement and justification responses. In the successive and activity duration tasksets, there were significant differences in group performance for both categories of responses. A significant group by condition interaction in the linear duration taskset reflected a pattern of performance suggested in the other tasksets. The 5-year-old group significantly increased performance with the clock, but the 6-year-old group generally utilized the clock the most effectively. The 7-year-old group, despite initially higher performance without the clock, did not increase performance proportionately with the use of the clock. The results were discussed in terms of the functions of psychological tools, as an operationalization of cultural conceptual systems, in the development of objective duration. It was proposed that valid theories of knowledge development must integrate logical and cultural conceptual systems.

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One way to approach the study of concept development is to focus on the issues that seem fundamental to a child's experience. Imagine a child searching to organize and connect her experiences of the pattern of events, objects and people around her. Concepts of time are central to the task of discovering meaning for a child, and continue to affect the interpretation and organization of our lives as adults.

Time is not a singular concept. The first task of a time researcher is to define the phenomenon under study by categorizing temporal experience. It is recognized that fundamental decisions on the nature of the phenomenon under study often guide the work in nontrivial ways. This is even more true when the phenomenon can be approached in a number of different ways (Lakoff, 1987; Lakoff & Johnson, 1980). There are at least as many categorizations of temporal phenomenon as there are writers on the subject (Fraser, 1981; Doobs, 1971; McGrath & Kelly, 1986; Friedman, 1978), with little agreement on how to organize or define temporal experience and concepts. Nevertheless, for the purposes of this study, several distinctions have been made among aspects of temporal experience. Although the lines drawn are consistent with several philosophical and psychological approaches, they are artificially created for the purposes of study and open to reexamination.

The first division of temporal experience which will serve to organize and direct this research is a distinction between subjective and objective time. Subjective time includes the feeling of the passing of time; the perception and intuition of individual temporal experiences. Subjective duration can be contrasted with objective duration, which is logically or socially verifiable independent of individual experience. The reconciliation of subjective duration with objective duration, variously conceived, is a central topic in time theory and research.

Questions about subjective time are often concerned with the nature of time and knowledge of time: What is being perceived when we experience duration? The perception of subjective time is an elusive, unresolved issue, both psychologically and philosophically. Three major possibilities are supported within independent traditions. Subjective time may be directly perceived (Ritchie and Bickhard, 1988) encoded in changes associated with duration (Gibson, 1985; Block, 1990) or constructed in retrospect (Michon, 1990).

One paradigm for exploring the complex relationship between subjective and objective time is represented by the time estimation and measurement literature. The goal of this research is to understand how reliably duration is estimated, measured, produced, reproduced and compared under varying conditions. Many of these tasks require a translation of subjective duration into conventional units of objective duration. Zakay (1990) summarizes the literature by noting that humans do have some time keeping ability, even in the absence of cues. However, the operation of this personal clock is characterized by sloppiness and sluggishness in comparison to more objective measures of duration. Developmental issues are generally not addressed.

Within developmental psychology, subjective time is considered to be developmentally prior to a concept of objective time. Several theorists propose a general developmental trend and socialization process which transforms subjective experience into knowledge integrated with the objective knowledge of cultural and logical systems of time (James, 1891; Piaget, 1954; Miller & Johnson-Laird, 1976; Friedman, 1978). In addition, more complex alternatives have been developed (Fraisse, 1982) in which subjective processes are supplemented, but not subsumed, by the development of objective time and temporal concepts.

The second categorization of duration central to this study is a distinction between two qualitatively different meanings of objective duration, logical objective duration and cultural objective duration. Logical objective duration is a pivotal concept in the system of logical time. The logical temporal system refers to the Newtonian physical time as embodied mathematically in the scientific tradition. Logical objective time, or duration, is a unidirectional, uniform, absolute scale which is independent of our actions and subjective impressions. It is an abstract frame of reference, along which events are ordered and their durations compared and measured. In Piaget's theory of the development of temporal concepts, achieving a concept of objective duration is both the product of a system of logical temporal integration, and a necessary prerequisite for the development of more advance understandings.

The second kind of objective duration is cultural objective duration. Cultural objective time is a cultural construction, as defined by Vygotsky (1978). It is a shared reference system created through a particular socio-historical pattern of cultural evolution. This system includes units of time, such as compose the clock and calendar, linguistic expressions of time, such as tense, and temporal mediational tools, such as clocks. Cultural time varies across cultures, and its meaning is relative to observers, objects and events. In Western cultures, durative time is a unitary scale which underlies all events. This imaginary time line, given form through our linguistic systems of tense, extends into the future and the past, and events can be located along the time line (Lyons, 1977). Duration is divided into conventional units (such as years, months, days, hours, minutes) which create linguistic objects of the abstract dimension of time (Whorf, 1956). These units can then be represented and compared with the culturally appropriate tools, from stopwatches to calendars. This temporal system of culturally defined meaning is objective in the sense that it is publicly observable and an agreed-upon reference system. Cultural objective duration functions as a tool to coordinate our individual activities along an independent scale. Meeting at 2 o'clock on Thursday, Oct. 25, 1990, establishes a point in time independent of individual experience. This allows the individuals who plan to attend the meeting a way to coordinate their individual subjective time frames along a scale that has objective meaning for the participants.

In contrast to the construction of logical temporal concepts studied by Piaget, culturally specific concepts of time are relativistic social constructions. The relationships between duration and its cultural representations are arbitrary in the sense that they are not derived from and bounded by the constraints of logical or mathematical definitions. The correspondence between units of duration and linguistic terms, for example, has been derived through a particular cultural evolution. Further, the numerical relationships among the units of duration (such as 60 seconds = 1 minute) are also culturally derived and defined. This system of meaning codefines its elements through conventional agreement of terms, and lacks properties of necessity and constraint which specify the elements of the logical temporal system.

The necessary properties of the logical temporal system imply that the relationships apply univerally. Logical constraints on temporal relations function, in this world, as reliably and predictably as Newtonian physics. In contrast, the cultural system of time is not universally predictable. The lack of universal concepts of cultural objective duration is consistent with the property of non-necessary relationships among the conventionally defined elements. The anthropological literature reveals a wide range of temporal concepts across cultures and within cultures historically and contemporaneously. The definitions and boundaries of past, present and future and the orientation towards each aspect of time vary widely. This can be demonstrated linguistically (Whorf, 1956) or assessed by inventories, such as the Stanford Time Perspective Inventory (Gonzales, Alexander, & Zimbardo, 1985) which surveys attitudes toward work, planning, and leisure activities. Studies of time perspective across the lifespan explore the relationship between life stages and time orientation (Hazan, 1984). In addition each culture, and to some extent individual, has an idea of the comfortable pace of events. (Levine & Wolff, 1985). The notion of measuring time more precisely than could be given by the sun had to be invented and is of relatively recent vintage. The clock, as a western invention to measure time has come to define cultural objective duration, but was not invented until the thirteenth century (Morris, 1985). Historians often link the cultural evolution of systems of marking time to economic events. The necessity imposed by the transition to an industrial economy form an agricultural society is considered to be a major factor in the development and use of clocks (Rifkin, 1987). Lakoff further reveals some of our embedded assumptions about time through the use of metaphors (Lakoff, 1980). Time is systematically represented through metaphors as a valuable commodity, associated with production, which needs to be precisely coordinated and quantified. Thus our western concept of objective time has been culturally invented through specific patterns of need for redefining duration and its meaning.

Logical & Cultural Conceptual Systems

The two objective temporal systems, the logical and the cultural, can be seen as representative of two different conceptual systems. Although logical concepts can be considered a subset of cultural concepts, their privileged position in Western thought and the distinctive properties of logical thought justify an independent category. This distinction parallels divisions in the nature of concepts or the processes of concept acquisition made by several other theorists. For example, Vygotsky (1986) noted distinctions between spontaneous and nonspontaneous concepts which, in part, correspond to systems with different properties and modes of acquisition. Applying a strict dichotomy to a complex phenomenon is obviously oversimplified. However, the distinction may be useful and justified as a temporary measure to understand the nature of relationships within conceptual systems and the processes through which these systems are acquired. In addition, the categorization helps to highlight assumptions made about knowledge as the acquisition or development of isolated conceptual systems. Theories of knowledge or concept development which seem philosophically incompatible in terms of their description of a child, may be reconciled if these assumptions are made explicit.

The distinction between two conceptual systems can be applied to two major theorists of knowledge acquisition. Piaget's theory of knowledge acquisition is primarily concerned with explaining the development of logical systems of knowledge (1946; 1987). The Piagetian theory of temporal development thus describes the construction of the system of logical time, with the concept of objective duration located within this system as a critical development. In contrast, Vygotsky's theories on the development of knowledge focus on the acquisition of cultural systems (1962; 1978). While Vygotsky did not specifically investigate the cultural temporal system, the general process of the transmission of cultural concepts can apply to the temporal domain. Each conceptual system, logical as represented by Piagetian theory and cultural as discussed in terms of Vygotsky's ideas, has different properties and developmental processes.

In Piagetian theory, the child interacts with the physical environment in order to construct knowledge. The endpoint of the development of knowledge is logical structures, which are isomorphic with the structure of physical reality. There is perfect consistency between the logic of the physical and biological world and the logic of our minds. The symmetry is due to the fact that the child as an acting subject is also an object in the world which must obey physical laws. The logic which permeates Piagetian reality is truth table propositional logic, characterized by mental operations (such as classification, seriation, conservation, reversibility), deductive reasoning and mathematical relationships. An essential property of the system of logical reality is necessity among its elements. There are logical constraints on the relationships that can exist. For example, in the temporal domain speed and duration have an inverse logical relationship, so that the faster an object moves, the shorter its duration. It is part of a logical, mathematical system with necessary constraints.

The reality, with which the child interacts to create higher mental functions for Vygotsky, is not a physical nor biological world, but a social and cultural world. Knowledge is constructed and mediated by culturally evolved systems of meaning and representation. These mediating activities influence the child and the world. Thus, as in Piagetian theory, the child can be both subject and object in the construction of reality. However, while Piaget affirms a structurally isomorphic and universal relationship between knowledge and reality, Vygotskian semiotic mediation transforms reality in a culturally specific manner. Locally constructed cultural systems of knowledge are not constrained by the necessity of Piagetian universal logic. Cultural systems of knowledge are arbitrary, in that the relationships among its members cannot be logically derived or mathematically constructed. Within the temporal domain, for example, units of conventional time, such as seconds, minutes, hours or days, are only related to one another by definition. The conventional relationship between seconds and minutes could be redefined in another temporal system. Temporal units were constructed through cultural patterns of events associated with naturally occurring cycles, such as days, months or years. Thus, in contrast to the logical properties of the Piagetian temporal system, which exist by mathematical necessity, cultural time is a system created through and mediated by meaning, and characterized by conventional, non-necessary relationships.

The nature of logical mathematical thought as a truth-table propositional logic affects the explanatory process of how concepts can be constructed in Piaget's developmental theory. Due to the properties of the logical knowledge, especially the constraint of necessity, the child constructs knowledge through interacting with the physical world. The child self-constructs logical knowledge through realizing the isomorphic logical properties which exist in the world. In contrast, the arbitrary cultural systems of knowledge which Vygotsky studied cannot be self-constructed. The most powerful logic applied to physical or cultural phenomenon will not yield the arbitrary, conventional systems of knowledge, such as language or temporal systems. These systems must be taught to children, either explicitly or implicitly, within a culture. Cultural systems of knowledge are dependent upon an interpersonal construction for their acquisition.

The role of social interaction in the acquisition of Piagetian knowledge is also dictated by the nature of the knowledge system. The construction of Piagetian knowledge is a search for a single truth or logical deduction, therefore the primary effect of social interaction is the creation of a cognitive conflict. Two opposing views cannot logically coexist, therefore one must be wrong. Disequilibrium created by this logical contradiction results in development toward more advanced cognitive stages. Despite the recognition that social interaction can lead to disequilibrium and therefore cognitive growth, social interaction cannot create new logical structures or concepts. Its role is to consolidate existing structures or to juxtapose contradictory ideas to initiate disequilibrium. This process of conflict and disequilibrium is radically different from Vygotsky's process of the social construction of knowledge.

Knowledge acquisition and the development of higher psychological functions to Vygotsky are fundamentally a process of social construction, determined by the historical and cultural world of the child. Two central concepts in Vygotsky's theory of development, the principle of inter- to intra psychological functioning and the notion of the zone of proximal development (ZPD) illustrate the importance of social interaction in development. Psychological functions, such as regulation of activity or memory, are first created interindividually through the interaction between two people. These functions are then internalized by the child and recreated on the intraindividual level. Thus social interaction is the origin of concepts and knowledge, and its acquisition by the child is the result of social interaction. The related notion of the ZPD refers to the difference in the unaided performance of a child, and the level of performance the child can demonstrate when helped by an adult or more capable peer. Development takes place in the ZPD, where social interaction creates psychological skill that goes beyond the child's current level of cognitive functioning. There is no conflict between the adult's and the child's thought, as assumed in Piagetian theory, because a logical model of the world is not assumed. The underlying assumption is of a reality of multiple interpretations and relativistic truths, coexisting perhaps in a hierarchy, but not necessarily conflicting.

In Vygotskian theory, the social and cultural world of the child can also be represented or mediated through psychological tools, such as language (Wertsch, 1985). Psychological tools are a product of sociocultural evolution that transmit cultural knowledge, and can then transform psychological functioning. In addition to language, duration is represented in our culture by a variety of marking devices, such as clocks and calendars, which then functionally define objective duration. These representations of duration also have the potential to redefine psychological processes through their use as tools for activities such as marking duration, regulating events and coordinating individual activities along an independent referent. Thus "man's alteration of nature alters man's own nature " (Vygotsky, 1978: 55). In addition, tools can function as a representation and extension of the social interaction to support behavior in the ZPD. In contrast, cultural tools in Piagetian theory are the product of cognitive processes, but do not have the power to transform cognition through their use. Neither social interaction nor tool use can create cognitive growth.

In the development of a concept of objective duration, it is hypothesized that a clock can function as a psychological tool. There are several theoretical aspects of psychological tool use that can be applied to the role of a clock in the acquisition process of objective duration.

First of all, the clock as a psychological tool represents social interaction on two levels, socio-cultural and interpersonal. The clock is a product of sociocultural evolution which cannot be discovered through the child's individual interaction with the world. As a member of our culture, at this moment in history, a child is introduced to the clock and its functions in our society. Through teaching a child to use a clock, the clock plays a role in the interpersonal interaction between members of the society.

Secondly, the clock as a psychological tool potentially changes the course of development. The description of the development of objective duration provided by Piaget may be challenged at the level of the fundamental processes of concept acquisition. The role of the clock is not just to accelerate development, but to potentially transform developmental processes. As Wertsch explains, in Vygotsky's theory, " ...psychological tools are not viewed as auxiliary means that simply facilitate an existing mental function while leaving it qualitatively unaltered. Rather, the emphasis is on their capacity to transform mental functioning" (Wertsch, 1985:79). It is hypothesized that the transformation of mental functioning through the use of psychological tools can be applied to temporal concept development and modeled microgenetically.

Finally, the clock represents cultural objective duration. This function of psychological tool use addresses the role of mediation in tool use and concept development. Meditated activity and symbol use refer to the social interaction inherent, by definition, in psychological tools. Children's abilities to effectively utilize psychological tools provides a diagnostic for their level of development. According to Wertsch, " ...Vygotsky defined development in terms of the emergence or transformation of forms of mediation..."(Wertsch, 1985:15). The way in which the clock is used in the formation of a concept of objective duration is an indication of the development level. Development can be considered not only in terms of temporal concepts, but also in terms of the development of symbol use (tool use). The representational function of the clock, initially, may not be entirely symbolic, but closer to direct representation. The nature of the representation, whether direct eidetic or mediated symbolic, depends on the child's use of the tool. However, the mediated activity is a critical component of psychological tool use, regardless of the level of abstract symbol development. If they are able to use clock to compare durations, then the clock functions as a symbol of objective duration. Conversely, if a clock can be used as a representation of objective time, then they can compare durations. The two aspects of development, concept development and development of symbolic tool use, are interdependent.

The goal of this study is to provide a theoretical and empirical integration of the logical temporal system and the cultural temporal system of conepts through the acquisition of a concept of objective time. Within the framework of logical temporal concepts, Piaget directly studied the development of objective duration. The Piagetian notion of logical objective duration is a central operationalization in this study, but the description of the developmental course is challenged for a lack of consideration of the simultaneous integration of the cultural conceptual system. Although Vygotsky never directly addressed the development of temporal concepts such as objective duration, his ideas on the social and cultural construction of knowledge potentially illuminate the acquisition process of cultural objective duration. One of the central aims of the study is to model a microgenetic process of concept development in which both systems of concepts, logical and cultural, are considered. This is assumed to be a more valid description of the tasks faced by the child in the development of concepts. The integration of conventional cultural concepts, and their social process of acquisition, with the development of logical systems would challenge the course of development of objective duration dependent solely upon logical integrations.

Logical Objective Duration

The most comprehensive theory of the development of a system of temporal concepts is Piaget's (1946) work on the child's concept of time. In Piaget's theory, a personal, subjective understanding of time is characteristic of the preoperational thought of a young child. Concepts of logical objective time then develop from the early temporal notions with the acquisition of concrete operational logic.

In Piagetian theory, preoperational, intuitive time is characterized by several incomplete understandings regarding time and temporal relationships. Time acquires meaning through events, movements or actions. Logical aspects of time, such as sequence and duration, cannot be separated from the experience of events. Duration is not an objective dimension separate from events and actions: it is considered part of an action. Thus, the child confuses duration with the outcome of an event, along the lines of more ____ = more time.

The lack of a functional system of logical temporal relations can be demonstrated through the independent consideration of the elements of the system. The intuitive notion of time is undifferentiated from space (distance) and velocity. (Piaget, 1946). Duration is not yet separate from its spatial origins. In addition, duration and succession can not be integrated, that is the order of events cannot be coordinated with their timespans. The lack of an integrated, logical system of temporal relationships prevents the meaningful comparison of the durations of two events. Without the logical temporal system in place, there is no objective time scale upon which the durations can be compared. Each event has its own independent time scale.

Within Piagetian theory, the construction of an objective time frame with the acquisition of operational logic is a pivotal temporal concept. Piaget's concept of objective duration is defined as, " a unique and homogenous time scale" (1946: 89). The objective time scale has three critical attributes: homogeneity, continuity and uniformity.

Homogeneity refers to the understanding that objective time is a dimensio that is common to the unfolding of any number of simultaneous events. Although the preoperational child may be able to understand sequence within one event, homogeneity refers to the aspect of objective time that requires a coordination among the sequences of two or more events. Homogeneous objective time is abstract and universal, no longer the local, event-based time of preoperational logic. Closely related to the homogeneity attribute, is the construction of objective duration as continuous. This involves the logical understanding that duration is uninterrupted, regardless of the discontinuous nature of events. If an event stops, or if change or motion is not perceptible (as in growth or aging) an operational child with a concept of objective duration understands that duration continues independent of these events.

Homogeneity and continuity are qualitative attributes of objective duration,in contrast, uniformity must be understood in a quantitative sense. Uniformity refers to the understanding that the rate of the passage of duration is constant, unchanging and independent of the rates of events or activities. The qualitative and quantitative aspects of objective time are closely related; as soon as homogeneity and continuity have been constructed, uniformity can be understood. The conservation of uniform velocity forms the basis for understanding the uniform flow of duration. To Piaget, a concept of objective duration is defined by the coordination of movements with different velocities. The unequal rates of the actions of different events must be coordinated in order to construct a common timeline. In Piagetian theory, velocity is also a central concept in the separation and integration of distance and duration. Events are ordered in both time and space, with the two dimensions defining one another through motion, or velocity, "Space is a still of time, while time is space in motion" (p.550:1977). Operational logic allows the child to fit events with different velocities into a single time- space framework.

The conservation of uniform velocities is discovered simultaneously with the unitization and measurement of time. A unit of time cannot be perceived but must be constructed from our direct perception of velocity. Thus, a unit of time is a motion at constant velocity that can be reproduced and applied across contexts independent of content. With unitization, time can be measured, quantified and related to the number system. Thus, the qualitative properties of objective time, homogeneity and continuity, allow an operational child to conceive of events as occurring within a common time frame, in contrast to the local and unintegrated, event-based time sequences of preoperations. The quantitative attribute of uniformity, and its logical results of unitization and measurement, are dependent upon the qualitative integrations of objective time. A full understanding of objective time is dependent upon the quantitative integration of velocities.

Evidence for the critical qualitative and quantitative attributes of operational time is provided by preoperational and operational performance on a criterion task that requires a comparison of the duration of two events (1946). In the classic variation, children are asked to judge the relative duration of the journey of two cyclists when the starting or ending points are staggered. A correct judgement requires a comparison of the sequential order of the starting and finishing points of the cyclists, and the coordination of this sequence information with the duration of the journeys. Preoperational children focus on either durative or sequential aspects of the task, not a consideration of both simultaneously. Successful performance on the task also requires an integration of the dimensions of duration, distance and speed. At the preoperational level, duration is not differentiated from distance. The cyclist that travels the farthest distance is said to have taken more time: the preoperational child cannot understand that faster cyclists can cover a longer distance in the same amount of time. Velocity is not understood as having an inverse relationship with duration. With the achievement of concrete operations, the logical integrations between sequence and duration, as well as among duration, distance and velocity can be constructed. The two durations can be compared with the use of a homogenous and continuous time frame. Thus, the logical achievements of the concrete operational period (the coordination of the duration, distance, speed relationship and the integration of duration and succession), provide the basis upon which the development of the concept of objective time and time measurement and quantification depend.

Subsequent work has demonstrated that there are precursors to the logical integrations that are not evidenced in the Piagetian tasks. Levin (1979) has argued that the inability of the preoperational child to compare durations of events is due to the interfering cues of the Piagetian tasks. By simplifying the tasks in nontrivial ways, Levin has demonstrated preschoolers' abilities to compare the durations of simple events. Levin made a crucial distinction among types of events that incorporate different cues from which duration can be inferred. The classic Piagetian task focuses on complex events, such as the comparison of two journeys with varying durations, distances and velocities. This event comparison of "linear duration" necessitates the full logical integration of speed and distance cues to infer duration, a definition of duration that is an integrated system of mathematical relationship. Levin added "still time" events to the duration comparison paradigm. Still time focuses on events such as sleeping (Levin, 1977). Comparing the durations of the sleeping time of two dolls does not involve distance or speed in the determination of relative duration. Although third grade children had difficulty with the linear time tasks, preschool children could correctly infer durations in the still time tasks (Levin, 1977; Levin, Isreali & Darom, 1978). Levin argues that distance and speed are interfering cues in the inference of duration: children are susceptible to salient information and attempt to use that information to help solve the task at hand. The fact that speed and distance are logically related to time is irrelevant; children can also be led astray with temporally irrelevant cues such as light intensity (Levin, 1979).

By changing the operational definition of objective duration, Levin may have transformed the theoretical meaning of objective duration to a more basic concept. In Piagetian terms, the still time duration task directly incorporates the homogeneity aspect of objective duration, but less directly implies the two additional definitional criteria of objective duration, continuity and uniformity. However, there are several grounds for questioning the terms of Piaget's definition of objective duration. First of all, Piaget's definition of objective duration and his description of its development are circular: the definition of objective duration incudes an understanding of uniformity, or the conservation of velocity, therefore the development of objective duration is dependent upon the integration of velocities. If objective duration can be understood as the concept of a standard of time, along which events can simultaneously occur and be sequentially ordered, then the properties, corollaries and implications of the concept are the subject of empirical investigation. The reconceptualization of objective duration as a basic concept allows the study of its development to be approached without a predefined system of logical integrations. The course of development of the concept of objective duration in Piagetian theory is predetermined by the necessary logical integrations. Challenging the description of development proposed by Piaget necessitates a redefinition of objective duration, for the Piagetian concept of objective duration is defined as the culmination of the development of a logical system of temporal relations.

Levin's demonstration of the early understanding of duration, independent of space and velocity, challenges the Piagetian course of development in which duration is constructed from its spatial origins in distance and speed. As an alternative course of temporal development, Levin concludes that duration is constructed from succession; that the different beginning and ending times of the two events are compared to infer the relative duration of the events. Levin, Isreali and Darom (1978) demonstrated that even preschool children explain duration judgments in terms of succession points.

There is a wealth of converging evidence that succession is a very early cognitive skill. There is considerable evidence that sequencing skills are demonstrable and flexible long before they are successfully integrated into a logical temporal scheme. Very young children, 17.5 to 23 months old, can correctly order familiar events with causal relations (Bauer & Shore, 1987; Bauer & Mandler, 1988). Preschool children are able to sequence the components of an event across a wide variety of conditions (O'Connell & Gerard, 1985: Fivush & Mandler, 1985). On a larger scale, three and four year old preschool children have extensive knowledge of their daily routines and can sequence the events (Friedman, 1977, 1990: Carbery, 1989). This early understanding of sequence may be utilized as a basis for other knowledge, particularly the development of a concept of duration.

Fraisse (1982) offers a comprehensive approach to the development of temporal concepts that is derived from and, in many ways, is consistent with the Piagetian framework. Fraisse adds an essential focus on the functional adaptation to time, emphasizing prelogical temporal experiences that are critical in development. This defines a course of temporal development in which the individuals' adaptation to change is the primary developmental task. The transformation of the perception of duration into knowledge or cognition of duration is viewed as an increasingly adaptive system, in which time (or change) is eventually mastered.

Fraisse describes three modes of adaptation to time. First, classical and operant conditioning to time intervals demonstrates discrimination among varying time intervals that does not require measurement nor conscious awareness. The second mode, the perception of time, refers to the perception and memory of a group of changes as a single, simultaneous event. The adaptation to a series of rapid changes is that the changes are perceived as a psychological point in space, not as a string of successive changes. The perception of time is not a series of qualitatively similar changes, but the perception of events. In addition, time is remembered within events. The properties among changes across time, which lead to the perception of an event, have a functional unity of adaptation. The third mode of adaptation to time includes two levels of the mastery or knowledge of time. These levels are consistent with the Piagetian distinction between preoperational intuitive time and achievement of logical temporal concepts with concrete operational thought.

Research on the first mode of adaptation to time, conditioning, specifies potential precursors of temporal concepts as described by Piaget. Infants can be conditioned to temporal intervals, thus demonstrating that they can discriminate durations. Fraisse stresses that these early adaptations to time are not conceptual, but reflect a biological skill of intersecting our activities with the demands of the physical environment. Fraisse illustrates this by citing literature on the successful conditioning of animals to temporal intervals (1963).

The theoretical differences between Fraisse and Piaget on the nature of duration and the developmental processes that allow children to understand duration are most clearly exposed when the second mode of adaptation to time, perception, is considered. First, Fraisse seems to replace Piaget's distinction between preoperational, subjective duration versus operational, objective time with a developmentally isomorphic differentiation between the perception of time and cognition about time. This idea is similar to Piaget's repeated statements about operational logic being able to overcome the perceptual data that is so overwhelmingly salient to preoperational children. Both subjective time and the perception of time are subject to inaccuracies, illusions and systematic distortions. However, according to Fraisse, these processes are supplemented, but not subsumed by the development of objective time and temporal concepts. Thus, while these processes are developmentally ordered, the higher functions of temporal concepts and objective time coexist with the more primitive capacities of temporal perception and subjective time. This is illustrated by the fact that adult performance on tasks, which require logical integration of temporal indices, is often not indicative of their capability of logical reasoning. Problems requiring duration estimates, comparisons or inferences invoke a dual attitude, of intuitive time and of metrical analysis (Fraisse, 1982). Thus, Fraisse emphasizes the dual nature of temporal experience as being qualitative and perceptual, as well as the simultaneous possibility of logical analysis in terms of coordinating dimensions of the physical relationship.

The second major difference between Piaget and Fraisse on the perception of duration focuses on whether duration can be directly perceived, or must be constructed. The concept of duration defined by Piaget is not a direct perception, but a scheme or concept that is constructed from elements that can be perceived by the more traditional senses. Vision provides a relatively direct metric of how far and how fast a model train travels. But the relationship between the distance and speed of the train in "how long" must be constructed from directly visible events. Duration, as a temporal relationship, must be inferred from information available through direct perception. In contrast, Fraisse argues for the direct perception of changes in our experience as the basis for the experience of duration. This direct perception of time as the number of experienced changes contrasts with the Piagetian position in which time must be perceived as a relationship. Piaget accepts Fraisse's notion that the perception of change is fundamental to the perception of duration, only if change is determined per unit of objective duration (Piaget, 1981).

Richie & Bickhard (1988) in a discussion of Piaget's constructed duration, note that this assumption rests upon

Piaget's model of perception, the traditional bottom up view that discrete sensory data is encoded and then combined to yield information. Richie and Bickhard suggest that alternative top down models of perception, such as Gestalt and Gibsonian models, in which relationships can be directly perceived, can offer a different starting point for the development of duration. If relationships can be directly perceived, perhaps duration as a temporal relationship is also directly perceived, not constructed. Richie and Bickhard offer empirical support for the direct perception of duration by 3 to 6 year old children. The children correctly judged the relative duration of bulbs that were lit. The standard duration comparison task of 4 versus 7 second duration was supplemented by a long (4 v. 28 seconds) and a short (1 v. 7 seconds) condition. Children solved the short and long tasks with less difficulty than the standard task. By solving these tasks, the children were not only able to perceive duration, but also able to use this perceptual information to qualitatively compare durations. This demonstration implies the use of a unique and homogenous time scale: by definition, Piagetian objective time. The authors conclude that the ability to perceive duration directly, rather than being derived inferentially from other information, necessitates a reconsideration of Piaget's model of temporal development, which rest on this assumption.

The third mode of adaptation to time described by Fraisse contains two levels, corresponding to the Piagetian transition between preoperational and operational logic. In Fraisse's first level, children under the age of 8 or 9 represent and adapt to past or actual changes, but cannot logically reason about their representations. At the second level, the deduction of temporal relations between events is possible. In addition, logical operations allow the construction of representations, which incorporate the temporal relations of change and enable the mastery of future change.

The transition between the two levels of the mastery of time is illustrated by several tasks, some of which are similar to Piaget's duration comparison tasks involving the coordination of the dimensions of duration, distance and velocity. In contrast to the Piagetian emphasis on the development of logical structures, Fraisse draws conclusions about the preoperational child's inability to correctly infer duration which are similar to Levin's (1979) position. Preoperational children cannot integrate a number of cues or number of changes in order to compare durations. With operational logic, the child is then able to perceptually contrast several changes and consider the relationships among them in order to infer durations. There are several other points of divergent emphasis between Fraisse and Piaget. First, while Piaget focuses on the relationship between time, distance and velocity in the construction of a concept of duration, Fraisse emphasizes the number of changes that are experienced as central to duration. Thus, while velocity or the speed of events is a critical element in Piaget's system, the number of changes or units of activity provides an important cue to duration to Fraisse. In addition, Fraisse's emphasis on the functional adaptation to change focuses on the role of intuitive subjective time and the child's activity in the transition between these two stages. For example, in a study that varies the task difficulty, the amount of effort required to perform the work becomes a subjective temporal cue to be integrated into the estimation of duration (1963). The difference in emphasis between Piaget and Fraisse reflects theoretical differences on the role of change in the perception and integration of duration.

Montangero (1985), expands upon the Piagetian concept of duration by proposing that the concept of duration is composed of three subsystems. Each subsystem involves the representation and relationships of three physical parameters. Duration as one of the parameters is common to all three subsystems. In a mature concept of duration, the parameters within the subsystems are triadically integrated. Thus, the value of one parameter can be inferred given the value of the other two parameters. In addition, a fully developed concept of duration is a system of meanings, with all the parameters of the three subsystems fully differentiated and integrated.

The first subsystem defines duration as an interval with initial and final boundaries; duration is the interval between successive points in time, or instants. Relative order duration involves the relationship among the parameters of the relative starting order of an event, the relative ending order of an event and the temporal interval or duration. In the comparison of two events, relative duration can be inferred from the succession points of the two events. The integration of succession and duration was identified by Piaget as part of the achievement of concrete operational logic in the development of objective duration, but was not independently studied. This understanding corresponds to Levin's (1977) distinction of "still time". Levin demonstrated that even 4 year old children can construct duration from the sequence information of the relative beginning and ending times of some events, such as the sleeping time of two dolls. Thus, within Montangero's categorization of durations, this seems to be the first subsystem acquired. In order to reflect the importance of sequential parameters in this subsystem, it can be termed the "successive duration" subsystem.

The third subsystem of duration (Montangero's second system will be discussed below) focuses on a concept of duration as an interval that can be fragmented by the periodicity or rhythm of a discontinuous activity. Thus, duration can be segmented into quantifiable units, which occur at a certain rate or frequency per unit of time. The representation of the physical parameters of discontinuous activity, which can be expressed by number or frequency, must be integrated in this duration subsystem. This includes comprehending the interrelationships among the parameters, such as understanding that as the rate of activity increases, the duration decreases, if the number of units of the activity is held constant. This subsystem of duration, as hypothesized by Montangero, corresponds to Piaget's concept of duration as a dimension needing to be differentiated from the child's own activity (1946). In line with the construction of objective duration in concrete operations, Piaget (1971) reported that 7 and 8 year old children are the youngest age group to assert the uniformity of motion of sand through an hourglass regardless of their own activity. Fraisse expanded upon the role of activity in constructing a concept of duration (1963; 1982). For example, one duration comparison task contrasted two activities performed by the child in succession. The activities required the child to transfer pellets from one container to another, first using a pair of tweezers, then using a ladle. The two activities vary on the frequency or rate of work accomplished as well as the absolute number of pellets transferred in a given interval. The duration of the two activities is independent of the frequency and number parameters, although the two parameters do provide cues related to the duration of the event. Fraisse differs from Montangero by considering this activity subsystem in terms other than frequency and number. To Fraisse, the frequency of an event and the number of units associated with the event contribute to subjective variables, such as the difficulty of the task, the amount of work accomplished and the amount of effort expended. This whole system of physical parameters and subjective variables contributes to the subjective impression of duration, which must be overcome in order to infer logical time. Thus, while Montangero has identified this frequency/number subsystem as part of the concept of duration, Fraisse's ideas about the role of the child's activity can expand this "activity subsystem" to incorporate notions of difficulty and effort as important parameters in the relationship between discontinuous activity and duration.

The second subsystem of duration identified by Montangero corresponds to Piaget's description of the logical construction of duration in the integration of the parameters of duration, distance and velocity. In Montangero's system, this linear duration is only one part of a system of duration, not the integration that defines objective duration. Montangero expands the concrete operational transition to incorporate triadic integrations not only within all three subsystems, but also across the three subsystems. Thus, preoperational children's understanding of duration is characterized mainly by dyadic integrations, with a general inability to differentiate or integrate the critical third parameter. The conservation of velocity is one of the three triadic integrations included in the concept of duration, but it is not a prerequisite understanding for the demonstration of objective duration in the other subsystems.

To summarize so far, the Piagetian definition of objective duration has been expanded, the precursors and necessary logical integrations clarified and the course of development challenged. Although Piaget's definition of objective duration as a common time scale, with the characteristics of homogeneity, continuity and uniformity has been challenged, the Piagetian duration comparison task remains the standard. The duration comparison paradigm was utilized explicitly by Piaget to operationally define objective duration. The correct comparison of duration of the two events necessitated a concept of objective duration, a common time scale. The many aspects of duration and its possible relation to events, all subsumed by Piaget under the single logical integration of velocities, or the motions of events, have been theoretically and empirically isolated. Thus, the concept of duration has been expanded to include sequential duration, activity duration and linear duration. Whether or not these subsystems develop separately or are different expressions of an underlying general course of development is an open question.

The general course of the development of objective duration, as the result of a logical integration based on the operational achievement of the conservation of velocities, has been challenged. Levin and her colleagues have demonstrated the construction of objective duration through the integration of sequence information. Richie and Bickhard, through the adoption of a logically equivalent method of the comparison of durations, have demonstrated the possibility that relative temporal relationships can be directly perceived. Both research programs have challenged the necessity of operational logic as a prerequisite for objective duration through their successful results with preschool children. One goal of this study is to continue to explore alternative conceptualizations of the developmental description of the concept of objective duration. A critical aspect of temporal concept development, which needs to be considered, is the effect of the system of cultural concepts of objective duration.

Cultural Objective Duration

The development of a Western system of cultural time includes the acquisition of linguistic expressions of conventional time, such as the tense system, temporal relational terms and units of time and the development of skill in using temporal mediational tools, such as clocks. Each of these areas of research remains fragmented within itself, with little or no integration across areas toward gaining an understanding of a system of cultural time. In addition, the coordination of the development of cultural temporal concepts with the development of a system of logical concepts remains empirically unexplored, despite some parallels drawn to general Piagetian developments. Nevertheless, there are fragments of insights into the acquisition process, which may guide the search for an integrated story of temporal development.

The course of experience is mapped onto the tense system in speech, which is often conceptualized as a time line with three categories of experience; past, present and future (Miller & Johnson-Laird, 1976). Tense serves a deictic function of locating the relative position of events to each other and to the time of speaking (Lyons, 1977; Weist, 1986). The issue of determining exactly which parameters of experience young children are encoding through the development of tense usage is controversial (Antinucci & Miller, 1976; Smith & Weist, 1987; Rispoli & Bloom, 1985; McShane & Whittaker, 1988). Nevertheless, research in several languages has demonstrated that children before the age of 2;6 are sensitive to the deictic function of tense (see Weist, 1986, for review). Comprehending and utilizing the deictic functions of the tense system implies an understanding, at some level, of a singular timeframe within which events can be ordered. This timeframe corresponds to a simple or precursor understanding of objective duration.

In addition to tense, temporal concepts are also encoded in lexical items, such as adverbials. No clear picture of the order of acquisition of these terms emerges, and attempts at detailed systemization are frustrated by high numbers of counterexamples. In addition, each research paradigm has defined and categorized the diversity of temporal concepts, making it difficult to compare the acquisition of the terms and temporal development across the systems. Summarizing the linguistic research, Clark (1985) suggests a general order of development, in which the first temporal terms refer to the present, such as 'now'. Then a contrast is made between present and non-present, resulting in the use of temporal locatives such as 'yesterday' and 'tomorrow'. These locatives are often used incorrectly at first, supporting the present versus non-present contrast, instead of a distinction between past, present and future. These locatives first mark events separately for temporal aspects, then the child can temporally relate events to one another, beginning at about 3;0 to 3;6 years. Using temporal locatives to interrelate events provides additional linguistic evidence for an early understanding of the singular time line aspect of objective duration.

Ames (1946) examined temporal expressions in spontaneous utterances and administered a time questionnaire to children from 18 months to 8 years. Her analysis, generally consistent with Clark's, traces several acquisitions of conventional expressions of duration and sequence, as well as units of time. The general conclusions apply to all of these terms. References to specific times were recorded before general references to indefinite periods. Also, phrases were at first context dependent and only gradually used in other situations. Children first used events and activities as reference points for answering questions about location in time, with most children unable to accurately use clock times until about 7 years old. Ames records a sharp increase in the usage of temporal terms between 3;0 and 3;6 months and a broad consolidation of concepts of past, present, future, duration and order by 48 months. Other survey studies (Friedman, 1986) are consistent with these general trends. There is also some evidence that shorter units of duration are understood before longer durations, presumably because shorter durations are more perceptually available (sometimes directly perceptible) and are repeated more frequently allowing the extraction of relevant features such as duration (Westman, 1987). A recent questionnaire update of the Ames study (Harner and Nelson, 1989) found that preschool children tend to respond to questions about the timing of recurrent daily events in terms of their relations to other events or parts of the natural day. Kindergarten to second grade aged children gradually coded recurrent daily events in terms of specific clock times. This result reflects an integration of the event based ordering of events and experience with the culturally objective representation of events in terms of clock time. A related result from this study bears on children's understanding of the relationship between the systems of cultural objective time and logical objective time. When asked the question, "Would time still exist if there were no clocks or calendars?", 70 % of the first graders, but only about half of the second graders responded affirmatively. This suggests that, in the process of mapping the cultural system onto individual experience, the objectivity of cultural time subsumes what appears to be a beginning notion of abstract, logical time.

In sum, the development of conventional terms is generally seen as the complex integration of experiential temporal notions with cultural terms and tools. The acquisition of these terms is assumed to depend upon the development of the underlying cognitive competence, which allows the child to understand the temporal concepts embedded in the linguistic terms. At least a beginning notion of objective duration is implied by the use of temporal adverbials, such as locatives. In addition, there is evidence that the acquisition of a concept of objective time is not a linear process, but a process that is complicated by the integration of objective time with a number of related lexical terms and logical concepts.

A more detailed theory on the acquisition of conventional temporal terms focuses more on the potential processes involved in understanding temporal terms. Friedman (1978) suggests a general trend in the development of conventional units of time. First, children use the units in verbal formulae, without an understanding how the units are related to time measurement or to the cultural representation of time. With the development of objective duration in concrete operations the Piagetian logical ability to unitize duration enriches the child's concepts of conventional duration units. Conventional units of duration then represent a socially shared, culturally objective, meaningful unit of duration. This demonstrates how the meaning of the elements of a culturally constructed system are potentially reorganized by logical constructions of objective time. Freidman's empirical work (1977; 1986; 1990) has identified more specific mechanisms in the acquisition process, which generally support the notion of an early understanding of conventional units being reorganized and deepened by cognitive developments.

There is growing support for a model of concept development that can be applied to the development of temporal concepts. The model of contextual support defines the acquisition process as a construction between the child and the context. This alternative suggests less emphasis on the transition from partial to absolute achievement of cognitive skill and linguistic competence. Instead, the early demonstration of competence in a supportive situation is followed by the gradual freeing of the competence from the context. This decontextualization of skill results in flexible use and transfer of competence across situations. Brown & Campione (1983) propose that development in the preschool years consists of learning to use information and apply skills flexibly.

The general applicability of the model of contextual support can be inferred from its consistency with temporal concept research and theory. Supportive contexts can be thought of as scaffolds for developing competencies, within the Vygotskian concept of the zone of proximal development (1987). As discussed above, Vygotsky's theories on the acquisition of cultural knowledge are hypothesized to be especially applicable to the development of the cultural temporal system. Consistent empirical results demonstrate the applicability of contextual support in the demonstration of unconsolidated skill. Spontaneous production of temporal lexical terms and tense use is reported at younger ages than laboratory production or comprehension tasks (Ames, 1946;

Miller & Johnson-Laird, 1976). This is consistent with the contextual model, for spontaneous utterances are directly related to the situation at hand and thus strongly contextually supported. The research on event knowledge (Nelson, 1986) offers a more detailed explanation of supportive contexts. Event representations provide a cognitive context that can support precursors and unstable forms of cognitive skill, including precursors necessary for the understanding of tense and temporality. Carni & French (1984) demonstrated the importance of familiar events in supporting the early use of the temporal relational terms, before and after. Thus, what develops is the child's ability to display temporal understanding and competence in complex and unsupportive environments.

Clocks

The development of children's understanding of clocks and their ability to use clocks to measure time has been investigated from a number of perspectives. Survey studies indicate that children learn to read time by an analog clock by 7 or 8 years of age (Friedman ,1978; Ames, 1946). There is also some evidence for a consistent order in the acquisition of component skills. First children can identify whole hours, then can read clock time in terms of parts of hours, then in terms of minutes. Friedman (1978) speculates that the underlying cognitive competence in reading time involves a Piagetian concrete operational achievement, the ability to coordinate the unequal velocities of the two hands of the clock and the ability to conceptualize the nonperceptible, inclusion relationship between the movement of the two hands. Despite this speculation, there is no empirical research on the development of clock reading skill.

Precursors of the ability to read clock time include understanding the purpose of a clock. Ames'(1946) observation and survey data offer some insights. Beginning at 3 years, children spontaneously pretend to read time using a clock and will offer an answer to the question, "what time is it?", although the answers are wildly inaccurate. This can be interpreted as an indication that these children have a notion that time is represented by a clock and that numbers are conventionally given as a response to a time question. Children at this age are able to understand time in terms of events, such as "lunchtime" or "time for music", but this event based time seems to be independent of clock time. By 5 or 6 years old, children either answer "I don't know" to the "What time is it?" question or give the correct time in terms of the hour. There seems to be a new understanding of the meaning of the question, beyond the formula of a numeric answer. The children are also aware of their lack of knowledge if they cannot read time. The 5 and 6 year old children are also able to give clock times for some of their routine events, such as bedtime and the time for school. The event based system is beginning to be coordinated with the system of numerical clock times. Although this analysis of the understandings involved in reading time is more theoretical than data derived, it serves to demonstrate the importance of precursor developments in clock reading skills.

Researchers have also investigated children's ability to use clocks or other temporal mediational devices to regulate their activities. Arieux (1982) asked kindergarten and second grade dyads to share a toy equally for ten minutes, with and without a time keeping instrument, such as an analog or digital clock or a sandtimer. About half of the second grade and kindergarten dyads shared the toy equitably without a timepiece. In the second grade dyads, equitable play increased to 80% with the timepiece. On the other hand, the percentage of kindergarten children who were able to share the toy equally decreased with the use of a timepiece. Thus, while second grade children were able to temporally regulate their activity with the use of a timepiece, the kindergarteners' performance was disrupted by the presence of temporal mediational devices. This suggests that the ability to temporally regulate behavior and the ability to regulate behavior through tool use may not be dependent upon the same competencies. In addition, the lack of a simple linear developmental process is highlighted by the finding that temporal mediational devices may disrupt performance at certain levels.

Another study performed with older children demonstrates that an understanding of the regulatory function of clocks may continue to develop into early adolescence. Ceci & Brofenbrenner (1980) investigated prospective memory in 10 and

14 year old children by observing their time monitoring strategies during tasks such as baking cupcakes. The results indicated that 10 year children were able to employ a sophisticated strategy of time monitoring, which reduced the amount of clock checking while successfully timing the task. The strategy involved an initial calibration of their subjective time sense with clock time through frequent clock checks. Then clock-checking behavior decreased during the estimated waiting period. Clock checking escalated as the end of the timing period approached. Both the Ceci & Brofenbrenner and the Arieux study focus on the children's behavior in using the clock as a tool to regulate temporal activities. There is no analysis of the underlying understanding or competence involved in the temporal regulation of activity using a clock. For example, the issues of spatially and cyclically representing time, the unitization of time or the mapping of the number system in the quantification of time in the use of clocks is not addressed in these studies. Research, which focuses on young children's ability to measure and quantify time, analyzes several of these component understandings.

Time measurement in Piagetian theory is dependent upon the logical constructions of concrete operational logic. Much of the above discussion on the status of Piaget's ideas on the development of logical time also applies to the prerequisites of measurement. According to Piaget, the child must first grasp the conservation of velocity, that is, the logical relationships among the concepts of duration and speed, and the ability to integrate order and interval or succession and duration. These constructions allow a concept of logical objective time, which must exist before a child can measure time with a standard. The quantitative attribute of objective time, uniformity, is also basic to the notion of dividing time into iterative units that can apply across situations, and the quantification of those units. The relative duration comparison paradigm, discussed above, is a method of testing for a concept of objective time without the additional complexities of units and quantification, which are often part of measurement. The use of a clock, or temporal device is seen by Piaget as another situation in which the child must coordinate the unequal velocities of the event being timed with the movement of the clock. Piaget investigated the effect of using a clock or an hourglass on preoperational children's performance in duration comparison tasks (Piaget, 1981). The children could not use the clock as a representation of objective time. The children assumed that the clock went faster as the pace of their activity increased. Similar tendencies by preschoolers to subsume objective clock time into the subjective feeling of the passing of time is reported by Westman (1987). It was not until second grade that subjects were able to differentiate the subjective feeling of time associated with the emotional tone of events from objective time as represented by the clock and calendar. Westman further notes that kindergarten children performed poorly due to their lack of fluency with the clock and calendar. Arlin (1990) found a concept of cultural objective time in younger children through a different method. When 4- through 7- year old children were asked,"What happens to the clock when you sleep?", 4 and 5 year old children were more likely to reply that it went slower. However, prior to the acquisition of preoperational logic, 6- and 7- year old children's responses were more likely to reflect an understanding of time constancy, as represented in the cultural tool of a clock.

Careful analysis of the complex skills involved in measurement and more sensitive indices results in the demonstration of greater understanding in preoperational children than found by Piaget. By 3 years old, children can reproduce a specified duration with some accuracy. For example, E. Friedman (1977) trained 2-1/2 to 5-1/2 year old children to reproduce a 15 second interval on a stopwatch. The children produced an average interval of 15.5 seconds, with a standard deviation of 4.5 seconds. Crowder and Hohle (1970) taught 5, 7 and 9 year old children to reproduce intervals of 2.7 and 5.4 seconds, which corresponded to the time it took a lion to reach his den. Without feedback the 5 year old children's performance declined, while the 7 and 9 year old children were able to accurately reproduce intervals without feedback. Although caution is warranted in claiming conceptual competence on the basis of conditioning studies, at a minimum, it appears that children as young as 2.5 years old can represent their subjective feeling of duration in objective units with the use of a cultural tool. The important role of feedback in accurate performance can be interpreted in terms of the need to calibrate subjective duration with the arbitrary standard, or unit that was required. Part of temporal development must include learning the correspondence between conventional units and our subjective experience of duration. Although this skill cannot be equated with a concept of cultural objective duration, nor with measurement skill, the evidence suggests that unitization is an important precursor to understanding the relationship between subjective and cultural objective time. This correspondence is not recognized by Piaget as a precursor, but is seen as a result of the concrete operational integration, upon which a concept of objective time depends.

Piaget's claim that young children cannot measure duration is also derived from the preoperational child's inability to make transitive inferences (Piaget, Inhelder & Szeminska, 1960) For example, measurement implies the use of a standard, such as a ruler, to compare the height of two towers instead of a direct comparison. Bryant and Kopytynska (1976) found that when the dimension to be compared cannot be perceived, as in the depth of holes, 5 and 6 year old children will measure depth with an instrument. Miller (1989) found that by reframing a similar measurement task in terms of the search for a hidden object, 3 year old children were able to use a measurement tool. This has important implications for the measurement of time with a tool such as a clock. The ability to use a standard to represent and compare a nonperceptible dimension seems to be an earlier achievement than claimed by Piaget.

Many studies which have examined children's ability to measure time have found, as predicted by Piaget, that children cannot measure time by counting until the achievement of concrete operational logic (Goldstein & Goldfarb, 1966; Friedman,1977; Levin, Wilkening and Dembo, 1984). Investigations of time measurement using different paradigms, however, have found support for early demonstration of time quantification skills. Wilkening (1981, 1982) focused on children's ability to infer a quantitative value for the missing parameter of a time, distance and velocity problem. The task was presented in terms of various animals (with different speeds, such as turtles or cats) fleeing from a barking dog. To infer duration, an animal was presented a certain distance from the dog, and the subject estimated duration by turning on the barking for the corresponding interval. Thus, the estimated quantity of duration was also integated with the marked distance that the animal with a certain speed would cover. Wilkening concluded that 5 year old children have a quantitative concept of duration. By simplifying the perceptual aspects of the tasks, Wilkening, Levin and Druyan (1987), have demonstrated that 5- year old children measure time by counting, especially when its appropriateness is suggested by a metronome. Some of the 5-year old children in this study who did not employ counting as a measurement technique used idiosyncratic strategies, such as rhythmically blowing air in and out or singing a song. These children seem to understand, at least implicitly, that time can be segmented into units and can be quantified. Both of these understandings are critical to a concept of cultural objective time. In contrast to Piagetian theory, however, these seem to be precursor skills that must be integrated into a concept of objective duration. Based on these results, the quantification and segmentation of duration into units are not results of the conservation of velocities, achieved only with Piagetian operational logic.

The development of cultural objective duration, in sum, is less studied and lacks a unifying approach. The available evidence on the acquisition of cultural temporal concepts, through language and clock usage skills, supports an intepretation consistent with a contextual model of concept development. Early precursor skills can be demonstrated in supportive contexts, but are unstable and unintegrated. In theory, then, these early skills become decontextualized, stable across contexts and integrated within the temporal system. However, current survey of the literature indicates a multitude of precursor skills demonstrated by preschool children. The challenge of describing the continued development, and possible stabilization and integration, of these concepts remains.

Conclusions and Hypotheses

Research on the development of objective duration, within both logical and cultural conceptual systems, is guided by the seminal work by Piaget on children's concepts of time. The overwhelming conclusion, which must be drawn from this research, is that the Piagetian description of the development of objective time must be reconceptualized. To Piaget, objective duration is a result of the logical integrations achieved with concrete operations. The qualitative aspects of objective time, homogeneity and continuity, however, can be demonstrated in children as young as 4 years old by a duration comparison paradigm. The temporal skills, which Piaget posits are a result of the construction of the quantitative aspect of objective duration, can be found in the repertoire of 4 and 5 year old children. Thus, it can be argued that unitization, measurement and aligning time with the number scale are not a result of the construction of objective duration. The development of objective duration in a cultural system represented by language competence and clock reading skills has been considered relatively independently of the development of logical time. However, the scattered evidence, as a whole, indicates early competence in supportive contexts that cannot be explained in terms of Piagetian competencies. Although there are only enough data to suggest the need for revision, not resolution, one potentially fruitful view is model of contextual support, in which concepts and skills are able to be demonstrated in increasingly less supportive contexts.

The goal of this study is to reconceptualize the concept of objective duration as a system of knowledge with both logical and cultural components. The development of objective duration must be considered in terms of both logical and cultural conceptual systems. Any model of temporal development, or of concept development in general, which is less comprehensive is not an ecologically valid representation of the process. This study is a starting point in a research program focused on this integrated development.

It is hypothesized that the Vygotskian concept of a psychological tool can be utilized to provide a potential mechanism for the integration of logical and cultural systems of concepts. A clock can be used to represent the cultural system of objective duration. As a psychological tool, the clock has several functions that can affect the demonstration of a concept of objective duration in the standard tasks of logical objective duration. First of all, the clock can extend performance and extend the limits of the ZDP. This idea is consistent with the contextual model of concept development. In those terms, the clock can assist in the demonstration of an unconsolidated skill. As a psychological tool, the clock brings the social interaction of cultural evolution to bear on the task. If the child can utilize the clock, it brings a powerful resource to their problem solving. Thus, in more concrete terms, it is hypothesized that the children can utilize the psychological tool of a clock to increase their demonstration of a concept of objective duration.

Integrating the two temporal systems is representative of interacting development of conceptual systems. The development of both, as interacting and codefining systems, will not be simply combining the two courses of development. The development of integrated objective duration will be significantly different than logical development studied in isolation. This describes the second critical function of psychological tools. As defined by Vygotsky, psychological tools do not simply extend performance, but fundamentally transform mental functioning. Thus, it is hypothesized that through using the clock to help construct a concept of objective duration, the developmental course of the concept will be altered. One goal of the study is to microgenetically demonstrate the differential course of development due to the impact of psychological tool use. This goal of the study is more exploratory, as there is also a need to search for a method to measure the developmental impact of psychological tools. The role of psychological tools in concept development is critical, not only to understanding the development of the concept of objective duration, but also to an understanding of differences in development across contexts with different psychological tools available.

Method

The development of objective duration within both a logical system and a system of cultural meaning were examined. The effect of cultural temporal concepts on the display of logical conceptual skill was directly compared with a baseline assessment of a concept of logical objective duration. It was hypothesized that children who failed to construct logical objective time, but whose skills were within the zone of proximal development, would be able to use a representation of the cultural system as a psychological tool to construct objective duration. This demonstration would challenge the validity of any theoretical course of the development of temporal concepts that does not consider both logical and cultural systems of meaning.

An analog clock represented the system of cultural time. The similarites and differences between the operationalized clock and clocks usually encountered by the children were discussed before the tasksets began. This discussion also included talk about the differences between analog and digital clocks, and specific clocks with which the children were familiar. Then, the children were shown how the clock was made and how to work it. A 4-inch square basketball timing clock was modified to consist of only a solid second hand. The clock did not have an hour or minute hand. This simplified the clock to its most basic function of marking short time spans (up to 60 seconds). Each 5 second interval was marked on the clock face by the numerals 1 through 12, for consistency with the numbering generally found on clocks. The clock could be turned on and off by a button on the top, and reset by pulling a knob on its side. For the duration comparisons, the beginning and ending points of the two intervals were marked on the clock face with colored stickers. Thus the succession points were perceptually available for duration comparison. Qualitative comparisons based on the relative order of the stickers or the spatial representations of duration between the stickers were sufficient to infer relative duration.

The basic design of the study compared performance without the clock (the no clock (NC) condition) with performance with the clock (the clock (CL) condition), across 3 tasksets of duration subsystems. Each taskset was presented first in the NC condition and then in the CL condition. Thus, the effect of cultural time on three types or subsystems of duration (Montangero, 1985) in the development of objective duration was examined. The first taskset was "successive duration", in which the beginning and ending of two events had to be coordinated in order to construct duration. The second taskset, "activity duration", focused upon the relationship between objective time and the subjective impressions of duration created by two different activities. The third taskset, "linear duration", coincided with Piaget's definition of objective duration through the coordination of the velocity, distance and speed of two events. For all three of the tasksets, the successful demonstration of a concept of objective duration was operationally defined by the comparison of two durations. This comparison implied the use of a unitary, independent and constant time scale, directly reflecting Piaget's definition and operationalization of objective duration. In addition to an assessment of objective duration, Taskset 1 provided training on the demands of the study and on the use of the clock. Tasksets 2 and 3 were counterbalanced to control for order effects. All sessions were videotaped.

Two dependent measures were used to assess objective duration. For each duration comparison pair, the children were asked to determine the longer duration. This was the judgement response. After a correct or incorrect judgement response, the children were asked to explain the basis for their judgement. This was the justification response. The clinical interview method was used to elicit the clearest demonstration of the child's understanding. Thus, the child's responses directed the experimenter's questions and comments. Individually structured comments and explanations scaffolded the child's demonstration of unconsolidated skill. The explicit goal of the experimenter-child interaction was to socially construct a concept of objective duration. The interindividual social interaction was a central component of both the NC and CL conditions. The CL condition added the effect of a product and a tool of socio-cultural interaction.

A total of 48 children participated, 3 different age groups of 16 each. The children, primarily white, middle class, were drawn from a suburban summer camp program and from a small private school in the same area. Group 1 consisted of 4 boys and 12 girls. Their mean age was 5;7, with a range of 5;0 to 5;11. Group 2 was comprised of 11 girls and 5 boys, who had completed the kindergarten year. Their ages ranged from 5;11 to 6;10, with a mean age of 6;4. Group 3 had completed the first grade level. There were 7 boys and 9 girls in this group, with a mean age of 7;2, ranging from 6;9 to 7;8. The high female to male ratio reflected the composition of the groups from which the subjects were drawn.

Procedure

Each child participated in three sessions, within the same week, to assess duration comparison in the three tasksets. Within each session, the appropriate duration taskset was presented first in the no clock (NC) condition and then with the use of the clock in the clock (CL) condition. The experimenter was introduced to the children as someone interested in how kids think, not about school things but about how long things take. Each session was videotaped and dependent responses were coded directly from the videotaped record.

The first session involved "successive duration", which entailed coordinating the relative starting and ending order of events with the intervals or durations of the events. Levin's (1977) still time task was replicated, in which the inference of relative duration by comparing the beginning and ending points of the sleeping time of two dolls was required. The props used for this taskset were one-inch tall plastic Fisher-Price figures and the green beds provided as part of the Fisher-Price Little People House. The experimenter stated when it was time for each doll to go to sleep and awaken. The children placed and removed the dolls from the beds at the appropriate times. The experimenter unobtrusively timed the duration of the sleeping times with the second hand of a watch. The taskset consisted of four basic variations of the succession points:

1. Beginning points same, end points different

    T1---------------------end

    T2---end

    T1 begins at 0 secs and ends at 15 secs.

    T2 begins at 0 secs and ends at 30 secs.

2. Beginning points different, end points same

    T1---end

    T2---------------------end

    T1 begins at 0 secs and ends at 30 secs

    T2 begins at 15 secs and ends at 30 secs

3. Beginning and ending points different; T2 contained within T1

    T1---end

    T2------------------end

    T1 begins at 0 secs and ends at 45 secs.

    T2 begins at 15 secs and ends at 30 secs.

4. Beginning and ending points different; T1 = T2

T1-----------------------------------end

T2------------------------------end

T1 begins at 0 secs and ends at 30 secs.

T2 begins at 15 secs and ends at 45 secs.

All four variations were presented first in the NC condition and then repeated in the CL condition. For each variation, the children were asked for a judgement and a justification response. At all points, the children were given feedback and the correct answers, if necessary, to assist in the construction of objective duration.

In the NC condition, for each variation, after the presentation of the two intervals the children were asked to judge relative duration:

" Which doll slept longer?"

" Which doll slept for more time?"

If the child did not seem to understand the question or how to answer it, a series of questions followed to help the child. First, her attention was drawn to the succession points to ensure at least a perceptual grasp and memory of the events:

"Who went to sleep first? Who went to sleep second?"

"Who woke up first? Who woke up second?"

If necessary, the relationship between the succession points and the inference of duration was made explicit. For example:

"So, if he went to sleep first and then she went to sleep and they both woke up together, who was sleeping for more time?"

"If he went to bed first, he was sleeping for a while before she got to bed. Then, she finally goes to bed. If they both wake up together, then that means .....? Who slept longer?"

If necessary, the situation was presented as a story about the child and their friends/siblings. And finally, if necessary, the variation was repeated with an emphasis on the succession points.

If the child correctly judged relative duration, then the child was asked to explain how he arrived at that conclusion. This was the justification response.

" How can you tell? How do you know?".

" How did you figure that out?"

If the child did not respond appropriately, the role of the succession points in the inference of duration was explained. The explanation was based on the experimenter's interpretation of the child's lack of understanding. For example:

" You just told me that he slept longer. Why?"

" He went to sleep first and was sleeping for a while. Then she went to sleep. And then they both woke up at the same time. That's why he slept longer."

In order to be scored as a correct justification, the child had to provide the reasoning and survive probe questions, which challenged their grasp of the justification.

In the clock condition, each doll's head was marked with a differently colored sticker. The experimenter started the clock when the first doll was put into bed. The starting time and stopping time of each doll's sleeping interval was marked on the clock with a colored sticker that corresponded to the color of the sticker on the doll. The children were then asked:

"Which doll slept longer? Which doll slept for more time?"

"How do you know? How can you tell?"

"How did you figure that out?"

With a correct judgement of duration, the child was asked to provide a justification for her judgement. With an incorrect judgement, the child was asked if he could use the clock to help them see which doll slept longer. The child's attention was directed to the stickers on the clock that corresponded to the succession points. The experimenter attempted to help the children compare relative duration through the beginning and ending points of the sleeping intervals. For example,

" Can you use the clock to help you see which doll slept longer?"

"Where on the clock did the yellow doll go to sleep? And where did she wake up?"

"Where did the red doll go to sleep and wake up?"

"So who woke up first/went to sleep first?"

If necessary, the next prompt demonstrated a qualitative comparison of the sleeping times as represented spatially by distance on the clock. The use of the numbers on the clock face or counting units were not used to explain how to compare the sleeping times, unless mentioned by the child. This spatial prompt included comments such as:

> (using the child's finger to trace) "So the red/yellow doll slept from there to there. Which is longer?"
> "The red doll was asleep all this time before the yellow doll went to sleep, but then the yellow doll was asleep after the red doll woke up."

If necessary, the sleeping intervals were reenacted with the child focused on the role of the clock to make the representation of duration on the clock explicit. In short, the children were trained to use the clock to compare durations if they were initially unable. This session ensured that all the children understood the representation of time on a clock and comprehended the task demands, which were similar across the sessions.

In the second set of tasks, "activity duration" was studied. This subsystem involved the understanding that the rate of a discontinuous activity, including the amount of work accomplished and subjective estimations of effort, are independent of objective duration. The differential rate taskset partially replicated a study performed by Fraisse (1963). The children transferred uncooked macaroni from one container to another, first using a ladle and then using a small baby teaspoon. The two actions varied on the rate of activity (the number of macaroni transferred per motion), the effort involved (the differential difficulty of the ladle versus the spoon), the amount of work accomplished (number of macaroni transferred) and thus the feeling of subjective duration varied.

There were three variations in this taskset. Within each variation, each pair of task activities were performed successively, first the ladle and then the spoon. The three variations were presented in the NC condition first, then repeated with the use of a clock. The experimenter surreptitiously timed each of the activities in the variations. There was sufficient macaroni so that the amount did not limit the duration of the task. The children were instructed as follows, with checks for understanding;

> " Remember that we've been talking about how long it takes to do things? This time, I'd like you to spoon macaroni from one container to the other first with the ladle, and I'll tell you when to start and stop: And then with the spoon and I'll tell you when to start and stop. Then I'm going to ask you which took longer, which you were using longer. Try to pay attention to how much time you're using each for, not how much macaroni you can put in the other box, or how hard it is."

The three variations of the taskset were presented in the following order:

1. Task 1 = Task 2 : The ladle activity and the spoon activity were each timed for 30 seconds.
2. Task 1 > Task 2 : The ladle activity was timed for 15 seconds and the spoon activity for 30 seconds.

3. Task 1 < Task 2 : The ladle activity was timed for 30 seconds and the spoon activity for 15 seconds.

After each variation, the children were asked for a duration judgement and justification:

"Were you using the spoon for more time or the ladle for more time? Which were you doing longer?"

"How can you tell? How do you know?"

"How did you figure that out?"

After the inference of duration was made, the justification of the duration judgement was not deeply probed. This was because there is no logical basis upon which to compare the durations of two successive activities, unless counting or measurement is used. The child was allowed to repeat any of the variations, if she were uncertain of her answers.

The children then repeated the three taskset variations with the use of a clock as a tool to represent duration. The handles of the spoon and ladle were labeled with colored stickers. In the clock condition, the beginning and ending points of the ladle activity were marked on the clock with corresponding colored stickers. Then the clock was reset back to 0, and the beginning and ending points of the spoon activity were marked with stickers the same color as on the spoon. Thus, the beginning and ending points of the two successively presented durations were marked on the clockface. After each variation, the children were asked to judge which duration was longer:

"Were you using the spoon for more time or the ladle for more time? Which were you doing longer?"

Then the child was asked to explain how they determined their choice, the justification response:

"How can you tell? How do you know?"

If the child could not explain their choice and did not spontaneously use the clock they were prompted:

"Can you use the clock to help you tell which one you were doing longer?

If necessary, a series of prompts, similar to those used in the successive duration taskset, directed the child's attention to the clock and to the relationship between the stickers on the clock and the intervals of their activities. The simultaneous representation of the two successive activities was a potential source of confusion, and was explicitly addressed;

"This is were you started using the ladle, and this is where you stopped using it. And then we reset the clock. This sticker marks where you started using the spoon and here is where you stopped. So you were using the ladle from here to here (tracing between stickers with child's finger) and the spoon from here to here. Which were you using for more time? Can you tell me how you figured that out?"

In order to be scored as a correct justification, a restatement of the experimenter's explanation had to survive probe questions. The goal of this session was to determine if the children could overcome the subjective impression of duration, based on the rate of their own activity, with the use of a cultural representation of objective duration.

Taskset 3, the "linear duration" subsystem corresponded to the logical understanding of duration as specified by Piaget. The understanding that duration and distance are linearly related must be coordinated with the understanding that duration and velocity are inversely related. To reiterate Piaget's position, this integration is not achieved until concrete operational logic and is the cornerstone in the construction of an independent, constant objective duration. Taskset 3 replicated the definitive Piagetian time task (1969), in which the duration of two journeys is compared, while varying the parameters of distance and speed. The figures used were a set of small, 1.5 inch, wind up toys. For the tasks involving equal velocity, the figures were a pair of differently colored owls. For the tasks involving unequal velocities, the figures were two different dinosaurs or a ladybug and a turtle. The task was presented in terms of the animals taking a walk.

Four variations of linear duration comparison were presented in invariant order in the NC condition, then repeated in the CL condition. The first two variations involved equal velocities, and thus temporal and spatial cues coincided for duration judgements. A correct judgement of longer or equal duration corresponded to the distance traveled, because the velocity of both figures was equal.

Temporal and spatial cues were confounded. The second two variations varied velocity, and thus temporal and spatial cues conflicted in the determination of relative duration. A duration judgement based on spatial cues would not be the same as a duration judgement based on temporal cues, such as succession points. The 4 variations were:

1. Equal velocities, unequal distance, unequal time

T1----------------------end (10 secs)

T2--end(20 secs)

Both figures begin their journeys at the same temporal and spatial point at the same constant rate of speed. T1 stops before T2 and thus journeys for a shorter distance and a shorter duration.

2. Equal velocities, equal distance, equal time

T1---------------------------------end (15 secs)

T2---------------------------------end (15 secs)

Both figures begin and end at the same temporal and spatial point and have equal velocities.

3. Unequal velocities, equal distance, unequal time

T1-----------------------------end (slower - 20 secs)

T2==============(faster - 10 secs)

Both figures begin their journeys at the same spatial and temporal point and cover the same distance. T2 is traveling faster than T1, and thus completes the journey in a shorter duration.

4. Unequal velocities, unequal distance, equal time

T1==============================end (faster - 15 secs)

T2------------------------------end (slower - 15 secs)

Both figures begin their journeys at the same spatial and temporal point. Both figures end their journeys at the same point in time, that is the duration of both journeys is the same. T1 is traveling faster than T2 and thus covers more distance.

After each variation the children were asked:

" Who took a longer walk? Who was walking for more time?"

Once the child made a duration judgement, correct or incorrect, they were asked to explain how they arrived at that conclusion:

"How do you know that? How can you tell? How did you figure that out?"

If the children focused on the wrong set of cues or were unable to answer, the relevance of the succession points to the duration judgement was made explicit. For example,

"Which one stopped first? So if he stopped first and the other one kept going, who was walking for more time?"

The next type of prompt depended upon the task variation. For variation 1 and 2, the difference between "longer" duration and "longer" distance would be explained:

"That's who got farther on the board, but is that who went for more time? It's not always the same."

For task variation 3 and 4, in which there were different velocities, a correct distance judgement would not result in a correct duration judgement. The role of velocity was used to explain why. For variation 3:

> "If the ladybug and the dinosaur both got to the same point on the board, how come it took the dinosaur so long to get there?"

And similarly for variation 4:

> "If they both were walking for the same amount of time, how come the ladybug got so far ahead?"

If the child still seemed uncertain about this explanation, the analogy of walking with a friend or playing "Red light, green light" was used. The variations were repeated as often as needed.

The taskset was repeated with the use of a clock to mark the durations. The succession points of the journeys were marked on the face of the clock with color coded stickers. The wind up toys had corresponding stickers on them. The children were asked to judge which duration was longer and to explain their answer. The series of prompts was similar to the previous tasks. First, the succession points were noted by referencing the stickers on the clock face. Then the correspondence between these points and the toys' journeys was noted. Finally, the integration of distance and velocity cues with duration as represented on the clock was discussed.

> "If you look at the board, you can see that the ladybug is farther ahead than the dinosaur. The board tells you traveled more distance. But now look at the clock. The stickers on the clock tell you who traveled more time."

The goal of this taskset was to determine if the children could use the clock to visually represent duration, and thus assist in the separation of duration from distance cues and the coordination of duration with velocity.

At the conclusion of the last session, the children were thanked again for their participation.

Scoring

The children's performance in the task variations was categorized on each task variation as successful or unsuccessful for two types of responses. First, a decision was made to determine if the child correctly compared the durations by indicating which of 2 durations was longer. This is the judgement response. The second decision determined whether or not the child could justify her choice. That is, in Piagetian logical terms, the child had to explain how she reached the relative duration decision. Thus, the coding created two dichotomous response categories, the judgement and justification response. Reliability checks were performed for the two dependent response categories.

The decision rules for determining a correct judgement applied across the tasksets. The child had to choose the longer relative duration, or make an equal duration judgement, if appropriate. If the child's first choice was correct, it was scored as a correct judgement, and the justification process began. If the child's initial judgement was incorrect, the experimenter tried to understand the basis for the incorrect choice through probing for the justification. The experimenter then attempted to correct any misunderstanding on the part of the child. A correct justification was constructed between the experimenter and the child. For example, the experimenter would question the child about the cues relevant to a correct decision, correcting any misperceptions. Then the experimenter would try to help the child coordinate the cues to make an inference about duration. The child would be asked again for a correct judgement. If the child could determine the relative duration, the experimenter would ask the child to justify their response as a check for understanding. Thus, the justification response in addition to being an independent response category, also provided a means of checking the child's understanding of a jointly constructed judgement response. If the child could justify their judgement and survive probe questions, she would be credited with a correct judgement (and justification).

Strict criteria were used to determine a successful justification. If the child's initial justification was incorrect, the experimenter attempted to help the child construct an understanding of the relationship of cues to duration. If the child could then restate the correct justification, and answer probe questions, then she was given a correct score. Probe questions focused on the individual components of the relationships between duration and the various cues, upon which the justification was based. The basis for correct justifications depended upon the task variation. Correct justifications for each variation in the NC condition include the following:

Taskset 1

Variation 1 - The focus should be on the relative order of the endpoints, for example, "this doll woke up first (second)"; "he woke up before (after) the other doll" or "she got up earlier (later) than he did."

Variation 2 - The relative order of the beginning points is central to the criterion explanation. Comments such as, " this one went to sleep first (second)"; "went to sleep before (after)" or "this doll went to sleep earlier (later)" were scored as correct.

Variation 3 - The relative order difference in both the beginning points and endpoints must be included. For example, "One went to sleep earlier (first, before) and woke up later (second, after)." If a child gave either beginning points or endpoints as an explanation, they were asked if there was another reason, a second reason. The experimenter pointed out the other reason through leading the child with questions. If the child could then state both reasons, and answer additional questions about the temporal relationships, then they were given a correct justification score.

Variation 4 - The relative order of the beginning points must be balanced against the relative order of the endpoints to correctly justify the judgement of equal duration. For example, "The red one went to sleep first, but he also woke up first, so it evens out" or "The time he was asleep before the yellow went to bed is the same as the time as the time the yellow one was asleep after he got up."

Taskset 2

Variation 1, 2 and 3 - Correct justifications must coordinate 2 or more cues. For example, the amount of macaroni must be balanced against the relative size of the ladle/spoon in order to be a sufficient cue for duration inference. Explanations which seemed to rely on perceptual information ("It just felt/seemed longer") were not scored as correct justifications.

Taskset 3

Variation 1 - Correct justifications focus on the relative order of the temporal succession points. For example, "This owl stopped before that owl" or "The red owl stopped first, and the other one kept walking for a while and then he stopped." References to spatial succession points were scored as incorrect justifications. Examples of incorrect spatial justifications include, "This owl went the whole way and this owl only went halfway" or " The yellow owl walked for more time because he's farther ahead."

Variation 2 - A correct judgement of equal duration was correctly justified by referring to the simultaneity of the endpoints. For example, "They both stopped at the same time". Spatial explanations were not scored as correct, "They both got to the same place."

Variation 3 - Correct justifications focused on the relative order of the stopping points. Examples include statements such as, "The ladybug stopped before the dinosaur." The ladybug stopped walking first, then the dinosaur stopped second." Statements on the role of velocity in the duration-distance relationship were not necessary for a correct justification. A focus on the spatial cues would lead not only to an incorrect justification, but also to an incorrect judgement of equal duration.

Variation 4 - The simultaneous endpoints of the ladybug and the dinosaur should be included in the correct justification. Statements such as, " They both stopped at the same time." ; "Neither one stopped walking first, they both did." would be scored as correct. It was not necessary to integrate the role of velocity to be counted as a correct justification. Reliance on spatial cues would lead to an incorrect judgement and justification.

<u>Clock Condition</u>

In the clock condition, correct justifications could be made without the use of the clock, however, the experimenter would generally prompt for an additional justification using the clock. The clock could be used in two ways to justify duration judgements. First of all, the marked succession points could be used to perceptually support an explanation based on relative beginning points or endpoints. An example of the use of the colored stickers in a justification would be, (Taskset 1, variation 1);

" The red and yellow doll went to sleep here (pointing to the 2 stickers at the beginning) and the red doll woke up here (pointing to the red sticker on the 15 second mark) and the yellow doll woke up here (pointing to the yellow sticker on the 30 second mark). So the yellow doll woke up after the red doll and slept longer."

If the child did not complete the justification with the inference, the experimenter would probe the understanding of the relative order (who woke up first?) and the connection to the duration inference (so which doll slept for more time?). Although the temporally related cues varied across tasksets, the clock could be used similarly to construct relative duration through succession points.

The clock could also be utilized to construct justifications through a comparison of the distance between the stickers on the clockface. The distance between the two stickers of the same color represent the temporal interval between the succession points. The differences between the two distances (and intervals) to be compared in each variation were discrepant enough that a qualitative comparison was possible. Justifications based on a qualitative comparison of the two distances include statements such as:

" (Taskset 1, variation 1) The red doll slept from here to here (tracing between the red stickers). But the yellow doll slept from here all the way to here (tracing between the yellow stickers). So the yellow doll slept for more time."

Probe questions were used to ensure that the child understood the relationship between the distance on the clockface and the temporal interval. This clock-based representative distance justification could be utilized across the variations of the three tasksets.

Results

Reliability checks for the dependent response categories were performed by a single coder on 15% of the data. Analyses determined that the percentage agreement on the judgement response was 96.2 %, and the percentage agreement on the justification response was 87.1 %. In addition, presentation order analyses revealed no effect. No differences were found in Taskset 2 performance as a function of presentation order for the judgement response in the NC condition ($t=.35$) or CL condition ($t=.085$). The order did not affect the justification response in either condition (NC- $t=.99$; CL- $t=.13$). Similarly, there were no differences in judgement responses (NC- $t=.57$; CL- $t=.13$) or justification responses (NC- $t=1.72$; CL- $t=.65$) in Taskset 3 as a function of presentation order. The preceding presentation order analyses all were performed with $df=47$, critical value of 2.012 at $p <.05$. The groups were combined for the rest of the analyses.

Two levels of analysis were performed on the data, multivariate anovas to determine group and condition effects and interactions, and McNemar tests to locate the differences in performance between the no clock (NC) and clock (CL) conditions. The first step in the multivariate analyses was the determination of taskset scores. For each taskset, a score was given which corresponded to the number of variations correctly solved. In Tasksets 1 and 3, a score of 4 was possible within each condition for the judgement responses and justification responses. In Taskset 2, the maximum score was 3 for each response type, corresponding to the three variations in Taskset 2. A 3 x 2 repeated measures analysis of variance was performed to test for group effects, the difference between performance in the clock versus the no clock condition, and the interaction between the group and condition variables. In addition, a doubly multivariate design was used to incorporate the two dependent response variables of judgement and justification. A separate analysis was performed for each taskset.

At the most molecular level of analysis, the McNemar Test was used to determine the significance of the change in correct performance across the two conditions, NC and CL. This test of significance is applicable to designs in which the individual serves as his own control and the dependent measure consists of a dichotomous nominal or ordinal determination (Siegel, 1956:63). A total of 66 individual McNemar tests were performed, one analysis for each task variation (11) performed by each group (3) for the judgement and justification response (2). The results of both analyses, multivariate anovas and McNemar tests, will be discussed within each type of duration taskset.

Taskset 1 - Successive Duration

This task replicated and extended the work of Levin and her colleagues on children's comparison of still time durations. The four task variations all required a judgement of the relative duration of the sleeping intervals of two dolls. Each variation consisted of different combinations of beginning points and endpoints to be considered for a correct judgement. The means and standard deviations of the taskset scores for each group for Taskset 1 performance are presented below. The maximum score for a correct solution, within one condition and response type, is 4. Judgement and justification responses are considered separately throughout the analysis. The final column combines responses across conditions for the analysis of a group main effect.

TASKSET 1 - TASKSET SCORES - MEANS AND SD						
JUDGEMENT						
	NC CONDITION		CL CONDITION		NC + CL	
	M	(SD)	M	(SD)	M	(SD)
GROUP 1	2.75	(.447)	3.13	(.719)	2.93	(.619)
GROUP 2	3.00	(.516)	3.69	(.479)	3.34	(.602)
GROUP 3	3.00	(.730)	3.56	(.512)	3.30	(.693)
JUSTIFICATION						
GROUP 1	1.25	(.931)	1.81	(1.167)	1.53	(1.077)
GROUP 2	2.31	(1.138)	3.56	(.727)	2.93	(1.134)
GROUP 3	2.56	(1.202)	3.38	(.806)	3.06	(1.014)

Multivariate and univariate tests of significance indicate that there was a strong condition effect, that is, that there were significant differences in correct responses between the NC and CL condition. This difference was found for both types of responses, judgement ($F\ (1,45) = 30.000$, $p < .0001$) and justification ($F\ (1,45) = 25.296$, $p < .0001$). For those children who did not correctly judge and justify the correct duration, the use of a clock improved performance. Thus, the clock helped the children make correct relative duration judgements and helped them justify their responses.

Analyses indicate that the hypothesis of no group effect should be rejected. Univariate analyses indicated that there was a significant difference across the three groups for each dependent variable, judgement ($F\ (2,45) = 3.522$, $p < .038$) and justification ($F\ (2,45) = 16.729$, $p < .0001$). Thus, the three groups' performances were significantly different from one another for both the judgement and justification response. An examination of Table 1 indicates that the significant effects are due to the differences in scores between Group 1 and the other two groups. The scores of Group 2 and 3 are more similar to each other. The six- and seven year old children performed more similarly to each other than to the five year old group.

Multivariate and univariate tests of significance indicate no significant group by condition interactions.

Thus, the results of taskset scores manovas indicate significant group and condition effects, for both the judgement and justification responses. There were no interactions between the two main effects.

McNemar Analyses

The results of the McNemar analyses for Taskset 1 locate the specific differences in performance from the NC to CL condition. Each group's performance across conditions was analyzed within the 4 taskset variations for both response types, judgement and justification.

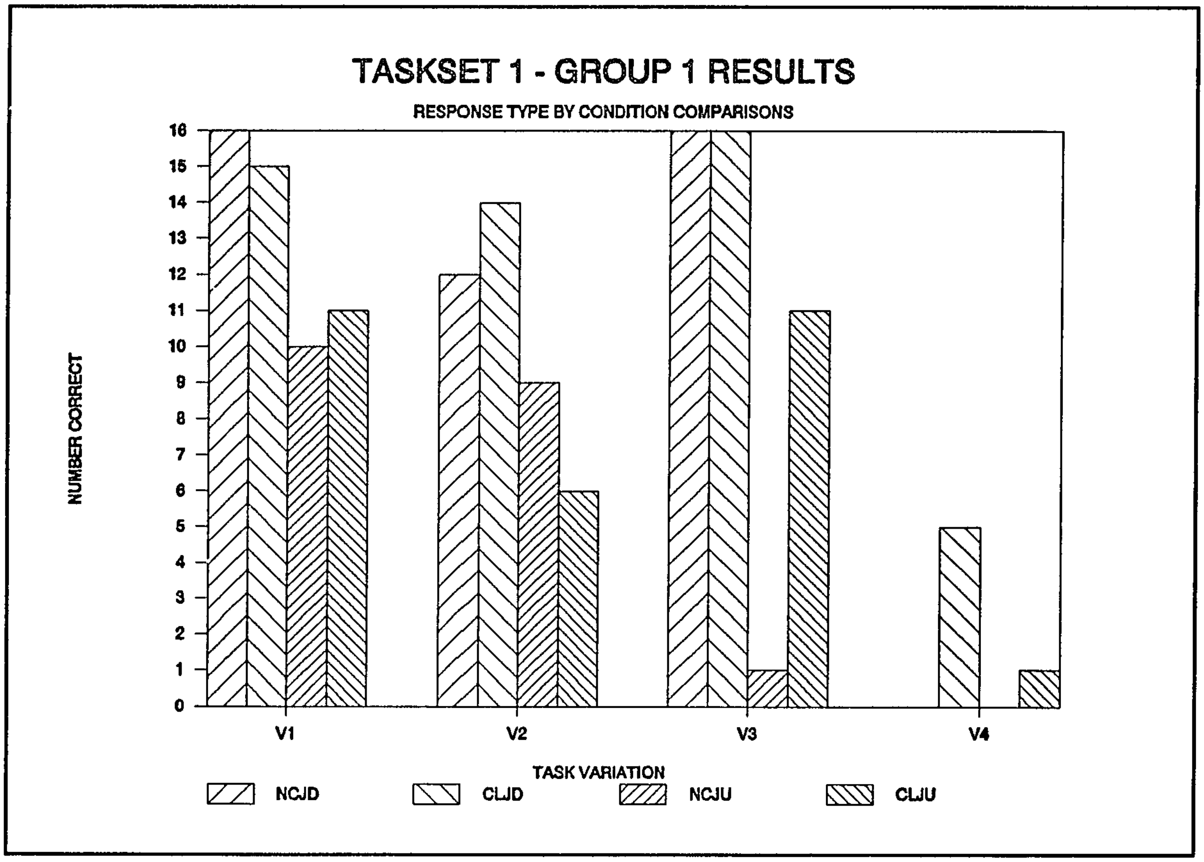

Figure 1

Group 1

Figure 1 presents Group 1 results across the four variations of the first taskset. None of the judgement response differences between the NC and CL condition were significant. In Variation 1 and 3, there was close to ceiling performance in the NC and CL conditions. On Variation 2 and 4, performance improved with the use of the clock, but not significantly. Variation 4 demonstrated a strong trend in improved performance at the significance level of $p < .06$. Group 1 seemed to be gaining familiarity with the task demands and learning how to use the simplified clock.

Only one difference between justification responses was significant. On Variation 3, there was a significant increase in correct justifications between the NC and CL conditions ($p < .002$). Performance in Variations 2 and 4 showed a nonsignificant increase, while there was a nonsignificant decrease in correct justifications in the CL condition of Variation 2. This was one of only two decreases in performance from the NC to CL condition across all the task variations for the entire sample. This variation involved staggered beginning times. Perhaps the perceptual salience of the endpoints was doubly reinforced by the waking of the dolls and by the representation on the clock face. This may have resulted in the child's focus on the endpoint overwhelming any simultaneous consideration of the beginning points.

<u>Group 2</u>

Figure 2 presents the results of Group 2's performance on Taskset 1. Group 2 achieved ceiling performance on Variations 1 and 3 across both conditions with their judgements of duration. Judgement responses improved from the NC to CL condition in both Variations 2 and 4, with only the difference

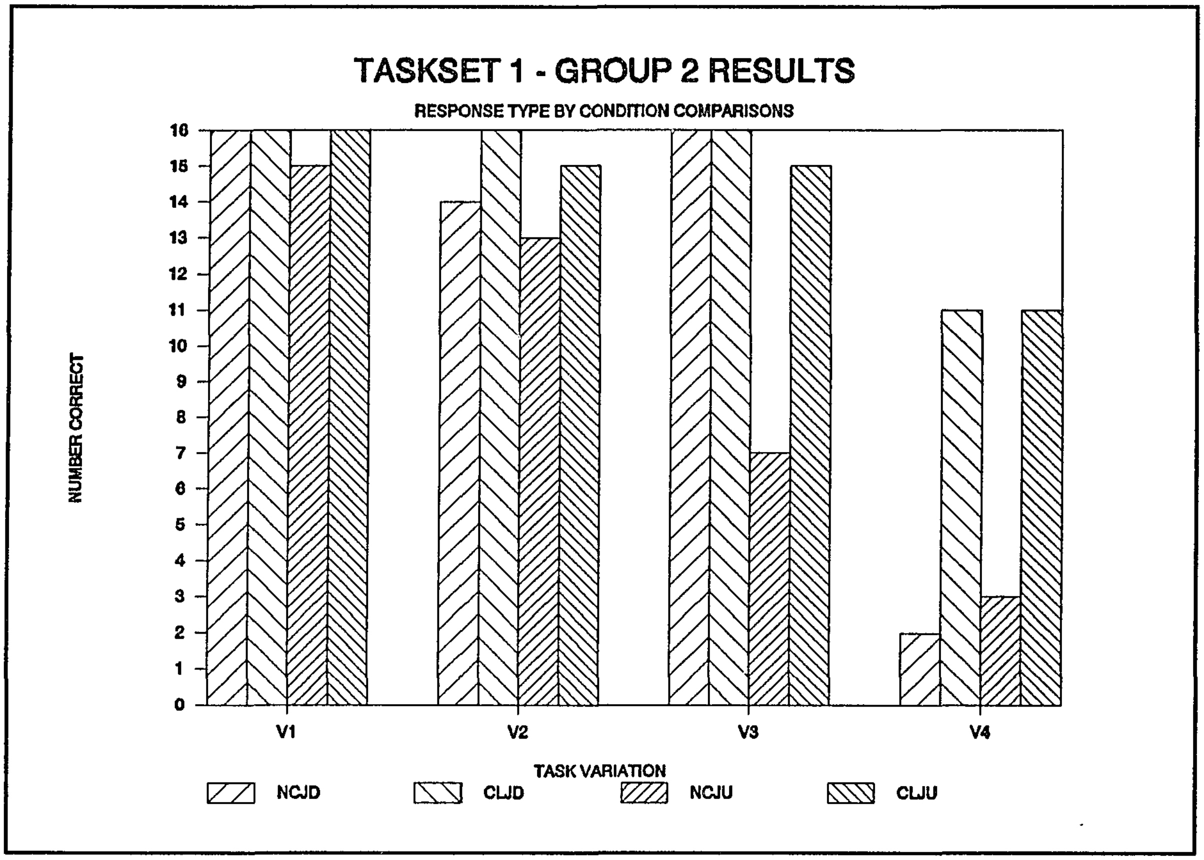

Figure 2

in Variation 4 significant (p <.004).

There was improvement in number of correct justifications given by the group from the NC to CL condition on all 4 variations. The differences in justifications are significant in Variation 3 (p <.008) and 4 (p <.008).

Group 3

Figure 3 presents the judgement and justification responses of Group 3 on Taskset 1. There was ceiling performance on the judgement responses of Group 3 on Variation 1 and 3. The number of correct judgement responses increased in the CL condition in both Variation 2 and 4, but the

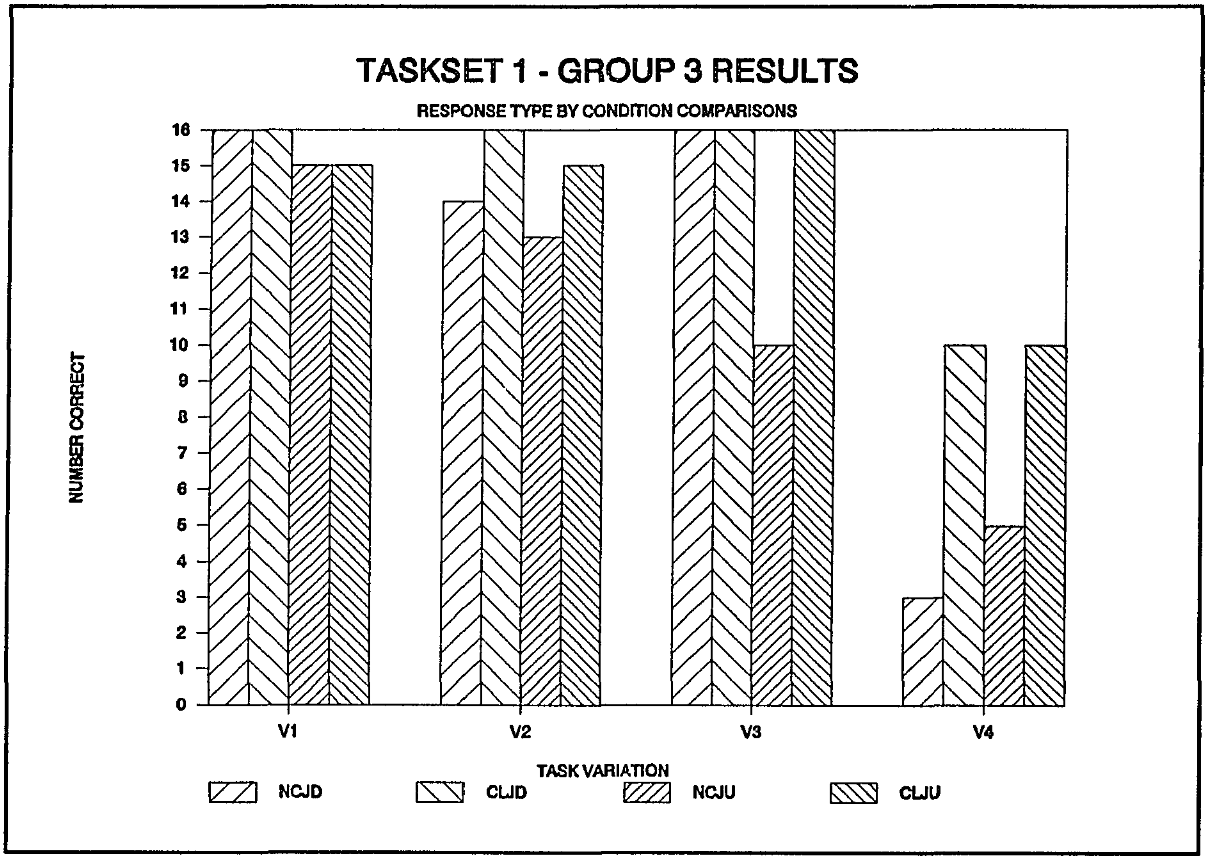

Figure 3

difference was significant only in Variation 4 (p <.03).

On Variation 1, there was no difference in correct justifications between conditions, with close to ceiling performance. For the other 3 variations, there were more correct justifications in the CL condition than in the NC condition. The difference was not significant in Variation 2, not significant, but a strong trend, in Variation 4 (p <. 06), and significant in Variation 3 (p <.03).

Task 1 Summary

TASKSET 1 MCNEMAR RESULTS						
	GROUP 1		GROUP 2		GROUP 3	
	JD	JU	JD	JU	JD	JU
VAR 1	NS	NS	CEILING	NS	CEILING	NS
VAR 2	NS	NS	NS	NS	NS	NS
VAR 3	CEILING	.002	CEILING	.0078	CEILING	.0313
VAR 4	(.06)	NS	.0039	.0078	.0313	(.06)

Table 2 summarizes the pattern of significant differences between the NC and Cl conditions for the 4 variations of the first taskset for the three groups of subjects. This demonstrates that for Variations 1 and 2, performance in the CL condition did not differ from performance in the NC condition. Variation 1 consisted of simultaneous beginning points and staggered endpoints, so that one doll slept longer than the other. Variation 2 presented the opposite configuration; staggered beginning points and simultaneous endpoints. For Group 2 and 3, this can be understood in terms of the high rate of performance in both variations. Group 1 seemed to be gaining familiarity with the task demands and learning how to use the simplified clock.

On Variations 3 and 4, in general, if performance was not at ceiling levels, the clock improved performance, in most cases significantly. The judgement response in Variation 3 resulted in ceiling performance for all 3 groups in both conditions. This variation consisted of one of the durations being included within the other duration. Thus, the judgement of relative duration was easily made on the basis of either the sequence information of the beginning points or of the ending points: the same doll went to sleep first and woke up last. Justifying the judgement was more difficult, for it required a consideration of both the beginning and ending times.

The single exception to the pattern of ceiling or improved performance was Group 1's justification response to Variation 4. This can be explained by the task difficulty for the youngest group. Variation 4 involved staggered beginning and ending points for both dolls, but both dolls actually slept for the same amount of time. In contrast to the other task variations, this task could not be solved by succession points alone. Variation 4 required some basis for comparing the two durations, in addition to coordinating the sequence information of the two events. The clock provided a perceptual means for comparing the amount of time in terms of the distance represented by the two sleeping durations. That is, comparing the relative amounts of time could be done perceptually by comparing the distances on the clock face. The variation was set up so that each doll slept for 30 seconds. On the clock face this duration is represented by one-half of the circle of the clock face. One doll slept from 0 to 30 seconds and the other doll slept from 15 to 45 seconds, and these points were marked on the clock face by stickers. There were several ways that a child could recognize the correspondence between the two representations. A child could discover that both dolls slept for half a circle. Another way to recognize the same quantities would be to realize that the time that Doll A was asleep before Doll B is the same as the time that Doll B was asleep after Doll A woke up. These recognitions of the perceptual correspondences between the distances, which represented the sleeping durations, were explicitly pointed out to the children, and, if given by the children, were scored as correct justifications. None of the youngest group were able to correctly judge relative duration (nor justify it) without the clock. With the use of the clock, a few children were able to judge the durations and to justify their judgements, but this slight increase was not significant.

The McNemar results demonstrated that the manova result of condition main effects for the judgement and justification responses were due to the performances in Variation 3 and 4. The use of the clock improved performance in these variations. This may be an indication of the appropriate level of difficulty of the task. The high levels of correct performance in the first two variations in the no clock condition potentially explain the limited value of the clock in improving performance in these variations.

Taskset 2 - Activity Duration

The second taskset consisted of three variations in which the children compared two durations involving the children's own activity. For each variation, macaroni was scooped from one container to another, first using a ladle, then a baby spoon. In contrast to the other tasksets, the activities were not presented simultaneously, but as successive intervals. It seems likely that successive presentations of the two events to be compared, in the NC condition, would place a larger demand on memory than on the capacity for simultaneous attention to several dimensions. In the CL condition, one of the primary roles of the clock would be to serve as a memory aid for the duration of the first activity, rather than as a tool to represent information in order to reduce the strain on simultaneous capacity.

The means and standard deviations of the taskset scores for each group for Taskset 2 performance are presented below. The maximum taskset score, within one condition and response type, is 3. Judgement and justification responses are considered separately thorughout the analysis. The final column combines responses across conditions for the analysis of a group main effect.

TASKSET 2- TASKSET SCORES - MEANS AND SD						
JUDGEMENT						
	NC CONDITION		CL CONDITION		NC + CL	
	M	(SD)	M	(SD)	M	(SD)
GROUP 1	1.56	(.727)	2.75	(.447)	2.16	(.847)
GROUP 2	1.75	(.447)	3.00	(0)	2.38	(.707)
GROUP 3	1.88	(.500)	3.00	(0)	2.44	(.669)
JUSTIFICATION						
GROUP 1	.63	(.885)	2.25	(1.125)	1.44	(1.294)
GROUP 2	1.19	(.911)	3.0	(0)	2.09	(1.118)
GROUP 3	1.25	(.931)	2.88	(.500)	2.06	(1.105)

Analyses indicated that the hypothesis that there was no group effect should be rejected. Univariate analyses indicated that there were significant differences in the correct responses across the three groups for each dependent variable, judgement (F (2,45) = 3.88, p <.028) and justification (F (2,45) = 5.81, p <.006). Univariate tests of significance indicated that there was also a strong condition effect, that is, there are significant differences in correct responses between the NC and CL condition. This difference was found for both types of responses, judgement (F (1,45) = 158.74, p <.0001) and justification (F (1,45) = 118.43, p <.0001). Thus, the use of the clock enabled children to correctly judge and justify relative durations if they were unable in the NC conditions. If NC performance was not at or close to ceiling levels, the number of correct judgements and justifications increased significantly in the CL conditions. With the use of the clock, Groups 2 and 3 achieved ceiling performance in all judgements and close to ceiling in all justifications. Group 1 improved their performance significantly from the NC to CL condition in all justifications and in all judgements, except Variation 2, in which there was close to ceiling performance without and with the clock.

Multivariate and univariate tests of significance indicate no significant group by condition interactions.

To summarize Taskset 2, the results of taskset scores manovas indicate significant group and condition effects, for both the judgement and justification responses. There were no interactions between the two main effects.

McNemar Analyses

The results of the McNemar analyses for Taskset 2 locate the specific differences in performance from the NC to CL condition. Each group's performance across conditions was analyzed separately for all three taskset variations for both response types, judgement and justification.

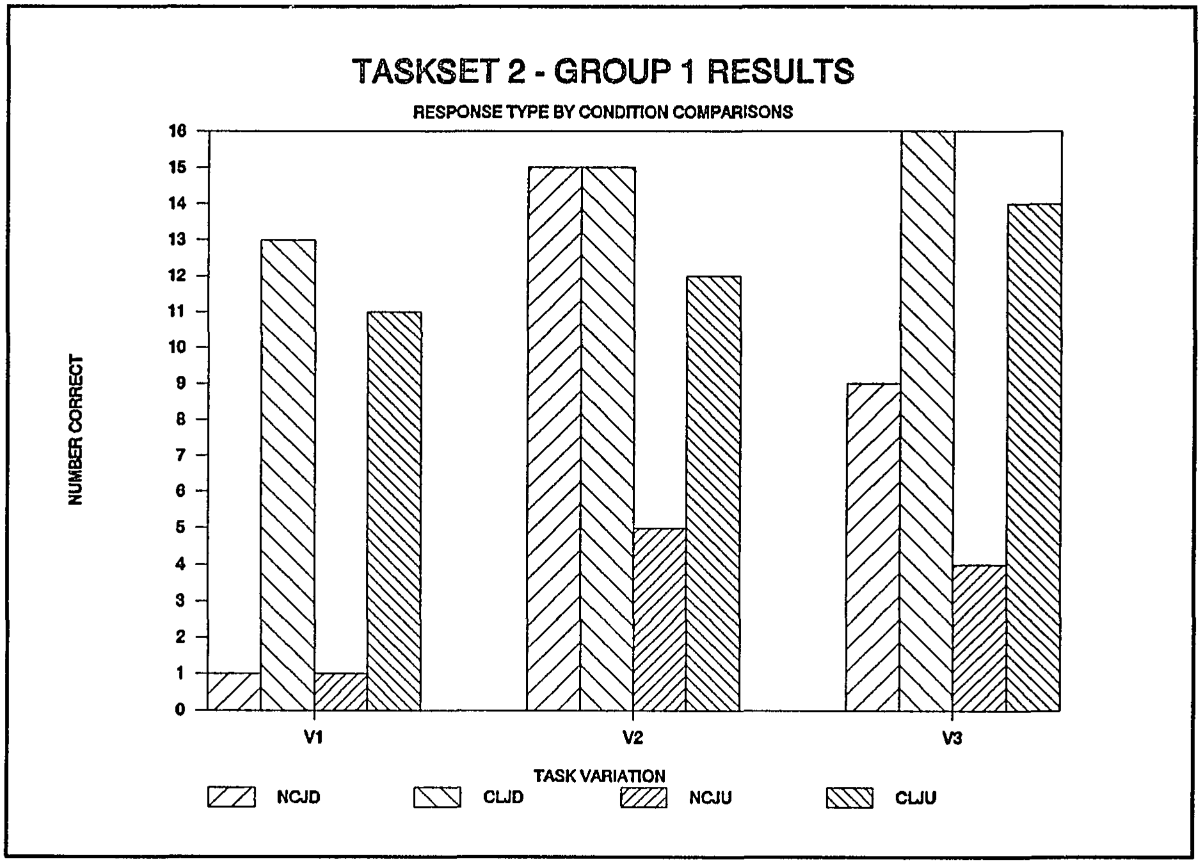

Figure 4

Group 1

Figure 4 presents Group 1's correct judgement and justification responses across the three variations of Taskset

2. There were significant differences in the number of correct judgement responses from the NC to CL conditions in Variation 1 ($p < .0005$) and 3 ($p < .03$). In Variation 2, judgements reached close to ceiling performance in both conditions.

There were significantly more correct justifications in the CL than in the NC condition for all three variations. In Variation 1, the difference was significant at the .006 level. For Variations 2 and 3, the significance levels were $p < .04$ and $p < .004$, respectively.

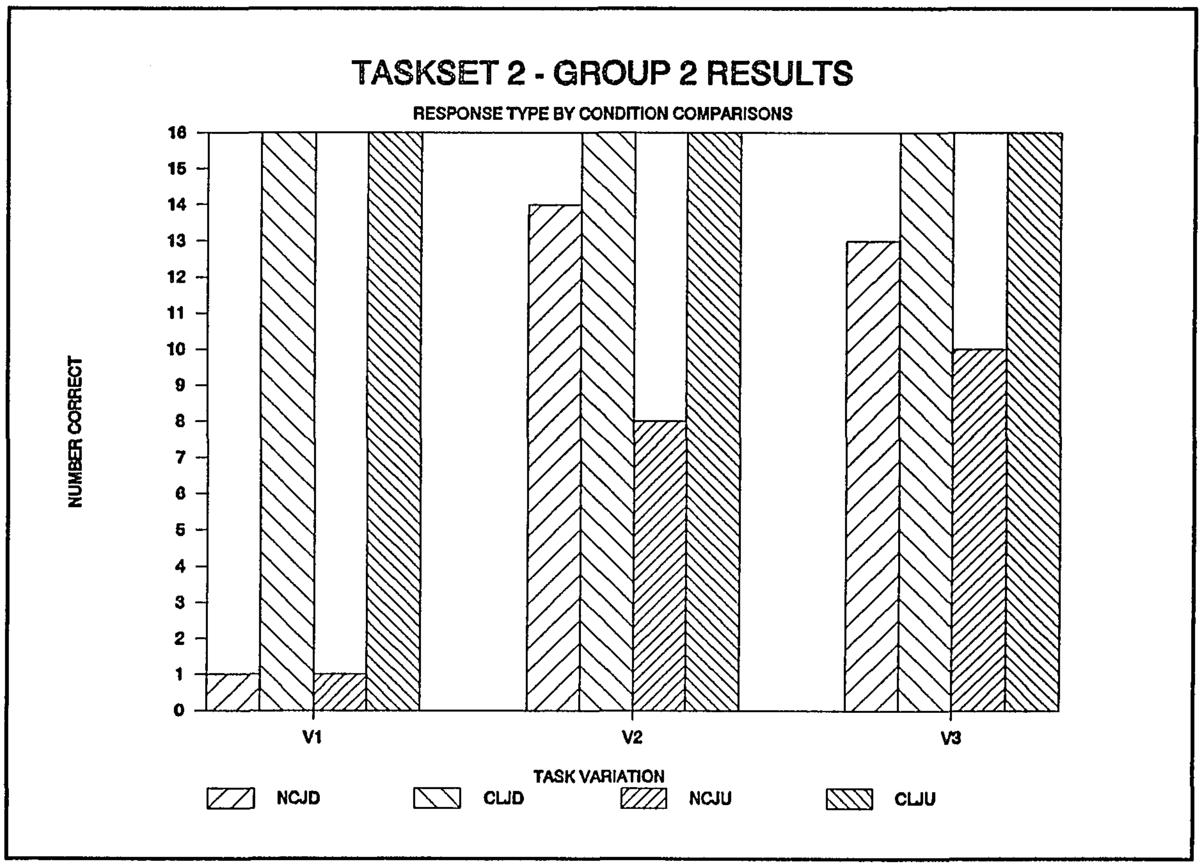

Figure 5

Group 2

Figure 5 presents the judgement and justification responses of Group 2 across the three task variations of Taskset 2. There were more correct judgements in the CL condition than in the NC condition in all three variations. The difference between conditions was significant only in Variation 1 ($p < .0001$). This may be due to close to ceiling performance in the other variations.

There were significantly more correct justifications in the CL than in the NC condition for all three variations. In Variation 1, the difference was significant at the .0001 level. For Variations 2 and 3 the significance levels were $p < .008$ and $p < .03$, respectively.

Group 3

Figure 6 presents Group 3's pattern of correct judgement and justification responses across the three task variations of Taskset 2. There were more correct judgements in the CL condition than in the NC condition in all three variations. The difference between conditions was significant only in Variation 1 ($p < .0001$). This may be due to close to ceiling performance in Variation 2 and 3.

There were significantly more correct justifications in the CL than in the NC condition for all three variations. In Variation 1, the difference was significant at the .0002 level. For Variations 2 and 3 the significance levels were $p < .02$ and $p < .03$, respectively.

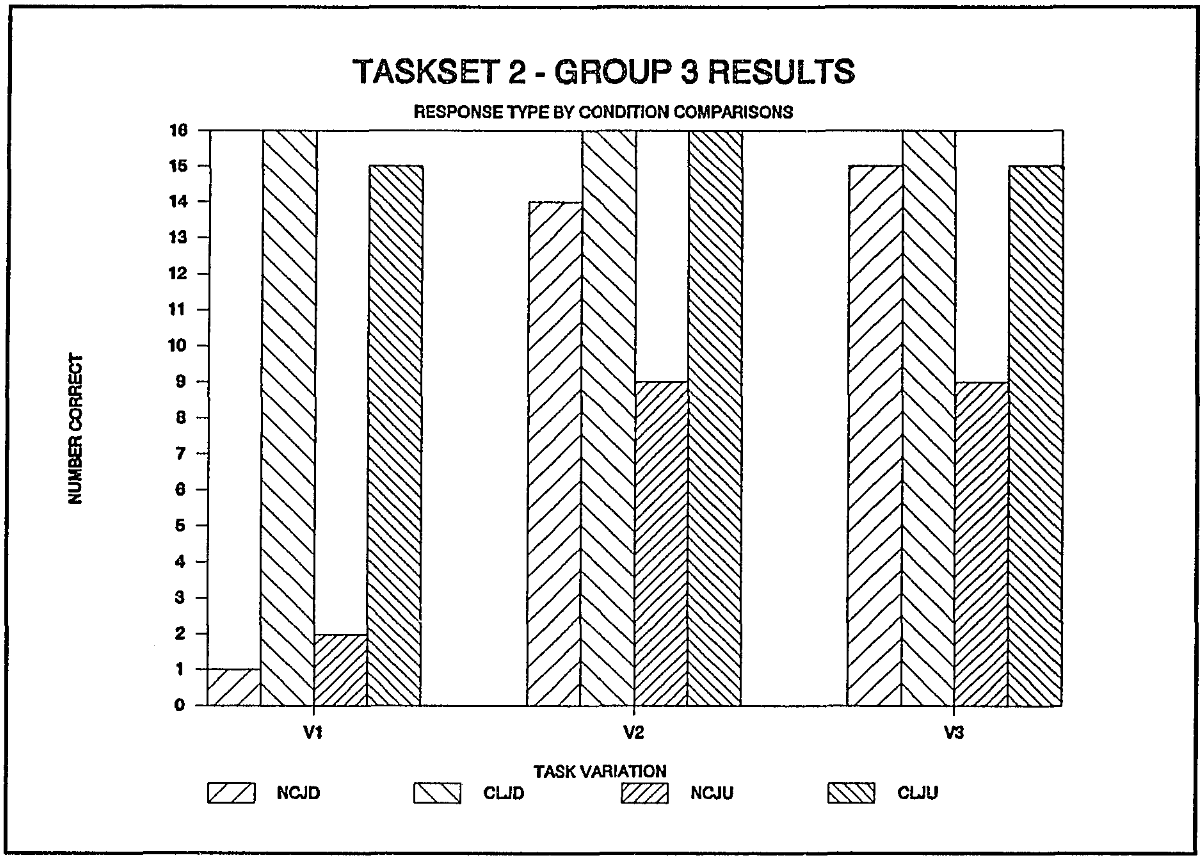

Figure 6

TASKSET 2 MCNEMAR RESULTS						
	GROUP 1		GROUP 2		GROUP 3	
	JD	JU	JD	JU	JD	JU
VAR 1	.0005	.0063	.0001	.0001	.0001	.0002
VAR 2	NS	.0391	NS	.0078	NS	.0156
VAR 3	.0313	.0039	NS	.0313	NS	.0313

Table 4 summarizes the pattern of significant differences between the NC and Cl conditions for the three variations of Taskset 2 for the three groups of subjects. In Variation 1, the two durations were equal - both activities were timed for 30 seconds. The difference in performance between the NC and CL condition was significant for all three groups, across judgement and justification responses. In the NC condition, only 1 child in each group correctly judged the two durations as equivalent. There are two issues which may have contributed to the difficulty of this variation. Even though the instructions clearly stated the possibility of equal durations, the children may have been biased, or may have thought that the experimenter was biased, toward differences in durations. In addition, potentially misleading cues, such as the amount of macaroni or subjective feelings of effort, may become more relevant in trying to discriminate between two similar durations. Thus, cues may play a stronger role in the judgement of relative duration when the durations cannot be easily discriminated perceptually. This effect may be accentuated when the duration are successive, not simultaneous, and when they involve the child's own activity.

Successful duration judgements were based on tending to relevant perceptual information and on ignoring or balancing the impact of potentially misleading cues. In the two task variations in which the durations differed, the shorter duration equalled 15 seconds, and the longer duration was 30 seconds. The longer duration doubled the short duration. This difference seemed easy to discriminate perceptually, even with the impact of potentially misleading cues. For task Variation 2, over 87% of all the children correctly judged the longer duration. In Variation 3, Groups 2 and 3 maintained their high level of discrimination. However, only 56% of Group 1 correctly judged the longer duration in Variation 3. One explanation may be the tendency, especially in young children, to overestimate the second task relative to the first (Fraisse, 1982). This may be related to or compounded by memory difficulties in the youngest group.

Additional support for the perceptual basis of judging relative duration in Taskset 2 is provided by the justification responses. The justification response across conditions was significant for the three groups in both Variations 2 and 3. The difference across conditions for the judgement response in Variations 2 and 3 was only significant for Group 1 in Variation 3. The intervals were sufficiently different (15 v 30 seconds) that it was easy to intuitively feel the duration difference, independent of macaroni scooping. However, it was very difficult for the children to justify their responses. Many of the children, although they were certain that they were correct, could not come up with a reason why. Comments like "it just seems that way ", " it felt longer" support the interpretation of a perceptual basis to the determination of relative duration. Other justification responses focused on cues which coincidentally supported the duration judgement, such as amount of macaroni or number of scoops. These justifications seemed to be afterthoughts; the cue information was not used as a basis for constructing duration. In support of this, the cue information used to support their decision was sometimes not accurate; the selection and direction of the cue seemed to be a response to experimenter pressure to provide a reason for the inexplicable.

In the CL condition of Taskset 2, the successive events were each represented on the clockface, resulting in a visual, simultaneous representation of the two intervals. The succession points of the two durations were both marked on the clockface. This allowed the children to perceptually/ visually compare the two durations, either in terms of succession points, or in terms of a qualitative or quantitative comparison of the representative distances. The children were able to use the clock representation to provide a means ofjustifying their correct judgement responses. For the justification response, the clock improved performance for all three groups for all three variations.

<u>Taskset 3 - Linear Duration</u>

The third taskset of linear duration corresponds to Piaget's definitive task, which is used to diagnose a concept of objective duration. Each variation presents the logical system of duration, distance and velocity in different relationships to one another. The task requires a duration comparison of the journey of two figures with varying parameters of the logical system. The means and standard deviations of the taskset scores for each group for Taskset 1 performance are presented below in Table 5. The maximum score for a correct solution, within one condition and response type, is 4. Judgement and justification responses are considered separately throughout the analysis. The final column combines responses across conditions for the analysis of a group main effect.

TASKSET 3 - TASKSET SCORES MEANS AND SD						
JUDGEMENT						
	NC CONDITION		CL CONDITION		NC + CL	
	M	(SD)	M	(SD)	M	(SD)
GROUP 1	2.88	(.719)	3.69	(.602)	3.28	(.772)
GROUP 2	3.44	(.892)	4.00	(0)	3.72	(.683)
GROUP 3	3.81	(.403)	3.88	(.500)	3.83	(.448)
JUSTIFICATION						
GROUP 1	1.38	(1.025)	3.38	(1.088)	2.38	(1.454)
GROUP 2	1.81	(1.276)	4.00	(0)	2.91	(1.422)
GROUP 3	2.31	(1.448)	3.38	(1.147)	2.84	(1.394)

Univariate analyses indicate that for the dependent variable of judgement there was a significant difference in responses across the three groups ($F(2,45) = 7.54$, $p < .001$). There were no significant differences across the groups in their justification responses ($F(2,45) = 1.53$, $p < .228$).

Univariate tests of significance indicate that there was a strong condition effect, that is, there were significant differences in correct responses between the NC and CL condition. This difference was found for judgement ($F(1,45) = 16.92$, $p < .0001$) and justification ($F(1,45) = 111.41$, $p < .0001$) responses.

Multivariate and univariate tests of significance indicate significant group by condition interactions. This difference was found for both categories of response, judgement (F (2,45) = 3.58, p <.0360 and justification (F (2,45) = 4.41, p <.018).

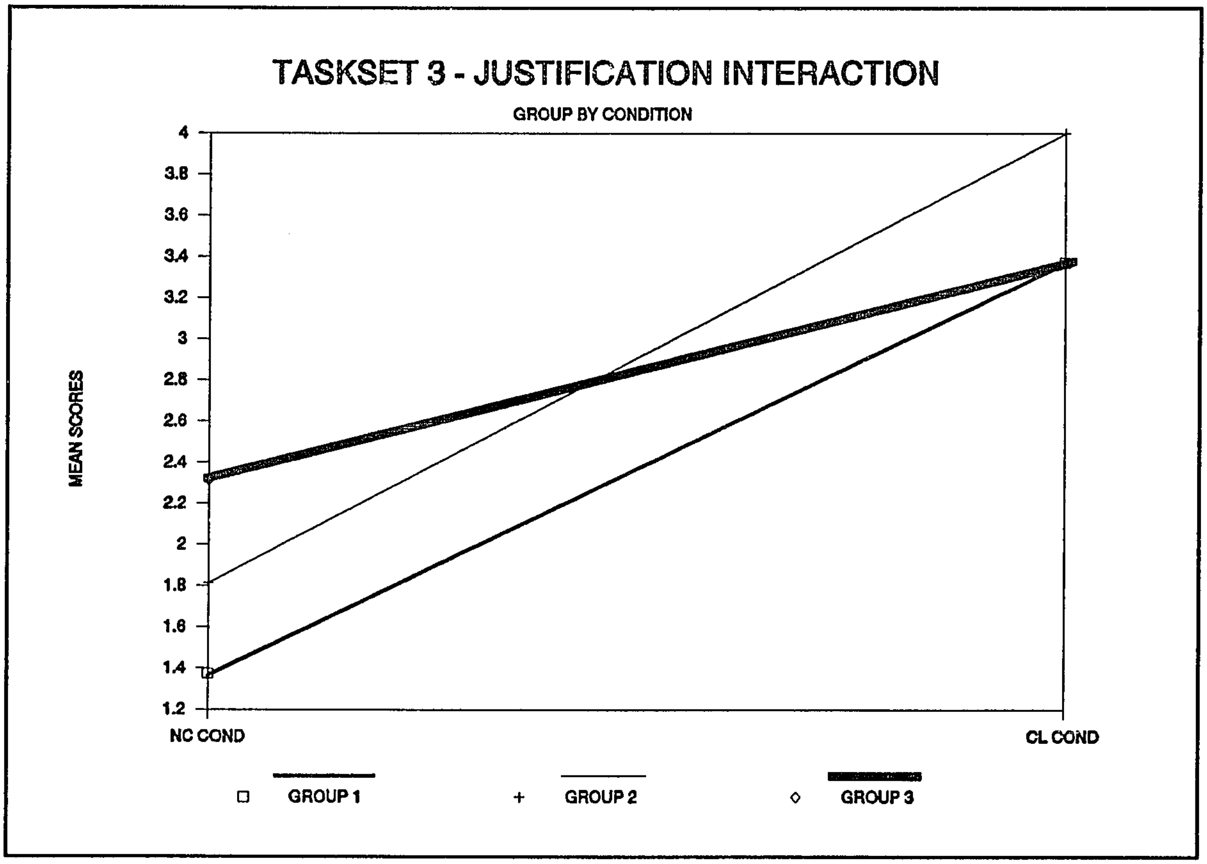

Figure 7

Figure 7 displays the interaction effect of group and condition variables for the judgement response. Performance in the clock condition improved for all three groups, however the percentage of improvement depends upon the group. Group 1 performance increased the most in the clock condition. Group 2 performance increased an intermediate amount with the use of the clock. Group 3, due to almost ceiling performance without the clock, were helped the least in the clock condition.

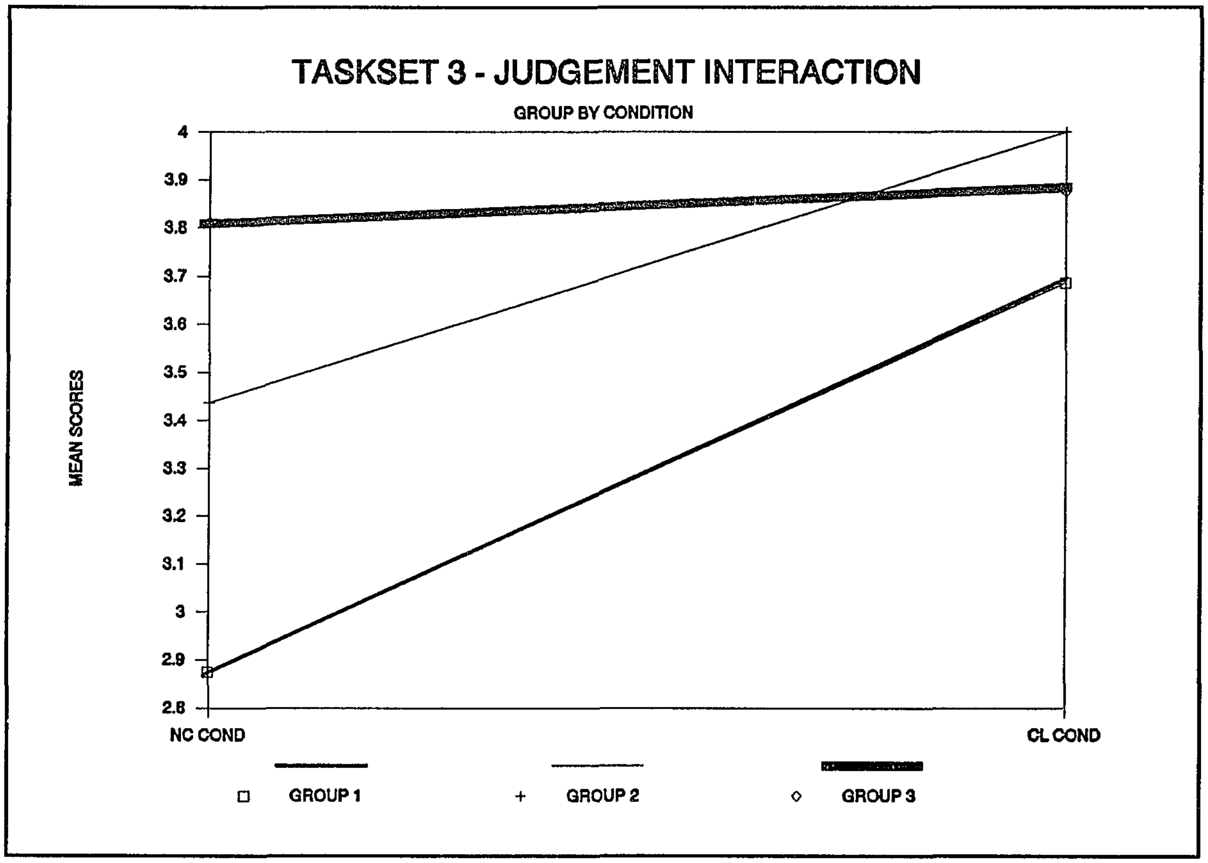

Figure 8

Figure 8 presents the interaction effect of group and condition for the justification response. The clock improved performance for all three groups. Performance of Group 1 and Group 2 improved by approximately the same percentage in the CL condition. The effect of the clock on Group 3 performance, however, was different. The percentage of children in Group 3 that successfully solved the task in the NC condition was higher than in Group 1 and Group 2. The improvement in the CL condition was less marked, and resulted in performance in the CL condition similar to Group 1 levels. Thus, despite a linear increase in performance over Group 2 in the NC condition, Group 3 performance in the clock condition was lower than Group 2 performance.

There are several potential reasons for the failure of Group 3, the 7 year-old children, to utilize the clock effectively. First of all, some of the comparatively weak performance may be due to lack of interest or boredom. As a qualitative impression, the 7 year-old children were less actively engaged in the task variations. While this may not have affected performance on the simpler task variations, the complicated variables of Taskset 3 required greater attention and focus. In contrast to the 5- and 6- year old children, who were willing to continue to listen and discuss the justifications, the 7 year-old children were more likely to give up, and lose interest. The 7 year old children were also more distracted, spending more time off-task, asking more irrelevant questions and needing to be refocused on the task variations. Some of the lack of interest may be related to the level of difficulty of the task variations. The task variations, especially those of Tasksets 1 and 2, may not have been a challenge. This expectation may have carried over to Taskset 3, with different performance results.

The second likely cause of lackluster Group 3 performance may be related to the effects of a U-shaped curve. The high level of performance by Group 2, the 6 year-olds, seems to indicate a high level of understanding the relationships involved in judging and justifying relative durations. It is possible, however, that this knowledge is still fragile and unintegrated. The apparent decrease in performance of the 7 year-olds may reflect a more advanced level of understanding. The 7 year-old children may be attempting to integrate some of the dimensions which are related to duration, and these integrations may initially result in increased errors. For example, there were more attempts by the 7 year-old children to integrate the task demands with the number scale. The emphasis of the method on socially supporting emerging competence through direct social interaction and through tool use, may also have provided a structure which differentially extended the level of performance of the two groups. It is possible that the 6 year-old group could utilize the support provided by the experimenter and clock more effectively, due to the lack of individual attempts to construct durative relationships. The most plausible explanation is a combination of factors which could account for the individual differences within Group 3. Further research is necessary to focus on the changes in performance between the 6- and 7- year old children, and to extend the inquiry to include an 8 year-old group.

To summarize the MANOVA results for Taskset 3, there were significant main group effects for the judgement, but not the justification response. The main condition effect was significant for both response categories. The group by condition interaction was significant for both judgement and justification responses.

McNemar Analyses

The results of the McNemar analyses for Taskset 3 locate the specific differences in performance from the NC to CL condition. Each group's performance across conditions was analyzed separately for all four taskset variations for both response categories, judgement and justification.

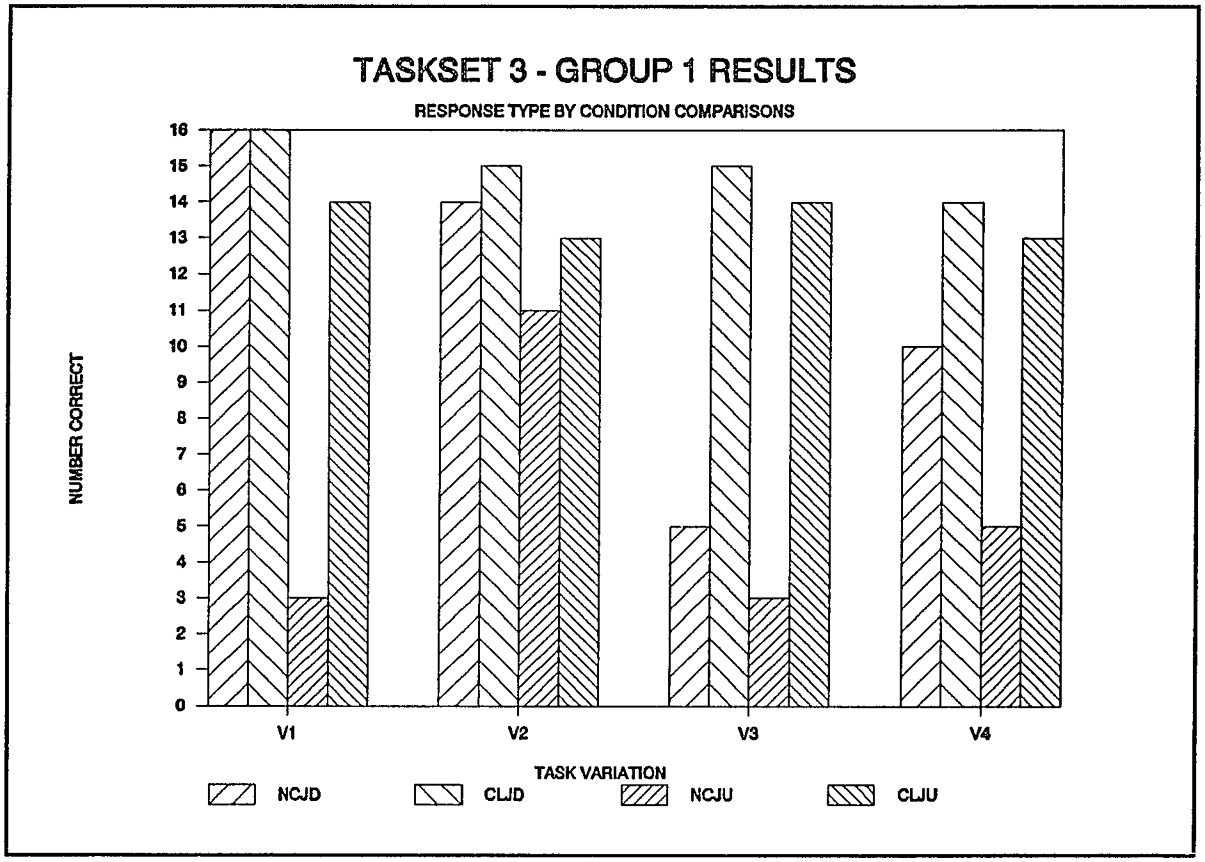

Figure 9

Group 1

Figure 9 presents the performance of Group 1 on Taskset 3. There was ceiling performance on correct judgements in Variation 1 in the NC and CL condition. The number of correct judgements increased from the NC to CL condition on Variations

2, 3, and 4. The only significant increase was in Variation 3 (p <.002).

There were increases in the number of correct justifications in the CL condition from the NC condition in all four variations. These increases were significant in Variation 1 (p <.001), in Variation 3 (p <.001) and in Variation 4 (p <.02).

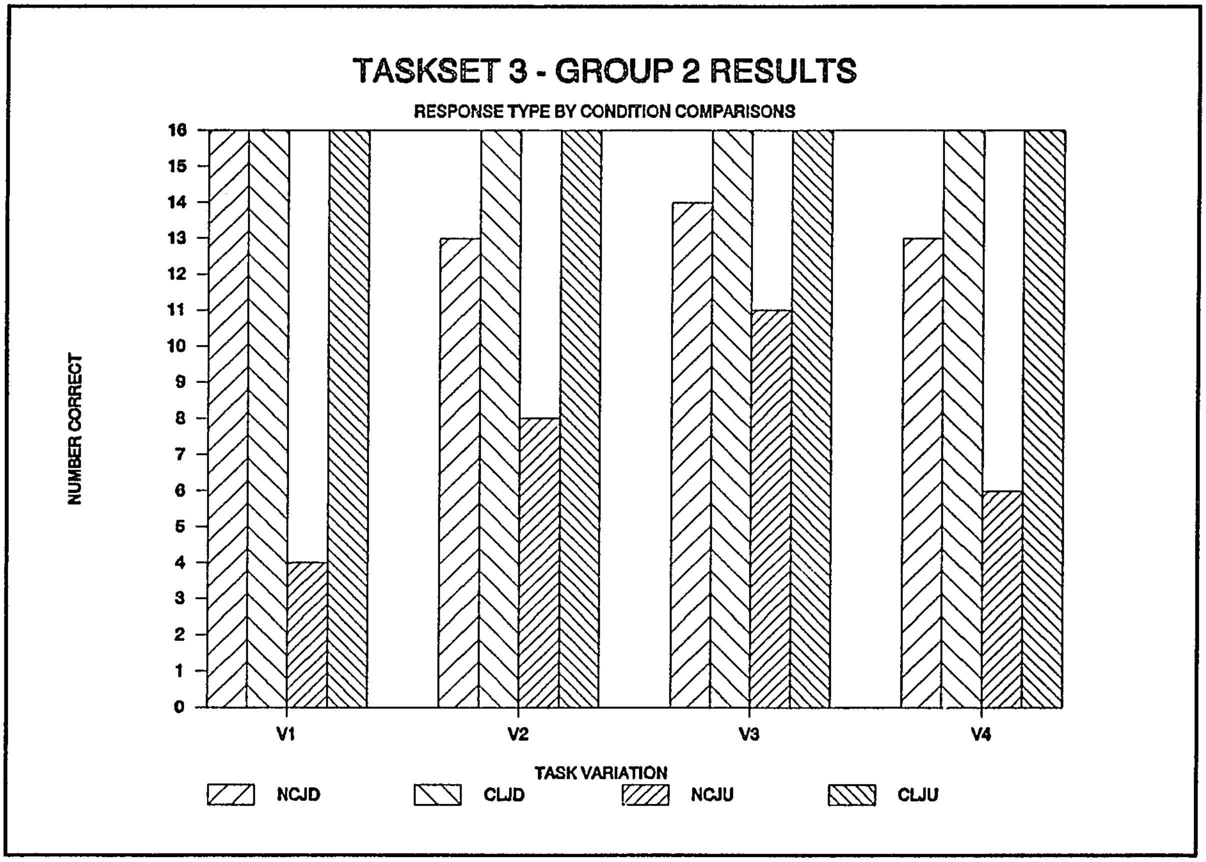

Figure 10

Group 2

Figure 10 presents Group 2 performance on Taskset 3. There was ceiling performance on correct judgements in Variation 1 in the NC and CL condition. The number of correct judgements increased from the NC to the CL condition in Variations 2, 3 and 4, however, none of the differences between the conditions were significant.

There were increases in the number of correct justifications in the CL condition from the NC condition in all four variations. These increases were significant in Variation 1 (p <.0005), in Variation 2 (p <.02), and in Variation 4 (p <.002). While not statistically significant, there was a trend toward a significant difference in Variation 3 (p <.06).

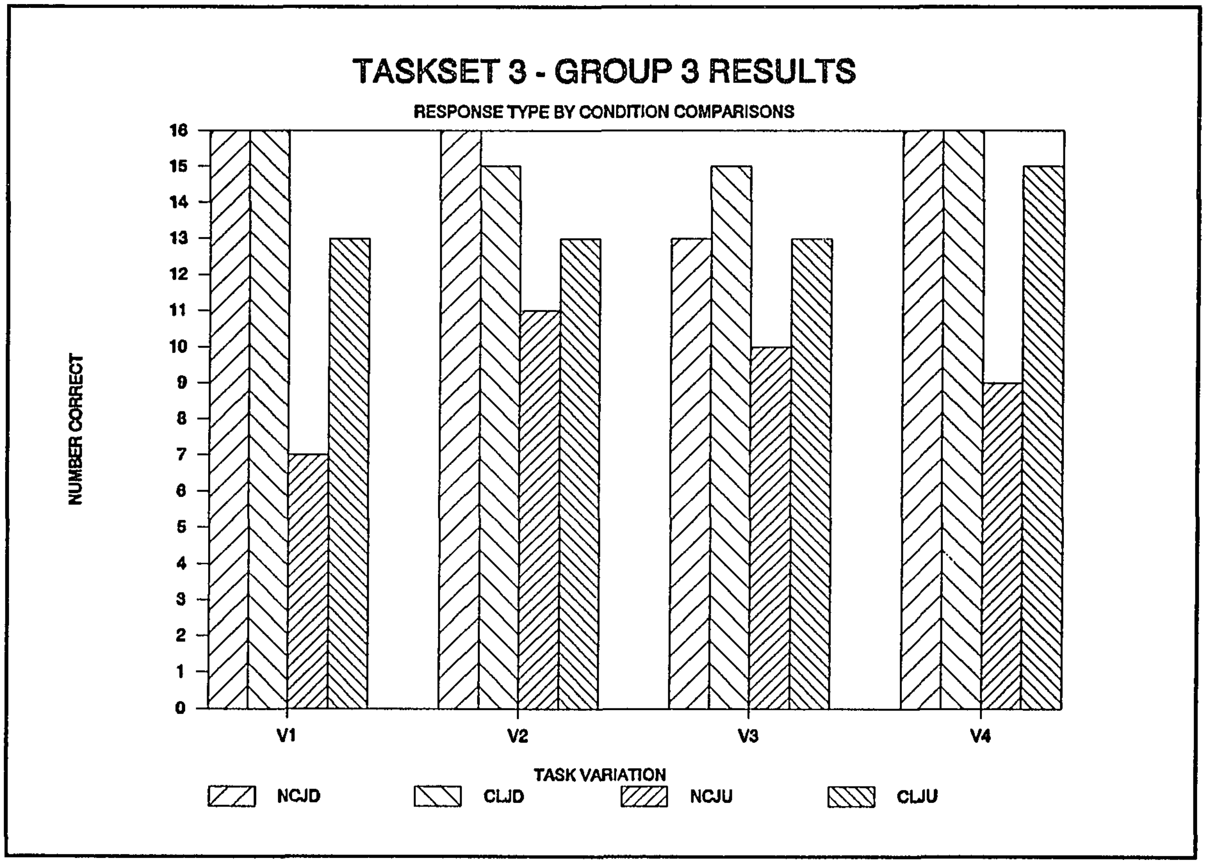

Figure 11

Group 3

Figure 11 presents the performance of Group 3 on Taskset 3. There was ceiling performance on correct judgements in Variation 1, 2 and 4 in the NC and CL condition. The number of correct judgements increased from the NC to the CL condition in Variation 3, however the difference between the conditions was not significant.

There were increases in the number of correct justifications in the CL condition from the NC condition in all four variations. These increases were not significant in any of the variations. However, there was a trend toward a significant difference in Variation 1 and 4, both at the p <.06 level.

Taskset 3 Summary

TASKSET 3 MCNEMAR RESULTS						
	GROUP 1		GROUP 2		GROUP 3	
	JD	JU	JD	JU	JD	JU
VAR 1	CEILING	.001	CEILING	.0005	CEILING	(.06)
VAR 2	NS	NS	NS	.02	NS	NS
VAR 3	.002	.001	NS	(.06)	NS	NS
VAR 4	NS	.02	NS	.002	CEILING	(.06)

Table 6 summarizes the results of the McNemar analyses by presenting the level of significance for each task variation by each group. In Variation 1 and 2, the spatial and temporal cues which specify a longer journey were consistent with each other. Variation 1 involved two figures starting together, traveling at the same velocity and then one figure stopped before the other. The figure that stopped first traveled a shorter time and less distance. The other figure traveled more distance, took more time and stopped after the first figure. All three groups achieved ceiling performance on the judgement response of Variation 1. Every child correctly judged the longer duration in this variation.

Variation 2 consisted of two figures traveling at the same speed and starting and stopping at the same time. The figures thus traveled for equal durations. NC judgements were high in this variation; however, in contrast to Variation 1, only Group 3 achieved ceiling performance. The children who chose one duration as longer than the other seemed to have an expectation that they had to choose one duration as longer, despite instructions which allowed for an equal judgement. These children focused on small unintentional differences between the figures' journeys, such as the lateral movements of the wind-up toys as they waddled. This was supported by the justifications given by the children who chose one duration as longer.

A correct justification was achieved by less than one-third of the children in Variation 1. There were more correct justifications in Variation 2 than in Variation 1, despite a lower level of correct judgements. It is plausible to suggest that once the children were told the correct answer, and realized that it was not a "trick" question, they were able to explain the duration judgements. The increased level of performance in Variation 2 justifications may also be influenced by an order effect; they had just had a demonstration of justifying their responses in terms of succession points.

The NC justifications for Variations 1 and 2 suggest that the children generally relied on spatial cues for their judgements. Correct justifications added a consideration of the sequence of stopping in order to infer relative duration. In Variation 2, the children focused on the simultaneity of the endpoints in addition to the simultaneity of the beginning points in Variation 1. Insufficient justifications generally used perceptually available spatial information to infer duration. Spatial information may have been more salient, for it was perceptually stable and available for reference. The temporal information of stopping could have been reconstructed, but this event information was not readily visible and dependent upon memory in the NC condition. When asked which figure was walking for more time, the child could rely on the spatial cue of more distance and arrive at a correct answer. Furthermore, the children resisted the experimenter's attempts to change their basis for justification through emphasizing the temporal cues. In some cases, there seemed to be a tendency toward parsimony, in that they recognized that the spatial information was sufficient for the task demands in this situation, and any further information was redundant and unnecessary.

In the CL condition of Variation 1, the ceiling performance reached in the NC condition for the judgement response was maintained. For Variation 2, the clock did not significantly improve judgement performance. This can partially be explained by initially high performance in the NC condition. With the use of the clock, Group 2 achieved ceiling performance, and only one child in Groups 1 and 3 could not correctly judge the durations as equal. In these variations, in which the temporal and spatial cues were consistent, the clock offered redundant information. The judgement of equal duration could be reached through spatial cues, or through the recognition of the salience of the succession points. The marking of the event durations on the clockface represented simultaneity and succession information, which was redundant for the judgement decision.

With the use of the clock in Variation 1, justification improved for all three groups. Groups 1 and 2, the 5- and 6-year olds, benefitted the most from the use of the clock. The percentage of improvement for both groups was similar, however,initially higher Group 2 NC performance resulted in ceiling performance in the CL condition. In Variation 2, the clock significantly improved performance for only Group 2. One half of Group 2 scored a correct justification response without the clock, and all of the children correctly justified their responses with the clock. In contrast, Groups 1 and 3 had initially higher NC justification performance than Group 2, yet did not improve upon this performance in the CL condition. For both the judgement and justification response categories, Group 2 utilized the clock the most effectively.

Correct justifications, for both the first and second variations, generally utilized the representation of succession points on the clockface, and incorrect justifications remained focused on the spatial positions of the figures. The redundant information provided by the temporal and spatial cues in these variations may have made it difficult for the children to understand why the experimenter was so focused on separating and naming the cues in the justifications.

Variation 3 and 4 involved two figures travelling at unequal velocities, therefore the spatial and temporal cues to a longer journey were contradictory rather than reinforcing. Variation 3 consisted of the two figures traveling the same distance. The unequal velocities resulted in the faster figure covering the distance in a shorter duration. At the end of the demonstration, spatial cues support an erroneous judgement of equal journeys. In order to arrive at a correct judgement, the child had to ignore the spatial cues, and remember the succession points of the two figures' journeys. Thus, a correct duration judgement was dependent upon remembering the relative order of the stopping points of the two figures. In task Variation 4 the journeys of the two figures were equivalent in duration. Both figures began and ended their journey simultaneously. One figure was traveling faster, and thus traveled for a longer distance. If the static display at the end of the demonstration were considered alone, the position of the figures would support the conclusion that one figure traveled for a longer duration. In order to correctly infer that the figures' journeys were of equal duration, the static distance cues must be ignored, (or integrated with the information of differential velocity) and the relative starting and stopping points of the two journeys must be considered. In contrast to Variations 1 and 2, the spatial cues in these variations supported an erroneous judgement and conflicted with the temporal cues of succession.

For task Variation 3, the percentage of correct Group 1 judgements was very low: only 19 % of the children correctly chose the longer duration. The youngest group focused more on the perceptually available spatial cues which led to a judgement of equal durations. On the other hand, more than 80% of Groups 2 and 3 correctly judged duration. In addition to overcoming the salience of spatial cues, the two older groups may have been able to remember, or use their memory of, the relative stopping points of the two figures more effectively. The same relative pattern of performance across the three groups was reflected in the justification responses. One-half to three quarters of the children who correctly selected the longer duration could justify their selection. Correct justifications focused on the relative temporal endpoints. Incorrect justifications focused on either the spatial cues or irrelevant information.

For Variation 4, the majority of the children in Group 1 correctly judged equal durations. Over 80% of the children in Group 2 successfully solved the task, and Group 3 achieved ceiling performance. The percentage of correct justification responses were similar for Groups 1 and 2. Approximately 1/3 of the children in both of these groups could correctly justify their responses. In contrast, over 1/2 of the children in Group 3 scored correct justifications. Correct justifications generally focused on endpoint simultaneity (integrating the starting points with the endpoints was not necessary, although the experimenter did point out its relevance). Incorrect justifications tended to focus on the spatial cues of the figures' positions, or on irrelevant cues such as the differential lateral movement of the figures.

With the use of the clock on Variation 3, the three groups' performance appeared the most different. Group 1 improved performance in the CL condition for judgement and justification responses. In contrast, only the Group 2 justification response improved in the CL condition, and the clock did not appear to help Group 3 improve either response. Group 1's performance improved dramatically for both judgement and justification responses. The performance of Group 2 and 3 also improved, although not significantly. One reason may be that the high NC initial performance did not leave much room for improvement. Group 2 achieved ceiling performance for both judgement and justification responses. Group 3, despite similar performance to Group 2 in the no clock condition, did not utilize the clock as effectively.

In the clock condition of Variation 4, Groups 2 and 3 achieved ceiling or near ceiling performance for both judgement and justification responses. Group 1's performance also improved, however, none of the NC to CL differences in judgement responses were significant. Thus, the use of the clock did not significantly help the children to construct and compare the durations, nor help them recognize and utilize the simultaneity of the succession points. For Group 2 and 3, this can be explained by initially high percentages of correct NC judgement responses, followed by ceiling performances. For Group 1, for some children there seemed to be some "limits" in the amount of information that could be integrated and represented even with the use of a representational tool, such as the clock. The clock improved performance in the justification response category for all three groups, with only Group 3 performance not achieving significance, but reaching the .06 level. Once again, Group 2 achieved ceiling performance and Group 3 did not use the clock as effectively.

In Variation 3 and 4, the representation of succession points on the clock helped the children construct and compare the two durations. The perceptual availability of the duration representation helped the children overcome the salience of the distance cues provided by the figures' positions. Distance and time were both represented perceptually, allowing the children to construct and compare durations independent of distance. In addition, the separate representation of duration helped some of the children to understand the relationship between duration, distance and speed. Some of the children were able to spontaneously integrate the spatial and temporal cues by specifying the role of velocity. Thus, contrary to Piaget, time and distance are not logical confusions, but dimensions difficult to separate and think about independently, partly due to perceptual and linguistic redundancy.

Results Summary

The results of the study can be considered in terms of the two proposed hypotheses. The first hypothesis addressed the difference in performance between the NC and CL conditions. The results were consistent with the first hypothesis. As indicated by the MANOVA analyses, there was a significant condition effect for all three tasksets. The results of the McNemar analyses indicated differences across conditions for each group on each of the 11 variations. This more specific analysis identified significant differences in 39 % of the task variations. Another 39 % were not significant, with the remaining percentage split between variations with ceiling performance in both conditions and variations with strong trends, at the .06 level of significance. It can be concluded that, overall, performance in the clock condition improved over performance in the no clock condition. Thus, the clock helped the children make correct relative duration judgements and to justify their responses. There were significant differences in performance across the three groups of subjects for both response types in every taskset, except for the justification response of

Taskset 3. Taskset 3 was the only taskset with a significant group by condition interaction. The interaction reflected a pattern of performance suggested in the other tasksets. The 6-year old group utilized the clock to improve performance the most effectively. Group 3, the 7-year old children, despite generally higher NC performance did not proportionately increase performance in the CL condition. Group 1, the 5-year old group, utilized the clock to improve performance, although not as effectively as Group 2. The lack of effective utilization of the clock by Group 3 merits further study to determine the causes.

General Discussion

The results will be considered in terms of the implications for three interacting issues of interest. First of all, Piaget's theory of temporal development has provided the framework for studying the development of objective duration. Piaget's description has been challenged by several theorists, and alternate developmental progressions proposed. The results and implications of this study continue the process of revision. The second issue addresses the impact of cultural knowledge on the development of objective duration. An understanding of the meaning of the differences in performance between the NC and CL conditions can be gained by examining the functions that the clock performed in the duration comparisons. The role of the clock in the process of cue differentiation and integration offers an insight into the process of cultural tool utilization. Finally, an integration of logical and cultural knowledge through a model of temporal concept development will be proposed. This description of the development of objective duration applies a contextual model, with a strong foundation of theoretical and empirical convergence. The issues presented serve an additional function of hypothesis generation, which will direct the future research program on temporal concept development.

In general, the results support an interpretation of a demonstration of objective duration in all of the subjects. The display of this conceptual skill varied depending on the level of the development of the child, task complexity and on the supports provided by the context. Within each subsystem of duration (successive, activity and linear) each group was able to successfully compare relative durations for at least some of the variations. Further, children in all three groups were able to demonstrate objective duration across the NC and CL condition in some variations. The social construction between the experimenter and the child, with and without the use of the psychological tool of a clock, resulted in 5, 6 and 7 year old children demonstratinga concept of objective duration. This is inconsistent with the Piagetian prediction that concrete operational logic is necessary for the development of this concept.

The successful use of the clock further challenges Piaget's description of objective duration. In Piagetian theory, preoperational children cannot use a clock until a concept of objective duration is constructed. Prior to that, the motion of the clock is considered part of the event being timed, and cannot be understood as independent motion representing duration. Thus Piaget has defined objective duration as a pivotal concept in the development of temporal concepts, upon which clock usage depends. The ability of children to use the clock to construct duration supports a reconceptualization of the developmental progression. In contrast to clock usage resulting from the development of a concept of objective duration, in this study, the clock was used to construct objective duration. The children were able to represent the succession points of two intervals and coordinate the durations of two events on the clockface. Preoperational children have precursor skills related to clock usage (Ames, 1946; Arieux, 198?; Bryant & Kopytynska, 1976). The demonstration of this skill is consistent with the interpretation that the supportive context provided by the interaction with the experimenter enabled the consolidation of clock skill within these tasksets.

Piaget has further stated that the use of a clock requires a concept of measurement, also dependent upon the integration of objective duration. Contrary to this statement, the children were able to measure duration with the clock. The use of the clock, at a minimum, implies the understanding that duration is a quantity with varying amounts, which can be represented spatially through beginning and ending points, and that judgements of relative quantity can be made. Some children demonstrated more quantitative understandings, such as the segmentation of duration into units, naming and counting the units, and using the units to compare durations. Unitization, aligning time with the number scale and counting units of durations are measurement skills which have been demonstrated in supportive contexts by preoperational children (Wilkening, Levin and Druyan, 1987; Levin & Wilkening, 1989; Levin, 1989; Gelman & Gallistel, 1978). The use of the clock appeared to facilitate the consolidation of measurement skills in the process of constructing objective duration. This indicates that the understanding of measurement can help in the construction of objective duration. These understandings, or at least fairly developed precursors of them, seem to be present prior to the logical development of objective duration.

The results of this study, in general, do not support a Piagetian description of the development of objective duration. However, the results are consistent with proposals of alternative developments of temporal concepts. The clearest, most reliable finding is that duration is constructed from sequence information. When sequence information was available, the children in all three groups were able to compare durations and justify their choice based on the relative succession points of the two intervals in both the NC and CL condition. This replicates and extends Levin's (1979, 1982) proposal that duration can be constructed through the sequence information provided by overlapping events, independent of other duration cues. Succession points were utilized in the NC conditions of the successive and linear duration subsystems, although spatial succession points complicated the use of temporal sequence in the latter subsystem. Sequence information was not available in the NC condition of the activity subsystem, and will be discussed below. In the CL conditions of the three subsystems, the beginning and ending points marked on the clockface were utilized to compare durations.

In the activity duration subsystem, the two intervals to be compared were not presented with staggered simultaneity, as they were in the other duration subsystems. The intervals in this subsystem were presented one after the other, effectively removing the relative beginning and ending points as useful cues in the NC condition. However, the majority of the children correctly judged relative duration in the NC variations in which the durations were unequal. This suggests that duration can be directly perceived and relative comparisons can be made on a perceptual basis, as argued by Richie and Bickhard (1989) or through the direct perception of changes associated with duration (Fraisse, 1963). The difference between the two durations was large enough (15 v. 30 seconds) to afford a relative duration judgement based on subjective estimation of duration without the use of sequence information, and despite the interference of potentially misleading cues. Duration did not seem to be constructed from logically related information, but directly perceived as an independent dimension. Thus, the study offers additional evidence that duration is not constructed from a logical integration of time, distance and velocity, but can be directly perceived as an independent dimension or constructed from sequence information.

Meaning of Differences Across Conditions

One central purpose of the study is to contrast children's ability to construct relative duration with and without the use of a psychological tool in three types of duration. There are several indicators of problem solving and potentially microgenetic concept development evident in the children's responses with and without the clock. Performance in both conditions is assumed to be considerably enhanced by the experimenter's efforts to elicit the best possible performance. The goal was to extend each child's performance as far as possible within the ZPD. The first judgement and justification responses were taken as a starting point of understanding, and the experimenter thereafter scaffolded (Bruner, 1987) the child's understanding of the task as much as possible. The steps taken toward that goal were outlined in the method section, generally including feedback, pointing out the relevant cues involved in the duration comparison, presenting contradictions or logical inconsistencies, restating the relationships in a more familiar form, and drawing comparisons and analogies more directly related to the children's experience. The no clock condition and the clock condition, thus, involved considerable social interaction in the construction of the child's understanding of duration and objective time.

The difference between the no clock and clock condition, therefore, is not a difference between cognitively isolated development and development within the context of social interaction. Rather, the clock condition extended social interaction beyond an interindividual construction. The use of the clock as a psychological tool added the benefit of a product of cultural knowledge, extending the child's interaction with other people across time and space. A psychological tool is an extension of culture and social interaction. Performance in the clock condition, therefore, resulted from direct social interaction created between the child and experimenter combined with the less direct social interaction afforded by the utilization of a psychological tool. If we accept the assumption that cognition is created through social interaction (Vygotsky, 1978; Wertsch, 1985; Brown & Campione, 1983) psychological tools serve a critical function in the process of knowledge acquisition and concept development. Specifying the processes through which children use tools to construct knowledge and concepts is necessary in order to understand the role of psychological tools in concept development.

Functions of the Clock

Several functions of the clock were in evidence across the task variations. First of all, the clock performed the function of a representational tool. The clock could be utilized to represent information relevant to the goal of comparing durations at several levels of abstractness. At a very basic level, the stickers placed on the clockface during each variation represented the beginning and ending points for each of the two events. Thus, the succession points were visually represented and perceptually available as the child engaged in reasoning about duration. This perceptual availability seemed to maintain the salience of succession cues, especially critical in tasksets in which there were cues that could confound the perception/construction of duration.

Within each event, the marked endpoints encoded the sequence information of the beginning and end of each interval. The representation of the succession points, through the distance marked between them, also encoded the temporal interval of each event. This clearly related distance on the clockface with an encoding of time - the representation of duration through distance. The interval of each duration was given visual and concrete form. On a more abstract level, in Piagetian terms, the relationship between succession and duration was made explicit,

The marking of both events to be compared on a common clockface also perceptually represented information that could be utilized for the task of duration comparison. As the events within the variation unfolded, their succession points were marked in order of occurrence on the same clock face. The relative order of the succession points of the two events was thus represented and perceptually available in a form which facilitated a comparison of duration. At a more abstract level of representation, the clockface represented a common timeline, along which both durations were ordered.

This understanding of time as a unique and homogenous time frame is a criterion aspect of objective time, according to Piaget. Operationally, in Piagetian theory and in this study, this concept is inferred when two durations can be successfully compared. However, Piaget has argued that children without a concept of objective time would not be able to utilize its representation on a clock. According to Piaget, a concept of objective time is a prerequisite skill for using a clock to compare durations. In contrast, one purpose of this study was to explore how children could utilize these representations to construct objective duration when presented within a context of supportive social interaction. This would support the proposal of a different developmental course of the concept of objective duration, in which an early, logically unintegrated concept of objective duration can be extended to incorporate the definitive Piagetian logical relationships, by means of the social interaction represented by a psychological tool. The representation of a common time frame potentially facilitated duration comparisons by perceptually representing the simultaneous overlay of the two events. Thus, the system of the two events within a single timeframe could be perceived as a whole, and the relationships among the durations within the time frame were made more explicit.

The clock also served as a mnemonic device, helping the children to focus attention upon and remember the important cues through which duration comparisons could be made. There is some evidence that memory limitations are a significant factor in young children's inability to solve Piagetian-type tasks (Seigler, 1985). Closely related to the role of the clock as a memory aid, is the potential of the clock to reduce demands on simultaneous information processing capacity. The amount of simultaneously considered information required to solve the task can be effectively reduced with skillful use of the clock as a convenient "place holder" for a relevant piece of information.

The use of the clock to represent the durations of the two events supported the comparison of the duration amounts on a qualitative and quantitative basis. There did not seem to be a clear boundary between qualitative and quantitative understandings, but a range of responses, from the most qualitative to the most explicitly quantitative. The majority of the task variations could be successfully solved on the basis of the relative order of the succession points. An alternate strategy of clock use involved a qualitative comparison of the representative distances to infer relative duration. This most qualitative strategy was based upon a perceptual comparison of the two distances to infer the longer duration. The relative judgement involved a comparison of the distance quantities. Some children combined the strategies of using succession points and qualitative comparisons within their justifications. For example, when the beginning points were simultaneous, the only relative amount comparison necessary focused on the endpoints. A more quantitative approach recognized the proportional relationships between the representational distances on the clockface. In the appropriate tasksets, some children recognized that one duration was represented by a distance of half of the clockface, and the other distance was a quarter of the clockface. The circular clockface may have made it easier to recognize and coordinate the fractional relationships.

Finally, the most quantitative strategy of duration comparison counted the units within each duration representation. The segmentation of the distance by the marks on the clockface were used to unitize the duration and counted by some children to justify their responses. Each segmentation was labeled by a number, corresponding to the numbers on the face of an analog clock. Although each segmentation mark and numeric label corresponded to a 5 second interval, each interval was treated as a single unit and labeled with a "time word", usually minute or hour. Each duration was counted separately and then the two amounts were compared and offered as justification. Only a few of the children subtracted the two amounts. Some of the children did not count the intervals, but reported the numeral corresponding to the sticker placement. This strategy was more common, and more successful when the beginning succession points were simultaneous. Consistent with emerging skill use, as some children tried to count the intervals, errors were made in their application of the strategy which reduced its initial effectiveness. Within this study, the experimenter assisted the children in these situations.

One important function of a psychological tool is to extend understanding beyond the immediate context. The clock, through representing duration, made a segment of the continuous flow of time static and perceptually available. This frees the temporal dimension from the immediate context of its occurrence. The here and now temporal information embedded in an event can be preserved and considered in a different time and place. This function of the clock is analogous to the function that writing performs for the ephemeral event of speech. Information can be preserved and thought about or communicated beyond the context of occurrence. Thus, within variations, the use of the clock mirrors one role of tool use in culture, as a means to capture fleeting information and communicate it across time and place.

The Role of the Clock in Cue Integration

The clock seemed to clarify the relationship between duration and potentially misleading cues. In general, the results of the NC and CL conditions, were consistent with

Levin's (1982, 1989) description of the course of temporal concept development. Levin suggested two separate processes involved in the development of temporal concepts. First, the relationship of duration and succession is understood. Then, the relationship between duration and various forms of output, or associated dimensions of the events is constructed. Thus, as demonstrated by this study, objective duration is constructed through the coordination of sequence information. The clock as a psychological tool helped the children represent the succession points of the two durations. Thus, the sequence information was available for the construction of duration. Other cues interfered with the construction of duration, and potentially misled or confused children's relative duration judgements. This description applies to the children's activities in the NC as well as CL condition. The improved performance in the clock condition can be explained in terms of the clock's emphasis on the relevant sequence information, which helped the children ignore the confusing cues.

Levin's second process, the construction of the relationship between duration and potentially misleading cues, was also evidenced in this study. For some children, the clock appeared to play an important role in the process of understanding the relationship of various cues to duration. It is suggested that the clock functioned to enable cue differentiation from, and integration with the dimension of duration. Once some children were able to construct duration through sequence information, and ignore the interfering cues, they could then coordinate the relationship of the cues to duration. The clock helped differentiate the dimensions involved in the task; to represent the sequence information and thus separate the dimension of duration from other dimensions of the task. Once differentiated, some children were then able to integrate the potentially confusing cues of the task into a logical system with duration. This is an expansion of Levin's developmental progression. The differentiation and integration of cues will be illustrated by children's performance in Tasksets 2 and 3. Taskset 1 is not discussed, for it involved the coordination of sequence information without interfering cues.

In Taskset 2, activity duration, the children compared the duration of two intervals during which the children spooned or ladled macaroni from one container to another. In order to correctly infer duration, the potentially useful cues of amount, frequency and effort had to be successfully ignored or counterbalanced with each other. These dimensions of task activity are related to duration, but only reliably aid in duration comparisons under very specific circumstances. In the 3 variations, these cues were generally misleading. The duration cue given by the amount of macaroni scooped during the two intervals had to be balanced against a consideration of the relative capacity of the ladle and spoon. The number of scoops, also a potentially useful indicator of duration if the rate of scooping remained constant, was compromised by the differential difficulty of using the ladle and the spoon. The subjective cue of effort depended on the degree of success in manipulating the ladle and the spoon. Thus, the basis for duration comparison could be one of the cues of amount, number or effort, but unless the cue was properly integrated with other dimensions of the task, it led to erroneous duration judgements.

The basis for relative duration judgements was inferred through the justification responses. In general, successful duration judgements were not constructed from the temporally related information of amount, number or effort. In the NC condition, judgements were based on relevant perceptual information and ignored the potentially misleading cues. In the clock condition, the representation of the two durations simultaneously then allowed child to use sequence information to construct the relationship between the two intervals. This is an illustration of the use of the clock to construct duration from succession, independent of other temporally related cues, as Levin proposes.

There was also evidence for the second process proposed by Levin, the integration of duration with other cues. Several children, with the tool of the clock representing the durations, were able to spontaneously discuss the interrelationships of amount, number and effort between the two intervals. For example, one 6 year old balanced the cue of the amount of macaroni with relative size of the scoops and the subjective feeling of duration to arrive at a conclusion about the relationship of these cues to duration:

> (Child correctly chooses the spoon as being used for a longer duration and justifies choice using the succession points on the clock)
>
> C: But if I were to be counting how much macaroni - this one would win (holds up ladle) because this one has a thing (the cup of the ladle) and this spoon can hardly hold one.
>
> E: OK. Is how much macaroni a good way to tell how long you've been scooping for?
>
> C: Uh-uh! (shakes head emphatically "no")
>
> E: Why not?
>
> C: You could be scooping forever and ever with this one (the spoon) and not even get the same (amount) as this one (the ladle) in one second.
>
> E: So it's not always the best way to tell.
>
> C: It just makes it feel faster or slower.
>
> (Subject 60 - Kelly - Age 6;10)

It is hypothesized that through the process of its construction, duration can be differentiated from the other dimensions of the events, especially the confusing cues. Once differentiated, then duration can be integrated with other cues into a temporal system. The process of differentiation and integration is supported by the representation of duration on the clock.

Taskset 3 presented the linear duration problem of the relationship between duration, distance and velocity. Distance can be interpreted as a cue potentially interfering with duration judgements, as defined by Levin. However, the relationship between time and space is complex. The distance of two journeys also yields succession points specified by relative spatial positions. Thus the "length" of a journey can be determined by comparing the spatial positions of the figures. Relative distance can be consistent or inconsistent with relative duration judgements, depending on the velocity of the two figures. Children can use spatial or temporal succession points to construct a duration judgement. If the velocities are equal, the common use of space to represent duration will be accurate. The role of succession in the construction of duration may need to be expanded to include spatial succession points, especially when they can represent duration. This refers to the common practice in our culture of equating the amount of distance with the amount of time, and to the spatial representation of duration on the clockface.

In Variation 1 and 2 the spatial and temporal cues that specified a longer journey were consistent with each other. The two figures traveled at the same velocity and either stopped simultaneously or one figure stopped before the other. The spatial positions of the figures, either next to each other or staggered supported a decision of an equal or longer journey that was the same as that reached through temporal cues of succession. The duration judgement could be based upon spatial cues, or through the recognition of the salience of the succession points. For these variations, the marking of the event durations on the clockface represented simultaneity and succession information, which was redundant for the judgement decision.

Correct justifications, for both the first and second variations, generally utilized the representation of succession points on the clockface, and incorrect justifications remained focused on the spatial positions of the figures. The redundant information, provided by the temporal and spatial cues in these variations, may have made it difficult for the children to understand why the experimenter was so focused on separating and naming the cues in the justifications. For Variations 1 and 2, the sequence information presented spatially and temporally formed the basis of the duration judgements. With the use of the clock to represent the temporal dimension, the children focused on the consistency between the cues. There was no need for the complete separation of spatial and temporal cues. The temporal information was used to confirm and reinforce the spatial duration judgements, but there was no conflict that would result in the separation of cues.

Variation 3 and 4 involved two figures travelling at unequal velocities, therefore the spatial and temporal cues to a longer journey were contradictory, rather than reinforcing. Variation 3 consisted of the two figures traveling the same distance. The unequal velocities resulted in the faster figure covering the distance in a shorter duration. At the end of the demonstration, spatial cues supported an erroneous judgement of equal journeys. In order to arrive at a correct judgement, the child had to ignore the spatial cues, and remember the succession points of the two figures' journeys. Thus, a correct duration judgement was dependent upon remembering the relative order of the stopping points of the two figures. In Variation 4, the journeys of the two figures were equivalent in duration. Both figures began and ended their journey simultaneously. One figure was traveling faster, and thus traveled for a longer distance. If the static display at the end of the demonstration was considered alone, the position of the figures would support the conclusion that one figure traveled for a longer duration. In order to correctly infer that the figures' journeys were of equal duration, the static distance cues had to be ignored, (or integrated with the information of differential velocity) and the relative starting and stopping points of the two journeys must be considered. In contrast to Variations 1 and 2, the spatial cues in these variations supported an erroneous judgement and conflicted with the temporal cues of succession.

In Variation 3 and 4, the representation of succession points on the clock helped the children construct and compare the two durations. The perceptual availability of the duration representation helped the children overcome the salience of the distance cues provided by the figures' positions. Distance and time were both represented perceptually, allowing the children to differentiate the dimensions of time and distance from each other. In addition, the separate representation of duration helped some of the children to understand the relationship between duration, distance and speed. Some of the children were able to spontaneously integrate the spatial and temporal cues by specifying the role of velocity. One 7 year old suddenly realized the relationship of velocity to duration and distance:

> (Variation 4 (same time, different distance) Child has correctly judged equal duration and is explaining her justification using the succession points on the clock.)
>
> C: (confidently, without hesitation, looking at the clock) This one went (looks at board - stops talking - looks back at clock - looks at board again and sits back in her chair and grins) I know why this one went half way. (the penguin that traveled the shorter distance)
>
> E: Why?
>
> C: (triumphantly) He was slower and this one (the owl) went (points to the whole length of the board) because he was faster than the penguin.
>
> (Subject 65 - Annemarie - Age 7;2)

Thus, duration judgements in the third taskset were based on succession points, presented either spatially or temporally. The clock helped children represent duration and overcome the perceptual salience of the visual spatial information. The representation of duration on the clock also helped some of the children differentiate duration from distance. Once differentiated, some children were able to integrate velocity, distance and duration.

To summarize so far, the clock appeared to play a critical role in the process of cue differentiation and integration. The comparison of relative durations was based upon succession points, and initially cues were ignored in order to correctly judge duration. Then, cues could be differentiated and integrated with duration, and could then be utilized under certain conditions to construct duration comparisons. The results of this study, therefore, offer support for Levin's proposals of the development of objective duration.

Implications for Development and Conclusions

The results of this study conflict with the Piagetian description of temporal concept development on several levels. In addition to the specific points discussed above, there are also points of divergence between the assumptions of the Piagetian approach and the explicit goals of this research program. One central goal is to reconceptualize the Piaget's description of cognitive development by assigning a primary developmental role to cultural and social concepts. Represented in this study by a cultural tool, interpersonal and socio-cultural knowledge can create cognition. A valid theory of concept development must recognize the social basis of cognition as well as the role of necessary logical integrations. The extent to which the Piagetian description of concept development is valid with the integration of cultural concepts still needs to be determined. However, a different framework, the contextual model of development, seems to account for the findings of this study and many others. In addition, this framework seems to theoretically parallel the statements of several other researchers across the Piagetian, Vygotskian and social constructionist tradition.

The contextual model of concept development defines the acquisition process as a construction between the child and the context. In contrast to Piaget, there is an emphasis on the precursor understandings of a concept and how the display of understanding varies as a function of the context. There are a multitude of acquisition patterns depending on the degree and kind of contextual support created. In the development of temporal concepts, Levin stresses the relationship of the task demands and the microgenetic integration of precursor understandings within the task context:

> "Principles can only be assessed in a particular context. The context provides a structure which calls for integration of the principles with a variety of skills, be they domain specific or general....Rather than viewing the situation as hopelessly confusing, we would argue that development can be richly described only by

> employing use of different tasks, inviting the use of different strategies on the part of the subject and calling for integration with various skills can, thus, shed light on the complexity of the use of principles (Levin, 1989:171).

This is a fundamentally different description of the developmental process than described by Piaget. Piaget emphasized the universal acquisition of abstract, logical relationships, which are essentially context independent and invariant. The variations in the display of a concept of objective duration, in this study, across tasksets and conditions, is consistent with the contextual model and cannot be explained through Piagetian mechanisms.

The role of social interaction as a developmental force is also an essential difference in assumptions. Social interaction in Piagetian theory can create cognitive conflict, but not cognitive growth. Cognitive development is self-constructed, not mediated by the social world. In contrast, the contextual model can incorporate the role of social interaction as a critical force in concept development. Social interaction is one aspect of context, both within tasks and within development, which provides scaffolding and support for the display and integration of unconsolidated skill. Psychological tools performs dual functions at the intersection of the contextual approach and statements on the role of social interaction. Psychological tools may be a way of operationalizing aspects of supportive contexts. The strategic use of tools can be examined, with the goal of specifying the mechanisms through which skills and concepts can be displayed. In addition, psychological tools extend the role of social interaction beyond the interpersonal. The interaction between the child and the point of historical cultural evolution is essentially social, and has enormous potential to examine the effect of the means by which our children learn on what they learn.

Clocks are a critical part of learning about time in our culture, to the extent of defining culturally objective duration. The use of a clock as a psychological tool, in this study, suggests that the developmental process of the integration of precursor understandings is altered in different types of contexts. Learning about time through a psychological tool, such as a clock, reconceptualizes assumptions that concept development is logical, acontextual and abstract and universal. Preschoolers seem to have many underdeveloped understandings, which are tied to context and unintegrated. Consistent with the contextual model of development and the results of this study, it is proposed that social interaction, both interpersonal and extended through psychological tools, creates a puzzle frame. Children fit precursor understandings, like pieces of a puzzle, into the available framework.

References

Ames, L.B. (1946) The development of the sense of time in the young child, The Journal of Genetic Psychology, 68, 97-125.

Antinucci, F. & Miller, R. (1976) How children talk about what happened. Journal of Child Language, 3, 167-189.

Arieux, M. (1985) Children's temporal regulation of activity. Unpublished manuscript. City University of New York.

Arlin, M. (1990) What happens to time when you sleep? Children's development of objective time and its relation to time perception. Cognitive Development, 5, 71-88.

Barker, R.G. & Wright, H.F. (1955) The Midwest and its children, New York: Harper and Row.

Bauer, P.J. & Shore, C.M. (1987) Making a memorable event: Effects of familiarity and organization on young children's recall of action sequences. Cognitive Development, 2, 327-339.

Bauer, P.J. & Mandler, J.M. (1989) One thing follows another: Effects of temporal structure on one- to two- year olds' recall of events. Developmental Psychology, 25, 197-206.

Block, R.A. (1990) Models of psychological time. In R.A. Block (Ed.) Cognitive models of psychological time. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Brown, A.L. (1976) The construction of temporal succession by preoperational children. In A.D. Pick, (Ed.) Minnesota Symposium on Child Psychology, (Vol. 10), Minneapolis: University of Minnesota Press.

Brown, A.L. & Campione, J.C. (1983) Three faces of transfer: Implications for early competence, individual differences and instruction. In, Advances in Developmental Psychology, Vol.3, New York: Erlbaum & Associates.

Bruner, J and Helen Haste (Eds.) (1987) The child's construction of the world, New York: Methuen, Inc.

Bryant, P.E. & Kopytynska, H. (1976) Spontaneous measurement by young children. Nature, 260, 773.

Carbery. M. (1989) Temporal knowledge of daily routines. Unpublished manuscript. City University of New York

Carni, E. & French, L.A. (1984) The acquisition of **before** and **after** reconsidered: What develops? Journal of Experimental Child Psychology, 37, 394-403.

Ceci, S. & Brofenbrenner (198?) " Don't forget to take the cupcakes out of the oven"; Prospective memory, strategic time-monitoring, and context. In Readings in child development: Minneapolis: University of Minnisota Press.

Clark, E.V. (1971) On the acquisition of meaning of **before** and **after**. Journal of Verbal Learning and Verbal Behavior, 10, 266-275.

Clark, E.V. (1983) Meanings and Concepts, In P. Mussen (Ed.) The Handbook of Child Psychology. New York: Wiley.

Clark, E.V. (1985) The Acquisition of Romance, With Special Reference to French, In D. Slobin (Ed.) The Cross-Linguistic Study of Language Acquisition. Hillsdale, NJ: Lawrence Erlbaum Associates.

Clemence, G.M. (1981) Time measurement for scientific use. In J.T. Fraser (Ed.) The voices of time: A cooperative survey of man's view of time as expressed by the sciences and by the humanities (2nd edition). Amherst, MA: The University of Massachusetts Press.

Cohen, J. (1981) Subjective time. In J.T. Fraser (Ed.) The voices of time: A cooperative survey of man's view of time as expressed by the sciences and by the humanities (2nd edition). Amherst, MA: The University of Massachusetts Press.

Cottle, T.J. & Klineberg, S. The Present of Things Future. New York: The Free Press/Macmillan, 1974.

Crowder, R.G. & Greene, R.L. (1987) On the remembrance of times past: The irregular list technique, Journal of Experimental Psychology: General, 116, 265-278.

Doob, L.W. (1971) Patterning of Time. New Haven, CT.: Yale University Press.

Fivush, R. & Mandler, J.M. (1985) Developmental changes in the understanding of temporal sequence, Child Development, 56, 1437-1446.

Fraisse, P. (1963) The Psychology of Time. New York: Harper and Row.

Fraisse, P. (1982) The adaptation of the child to time. In W.J. Friedman (Ed.), The Developmental Psychology of Time. New York: Academic Press.

Fraser, J.T. (1981) The Voices of Time: A Cooperative Survey of Man's Views of Time as expressed by the Sciences and the Humanities. Amherst, MA: Univeristy of Massachusetts Press.

Fraisse, P. (1984) Perception and estimation of time. Annual Review of Psychology, 35, 1-36.

French, L.A. (1988) The development of children's understanding of **because** and **so**. Journal of Experimental Child Psychology, 45, 262-279.

Friedman, E.R. (1977) Judgements of time intervals by young children. Perceptual and Motor Skills, 45, 715-720.

Friedman, W.J. (1977) The development of children's understanding of cyclical aspects of time. Child Development, 48, 1593-1599.

Friedman, W.J. (1978) Development of time concepts in children. In H.W. Reese & L.P. Lipsett (Eds.) Advances in Child Development and Behavior (Vol. 12), New York: Academic Press.

Friedman, W.J.(Ed.) (1982) The Developmental Psychology of Time. New York: Academic Press.

Friedman, W.J. (1986) The development of children's knowledge of temporal structure, Child Development, 57, 1386-1400.

Friedman, W.J. (1990) Children's representations of the pattern of daily activities. Child Development, 61, 1399-1412.

Gabbay, D. & Rohrer, C. (1979) Do we really need tense other than future and past? In R. Bauerle, U. Egli & A. von Stechow (Eds.) Semantics from different points of view. New York: Springer-Verlag.

Gay, J. & Cole, M. (19) The New Mathematics and an Old Culture: A Study of Learning among the Kpelle of Liberia. New York: Holt, Rhinehart & Winston.

Gelman, R., & Gallistel, C.R. (1978) The Child's Understanding of Number. Cambridge, MA: Harvard University Press.

Gibson, J.J. (1975) Events are perceivable but time is not. In J.T. Fraser & N. Lawrence (Eds.), The study of time II. New York: Springer-Verlag.

Gonzalez, A & Zimbardo, P. (1985) Time in Perspective. Psychology Today, 19, 20-26.

Harner, L. (1980) Comprehension of past and future reference revisited. Journal of Experimental Child Psychology, 29, 170-182.

Harner, L. & Nelson, K. (1989) Conventional time knowledge in early childhood. Paper presented at Annual Meeting of the American Psychological Society: Alexandria, Va.

Hazan, Haim (1984) Continuity and transformation among the aged: A study in the anthropology of time. Current Anthropology, 25, 567-578.

James, W. (1891) Principles of Psychology, London: Macmillan.

Lakoff, G. (1987) Women, Fire and other Dangerous Things: What Categories Reveal about the Mind. Chicago: University of Chicago Press.

Lakoff, G. & Johnson, M. (1980) Metaphors we live by. Chicago: University of Chicago Press.

Levin, I. (1977) The development of time concepts in young children: Reasoning about duration. Child Development, 48, 435-444.

Levin, I. (1979) Interference of time-related and unrelated cues with duration comparisons of young children: Analysis of Piaget's formulation of the relationship of time and speed. Child Development, 50, 469-477.

Levin, I. (1982) The nature and development of time concepts in children: The effect of interferring cues. In W.J. Friedman (Ed.). The Developmental Psychology of Time. New York: Academic Press.

Levin, I. (1989) Principles underlying time measurement: The development of children's constraints on counting time. In I. Levin & D. Zakay (Eds.). Time and Human Cognition. North-Holland: Elsevier Science Publishers B.V.

Levin, I., Israeli, E., & Darom, E. (1978) The development of time concepts in young children: The relation of durati on and succession. Child Development, 49, 755-764.

Levin, I. , Wilkening, F., & Dembo, Y. (1984) Development of time quantification: integration of beginnings and endings in comparing durations. Child Development, 55, 2160-2172.

Levin, I. & Wilkening, F. (1989) Measuring time via counting: The development of children's conceptions of time as a quantifiable dimension. In I. Levin & D. Zakay (Eds.). Time and Human Cognition. North-Holland: Elsevier Science Publishers B.V.

Levine, R. & Wolf, E. (1985) Social time: The heartbeat of culture. Psychology Today, 19, 28-35.

Lyons, J. (1977) Semantics (Vol.2) Cambridge: Cambridge University Press.

McCawley, J.D. (1971) Tense and time reference in English. In C.J. Filmore & D.T. Langendoen, (Eds.), Studies in Linguistic Semantics. New York: Holt, Rhinehart & Winston, Inc.

McGrath, J.E. & Kelly, J.R. (1986) Time and human interaction: Toward a social psychology of time. New York: The Guilford Press.

McShane, J. & Whittaker, S. (1988) The encoding of tense and aspect by 3 to 5 year old children. Journal of Experimental Child Psychology, 45, 52-70.

Medrich, E.A., Roizen, J.A., Rubin, V. & Buckley, S. (1982) The Serious Business of Growing Up: A Study of Children's Lives Outside School. Berkeley: University of California.

Michon, J.A. (1990) Implicit and explicit representations of time. In R.A. Block (Ed.) Cognitive models of psychological time. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Miller, G.A. & Johnson-Laird, P. (1976) Language and perception. Cambridge, MA.: Harvard University Press.

Miller, K.F. (1989) Measurement as a tool for thought: The role of measuring procedures in children's understandin g of quantitative invariance. Developmental Psychology, 25, 589-600.

Montangero, J. (1985) Current perspectives on the development of the concept of time. In T.S. Evans (Ed.), Genetic Epistemology: Yesterday and Today. New York: Graduate School and University Center of CUNY.

Montangero, J. (1985) The development of temporal inferences and meanings in 5 to 8 - year old children. In J. A. Michon & J. L. Jackson (Eds.) Time, Mind and Behavior. New York: Springer-Verlag.

Nelson, K. (1985) Making Sense: The Acquisition of Shared Meaning. New York: Academic Press.

Nelson, K. (1986) Event knowledge: Structure and function in development. Hillsdale, NJ: Lawrence Erlbaum Associates.

Newson, J. & Newson, E. (1974) Cultural aspects of childrearing in the English-speaking world. In M. Richards (Ed.) The Integration of a Child into a Social World. New York: Cambridge University Press.

O'Connell, B.G. & Gerard, A. B. (1985) Scripts and scraps: The development of sequential understanding. Child Development,56, 671-681.

Piaget, J. (1946\ 1969) The child's conception of time. New York: Basic Books.

Piaget, J. (1954) The Construction of Reality in the Child. New York: Basic Books.

Piaget, J. (1946\1977) The child's concept of time. In H.E. Gruber & J.J. Voneche (Eds.) The essential Piaget: An interpretative reference and guide. New York: Basic Books.

Piaget, J. (1987) Possibility and necessity: The role of necessity (Vol. 2). Minneapolis, MN: University of Minnesota Press.

Piaget, J., Inhelder, B., Szeminska, A. (1960) The child's conception of geometry. London: Routledge & Kegan Paul.

Piaget, J. (1981) Time perception in children. In J.T. Fraser (Ed.) The voices of time: A cooperative survey of man's view of time as expressed by the sciences and by the humanities (2nd edition). Amherst, MA: The University of Massachusetts Press.

Pouthas, V. (1985) Timing behavior in young children: A developmental approach to conditioned space responding. In J. A. Michon & J. L. Jackson (Eds.) Time, Mind and Behavior. New York: Springer-Verlag.

Pouthas, V., Droit, S., Jacquet, A.-Y., & Wearden, J. H. (1990) Temporal differentiation of response duration in children of different ages: Developmental changes in relations between verbal and nonverbal behavior. Journal of the Experimental Analysis of Behavior, 53, 21-31.

Richards, D. & Siegler, R.S. (1982) U-Shaped behavioral curves: It's not whether you are right or wrong, it's why. In S. Straus & R. Stavi (Eds.). U-Shaped behavioral growth. New York: Academic Press.

Richie, D.M. & Bickhard, M.H. (1989) The ability to perceive duration: Its relation to the development of the logical concept of time. Developmental Psychology, 24, 318-323.

Riechenbach, H. (1947) Elements of Symbolic Logic. New York: Free Press.

Rispoli, M. & Bloom, L. (1985) Incomplete and continuing theoretical issues in the acquisition of tense and aspect. Journal of Child Language, 12, 471-474.

Rogoff, B. (1981) Schooloing and the development of cognitive skills. In H.C.Triandis & A. Heron (Eds.) Handbook of cross- cultural psychology: Developmental psychology (Vol.4). Boston: Allyn & Bacon.

Rosch, E. (1978) Principles of categorization. In E. Rosch & B.Lloyd (Eds.), Cognition and categorization. Hillsdale, NJ.: Lawrence Erlbaum Associates.

Seigel, S. (1956) Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill.

Siegler, R.S. & McGilly, K. (1989) Strategic choices in children's time telling. In I. Levin & D. Zakay (Eds.) Time and human cognition: A life-span perspective. New York: North-Holland.

Smith, C.S. & Weist, R.M. (1987) On the temporal contour of child language: A reply to Rispoli & Bloom. Journal of Child Language, 14, 387-392.

Stevenson, R.J. & Pollitt, C. (1987) The acquisition of temporal terms.Journal of Child Language, 14, 533-545.

Tai, J. (1984) Verbs and times in Chinese: Vendler's four categories. In D. Testen, V. Mishra & J. Drago (Eds.) Papers from the Session on Lexical Semantics. 27-28 April: Chicago.

Vygotsky, L. (1978) Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Vygotsky, L. (1986) Thought and language. Cambridge, MA.: M.I.T. Press.

Weist, R.M. (1986) Tense and aspect. In P. Fletcher & M. Garman (Eds.) Language Acquisition. (2nd Edition), New York: Cambridge University Press.

Wertsch, J.V. (1985) Vygotsky and the social formation of mind. Cambridge,MA: Harvard University Press.

Westman, A.S. (1987) Development of time concepts: Differentiating clock and calendar times from apparent durations. Journal of Genetic Psychology, 148, 259-270.

Winer, B. J. (1971) Statistical principles in experimental design. New York: McGraw-Hill.

Whorf, B.L. (1956) Language, Thought and Reality: Selected Writings of Benjamin Lee Whorf. Cambridge, MA: M.I.T. Press.

Wilkening, F., Levin, I. & Druyan, S. (1987) Children's counting strategies for time quantification and integration. Developmental Psychology, 23, 823-831.

Zakay, D. (1990) The evasive art of subjective time measurement: Some methodological dilemmas. In R.A. Block (Ed.) Cognitive models of psychological time. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.