

What Happens While We Learn?
The Idiosyncratic Nature of Learning from Experience

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DEDICATION

To my wife, Maria, for the inspiration to live, love and learn.

To my parents and brother, Dee, Clancy and Tom, for their unshaken confidence in me,
and belief in education and learning.

To all of my children and grandchildren ... Kerry & Matt, Jack & Rachel, Katie & Aaron,
Larissa & Zoltan, Mark & Dora, Nathan, Isaiah, Andrew, Milan and Keely...
the source of my motivation and purpose.

To my father-in-law Zynowij Kwit, who shared and cared deeply in this endeavor.

GENERAL ABSTRACT

In this dissertation I explore how individuals learn from experience by capturing the detailed actions of new learners as they face a new and unfamiliar task. Subjects faced a common, though unfamiliar, online game environment. While the context required demonstration of a common set of learned behaviors, prior empirical research suggests individual learners might exhibit unique patterns of behavior while learning. In a first study, a highly detailed record of individual behavior within game trials revealed highly idiosyncratic behavioral paths for individual learners while higher-level commonalities in techniques and tactics guiding game play and outcomes emerged. I examine factors that guide and help to explain patterns of learning behavior and their influence on learning outcomes.

In a second study, I examine behavior in an online game environment modified to heighten cognitive load and explore the interaction of cognitive ability and the use of breaks in predicting learning outcomes. Individuals with higher cognitive ability generally achieve greater learning outcomes across a wide variety of tasks. Cognitive load speaks to the demands placed on limited cognitive resources during learning (James, 1976). Learner's limited cognitive resources can be overwhelmed during learning by the data and cognitive processes they must attend to. I hypothesize a benefit to the use of short breaks by subjects with lower cognitive ability. In contrast to previous research, our findings indicate short incremental breaks do not improve learning.

ACADEMIC ABSTRACT

In this dissertation I examine the actions of learners while they navigate a new learning context to gain insight into how learning occurs during learning events. Building on Kolb's (2014) experiential learning model and incorporating research from cognitive psychology, I explore discrete patterns of learning activity and tactical emergence to gain insight into how learning evolves and outcomes are achieved. Kolb's conceptual work points to the complexity of most learning experiences. This dissertation offers a framework and language supporting a more detailed analysis of the cognitive processes and knowledge development which occur during learning events, a new perspective to help interpret the dynamics and complexities of in-situ learning. I adopt a refined view of learning which anticipates the interplay between discrete processes and knowledge elements. In the proposed conceptual model, process and content dynamics are managed by executive function through three specific mechanisms; dialectics, goal pursuit, and the scaffolding of knowledge.

Using a new game environment developed for this research, I trace the actions of learners as they interact with a "new-to-them" task. In Study 1 (n=50), I examine the behavior of subjects as they progressively learn and adopt new tactics while playing the game and seek evidence of the three proposed mechanisms that guide decisions during learning, dialectics, goal pursuit, and scaffolding. Study 2 (n=194) builds upon the patterns of learned behavior observed in Study 1, and examines how breaks, or their absence, influence learning under enhanced cognitive load. In this study, I explore how incremental break time contributes to learning outcomes. Cognitive ability and incremental break time were hypothesized to interact; subjects with high cognitive ability were expected to find little benefit from break time, while those with lower ability were expected to positively benefit from time in breaks. Surprisingly, and in contrast to previous

research, incremental break time was negatively related to learning and outcomes. No interaction between cognitive ability and break time was observed. I discuss the importance of this finding.

This dissertation contributes to a refined understanding of learning process, knowledge content, and the dynamic nature of their interactions. Learners demonstrate idiosyncratic differences in how they interpret and respond to the environment. This includes how quickly and effectively they recognize problems or opportunities while learning, establish goals to guide their pursuit, and construct and leverage new knowledge to shape more effective behaviors. Contributions to learning theory, explored and developed here, may be transferrable to individualized instruction environments, including new insights about the microdynamics of learning and knowledge states which are developed in this dissertation.

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1.0 INTRODUCTION

Adapting to the world around us is an activity undertaken by every human being (Mayr, 1988). Growth and survival depend on it (Dobzhansky, 1968); from meeting basic human needs (Smith, 1993), to creating and sustaining social relationships (Schulkin, 2011), to developing innovative procedures and new products (Rodima-Taylor, Olwig, & Chhetri, 2012). To adapt, individuals must learn, and evidence suggests that individuals who have learned are more likely to solve difficult problems and change behavior effectively (Mayer, 1983). Research on adaptation speaks to the dire consequences of failures to adapt (Cronshaw, Ong, & Chappell, 2007). How individuals learn and adapt therefore is critically important. Yet, the cognitive mechanics connecting learning and adapting are often expressed in the literature only in general terms, often ignoring the specific actions of learners within those events.

There is still much to learn about the cognitive mechanics that drive learning and our ability to adapt. In particular, our understanding of what happens during individual learning events is only beginning to emerge. How learners create and accumulate knowledge, update it, discard select elements, organize and use it are fundamental mechanisms of learning. Differences may at times be reflected in the different questions asked by learners, differences in content learners retain or fail to retain, and the different types of errors learners make when processing facts, concepts, relationships, and processes. That some learners correct these errors and others do not is further evidence of differences in learning.

Increasing our understanding of the dynamics associated with learning events would provide timely and important insights into factors which inhibit or enhance learning. These insights are likely to contribute theoretically and practically to learning, identifying improved learning strategies and methods and identifying shortfalls which may occur when mastering a

new task. Further, while almost every individual is capable of learning, substantial evidence demonstrates the experience of learning can and does differ across learners. Individuals, for instance, respond differently to training activities. In educational research, assessments of learning commonly show participants in the same learning program differ in the levels of outcomes achieved. These differences are the focus of research on aptitude-treatment interactions, where outcomes have been associated with learner differences in cognitive ability, prior learning and motivation. However, aptitude-treatment interactions as currently understood account for only a portion of the observed differences (Snow, 1991).

In an attempt to add to our understanding of how individuals learn, I build upon Kolb's (1984) theory of experiential learning to develop a concept I describe as the microdynamics of learning. Learning microdynamics refer to the dynamic interplay between the cognitive processes of learning and the evolving knowledge content possessed by a learner. Learning microdynamics are assumed to be guided by an executive function, which makes decisions about the engagement and sequencing of cognitive learning processes and the retention and structure of knowledge content. Despite advances in neuroscience and learning theory, the gap between our understanding of brain function and learning remains wide. The duration of many brain processes is measured in microseconds; research on eye-blinking has tied the eyeblink to switching between cognitive processes (Nakano, Kato, Morito, Itoi, & Kitazawa, 2013). An account of learning that addresses learning units of time closer to that which occurs in the brain may help to close this gap. Learning microdynamics may offer new insights and a more detailed account of learning.

A fundamental challenge to studying learning microdynamics is that few studies in the research literatures in learning, education or training and development attempt to examine in

detail the cognitive activities and processes that occur within learning events. A clear exception to this is the work of Anzai and Simon (1979) in their examination of a single subject while learning the Tower of Hanoi game. As a consequence, theoretical frameworks and the vocabulary necessary to address this level of analysis are underdeveloped. This is particularly true in the domain of knowledge, where existing descriptive frameworks fail to provide terminology capable of describing fine-grained changes in knowledge (Nokes & Ohlsson, 2005). Distinctions between declarative versus procedural knowledge, explicit versus tacit knowledge, and data, information and wisdom as knowledge, offer limited functional insight into how knowledge changes and this limits our ability to describe or explain the ongoing dynamics of accumulation, creation, assimilation, curation and application of knowledge during learning events.

Existing process models of learning are limited in two ways. First, most process models of learning do not incorporate discrete learning activities, but instead reflect broad categories of cognitive emphasis. An example is Kolb's (2014) experiential learning model which incorporates four general processes, concrete experience, reflective observation, abstraction, active experimentation. Each high-level process category encapsulates an unidentified set of discrete activities which collectively focus on a broad learning objective or phase. A second limitation is that the processes by themselves are incapable of providing an account of which learning processes should be engaged at a given point in time and in what order. Most often these models propose a general sequence in the progression of learning that, anecdotal evidence suggests, is frequently violated in practice. The learning microdynamics framework offered here extends existing learning process frameworks to recognize the potential for a much wider array of specific cognitive learning activities.

Adopting more fine-grained views of knowledge elements and cognitive learning processes may ultimately provide the capacity to model the dynamic nature of learning. A key insight is recognizing that processes must act on something—in this case, they process knowledge elements or clusters of elements. I suggest the microdynamics of learning events can be depicted as long sequences of process nodes. Each node encompasses an input-process-output sequence that incorporates knowledge element inputs that are acted upon by a distinct cognitive process that generates one or more new knowledge element outputs. I believe it is the connecting of knowledge elements to cognitive processes that makes this framework capable of describing actual learning behavior. Recognizing that the selection of cognitive processes is likely determined by the existing state of knowledge, may offer insight into how executive function sequences cognitive processes and behavior during learning events.

In this dissertation, I conduct two studies to explore the dynamics of learning using an experiential learning task. A unique “learning by doing” game environment is developed and used to examine how people acquire, create and leverage knowledge through their interactions with a “new-to-them” task. Learning by doing contexts (e.g. Anzai & Simon, 1979) have several useful features for studying learning dynamics. First, they require a wide range of learning activities. Unlike some classroom learning settings, subjects are required to develop the skills required to engage with their environment, rather than simply acquire domain understanding. Second, as in many real-world learning scenarios, subjects are not provided organized and structured content about the environment. They can and often must discern what data about the environment is relevant to developing their own understanding. Third, while some content can simply be observed, in most cases learning by doing environments require learners to actively engage with the environment in order to elicit new data about how the environment really works.

Choosing how to engage with the environment may involve the retrieval of stored routines, but often requires the creation of new tactics based on reflection about what learning or performance goal is to be achieved. Finally, learning by doing environments require not only the development of tactics and techniques, but also developing the capacity for skillful execution. This creates substantial opportunities for choice as learners navigate the learning environment, and also provides an experimental environment that has many of the same features as real-world task and problem-solving environments.

Study 1 is an initial attempt to understand learning dynamics. It examines 50 learners as they learn a computer-based strategy game. Using detailed behavioral observations of actions taken in game-play, I examine learning through the evolution of observable changes in the tactics learners use to navigate the environment and pursue game outcomes. During 75-minute trial sessions, subjects complete an average of 77 game attempts (trips in the context of the game). These data provide a detailed account of the magnitude of variations in activities undertaken while learning both within and between learners across a relatively large number of learners. These data verify that learner behaviors often do not follow a common script, but instead demonstrate dramatic differences in the content, timing and sequence of actions adopted. Differences in behavior exist within and across trip attempts, within and between learners, and in overall game outcomes. However, these data also show consistencies in the patterns of game play tactics developed and used. Most subjects do indeed find their way to a relatively common set of tactics and techniques, but do so following markedly different timelines, sequences and learning paths.

Study 2 builds on the patterns of learned behavior observed in Study 1 and examines the role of cognitive load on learning. Building on research on the effects of cognitive load, I sought

to further understand how the *ability* to take breaks and the *duration* of breaks taken, influence learning. Study 2a (n=92) examines learning where subjects are unable to take breaks. Study 2b (n=102) provides an opportunity for subjects to take breaks of varying duration while learning. While expecting cognitive ability to increase performance, I also hypothesized that cognitive ability and break time would interact in their effects on game outcomes. Learners with high cognitive ability would perform equally well, irrespective of breaks taken while learning. Those with lower cognitive ability would experience improved learning outcomes while taking more breaks. Data from Study 2b subjects (n=102) who completed 60 minutes of game play with an ability to take incremental breaks, produced little evidence of interaction. Both cognitive ability and breaks produced substantive main effects. However, in sharp contrast to the collective literature that examines breaks between learning events, the use of breaks led to poorer learning outcomes. Possible reasons for this unexpected outcome are considered. Study 2 also demonstrated and reinforced many of the detailed behavioral patterns observed in Study 1.

This dissertation is organized as follows. Chapter 2 provides a review of theory informing learning in the experiential context and concludes with a proposal illustrating how a microdynamic view of learning might function. Chapter 3 describes Study 1, which provides a detailed record of the actions of 50 learners during multiple learning events. Chapter 4 describes Study 2, which examines cognitive load and the use of break time while learning. Chapter 5 discusses the contributions of this research, its limitations and implications for future research and practice.

2.0 LEARNING IN THE LITERATURE

2.1 Learning

Learning has been defined in many different ways. Knowles (1973) described learning as “the process of gaining knowledge and expertise”. Other definitions of learning also emphasize the *process* nature of learning; Bingham and Eisenhardt (2011) define learning as a “transformative process”, and Ambrose, Bridges, DiPietro, Lovett, and Norma (2010) suggest that learning “is a process that leads to change”. Learning is frequently equated with a problem-solving process in the literature. Mayer (1983) used the terms thinking, problem solving, cognition and learning interchangeably noting that thinking and learning frequently result in problem solving behavior. Behavioral definitions of learning are frequently referenced as well; Driscoll (2005) suggests that learning reflects “a persisting change in human performance or performance potential” resulting from a “learner’s experience and interaction with the world.”

Smith (1982) suggests that learning “defies singular definition because of its many uses but may refer to (1) the acquisition and mastery of what is already known about something, (2) the extension and clarification of meaning of one’s experience, or (3) an organized, intentional process of testing ideas relevant to problems.” While researchers often seek explanations for the common and broadly generalizable dimensions of learning, this dissertation explores the detailed differences and dynamics which may distinguish how learning progresses within learning events. Therefore, learning is examined here in the context of new experience.

While learning may encompass all of the dimensions highlighted above, it may also be argued that much of what we call learning has experience at its core. An individual may learn through the structured experience of others, by reading or observing their actions. In contrast, a learner may also learn by doing, implying that the individual engages directly with the

environment, including social interactions, and through learned behavior extract data useful to construct new meaning. The richness and novelty of the experience reflected in the environment, and the number of opportunities to apply and test new behavior against the environment define how “experiential” a learning context is likely to be. Thus, the experiential learning context is different from other learning contexts to the extent that action is a prerequisite for learning to occur. The actions taken reflect the self-directed characteristics of learning in this context; the learner decides both the pace and direction learning will take. Self-directed action is necessary to participate in the experience and surface the data we need for continued learning. Arrow (1962) lends credence to this perspective:

One empirical generalization is so clear that all schools of thought must accept it

Learning is a product of experience Learning can only take place in an attempt to solve a problem Even the Gestalt and other field theorists, who stress the role of insight in the solution of problems, have to assign a significant role to previous experiences in modifying the individual’s perceptions (pg. 155).

Understanding the detailed nature of how experience is transferred and reconstructed in the minds of learners and is used to construct new behavior is of great importance and functions as a central objective of this dissertation.

2.2 Process Models of Learning

Kolb (1984) also emphasizes process to describe learning; “Learning is a process whereby knowledge is created through the transformation of experience”. While experience has been noted as central to most of what we learn (Arrow, 1962), the context surrounding that experience may vary significantly. While a classroom setting controls many aspects of the learning environment and may limit opportunities to overtly test new learning and behavior, an

experiential context offers an open and uninhibited environment where new experiences abound and a learner is expected or required to interact with and adapt to the environment. In the latter context, the learner is on his or her own to decide how to exercise the environment and extract the data necessary to understand how things work. Operating in an experiential setting where nothing is known in advance suggests that the learner is without “recipe” guiding actions and behaviors to follow; a learner must develop a set of alternatives and become skilled at using them.

Arrow (1962) clearly notes the importance of experience to learning as well as the centrality of processes and problem solving in its description. Experiential theories of learning are grounded in each of these dimensions and describe learning from a distinctly process centric point of view. Within leading theories of experiential learning, distinctions are made in the description of individual processes involved and the sequence with which they are invoked. Lewin’s (1951) model of learning describes a distinct set of macro-processes progressing in cyclical fashion. Many components of his model have been embraced in more recent learning research, including Kolb (1984).

2.2.1 The Cyclical Nature of Learning

Lewin (1951) suggests that the learning process follows a repeating path moving from 1) concrete experience to 2) reflective observation to 3) abstract conceptualization to 4) active experimentation. The concrete experience phase serves as a touchpoint between cognition and the environment, feeding the sensory and perceptive processes with the data necessary to learn. The observational phase of Lewin’s (1951) learning cycle is conceptualized as the step where the learner begins to assimilate what was observed in the preceding interaction with the environment. Learners reflect upon characteristics and changes observed in the environment, and how applied

behavior and observed outcomes might relate to what has been observed. Observation and reflection feed the formative process where broader concepts and generalizations are constructed. In the experimenting phase of Lewin's model, concepts may be organized and positioned to allow for testing in the environment through behavior and action. It is assumed in Lewin's model that knowledge gained thus far is ready to support a learner's intent and action, first in testing and then through full engagement with the environment in the concrete phase. Lewin anticipated that the four steps in his model would be repeated multiple times while learning.

Dewey's (1925) model of experiential learning, a precursor to Lewin's (1951) work, shares features with Lewin's model. Each model identifies four distinct steps in a learning process. More specifically, Dewey's model includes, 1) impulse, 2) observation, 3) knowledge, and 4) judgment. Dewey's model views learning as progressive, suggesting that no two cycles of learning are exactly alike. He argued that growing knowledge of the environment enhances judgment and decision making in a spiraling set of progressive cycles. Behavior as a result becomes less impulsive and more purposeful incrementally over time. Dewey's purposeful nature of learning has been accepted in many contemporary definitions and conceptualizations of the learning process. It also contributes to Dewey's observation that delaying action (e.g. decisions or new behavior), until an adequate base of knowledge has accumulated, is often sound judgement and the best course to minimize errors.

2.2.2 The Cycle May Be Broken

Piaget's (1970) theory of learning is oriented to the macro stages of childhood development. None the less, his theory is sometimes used to examine learning in discrete learning events. Piaget introduces the potential for stages in learning to progress in non-sequential fashion. Shifts in learning emphasis which accompany a particular stage are driven by

“tensions” which emerge while interacting with the environment, which he describes specifically as *extension*, and while developing an accurate cognitive representation and effective behaviors, which he describes as *intention*. Piaget identifies four stages to the learning development process, where a child’s predominant mode of learning cumulatively progresses from one to the next including: (1) Sensory Motor, (2) Presentational (or Pre-Operational), (3) Concrete Operations, and (4) Formal Operations.

At birth and during early childhood, children are absorbing and responding to the massive amount of new sensory information being presented to them. Starting at around age two, children may be seen to become increasingly reflective, as they organize learning with images based on preceding observations; this stage is noted as the Presentational Stage. At around age seven, children enter what he termed the Stage of Concrete Operations. Inductive learning incrementally contributes to new and more advanced conceptualizations, with a level of generalization and abstraction not seen before. Drawing from the preceding phase, a child at around the age of twelve enters the final stage of Formal Operations. In this phase, the learner begins to formulate and manipulate hypotheticals in deductive fashion and is now capable of self-directed behavior and action applied to test and refine interaction with the environment.

The four stages of Piaget’s model (1970) may be extrapolated to illustrate the core processes explaining specific learning events in adults. For instance, a learner, placed in an unknown situation, often responds to that situation with all senses alert to the characteristics accompanying a new environment. Like a child, he or she may initially rely upon sensory and motor-based action to interact with the new context, forming simple representations of the environment. With added reflection, the learner begins to gather and organize knowledge

inductively and then increasingly uses deductive methods to inform and test new behaviors to better direct action in the context.

Piaget (1970) also suggests that a “staged” sequence associated with learning, though conveniently represented as a progressive cycle, may actually ebb and flow in less predictable form. His work identifies the tension and interaction that exists between reflection versus action, as well as concrete versus abstract thinking. Reciprocating movement between these dimensions of thought, irrespective of order or precedence, is theorized by Piaget to be an important precursor to cognitive development. This thinking marks a clear break from the predominately sequential orientation of preceding theory. It also expands the possibility for differences in the potential learning paths associated with a learning event.

Piaget’s (1970) model applied to discrete learning events falls short when seeking answers to how and when shifts between learning processes (stages) might occur. (This is not unexpected from a macro theory originally intended to describe the phases of childhood development.) The tensions which precipitate a change in cognitive focus do not attempt to describe the nature of the inputs and resultant cognitive activities which may follow. This limits our ability to explain and predict patterns of learning and behavior during discrete experiential learning events. Executive function provides additional insights into how the mind oversees learning activity and decides when to reprioritize attention and behavior while interacting with the environment.

2.3 Executive Function: Determining What Comes Next

Learning, particularly in the experiential context, is a complex endeavor. A fixed sequence of processes is unlikely to meet every need. But how does the learner decide what to do next and what is most important? Much like the conductor who stands above and leads the

orchestra, the cognitive requirement for oversight, coordination, and decision making is vital to effective learning. Executive function responds to these requirements in the cognitive domain.

Executive function describes the attention and supervisory processes which oversee learning (Baddeley, 2012) and is central to an individual's ability to learn and solve complex problems. In support of learning, an executive function is needed to invoke process selection and execution (Anderson, 1982; Anderson, 1996; Shiffrin & Atkinson, 1969; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). Decisions must be made regarding what to attend to in the environment, how to organize and process what is observed, what processes to use to solve problems and construct new knowledge, when and how to leverage current knowledge to develop new behavior and procedures, and to assess how effectively that behavior is supporting the accomplishment of objectives.

According to Shiffrin and Atkinson (1969), executive function resides between critical resources associated with memory and vital learning processes attending to the environment. Cowan (2012) suggests that executive function provides an important point of integration between the processes and content involved in learning. More specifically, Diamond (2013) proposes that executive function enables learning through the mental manipulation of ideas; taking the time to think before acting; meeting novel, unanticipated challenges; resisting temptations; and staying focused.

Norman and Shallice (1986) proposed that behavior is controlled in two distinct ways. The first by schemata describing a well learned set of habits, the second by a supervisory element to deal with situations where habits did not preexist, the realm of executive function. Baddeley (1986), uses control executive to describe executive function. In his conceptualization, control executive plays an important role in more than simple recall, but in the knowledge building

process itself. Control executive functions include 1) attention focus, 2) attention division between “stimulus streams”, 3) task switching, and 4) long term memory access. A final important evolutionary step in Baddeley’s (2012) model is the addition of an episodic buffer described as a loop and a sketchpad. This buffer allows a combination of knowledge emanating from multiple sources to be bound into episodic or experiential chunks for processing. Chunking of knowledge elements is thought to reduce the cognitive load associated with the manipulation and storage of knowledge, an important role generally attributed to executive function (Anderson, 1996).

Miyake et al. (2000) noted that differences in operational factors had long been observed in neuropsychological research studying frontal lobe damage. In many cases, some cognitive functions remained largely intact while other control and inhibitory functions were severely degraded. They theorized that a strong case could be made for the multi-functional nature of executive function empirically and generated evidence for the following three component theory.

First executive function allows for shifting between tasks or mental sets (Miyake et al., 2000). This aspect is sometimes associated with cognitive flexibility. Second, executive function supports the monitoring and updating of working memory. This was theorized to include decisions on what to process (store or recall from long term memory) among experiences observed and perceived in the sensory realm. Monitoring and marking changes in knowledge deemed relevant to the current priority tasks as well as the temporal dimension of keeping track of new versus old in considerable detail are integral to working memory processes. Last, executive function may serve to inhibit previously “dominant processes”. This component was central to selective attentional or regulatory decisions a learner might continually make.

The breadth of roles attributed to executive function has resulted in numerous descriptions of what it is and how it works. Baggetta and Alexander (2016) have examined the current breadth of definitions, processes involved, research domains, assessment tasks, and executive function's relationship to human performance. Their review of 106 studies of executive function in educational domains informed the following consolidated definition of executive function:

... a set of cognitive processes that: 1) guides actions and behaviors essential to aspects of learning and everyday human performance tasks; 2) contributes to the monitoring and regulation of such tasks; and 3) pertains not only to the cognitive domain, but also the socioemotional and behavioral outcomes of human performance (Baggetta & Alexander, 2016, p. 24).

In summary, a comprehensive set of supervisory processes have been developed and attributed to executive function in preceding research. These include switching between tasks and learning processes, deciding where attention should be focused next, managing the movement of knowledge content throughout the cognitive system, and facilitating the construction of new knowledge. However, descriptions of executive function provide limited insight into how and when these functions are solicited and prioritized.

2.3.1 Control Theory: Deciding When to Act

Control theory and its more human centered extensions offer some insight into when and how the mind makes decisions and directs pursuit while learning. In his work on cybernetics, Wiener (1948) mathematically described how variations of electro-mechanical feedback systems are related to the cognitive and behavioral mechanisms theorized by several leading psychologists in the field, including Locke (1968), Hume (1965), and Pavlov (1927). Powers,

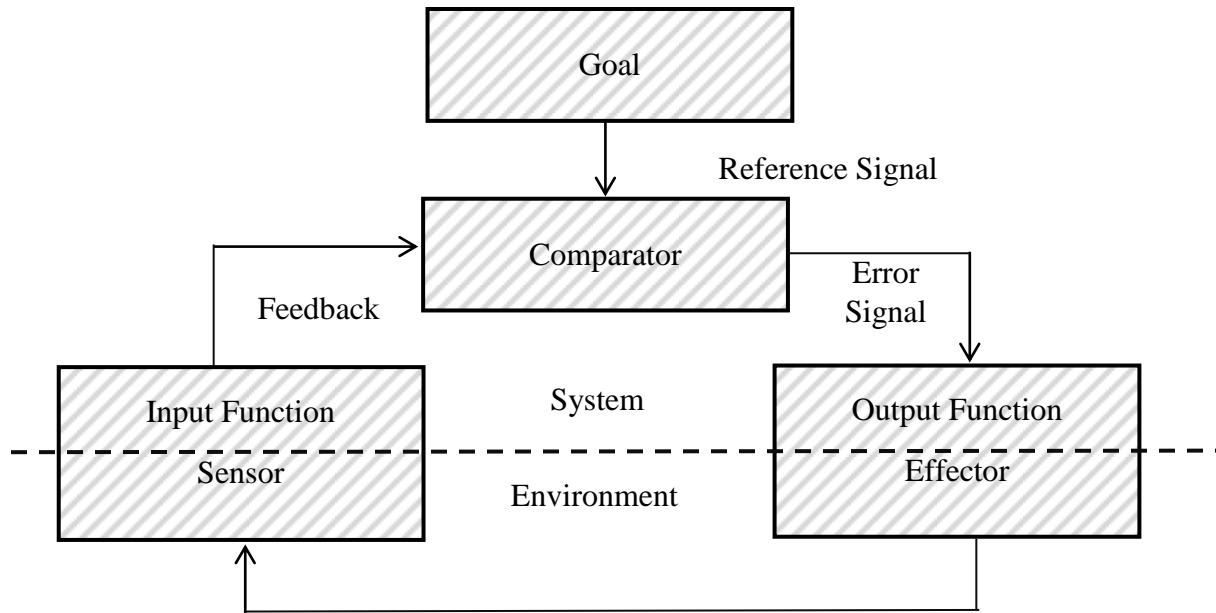
Clark and McFarland (1960) extended Wiener's original thinking to posit a *general feedback theory of human behavior* as illustrated in Figure 2.2. Their model describes a system which relies upon a series of feedback loops which compare *feedback-signals* (current state) to *reference-signals* (goals) and generates *output* (error-signals). As a control system, the system responds to any error signal with the express purpose to bring the current state closer to the goals resident in the system. This basic feedback system or loop forms the building block of a more complex multilayered system. Control loops, representing the organizational and reorganizational activity of neural networks, were incorporated as well as memory and recall functionality. In addition, function and systems which allowed for the generation of "internal feedback" loops to accommodate imagining (not simply responding to external feedback signals) were incorporated in the model. The need for higher level function resident in the restructuring loops with memory and imagining is driven by the persistence and magnitude of error signals in the system.

Carver and Scheier (1982) in a discussion of self-regulation and attention, integrate the process thinking inherent in control theory with content dimensions of cognition including schemas and attributes. As people learn from their environment, abstraction is used to interpret and simplify the feedback provided and organize and categorize it in efficient forms for memorization and recall.

A more contemporary view of control theory applied to human behavior is represented in Klein's (1989) framing of integrated control theory (ICT) as meta-theory for work motivation at large. The theory offers a high-level framework incorporating feedback, goal setting, expectancy, attribution and social learning theory. In doing so ICT embraces both the cognitive and affective dimensions of motivation.

Figure 2.2

General Model of Control Theory



Control theory provides a rational explanation for when and how the decision-making and attention focusing activities of executive function may occur, contributing to our understanding of the dynamic shifts that may occur while learning. Yet the mechanistic depiction of error conditions and their consistent recognition does not fully account for the uncertainty which often surrounds learning. How does the need for a given action surface while learning from experience?

2.4 Impetus for Action and Thought in an Experiential Context

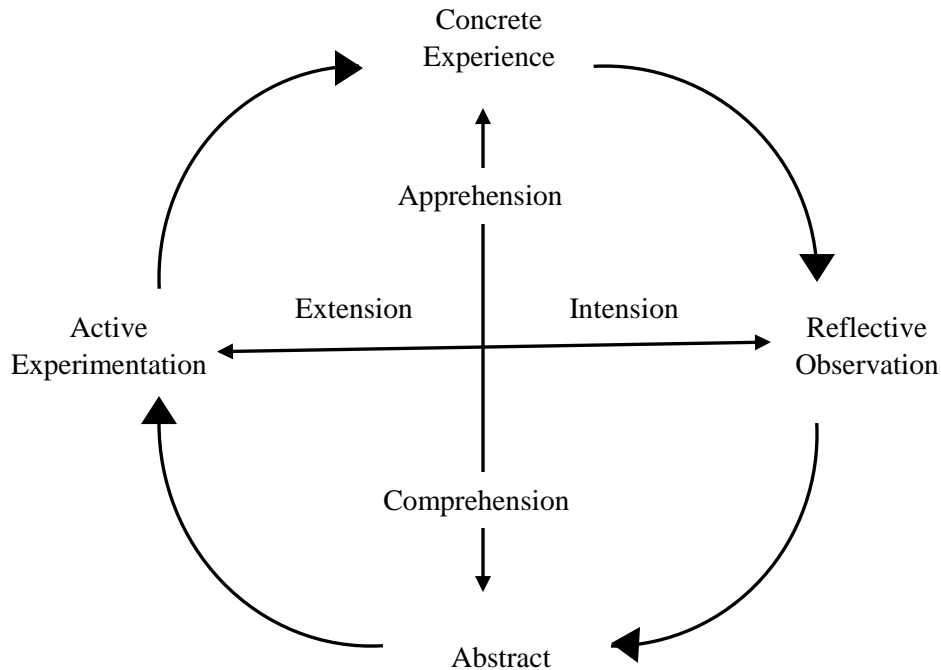
Kolb (1984) was the first to comprehensively integrate an evolving set of learning processes with a set of dialectic mechanisms resulting in a highly generalizable model of experiential learning (Kayes, 2002). His learning cycle model has become one of the most referenced illustrations of experiential learning in management education (Vince, 1998). His

theoretical perspective centers on the relationship between a person and the environment while learning. Drawing from the intellectual origins of experiential learning, including works of Lewin (1951), Dewey (1925) and Piaget (1970) noted earlier, Kolb (1984) proposes a model, illustrated in Figure 2.1, extending the dynamics of thought, knowledge and action which support learning. In Kolb's conceptualization, the person and environment are not static, nor are they isolated. In many cases the environment is seen as shaping the knowledge within the person and the person's behavior is impacting the environment. He suggests that knowledge when viewed through a strictly behavioral lens is constructed by assembling and reorganizing a static set of simpler ideas and constructions. This constrained perspective fails to account for the continuous and dynamic nature of the adaptive process of learning and knowledge building. Kolb expands upon the adaptive mechanisms he calls dialectics, similar to tensions in Piaget's (1970) model, which collectively contribute to the overall learning process. Two dialectic dimensions are brought forward; first, between the concrete environment and abstract thinking and second, between action-based and reflective thought (Piaget, 1970). Kolb suggests that the continuing give and take between dialectics is driven by the tension that exists between them, and that this tension fuels the oscillation between the active and cognitive domains.

The first dialectic he calls prehension. For Kolb (1984), the dialectic of prehension speaks to a process described as "grasping" as a learner reaches out to the concrete world of experience or inward to concepts within the mind. When grasping for knowledge through concrete experience, grasping is addressed as apprehension relying upon perceptive resources. When grasping for knowledge in the conceptual realm, Kolb defines the act as comprehension. To comprehend invokes a process of generalized thinking. Kolb argues that apprehension is more likely to perceive the rich detail describing the environment. If, however what is perceived

FIGURE 2.1

Experiential Learning Cycle and Dialectics (Lewin, 1954; Kolb, 1984)



is not fully comprehended and generalized, much of this detail may be lost. To the degree a learner succeeds in focusing his perceptive efforts (apprehension) and narrowing the field of view, the more likely he or she might recognize and ultimately comprehend what is experienced.

The second dialectic dimension Kolb (1984) explores is when a learner resolves the push and pull between inward reflection (intention) and the need for outward action (extension). According to Kolb, action purposely applies convergent or accommodative knowledge (behavioral distinctions) to the environment or task. Ultimately the objective of this transformational dialectic or movement between action and reflection is knowledge creation.

The importance of dialectics in Kolb's model of learning hints at the dynamic nature learning may assume and when and why changes in learning may occur. The model stops short

of fully explaining how the underlying dialectic tensions are formed, processed and responded to. The explanation for the mechanisms which support decisions and movement among processes while learning is limited. How does learning respond and adapt when changes in the environment are observed, or when inconsistencies or inadequacies in prior learning are perceived? Some answers may be found in the supervisory role of executive function.

However, theories of learning processes including executive function do not fully describe the precipitating knowledge and events which may direct changes in learning. A refined understanding of the specific learning processes called upon while learning would be helpful. A similarly refined understanding of knowledge is also needed. Each process model discussed thus far makes some reference to knowledge as a necessary precursor to or likely outcome of the processes described but, stops short of describing content in adequate detail to predict when and why changes in knowledge or process choice might occur.

2.5 Content in Learning

Understanding the form which knowledge assumes is vital to understanding learning. The accuracy and completeness of the knowledge framework which a learner assembles and constructs provides the foundation for increasingly effective behavior and action in the environment. Knowledge also serves as an important outcome driven by the experience a learner gains and the behavior a learner applies while interacting with the environment. Davenport and Prusak (1998) define knowledge as:

... a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. (p. 5).

This definition captures the central importance of experience and context as raw materials in support of learning. It also recognizes insight, a deeper understanding of a person or thing and how they function. It also suggests that an existing base of knowledge may frame how we evaluate and incorporate new learning. The definition concludes by suggesting all knowledge is first constructed and proceduralized in the mind. It stops well short of describing the different types of knowledge which may exist and how each might function within a learning process.

Many types of knowledge have been identified and studied in research including declarative and procedural (Posner, 1978), semantic (Gentner & Stevens, 1983), episodic (Bransford, 1979), experiential (Wagemans & Dochy, 1991), conceptual (Dochy & Alexander, 1995), domain (Glaser, 1984), and tacit and explicit knowledge (Polanyi, 1966). Each type of knowledge offers interesting distinctions regarding knowledge in a general sense. Yet these descriptive frameworks fail to provide terminology capable of describing fine-grained differences in what is learned and how it may be used (Nokes & Ohlsson, 2005). For example, describing knowledge as declarative offers little insight into what the knowledge describes and what purpose it may serve. This limits our ability to describe how knowledge actually functions in a learning context.

2.5.1 Knowledge Describing How Things Work

Semantic knowledge addresses the meaning a person extracts from his experience with the environment, whether that experience is an active problem-solving setting or reading a book. This understanding frames a learner's conceptualization of how things work in the environment or in a hypothetical sense, how things *might* work. How we interpret words and experiences is uniquely personal and also likely to be shaped by context. Semantics as a conceptualization of

knowledge is foundational to a considerable body of work in memory mapping and modeling (e.g. Gentner & Stevens, 1983). This work includes the development of schema's or problem spaces in many domains of learning. Semantic knowledge is sometimes contrasted with episodic knowledge (Bransford, 1979). Episodic knowledge carries the spatial and time-based context associated with knowledge specific to an experience. Semantic knowledge is thought to be an abstraction above the episode, likely stripped of episodic context. Both concepts can be cumbersome and have been questioned regarding empirical usefulness (Dochy & Alexander, 1995). While a declarative, semantic, or episodic framework may be relied upon to construct a highly descriptive mental model of the environment, that description remains static and does not describe how knowledge functions or changes in a dynamic learning context.

2.5.2 Knowledge Describing What Might Be Done

Procedural knowledge describes knowledge developed and organized to support behavior and action. Included in this description may be knowledge of strategies, tactics, techniques, procedures, skills, rules, or plans (Cohen, 1983). Only procedural knowledge has the potential to be enacted in the environment. Procedural knowledge contains an ostensive component as well as a performative component. The ostensive component captures the “general idea” embodied in the knowledge, while the performative component describes the specifics of the intended action.

Procedural knowledge includes several more descriptive subtypes. A *tactic*, a specific type of procedural knowledge, identifies the method or means used to accomplish a specific end. A tactic may or may not be coupled to a preceding strategy, but at a minimum it is associated with a specific goal, sub-goal or desired end state. A *technique* is defined as a way of doing something by using a special combination of knowledge or skills. When coupled with the specifics associated with a procedure, a description of a refined executable action may result. A

procedure refers to a series of actions or steps that are done in a certain way or order. Procedures often provide a level of detail capable of supporting programming or what has been identified as a *production* in the information processing literatures (Anderson, 1993). The combination of tactics, techniques and procedures (TTP) together form the core of theory in actionable response in the military. TTP operate collectively in support of broader military strategies and campaigns (Dictionary of Military and Associated Terms, Department of Defense, 2011).

Continued learning and experience with new tactics, techniques and procedures also includes making informed decisions on what elements of behavior to retain and use consistently and what elements to discard or replace. In this sense learning is not simply about the accumulation of knowledge, but also about thinning and refining the knowledge framework that a learner maintains, eliminating elements which are inaccurate or less relevant to anticipated needs. The formation of routinized behavior is important to learning and serves as a readily accessible collection of procedural knowledge at the learner's disposal. Automating behavior and interaction through the use of habits or routines frees up limited cognitive resources to attend to other learning demands.

Procedural knowledge does not exist in isolation. Procedural knowledge in its construction may draw insight from preceding knowledge in conceptual form. The accuracy and precision of conceptual knowledge may improve the likelihood that the procedural knowledge constructed in the mind will be effective when applied (Greeno, 1980).

A considerable gap exists between describing knowledge as procedural and the specific details of a well-crafted procedure. If procedural knowledge exists in the realm of intended or applied behavior, deeper descriptive insight regarding its function and use may help to describe and evaluate its application and associated outcomes.

2.5.3 Functional View of Knowledge

Learning in a new experiential context often shares much in common with problem solving. Frequently, multiple problems must be solved on the path to learning something new. A knowledge typology which is tuned to problem solving and clearly describes knowledge form and function would be useful. This includes an ability to differentiate knowledge associated with the environment from knowledge associated with behavioral dimensions, as well as the form knowledge might take, as data or more complex constructions (e.g. variables or theories).

An alternative knowledge typology capturing and describing the dynamics through which knowledge serves as both input and output to a problem-solving process is available in the knowledge matrix (Carlson, 2003). The knowledge matrix maps knowledge form and function to a specific problem space. This typology includes functional descriptions describing how knowledge is used and set of sub category forms which together help describe the types of knowledge associated with a problem space. In this sense, the knowledge matrix functions as a problem-oriented schema. The focus of a problem-oriented model is the outcomes a problem solver or learner may achieve, and the factors which combine to shape those outcomes. Outcomes may reflect goals or actual achievement, bounding a problem by describing the difference between a current state and a goal state.

Contributing to outcomes in the model are two classes of inputs, environmental inputs and behavioral inputs (Carlson, 2003). Three general types of individual behavior may be applied as input(s) to a given problem in addition to the environmental inputs which may be active and relevant to the problem. These include the *tactics* available to the problem solver, and the *enactments* applied to the environment. Enactments describe execution elements including the *skillfulness* and *effort* applied (Campbell, 1990; Carlson, 2000; Hackman, 1987). In the knowledge matrix, outcomes (\mathbf{O}_i) are viewed as a function of environmental inputs (\mathbf{I}_i) and

behavior (\mathbf{B}_i). Behavior in turn is a function of the tactics, skillfulness and effort a learner applies to the

$$\mathbf{O}_i = f(\mathbf{I}_i, \mathbf{B}_i) \text{ where } \mathbf{B}_i = f(\mathbf{T}_i, \mathbf{S}_i, \mathbf{E}_i)$$

problem. The functional view of knowledge contained within the model adds language for thinking about how knowledge changes as we learn, though additional specificity may be necessary to fully capture the dynamics of learning events.

2.6 Dynamic View of Learning

Theories of experiential learning, executive function, and knowledge offer insight into how people learn. Experiential theory (e.g. Kolb, 1984) highlights the importance of context in shaping how people respond to the environment while learning. It also highlights the progression of high-level processes that learners must progress through to learn. It hints at the importance of content to feed and receive from these processes, and how cognitive focus and priorities may respond to perceived gaps or inconsistencies (dialectics) which exist in the present state of knowledge. Executive function (Baddeley, 2012) and control theory (Powers et. al., 1960) provide additional insights regarding the types of cognitive decisions which may occur while learning including how the mind may notice and respond to dialectics to decide what to do next. Executive function also emphasizes the decisions and management of knowledge as learning progresses. This is central to appreciating how the construction and organization of new and old knowledge may follow different and idiosyncratic paths while learning. Executive function (Baddeley, 2012) and control theory (Powers et. al., 1960) suggest that goals and meta strategies may be constructed and pursued to optimize learning. In combination, these important foundations, provide the building blocks to more deeply explore what goes on while learning, and how learning events in a new and experiential context are likely to unfold.

In this section, I propose a refined and dynamic view of learning to better illustrate the constant interactions and dependencies which exist between learning processes and knowledge content as we learn. A “microdynamic view” of learning suggests that succinct combinations of content and process work together across short increments of time. The microdynamic view contributes to learning theory in three distinct ways; (1) it embraces the dynamic interaction between learning processes and knowledge content, (2) it refines the discussion of learning process and content by recognizing that a set of discrete processes interact with distinct knowledge elements while learning, (3) it recognizes the central importance of executive function. Executive function in turn, leverages three distinct control mechanisms including; (1) *dialectics* to direct attention, (2) the pursuit of *goals* and learning strategies, and 3) *scaffolding*, a process which differentially assembles and constructs knowledge enabling new behavior.

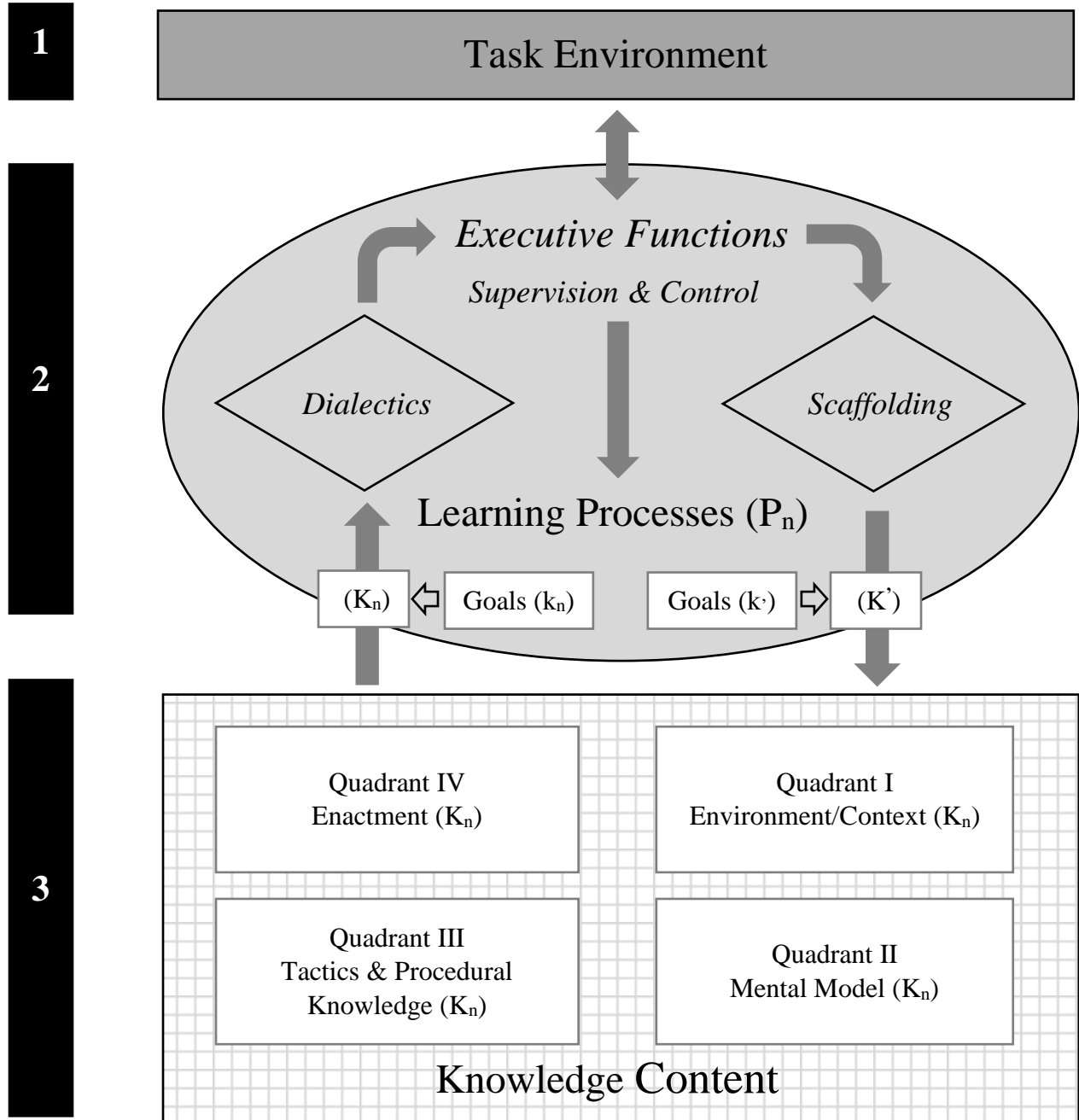
The microdynamics of learning describe a system in which a refined and interactive set of learning processes reside, with access to content overseen by the control and organizing capabilities of executive function. I propose that the dynamic and elemental nature of the system provides a framework to help account for differences during learning events.

2.6.1 Integrated Process – Content Model of Learning

An integrated model of learning, illustrated in Figure 2.3, describes three aspects of learning arranged vertically (1, 2 and 3). Level 1 recognizes the external task environment with which the learner interacts. Level 2 describes the fundamental processes involved with learning including a broad set of specific learning processes (P_n). Any process residing at this level may be called upon at any time to support learning needs in the moment. Executive function is positioned at level 2 as well, providing the important control and decision-making functions

FIGURE 2.3

Conceptual Model: Knowledge Content Interacts with Learning Processes



needed for learning including the attention (dialectics), supervisory (goal pursuit), and knowledge management (scaffolding) activity.

In this model, learning contributes to and draws from four descriptively distinct knowledge domains, noted in level 3. The upper right Quadrant (I) is the domain of descriptive data about the environment or context. Data which are observed, retained and processed contribute to the mental model (Gentner & Stevens, 1983) or schema (Reeves & Weisberg, 1993) illustrated in Quadrant (II). Here processes associated with reflection lead to the formation of concepts (e.g., entities or variables), data attributes about those concepts (e.g., attributes and ranges of possible values of those attributes) and, patterns and relationships among entities. The concepts and theories constructed and retained may vary considerably in both completeness and accuracy. With continued learning in the environment they may be supplanted by more accurate representations and interpretations. Quadrant II reflects the learner's current understanding of "how things work" in the environment.

The lower left Quadrant (III) contains knowledge about possible actions available to the learner and knowledge of the consequences of those actions, all elements of procedural knowledge (Anderson, 1993; Egan & Greeno, 1973; Greeno, 1980). The upper left Quadrant (IV) is the domain of behavior and action. Here, procedural knowledge is positioned for action with the potential to influence the task environment. This may be observable in the tactics, techniques and procedures enacted through behavior as well as the effort and skillfulness with which they are applied. It is important to note that newly constructed procedural knowledge may not be deployed immediately in the environment. It may be held back indefinitely and cognitively tested and manipulated. This "mental deployment" may further refine tactics and procedures before they are enacted.

While distinct sets of cognitive (learning) processes contribute to each of these Quadrants, it is the dynamic capacity to contrast content across quadrants that appears to create particularly powerful learning opportunities, as well as the capacity for the system of processes to guide learning and be self-correcting. For instance, leveraging content in Quadrant II, reflection on new content could extend understanding, but reflection on existing content could also create recognition of content that is missing. Recognition of missing content in Quadrant II, may prompt the development of new tactics in Quadrant III that when enacted in Quadrant IV might create data in Quadrant I which when reflected upon in Quadrant II could offer new insight into the missing elements. New knowledge about relationships among concepts in Quadrant II might lead to the development of useful new tactics in Quadrant III, which could also occur if that tactic or a related one had been observed in Quadrant I.

Further, poor execution of tactics during enactment in Quadrant IV could be recognized by comparison to the intended tactic in Quadrant III, or by observation of different than expected outcomes observed in Quadrant I. Fortunate accidents can occur when poor tactical execution leads to unexpectedly positive outcomes. Observing such outcomes could cause updating of tactics and their consequences in Quadrant III, but also lead to additional reflection on Quadrant II knowledge structures if the observed outcomes are inconsistent with current understandings of the relationships among entities in Quadrant II.

2.6.2 Cognitive Mechanisms Support Decision Making while Learning

I believe that specific learning processes, supporting knowledge and decisions driven by executive function collectively account for in situ differences learners experience and respond to while learning. While engaged in learning, differences exist in what learners observe, when it is observed, and the episodic context attached to the observation. How quickly, if at all, do learners

notice characteristics not seen before in the environment or patterns that are inconsistent with expectations? Differences also exist in how simple observations are converted to more meaningful concepts and when this occurs. Is knowledge of how things work in the environment captured quickly and accurately? Learners also vary in how quickly and effectively learned theories and concepts are converted to action through the construction of new procedural knowledge. What accounts for sudden shifts in the behaviors that a learner may construct and use? Together, many factors combine to suggest that learning may be highly variable.

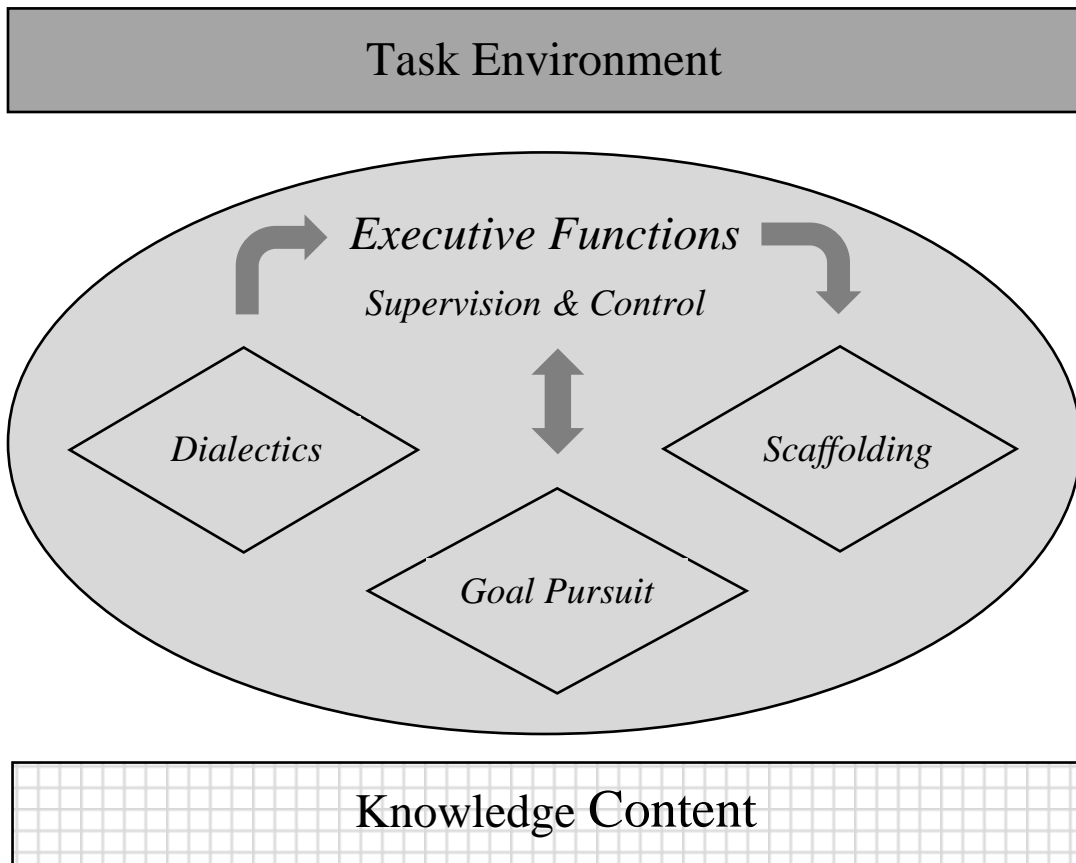
I propose that three specific mechanisms contribute to these differences within learning events. As illustrated in Figure 2.4, they include (1) *dialectics* which arise when gaps or inconsistencies in knowledge are recognized during learning, (2) *goal pursuit* used to direct decisions and learning strategies while learning, and (3) *scaffolding* which assembles and constructs unique knowledge structures while learning.

2.6.2.1 Dialectic Mechanisms Direct Attention

While the emphasis espoused in most models of learning note the cyclical nature of learning processes, dialectic recognition and response suggests that learning may be better illustrated as reciprocating, multi-directional and spontaneous, as cognitive functions react to perceived competing knowledge-informed needs in the moment. Executive function orchestrates the necessary recognition and response and provides an active bridge linking available learning processes with knowledge content stored in memory. It provides critical functions including 1) decisions directing action and attention while learning, 2) supervisory functions including controlling and monitoring levels of automaticity, and interrupting or inhibiting select behavioral objectives and responses, and 3) monitoring and updating memory including initiating store and recall functions as required, and (Cowan, 2013).

FIGURE 2.4

Conceptual Model: Cognitive Mechanisms Direct Learning



Building on Kolb (1984), dialectics address the gaps or inconsistencies in existing knowledge. The tension which accompanies the emerging dialectic is thought to motivate attempts to resolve them. It is generally assumed that learners have the ability to sense when something may be missing and have a variety of responses which they may then invoke to solve such dilemmas. Learners may also sense that inconsistencies exist between new observations in the environment and mental interpretations they have previously established. Mechanisms invoked to resolve inconsistencies may include a variety of problem solving techniques.

Inductive methods may be used to increase the number of useful observations and associated data surrounding the problem. Learners may also opt to use a deductive approach to form and test hypotheticals associated with a new prospective behavior or tactic.

While attempting to resolve gaps or inconsistencies in what was believed to be true, the potential for error exists. Observations may be missed; the wrong variables could be considered important; relationships among variables may be misunderstood; tactics and techniques may be incomplete or ineffective. Reducing errors progressively across learning episodes is expected to improve learning outcomes. However, errors may also provide an opportunity to learn. Capitalizing on them while learning depends first on recognizing the mistake or contradiction. Recognizing errors early in the learning process is not always easy.

The dialectic “tension” between ongoing learning processes and existing content signals that a problem exists which may suggest a new response. Specific changes to behavior may result. Therefore, learners may direct behavior in different ways depending upon how dialectic mechanisms perceive gaps or inconsistencies in knowledge and how executive function chooses to respond.

Proposition 1: Gaps, inconsistencies or errors in a learner’s knowledge when perceived by learners are reflected in the changes they make to behavior while learning.

2.6.2.2 Goal Pursuit Aligns Strategies and Behavior

Executive function supports the many supervisory decisions which must be made while learning and performing any new task. Absent established routines and procedures, attention must be frequently adjusted, and learning processes must be readily changed to learn and make progress against the task. Decisions on what data to interpret and retain, and in what form is likely to demand significant effort. For instance, a multitude of goals and sub-goals may be

adopted by a learner at varying points during the learning process, each of which present new control parameters which executive function must accommodate.

The task environment and its embedded context may alter the complexity of supervisory decisions considerably. New learning tasks which include notable performance demands or expectations add to the complexity and significance of supervisory decisions to be made. When is it possible and appropriate to shift between a targeted performance goal and a more focused learning objective, the latter of which may include considerable experimentation and risk? Is this strategy possible or practical at all? When knowledge in a domain is limited, pursuit of learning strategies may occur more frequently and function more productively. As knowledge in the domain accrues to the learner, performance-oriented strategies and decisions may become more prevalent.

To accelerate learning and/or performance, executive function may embrace and move between a variety of goals and accompanying strategies which balance the demands of the environment and the knowledge available to the learner. Strategies adopted may focus on learning objectives at one time and performance objectives at others. Variation in the development and adoption goals and strategies guides decision making with respect to where attention is given and new behavior is developed and applied. Learning behavior may respond and change with decisions made regarding goal pursuit and the learning strategies which accompany them.

Proposition 2: Learners adopt different goals while learning. Changes in goals and accompanying strategies will be reflected in changes in behavior while learning.

2.6.2.3 Scaffolding of Knowledge Enables New Learning

Learning occurs in the collection and construction of knowledge elements, some of which are observed (e.g. data) and some of which are created (e.g. concepts and tactics) as we learn. Learners do not learn everything at once and continued progress in learning builds upon the knowledge captured and/or constructed previously. Learning is more than a measure of how much knowledge has accumulated, but which specific elements of knowledge have been learned, how they relate and build upon what was previously known, and how well the assembled set of prior knowledge positions the learner for action. Also important is how well knowledge gained aligns with the goals and objectives a learner may have adopted in pursuing the learning activity.

This process resembles the *scaffolding* process workers use to construct a building. Each level of scaffold rests upon preceding levels which have been successfully constructed in the past. In spite of these dependencies, a variety of approaches to scaffolding while constructing a large structure may exist. Assembling certain components with their unique characteristics while scaffolding, may be more effective than others, while other component assemblies may not be a matter of choice. Their assembly must be completed before further scaffolding efforts may proceed. In other cases, a missing component may not present an immediate challenge to the scaffolding effort, but the problem may become apparent later in the process. The missing component may require disassembling supporting structures before scaffolding may resume.

Learning and knowledge building may proceed in much the same way. Learning is gradual and accretive. The opportunity to learn is dependent upon preceding knowledge. Missing or inconsistent knowledge may interrupt the ability for continued learning without resolving the inconsistency or acquiring the missing knowledge. Multiple paths may be pursued to acquire and construct the necessary knowledge. Some paths may be more efficient and more likely to

succeed than others. The cognitive process of scaffolding progresses through the sequential collection and construction of knowledge elements.

New knowledge elements build upon previously developed knowledge consisting of data, variables and theories. Knowledge structures reflect the current state of what is known and how things work. They may also represent an aspirational view, that aligns more accurately with a yet to be attained goal or objective. In this sense, knowledge may be assembled to support a hypothetical, something surmised to be true or possible, but not yet tested. Knowledge structures must accommodate the what-if set of alternatives which provide the hypothetical foundation for deductive thought and action. This last dimension is a central to how we learn. The scaffolding process must accommodate and account for different types of knowledge, accumulated and constructed in different ways. The underlying completeness, accuracy, and relevance of the knowledge which is acquired and assembled may enable or inhibit continued learning.

Proposition 3: What we learn is a product of what we know. What we know enables the learner to reach beyond what is currently understood and hypothesize about what might be.

2.7 Summary

Theories in experiential learning, executive function and knowledge combine to provide a partial explanation of how a person faced with a new task or problem is likely to respond through new and adaptive behavior. A microdynamic view of learning, as illustrated in Figure 2.3, extends thinking and suggests that learners are likely to experience and behave differently while learning. Many opportunities exist for idiosyncratic behavior guided by the specifics of a learner's experience in a new context. I propose that what learners notice (*dialectics*), know (*scaffolding*) and choose to pursue (*goal pursuit*), combine resulting in differences in behavior.

Learners may choose to attend to different data and do so at different times. Differences in what is observed and perceived are likely to result in differences in interpretation resulting in different conceptualizations of an otherwise common environment. Decisions may therefore vary on how to engage with the environment going forward. Unique combinations of learning processes and new knowledge increase the likelihood that notable differences will exist within learning events at varying points in time.

Differences in behavior may reflect more than what is or is not known at the time but, may also relate to the learner's ability to recognize or anticipate gaps or inconsistencies in existing knowledge structures. Able learner's may recognize and respond to dialectics more quickly and may adjust attention and approaches to learning more fluidly. Goals supporting an evolving set of strategies may contribute directly to changes in behavior while learning. A scaffolding process allows learners to construct and associate knowledge in different ways at different rates also contributing to differences in behavior across and between learning events.

3.0 EXPLORING ACTIONS AND BEHAVIOR WHILE LEARNING

In the preceding chapter I offer a dynamic learning model suggesting that processes and knowledge content combine to determine how learning progresses. The components and mechanisms of the model support a view of learning that is likely to be highly idiosyncratic within and between learning events and where differences in learning are likely to predict a wide variety of outcomes. But does this view of learning hold up when examining the detailed actions and behavior that accompany a new learning experience?

A primary goal of Study 1 is to gather detailed data about the actions of a set of new learners. I probe for consistencies and deviations in behavior and their consequences. While the learners bring their individual differences with them to the learning environment, the environment tested here is in fact identical for each learner, suggesting that while differences may be observed, common elements of learning are also likely to emerge.

Research Question 1: What actions will subjects demonstrate while learning?

Research Question 2: What commonalities and differences will be observed in learner behavior within and between learning events?

I also seek to understand how learning occurs over time in a distinctly experiential context and how that learning is reflected in new actions and behavior. Learning theories help explain the dynamics of traditional learning events. Yet, there is still much to learn about the cognitive mechanics that underpin learning in an active context and the adaptive behavior that often accompanies that experience.

Research Question 3: What can account for any differences in observed behaviors?

In this Study, using a microdynamics lens, I examine the detailed activity of learners engaged in a learning event. A learning event, in the context studied here, encompasses a single and contiguous learning opportunity or trial presented to each subject. I use a new computerized “learning by doing” game environment to examine how people acquire, create and leverage knowledge through their interactions with a new-to-them task. Using detailed behavioral observations, I examine learning as reflected in the actions and behaviors used to navigate the environment and pursue game outcomes. The resulting data offer detailed insights into the experience of learning by doing, demonstrating how novices adapt idiosyncratically to a new environment and shape increasingly effective behavioral responses to the task.

3.1 Methods

3.1.1 Description and Design

In this research, subjects are asked to learn a new video game from scratch, with instructions limited to a brief introduction of the visible features of the game on the screen. A key objective of this observational study is uncovering, differentiating, and mapping the behaviors which evolve while learning. I use descriptive techniques to measure and compare how the actions and behaviors developed and applied by subjects contribute to improved outcomes. I seek detailed insights into how subjects learn, and what resultant behaviors and actions best predict improved outcomes.

This study is conducted in a behavioral laboratory with a single group of subjects (n=50), each independently pursuing a common learning task. Game programming, audio recording and an attending researcher capture descriptive and quantitative data for analysis. Each 75-minute subject trial was conducted over a three-week period.

3.1.2 Contextual Requirements

In seeking a suitable context to explore the dynamics of learning, several requirements were considered. I first sought an environment where a subject's actions were easily observed and distinguished. Capturing a substantive and refined set of behaviors were important to inferring the procedural learning and knowledge which preceded their enactment. Clear markers of behavioral change should be visible to the researcher. The learning context should also support scoring for measurement of progress while learning. Establishing a comparative reference point which could be objectively assessed and quantitatively evaluated was important.

I also sought a context which offered multiple solutions as opposed to a singular intuitive answer, where several alternative solutions might be hypothesized and pursued. I hoped that this would add a dimension of real world complexity and ambiguity, often associated with problems faced while learning. While evaluating learning as an accumulating measure of growing knowledge through inductive processes is interesting, in most experiential settings deductive methods to formulate and test new ideas are equally important. Alternative solutions and outcomes in the tested context might heighten the need for hypothetically driven behavior.

It was also important that the learning context be unfamiliar to prospective subjects. Though this would eliminate many games from consideration, it was important that each subject initiate the learning process from scratch. Starting from a common and limited base of knowledge was necessary to measure progress and compare results across subjects.

Finding the balance between simplicity and complexity in the learning context was challenging. I sought a game environment with a limited list of task attributes to discover and learn, but a range of tactical alternatives which might be pursued. My preference was for the limited learning time in the laboratory to emphasize procedural constructions and behaviors over

time invested in absorbing large amounts of contextual information before new behavior might be learned and exhibited.

A variety of problem solving games were initially considered including a number of video/computer games in the public domain. This review revealed that many games used in the literature were oriented toward learning single solutions, more puzzles with single correct outcomes, than multiple solution problems. Other games, which presented a multiplicity of possible outcomes as well as a rich set of tactics to be discovered, tended to be considerably more complex and unlikely to be sufficiently mastered to demonstrate meaningful learning outcomes during the constrained trial timeframe. Several alternatives were more contemporary games, but this increased the likelihood that some subjects would have played them, a factor to be minimized.

In the process of exploring alternatives, I identified a game in the public domain that appeared to address many of the requirements outlined. However, the game included unneeded features including a tiered structure of difficulty driven by additional obstacles added to each level of gameplay. The features slowed the learning process and greatly reduced the likelihood that mastery might be observed in a reasonable timeframe. The game also lacked a robust tracking and administrative function. A decision was made to develop a new game, using an older existing game in the public domain as a model of basic gameplay.

3.1.3 Game Design and Features

The new game, called *OnTrack*, illustrated in Figure 3.1, is a computer based interactive game where a train travels from a designated entry point along a track pattern constructed by the subject. A reasonable objective of the game, not always adopted, is to complete a route, in advance of a moving train which exits a tunnel after a twelve second

countdown. The train progresses on the track placed in front of it. The result is either a crash (the train ran out of track) or a complete trip to the train station on the opposite side of the grid. The longer the constructed route, the greater the number of points scored. Longer routes also increase the chance of a crash. It is difficult to stay ahead of the train for most learners. A multi-component scoring system is included in the game which adds to the learning requirements. The train track to be assembled on the grid is selected from a tray presenting three of nine available types of track at a time. The track selection tray presents a random element to gameplay, which forces the development of tactics to accommodate the obstacles this randomness might present. Track pieces include four distinct 90 degree turns, a horizontal and vertical straight track, two distinct double turn tracks and a cross track. With a mouse, a single-track piece is selected from the tray and dragged and dropped within an eight by eight track grid. A track eraser, allowing subjects to remove a previously placed track piece, and a function offering three different train speeds, are presented on the game display for the player to explore and use.

As illustrated in Figure 3.2, several features of the game may be adjusted in setting up gameplay using an administrator screen, including the number of rounds in a subject trial, round time, goal presentation, and feedback associated with scoring, placements, and completed trips. In this Study, I limited the feedback available to the subject to trip time (measuring clock time with subject-initiated start of each new trip attempt), trip number (the accumulating upward-count of each new trip attempt), round time (the 75 minutes of total game time was broken into three consecutive, 25- minute rounds for data transmission purposes), and accumulating trip score for the current trip being played (further described in the measurement section). Features were added to support desired experimental manipulations. The new game, was designed, developed and tested at length prior to use in this study. A post trial playback function

Figure 3.1 OnTrack Game Interface – Study 1

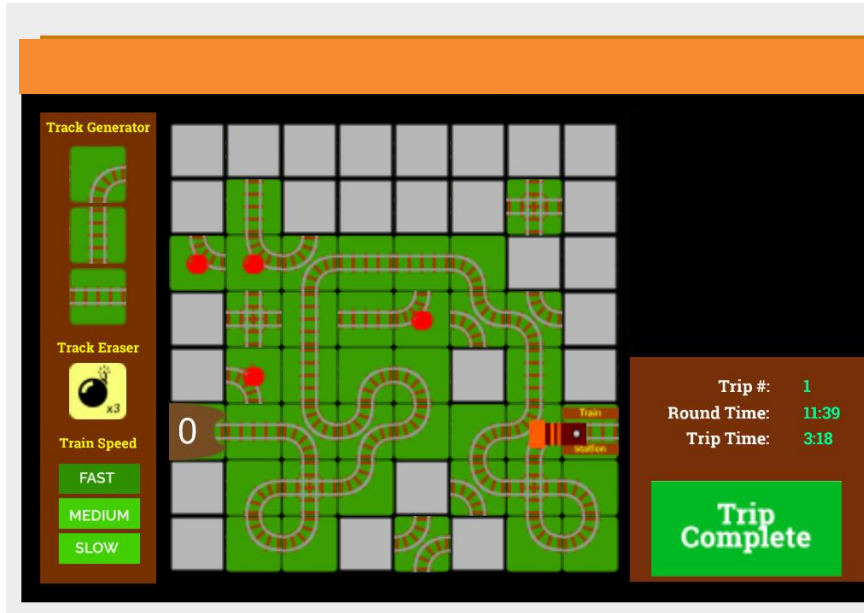


Figure 3.2 OnTrack Trial Administrator

Input the settings desired

Name
Example Test

Round 1 Delete

Goal
Goal: score as much as possibl

Round Time
5

Post Round Break Time
.25

Show Trip Scoring Live
 Show Trips Complete Live
 Show Track Placements Live

Round 2 Delete

Goal
Enter Round Goal in Here

Round Time
Time in minutes

Post Round Break Time
Time in minutes

Show Trip Scoring Live
 Show Trips Complete Live
 Show Track Placements Live

+ Add Round Create

is available to the researcher providing a graphical presentation of the detailed data associated with each trip attempt, including sequencing of track placements and timings on the game play grid, as illustrated in Figure 3.3. Trip playback is integrated with a scoring trace (Figure 3.4) associated with each subject trial. An array of descriptive data captures the detailed action associated with each trip attempt. The game was programmed using Unity software with Parse used for backend administrative functions and data capture. The local system was networked to a hosted application accommodating capture of gameplay data, statistics and parameters. A second workstation running Audacity was used for voice recording of each session.

3.1.4 Recruitment of Subjects

Subjects were recruited from a large (n=150) undergraduate course in business management. Following IRB approval, students were presented with a short in-class announcement followed by an invitation to participate via an announcement delivered through the course management system (Scholar). The announcement identified the laboratory experiment as a “learning by doing” exercise. The study opportunity was one of many possible activities students could use to complete the supplemental activity points required by the course. Prospects were pre-informed that the trial is estimated to last approximately ninety minutes, which included a brief follow-up survey. Those responding were assigned to a two-hour time slot using an online scheduling tool, Sign-Up-Genius. Five trial slots were offered each day, two in the morning and three in the afternoon. Respondents were asked to arrive five minutes early.

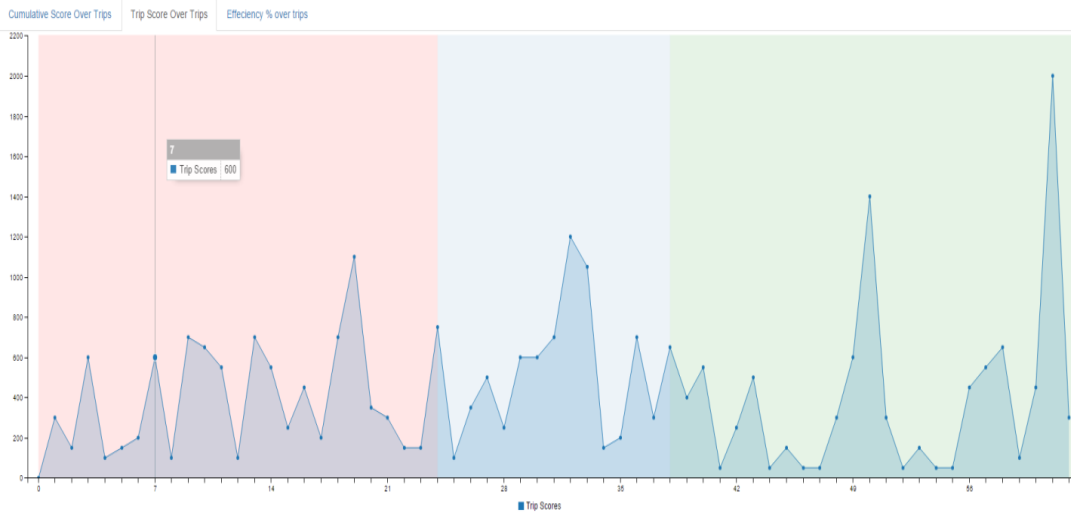
3.1.5 Sample

A total of 81 members of the class volunteered to participate. Of the 81 volunteers, 56 students arrived for their scheduled appointment and completed the exercise. Six subjects participated in pilot testing. Study participants (n=50) were 46% female and the majority were college juniors pursuing various undergraduate majors in business.

Figure 3.3 *OnTrack* Trip Playback



Figure 3.4 *OnTrack* Scoring Trace



3.1.6 Lab Protocol

Each experimental session was conducted with individual subjects in a single private “office”. A computer with an attached monitor and mouse supported the local gameplay software

environment. Each trial session included 75 minutes of gameplay. Approximately 15 minutes were required for setup and a debrief survey for a total trial session time of 90 minutes. All sessions were conducted by the lead author or one of two trained research assistants.

On arrival at the scheduled time for their session, subjects were escorted to the desk and asked to review the IRB information and consent form, included in Appendix A. They signed and completed the form including their student ID number, name, university email address, and trial ID#. The information sheet noted the “learning by doing” nature of the study and the use of a video/computer game likely to be new to them. They were asked to sign a non-disclosure statement within the consent form. Upon signing and completing the consent form, subjects were given a one-page instruction sheet which listed the fundamental features of the game including the track generator from which to select track, the grid on which to place track, and the speed and eraser buttons available to them, all of which they would see in a moment on the monitor. They were told they might refer back to the instruction page at any time. No mention was made of how the features functioned or the specific goals of the game beyond the placement of track on the grid. Subjects were invited by an attending researcher to “play the game”.

Gameplay and audio recording were then initiated. A researcher stayed in the room with the subject during gameplay. In addition to each action being recorded in the gameplay system, the researcher in the room also recorded observed changes in gameplay behavior and subject verbalization on a form that tracked each gameplay attempt. Researchers asked a prompt question every three to five trip attempts to encourage subjects to verbalize what they were experiencing. The prompt was open-ended and included three variations; 1) “What have you learned in the past few trip attempts? 2) What have you observed in the last few trip attempts? 3) Are you doing anything differently in the past few trip attempts?” Subjects were forewarned of

the prompt questions to come and were encouraged to volunteer new learning and observations as they proceeded. As subjects became more comfortable they began to volunteer information consistent with the prompts. With increased volunteering of information, prompt frequency was reduced. Recognizing the possibility that questions might inadvertently shape a subject's tactics and associated outcomes, care was taken to disassociate the timing of prompts with notable changes in tactics.

A form developed during the pilot and included in Appendix C was used by the researcher in the room to capture information including the trip number, observed general strategy, whether or not a prompt was administered during the trip, if the trip was successfully completed, and most importantly notes capturing the investigator's observations (marked "O") or the subject's verbalizations (marked "V"). This information proved useful as an index to gameplay allowing triangulation of the researcher's notes with game data and audio recordings.

3.1.7 Pilot Testing

Following development of the game environment by the research team, a pilot study (n=6) was conducted. The pilot was directed at refining the protocol, particularly the observer data gathering process. The pilot was also used to observe and train the two research assistants. Research assistants each invested two or more hours in playing the game to gain adequate familiarity, and then each directed three subject trials under my observation. Follow on discussions helped to refine and standardize the overall process including verbalization and notetaking behavior as well as an initial list of the tactics and techniques which subjects may learn and use.

3.1.8 Measures

3.1.8.1 Trip Attempts and Trips Completed

I calculated the number of trip attempts and trips completed in the game software for each subject. A trip attempt is defined as each time a subject starts the countdown clock (12 seconds) to set the train in motion. A trip attempt concludes with either a “crash” or a completed trip to the station. Each trip attempt was sequentially numbered and recorded by the game software.

3.1.8.2 Actions and Behavior

The game software captured every action of each player during 75 minutes of gameplay. A subject’s actions during gameplay provided the raw material necessary to track learned behavior over the course of each trial. Review of the detailed actions observed and during gameplay allowed the identification of the behavioral patterns and sequences associated with learning. Attending researchers noted the actions and learning they observed in accompanying notes. Observations were reinforced directly by gameplay data and verbalizations from subjects.

Determination and measurement of first use of the speed (T1) and erase techniques (T2) was straight-forward. The subject must first notice the select feature on the screen, and then choose to use it. Though this demonstrated “first learning”, it did not assure effective use. The timing and choice in speed select was important to learn and understand. Use of the erase function adds time to route assembly, similar to the placement of an additional piece of track. Although this was not immediately clear to most subjects, its “best use” was limited to select situations during gameplay.

First use and measurement of the discard technique (T3) was sometimes more difficult to assess. This technique was often discovered by accident initially. When selecting a piece of track

from the selection tray with the mouse, the piece was occasionally dropped on the grid prematurely. This usually resulted in a new track type replacing it in the selection tray. Usually the first time this happened, the value of the quick discard to solicit a new track type in the tray was missed. The use of discard to expand available track types was easy to observe when multiple discards first appeared in a trip attempt and measurement of first use was calculated in this way.

The loop technique (T4) was accommodated using one of two track types, the “double-turn” piece or the “cross-track” piece. Learning how to use these pieces as a distinct technique required that the subject construct a route which would “return” to the track piece with a looping turn, allowing the train to cross it once again as it progressed along the route. In doing so the piece would add to the score a second time and do so without requiring an additional placement. The tactic was often used to help extend routes and more fully exploit the 64-cell grid. Thus, measurement of this tactic required the successful construction and second crossing with the train.

The more advanced tactics including extend (T5), bonus scoring (T6), play ahead (T7), and close loop (T8) were each demonstrated during the pilot as well, but with less frequency. Again, verbalization and notes supported their use and their importance to performance in the game. While the more advanced tactics were noted and observed during the pilot, clarity regarding the specific parameters which would ultimately define their use was left open, until the full study was completed. Ultimately the detailed data available at the end of the Study, was used to refine interpretation of the behavior observed.

While the play ahead (T7) and close loop (T8) tactics were easy to consistently discern and measure as unique behavior, the extend tactic (T5) and bonus placement tactic (T6) required

closer examination. Observation and verbal feedback noted that a subject's early focus in gameplay was to assemble a simple and direct route to the station. Though this might be accomplished by selecting and placing five straight sections of track, random draw of track pieces often made this difficult. Most subjects initially resisted placing track outside the three most direct grid lanes to the station to reduce the perceived risk of a crash. With experience and growing confidence, many subjects would realize that a longer route would generate higher scores and would thus adjust their initial goal of simply staying ahead of the train and making it to the station. The development of the extend (T5) tactic appeared to be a milestone in gameplay. The placement of 16 contiguous track placements was used to indicate adoption of this tactic. This count assured that subjects had successfully laid an extended course and that the path of the train extended beyond the three most direct grid lanes (5 track per lane) between entry tunnel and station.

The bonus placement tactic (T6) often developed building upon the learning which accompanied a subject's effort to extend the constructed route. Red apples would temporarily appear on the four 90-degree turn track types when placed on the grid. The apples would "pop" and disappear when the train passed over them. An observant subject after experiencing this a few times, would learn that these track types carried a double score bonus (100 points versus 50 points per track), by watching the running score on the feedback panel. With the benefit of that learning, many subjects were observed to intentionally construct routes which optimized the use of 90-degree turns to optimize score. This also was a major milestone in learning. I ultimately used the placement of four 90-degree turns in the constructed route, together with verbal confirmation from the subject to confirm and measure the development and adoption of this tactic.

3.1.8.3 Track Selection and Placement

Actions specific to track selection and placement including elapsed time were captured within game software and were available to the researcher through playback functionality. These data included the track type selected and where on the 8 X 8 grid each track piece was placed. The sequence of track placements, how many track pieces were discarded (placed on the grid, but outside the route), and the number of contiguous track pieces traversed by the train in each trip (inline count) are captured as well. These detailed measurements allow full reconstruction and replay of a subject's trip experience and capture the detailed actions of each user operating in the game playing context.

3.1.8.4 Scoring

Each trip generates a score. The highest score achieved up to that point in gameplay is identified as the frontier score. Frontier score was used to estimate maximum learning demonstrated during the subject trial. The score is determined by a combination of base and bonus scoring. Scores are calculated based on the number of track pieces traversed by the train (50 points each), bonus track traversed (100 points each), and whether the trip was completed (doubles the earned score). A total score for each trip is recorded and a current score during a trip is presented progressively during gameplay.

Individual trip data is aggregated to provide experiment level data. In addition to trip scoring, aggregated outcome data would include the number of trips attempted, the total trips completed, and the highest score achieved to that point in gameplay as well as over the course of the entire subject trial.

3.1.8.5 Elapsed Time

Every action within the game was time recorded. This included the time each trip started, the time required to select and place each piece of track, the time each trip ended and the amount of time that occurred between the end of one trip and the beginning of the next. The average trip lasted approximately 47 seconds. Running clock time by round and across the trial was captured and associated with each distinct action in gameplay. This level of detail supports video playback which helped in interpretation and validation of gameplay behavior.

3.2 Results

In a first test of the new learning context evaluated in this study, Research Question 1 asked; *What actions will subjects demonstrate while learning?* Study 1 elicited several distinct behaviors, many common to most learners, though significant differences were noted particularly in the speed with which new tactics and techniques were demonstrated, the sequence of their discovery, and how effectively that knowledge contributed to scoring outcomes. A summary of several key characteristics and outcomes of the Study are captured in Table 3.1.

The 50 subjects generated an aggregate 3,865 trip attempts, averaging 77 trips per subject. The variation in the number of trip attempts ($SD = 23.3$) during 75 minutes of gameplay was large ranging from a minimum of 31 trip attempts to a maximum of 137. The percentage of trip attempts successfully completed by subjects also varied widely, from 3% to 76% of trips attempted. Trip attempts averaged approximately 47 seconds ($SD = 19.3$) among subjects.

The number of track pieces placed and traversed in a single trip attempt ranged from a single section of track in early rounds of gameplay to 49 pieces placed and traversed on the 64-square grid. With a mean of 16.9 track select and place actions ($SD = 4.5$) per trip attempt, on

TABLE 3.1**Study 1 - Summary of Select Outcomes**

Outcome	Mean	SD	Min	Max
Trip Attempts	77	23.3	31	137
Trip Completes	32	17.3	2	75
Percentage Complete	41.70%	18.90%	2.60%	76.40%
Average Score	1,865	2,536	581	18,239
Frontier Score	15,981	27,083	1,500	145,900
Max Inline Placements	27.7	8.3	10	49
Trip Time (Seconds)	46.7	19.3	22	132

Note : Means, standard deviations (SD), minimums and maximums; columns include number of trips attempted and completed with associated completion percentage, average and highest score (frontier), maximum track placements traversed by train, and trip time.

average each subject demonstrated 1,301 distinct actions across their respective trial. In aggregate, this represents 65,065 actions observed and captured in the study. These actions do not include the use of other features in the game including the speed, eraser and discard feature. While the average trip score across all trials was 1,865 points, scores varied (SD = 2,535.7 points). Scores on individual trips ranged from a low score of 50 (train traversed one pre-placed track) to a high score of exactly 145,000 points. Frontier scores, used to estimate maximum learning, averaged 15,981 points (SD = 27,082.6).

3.2.1 Differences and Similarities in the Learning of Tactics and Techniques

Research Question 2 sought to understand; *What commonalities and differences will be observed in learner behavior within and between learning events?* Capturing new behavior in the form of tactics and techniques used during gameplay was an important objective of this Study. To identify tactics and techniques I reviewed notes across all trials and conducted interview discussions with attending researchers while selectively reviewing playback of subject gameplay.

I was particularly interested in the tactics and techniques which appeared to be central to learning the game. In spite of the distinction between tactics and techniques used in this study, both types of behavior are considered to be part of the same set of procedural knowledge developed and used by learners of the game.

If a new action of consequence was discovered and learned by a majority of subjects and was observed to have a substantive relationship to gameplay outcomes (scores, trip completes, discovery or the use of other tactics) I retained and coded it as a “focal” tactic or technique, consistent with the definitions previously described (Chapter 2, page 23). Candidates for “focal” tactics and techniques were also reviewed using playback functions available in gameplay software. Data associated with first demonstration of each new focal tactic or technique along with each repeated use by all subjects was captured and assembled. Ultimately, I identified and coded eight focal tactics and techniques, as illustrated in Figure 3.5. The close loop tactic proved so significant to outcomes, that it was included even though it was discovered less frequently (n= 24 of 50).

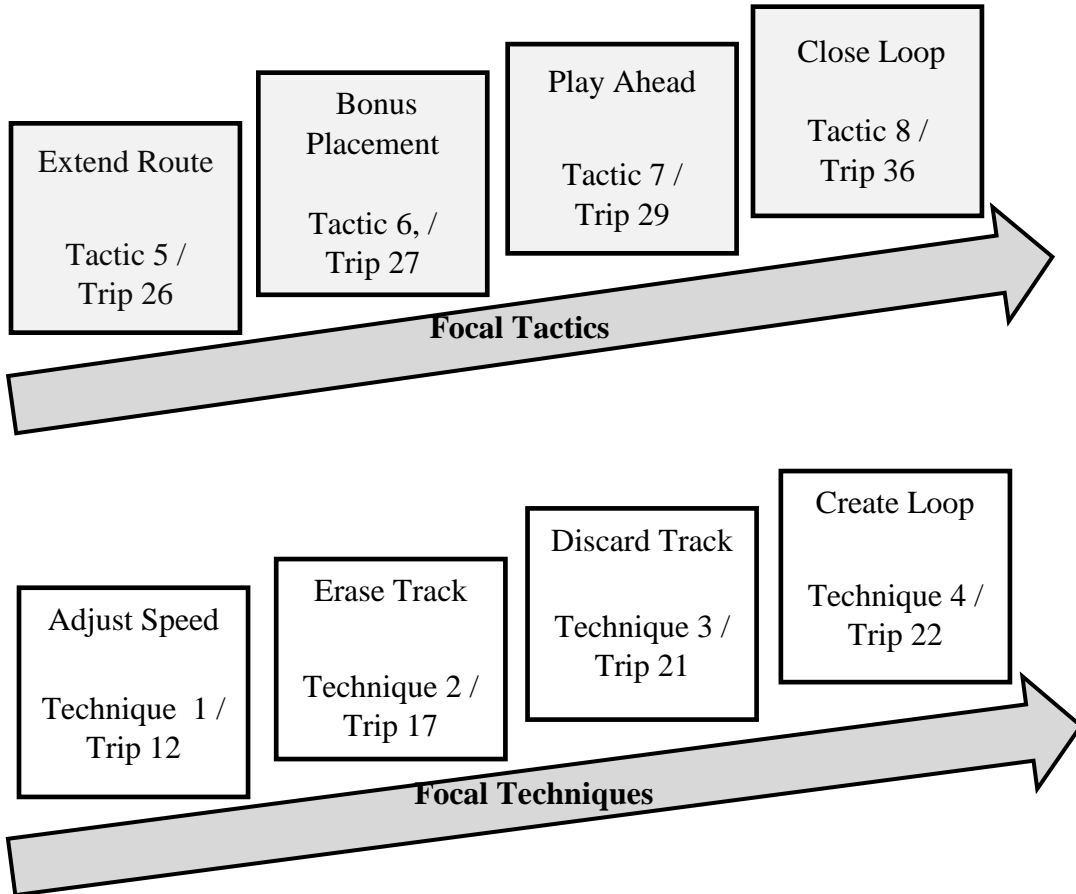
Descriptions of the individual focal tactics and techniques learned and demonstrated by subjects follows:

Adjust Speed (T1). Speed adjustment (n = 48) was an important technique in gameplay to discover and deploy. By lowering speed, subjects had additional time to assemble routes and experiment with new tactics. On average adjusting speed was first used as a technique in gameplay on the 12th trip attempt (SD = 22) at a mean of 459 seconds (SD = 816.8) into gameplay.

Erase Track (T2). Discovery and use of erasers (n = 46) appeared to add to a subject’s confidence in using them and contributed to the successful development and learning of more

Figure 3.5

Average Progression of Techniques (T1-T4) and Tactics (T5-T8) in Gameplay.



Note. Techniques and Tactics Sequenced and Numbered by the Average # of Trip Attempts Preceding First Demonstration.

advanced tactics and techniques. On average, this technique was first used at 720 seconds ($SD = 973.7$) of gameplay on the 17th trip ($SD = 23$).

Discard Track (T3). The *discard* technique ($n = 49$) was first used on average on the 21st trip ($SD = 21$) at 1,001 seconds of play ($SD = 1,032.9$). Discard allowed subjects to clear the selection tray quickly to seek new track types.

Create Loop (T4). Creating loops ($N = 44$) were frequently demonstrated in track routes incorporating higher numbers of track. Discovery and experience with loops helped subject extend routes and score more points. Loops were first deployed as a technique at an average elapsed time of 1,009 seconds ($SD = 849.9$) of gameplay on the 22nd trip ($SD = 20$) attempt.

Extend Route (T5). The average time at which a subject first demonstrated the extend route tactic ($N = 47$) was 1,188 seconds ($SD = 1,014.4$) into gameplay on the 26th trip ($SD = 22$).

The placement of 16 or more inline track was the threshold used to represent an extended route. It was selected to reflect a subject's willingness to more fully exploit the grid for scoring purposes and move beyond a three-lane path (maximum 15 track) to the station.

Bonus Placement (T6). Averages to demonstrate bonus placement ($n = 44$) is 27 trips ($SD = 19$) and 1,332 seconds ($SD = 935$ seconds) into gameplay. Bonus placement required recognition of the track types associated with higher scoring.

Play Ahead (T7). Using the play ahead tactic ($n = 43$), subjects were able to cognitively project the route forward before physically and contiguously constructing it. In so doing they would recognize and forward place track types, allowing the track generator to replace the previously selected and placed track, often with the track types needed to connect the track pieces placed ahead in the route. Subjects first demonstrated this tactic on average at 1,433 seconds ($SD = 1145$ seconds) into gameplay on the 29th trip ($SD = 22$).

Close loop (T8). Subjects who successfully developed and deployed this tactic ($n = 24$) succeeded in demonstrating all other tactics, except for two subjects. A close loop allowed a subject to leave a train unattended and moving and scoring in a continuous loop while the subject continued to build and extend the intended route. Closed loops were initially demonstrated on

average at 2,169 seconds ($SD = 1,282$) on the 36th trip ($SD = 20$). In most cases, the skillful and repetitive use of preceding tactics appeared important to discovering the close loop tactic.

Exceptions and “one-off” tactics were noted as well in my analysis. The one-off tactics appeared infrequently and added little to game performance. These included (1) bombing the selection tray, (2) constructing a return route to the entry tunnel, (3) routing the train vertically to the wall, (4) building artistic track patterns, (5) entering the station from above and below, (6) minimizing completed route time, (7) variable use of speed, (8) attempts to alter cross-track function, (9) maximizing rapid discard of track from selection tray. Select examples of less common behaviors of interest are noted in the discussion section which follows. The decision to emphasize and examine a restricted set of focal tactics, each with a performance orientation, limited systematic examination in this study of tactics and techniques which were not frequently used, or of lesser impact. Further study to examine them in more detail may enhance our understanding associated with unique behaviors.

The new tactics and techniques when first demonstrated served as markers of new learning in the context of gameplay. In fact, a common set of new tactics and techniques were discovered by most subjects learning the game, illustrated in Figure 3.5.

In Table 3.2, several distinctions are noted in the timing and sequence of tactical development, however. The types of procedural knowledge embedded in a tactic or technique may be differentiated by their inherent complexity. For instance, the discovery and use of speed (T1), erase (T2), discard (T3), and loop (T4) techniques was easier to develop than the construction and use of tactics for extend route (T5), bonus placement (T6), play ahead (T7), and close loop (T8). The discovery of select tactics and techniques appeared to improve the likelihood that others would later be discovered. While most subjects did uncover a common set

of tactics and techniques, not all did so. In most cases, the number of trip attempts needed to discover and use the tactic or technique for the first time varied widely between subjects. This is highlighted in Table 3.2 in the standard deviation and minimum and maximum values associated with the discovery of each tactic and technique. Results relative to two subsamples (CL – those ultimately discovering the close loop tactic and NCL – those who did not) are also compared in Table 3.2.

It is also interesting to note that no two learning paths were exactly alike among the 50 subjects playing the game. As illustrated in Table 3.3, while two pairs of subjects did share a sequence pattern in their first use of tactics and techniques (Subject 14 and Subject 21; Tactics 1-2-4-5-3-6-7-NA; and Subject 5 and Subject 19; Tactics 2-1-3-7-6-5-4-8), neither pair of subjects demonstrated a similar number of trips to complete their learning (Subject 14 - 80 trips versus Subject 21 – 67 trips; Subject 5 – 73 trips versus Subject 19 – 56 trips). In both comparisons, the subjects requiring less trips to complete their learning, demonstrated higher frontier scores.

3.2.2 Learning Mechanisms Supporting Executive Function

Research Question 3 asked; *What can account for any differences in observed behaviors?* While common aspects of how people learn was evident in the data, considerable variance was also noted. Some of the differences observed appeared related to the cognitive mechanisms previously proposed including; (1) *dialectics* - the recognition of gaps, inconsistencies or errors in a learner's knowledge, (2) *scaffolding* - unique knowledge structures which may enhance or inhibit a subject's progress in the game, and (3) *goal pursuit* - the adoption of different goals while learning. A closer look at learner behaviors specific to the proposed mechanisms follows.

TABLE 3.2

Summary of Tactical Development for Full (n=50), Non-Closed Loop (n=26) and Closed Loop Samples (n=24) Using First Trip Number and First Trip Time

Tactic	Sample	Trip Number First Use				Time to First Use (Seconds)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
1. Adjust Speed	Full	12	22	1	106	459	817	1	3,953
	NCL	20	29	1	106	738	1,091	1	3,953
	CL	5	2	2	11	180	105	44	451
2. Erase Track	Full	17	23	1	119	720	974	1	4,424
	NCL	27	30	1	119	1,115	1,256	1	4,424
	CL	8	6	1	24	358	360	1	1,292
3. Discard Track	Full	21	21	2	104	1,001	1,033	41	4,390
	NCL	26	23	3	104	1,106	991	58	3,895
	CL	17	18	2	72	883	1,088	41	4,390
4. Create Loop	Full	22	20	2	119	1,009	850	44	3,919
	NCL	27	27	5	119	1,163	1,069	125	3,919
	CL	17	10	2	39	881	607	44	2,108
5. Extend Route	Full	26	22	4	87	1,188	1,014	158	4,420
	NCL	37	26	5	87	1,665	1,153	158	4,420
	CL	15	9	4	33	732	584	189	2,591
6. Bonus Placement	Full	27	19	6	93	1,332	935	164	4,268
	NCL	34	24	6	93	1,483	1,030	164	4,071
	CL	21	11	8	53	1,193	839	375	4,268
7. Play Ahead	Full	29	22	1	77	1,433	1,145	1	4,224
	NCL	36	24	1	77	1,579	1,155	1	4,224
	CL	24	19	3	71	1,306	1,146	38	3,892
8. Close Loop	Full	NA	NA	NA	NA	NA	NA	NA	NA
	NCL	NA	NA	NA	NA	NA	NA	NA	NA
	CL	36	20	4	74	2,169	1,282	189	4,262

Note : Comparing tactical development sequence by trip attempt number and trip time (seconds) between three subject groups, Full, those not completing closed loop (NCL) and those completing closed loop (CL); comparing means standard deviations and range

Table 3.3

Tactical Sequences Sorted by Frontier Score (Study 1)

Study 1 Trial #	Frontier Score	Tactical Sequence	#Tactics Learned	Study 1 Trial #	Frontier Score	Tactical Sequence	#Tactics Learned
47	145,900	1 2 3 5 8 4 6 7	8	21	4,200	1 2 4 5 3 6 7 9	7
37	86,300	3 1 4 5 6 2 7 8	8	25	4,200	1 2 6 4 5 3 7 9	7
19	70,100	2 1 3 7 6 5 4 8	8	7	4,000	1 2 3 4 6 5 8 7	8
12	66,200	7 1 2 4 3 5 6 8	8	28	4,000	1 2 5 3 6 7 4 9	7
42	48,200	1 3 7 5 4 6 2 8	8	14	3,800	1 2 4 5 3 6 7 9	7
36	44,100	1 3 6 7 5 4 2 8	8	13	3,800	1 4 2 8 5 3 7 6	8
9	41,650	1 4 2 5 8 3 7 6	8	16	3,800	4 7 3 2 1 5 6 9	7
50	37,700	1 5 4 3 2 6 8 7	8	1	3,400	1 2 7 6 4 5 9 9	6
23	26,300	1 2 3 4 5 6 7 8	8	10	3,200	1 2 3 7 6 4 5 9	7
5	24,600	2 1 3 7 6 5 4 8	8	8	3,200	1 3 7 6 2 5 9 9	6
40	21,800	2 1 3 5 6 4 7 8	8	6	3,200	4 3 6 7 5 2 9 9	6
41	21,350	1 3 7 6 5 2 4 8	8	27	3,100	2 3 4 5 1 7 9 9	6
22	15,600	2 1 4 7 3 6 5 8	8	11	2,900	7 3 4 1 5 6 2 9	7
20	13,400	2 1 4 5 6 8 3 7	8	15	2,800	1 6 3 2 5 9 9 9	5
48	8,650	1 2 5 6 4 8 3 7	8	18	2,600	1 2 5 7 3 9 9 9	5
46	6,800	1 2 3 5 6 4 7 8	8	26	2,600	4 5 3 7 2 1 9 9	6
33	6,600	3 1 2 6 7 5 4 8	8	38	2,500	2 3 4 5 9 9 9 9	4
4	5,800	1 2 3 6 5 7 4 9	7	24	2,300	1 2 6 4 5 3 9 9	6
3	5,600	1 3 4 6 5 7 9 9	6	2	2,300	1 2 6 7 4 5 9 9	6
45	5,600	2 1 5 4 8 3 6 7	8	31	2,300	1 6 2 4 3 7 5 9	7
32	4,900	1 2 4 5 8 3 6 7	8	49	2,300	1 7 2 5 4 8 9 9	6
34	4,900	1 5 2 3 6 9 9 9	5	29	2,100	4 7 3 1 2 9 9 9	5
39	4,800	1 2 4 5 8 7 3 6	8	43	1,600	7 2 3 6 1 4 9 9	6
44	4,600	1 3 4 5 7 6 9 9	6	30	1,500	1 2 3 6 9 9 9 9	4
35	4,400	1 2 5 4 6 8 3 9	7	17	1,500	2 1 5 3 6 9 9 9	5

Note. Tactical Sequence denotes a sequenced list of tactics as demonstrated during each trial: 1 – Speed, 2 – Erase, 3 – Discard, 4 – Loop, 5 – Extend, 6 – Bonus Scoring, 7 – Play-Ahead, 8 – Close Loop. A “9” in the tactical sequence reflects a failure to demonstrate one of the eight focal tactics. Matching sequences Trial # 19 and 5; Trial # 21 and 14 are highlighted.

3.2.2.1 Dialectics and Variation in Learning

How quickly subjects worked to develop an accurate representation of the game environment was clearly important to their success in demonstrating a full complement of effective behaviors and succeeding at the game. The learning by doing environment used in this experiment presented all subjects with many unknowns and a general lack of context with which to begin their pursuit. Initial trip attempts were accompanied by considerable surprise, flailing about, and making mistakes resulting in generally poor initial performance. Yet subject experimentation was vital to exposing the contextual features of the game and their basic operation: “I’m curious to see if speed has anything to do with points?” (Subject 13); “I must test this! (Subject 25 discovering loops); “You can place tracks everywhere! (Subject 19 discovering discard). Sometimes new learning accompanied observed errors in playing the game: “The cross track does not function the way I want it to?” (Subject 7); “I tried to maximize bonus track ... but complex patterns can fail” (Subject 15).

The results and outcomes reflecting adaptation in early phases of learning are illustrated in the initial trip attempts of many subjects, and in the sample learning trace for Subject 14 in Figure 3.6a below. A stepped scoring trace, as illustrated below, was created and examined for all subject trials. A trace of individual trip scores (grey line) is overlaid by a solid black line capturing the progressive set of frontier scores associated with the subject trial. White rectangles denote the discovery and first use of new techniques and tactics, while the grey rectangles note tactics and techniques not learned and demonstrated during gameplay.

Considerable “bounce” is observed in most subject scores (grey line), as subjects appear to apply knowledge, skill and effort differently across their respective trials. In Figure 3.6a (Subject 14), only two of the first 10 trip attempts exceeded a 500-point threshold. With the

context of the environment increasingly understood, a growing repertoire of behavioral tactics and techniques began to emerge and, used in combination, drove higher performance levels across a series of trips.

When subjects failed to uncover important contextual knowledge, normally captured earlier in gameplay, significant constriction in tactical development and behavior was observed. Figure 3.6b (Subject 38) suggests an interesting example. In this case, the subject failed to note or explore the speed function and develop the technique (T1) to use it throughout gameplay. Without intentionally reducing train speed to “slow” as each trip begins, placement options were severely constrained. Bonus driven routing also remained untouched in this series of trips, as the scoring and bonus mechanism did not appear to be recognized, understood or attended to by this subject. Observation processes somehow failed to capture knowledge associated with two vital features of the game and use that knowledge to construct associated tactics. The scoring frontier in this session only reached 2,500 points, in spite of a high number (n=137) of trip attempts. These results suggest that learning strategies which optimize an early understanding of the game may demonstrate an advantage in this learning and problem-solving environment.

3.2.2.2 Goal Pursuit and Variation in Learning

In observing gameplay, the strategies and goals adopted by subjects was an area of great interest and at times great frustration to many subjects. Lacking an initial understanding of the game and associated goals appeared problematic to many. “They never tell you the objectives! (Subject 25); “I wish I had a clearer objective” (Subject 46). Some subjects were proactive in their efforts to uncover the objectives of the game. “I am trying to find the end-goal” (Subject 22). Most subjects at some point stated and pursued at least one self-directed objective while playing the game (n=36). Several (n=5) verbalized five or more during their respective trial.

FIGURE 3.6

Learning Traces Reflecting Dialectic Responses to Missing Knowledge and Goal Variation

Figure 3.6a: Learning Trace (Grey) and Frontier Score Trace (Black) for Subject 14: Tactical Learning Pattern without Continuous Loop – Scores by Trip Attempts

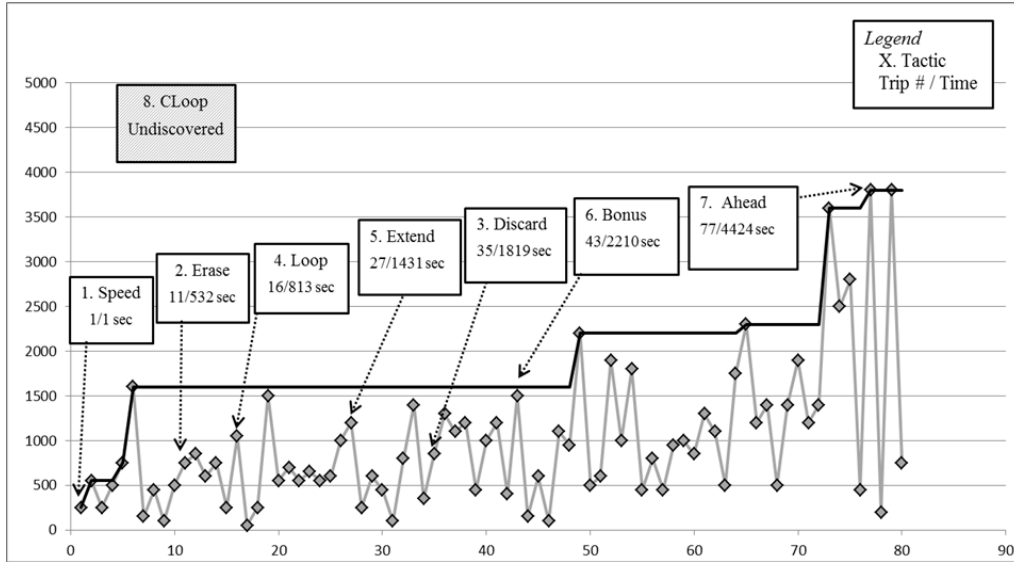
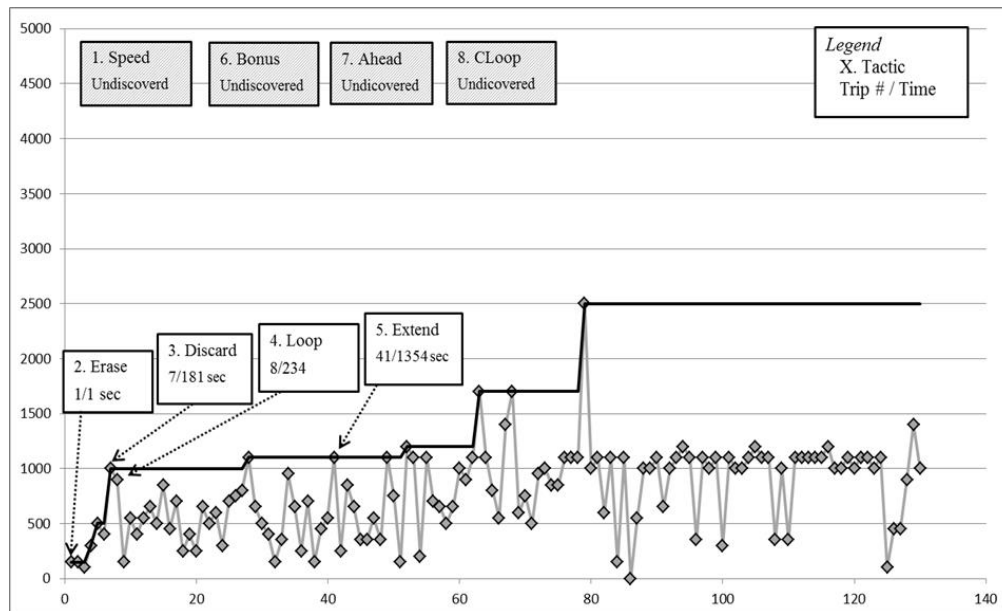


Figure 3.6b: Learning Trace (Grey) and Frontier Score Trace (Black) for Subject 38: Tactical Learning Pattern with Missing Knowledge Elements and Fixedness on Trip Complete Goal – Scores by Trip Attempts



Self-directed goals appeared to take many forms. Some goals appeared to reference specific learning objectives: “I’m curious to see if speed has anything to do with points?” (Subject 13). Other goals demonstrated stronger performance orientations: “Did I win? I think I beat it this time! (Subject 11); “I want to keep the score up!” (Subject 19).

An interesting example of a unique learning approach including an accompanying self-directed goal was observed in the behavior of Subject 38, illustrated previously in Figure 3.6b. A persistent focus on a single goal, reducing the time needed to assemble a common straight route to the station, is observable in the repeating scores toward the end of the trial. This particular learning strategy and accompanying goal was fixed and appeared to impede continued learning and the realization of higher level outcomes. Goals and objectives often demonstrate an ability to motivate a problem solver or learner, but as illustrated in this example, they may also function as a boundary or constraint. Goals appeared to be important to most subjects in directing their learning and mastering the game. Those who gave little evidence of establishing goals appeared to struggle in their effort to learn: “Sometimes it’s hard ... sometimes it’s easy ... I feel lost” (Subject 16).

The process of learning appears to be influenced by the problem solver’s thoughts with respect to priorities, objectives and overall strategies. Some subjects were unabashedly uncertain and confused by the overall problem setting, which intentionally did not indicate a specific goal or objective. In these cases, frustrations and verbalizations often accompanied gameplay throughout the game. “Game is impossible ... totally up to chance!” (Subject 30). Others were much more intentional in their approach, either adopting a specific goal and consistently attacking it, or moving around between goals to explore what might be uncovered using a different perspective. “I attempted a vertical entry to the station ... doesn’t work!” (Subject 15);

“Can I blow up track while in the generator ... it works!” (Subject 37). They were often observed to do this dynamically, using known tactics for different purposes. Beyond the specificity and dynamics surrounding goals, subjects demonstrate varying learning strategies and approaches to problem solving in general. Some back down the pace of play to think about strategies and tactics more fully, at times putting thoughts to paper (n=8). Others prefer to drive the process compressing as many trips into the time period as possible

3.2.2.3 Knowledge Scaffolding and Variation in Learning

Differences in what appeared to be highly idiosyncratic learning paths between individual subjects were often observed. The number of new techniques and tactics developed and the time necessary to develop them was often different and ultimately had a significant relationship to game outcomes. The correlation between the number of tactics and techniques learned and demonstrated and resulting frontier scores was positive, substantive and significant; $r = .45$ ($p < .01$). The correlation between time needed to develop and deploy the first five techniques and tactics in gameplay and frontier scores ($n = 36$), representing a sub-sample of Study 1 subjects including only those successful at developing all five, rendered a substantive negative correlation as well; $r = -.42$ ($p < .01$).

In Figure 3.7a below, Subject 13, a highly proficient subject overall had identified and used all eight tactics and techniques within the first 23 learning attempts (trips), the only subject to achieve this so quickly. The sequence however, included a unique anomaly, a closed loop (T8), stumbled upon very early in gameplay, at trip 16. This significantly preceded the development of knowledge and insights about bonus placement (T6) and extended routes (T5) and their effect on scoring. The subject, demonstrating strong overall placement skills in the early going, executed the close loop tactic, and quickly exited it, apparently not realizing the

FIGURE 3.7

Learning Traces Reflecting Variation in Knowledge Scaffolding

Figure 3.7a: Learning Trace (Grey) and Frontier Score Trace (Black) for Subject 13: Tactical Learning Pattern Illustrating Early Adoption of Continuous Loop – Scores by Trip Attempts

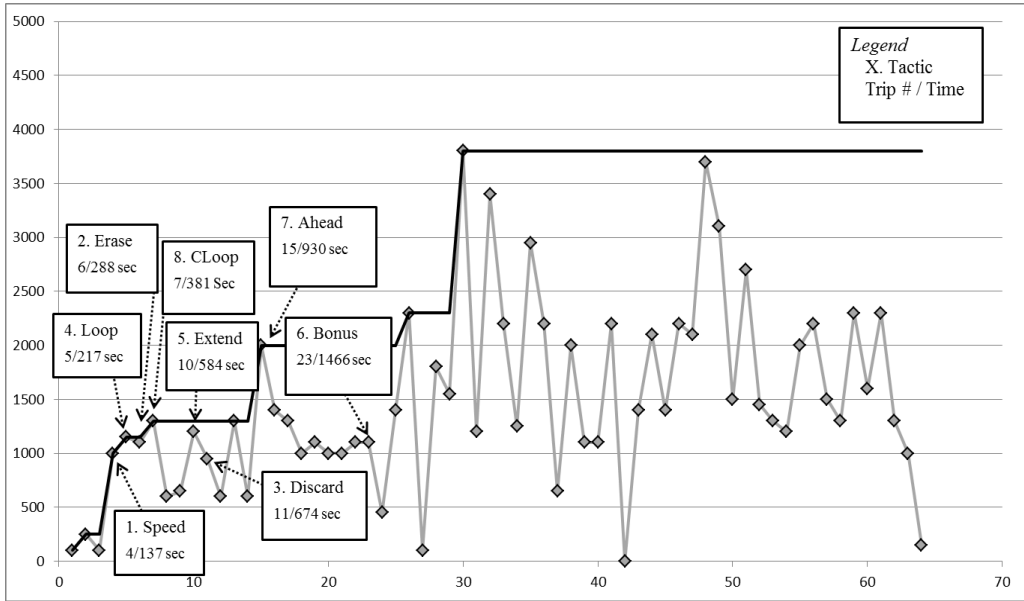
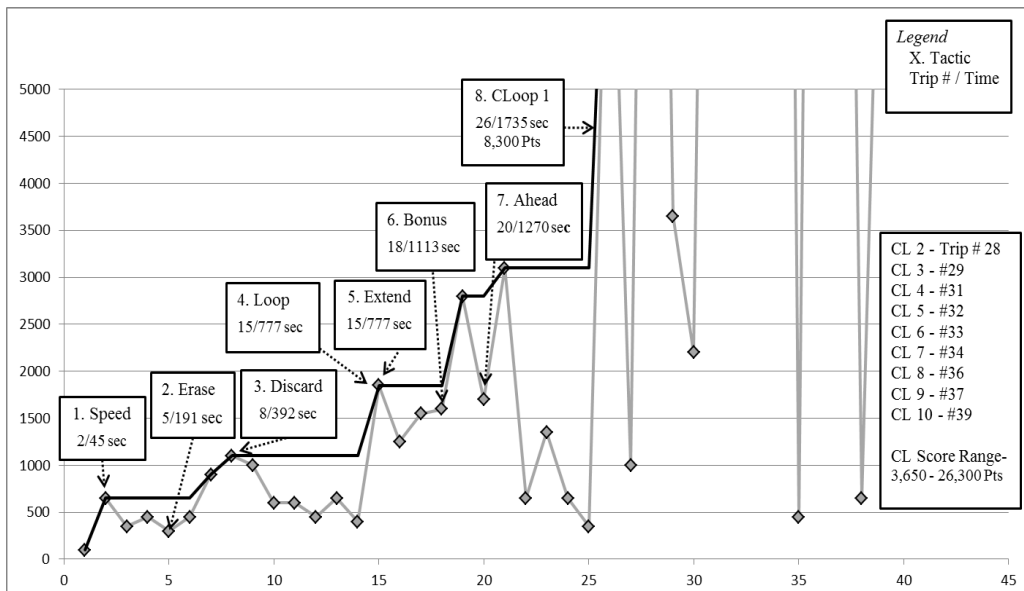


Figure 3.7b: Learning Trace (Grey) and Frontier Score Trace (Black) for Subject 23: More traditional Tactical Learning Pattern with Continuous Loops – Scores by Trip Attempts



value of what had been achieved. The subject failed to attempt construction of any additional closed loops, perhaps failing retain the episode and learning the scoring potential associated with constructing a closed loop.

As noted earlier, in more than half the trials involving closed loops, this tactic was the last to be learned. Many of the preceding tactics appeared to contribute to the likelihood of discovery and successful use of the tactic. With success in discovering the other focal tactics and techniques, most subjects did discover and use the close loop tactic and, after discovering it, often executed it multiple times (as many as 10). They explored its potential to drive higher scores, complex patterns or a higher percentage of trips. Subject 23, in Figure 3.7b, illustrated the more typical learning pattern associated with the tactic. The subject was surprised when he/she successfully discovered the close loop. “Huh ... that’s new ... didn’t know that you could close loops!” (Subject 23). As the trial continued, the subject constructed 10 closed loops, including more than one in a single trip. The subject’s final frontier score exceeded 26,000 points. While typical patterns for the development of new tactics and techniques is difficult to discern, unusual patterns and sequences did occur. Sometimes they appear to reflect unique events in which learning has failed, at other times learning was actually accelerated. In some cases, the discovery and perfecting of one technique was observed to be instrumental to the success in developing another. For instance, early familiarity and proficiency with the eraser technique (T2) appeared to be a requirement for executing the close loop tactic (T8). “The track eraser just erases a piece of track? ... This could be helpful later.” (Subject 24). Several subjects after visualizing aloud the interest in and benefit of constructing a closed loop were unable to do so as the eraser tactic was the only way into and out of a closed loop “Made a closed loop ... ran out of bombs ... can I fix this?” (Subject 37). Looking back on preceding trip attempts confirmed

a failure in the discovery of or in perfecting the use of erasers, needed to quickly draw the train into a loop and then out of a loop to complete the trip.

Other missing tactics or techniques may be severely limiting as well. Reaching to more advanced tactics like extend route (T5) or play ahead (T7) without the awareness and mastery of reduced speed (T1) or discard (T2) increases the risk and likelihood of a premature crash and a reduced score. At other times, tactical and technique development appeared to be accidental and premature. One subject's experience (Subject 13), noted previously, involving the early discovery of the close loop tactic, never to be used again, stands in contrast to a more typical pattern of learning. Premature discovery of an advanced tactic, without the knowledge necessary to understand what had been achieved, may limit full and continued use of the tactic and future outcomes in gameplay.

3.3 Discussion and Conclusions

Study 1 gathered detailed data about the actions and behavior of 50 new learners in an experiential context they were not familiar with. Though several examples of common patterns of learning were noted, the variability observed in learning paths was significant. The unique number of learning paths witnessed and captured, support the underlying complexity and granularity of learning processes and sequences. In some instances, a connection between learning processes and knowledge content may be reasonably inferred. For instance, while observing a subject's learning during gameplay, it was useful to distinguish whether a failure or delay in demonstrating a new tactic, was anchored in missing data (they did not see the speed button), a missing variable (understanding that speed slows the train's progression), or lacking theory (if I select a slower speed, I might be able to assemble a longer route). The three

knowledge types demonstrated interesting dependencies, and the ability to apply them discretely, while examining learning at a more elementary level was often helpful.

The development of tactics and techniques were a central aspect of this Study. Results suggest that the tactics and techniques which were learned and how quickly they were learned played a central role in improved learning outcomes. Variance in tactical discovery was therefore closely observed and recorded. Not fully anticipated in the methods and analysis used in this study was the variance observed regarding the routine use of new tactics and techniques after initial discovery. A retrospective look suggests that sequences and habits in tactical behavior would offer additional insight into the microdynamic pairings of knowledge and process as learning progresses. The sequences and combinations of tactical learning and behavior is a question of particular interest for future research.

Key mechanisms theorized to contribute to learning and explaining why learners often follow different paths, including dialectics, scaffolding and the self-directed adoption of goals and learning strategies, were observed in this effort, though more study is needed. The dialectic mechanism proposed to signal gaps and inconsistencies in knowledge structures and function as a catalyst for attention and action through executive function may be loosely inferred through the learning behaviors that were observed. Also, evidence of the use of idiosyncratic scaffolding processes were observed as learners worked to construct new knowledge based upon what was previously learned and associate that learning in unique and different ways. The adoption of self-directed goals was directly observed and varied widely in the specific goals adopted by many learners, as well as the sequence and timing of goal adoption and dismissal.

4.0 COGNITIVE ABILITY, LOAD AND BREAKS WHILE LEARNING

4.1 Study 2 Approach

Many subjects in Study 1 opted to take extended breaks, often early in gameplay while many aspects of the game remained hidden and unknown. Operating in a new context appeared to generate considerable cognitive load for most subjects, particularly early in gameplay. Learning challenges our cognitive capabilities. Cognitive resources are used to sense, interpret, construct and retain the knowledge necessary to perform effectively, often in constrained periods of time.

The cognitive resources engaged in learning are limited. Therefore, learners may benefit from periods of “offline” time to reflect and process the data garnered from preceding action episodes. Concentrated processing, free from the continuing assault of new information, is thought to promote more accurate interpretation of what was previously experienced while learning (Jabr, 2013). It does so in part by improving the consolidation of the knowledge gained, resulting in additional learning and the heightened potential for recall of knowledge when needed (Alberini, 2005).

While breaks between learning sessions appear to improve learning and outcomes, it is unclear whether these effects generalize to short breaks within learning events. An emphasis in prior research on breaks centers on rest or reflection time during structured learning tasks, often memorization exercises. In these cases, evidence of learning is evaluated by the retention of specific declarative elements gleaned from the presented material. Retention rates of the structured learning material are then compared under a variety of break conditions often resulting in a positive relationship (Cepeda, Coburn, Rohrer, & Wixted, 2009). Whether these effects translate to learning contexts that emphasize the development and application of new behavior as opposed to the retention of facts, is unclear. Further, the duration of breaks studied in prior

research often involves periods of hours or days. Whether these positive effects will occur with short breaks during learning events is less understood.

4.2 Cognitive Load: High Demand for Limited Resources

Cognitive load speaks to the demands placed on limited cognitive resources during problem solving and learning (James, 1976). As working memory (WM) is often considered the most limited of cognitive resources, considerable attention has been paid to how WM contributes to executive function and is challenged during learning episodes. WM and fluid intelligence (G_f) are believed to be closely related constructs with G_f often serving as a reasonable proxy for WM and its inherent attentional control dimensions in empirical research (Kane, Hambrick, & Conway, 2005).

WM represents a small subset of activated memory that is being manipulated in the moment to support learning and decision-making activities associated with executive function. Similar to cache memory in a computer system, knowledge resident in WM is short term in nature and after being processed is most often transferred to long term memory. WM functions as an interface to sensory memory, where data observed through the senses may be processed and filtered and then, if appropriate, sent to long term memory (LTM). Tightly integrated with the data and knowledge handling aspects of WM are the executive function processes which make decisions and direct WM activity (Baddeley, 2012). As a limited cognitive resource, WM may at times be overwhelmed by the sheer volume of data presented by sensory systems. If the data is unfamiliar, executive function may struggle to determine how to best interpret and store data and make it ready for future use. Monitoring change in a learning environment also requires cognitive resources, as does organizing new and preceding knowledge to construct, refine and enact new procedural approaches.

WM is constrained in the knowledge it is capable of storing at one time (Miller, 1956). These constraints may be relieved, freeing WM for other work, by several means including the elimination of extraneous knowledge in WM or by appropriately organizing and converting the knowledge stored in WM to long-term memory (LTM). LTM provides a virtually limitless store. The challenge for LTM is not capacity, but how effectively the knowledge within is organized and linked to other knowledge elements, assuring rapid and appropriate recall and access (Baddeley, 2012). Consistent with dual-process theory, with practice LTM knowledge and routines may become more automatic, reducing load on WM (Schneider & Shiffrin, 1977a).

Sweller (1988) formalized thinking in cognitive load theory (CLT) focusing upon the limits of WM and specifically how those limits are likely to interfere with effective learning in select scenarios. Referencing earlier work examining the techniques of chess masters and novices (Chase & Simon, 1973), Sweller noted differences in the complexity of board patterns and move sequences remembered by the masters as opposed to novice players. Yet he found no difference in the actual breadth or depth of search patterns aligned with these patterns and sequences. Instead, it appeared that masters were accommodating larger “chunks” of knowledge with similar memory resources than novices were capable of doing.

More recently CLT has been framed as theory “concerned with the learning of complex tasks, in which learners are often overwhelmed by the number of interactive information elements that need to be processed simultaneously before learning can occur” (Paas, van Gog, & Sweller, 2010). The foundation of CLT remains tightly coupled to continuing work in cognition. Evolving models of working memory (Baddeley, 2012; Cowan, 2013) and its interaction with other cognitive resources (e.g. LTM, sensory systems) have been increasingly included in CLT research. CLT suggests three distinct and additive types of load; intrinsic, extraneous and

germane (Paas, Renkl, & Sweller, 2004). Intrinsic load identifies the cognitive demands imposed in identifying and learning the data elements within the task environment that contribute to progress in solving the problem. Intrinsic load includes the WM activity involved in the construction of increasingly comprehensive and robust schemas stored in LTM.

Extraneous load suggests that much of the data and information that exists in the task environment elicits an investment in cognitive resources but, offers little in necessary learning on the path to solving a problem (Paas & Ayres, 2014). Recognizing, isolating, and reducing extraneous load is therefore advantageous, freeing up cognitive resources to more fully address the intrinsic demands of the problem or learning activity. This is clearly most important when the intrinsic demands of the problem are high, taxing available WM resources, and less so when intrinsic demands are low.

Germane load was proposed by Sweller a decade following CLTs initial debut (Sweller, 2010). The conceptualization of germane load addressed the growing realization that cognitive resources must be applied to learn and solve problems, and within reasonable limits, might be a factor to maximize in order to expedite learning (Paas et al., 2010). Initially proposed as a third additive factor, convincing arguments have been offered suggesting that the addition of the third “germane” component over-specifies cognitive load as a whole (Kalyuga, 2011). This perspective concluded that cognitive load is best evaluated and measured with a simpler two-factor model, including intrinsic and extraneous dimensions of load.

Though discussed less frequently in the literature, CLT theorists have given some attention to cognitive load as it relates to real world learning scenarios as well. They note that the novice is often overwhelmed with cognitive load in new task environments and that conventional load reducing strategies may be inadequate (van Merriënboer & Sweller, 2005). It is quite likely

that subjects faced with new problems initially fail to adequately distinguish whether data observed in a task environment should be viewed as intrinsic and useful to learning or be treated as extraneous information. Additional load is likely to accompany the early interaction with the problem as the solver attempts to decide what to attend to, in addition to developing workable approaches and tactics.

Discussions of cognitive load assume that a maximum level of resources are available to each learner. This “maximum load” or cognitive ability is understood to vary significantly by individual. Thus, what may function as a burdensome load for one learner may in fact be easily processed by another. To better understand how learning outcomes might be optimized, it is important to explore how learners manage their time while responding to cognitive load.

4.3 Use of Time While Learning

Learners make decisions on the use of time while learning including the use of breaks. In the learning literature, a “break” is a commonly used term to describe an interruption of continuity or uniformity or a pause during an activity or event (Shohamy & Wagner, 2008). Breaks are believed to relieve cognitive load and accompanying stress while enhancing learning, allowing cognitive resources to catch up in the sorting, categorizing, constructing and storing of new knowledge (Jabr, 2013).

Studies in learning and cognition have suggested that taking breaks at different times in different amounts often results in improvements in learning outcomes (e.g. Kang, 2016). The effect of break taking behavior has been carefully examined in instructional research. Here, studied in the context of massed versus distributed practice (Ebbinghaus, 1913), learning frequently benefits from spacing “study time” or “practice time” over varying lengths of time

(Cepeda et.al., 2009). Across 254 studies, massed versus distributed practice, the latter with breaks in between, showed consistent benefits in memory recall (Cepeda, Pashler, Vul, & Wixted, 2006). Although the study of memory and verbal retention related to break taking behavior is extensive, research has suggested that spacing learning practice with breaks may also benefit learning in a broader context (Glenberg, 1979). In this case, repeated distributed experience is observed to be richer and more variable, and is thought to cue retrieval across a broader set of circumstances. In contrast, practice that is massed without breaks, shows evidence of being less effective; it is thought to narrow focus and attention and reduce the likelihood of recall across contexts (Magliero, 1983).

Two useful perspectives to consider regarding break-taking behavior are breaks used for *reflection*, and breaks used for *rest*. Literature in experiential learning has studied breaks as “reflection time” (e.g. Kolb, 1984). Dewey (1925) suggests, “We do not learn from experience. We learn from reflecting on experience”. Experiential learning studies have noted that reflecting on past performance is vital to learning by enhancing awareness of accumulated experience and providing an opportunity to organize and build upon that knowledge. Accompanying improvements in performance are often observed following reflection (Ellis, Carette, Anseel, & Lievens, 2014). Rest time, an alternative metric associated with breaks, is frequently studied in cognitive psychology (e.g. Immordino-Yang, Christodoulou, & Singh, 2012). Where break time, an opportunity for reflective thought, focuses on the conscious dimensions of cognition, breaks used as rest time may be viewed more inclusively. Rest may provide opportunities to engage both conscious and unconscious cognitive mechanisms. “Awake at rest” is used to delineate break time during consciousness as opposed to rest during unconsciousness periods of sleep.

4.3.1 Reflection Time

Reflection is an inherently cognitive process where a person intentionally heightens awareness and attention on preceding experiences to enhance learning (Hullfish & Smith, 1961). Reflection involves the absorption of new learning and the incorporation of that learning into new or existing knowledge structures in memory, and as such may place significant demand on cognitive resources (Gray, 2007; Craik & Lockhart, 1972). Isolating and exploiting “offline” time, independent of other cognitively demanding activity, is important to optimizing the learning potential offered by reflection. Reflection is believed to operate by enhancing the elaboration of data emanating from the task environment as it is stored and refined in memory.

How extensively new data is evaluated and processed has been shown to affect a variety of behavioral outcomes as predicted by the “depth of processing” framework initially proposed by Craik and Lockhart (1972). Complementing dual process models of cognition (Kahneman, 2003), deep processing or elaboration is believed to require the focused and effortful use of cognitive resources (type2) as opposed to the more superficial and “shallow” processing associated with the automatic mode of cognition (type 1) (Evans, 1984). Deep processing is most relevant to novel problem-solving situations where new facts, rules and procedures must be derived and learned. The demands for deep processing while learning, are expected to heighten the need for and potential benefit resulting from dedicated time in reflection.

Different types of reflective breaks have been identified and examined in research. These include *questioning* where a learner formulates his or her own questions regarding what has been experienced, read or observed, *evoking* or intentionally recalling to mind what has been read or observed (Pedrosa de Jesus & Moreira, 2009), and *self-assessing* or a learner’s review of the strengths, weaknesses and potential deficiencies of his or her current interpretation of what has

been observed or learned (Taras, 2002). Reflection on both successful and un-successful experience has generally demonstrated greater impact including the development of richer learning and “cognitive structures” (Matthew & Sternberg, 2009) and improvements specific to task performance (Anseel, Lievens, & Schollaert, 2009).

4.3.2 Rest Time

Neuro-psychology research has examined how periods of rest and periods of active engagement interact to effect cognitive processes and outcomes (Vincent, 2009). This research draws on common assumptions that cognitive resources are limited, with short-term memory or working storage being the most constrained. How learners quickly and efficiently capture and store newly observed information, noted as knowledge *acquisition* in the literature, is an important early step in the learning sequence. The *acquisition* process generally occurs during the awake or conscious state.

Memory consolidation is a function of central importance to contemporary thinking regarding rest time and learning (Alberini, 2005). Consolidation was first coined a century ago in work by Muller and Pilzecker (Dudai, 2012), speaking to the means through which the observed fragility of fact-based memory was reduced (Lechner, Squire, & Byrne, 1999). In applying consolidation to procedural or skill-oriented learning, two characteristics emerge (Robertson, Pascual-Leone, & Miall, 2004). As with fact-based memory, fragility in the procedural memory trace is often observed prior to consolidation. A second characteristic is “offline-processing” which is often observed in fMRI supported studies. A period of rest, following an active learning episode may reflect continued learning as well as heightened retention.

Stabilization of the newly acquired knowledge in long-term memory has been identified as a first step in the consolidation process in most contemporary models of cognition (Alberini,

2005). Time at rest (conscious) has been associated with effective stabilization of memory traces (Walker, 2005). Stabilization is thought to protect knowledge from loss over time and during periods of notable interference. Memory enhancement, a second component of consolidation, is thought to both refine and enrich knowledge stored in memory by both strengthening and eliminating associations with other knowledge elements. Though sleep has been heavily studied, and continues to merit further research, more recent work suggests that off-line processing may also occur at wake, or in planned or unplanned break periods (Peigneux et al., 2006). Time between skill learning episodes has been noted to reduce interference and enhance resulting consolidation and stability of procedural memory (Goedert & Willingham, 2002). fMRI based research has noted that functional connectivity patterns during immediate post task rest are strongly correlated with related future memory particularly for task elements which demonstrate high associativity in memory (Tambini, Ketz, & Davachi, 2010). Rest time has been shown to support and expedite effective consolidation, enhance reactivation and offer opportunities for memory refinement and reconsolidation (Schlichting & Preston, 2014). Breaks also appear to provide opportunities for integrative encoding, enhancing the availability of more refined and accurate knowledge in support of problem solving (Shohamy & Wagner, 2008).

It would appear that breaks and time at rest, whether viewed through the lens of learning research or neuro psychology and biology, is somewhat of an oxymoron. Clearly evidence abounds that important cognitive activity and learning continue during a variety of resting states, from very short to very long.

4.4 Learning under Cognitive Load

While learning, levels of cognitive load may vary widely as cognitive processes respond to the complexity of the task and the learner's preceding familiarity with it. Executive function

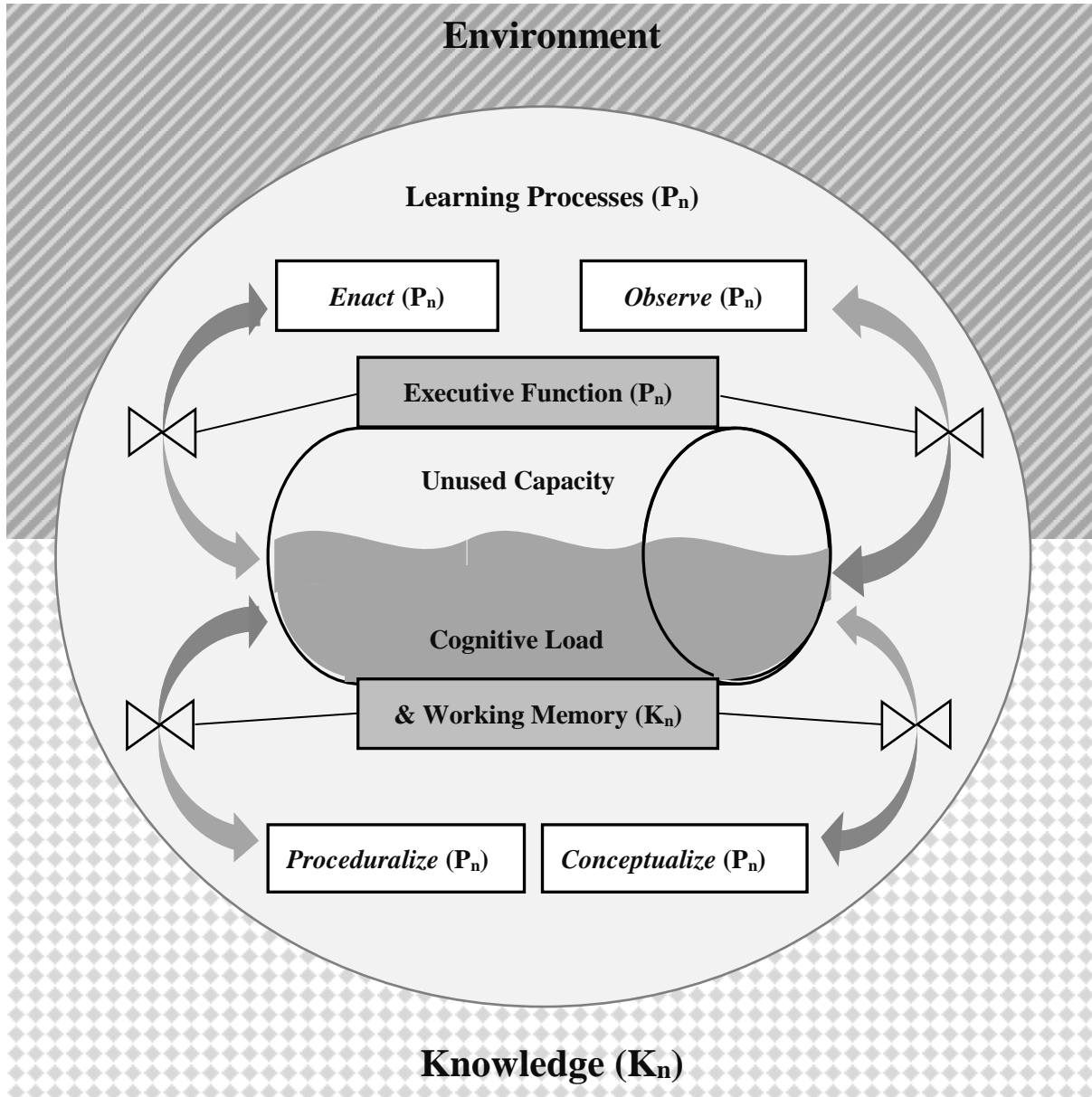
and WM, depicted as a “pipe” in the illustration in Figure 4.1, are considered to be limited resources which often constrain our ability to learn when maximum load is approached or exceeded. As illustrated, cognitive load reflects the “used” capacity of executive function and WM involved in coordinating and directing learning processes engaged at a particular point in time. Consistent with the theoretical perspectives previously reviewed (Baddeley, 2012; Cowan, 2013), WM and executive function are conceived as conjoined resources. The “pipe” in the illustration has a fixed capacity and may at times be overwhelmed. At other times, as depicted with fluid levels in darker gray, the full capacity of WM and executive function may not be fully utilized, leaving room for additional productive activity.

When loads reach a maximum threshold, represented by the full diameter of the “pipe” in the illustration, executive function must intercede and assess priorities. A decision may be made to selectively ignore, bypass or constrain some of the learning processes (P_n) previously active, reducing the flow of knowledge and activity “feeding” the pipe. Attention may be redirected, goals may be replaced with new objectives, and a new sequence of discrete processes may be engaged.

One option available in many task settings involves the use of a break. The ability of breaks to accommodate excessive cognitive load is depicted in Figure 4.1, with the control valves denoting executive decisions to vary the intensity of any or all learning processes. In this illustration, macro-processes drawn from theory in experiential learning (Dewey, 1925; Kolb, 1984; Lewin, 1951; Piaget, 1970), are used to illustrate sets of processes used to pursue generalized learning objectives including to *observe*, *conceptualize*, *proceduralize* and *enact*. When faced with high cognitive load, as opposed to facing the risk of lost data and suboptimal

Figure 4.1

Conceptual Model of Learning under Cognitive Load with the Use of Breaks



behavioral response, executive function may direct the learner to take a break. This effectively closes the “valve” to new observations (*observe*) and ongoing action (*enact*), freeing resources

to better understand (*conceptualize*) and prepare (*proceduralize*) new behavior, reducing the risk of lost data, inaccurate interpretations, or errors in procedure and action.

However, the very nature of the ongoing task environment may levy a significant cost for such withdrawal, seen in missed information and missed opportunities for action. In other contexts, the task environment may offer an opportunity to periodically take a break. In doing so, the need for action and observation temporarily subsides with executive function effectively calling for a temporary withdrawal from the environment, and cognitive resources may be fully applied to necessary and overdue mental activities without the risk of missing out on new observations in the task environment or the need to take immediate action. An executive decision to shut down environmentally facing processing effectively reduces the associated cognitive load and offers an opportunity to redirect cognitive activity.

4.5 Breaks and Cognitive Ability: Interaction While Learning

Individual differences in cognitive ability are expected to be substantive predictors of learning outcomes in most learning contexts (Schneider & Shiffrin, 1977). Differences in cognitive ability predict performance outcomes across a wide variety of tasks. Dual process theory (Schneider & Shiffrin, 1977) helps to explain why novel versus familiar tasks exploit general intelligence differently. The difference in cognitive load associated with automatic and controlled processes, in particular the resultant impact of load on the attention system, helps to explain expected variance in performance across different stages of learning and across different types of tasks (Ackerman, 1987). To the degree processes engaged in learning may be automated, limited resources associated with executive function and WM may be freed up to attend to other activity of greater immediate priority. A need for constant control ties up executive function and WM, precluding other important work. Individuals with more cognitive

resources and ability are expected to learn more and learn more quickly as suggested in Figure 4.2.

Hypothesis 1: Cognitive ability will be positively associated with the achievement of higher learning and performance outcomes while engaged with a novel task.

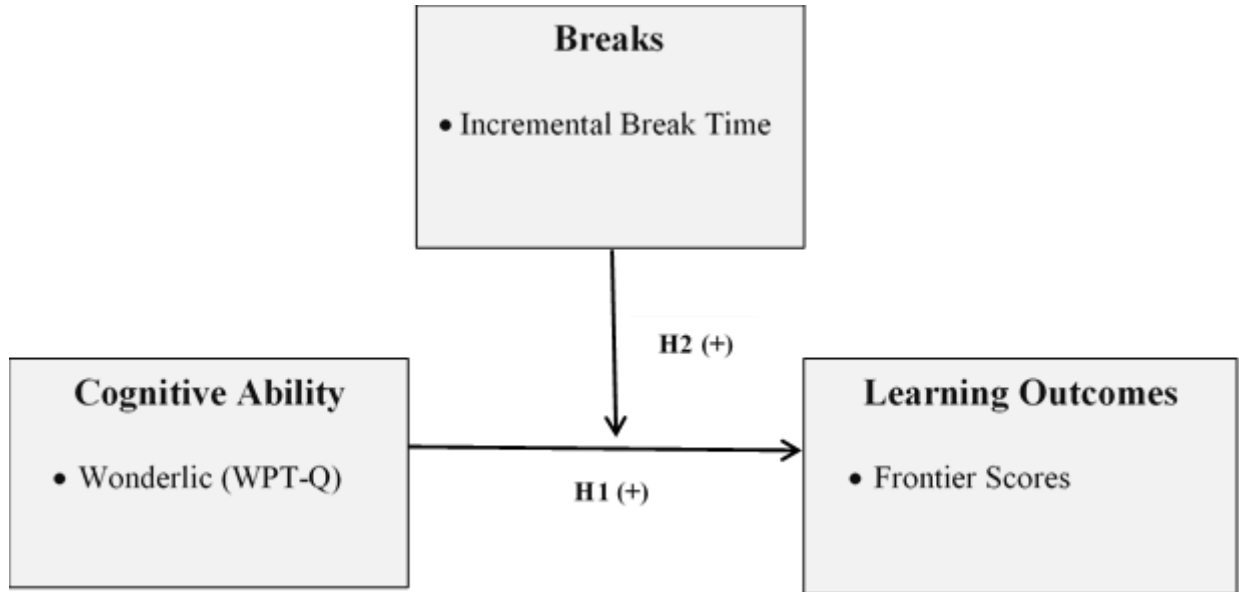
Breaks are hypothesized to interact with the cognitive ability of a learner while learning. Breaks provide a “pause in action”, stopping the flow of data and allowing increased time to reflect and develop new behavioral approaches. Breaks, which effectively interrupt continued active exposure to the task, provide additional time to process data helping to reduce the cognitive load facing the learner. Breaks have been shown to relieve cognitive load and accompanying stress while allowing cognitive resources to catch up in the sorting, categorizing and storing of new learning (Dewar, Alber, Butler, Cowan, & Sala, 2012; Tambini et al., 2010). It is reasonable to assume, that most subjects, given an opportunity to elect added time for reflection while learning will do so periodically.

How long and how frequently learners choose to take breaks are likely to vary by an individual’s overall cognitive capacity. Individual differences in cognitive ability have been observed in many studies (Ackerman, 1990). Those with greater ability are less likely to need added time for reflection in the form of breaks. Those with lower ability are expected to require additional time to optimize learning during gameplay and mitigate the effects of cognitive overload.

With individuals demonstrating higher ability, break frequency and duration may diminish. Individuals with high cognitive ability, due to the availability of additional resources are less likely to be cognitively overloaded. Therefore, as hypothesized in Figure 4.2, high ability

Figure 4.2

Operational Model Relating Cognitive Ability, Learning and Break Moderation



subjects are likely to achieve higher level outcomes while learning, with or without the significant use of breaks. Those with lower cognitive ability will find breaks more useful. While lower cognitive ability individuals are expected to achieve lower learning and score outcomes overall, the use of breaks may provide a means of mitigating cognitive overload and as a result, increase learning outcomes compared to those with lower cognitive ability using less break time.

With individuals demonstrating higher ability, break frequency and duration may diminish. Individuals with high cognitive ability, due to the availability of additional resources are less likely to be cognitively overloaded. Therefore, as hypothesized in Figure 4.2, high ability learners are likely to achieve higher level outcomes while learning, with or without the significant use of breaks. Those with lower cognitive ability will find breaks more useful. While lower cognitive ability individuals are expected to achieve lower learning and score outcomes

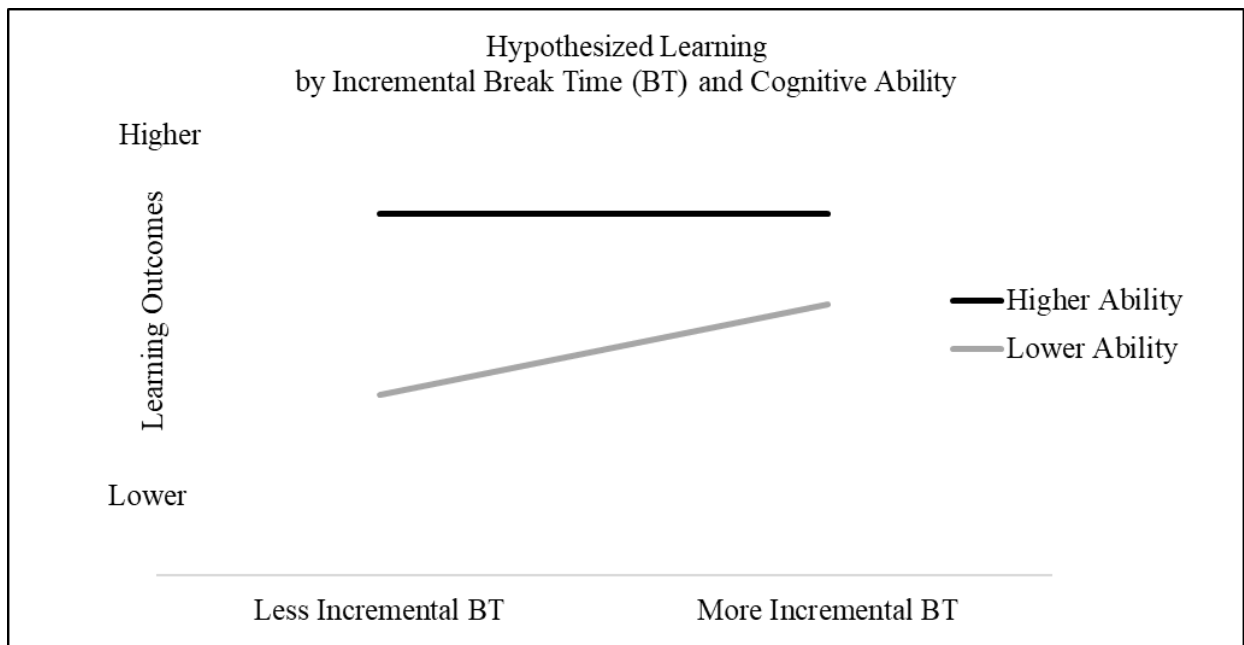
overall, the use of breaks may provide a means of mitigating cognitive overload and as a result, increase learning outcomes compared to those with lower cognitive ability using less break time.

Hypothesis 2: Cognitive ability will interact with the use of breaks to predict learning outcomes. More incremental break time will demonstrate little relationship to learning outcomes for individuals with high cognitive ability but, will contribute to higher learning outcomes for individuals with lower cognitive ability.

This hypothesized interaction is further illustrated in Figure 4.3.

Figure 4.3

Learning Outcomes: Interaction of Cognitive Ability and Incremental Break Time



4.6 Methods

4.6.1 Description and Design

Study 2 seeks to understand how cognitive ability and the capacity and choice to take breaks influence learning behavior and outcomes. While breaks in learning have been shown to

improve learning and outcomes, it is unclear whether these effects generalize to short breaks while learning by doing. Study 2 is divided into two parts. The first part (Study 2a, n=92) examines subjects without the opportunity to take breaks, a direct test of *hypothesis 1*. The second part (Study 2b, n=102) examines subjects with an option to take incremental breaks, whether they do so, and how the use of breaks influences learning outcomes testing *hypothesis 2*.

Study 2 again uses the OnTrack game environment and replicates several features of Study 1 while heightening the cognitive load characteristics associated with gameplay. In Study 2a (n=92), breaks are fixed with each interlude between trip attempts set for a constant six second pause. In the second treatment condition (Study 2b, n=102), subjects self-initiate each new trip after the initial six second pause, effectively managing each incremental break and its duration.

4.6.2 Contextual Requirements

Study 2 employs many of the aspects of Study 1's design (section 3.2.2). However, several game parameters were adjusted in order to accommodate examination of break behavior under cognitive load while learning. These adjustments included 1) adjustments to the game designed to heighten cognitive load, 2) incorporation of a control survey and cognitive ability test preceding the lab experiment, 3) removal of the verbal protocol and the researcher from the room during gameplay, and 4) the addition of a consistent goal to reduce anticipated variance associated with goal behavior while exploring the impact of incremental breaks.

4.6.3 Game Design and Features

To better understand the effect of heightened cognitive loads on the learning process and how that might impact the use of breaks, an effort was made to increase the cognitive load of gameplay. In Study 2a (n=92), subjects were given a fixed six second interlude between trip

attempts. In establishing six seconds as an appropriate load inducing threshold, data from Study 1 was carefully examined. Break patterns across the 50 trials in Study 1 demonstrated a mean of trial break means of 16.3 seconds, the mode of trial break modes of 9.0 seconds and the mode of trial break minimums of 8.0 seconds across all trials. Approximately 85% of all individual breaks taken in Study 1 were 6.0 seconds or higher. Ultimately, 6.0 seconds was selected to set the automated and fixed “between trip interlude” for all subjects, with confidence that this would induce added load across most subjects in the trial. This represented less time than most subjects would choose to take between trips if given the chance. For Study 2a subjects this automated and fixed six-second “break” separated all trip attempts. Study 2b subjects would independently reinitiate their next trip attempt, but only after the 6.0 second fixed period had expired, leaving break duration control in the subject’s hands.

A second step taken to increase the cognitive load in Study 2 was increasing train speed. Time to cross each track piece was reduced by one-half second for each of the three speeds resulting in 1.5 seconds, 1.0 second and 0.5 seconds for slow, medium and high-speed settings in both treatment conditions. By “dialing up” the speed associated with each speed selection, subjects would face a heightened pace in gameplay, which added to the cognitive load they were likely to experience.

In addition, observations from Study 1 captured significant differences in individual self-directed goal pursuit. A decision was made to center gameplay around a single high-level objective, “maximize your highest individual trip score”. This was not likely to eliminate self-directed sub-goals but did lend a common focus to the exercise. The objective of goal inclusion was to minimize one source of variation in behavioral response as I explored the use of breaks

under cognitive load. This objective was noted in instructions as well as indicated on the top of screen display during each trip attempt as illustrated below in Figure 4.4.

To allow time for subjects to complete a post-trial survey in Study 2, a subject's total trial time for gameplay was reduced from the 75 minutes used in Study 1 to 60 minutes. This reduction in game time accommodated the preliminary and post-trial survey in the same 90-minute window. Ninety percent of Study 1 subjects who were successful in discovering the most advanced tactic, close loop, did so within a 60- minute timeframe in Study 1. Specific actions and track placement patterns were used to identify the tactics and techniques used during gameplay. Where necessary for accuracy, this was supplemented by researcher observation of the trip replay capabilities integral to the game environment.

The following logic identifying tactics and techniques in gameplay was codified:

Speed (T1) – First select of speed adjustment button.

Erase (T2) – First use of “bomb” eraser to remove a previously positioned piece of track.

Discard (T3) – First instance (trip attempt) where at least two pieces are drawn from the tray and not placed within route. This was then visually inspected to assure the discard was not a clear “play-ahead” attempt in close proximity to the end of the route being assembled.

Loop (T4) – The cross-track or double-loop track was placed and traversed twice by the train.

Extend (T5) – The subject successfully placed at least 16 pieces of track which the train traversed. This assured that the route constructed moved outside of the two grid lanes surrounding the straight lane from entry tunnel to station.

Figure 4.4 *OnTrack* Game Interface – Study 2



Play-Ahead (T6) – A piece of track was placed disconnected from the contiguous track placed and extending from the entry tunnel. It was later connected to the contiguous route and the train successfully traversed the play-ahead section of track.

Close Loop (T7) – The train passed over a preplaced track a second time (not including the cross track or double turn pieces).

The “auto identify” features were fully tested with manual comparison of results. After testing, programming proved accurate and reliable in capturing first use of speed (T1), erase (T2), loop (T4), extend (T5), and close loop (T7). Programming for discard (T3) and play-ahead (T6), though generally accurate would occasionally include “false-positives”. For these tactics, I did review each trial using the playback function at the trip number flagged for first use of the tactic and if necessary, I manually corrected the data.

The scoring algorithm in Study 2 was adjusted to reduce the scoring range by reducing the trip complete bonus as well as restricting the number of close loop cycles a train might traverse to a maximum of six completed loops. This prevented the potential for placing the train in a continuous closed loop, which may result in unconstrained scoring while the subject disengaged from the task environment.

4.6.4 Recruitment of Subjects

Subjects for Study 2 were recruited from multiple sections of a large undergraduate course in business management (Management 3304). Following IRB approval and the identification of a target subject pool, students were presented with a short in-class announcement followed by an invitation to participate via the course management software, Scholar. The announcement identified the laboratory experiment as a “learning by doing” exercise and provided limited additional information beyond what was required by IRB guidelines. Invitations to participate in the experiment were offered to 482 students as an extra course credit opportunity in a mid-level undergraduate management course taken mostly by business majors. The pilot week 1, week 2 and week 3 invitations were staggered. Online signups using Sign-Up-Genius triggered an email with a link to the Qualtrics survey and within, an embedded link to the Wonderlic WPT-Q cognitive ability test which were both completed prior to the scheduled appointment in the laboratory, with few exceptions. Survey completion was confirmed prior to lab arrival. Nine exceptions were granted permitting the survey and test to be completed within 48 hours of the experimental session. Subjects ultimately failing to complete the survey or test were excluded from results.

Multiple sessions, with six subjects per session, were scheduled on two-hour intervals over a three-week period. Due to the nature of the experiment, subjects were not allowed to

participate in the study more than once as familiarity with the game is likely to affect results. Names of Study 2 volunteers were checked against Study 1 participants to assure that this did not occur.

4.6.5 Sample

A total of 294 of the 482 students enrolled in the class (61%) volunteered to participate. Of the 294 volunteers, 247 students (84%) arrived for their scheduled appointment and completed the laboratory exercise. The first 25 subjects scheduled participated in pilot testing. This occurred two weeks in advance of the primary study in which 222 students completed their respective laboratory trial. Fourteen students failed to complete the accompanying surveys or tests, data for nine were lost when the data failed to upload, and five subjects experienced technical failure during gameplay. Data for 194 subjects were available for analysis, of which 92 were in the Study 2a “no break” condition and 102 were in the Study 2b “breaks available” condition. Subjects were 55% female in Study 2a and 48% female in Study 2b. The combined groups straddled sophomore and junior status and averaged 20.3 years of age.

4.6.6 Lab Protocol

Study 2 took place in a behavioral laboratory where six isolation rooms and a control area were available. Each identical room was equipped with a matching desktop computer, monitor, keyboard and mouse. OnTrack was loaded on each computer and graphics were adjusted for the common screen size. Three rooms (Rooms 2,4,6) were allocated for Study 2b subjects, and three rooms (Rooms 1,3,5) for Study 2a subjects, helping to assure previously randomized assignments were maintained. Computers were equipped with Logicam video / audio recording devices with supporting software to support the recording of each session.

Upon arrival at the lab, subjects signed in at the control desk for their scheduled appointment time and their ID's confirmed. They were then escorted to preassigned rooms to complete and sign consent forms and review a brief set of instructions. Once a timeslot with an associated room number was elected, a subject's group assignment would not change.

Cancelations and no-shows resulted in differences in group size.

A single page set of instructions offering a brief description of the game was given to subjects (Appendices G and H). Subjects were left with the instructions and three sheets of blank paper, to use if they wished. Video recording was initiated by the researcher, and game start was readied. Subjects were invited to take their seat in front of the monitor and told when the screen turned blue after 60 minutes of gameplay, to bring their paperwork and return to the control desk. The researcher observed the start of the game, and then left the subject to complete the exercise. Once started, the game continued for 60 minutes of gameplay. When finished, each subject completed a brief survey of their experience and then departed. Though available for review, the primary intent of the video and audio recording was to reinforce attentiveness to gameplay. To further reinforce attentiveness, subjects were informed that if the game were to solicit their feedback on their experience at any point during gameplay, please respond verbally as play continues into the microphone. This solicitation was not enabled.

With the completion of each round, the researcher had the ability to remotely examine gameplay in progress. This was helpful to identify in near real time any technical anomalies associated with the data gathering program and uploading process. Subjects were also made aware of this capability, again with the hope that attention to task was re-enforced.

4.6.7 Pilot Testing

A pilot study (n=25) preceded the live experiment by two weeks and was not included in the final data set to be analyzed. The pilot was used to test the protocol changes and adjustments made to the game environment based on Study 2 objectives and Study 1 experience.

4.6.8 Measures

4.6.8.1 Trip Attempts and Trip Completed

Measures of trip attempts and trips completed remain the same, as noted in Study 1.

4.6.8.2 Actions

Seven focal techniques and tactics were captured in Study 2. These include the techniques 1) adjust speed, 2) erase track, 3) discard track, and 4) create loop, and the tactics 5) extend route, 6) track play ahead and 7) close loop. Study 2 involved a much larger sample of subjects; Study 2a (n=92) and Study 2b (n=102) versus Study 1 (n=50). This would result in more than 12,000 recorded trip attempts with the game. In addition, a researcher would not be present taking notes to triangulate the development of new tactics or techniques while playing the game, as was done in Study 1. Calculations regarding first use of a new tactic or technique would rely on the other two legs of the methodology, including the calculations programmed in the software (coding logic described previously on page 87-88) and a visual check of game progression by the lead researcher using the playback feature built into the game.

4.6.8.3 Scoring

The game provides a score for each trip. The score is determined by a combination of base and bonus scoring. Scores are calculated using the number of track pieces traversed by the train (50 points each), bonus track traversed (100 points each), and trips completed (1.5 times the earned score). The total score for each trip is recorded. Subjects may notice the accumulating and final score associated with each trip attempt. Individual trip data is aggregated to provide trial

level data. In addition to trip scoring, aggregated outcome data would include the number of trips attempted, the total trips completed, and the highest score achieved, described as the frontier score.

A retrospective examination of the scoring adjustments between Study 1 and Study 2, showed a drop in the frontier score means from 15,981 to 5,318 points, maximum frontier scores from 145,900 to 36,900 and minimum frontier scores from 1,500 to 1,000. Given the scoring changes between Study 1 and Study 2 and the trial length changes from 75 to 60 minutes, it is not appropriate to compare and assess absolute scores directly.

4.6.8.4 Track Selection and Placement

Track selections and placements as in Study 1 were also recorded in Study 2 for each action taken by a subject in each trip attempted.

4.6.8.5 Elapsed Time

As in Study 1, time was recorded for each trip.

4.6.8.6 Cognitive Ability

To assess Cognitive Ability, I used the Wonderlic Personnel Test – Quicktest (WPT-Q). The WPT-Q consists of 30 questions, each scored equally (1.66 points per question). A skipped or wrong answer earn “0” points. The assessment tool was selected after reviewing a number of instruments including the Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999), the WRIT (Glutting, Adams, & Sheslow, 2000), and the Wonderlic Personnel Test (WPT – R). Each alternative was designed to be conducted in abbreviated periods of time ranging from 10 to 30 minutes and are commonly used across diverse samples from children to seniors, including college age students as targeted for this investigation. The abbreviated Wonderlic Personnel Test (WPT-Q) is an economical alternative that compares

favorably with the extended WPT-R exam. Reliability measures have demonstrated a Cronbach's alpha (KR-20) of 0.81 (DuVernet, Wright, Meade, Coughlin, and Kantrowitz, 2014). The examination is administered online and was ultimately accessed in integrated fashion via the Qualtrics based survey tool used to accommodate other control dimensions described below. The online test is constrained to 30 questions and eight minutes and was positioned at the end of the Qualtrics survey. The Qualtrics survey and Wonderlic Test were requested and administered several days in advance of the scheduled laboratory survey.

4.6.8.7 Breaks

As break time was a central measure in Study 2, break data within the game was tracked in several different ways. This included capturing Total Break Time, the aggregate time across the subject's trial period when the game is suspended between trip attempts, the number of longer breaks (12 seconds or longer) judged to be Substantive Breaks in gameplay, and the timing of breaks. In Study 2b, Incremental Break Time is also recorded, representing the aggregate incremental time between trip attempts beyond the fixed six second interlude between trips. Incremental Break Time was judged the most construct valid measure of break time in this Study and was used to test Hypothesis 2. It was calculated by subtracting the fixed six second interlude occurring after each trip attempt from the total break time used after each attempt.

4.6.9 Control Variables

Several control variables were introduced in Study 2 including measures of the Big Five personality traits, demographics and experience. Personality traits have demonstrated significant explanation of variance in learning (Poropat, 2009) and might reasonably be expected to do so in the context examined here. Demographic measures were limited to gender and age. Gender was reasonably expected to demonstrate variance in learning with an anticipated positive relationship

for males associated with computer game learning and outcomes. Age, though measured, was tightly constrained in the measured sample, and was not expected to demonstrate a substantive relationship. Previous experience with computer games was also expected to contribute positively to learning outcomes. A total of 35 items were captured in a Qualtrics survey with an embedded link to the Wonderlic cognitive aptitude test described above. The combined test and survey time for most respondents fell within a range of 13 to 22 minutes with a few outliers in the response set.

4.6.9.1 Personality

Individual differences in personality and their relationship to learning and problem solving have been broadly tested in the literature (Ackerman & Heggestad, 1997). Feist (1998) conducted a meta-analysis focusing on the quantitative relationship between measures of creativity in problem solving and the Big-5 personality factors - Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. In examining a large sample (n=10,000), using scientific and artistic creativity, Feist notes the largest effect size differences between “creatives” versus “non-creatives” on Big-5 dimensions, fell in the areas of Openness (+) and Conscientiousness (+). It is possible that a similar relationship might be observed in the context tested in this study and it is therefore prudent to include the Big Five personality assessment in the design. With concerns regarding the length of trials and the accompanying fatigue placed on subjects, an abbreviated personality assessment tool was sought. Though the two dimensions of personality noted above were of greatest immediate interest, it was practical and appropriate to test each of the Big-5 dimensions. A 20-item measure, the Mini-IPIP, reviewed by Donnellan, Oswald, Baird and Lucas (2006), is widely used and when compared to the more familiar 50 item IPIP, convergent, discriminant and criterion-related validity patterns were comparable

between the instruments. Cronbach's alpha reliability measures ranged from .65 (imagination/openness) to .82 (neuroticism) across the five factors examined in two studies. Test times for the mini-IPIP components range from 5 to 10 minutes.

4.6.9.2 Gender

Gender was assessed in this Study with the expectation that it may relate to computer games outcomes. Gender was coded male = 0, female = 1.

4.6.9.3 Game Experience

I also controlled for Video Game Experience with items probing for experience in video and computer games. A scalar composite was calculated for video game experience, merging three scalar items. The items were adapted from an experience survey and scale used in computer game research (Sobczyk, Dobrowolski, Skorko, Michalak, & Brzezicka, 2015). These items included a self-report measure of video or computer gameplay frequency, a self-assessment of gameplay experience and a self-assessment of video or computer gameplay skill, were assessed using a seven-point Likert scale. Item scores were averaged to produce an overall game experience score ($\alpha = .91$).

4.7 Results

In spite of differences in objectives and design between Study 1 and Study 2, many of the same patterns in procedural learning and variations in learning outcomes were observed and captured. Scoring traces denoting the sequence and pace of learning for both Study 1 and Study 2 (2a and 2b) are included in Appendices Q, R, and S. Study 2 results include examination of two treatment conditions. Study 2a subjects (n=92) were not given the opportunity to take Incremental Breaks; Study 2b subjects (N=102) were allowed to take Incremental Breaks.

4.7.1 Comparing Learning with and without Incremental Breaks

Descriptive statistics for both studies are included in Table 4.1. Independent variables of interest included Cognitive Ability and Incremental Break Time. Variation in break behavior between Study 2a and Study 2b was expected and observed. Study 2a subjects (fixed six second breaks between trips) took combined breaks averaging a total of 624.95 seconds ($SD = 126.47$), representing 17.34% of the total clock time (3,600 seconds) available in each subject trial. Most Study 2b subjects opted for Incremental Break Time, averaging 920.94 seconds ($SD = 285.57$) in total “between-trip” break time. This represented 25.58% of total clock time available. Variations were not only reflected in Total Break Time taken, but also in the timing and duration of individual breaks taken. While Study 2a breaks were fixed at six seconds, the Mean Break Time between each trip for Study 2b subjects was 10.95 seconds ($SD = 4.91$).

Cognitive Ability was assessed for both Study 2a and 2b subjects. As indicated in Table 4.1, little difference was noted between samples in Cognitive Ability; Study 2a assessment demonstrated a mean of 26.99 ($SD = 4.22$) while the Study 2b mean measured 27.20 ($SD = 4.63$). The measured range for Study 2a subjects included scores from 14 to 36 while the Study 2b range included scores from 17 to 35. Little variation was observed between the samples in Gender, Age, Experience, and Big-Five personality factors.

Frontier Score, the primary dependent variable, was not significantly different between Study 2a and 2b; Study 2a subjects achieved an average high score of 5,263.59 points ($SD = 4,343.44$) while Study 2b subjects achieved an average high score of 5,518.63 points ($SD = 4,840.83$). A group comparison of Study 2a and 2b with Frontier Score outcomes rendered a small correlation of $r = .03$, which was neither substantive nor significant. The removal of one subject Frontier

Table 4.1

Descriptive Statistics and Correlations: Study 2a (No Incremental Breaks; n=92) Above Study 2b (Incremental Breaks; n=102)

FACTORS	Study 2b N	Study 2b Mean	Study 2b SD	1	2	3	4	5	6	7	8	9	10	11	12
				92	92	92	92	92	92	92	92	92	92	92	92
Study 2a - N				26.99	0.00	0.00	3.39	4.07	3.78	2.63	3.77	.55	20.43	3.16	5,263.59
Study 2a- Mean				4.22	0.00	0.00	.85	.67	.77	.83	.68	.50	3.22	1.77	4,343.44
Study 2a- SD															
1. Ability	102	27.20	4.60		a	a	-.12	-.12	-.06	-.18	.07	-.29	-.03	.18	.21
2. Incremental Break Time	102	388.06	313.18	-.09		a	a	a	a	a	a	a	a	a	a
3. Ability X Incr. Brk. Time	102	10,423.63	8,640.91	.11	.97		a	a	a	a	a	a	a	a	a
4. Extraversion	102	3.56	.92	.02	.07	.10		.42	.09	.17	.20	.10	.00	-.07	.02
5. Agreeableness	102	4.09	.69	-.07	-.07	-.08	.34		.21	.17	.19	.23	.05	-.32	-.08
6. Conscientiousness	102	3.58	.83	-.27	.09	.03	.06	.07		.02	-.23	.20	-.04	-.32	-.17
7. Neuroticism	102	2.75	.83	-.16	.12	.12	-.05	.01	-.19		.14	.30	-.06	-.10	-.06
8. Imagination	102	3.72	.71	-.03	-.08	-.08	.15	.31	.02	.08		-.29	.10	.25	.12
9. Gender, 0-M, 1-F	102	.47	.50	-.15	.01	.00	.05	.07	.02	.32	-.09		.03	-.65	-.24
10. Age	102	20.26	1.74	-.08	-.02	-.05	-.24	-.07	.10	-.02	.05	.02		-.02	-.04
11. Video Experience	102	3.26	1.79	.20	-.04	-.01	-.20	-.14	-.08	-.32	.09	-.72	.01		.42
12. Frontier Score	102	5,518.63	4,840.83	.31	-.22	-.18	-.21	.05	.01	-.29	.06	-.26	.03	.29	

Note. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a a subjects trial. "a" cannot be computed because one of the variables equals "0". Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set.

Score outlier (36,900 points), reduces the Frontier Score mean in Study 2b to 5,207.92 points (SD = 3,704.39), effectively eliminating the mean differences between studies on Frontier Score, and rendering a study comparison correlation with Frontier Score of $r = .00$. An alternative set of regression models without the outlier is included in Appendix P for reference.

4.7.2 Cognitive Ability and Learning Outcomes

Hypothesis 1 states that Cognitive Ability will be positively associated with the achievement of higher performance outcomes while engaged with a novel task. As reflected in Table 4.2 using Study 2b subjects, a significant correlation ($r = .31$, $p < .01$) was demonstrated. Standardized regression coefficients remained substantive and significant across regression models 1 through 8 (β from .28 to .33, $p < .05$). Cognitive Ability demonstrated a $\beta = .28$ in the fully loaded model 7 (without interaction term) which included Incremental Break Time, psychological factors and control variables. Cognitive Ability demonstrates a modest positive relationship to frontier score in Study 2a ($n=92$), with a correlation of .21 ($p < .05$).

4.7.2.1 Interaction of Cognitive Ability and Break Time

Hypothesis 2 stated that cognitive ability will interact with the use of breaks to predict learning outcomes. More Incremental Break time will demonstrate little relationship to learning outcomes for individuals with high cognitive ability; but will contribute to higher learning outcomes for individuals with lower cognitive ability. Subjects with higher Cognitive Ability were expected to gain little benefit from additional break time while subjects with lower ability were expected to do so. Higher ability subjects were expected to experience less cognitive overload while learning and therefore, were expected to require and elect less break time as a result. Although a modest effect may be inferred from the interaction plot captured in Figure 4.5a below, regression Model 2 in Table 4.2 fails to demonstrate significance ($p = .15$) in the

Table 4.2

Study 2b (n=102): Standardized Regression Analysis with Incremental Breaks, DV is Frontier Score

Model / Variables	Mean	SD	Correlation	M1	M2	M3	M4	M5	M6	M7	M8	Ru
DV - Frontier Score (Fs)	5,518.63	4,840.83										
Hypothesized Variables:												
Cognitive Ability	27.20	4.63	.31	.29	.47		.29			.28	.33	.06
Incremental Break Time	388.06	313.18	-.22	-.20	.67		-.14			-.15	.10	.02
Ability X Incremental Break			-.18		-.88						-.25	.00
Psychological Factors												
Extraversion	3.56	.92	-.21			-.27	-.28		-.26	-.26	-.25	.05
Agreeableness	4.09	.69	.05			.12	.13		.14	.15	.15	.02
Conscientiousness	3.58	.83	.01			-.04	.07		-.01	.09	.09	.01
Neuroticism	2.75	.83	-.29			-.32	-.23		-.24	-.17	-.16	.02
Imagination	3.72	.71	.06			.09	.08		.06	.05	.05	.00
Control Variables												
Gender, 0-M, 1-F	.47	.50	-.26					-.10	-.10	-.11	-.11	.00
Age	20.30	1.74	.03					.03	-.03	-.02	-.02	.00
Videogame Experience	3.26	1.79	.29					.21	.11	.07	.08	.00
Model Summary												
R				.36	.39	.40	.51	.30	.44	.53	.53	
R Squared				.13	.15	.16	.26	.09	.19	.28	.28	

Note. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a a subjects trial. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. One outlier with excessive frontier score is retained in the data set (36,900 points; > 3.0 standard deviations from the mean). Ru is calculated using Model 7 combined R value minus Model 7 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M1 thru M8 are regression model numbers.

Figure 4.5

Breaks Moderation on Cognitive Ability and Frontier Score

Figure 4.5a: Frontier Score by Cognitive Ability and Incremental Break Time. Study 2b (n=102)

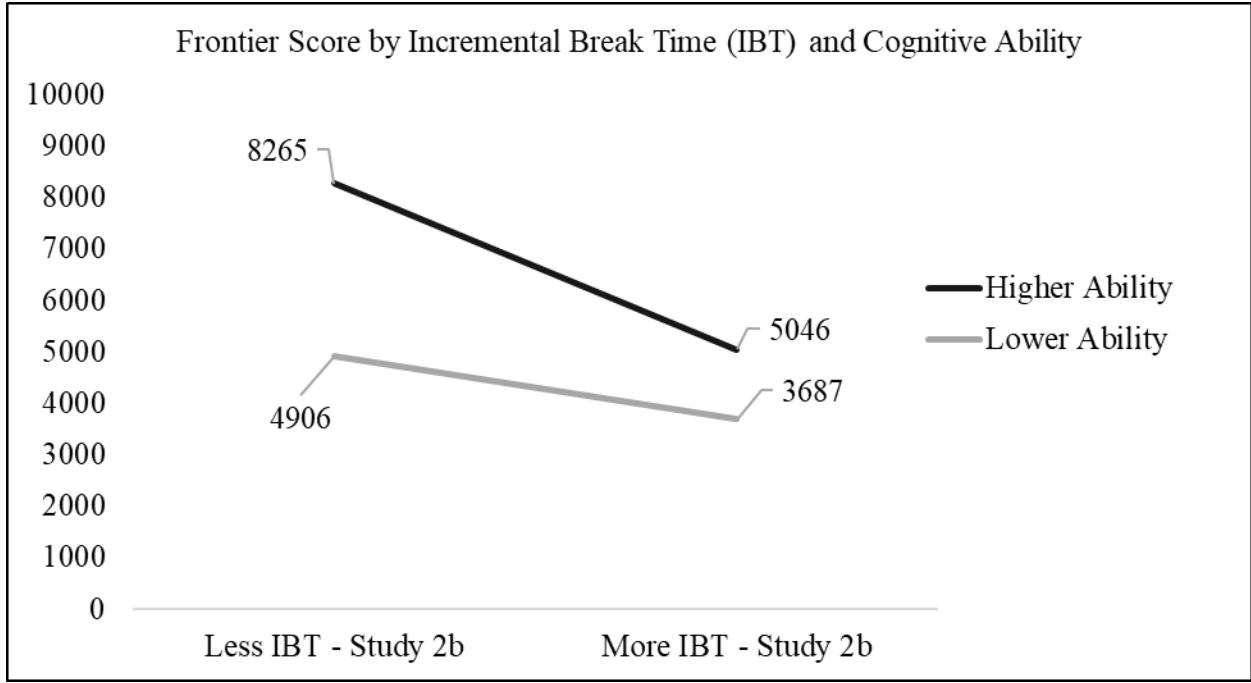
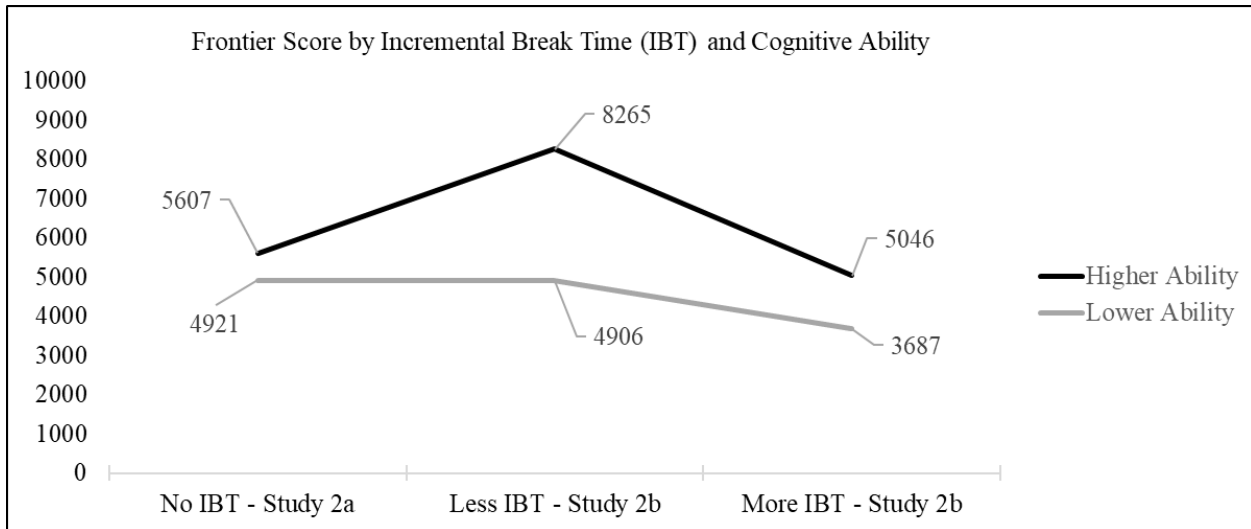


Figure 4.5b: Frontier Score by Cognitive Ability and Incremental Break Time. Study 2a (n=92) and Study 2b (n=102).



measured interaction and accounts for little added variance ($\Delta R^2 = .15 - .13 = .02$; $\Delta R = .39 - .36 = .03$) over the direct effects associated with Cognitive Ability and Incremental Break time ($R^2 = .13$; $R = .36$) in Model 1.

A notable outlier (> 3 standard deviations), with a frontier score of 36,900 points is included in the high ability / less incremental break time data set. The next highest score in the set is 15,200 points (< 2 SDs from Mean). Playback and review of subject gameplay demonstrated no apparent anomaly in gameplay, beyond the subject's rapid learning and discovery of all tactics and techniques and overall skillfulness in execution. Removing the outlier ($n = 101$) results in a modest reduction in the visible slope associated with the interaction and modest changes to correlations and regression coefficients as noted in Appendix O. Regression Model 2 again fails to demonstrate significance ($p = .21$) in the measured interaction and accounts for little added variance ($\Delta R^2 = .16 - .14 = .02$; $\Delta R = .40 - .38 = .02$) over the direct effects associated with Cognitive Ability and Incremental Break time ($R^2 = .14$; $R = .38$) in Model 1.

Although Study 2b subjects ($n = 102$) alone were provided the opportunity to elect incremental breaks, juxtaposing the interaction plot in Figure 4.5a, with the frontier scores of a high and low ability group in Study 2a ($n = 92$), where no incremental breaks were possible, offers an interesting comparison. In Figure 4.5b, the X-Axis denotes three groups, subjects unable to take incremental breaks (Study 2a), subjects electing less Incremental Break Time (Study 2b), and subjects electing more Incremental Break Time (Study 2b). The Y-Axis denotes Frontier Score Outcomes. The black line captures data points associated with higher ability subjects, the grey line associated with lower ability subjects. Results would infer that high ability subjects maximized learning outcomes when Incremental Break Time was reduced, but not

entirely eliminated. Low ability subjects experienced roughly equivalent outcomes when Incremental Break Time was not available (Study 2a) or was reduced, with a moderate decline in Frontier Score performance when Incremental Break Time was increased. It is possible that the interpretation that “less is more” in break time in the measured context may be premature. The ability to add a small amount of break time when compared to the fixed nominal six-second pause between trips associated with Study 2a subjects demonstrated a notable difference in frontier scores (8,607 points to 5,607 points) for higher ability subjects. Perhaps small increments of break time at select points on the learning path were indeed meaningful, particularly to those with higher ability. No notable difference in results was apparent when comparing “no incremental” to “less incremental” break time subjects of lesser Cognitive Ability (4,921 points to 4,906 points).

4.7.3 Regression Models: Variables of Interest with Frontier Score

The regression models for Study 2b (n=102) in Table 4.2 account for the observed effects of the hypothesized variables previously discussed together with psychological factors and control variables introduced over a series of eight models. Model 1 regressed Frontier Score on Cognitive Ability ($\beta = .29$, $p < .01$) and Incremental Break Time ($\beta = -.20$, $p < .05$) rendering a modest explanation of variance ($R^2 = .13$; $R = .36$). Model 3 regressed Frontier Score on the Big-5 psychological factors, with Extraversion ($\beta = -.27$, $p < .01$) and Neuroticism ($\beta = -.32$, $p < .01$) demonstrating substantive and significant effect with an $R^2 = .16$ ($R = .40$). Model 4 combined hypothesized and psychological factors without the interaction term. Together, this model rendered a substantive explanation of variance ($R^2 = .26$; $R = .51$). Model 5 regressed Frontier Score on control variables including Gender, Age, and Videogame Experience. Only Video Game Experience demonstrated a modest substantive effect ($\beta = .21$, $p < .10$), with the overall

model demonstrating an $R^2 = .09$ ($R = .19$). Regression Model 7 combines all of the variables noted above with a combined explanation of variance of $R^2 = .28$ ($R = .53$). In this model, only Cognitive Ability ($\beta = .28$, $p < .01$) and Extraversion ($\beta = .26$, $p < .01$) retain substance and significance. Cognitive Ability ($R_U = .06$) and Extraversion ($R_U = .05$) also rendered substantive unique contributions to the fully loaded model. R_U is the reduction in R that occurs when the focal variable is removed from the regression model containing all other study variables. This provides a measure of the unique contribution of the variable to overall R (Carlson & Kunkel, 2011).

4.7.4 Supplemental Findings - Regression Analysis with Tactical Learning

The variance explained by the factors included thus far, $R^2 = .28$ ($R = .53$), provides a modest account of differences in learning. As observed in Study 1, a growing base of procedural knowledge in the form of tactics and techniques may help to explain some of the unaccounted-for variance. Table 4.3 (Study 2b, $n=102$) regresses Frontier Score on the previously hypothesized variables and other factors reported in Table 4.2, together with the seven measured tactics and techniques examined in this Study.

Speed of learning measures the number of trip attempts needed to first learn and demonstrate a new tactic or technique. The seven tactics and techniques combined, without the contributions of the previously included factors in Table 4.2, demonstrate an $R^2 = .31$ ($R = .55$) in model 11, slightly larger than noted with model 7 previously, ($\Delta R^2 = .31 - .28 = .03$; $\Delta R = .55 - .53 = .02$). When the learning of tactics and techniques are combined with previously hypothesized variables, Cognitive Ability and Incremental Break Time, along with psychological and control factors, model 14 demonstrates an $R^2 = .51$, notably higher than preceding models 7,

Table 4.3

Study 2b (n=102) Standardized Regression Analysis, Techniques, Tactics, Hypothesized and Other Variables; DV is Frontier Score

Model / Variables	TGroup 2 N	TGroup 2 Mean	TGroup 2 SD	Correlation with Frontier Score	M9	M10	M11	M12	M13	M14	Ru
Technique and Tactic Learning											
Speed - Technique 1 (# trips)	100	3.85	6.59	-.19	-.08		-.09			-.07	.00
Erase - Technique 2 (# trips)	99	15.88	15.09	-.21	-.09		.02			.06	.00
Discard - Technique 3 (# trips)	94	29.33	23.05	-.25	-.21		-.12			-.11	.00
Loop - Technique 4 (# trips)	99	22.35	17.19	-.35	-.30		-.23			-.24	.03
Extend - Tactic 5 (# trips)	92	32.76	24.31	-.37		-.25	-.15			-.08	.00
Ahead - Tactic 6 (# trips)	96	32.05	26.17	-.28		-.13	-.06			.02	.00
Close Loop - Tactic 7 (# trips)	50	46.86	23.56	-.41		-.27	-.27			-.36	.04
Hypothesized Variables:											
Cognitive Ability	102	27.20	4.60	.31				.29		.17	.01
Incremental Break Time (IBT)	102	388.06	313.18	-.22				-.20		-.19	.02
Other Factors											
Extraversion	102	3.56	.92	-.21					-.26	-.30	.05
Agreeableness	102	4.09	.69	.05					.14	.22	.02
Conscientiousness	102	3.58	.83	.01					-.01	.06	.00
Neuroticism	102	2.75	.83	-.29					-.24	-.12	.00
Imagination	102	3.72	.71	.06					.06	-.02	.00
Gender	102	0.47	0.5	-.26					-.10	-.04	.00
Age	102	20.26	1.74	.03					-.03	-.11	.00
Video Experience	102	3.26	1.79	.29					.11	.05	.00
Model Summary											
R					.44	.49	.55	.36	.44	0.71	
R Squared					.19	.24	.31	.13	.19	0.51	

Note. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. Ru is calculated using Model 14 combined R value minus Model 14 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M9 thru M14 are regression model numbers.

or model 11 ($\Delta R^2 = .51 - .28 = .25$; $\Delta R = .71 - .53 = .18$) or model 11 ($\Delta R^2 = .51 - .31 = .20$; $\Delta R = .71 - .55 = .16$). The extended model lends support to the importance of the pace of learning associated with a new task, and how specific elements of knowledge being constructed and applied contribute to performance. In this case, growing knowledge contributing to new tactics and techniques applied to the task offers added explanation ($\Delta R^2 = .25$) for gains in overall learning performance. In the combined Model 14, the largest unique contributions included Extraversion ($R_U = .05$), the Close Loop tactic ($R_U = .04$), the Loop tactic ($R_U = .03$), Incremental Break Time ($R_U = .02$), and Agreeableness ($R_U = .02$).

Variance in learning was noted across a spectrum of measurements. This includes the number of trips needed for subjects to first demonstrate each focal tactic, as illustrated in Table 4.3. Variance between subjects is notable with standard deviations often approaching and at times exceeding the mean. Scoring was captured and traced with each successive trip or learning cycle. Scoring traces for each subject trial in Study 2 are provided in Appendices Q and R.

4.8 Discussion and Conclusions

Cognitive Ability demonstrates its anticipated relationship to learning outcomes. Though modest, its association with learning appears consistent with prior research. Our finding regarding the contribution of breaks for reflection and rest, however, run counter to previous findings. Research suggests that breaks and reflection have a positive effect on learning in many contexts (Cepeda et al., 2006). In Study 2b (n=102), in which subjects were allowed to elect additional break time, taking more Incremental Break Time was associated with less learning. This appeared to be true irrespective of a learner's Cognitive Ability. The hypothesized interaction of Cognitive Ability and Incremental Break Time was also not supported. The data suggested main effects for Cognitive Ability in the direction expected and a main effect for

Incremental Break Time in the opposite direction. Interestingly, though, the pattern of effects as observed in Figure 3 generally replicate the expected pattern of effects, with the exception that all results for individuals who took more Incremental Break Time were below the levels hypothesized.

There are several possible explanations for this unexpected finding. It is possible that the game context did not create the cognitive load expected. Our previous experience with the game environment suggests that stress accompanies game play, and we adjusted several game parameters to amplify this effect. Though the context may appear challenging to the new learner, it may not overwhelm the system to the point where a break is required. Second, it is possible that short breaks, a few seconds to a minute, in the context of game play may not have the expected effect. Subjects did in fact have an opportunity to further extend an elected break, and some subjects extended breaks to several minutes. A third possibility is that it is not total Incremental Break Time that matters. Perhaps cognitive load varies over time and taking targeted breaks at times when load spikes, are what may generate benefits in this context. These micro events may benefit from a short break, but only in specific circumstances where added effort must be applied to interpreting a new observation or refining or adding a new procedure. This would suggest that examining total Incremental Break Time would not necessarily capture the desired effect. In addition, it might be possible that cognitive load was substantive and did influence learning, but subjects were able to develop other means of mitigating its effect, including automating other learning and performance tasks or thinking in parallel with gameplay when the task itself did not fully expend available resources.

It is also possible that despite variance in Cognitive Ability, few objectively low ability subjects were included in the sample. The ability of subjects in the sample may have been higher than measured, enough not to create the hypothesized low CA effect.

I did observe that as experience was gained and repetition continued, break taking generally subsided, And, then suddenly, many subjects would elect a substantive break once again. This might be driven by a dialectic response to a new observation, or simply building frustration with a string of attempts demonstrating little progress in learning or associated outcomes. This pattern illustrated in Figure 4.6 for subject (study) 2288, is repeated for many other subjects. The lower panel histogram, notes substantive (12 second or longer) breaks in the darker grey bars. Break length (y-axis) and frequency across trip attempts (x-axis) are easily observed. (A complete set of Break Histograms for each trial in Study 2 are available in Appendix R.)

The impact of short breaks while learning may also be lost in the more general measures of learning outcomes adopted in this Study. An additional explanation for the unexpected failure of breaks to benefit performance, may be visible in the individual scoring traces themselves. Why does learning proxied by trip scoring exhibit such significant bounce over trips? Although the game includes a degree of randomness built into the track selection algorithm, the effect of this perceived randomness declines with learning and experience. Several tactics when learned minimize the potentially negative effects of random track generation. And yet, even with this learning, continued variability is often observed for many subjects. In fact, a decline in scoring between trips, notably below a previously established frontier score, may represent a “hidden break”. While game play in trip continues, a subject may redirect cognitive resources to emphasize scaffolding, or organizing and constructing new knowledge, thus inhibiting the

Figure 4.6

Trip Score and Break Progression Trace – Study 2b

Figure 4.6a (Top Chart): Scoring Trace Capturing Trip by Trip Scoring (Y-Axis) and Trip Number (X-Axis). Dotted Line Represents Individual Trip Score Progression. Solid Line Represents Frontier Score Progression. Bars Identify When Tactics Learned (T1 – T7).

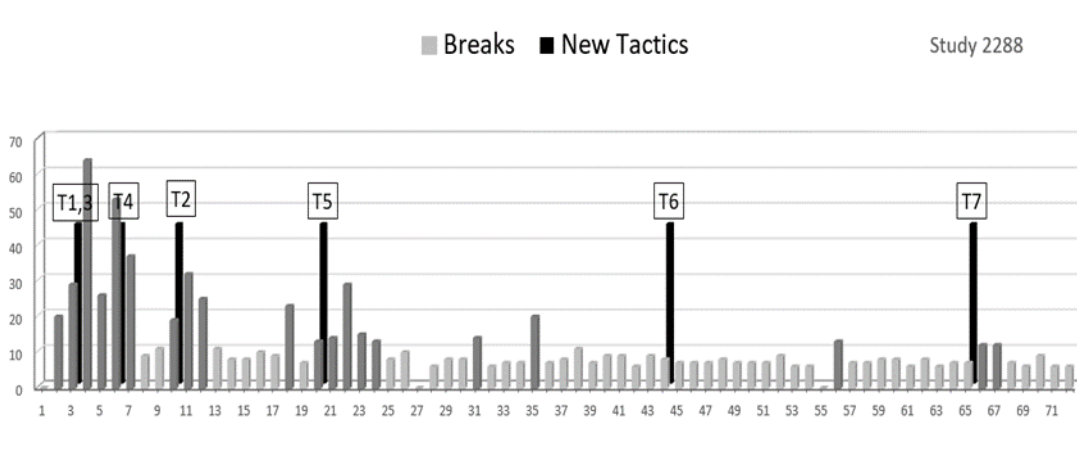
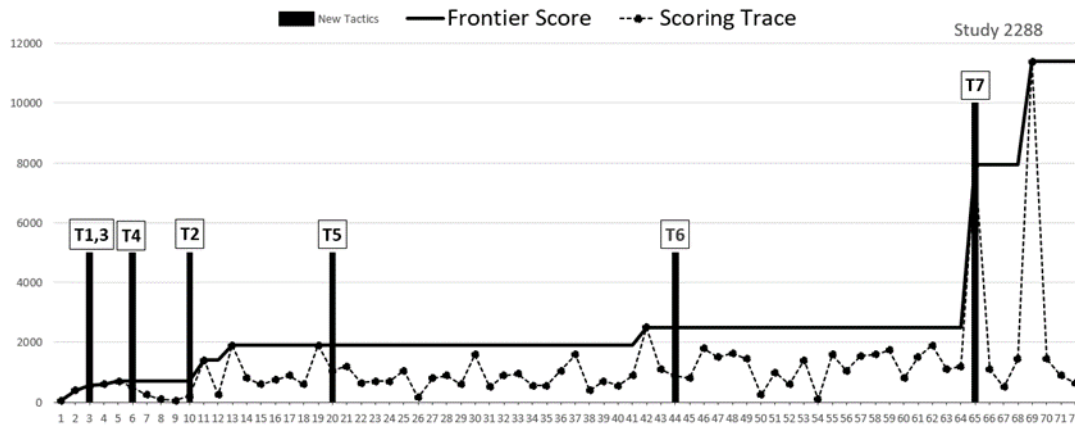


Figure 4.6b (Bottom Chart): Break Progression Measuring Break Duration (Seconds on Y-Axis) Over Trip Attempts (X-Axis). Tactics Learned (T1 – T7, Black Bars) and Break Patterns by Duration in Seconds (Dark Gray Bars - 12 seconds or more, Light Gray Bars < 12 seconds).

enactment of existing procedures within the trip. In the context tested in this Study, which includes an overarching goal to seek the single highest trip score, there is no penalty for this behavior.

In spite of several alternative explanations, results did suggest that higher levels of break time did relate to impeded learning progress in all examined scenarios. Time in action, focused on the task, appeared to optimize results. The highly procedural nature of the task, and an accompanying skill building component, may contribute to this observed effect by emphasizing repetition above other aspects of learning. With each new tactic discovered, a learner's chance to find or construct another may grow. Each learning cycle offers the learner not only an opportunity for a new discovery, but a chance to associate previously discovered tactical knowledge with an increasingly effective set of detailed procedures, elongating the time in game and the chance for new learning. Though aspects of learning may indeed be enhanced by a select use of break time, in the tested context, the benefits may have been overwhelmed by the those associated with staying on task. This may in fact differentiate some learning by doing contexts from more traditional learning scenario's, but it is unclear just how much. Experiential learning settings commonly examined in the literature, may be subject to similar effects. Caution must be used in interpreting the modest negative relationship observed here. Further examination of break strategies versus time on task may be useful in research and application settings. When, if at all, is it appropriate to promote the use of break time in intense and active learning settings as opposed to simply encouraging continued effort?

The learning by doing game used in this study was also expected to demonstrate a positive relationship between cognitive ability and the learning outcomes tested. This relationship was largely supported. As noted in the preceding theoretical discussion of cognitive

ability (e.g. Ackerman, 1997), results of this nature are frequently observed. It is possible that factors difficult to control in the laboratory may effectively mute the contributing potential of ability on learning. Although efforts were made to limit motivational differences in Study 2 (e.g. common goal setting and video recording) they likely had some effect in the individual results that were recorded. A lack of motivation for continued investment of time and effort throughout the game, may in fact be higher for those higher on the ability scale. This and other factors may dilute the actual contribution of cognitive ability as measured here. It is also possible, that the nature of the game itself is not overly demanding, but more responsive to persistence in effort to expedite learning. If this is the case, the results may be an accurate reflection of the reserved influence of cognitive ability on learning this particular task.

4.8.1 Limitations

Several limitations exist in the design of the Study 2. Break frequency and proximity relative to specific events in learning for individual subjects are not systematically examined. Doing so may lead to a better understanding of how breaks best support the learning process, as opposed to impede it. A preference for time on task, as supported in this study, may in fact represent a partial story of the value of breaks in a learning context focused on procedural learning.

The design attempted to create cognitive load that was sufficient to establish a genuine need for breaks. Although considerable evidence in this Study and in Study 1 suggested that this was true, no validation measurements were constructed or added to the context specifically to measure this assumption and its variance across individuals.

As discussed earlier, in spite of best efforts in protocol and design, it is quite possible that a portion of break taking reflects a suboptimal level of goal commitment and motivation.

Although post evaluations using self-reporting suggest most subjects were committed to the goal accompanying the task, this may or may not accurately reflect the actual and consistent effort applied to the task. Performance incentives are a potential remedy to this unknown in future studies using this game environment and deserve serious consideration, though resulting improvements in motivation may be imbalanced across the sample and could skew results.

4.8.2 Conclusion

In conclusion, this study offers interesting alternative insights regarding the value and use of break time in select learning contexts. While the use of breaks and reflection may contribute to learning in many traditional settings, in the current context, time away from direct interaction with a task appears to be lost time for learning. In this setting, managing time on task appears to lead to optimal outcomes. A more detailed assessment of the learning context and a learner's position within a specific learning path may be necessary to more precisely understand the impact of breaks on learning.

5.0 Summary Conclusion

5.1 Idiosyncrasies in Learning

The data captured in this dissertation suggests that individuals often approach and execute learning differently. I believe that understanding these differences is fundamental to understanding how people learn. While points of commonality are suggested in the high-level processes (categories) called upon to support learning, interesting differences were apparent in the decisions that learners made, the paths they elected to follow and their general approach to learning.

Notable variance was observed in what individual learners attended to while playing the game. Data indicate that some learners passed over obvious features of the game for considerable time, before discovering and making use of them later in gameplay. Other learners appeared much more observant, quickly noting the availability of features presented on the screen and testing them. I found the ability of some learners to cast a “wide net” while learning the game and to do so facing the pressure of “an oncoming train” striking to observe when compared to others who appeared unable or unwilling to do so.

Learners’ understanding of how the game actually worked appeared to vary widely at different times during their respective trials. While some learners mastered select functions of the game quickly, I noticed that others struggled to do so, as reflected in the data. The directional implications of select pieces of track were not immediately understood by some learners. Determining how the selection tray functioned (random presentation of nine track types) took considerable time for some while it took little time for others. Some learners chose to methodically test for track types and the probability of their occurrence in the selection tray, a time-consuming task judged unnecessary by others.

The pace at which subjects developed and converted a growing understanding of the game into an effective set of tactics also varied. While the data indicates that most learners found their way to a common set of focal tactics and techniques, this was not always the case. How quickly and completely tactics and techniques were discovered varied widely. How skillfully the new tactics and techniques were deployed to improve scoring was also quite different. Differences were also inferred in how well learners retained what was initially learned and practiced. First demonstration of an effective new tactic did not guarantee its continued use.

Differences were observed not just between subjects playing the game, but by individual subjects within each learning trial. The differences between learners were readily captured in the data and quite visible in the results. Yet differences within individual trials were of particular interest, given the dynamic nature of each learning opportunity. I observed that learning often appeared cautious and reflective early in a subject's gameplay; the same learner often became increasingly bold and aggressive as their respective trial continued. Efforts to interpret what was happening and how the game worked appeared to shift increasingly toward testing strategies and tactics to do something about it. And just as quickly this progressive pattern might change, with a perceived need for further reflection.

5.2 How Might We Explain the Variant Paths Taken While Learning?

I would suggest that learning might be viewed as a continuing set of choices where learners choose what to do next to advance their learning. It was easy to infer that many decisions were being made while learners played the game. Decisions to retain and repeat learned behavior also appeared important to me, though doing so at times became an impediment to learning when change was clearly needed. When and how well decisions were made are likely predictors in determining how effectively and how quickly subjects learned. I believe that in combination, the multitude of decisions made contributed to many of the differences exhibited

while learning. In conducting this research, it became clear that oversimplifying the process of learning risks missing essential steps in a complicated string of decisions that learners repeatedly make. While most of these decisions are broadly grouped in the realm of executive function, understanding their nature more specifically and how they were made is important to a refined understanding of how we learn. Several factors appeared to contribute to decision making while learning. These include dialectics, self-directed goals, and scaffolding.

Dialectics often appeared to foretell a decision to reconsider aspects of the game and decide what behavior was needed next. Learners appeared to recognize when gameplay was not progressing as anticipated or that actions taken previously did not have the desired effect. This recognition, often verbalized in Study 1, was frequently followed by decisions to change behavior, in an attempt to resolve a problem or discover something new. I believe that learner recognition and response to dialectics, the gaps or inconsistencies in their current knowledge, contributed to decisions to change behavior and many of the differences observed in behavior within and between trials.

Adopting and moving between *self-directed goals* also appeared to guide attention and behavior. Some learners were quite adept at creating and moving between various goals while playing the game. While some learner's expressed frustration with a lack of clear goals accompanying the game, others took advantage of this void and created goals on their own as an integral part of their learning strategy. Some of their adopted objectives as stated had distinct performance orientations, while others were clearly focused on a specific objective in learning. Though not studied systematically here, my own observations suggest that the fluid movement between goals and goal types appeared to accelerate learning. I am left to hypothesize that

differences in objectives at varying points in time while learning account for some of the differences observed in learning and performance.

Scaffolding suggests decisions which contribute to what knowledge is constructed, retained and organized. The data collected here offered several examples where important elements of procedural knowledge were missed, were inaccurate, or were improperly related to other knowledge elements. Drawing from this data and additional observations made, I propose that learners made many decisions regarding what knowledge was useful, how different elements of knowledge were related, and how that knowledge might change over time. These decisions are likely contributors to progress with the game and many of the differences observed within and between trials.

Understanding these three mechanisms may help to explain how Executive Function (EF) guides decision making while learning. I believe that deciding what to attend to next (dialectics), when to adjust goals and objectives in learning (goal pursuit), and how to structure and retain new knowledge (scaffolding) are central to learning. In a microdynamic view of learning these mechanisms also function as the guideposts (interfaces) between individual microevents where, within each, existing elements of knowledge inform specific learning processes resulting in new knowledge elements to be stored for future use. The coordinating function that EF introduces many decision points into the dynamic progression of learning. Together this suggests that the multitude of idiosyncratic decisions learners regularly make are likely to contribute to the variant paths that learners follow while learning.

5.3 Experiential Learning or Simply Learning?

An important question I grappled with throughout this dissertation was determining whether my work was about experiential learning or simply learning in an experiential context. My conclusion is this dissertation is fundamentally about learning. The context used to support

this study is indeed experiential. The experiential context is different from other contexts in which we learn. In an experiential context, interactions with the environment serve as the source of new data as well as the setting in which we develop and test new behaviors. In this study, an unfamiliar game environment is presented to the learner. The learner interacts with the game to expose its characteristics, interpret how the game works, and develop and test tactics and procedures to play the game effectively.

A fundamental difference I perceive to exist between learning in an “experiential context” and other types of instructional contexts is that the experiential context enables a capacity to act in support of learning. Learning in this context is also self-directed, relying upon the learner to set both the pace and direction of learning activities. Self-directed decisions are made regularly to balance both pace and direction. For instance, learners may choose between thinking more deeply about the data gathered from the environment so far or, continuing to actively explore the environment to gather more data. Across a learning experience, both decisions are likely to be made multiple times. Setting the pace of movement between the two alternative directions may prove critical to optimizing the learning that occurs.

In the context studied here, instructions provided to new learners prior to gameplay were intentionally restricted. Learners were expected to learn the game from scratch by setting pace and course for repeated active engagement. Gameplaying provided the opportunity for action to expose the data necessary to learn. Subjects had to initiate gameplay and continuously make decisions while learning. Observation without action generated little feedback or data from which to learn. More data, leading to deeper insights, are exposed by extending interaction with the game. While learners played the game, learner behavior appeared to be more than a means to generate new data to learn from; it also allowed learners to test and refine new behaviors.

In this sense, the game provided a learning environment with an opportunity for both inductive and deductive thinking and supporting actions. A learner's success with exploring and accumulating useful data through action and observation was a vital first step to learning. As the conceptual understanding of the environment grew, subjects were better prepared to craft new behavior to accelerate learning and performance. Formulating new hypothesis regarding how new tactics and procedures might work was an important next step in learning. Unique to the experiential context, the hypothetical knowledge describing how things work, or might be induced to work through new learner behaviors, was immediately testable by subjects playing the game. Being able to act upon an idea, validate it or invalidate it, and move on was powerful for many learners.

Are there additional advantages to learning in an experiential context when compared to other learning contexts? The answer to this may be determined in part by the nature of the learning requirements facing the learner. Common alternatives to the experiential context may include vicarious learning where the student observes and interprets the learning of others and guided instruction where knowledge is organized and taught. While knowledge transfer associated with both alternatives may approximate the experience associated with learning by doing, limitations are likely to remain. Active engagement in the environment often presents a rich set of multisensory data, adding clarity to how things work, including the effects of applied behavior.

While vicarious or guided learning may expose some of the knowledge and behaviors of others, the full set of thoughts and ideas that accompany the original experience may be lost to the "second-hand" learner. The rich set of thinking which accompanied learning from an experience is quickly synthesized and consolidated leaving only remnants for sharing with

others. In instructional settings, the details which informed the concepts of how things work, and which of those ideas stimulated a refined set of behaviors are likely to be limited. The opportunity for the learner in an instructional or vicarious setting to build skill in the application of those behaviors may be constrained as well. An experiential opportunity to learn “first-hand” by doing overcomes many of these limitations. There appears to be significant value in some learning situations to be the learner “driving the bus”, rather than the learner “going along for the ride”.

Yet alternative forms of learning, like guided instruction or vicarious learning, do have value. In some situations, relevant knowledge may be effectively transferred directly in structured form. Guided instruction and vicarious opportunities to learn may also be very efficient, particularly when groups of learners are involved. In some cases, patiently waiting for each new learner to individually “stumble upon” the same targeted knowledge may be impractical and cost prohibitive. Hybrid forms, blending each of these alternatives, are also available and may strike an effective and efficient balance in some learning situations. In my own observations in this study, priming learners with additional instruction upfront or providing some select mentoring along the way may very likely reduce learning time and improve outcomes substantially.

5.4 Learning in an Unknown Context

Many learning and problem situations we face in the real world are new to the learner. At times, no one may have faced them before. Descriptions of how things work or the means to discover them are simply unavailable. Learners are faced with the challenge of building their own mental model from scratch. In truly novel situations, an experiential approach to learning may be the only reasonable alternative. Observation of others or instruction requires that

someone has complete understanding of the problem. In many instances, this understanding may not exist, or is simply unavailable. I believe learning in an experiential and unknown context together are likely to maximize the cognitive mechanisms and content called upon while learning.

In this study, the experiential and unknown contexts associated with gameplay appeared to collaborate and place added demands on learners. I believe some of the demands were unique to this context, seldom invoked in structured and “known” settings. For instance, learning the new game motivated many learners to engage, take risks, and try new approaches with uncertain results. This behavior appeared essential to maximizing learning and is not common to other contexts. The best learners appeared to be highly observant and discerning, and somewhat flexible in their initial interpretations of how the game operated. In other contexts, we are often told how things are supposed to work and flexibility in interpretation is thus reduced. The intensity of the pace adopted by some learners appeared to be rewarded in efforts to understand the game. Structured environments often fix the pace associated with learning, optimal for some but not for everyone. While playing the game, new procedures were frequently tested while not yet fully formed or developed. Testing through action in the unknown setting was very important to learning to play the unfamiliar game. This opportunity does not exist in many other learning contexts. Testing new behaviors provided a learning opportunity with many embedded decisions (e.g. Should I try this again ... Should I not ... What might I change?). In combination, the novelty of the unknown game and the experiential context for learning appeared to challenge most learners. I believe this ultimately provided a comprehensive test of most learning mechanisms available, important to our continuing efforts to understand learning.

5.5 Implications for Theory Development

This dissertation examines what happens while people learn. Using a novel and experiential task, my research design was able to highlight changes in learner behavior while learners are “in the act” and gain insight into potential guiding mechanisms. Inscribed within the idiosyncratic learning path of every learner is a conscious set of decisions in support of learning in the moment. I believe that many of these decisions rely on the current state of specific knowledge elements which both inform these decisions and from which modifications or additions to these knowledge elements result.

Observing what happens while people learn strongly reinforced for me the importance of the state of knowledge to learning behavior. While learning is ultimately concerned with the growth of our combined state of knowledge, the incremental elements of knowledge which contribute to that structure were of particular interest. Most typologies and content models remain general, and do not fully account for the functional role that increments of knowledge contribute to learning. Data developed here suggests that highly specific elements of knowledge, when they do not develop, throttle progress while we learn. Knowledge was observed to function as a continuing input to learning in the moment, not simply the product of preceding efforts to learn.

In this dissertation I used a refined problem-oriented method and vocabulary to explore knowledge types and function more discretely. Pushing beyond this initial attempt and adding granularity to the model may help to identify the functional interfaces where specific knowledge content “primes” a dialectic response deciding where to go next and what cognitive processes to invoke. Learning is much more than a discussion of the processes involved while we learn. I believe further emphasis examining knowledge content in greater detail and in close proximity to

the processes engaged at a particular point in time is central to understanding why learning progresses as it does and when it does.

A microdynamic perspective may be helpful to account for the idiosyncratic nature of learning. Distinct sequences of knowledge and process appear to fuel learning. New knowledge is the frequent result. Targeted associations of process and content (e.g. K_i , P_i , K_j) are conceptualized here as the fundamental building blocks of learning. Executive function plays a unique supervisory role by examining knowledge in its current state and deciding what process to invoke next. In doing so, I propose that executive function relates specific elements of knowledge with select learning processes to further advance learning and behavior. This may be viewed as a dynamic string of learning events coupling decisions about knowledge and process in elemental form.

Three elements within the supervisory set available to executive function are called out in this study as powerful mechanisms to drive decision making while we learn. These include (1) the dialectic response of executive function to perceived gaps or inconsistencies in the existing knowledge, (2) the construction and use of goal-oriented knowledge to monitor and direct learning behavior at varying times during a learning event, and (3) the scaffolding of new knowledge within and among existing knowledge structures. Operating together, I propose that these mechanisms inform a multitude of decisions which together may help to explain why learning progresses differently within learning events and between learners. In this way, learning might be described as more than a cycle of learning processes but as a sequence of specific learning processes, knowledge content and decision making conjoined.

Goal pursuit during learning events was one of the striking behaviors I observed during trials in Study 1. Subjects that frequently adopted self-directed goals appeared to follow a plan

while learning. Verbalized goals and objectives appeared to contribute to the decisions learners would make regarding where to apply attention and effort next. It was likely that many subjects, though not verbalizing goals, were quietly pursuing them as well. Goals were not all the same. Some appeared to be distinctly learning oriented while others focused on overall performance (i.e. scoring). The impact of goals on behavior appeared to be pronounced at times, with patterns of action tied to specific objectives. Some subjects were fluid in moving between goals and performance and learning goal types. This fluid movement appeared to relate to an increasingly effective and purposeful flow to the overall learning process. While goal pursuit has been included in the executive function set conceptualized in this effort, I believe a more targeted analysis of this mechanism in an experiential learning context would provide added insights regarding how people learn.

5.6 Aspects of Learning Not Examined

While many characteristics of learning were examined in this dissertation, several aspects were not. For example, the individualized context I chose to explore in this study ignores social influences on learning. Social interaction may be an integral part of many of the experiential learning contexts we learn from regularly. By design, this dissertation was clearly focused on learning at the individual level. This does not negate the importance or differences that an examination of learning in a group or social context might introduce. Ultimately though, the individual is left to interpret, internalize and act upon the learning that occurs, even within a social context. Studies of learning in social contexts are likely to be enhanced by a better understanding of how individuals learn.

Affect and motivation and their relationship to learning are not studied systematically here as well. Differences in affect, from boredom to excitement, were frequently observed among subjects in Study 1. Differences in affect and motivation likely had some influence on

outcomes across both studies in spite of efforts to promote consistency in effort. Though differences in affect in Study 1 were observed, their impact remains unclear. For instance, in Study 2, four subjects (removed from the data set) appeared to make excessive use of break time, which I interpreted as waning motivation. Affect and motivation are likely to be notable contributors to learning in many settings and should be examined in future research.

This study did not compare other approaches to learning to the experiential learning by doing approach examined here. Although an interesting context for study, this research stops short of examining the effects of mixing experiential elements of learning with other forms of programmed guidance or instruction. It was evident to me at times during trials, that a richer set of instructions or some select guidance at various points while learning, were likely to have notable effect. However, these points can be examined in future research.

Also, this study design did not systematically examine the repeated or routine use of new learning and its relationship to learning outcomes. It appeared that new tactics once learned were used to best effect when used repetitively and combined with others. Though first use of a new tactic often predicted continued use, this was not always the case. At times, repeated use of select behaviors appeared hard to break, even though doing so may have improved learning outcomes. Overall, it remained unclear why habits and routines failed to develop for some learners as quickly as others and what was the result of these shortfalls on patterns of learning and related outcomes. Once again, the need to control scope of effort led me to exclude this dimension of tactical learning at this time.

5.7 Limitations

The design of Study 1 relies on data collection and analysis of behavioral data, focusing on changes in behavior and behaviors most useful to gameplay. Performance outcomes were of particular interest. This restricted systematic examination of other interesting “one-off”

behaviors, particularly those associated with learning strategies. The identification of newly demonstrated behaviors served as milestones in the progression of learning throughout the study. Tactics and techniques provided the framework to capture these key milestones for each learner over the course of their respective trials. A focal list of tactics and techniques resulted and provided an opportunity to automate the capture of behaviors important to performance in Study 2, a very large set of learning events. (More than 12,000 trips were attempted across Study 2 trials). While many one-off behaviors were captured and discussed ad-hoc in Study 1, had I included a systematic evaluation of the more unique behaviors, further insights regarding the various paths learners pursue may have resulted.

While this study produced considerable data about how individuals learned, further emphasis within specific learning events may have surfaced additional insights into the microdynamic nature of learning. The data generated in this dissertation provided many opportunities to compare learners using “between learner” analyses. This was done across a multitude of factors, particularly in Study 2 where regression techniques were used. Digging more deeply within each trial may have helped to identify and relate the refined elements of knowledge and learning process which contributed to new behaviors as they emerged. I believe that an adjusted design, with less emphasis on large samples, and more on refined examinations of in situ learning (e.g. Anzai & Simon, 1979) may provide additional insight.

Selecting a suitable and valid measurement relating break behavior to ability and performance proved difficult. Breaks were operationalized and evaluated in several ways and in broad measure. Incremental Break Time ultimately proved the most construct valid approach. Incremental Break Time captured the self-elected portion of break time that a learner chose to initiate. In spite of the unexpected negative relationship relating Incremental Break Time to

learning, there is some evidence to suggest that the timing of breaks may contribute positively to learning. I believe that a refined design to more vigorously test this possibility would be useful. Ultimately, examining breaks individually including their proximity to new learning would help us better understand why learners take breaks when they do and how each decision to do so might affect learning.

5.8 Implications for Research Practice

I believe there are several advantages to studying learning in experiential and unknown contexts. Experiential learning provides a comprehensive view of learning, encompassing both learning and performance. Inferences drawn from behavior demonstrated in an experiential context provide a comprehensive view of many of the mechanisms involved while learning. Using an unknown context further magnifies some of these benefits by forcing the learner to construct an initial model of the environment from scratch and develop unique approaches to learning at the same time. This detail is useful to explore many aspects of learning and to enhance our ability as researchers to make reasonable inferences with added confidence.

Observing the development of new tactics and techniques in an experiential context is a useful reference point to study what happens while we learn. As researchers in learning and cognition, it has always been difficult to move upstream from behavior and interpret what really happens while we learn. A variety of techniques have been shown to be useful in this regard, including the use of knowledge tests and verbal protocols. Both methods have their strengths and weaknesses. Verbal protocols used here were particularly useful to understand when learning was occurring and what knowledge was used or resulted from a learner's efforts. However, neither verbal protocol's or knowledge tests are innocuous. Even great caution to assure that questions do not cue learners on something they might have learned or a tactic which might be

particularly useful may be unable to prevent subject learning from the questions themselves, which introduces its own influences on learning trajectories.

Another promising approach is combining learner's actions with the expertise and verbal protocols of subject matter experts. As many of the learners' tactically based behaviors were familiar to the researcher, it was often easy to infer when learning was happening and what knowledge was likely being constructed and used. Tactics and techniques were bold markers of new learning, and enabled attending "experts" to infer based on their own experience what knowledge the learner was likely constructing at that point and when new procedural knowledge was likely being created. Learners developed tactics and techniques in support of different objectives. Some appeared to align with efforts to improve performance in the game. Others appeared centered on achieving specific objectives in learning. Attending researchers with their own expertise were able to recognize and distinguish among these two types in most cases. I believe continued use of verbal protocols and "context experts" to help interpret how and when learners develop and deploy various tactics and strategies may be a useful tool to enhance our understanding of why learning proceeds as it does, and what patterns prove to be most effective.

I developed a new computer game to conduct this research. OnTrack appeared to achieve a reasonable balance between the complexity needed to challenge learners and elicit new behaviors and the capacity for subjects to develop expertise in the timeframes necessary for laboratory research. Cloud and local server programming proved generally reliable and supported multiple subjects (n=6) playing the game at the same time. Programming allowed capture of many learning milestones automatically, reducing researcher time significantly. The ambiguity which may accompany learning the game, when no significant instruction or knowledge is shared up front, renders the game representative of many real-world tasks where

structure and purpose may be lacking. The game is also able to record behavior in many small increments of time and content, particularly useful for probing the microdynamic aspects of interest. I invested additional time to build game features and capabilities which might allow the game to do added work and accommodate further manipulations in the future. These include function for goal setting and feedback treatments, further break manipulation, learning in small groups and teams, and other approaches to learning beyond the strictly experiential context used here.

5.9 Implications for Learning Practice

I believe the practical implications of this work center on foundational elements for instructional strategies and techniques. Uncovering learning patterns and strategies which predict superior learning and performance has been the goal of educational research for some time. Probing more deeply for knowledge and process sequence patterns, and how they evolve in novel learning contexts may ultimately help to develop more prescriptive methods of guidance, instruction and mentoring. How to guide an experiential learner at varying points along the learning path is important. How to promote the best use of time, in action or reflection, may be enhanced by better understanding the microdynamics which underlie how we learn. Knowing how and when to encourage the construction and adoption of self-directed goals may be enhanced by increasing our understanding of how goals work to stimulate and focus attention. Recognizing the differences involved with supporting learning in unknown versus known learning contexts may contribute to better prescriptions for learning strategies in a variety of contexts.

5.10 Future Research

The findings of this research suggest several avenues I believe to be worthy of further investigation. These include: To what extent is experiential learning or “learning by doing” an

efficient or effective way to learn when compared to more structured forms of learning? While experiential and active modes of learning are often thought to be optimum environments for learning, what are the tradeoffs and how are outcomes affected when examining alternative forms of learning? Comparing learning conditions including, (a) strict reliance on learning by doing, versus (b) the addition of targeted observation and guidance, versus (c) providing instruction alone, would offer interesting insights on the merits of different learning models.

How and when do learners develop learning strategies and supporting goals when faced with an unknown task? What is the impact of doing so on learning and performance? I believe an additional opportunity worthy of pursuit involves the learning strategies and tactics learners use as they work to master a new task in a novel environment. Watching select subjects move fluidly between a variety of learning strategies, often accompanied by self-directed goals, was a key observation in Study 1. Some goals and strategies appeared to have distinct learning versus performance orientations. What made this flow in the learning process so natural for some and so difficult for others? Variation in goal setting behavior specifically was notable between learners and within individual learning trials. Learning strategies appeared to invoke the development of targeted tactics used to accelerate the learning of particular aspects of the game. Understanding how and when learners chose to adopt new goals and strategies while learning and the impact of doing so would enhance our understanding of how people learn.

How does the selective use of breaks at precise points in time during learning contribute to how we learn and to learning outcomes? This third opportunity builds on Study 2 examination of how people use their time while learning. Though I found the relationships difficult to interpret, the data in Study 2 showed some evidence that longer breaks were often closely paired with new learning. Pairings often preceded first use of a new tactic and at other times directly

followed. Understanding how breaks relate to precise points of learning measured by proximity and duration may provide additional insight into the importance of break behavior within discrete learning events. Study 2 also provided some evidence that longer time in breaks had a negative effect on demonstrated learning. A closer look comparing Study 2a and 2b appeared to offer an interesting counterpoint. When comparing no breaks to less break time to more break time, less break time appeared to have an advantage. Could “Goldilocks” predict our best use of time ... just the right amount in action and reflection? I believe that understanding break time with added refinement is likely to provide additional insights regarding the use of time in an experiential setting.

How does the routinization of tactical behavior affect learning and performance? A final opportunity I find to be interesting involves the development and discard of routine behaviors. While “first learning” was closely examined in this dissertation, how and when procedural learning is made routine and then later discarded is a very important dimension of learning not explored in the context examined here. The focal tactics used and tracked in this study appeared most effective when refined and used repetitively and in combination. And yet many subjects failed to do so. Also, observed in the variety of learning paths taken, are patterns of routine fixation which at times appeared to impede continued learning. Gaining insights into how learners build routines from the procedural components of new learning would be valuable. Also understanding what factors may enhance or impede their formation would be an important contribution. I believe this examination should include the role of individual differences as well as other factors like goal seeking behavior. Some learners appeared unable to break with a routine, at points in the learning process when doing so may have been advantageous to

continued learning. What contributed to this unwillingness or inability to change routine behavior?

5.11 Conclusion

This dissertation has provided an opportunity to closely examine how people learn. Though I often observed similarities between learners, idiosyncratic differences presented themselves regularly within learning events and across learners. It is clear that there is much more to learning than I could have imagined when I first proposed this dissertation. Considerable work remains if we are to explain with precision why each of the many subjects I accompanied in the laboratory followed distinctly different paths while learning the game. Although some answers have been proposed in this effort, the task remains to more deeply understand what contributes to the differences which regularly occur in many learning situations. The experiential learning context leveraged here, provided a useful environment to study the details of learning. Action in this context appeared to enable the opportunity to learn, and much of that action is on full display for the attentive researcher. Many insights lie within the details of the discrete patterns of behavior observed in this context. Continued examination of learning events through a microdynamic lens may indeed be helpful.

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APPENDIX A: IRB Approval and Study Overview (Study 1)

Learning by Doing Study > STUDY ID # _____

Overview, Consent Form and Instructions - Study 1

Principal Investigator: Dr. Kevin Carlson (kevinc@vt.edu); Co-investigator: Jerry Flynn (jpflynnl@vt.edu), 540-553-1463.

Overview & Purpose:

Thank you for signing up to help with our research in Management at the Pamplin School of Business! As noted in your invitation to participate, we are examining learning in a unique problem-solving environment. The environment involves a "learning by doing" exercise supported by a video game likely to be new to the problem solver. Patterns of learning and knowledge building will be studied and examined. Study results are expected to contribute to the completion of a dissertation and future publication. A researcher will accompany you during a gameplay exercise, periodically asking questions.

The computer game will involve a series of repeating pattern exercises using a mouse, each typically one minute or less in duration. The researcher will function as a passive observer, except when asking questions during gameplay. The trial will be conducted in the Pamplin Office #2105 and will be audio recorded. Your participation will require approximately two hours of your dedicated time. In Study 1, we will be testing a group of volunteers estimated to be fifty to sixty in number, drawn from Pamplin's undergraduate student population.

Anonymity and Confidentiality:

Personal information from this study will be treated confidentially. Data will be attached to a study ID number. Only the principal and co-investigator will have access to the file linking subject identification to a study ID number. Though the data file associated with this study may be maintained by principal and co-investigators indefinitely, the file linking individuals to study ID numbers will be destroyed following project completion, no later than 12/31/17.

Volunteers agree to treat the nature of this experiment, including the game and game playing exercise in strict confidence, including among and between classmates, to limit the potential for bias in results.

Compensation and Freedom to Withdraw:

As noted in the invitation, your participation in this study will earn 4 extra credit points in your Management 3304 class. Other extra credit opportunities are available to class participants. No additional compensation will be provided. Participants are free to withdraw from the study at any time without penalty.

Subject's Responsibility and Permission:

The subject agrees NOT TO REVEAL OR DISCUSS DETAILS OF THIS EXPERIMENT AND THE SUPPORTING VIDEO GAME WITH OTHERS FOR A PERIOD OF ONE YEAR.

With signature below, you voluntarily agree to participate in this study and complete all associated tasks to the best of your ability and agree to the following:

"I have read this Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:"

_____	_____	_____	_____
Printed Name	Email Address	Signature	Date

VTID Number	VTPID		

Please check the box if you would like to receive a summary of study results when work is completed.

Please contact the researchers for questions about the study.

Should you have any questions or concerns about the study and researcher conduct or your rights as a research subject or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

APPENDIX B: Subject Hardcopy Instructions (Study 1)

Study ID # _____

Trial Instructions & Procedures - Study 1:

The game involves placing track on a grid which allows the train to proceed from the tunnel on the left to station on the right.

Briefly familiarize yourself with the game features on the screen. Features include:

- 1) The track generator from which you select track for placement anywhere on the grid.
- 2) The track erasers identified as "bombs".
- 3) The train speed feature.
- 4) The playing grid upon which selected track are placed. This includes 3 preplaced track pieces including an entry tunnel and one straight track, and a train station.
- 5) A "dash board" which includes current or last trip attempt#, round time countdown, trip time, and score.

Your first and follow-on trip attempts are initiated by a 3 step process.

- 1) Tap the microphone with the mouse
- 2) Announce the next trip number.
- 3) Start the trip by clicking the mouse on the green start button.

Repeat this process for each trip attempt at your own pace when ready. A scratch pad with pencils is provided. Feel free to use them if they are useful to you. Your trial consists of three rounds of 25 minutes, each separated by a short round reset. You determine the number of trip attempts that you initiate within each round.

There will not be a convenient opportunity to leave the game once you begin, until you complete the trial. If you do need a moment before you begin please notify the researcher who will wait until you return.

APPENDIX D: IRB Approval and Study Overview (Study 2a)

Learning by Doing Study > STUDY ID # _____

Overview, Information Sheet and Instructions- Study 2a

Principal Investigator: Dr. Kevin Carlson (kevinc@vt.edu); Co-investigator: Jerry Flynn (jpflynn1@vt.edu), 540-553-1463.

Overview & Purpose:

Thank you for signing up to help with our research in Management at the Pamplin School of Business! As noted in your invitation to participate, we are examining learning in a unique problem solving environment. The environment involves a "learning by doing" exercise supported by a video game likely to be new to the problem solver. Patterns of learning and knowledge building will be studied and examined. Study results are expected to contribute to the completion of a dissertation and future publication.

The computer game you will be playing will involve a series of repeating pattern exercises using a mouse. After being briefly assisted by a researcher to initiate your first trip attempt in the game, the researcher will leave you in your dedicated work area to complete the session. Your gameplay results will be observed remotely during gameplay. Your lab session will be recorded in audio and video to supplement learning information captured. Your full commitment and attention during gameplay is necessary and appreciated. All phones and electronics must be turned off before the game is initiated. The researcher will be available should you have difficulties with the game environment, although he or she will not be able to answer specific questions regarding how to play the game. The trial is being conducted in the Pamplin Laboratory, Room 3003. A brief one page written survey form will be requested when gameplay concludes. Total time is estimated to be less than 75 minutes.

Completion of the game will be rewarded with receipt of extra credit in your management 3304 class per the guidelines noted by your instructor and indicated in the syllabus.

Step 1: A preliminary survey was offered online to be conducted at a place of the subject's choosing and convenience. It requires a PC, and is not appropriate for smart phones. The subject agreed to complete the survey online prior to attending this scheduled lab appointment. The survey was expected to require approximately 20 minutes. If for any reason the survey was not completed prior to arriving for the lab appointment, at the researcher's discretion a second opportunity may be offered to complete the survey, after completing this lab appointment. Receiving the extra credit associated with either step will require the completion of both steps in a period of time designated by the researcher.

Anonymity and Confidentiality:

Personal information from this study will be treated confidentially. Your study data will be linked to a study ID number. Data from the lab study and the Qualtrics survey will be shared with Wonderlic, including: test data, survey data, scores from the gameplay experience, and study ID number. Qualtrics and Wonderlic will not have access to the file linking your name or email address to your study ID number, which will be stored securely by the researcher. Wonderlic may use and maintain your anonymous data indefinitely for inclusion in normative and item research analysis.

Though the data file associated with this study may be maintained by principal and co-investigators of the Virginia Tech study team indefinitely, the file linking your name and email address to your study ID numbers will be destroyed following project completion, no later than 12/31/17.

Volunteers, including you, agree to treat the nature of this experiment, including the game and game playing exercise, in strict confidence among other potential participants/students. This does not include the members of the research team or IRB staff. This is necessary to limit the potential for bias in learning results.

Compensation and Freedom to Withdraw:

As noted in the invitation, your participation in this study will earn extra credit points in your Management 3304 class. Other extra credit opportunities are available to class participants. No additional compensation will be provided. Participants are free to withdraw from the study at any time without penalty.

Subject's Responsibility and Permission:

The subject agrees NOT TO REVEAL OR DISCUSS DETAILS OF THIS EXPERIMENT AND THE SUPPORTING VIDEO GM1E WITH OTHER POTENTIAL STUDENTS AND PARTICIPANTS FOR A PERIOD OF ONE YEAR.

With signature below, you voluntarily agree to participate in this study and complete all associated tasks to the best of your ability and agree to the following:

"I have read this Consent Form and conditions of this project. I confirm that I am eighteen years of age or older and that I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:"

Printed Name	Email Address	Signature	Date
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VTID Number	VTPID
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Please check this box if you were unable to complete the preliminary Step 1 survey prior to arrival for the lab portion (Step 2) of the experiment. You note that extra credit for both steps will require completion of both steps within a timeframe designated by the researcher

Please check the box if you would like to receive a summary of study results when work is completed.

Please contact the researchers for questions about the study. Should you have any questions or concerns about the study and researcher conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Virginia Tech Institutional Review Board Project No. 16-315
Approved March 28, 2016 to March 27, 2017

APPENDIX E: IRB Approval and Study Overview (Study 2b)

Learning by Doing Study > STUDY ID # _____

Overview, Information Sheet and Instructions – Study 2b

Principal Investigator: Dr. Kevin Carlson (kevinc@vt.edu); Co-investigator: Jerry _____ (jpflynn1@vt.edu), 540-553-1463.

Overview & Purpose:

Thank you for signing up to help with our research in Management at the Pamplin School of Business. As noted in your invitation to participate, we are examining learning in a unique problem solving environment. The environment involves a "learning by doing" exercise supported by a video game likely to be new to the problem solver. Patterns of learning and knowledge building will be studied and examined. Study results are expected to contribute to the completion of a dissertation and future publication.

The computer game you will be playing will involve a series of repeating pattern exercises using a mouse. After being briefly assisted by a researcher to initiate your first trip attempt in the game, the researcher will leave you in your dedicated work area to complete the session. Your gameplay results will be observed remotely during gameplay. Your lab session will be recorded in audio and video to supplement learning information captured. The game may periodically request your verbal feedback. Please respond in brief by speaking into the microphone and then continuing with game-play.

Your full commitment and attention during gameplay is necessary and appreciated. **All phones and electronics must be turned off before the game is initiated.** The researcher will be available should you have difficulties with the game environment, although he or she will not be able to answer specific questions regarding how to play the game. The trial is being conducted in the Pamplin Laboratory, Room 3003. A brief one page written survey form will be requested when gameplay concludes. Total time is estimated to be less than 75 minutes.

Completion of the game will be rewarded with receipt of extra credit in your management class per the guidelines noted by your instructor and indicated in the syllabus.

Step 1: A preliminary survey was offered online to be conducted at a place of the subject's choosing and convenience. It requires a PC, and is not appropriate for smart phones. The subject agreed to complete the survey online prior to attending this scheduled lab appointment. The survey was expected to require approximately 20 minutes. If for any reason the survey was not completed prior to arriving for the lab appointment, at the researcher's discretion a second opportunity may be offered to complete the survey, after completing this lab appointment. Receiving the extra credit associated with either step will require the completion of both steps in a period of time designated by the researcher.

Anonymity and Confidentiality:

Personal information from this study will be treated confidentially. Your study data will be linked to a study ID number. Data from the lab study and the Qualtrics survey will be shared with Wonderlic, including: test data, survey data, scores from the gameplay experience, and study ID number. Qualtrics and Wonderlic will not have access to the file linking your

name or email address to your study ID number, which will be stored securely by the researcher. Wonderlic may use and maintain your anonymous data indefinitely for inclusion in normative and item research analysis.

Though the data file associated with this study may be maintained by principal and co-investigators of the Virginia Tech study team indefinitely, the file linking your name and email address to your study ID numbers will be destroyed following project completion, no later than 12/31/17.

Volunteers, including you, agree to treat the nature of this experiment, including the game and game playing exercise, in strict confidence among other potential participants/students. This does not include the members of the research team or IRB staff. This is necessary to limit the potential for bias in learning results.

Compensation and Freedom to Withdraw:

As noted in the invitation, your participation in this study will earn extra credit points in your Management 3304 class. Other extra credit opportunities are available to class participants. No additional compensation will be provided. Participants are free to withdraw from the study at any time without penalty.

Subject's Responsibility and Permission:

The subject agrees NOT TO REVEAL OR DISCUSS DETAILS OF THIS EXPERIMENT AND THE SUPPORTING VIDEO GAME WITH OTHER POTENTIAL STUDENTS AND PARTICIPANTS FOR A PERIOD OF ONE YEAR.

With signature below, you voluntarily agree to participate in this study and complete all associated tasks to the best of your ability and agree to the following:

"I have read this Consent Form and conditions of this project. I confirm that I am eighteen years of age or older and that I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:"

_____	_____	_____	_____
Printed Name	Email Address	Signature	Date
_____	_____		
VT ID Number	VTPID		

Please check this box if you were unable to complete the preliminary Step 1 survey prior to arrival for the lab portion (Step 2) of the experiment. You note that extra credit for both steps will require completion of both steps within a timeframe designated by the researcher

Please check the box if you would like to receive a summary of study results when work is completed.

Please contact the researchers for questions about the study. Should you have any questions or concerns about the study and researcher conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

APPENDIX F: Subject Hardcopy Instructions (Study 2a)

Study ID # _____

Gameplay Instructions & Procedures – Study 2a:

Please ensure all electronics in your possession are turned off prior to gameplay. Your full attention and commitment are important to the quality of results in this study.

The "game" involves placing track on a grid in advance of the moving train. Within each of three progressive rounds of play, lasting 20 minutes each, you will have multiple trip attempts. After you initiate your first trip attempt, the game will self-initiate each follow on trip at short intervals.

Before beginning, briefly familiarize yourself with the game features on the screen. Features include:

- 1) The track generator from which you select track for placement on the grid.
- 2) The track erasers identified as "bombs".
- 3) The train speed feature.
- 4) The playing grid upon which selected track are placed. This includes 3 preplaced track pieces including an entry tunnel and one straight track, and a train station.
- 5) A "dash board" which includes current or last trip attempt #, round time countdown, trip time, and score.

A scratch pad with pencils is provided. Feel free to use them if they are useful to you. Researchers will ask to retain your notes following gameplay.

At the end of your game session, please notify the attending researcher that you are finished and leave the game screen AS IS. The researcher will provide you with a simple one page concluding survey for you to complete.

There will not be a convenient opportunity to leave the game once you begin, until you complete the trial. If you do need a moment before you begin please notify the researcher who will wait until you return.

The researcher will initiate the game and first trip when you indicate you are ready. He or she will then leave you, but remain down the hall should you have any problems. They will not be able to answer specific questions regarding gameplay, however. As noted in the preceding information sheet, game-play is recorded.

Your OBJECTIVE in gameplay is to:

MAXIMIZE YOUR HIGHEST INDIVIDUAL TRIP SCORE

Your gameplay action and results may be observed remotely as you proceed through the trial. Thank you for your assistance!

APPENDIX G: Subject Hardcopy Instructions (Study 2b)

Study ID ## _____

Gameplay Instructions & Procedures – Study 2b:

Please ensure all electronics in your possession are turned off prior to gameplay. Your full attention and commitment are important to the quality of results in this study.

The "game" involves placing track on a grid in advance of the moving train. Within each of three progressive rounds of play, lasting 20 minutes each, you will have multiple trip attempts. After you initiate your first trip attempt, the game will offer you the opportunity to PAUSE play between each trip. After pausing you may start your next trip at any time. The round clock timer will continue to count down. Use this feature if helpful to you in pursuing game objectives.

Before beginning, briefly familiarize yourself with the game features on the screen. Features include:

- 1) The track generator from which you select track for placement on the grid.
 - 2) The track erasers identified as "bombs".
 - 3) The train speed feature.
 - 4) The playing grid upon which selected track are placed. This includes 3 preplaced track pieces including an entry tunnel and one straight track, and a train station.
 - 5) A "dash board" which includes current or last trip attempt #, round time countdown, trip time, and **trip score**.
 - 6) A "Begin Next Trip" button used to initiate your next trip when you are ready.
- A scratch pad with pencils is provided. Feel free to use them if they are useful to you.

Researchers will ask to retain your notes following gameplay.

At the end of your game session, please notify the attending researcher that you are finished and leave the game screen AS IS. The researcher will provide you with a simple one page debrief survey for you to complete.

There will not be a convenient opportunity to leave the game once you begin, until you complete the trial. If you do need a moment before you begin please notify the researcher who will wait until you return.

The researcher will initiate the game and first trip when you indicate you are ready. He or she will then leave you, but remain down the hall should you have any problems. They will not be able to answer specific questions regarding gameplay, however. As noted in the previous information sheet, your session is being recorded.

Your **OBJECTIVE** in gameplay is to: **MAXIMIZE YOUR HIGHEST INDIVIDUAL TRIP SCORE**. It is important to note that you control the number and frequency of trip attempts made during your session. You decide how much time is used in active game-play (within trips) versus pausing between trips to plan or reflect. Use the approach which you believe best supports your ability to pursue the OBJECTIVE.

Your gameplay action and results may be observed remotely as you proceed through the trial. Thank you for your assistance!

APPENDIX H: Follow Up Survey (Study 2a)

**Learning
by Doing
Study
Study 2a - Gameplay
Feedback Survey**

Name: _____ **email:** _____ **Study ID:** _____
—

Thank you for your participation! Your thoughtful answers to the following questions are appreciated.

1. What learning proved important in playing the game? Please include tactics which you feel contributed most.
2. Did you find the game stressful or challenging? In what way? How did you manage this?
3. What was the OBJECTIVE of the game as you remember it?
4. On a scale of 1 to 7, how committed were you to the stated OBJECTIVE of the game:
_____ (1=Not committed at all / 7=Fully Committed)

(Continued on back of page)

5. If not fully committed, please explain why? Did you adopt any other objective(s) at varying points in the game? What was it? Did it help your progress in gameplay?
6. We welcome your suggestions regarding any aspect of the lab or game experience.

APPENDIX I: Follow Up Survey (Study 2b)

Learning by
Doing
Study
Study 2b - Gameplay Feedback Survey

Name: _____ email: _____

Study ID: _____

Thank you for your participation! Your thoughtful answers to the following questions are appreciated.

1. What learning proved important in playing the game? Please include tactics which you feel contributed most.
2. Did you find the game stressful or challenging? In what way? How did you manage this?
3. Did extending the time between trips (pausing) help in your learning and progress? Circle Yes / No
4. Please estimate the number of times you took extended delays between trips? _____
5. How did this delay contribute to your learning and / or pursuit of the OBJECTIVE? Please explain.

Continued on back of page)

6. What was the OBJECTIVE of the game as you remember it? _____
7. On a scale of 1 to 7, how committed were you to the stated OBJECTIVE of the game:
_____ (1=Not committed at all / 7=Fully Committed)
8. If not fully committed, please explain why? Did you adopt any other objective(s) at varying points in the game? What was it? Did it help your progress in gameplay?
9. We welcome your suggestions regarding any aspect of the lab or game experience.

APPENDIX J: Qualtrics Research Description and Consent Form (Study 2)

LBD Phase 2 Survey 030116

IRB Research Description and Consent

Principal Investigator: Dr. Kevin Carlson (kevinc@vt.edu); Co-investigator: Jerry Flynn (jpflynn1@vt.edu), 540-553-1463.

Overview & Purpose:

Thank you for signing up to help with our research in Management at the Pamplin School of Business! As noted in your invitation to participate, we are examining learning in a unique problem-solving environment. The environment involves a “learning by doing” exercise supported by a video game likely to be new to the problem solver. Patterns of learning and knowledge building will be studied and examined. Study results are expected to contribute to the completion of a dissertation and future publication.

This survey is the first step in the research process you are volunteering for. After the survey, an individually scheduled lab session will complete your commitment.

This preliminary survey is offered online and may be conducted at a place of the subject’s choosing and convenience. It requires a PC and is not appropriate for smart phones. You agree to complete this survey in one sitting prior to attending your scheduled lab appointment. This survey is expected to require approximately 20 minutes. If for any reason the survey is not completed prior to arriving for the lab appointment, at the researcher’s discretion a second opportunity may be offered to complete the survey. Receiving the extra credit associated with either step will require the completion of both steps in a period of time designated by the researcher.

Anonymity and Confidentiality:

Personal information from this study will be treated confidentially. Your study data will be linked to a study ID number. Data from the lab study and the Qualtrics survey will be shared with Wonderlic, including: test data, survey data, scores from the game-play experience, and study ID number. Qualtrics and Wonderlic will not have access to the file linking your name or email address to your study ID number, which will be stored securely by the researcher. Wonderlic may use and maintain your anonymous data indefinitely for inclusion in normative and item research analysis.

Though the data file associated with this study may be maintained by principal and co-investigators of the Virginia Tech study team indefinitely, the file linking your name and email address to your study ID numbers will be destroyed following project completion, no later than 12/31/17.

Volunteers, including you, agree to treat the nature of this experiment, including the game and game playing exercise, in strict confidence among other potential participants/students. This does not include the members of the research team or IRB staff. This is necessary to limit the potential for bias in learning results.

Compensation and Freedom to Withdraw:

As noted in the invitation, your participation in this study will earn extra credit points in your Management 3304 class. Other extra credit opportunities are available to class participants. No additional compensation will be provided. Participants are free to withdraw from the study at any time without penalty.

Subject’s Responsibility and Permission:

The subject agrees NOT TO REVEAL OR DISCUSS DETAILS OF THIS EXPERIMENT AND THE SUPPORTING VIDEO GAME WITH OTHER POTENTIAL STUDENTS AND PARTICIPANTS FOR A PERIOD OF ONE YEAR.

By proceeding with this survey, you voluntarily agree to participate in this study and complete all associated tasks to the best of your ability and agree to the following:

“I have read this Consent Form and conditions of this project. I confirm that I am eighteen years of age or older and that I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:”

Please contact the researchers for questions about the study. Should you have any questions or concerns about the study and researcher conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Question 0

With your selection and consent below, you voluntarily agree to participate in this study and complete all associated tasks to the best of your ability and agree to the following:

“I have read this Consent Form and conditions of this project as described above. I confirm that I am eighteen years of age or older. I hereby acknowledge the above and give my voluntary consent:”

- I agree and by proceeding with this survey offer my full consent
- I do not agree and elect to end this survey now

APPENDIX K: Qualtrics Demographic Survey (Study 2)

Block 1 - Demographic

Section 1: Please answer a few questions about yourself

Question 1

Please enter your Study ID # (4 digits) provided by email after you registered for this study using Sign-Up-Genius. Add your first, middle and last name initials to the 4 number Study ID. If you do not have a middle name, use the letter "Z" as your middle initial. For example 1023jZf.

Question 2

What is your current Class Year?

Freshman

Sophomore

Junior

Senior

Graduate Student

Question 3

What is your age?

Question 4

What is your gender?

[Click here to edit choices](#)

Question 5

What is your current or intended major(s)?

APPENDIX L: Qualtrics Experience Survey (Study 2)

Block 2 - Video/Computer Game Experience

Section 2: Please respond to the following questions regarding your experience with video/computer games

Question 6

How often do you play video/computer games? (1 = Not at all / 4 = Once a week / 7 = More than once per day)

	7
	6
	5
	4
	3
	2
	1

Question 7

On which devices do you play video/computer games? (Select all answers which apply)

- a. PC, Mac, laptop
- b. Console (PlayStation, Xbox, Wii etc.)
- c. Tablet or smartphone (iPhone, Blackberry, Android phone etc.)
- d. Other
- e. I do not play video games

Question 8

In the past month, how many hours per week on average did you spend playing video/computer games?

Question 9

For how many years have you played video/computer games?

Question 10

Please rate your level of experience with video/computer games: (1 = No experience / 7 = Very experienced)

	7
	6
	5
	4
	3
	2
	1

Question 11

Please rate your overall skill level with video games in general: (1 = Not good at all / 7 = Very skilled)

	7
	6
	5
	4
	3
	2
	1

Question 12

If applicable, please note by type or name the computer/video games which you play most:

APPENDIX M: Qualtrics Hosted Mini – IPIP Survey (Study 2)

Block 3 - Mini-IPIP

Section 3: Following are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes you. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then select the answer that best describes you.

Question 13

Am the life of the party

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 14

Sympathize with others' feelings

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 15

Get chores done right away

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 16

Have frequent mood swings

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 17

Have a vivid imagination

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 18

Don't talk a lot

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 19

Am not interested in other people's problems

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 20

Often forget to put things back in their proper place

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 21

Am relaxed most of the time

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 22

Am not interested in abstract ideas

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 23

Talk to a lot of different people at parties

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 24

Feel others' emotions

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 25

Like order

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very **Accurate**

Question 26

Get upset easily

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 27

Have difficulty understanding abstract ideas

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 28

Keep in the background

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 29

Am not really interested in others

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 30

Make a mess of things

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 31

Seldom feel blue

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

Question 32

Do not have a good imagination

- 1=Very Inaccurate
- 2=Moderately Inaccurate
- 3=Neither Inaccurate or Accurate
- 4=Moderately Accurate
- 5=Very Accurate

APPENDIX N: Qualtrics - Wonderlic WPT Link and Qualtrics Completion

Block 4 - Wonderlic Link / Completion

Section 4: Please complete the 8-minute Cognitive Ability Pretest hosted by Wonderlic by copying and pasting the following html address into another browser window, leaving this survey window open. When you complete the Wonderlic test, return to this survey when finished. Once again please use your email address and survey study ID to log in to Wonderlic:

<https://rnd-testing.wonderliconline.com/WebPages/Links.aspx?lid=FlynnVT3>

Question 33

Have you completed the Wonderlic Test?

- Yes
- No

Question 34

Thank you for your time. If you are not already scheduled for the Learning by Doing (LBD) lab session which is required to receive your extra credit points, may we forward you an invitation and link to the appointment scheduler using your email address provided in this survey?

- Yes, please do!
- No, I would prefer to schedule through Scholar Announcement
- I already have an appointment for my LBD trial.

Thank you again for your help on this important research! We look forward to your visit to the Lab!

Appendix O

Study 2b' (n=101) Standardized Regression Analysis with Frontier Score (DV) Outlier Removed

Model / Variables	Mean	SD	Correlation (Fs)	M1	M2	M3	M4	M5	M6	M7	M8	Ru
DV - Frontier Score (Fs)	5,207.92	3,704.39										
Hypothesized Variables:												
Cognitive Ability	27.16	4.64	.33	.32	0.47		.31			.30	.33	.08
Incremental Break Time	391.15	313.17	-.21	-.18	.56		-.15			-.16	-.01	.02
Ability X Incremental Break			-.16		-.76						-.16	
Psychological Factors												
Extraversion	3.57	.91	-.16			-.18	-.19		-.18	-.19	-.18	.02
Agreeableness	4.08	.69	-.04			.04	.05		.05	.07	.07	0
Conscientiousness	3.58	.83	-.02			-.07	.05		-.05	.06	.06	0
Neuroticism	2.76	.82	-.28			-.30	-.22		-.24	-.16	-.16	.02
Imagination	3.70	.70	-.07			-.02	-.03		-.05	-.05	-.05	0
Control Variables												
Gender, 0-M, 1-F	.48	.50	-.27					-.21	-.21	-.22	-.21	.02
Age	20.26	1.75	.01					.00	-.03	-.02	-.02	0
Videogame Experience	3.22	1.77	.23					.08	-.02	-.05	-.04	0
Model Summary												
R				.38	.40	.34	.47	.27	.38	.50	.50	
R Squared				.14	.16	.11	.22	.07	.15	.25	.25	

Note. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a a subjects trial. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. One outlier with excessive frontier score is removed (36,900 points; > 3.0 standard deviations from the mean). Ru is calculated using Model 7 combined R value minus Model 7 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M1 thru M8 are regression model numbers.

Appendix P: Study 1 (n=50) – Scoring and Tactical Development Traces

ILLUSTRATION

Study 1 – Example

In Appendix P, individual subject scoring traces illustrate scoring performance (y-axis) by trip number (x-axis). The scoring trace is represented by the dotted line and progressing high scores (frontier scores) by the solid line. The bars and boxes note first use of a new tactic by trip number and do not relate directly to score.

For instance, subject 0001 below conducted 57 trips in 75 minutes of gameplay. The subjects first score was approximately 600 points. His highest scores on trip 29 and 40 earned 3400 points, this subjects overall frontier score. Of the eight focal tactics evaluated, only six were discovered and deployed. Tactic 1, for instance, was first used on trip 4. That trip appears to be associated with 600 points.

Tactic Indicators -

T1 = Speed

T2 = Erase

T3 = Discard

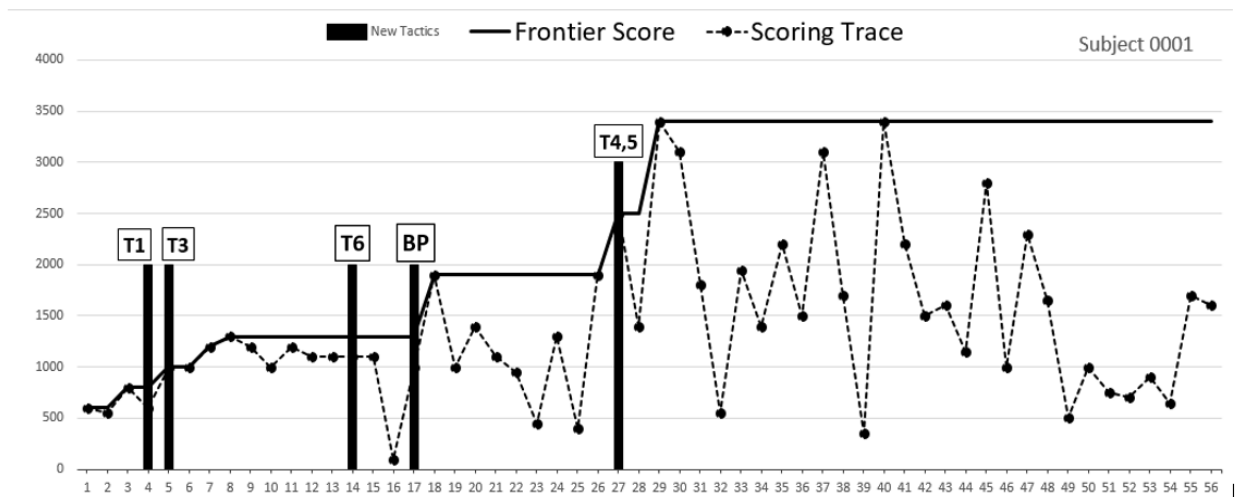
T4 = Loop

T5 = Extend

T6 = Play Ahead

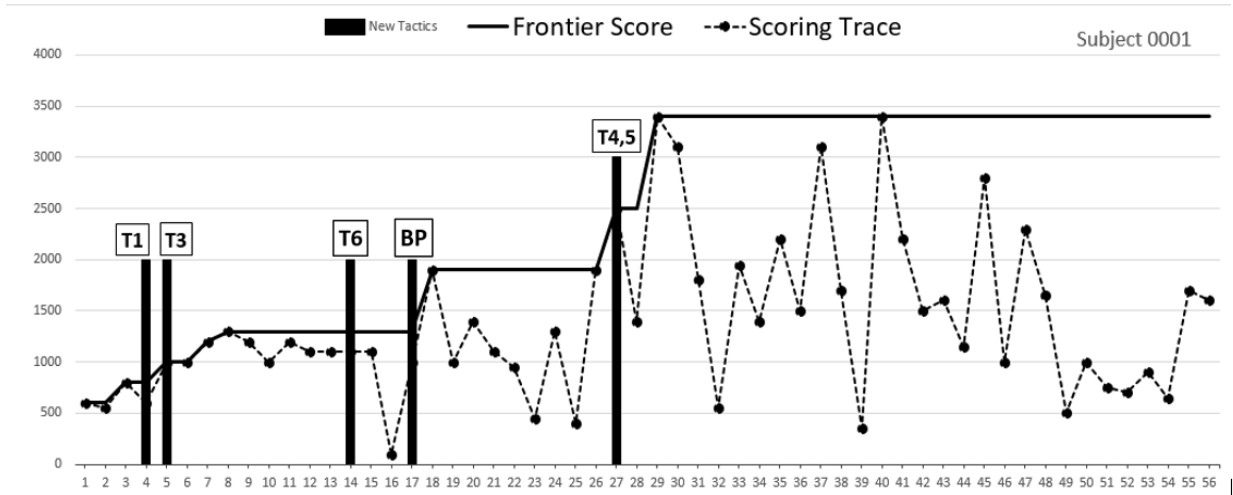
T7 = Close Loop

BP = Bonus Placement

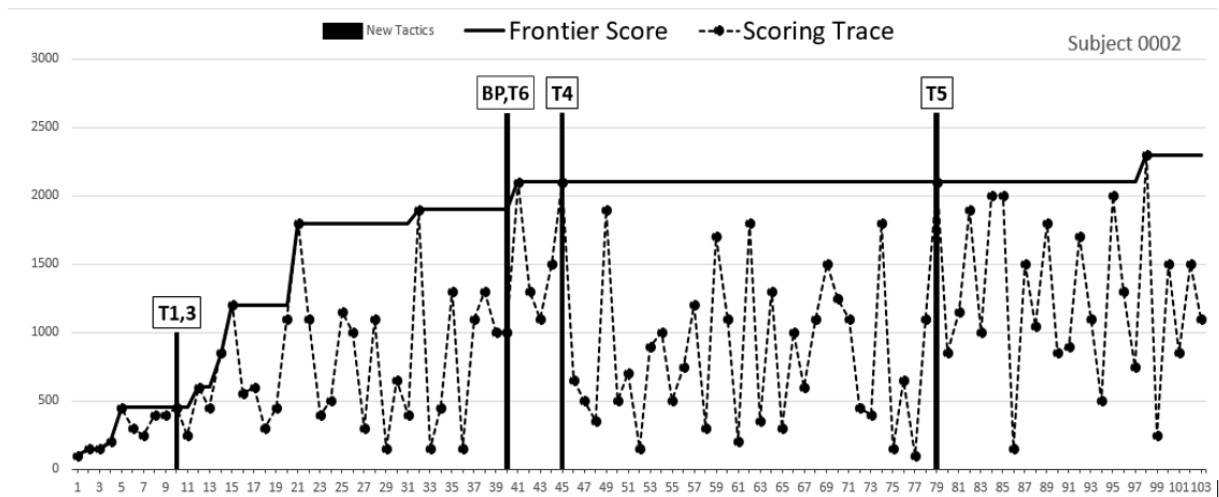


Appendix P: Study 1 (n=50) – Scoring and Tactical Development Traces

Study 1 – Subject Number 1

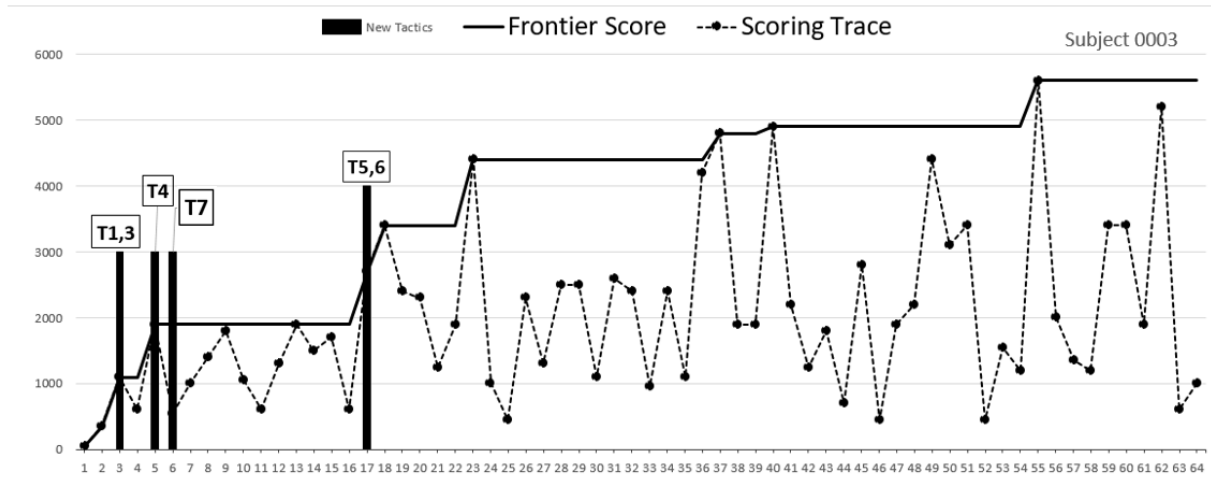


Study 1 – Subject Number 2

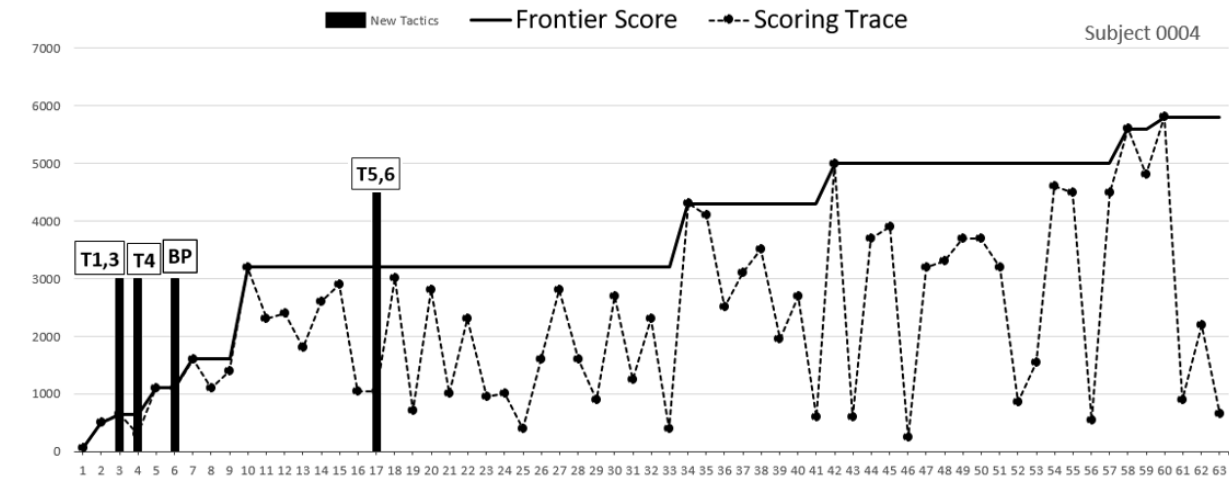


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 3

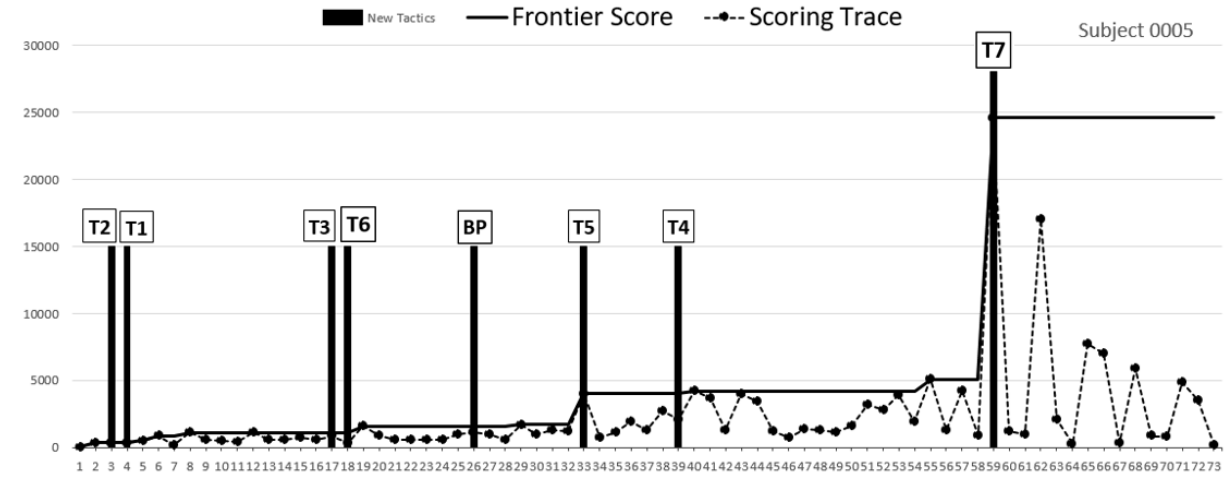


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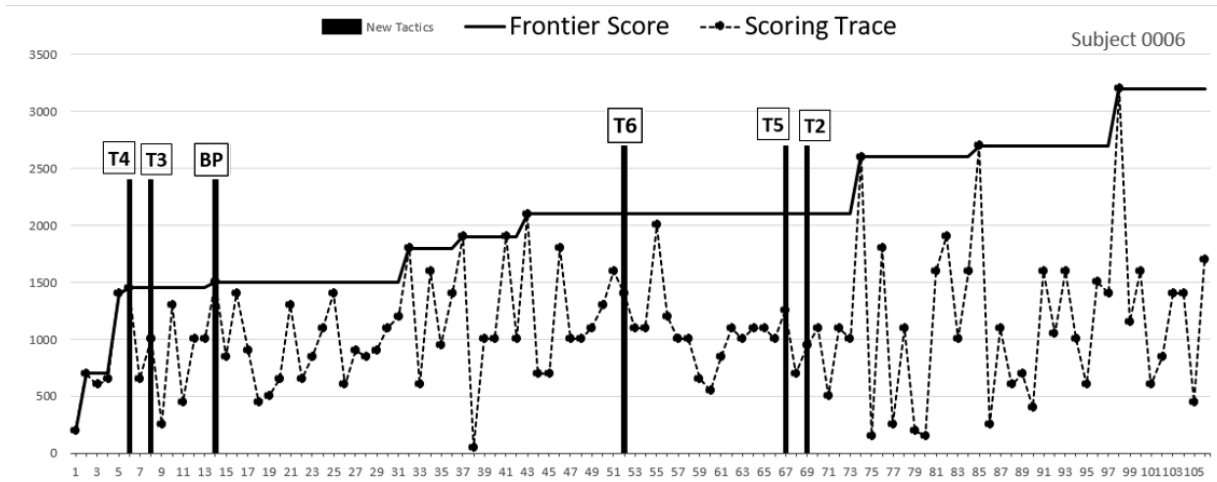


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 5

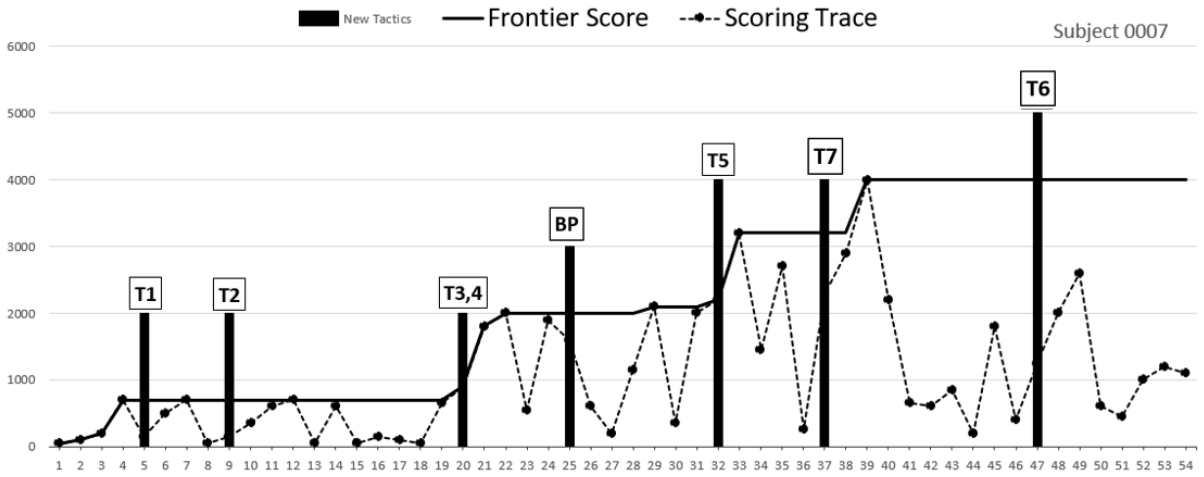


Study 1 -Subject Number 6

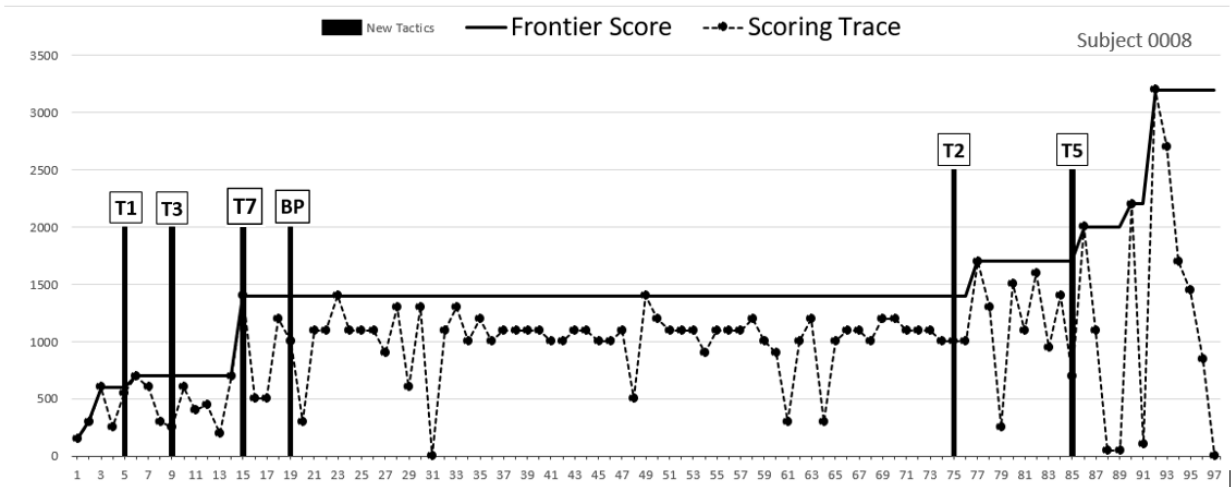


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 7

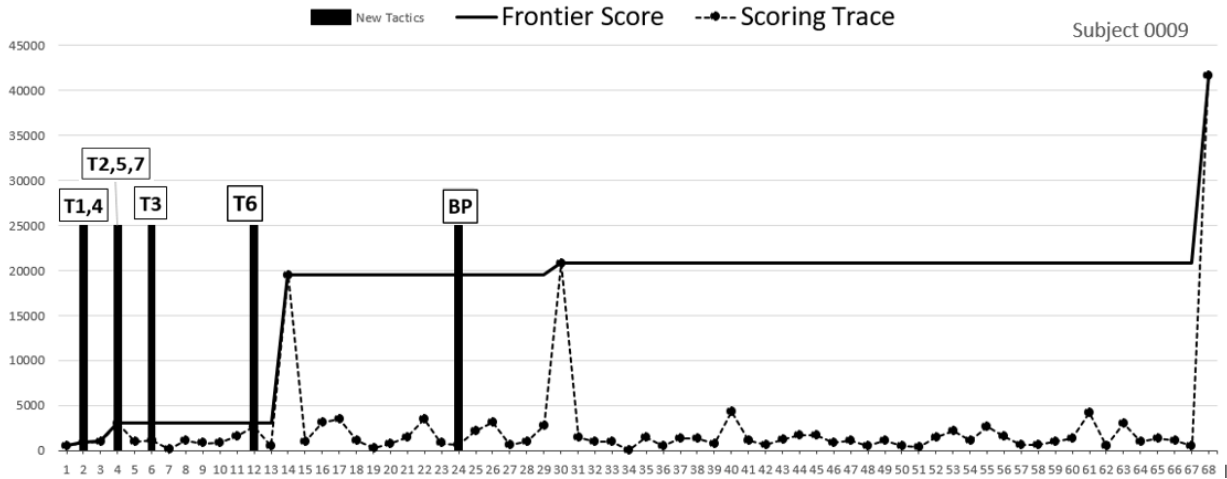


Study 1 -Subject Number 8

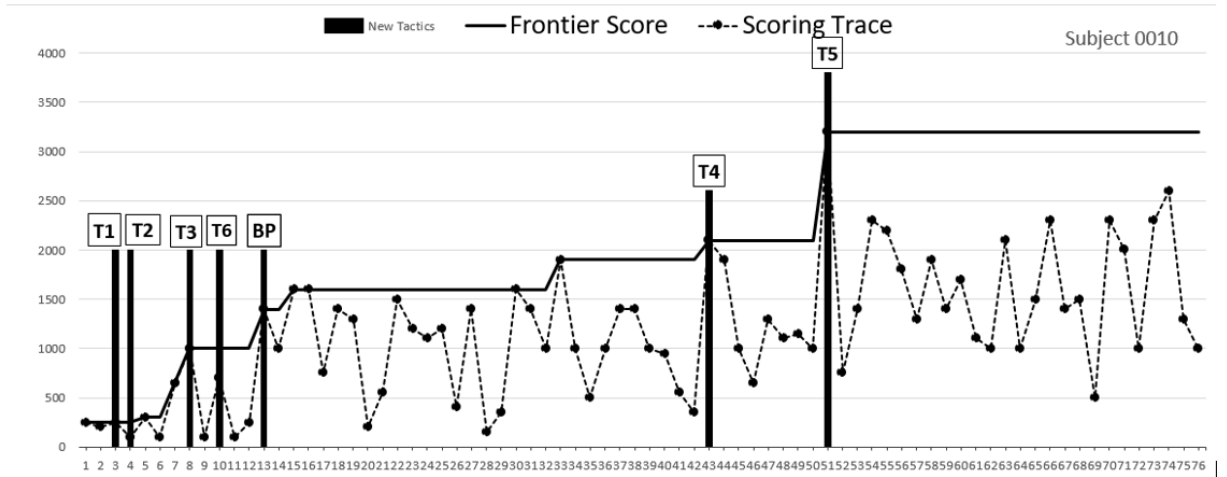


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 9

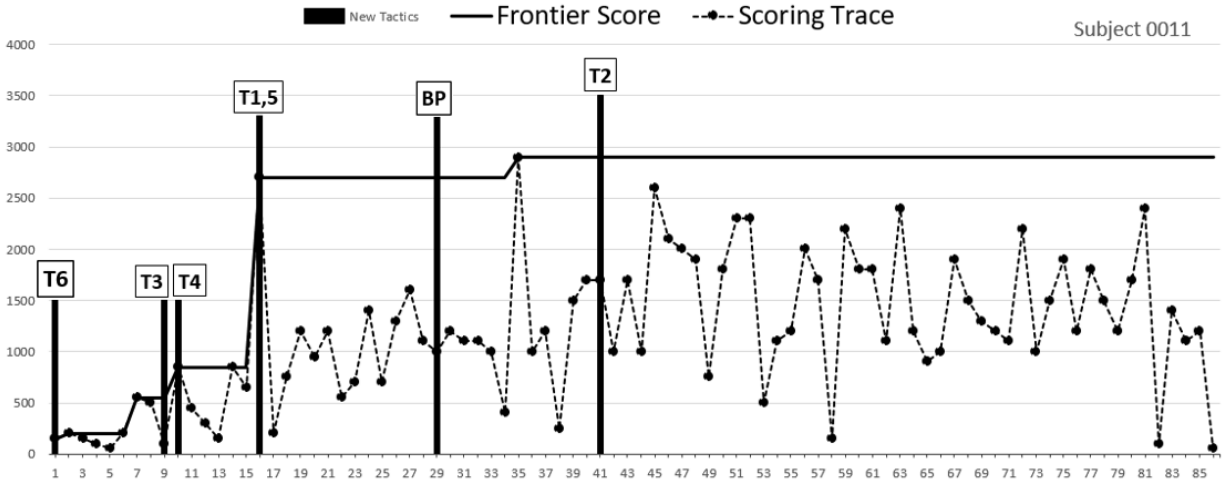


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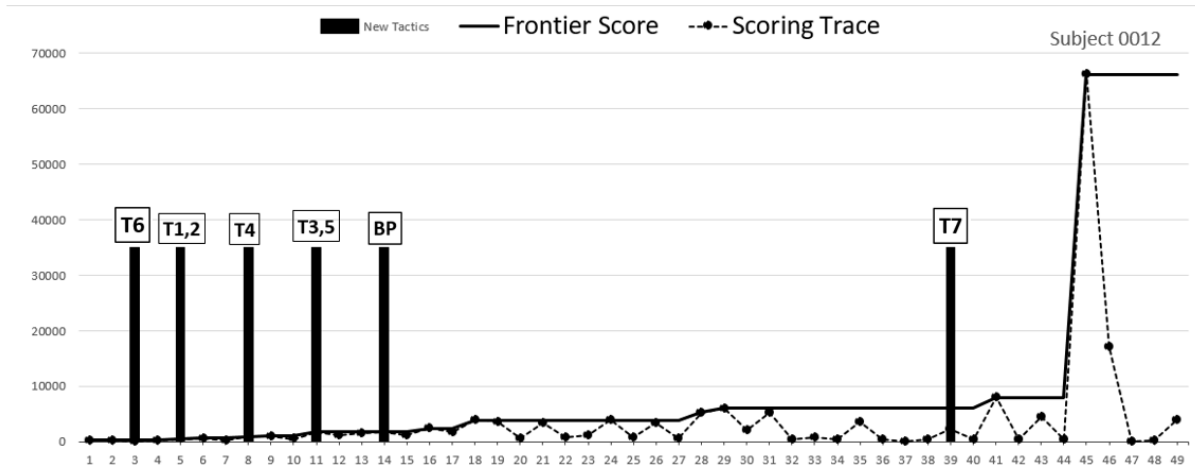


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 -Subject Number 11

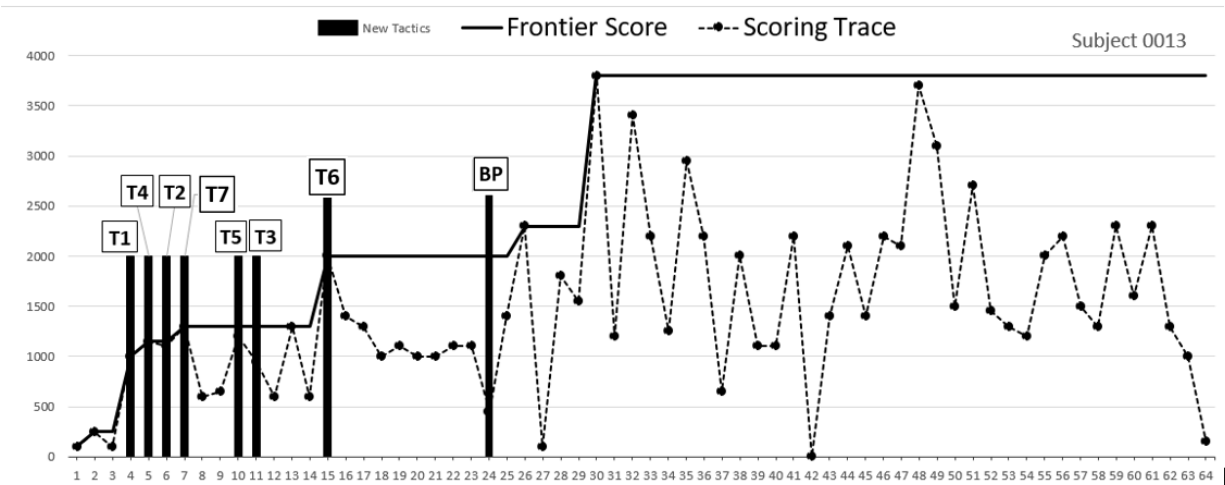


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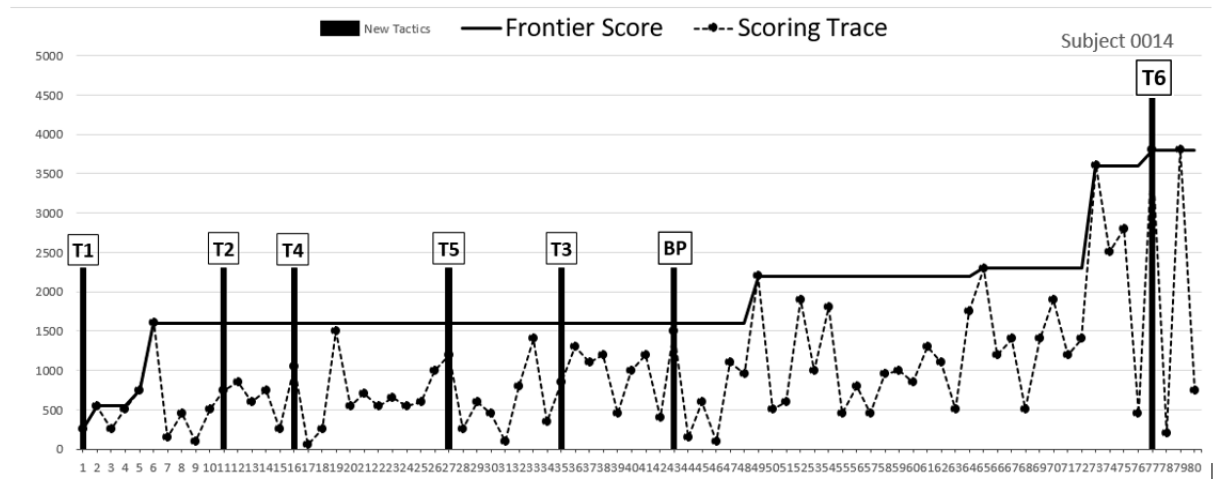


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 13

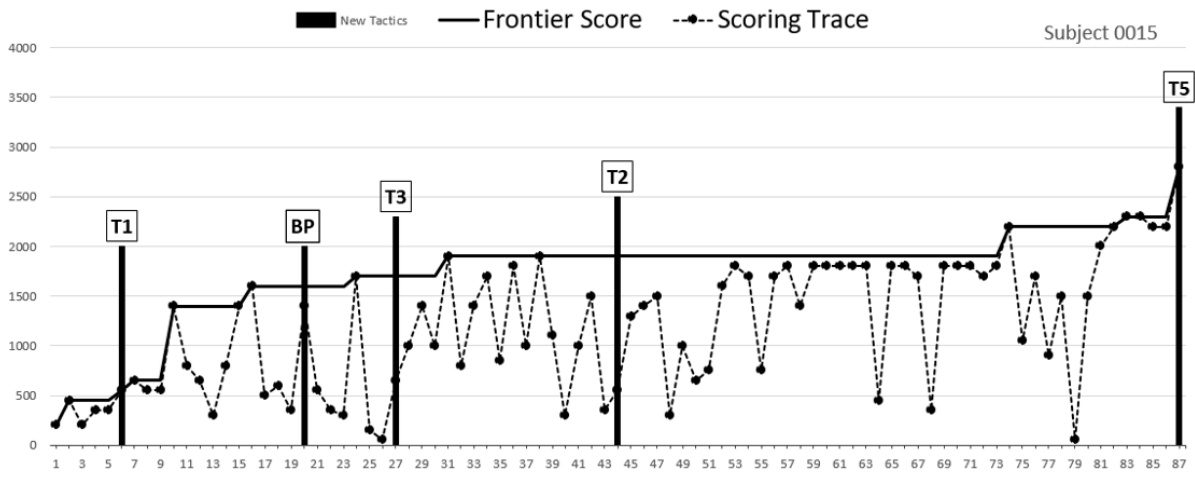


Study 1 -Subject Number 14

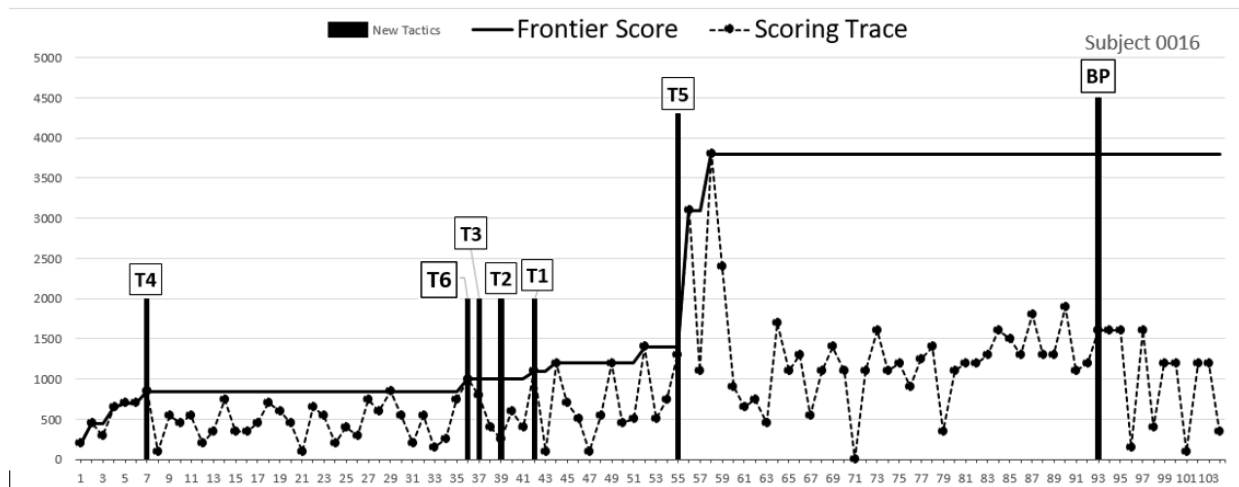


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 15

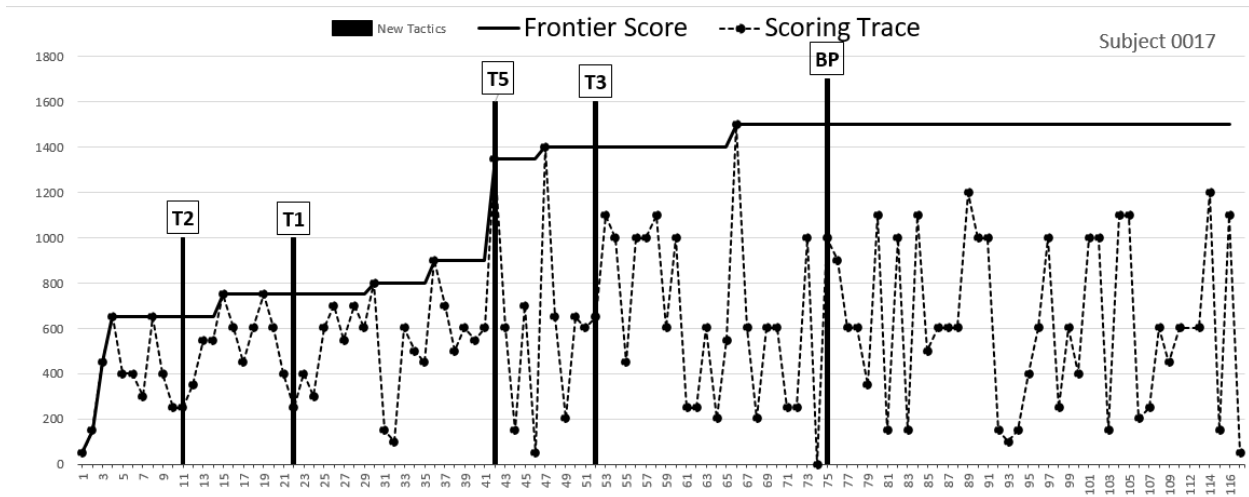


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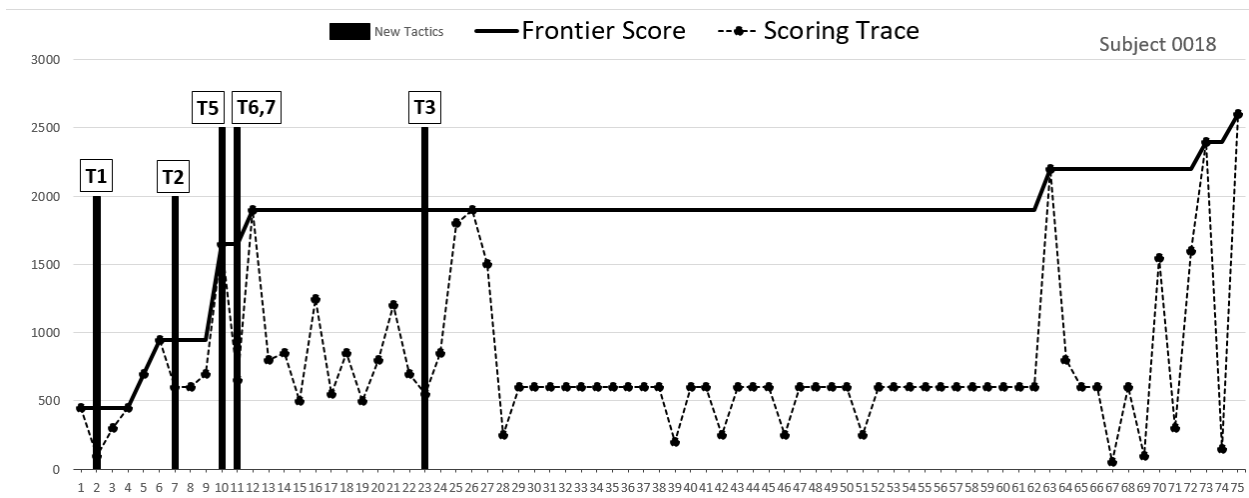


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 17

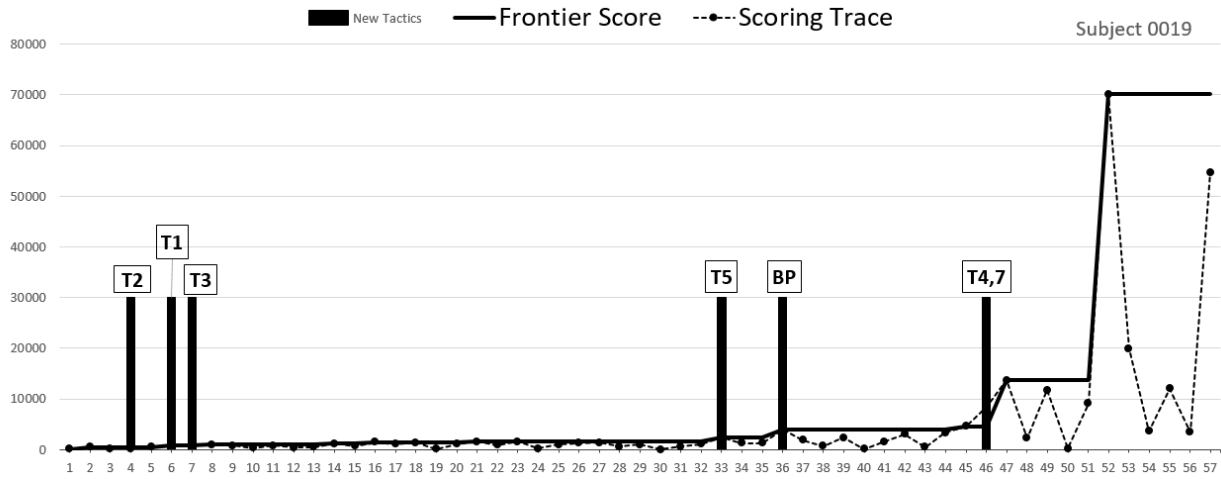


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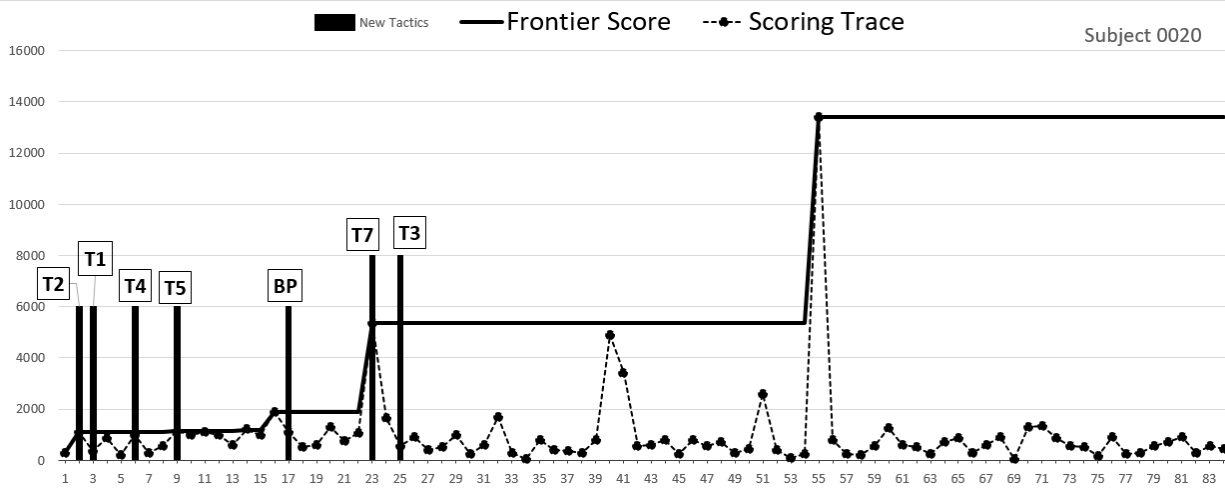


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 19

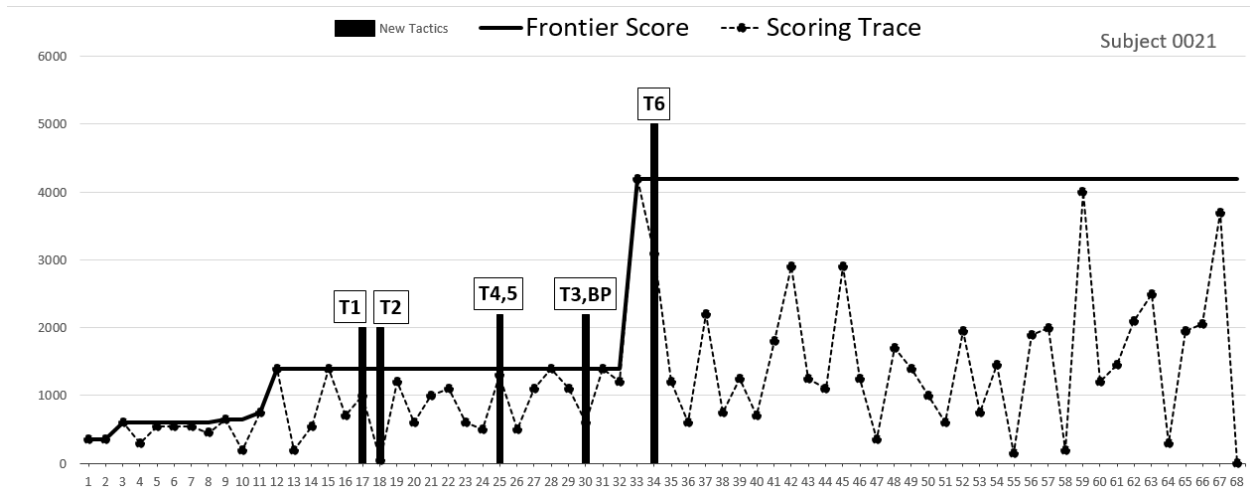


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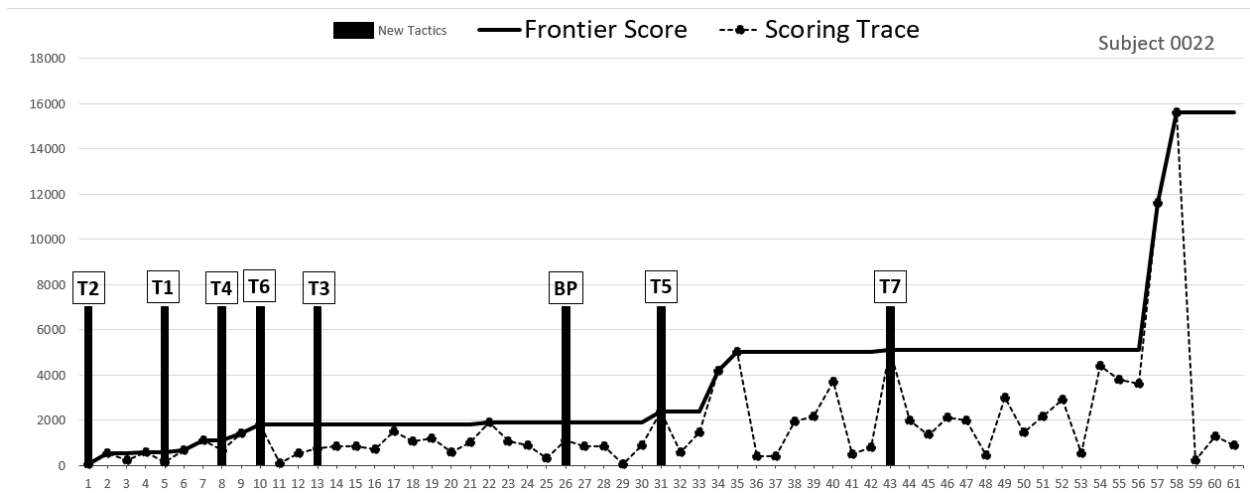


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 21

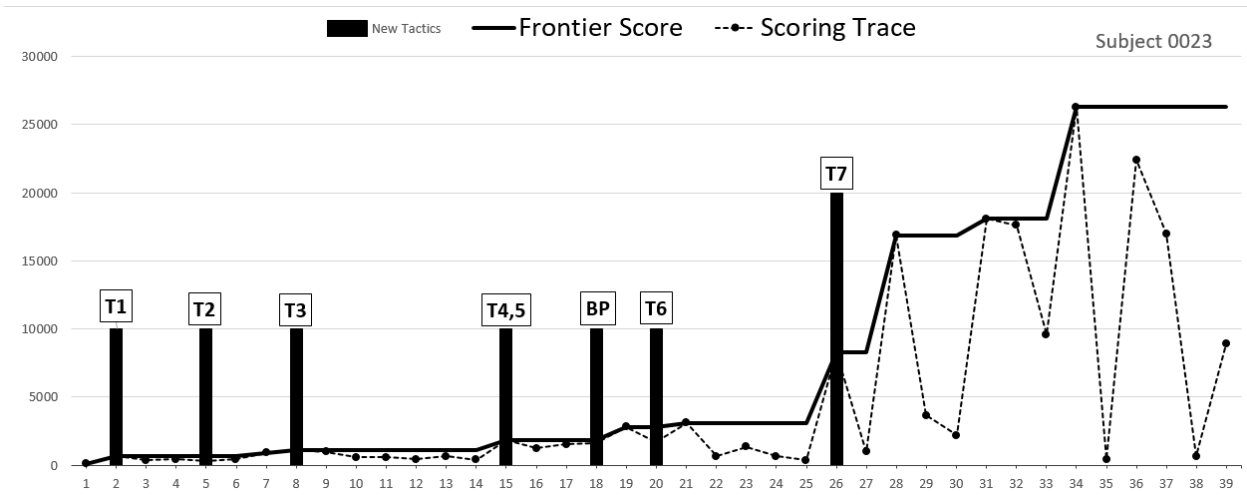


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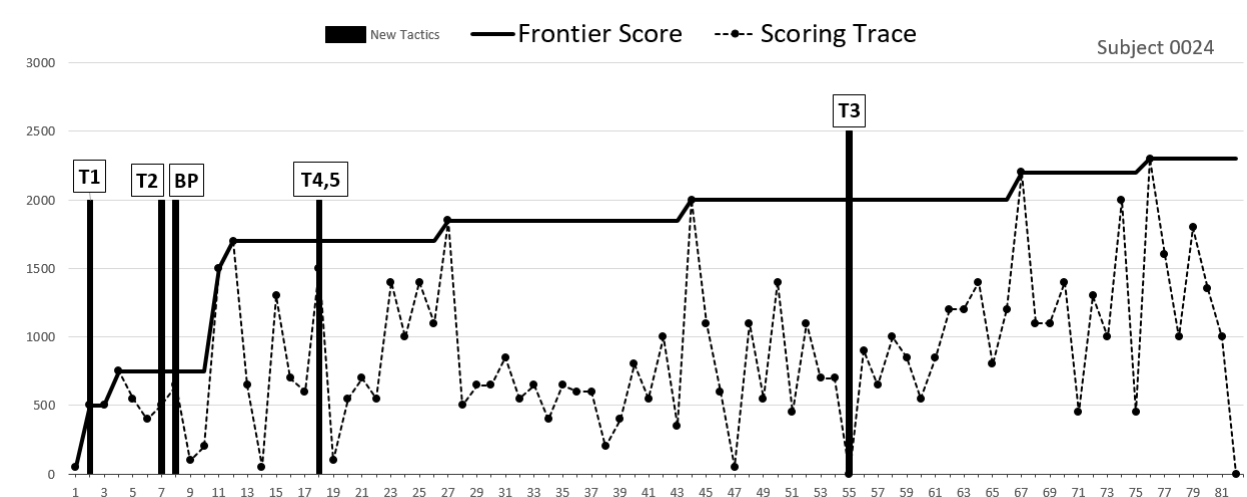


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 23

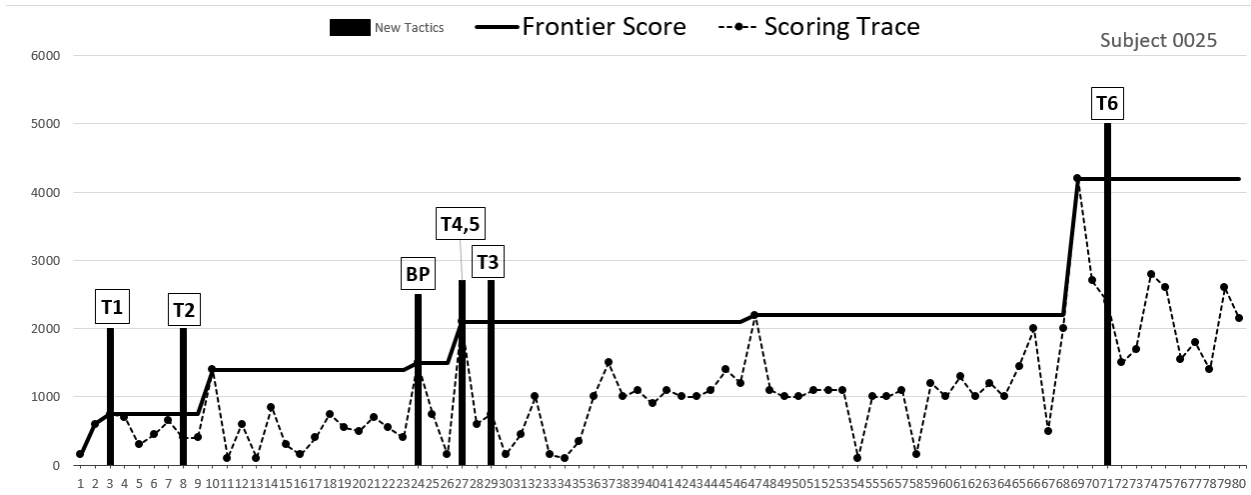


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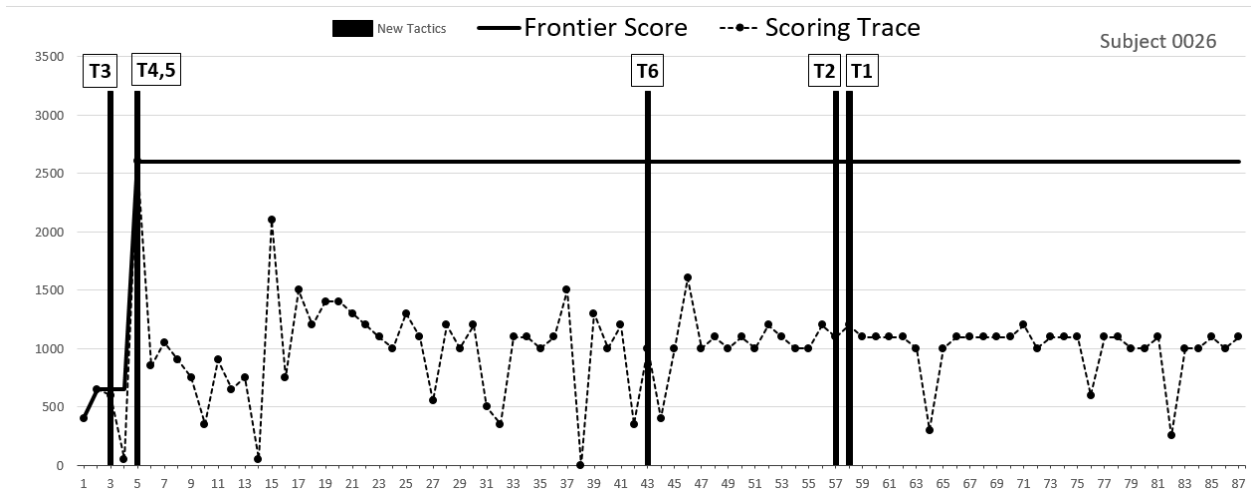


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 25

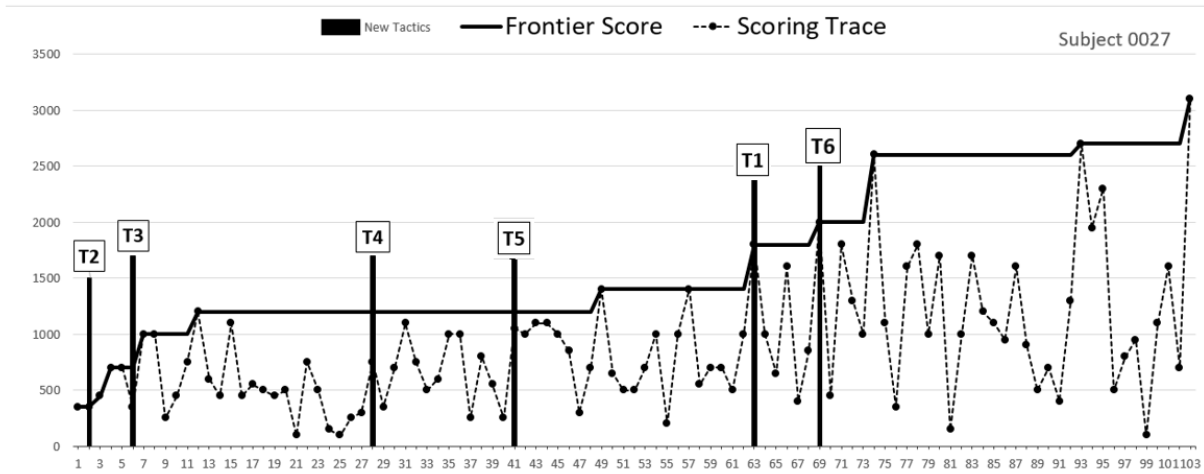


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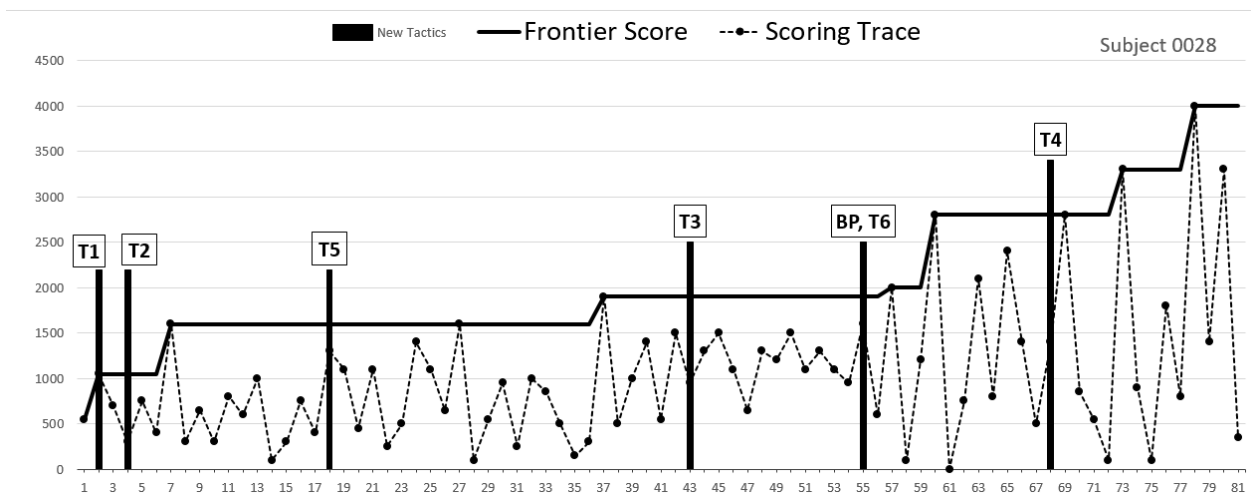


Appendix P: Study 1 – Scoring and Tactical Development Traces

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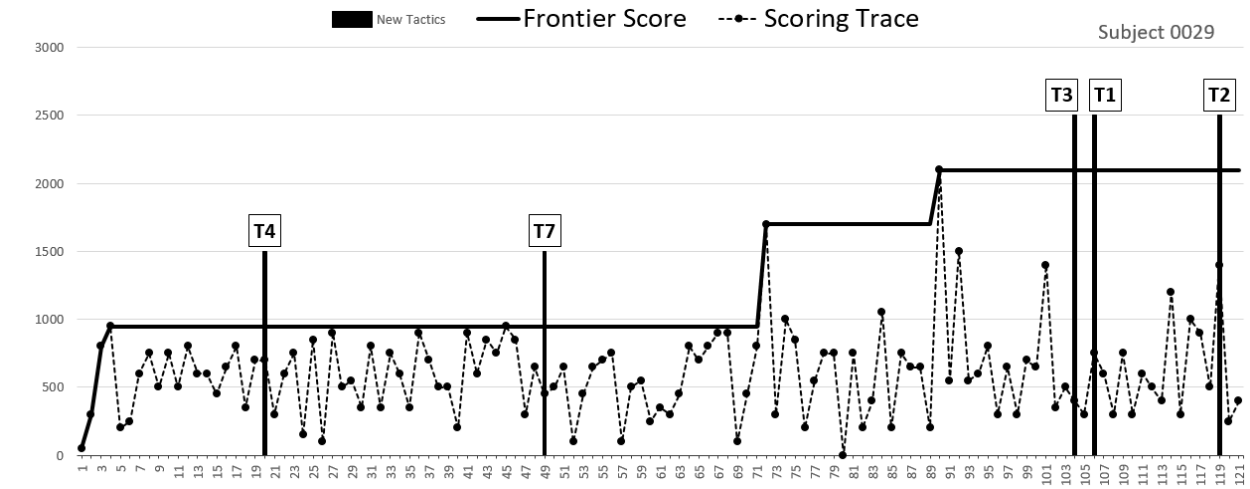


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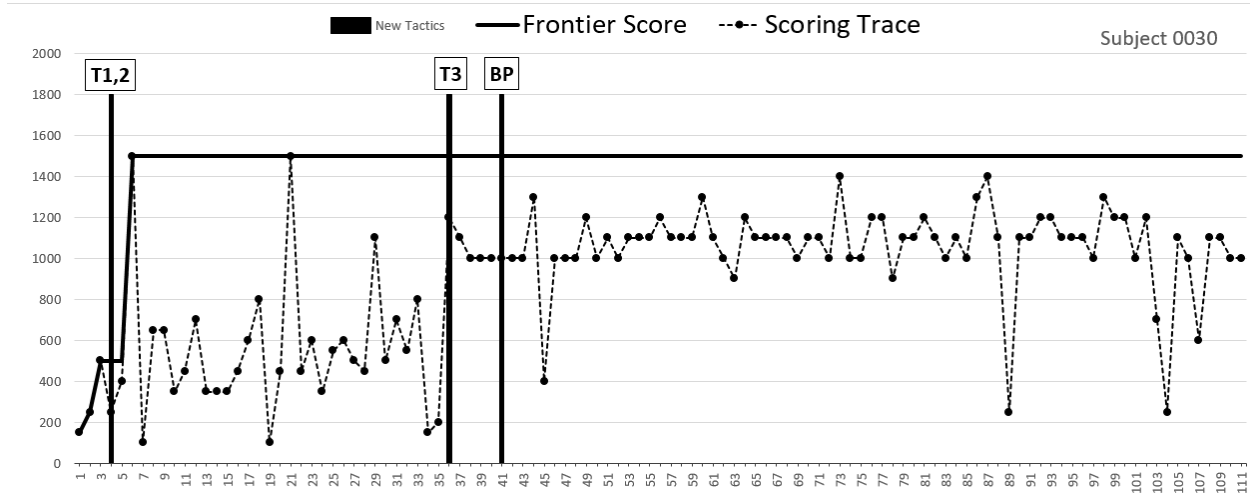


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 29

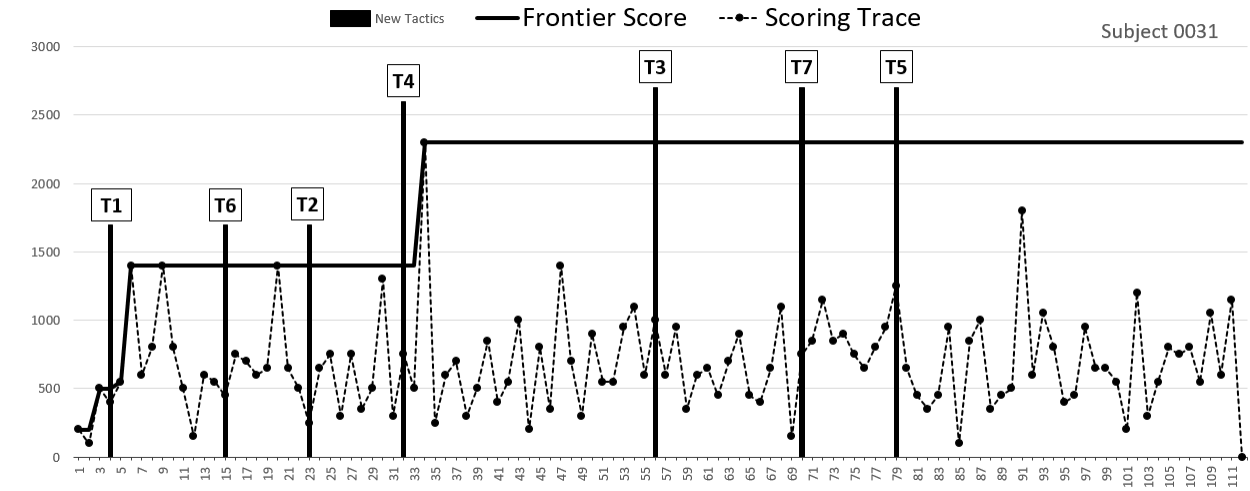


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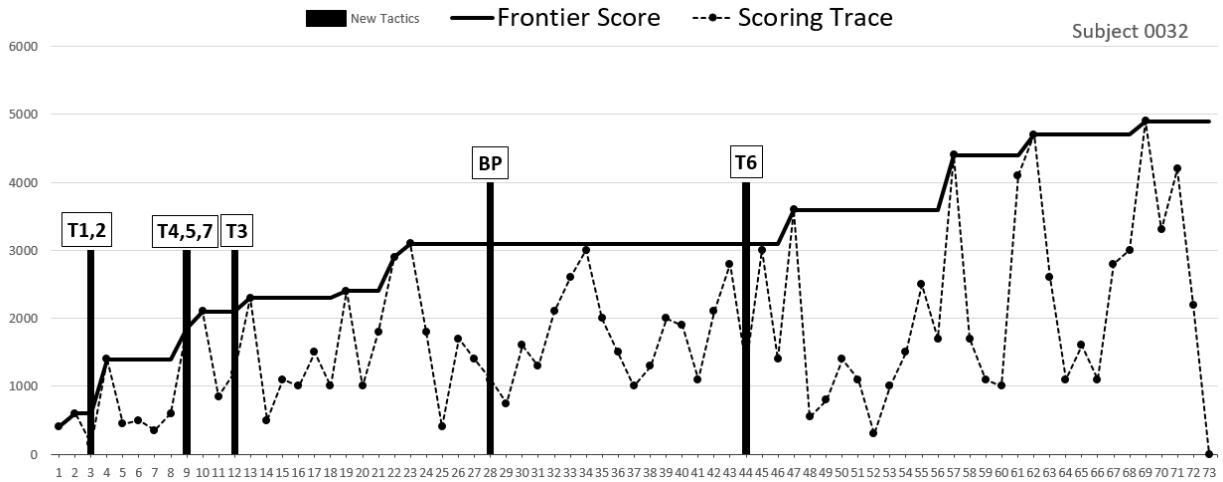


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 31

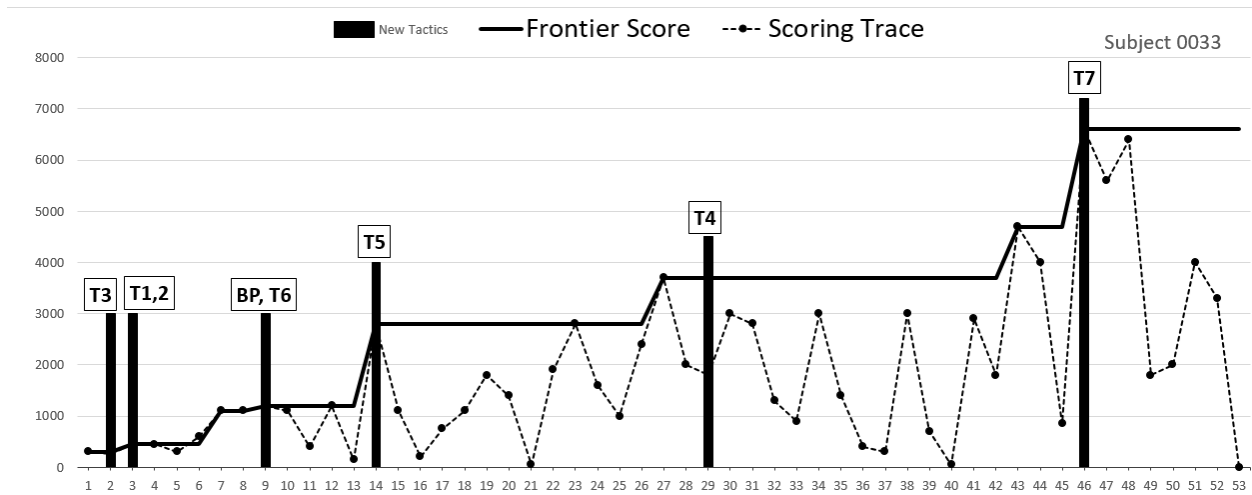


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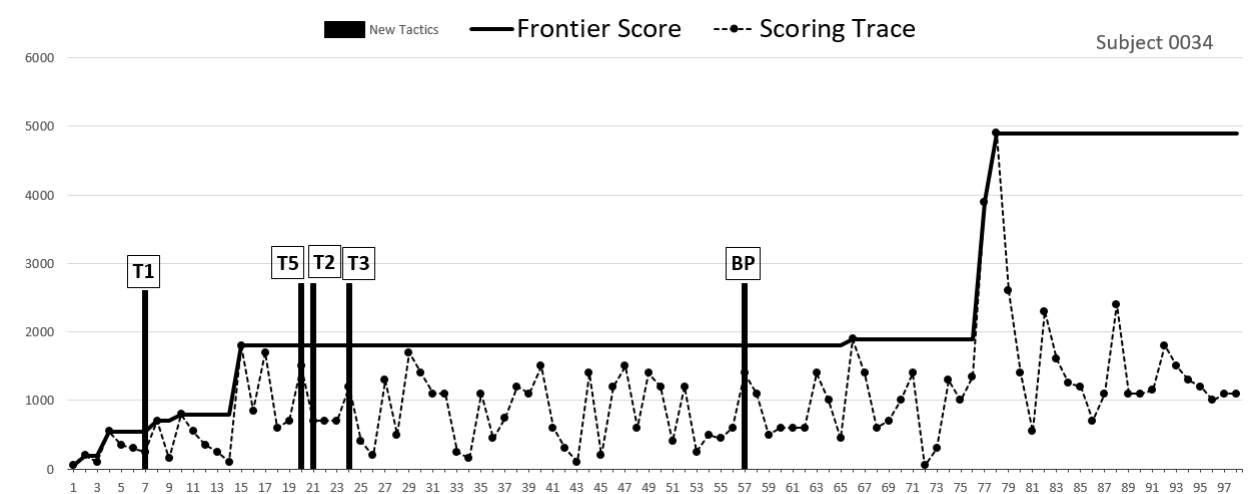


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 33

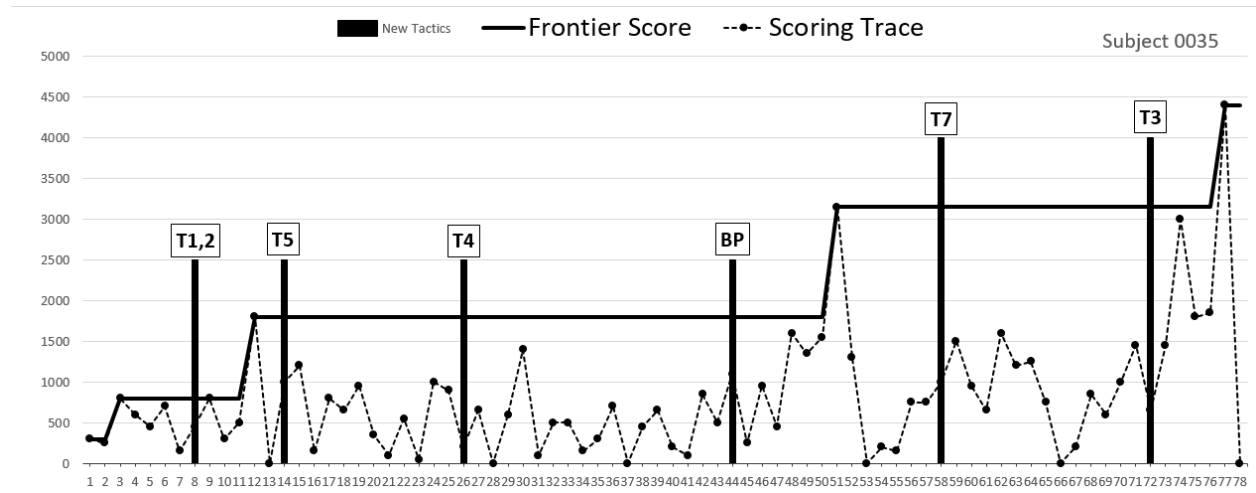


Study 1 – Subject Number 34

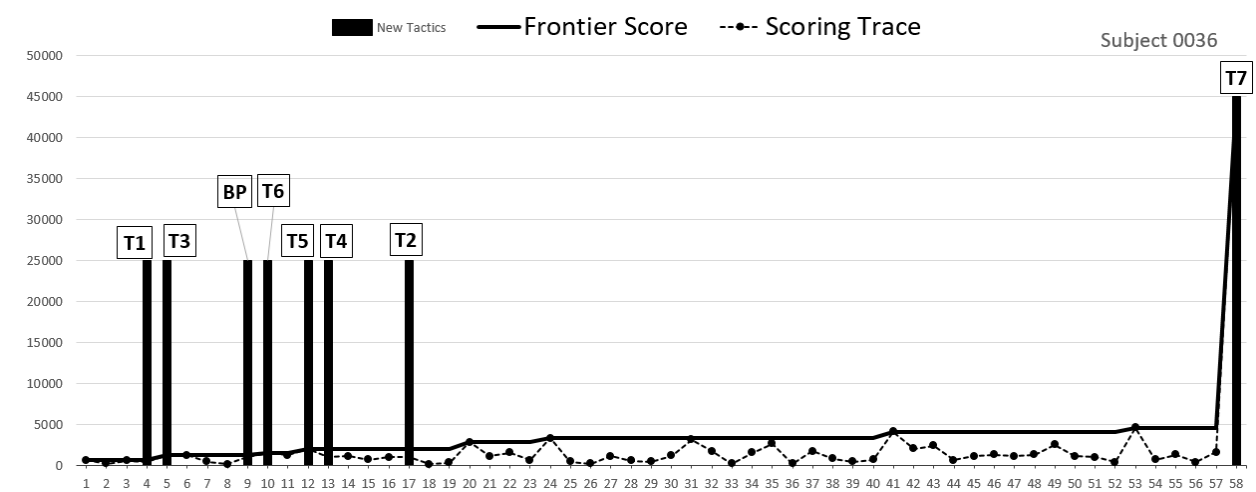


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 35

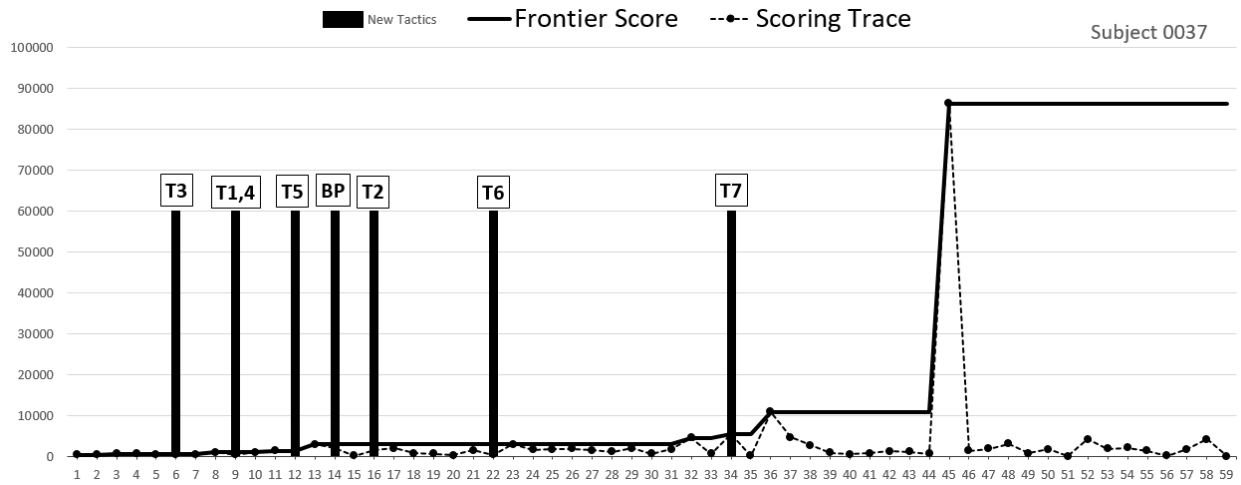


Study 1 – Subject Number 36

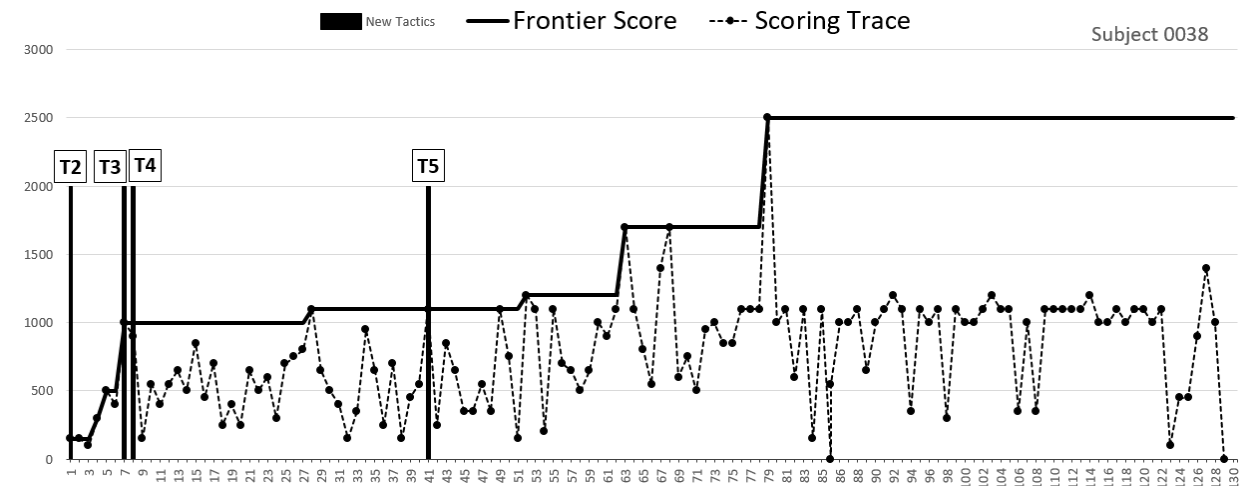


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 37

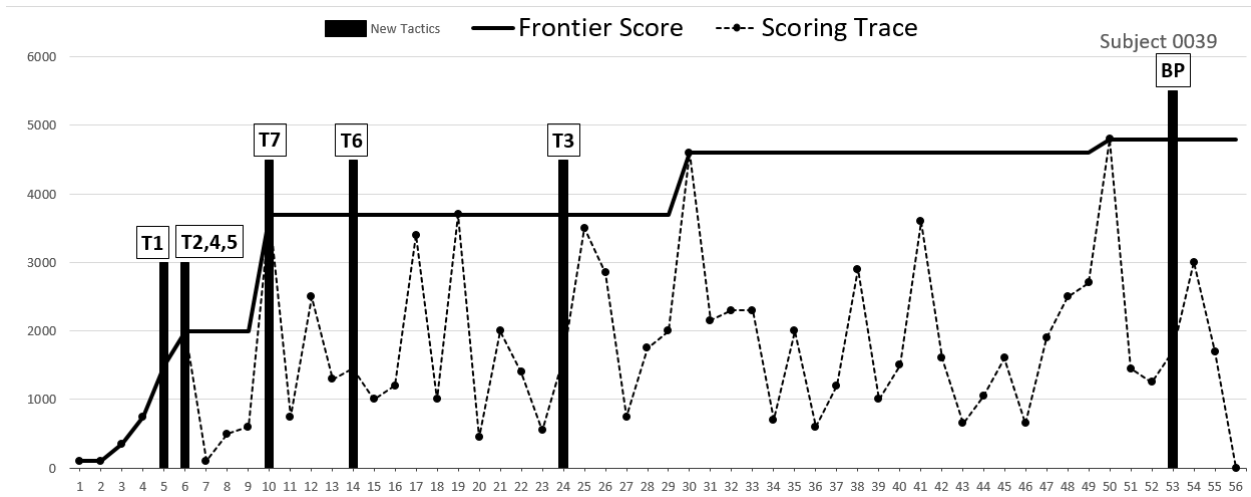


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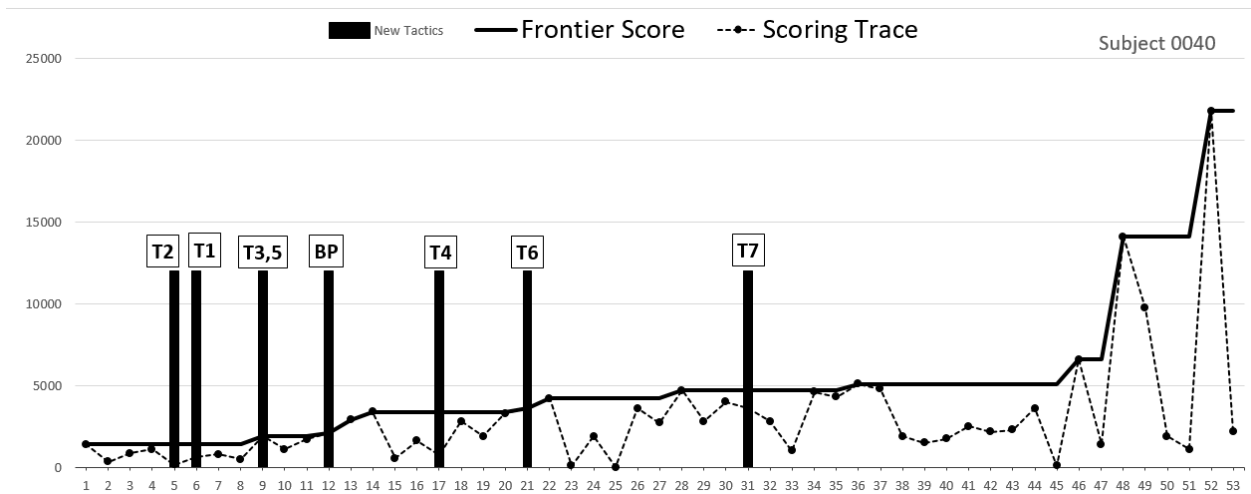


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 39

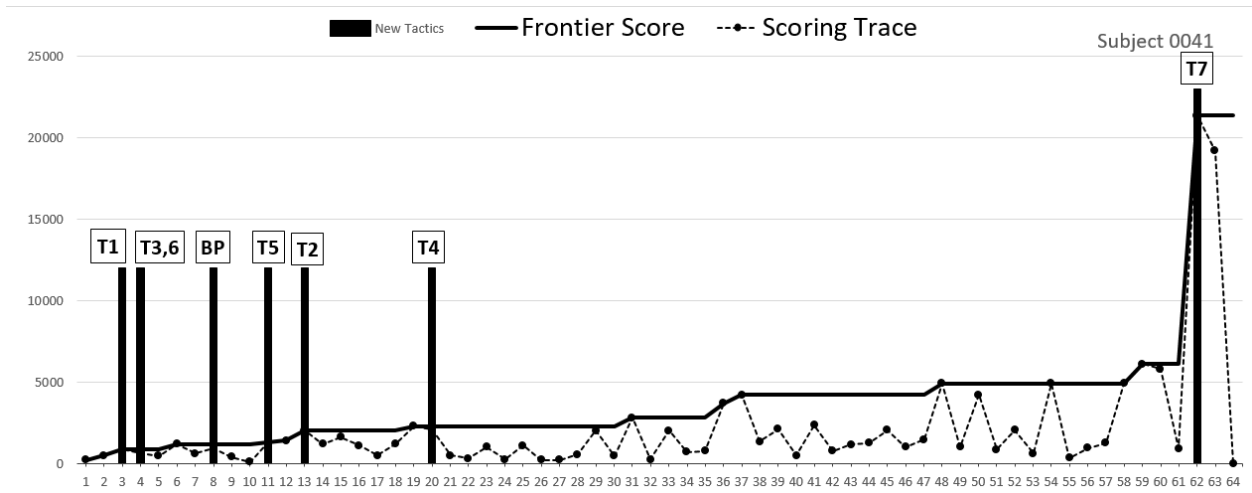


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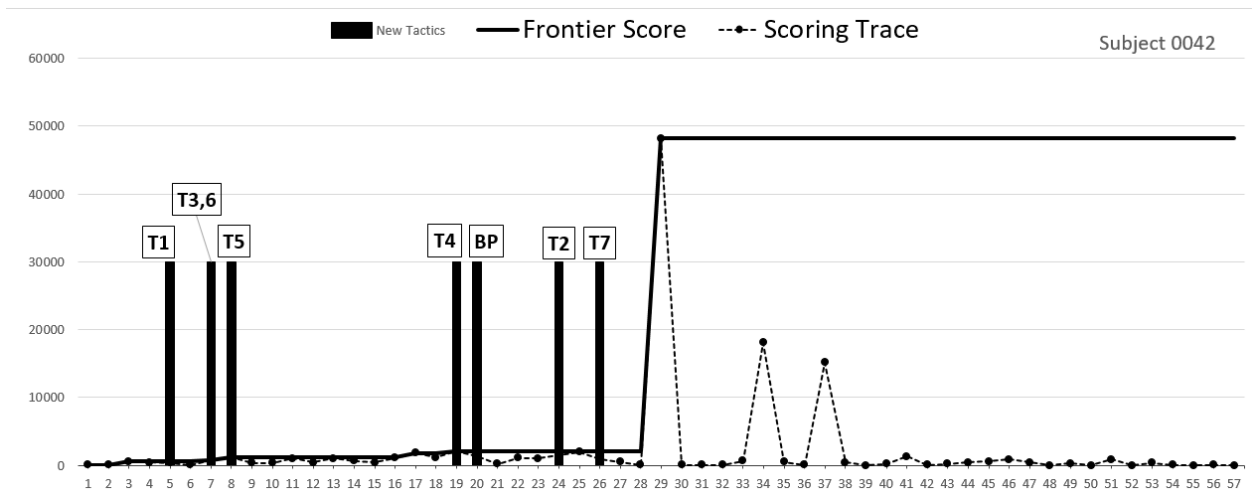


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 41

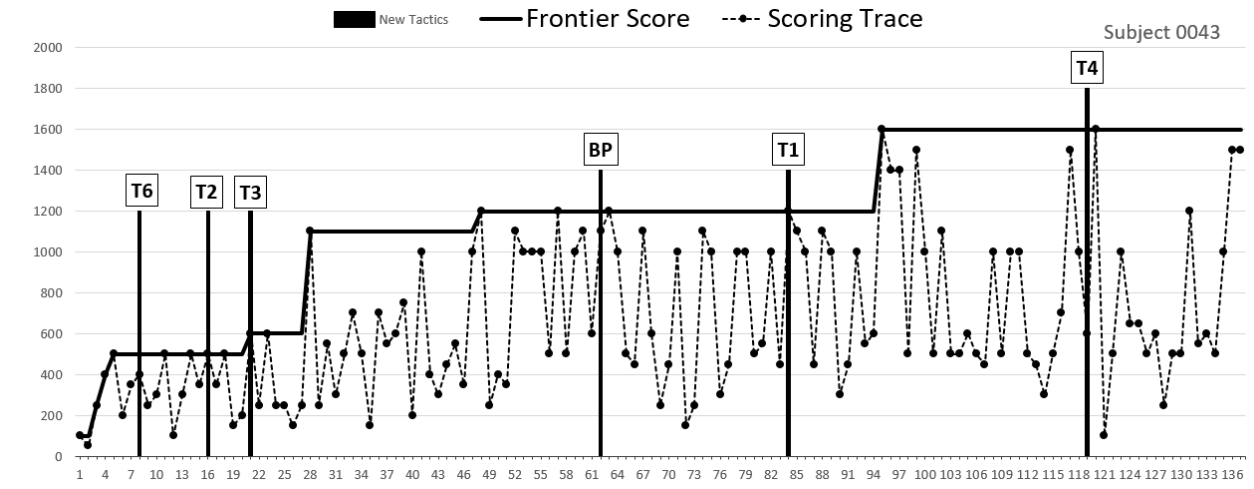


Study 1 – Subject Number 42

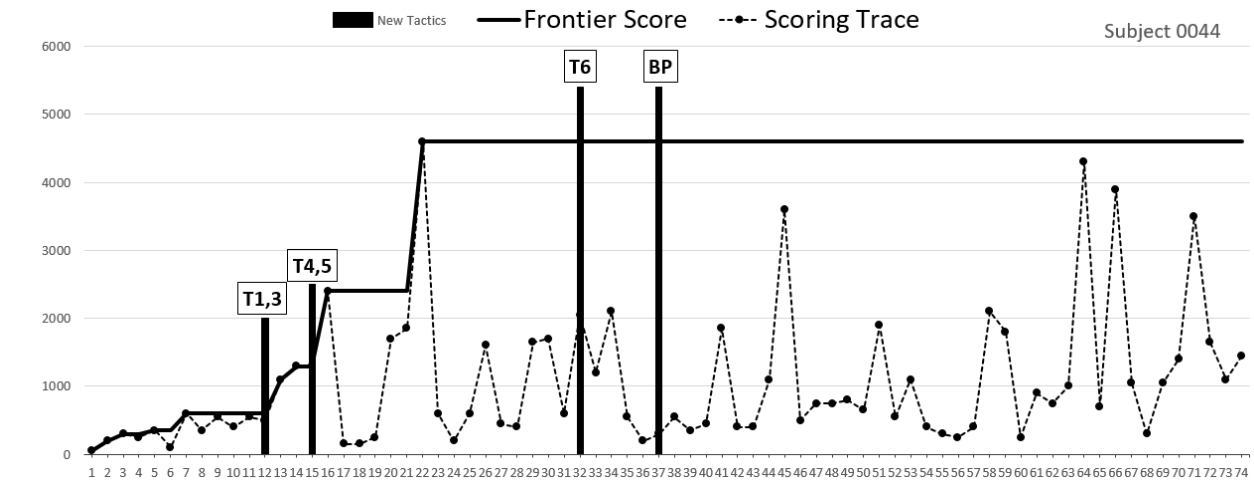


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 43

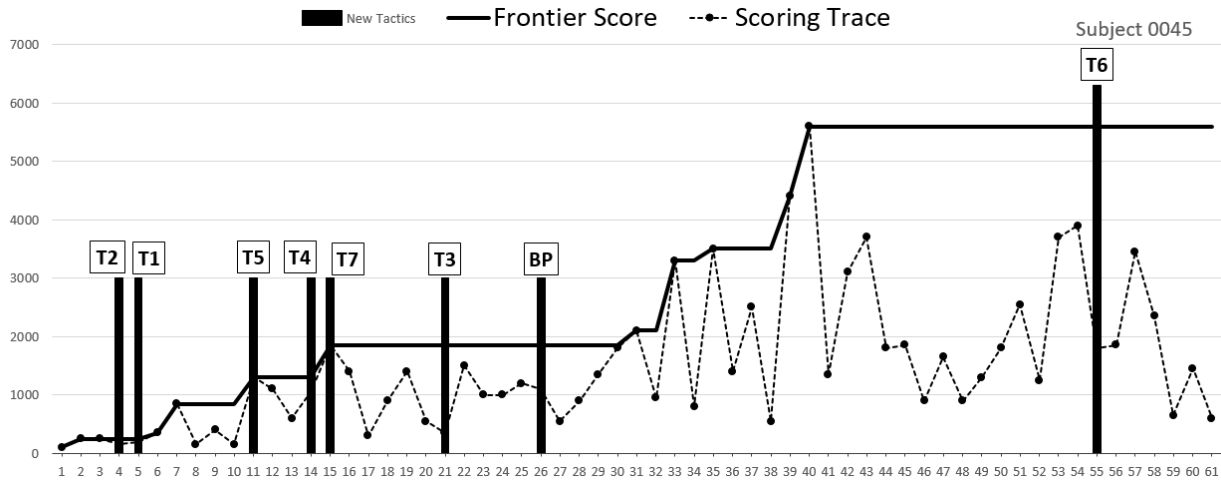


Study 1 – Subject Number 44

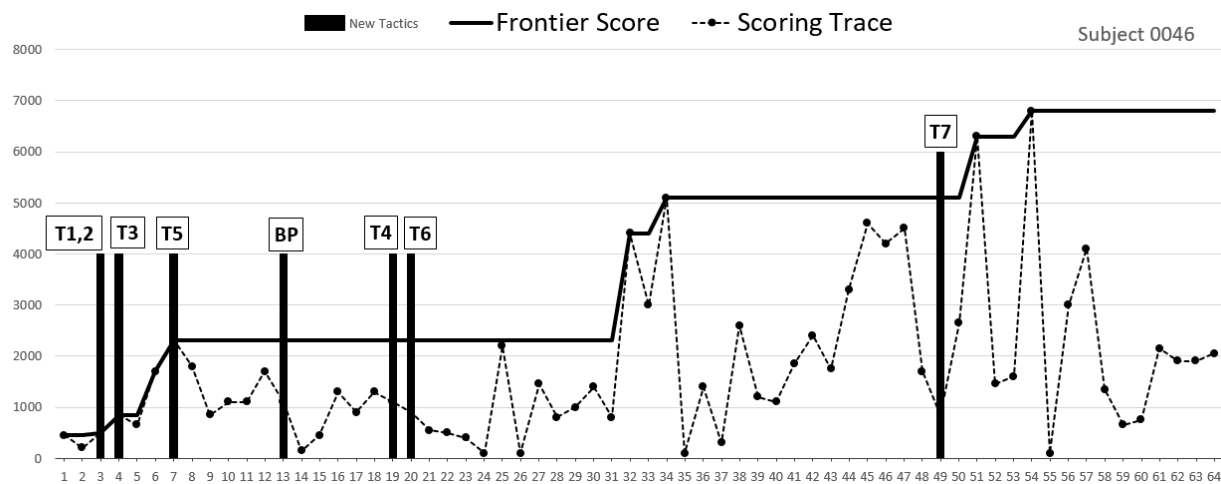


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 45

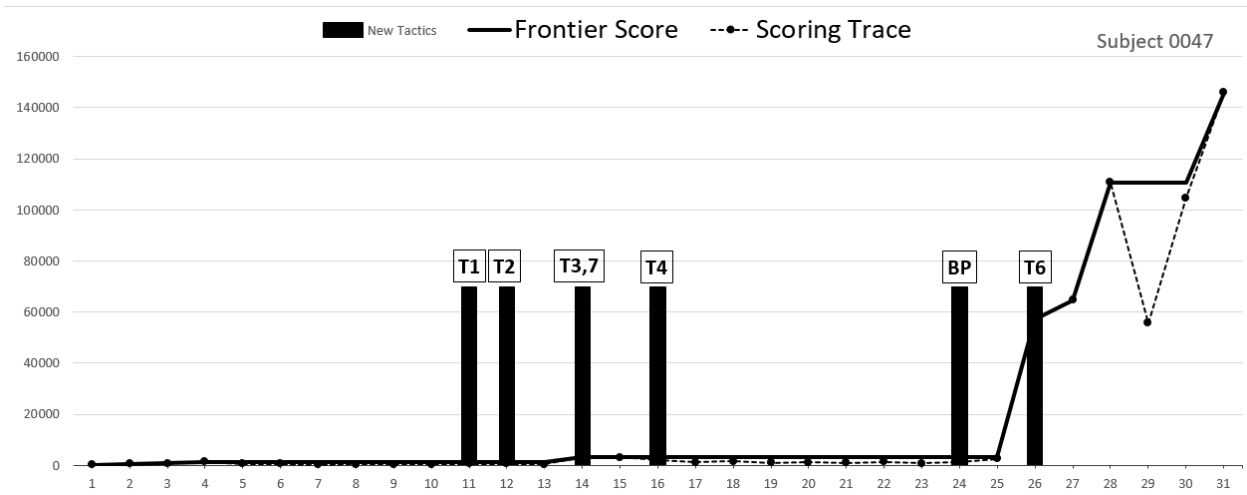


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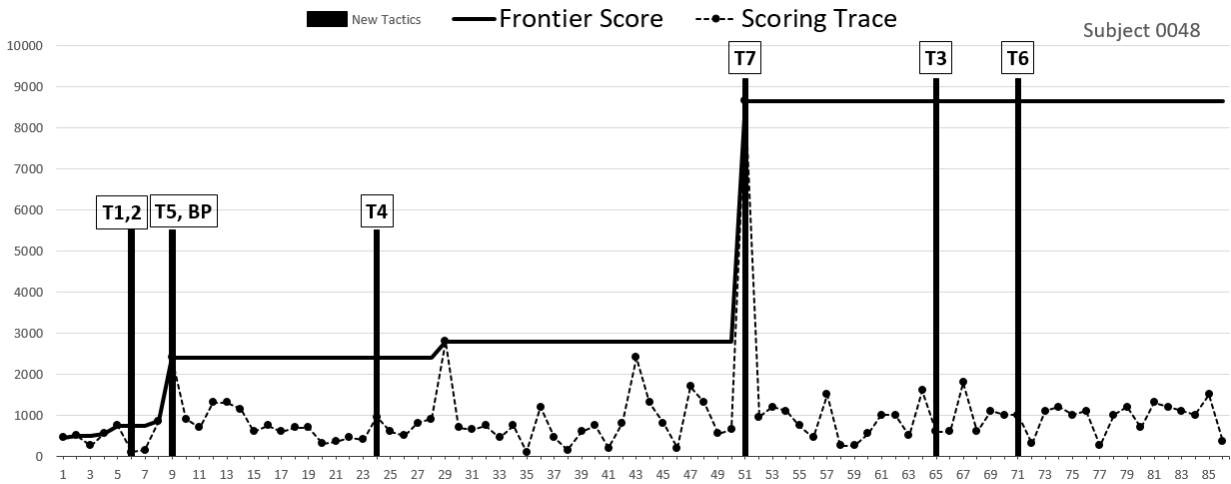


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 47

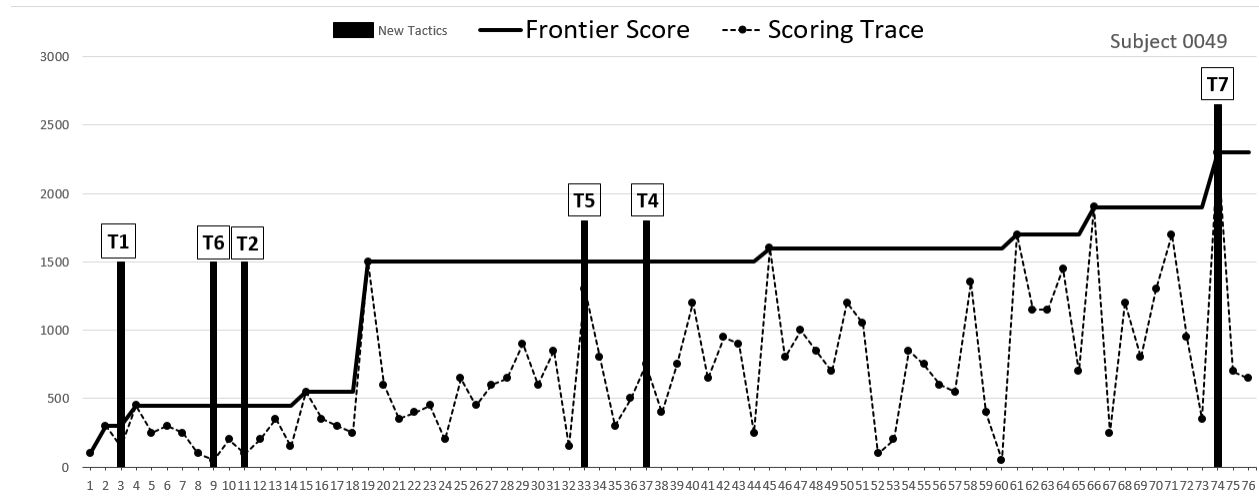


Study 1 – Subject Number 48

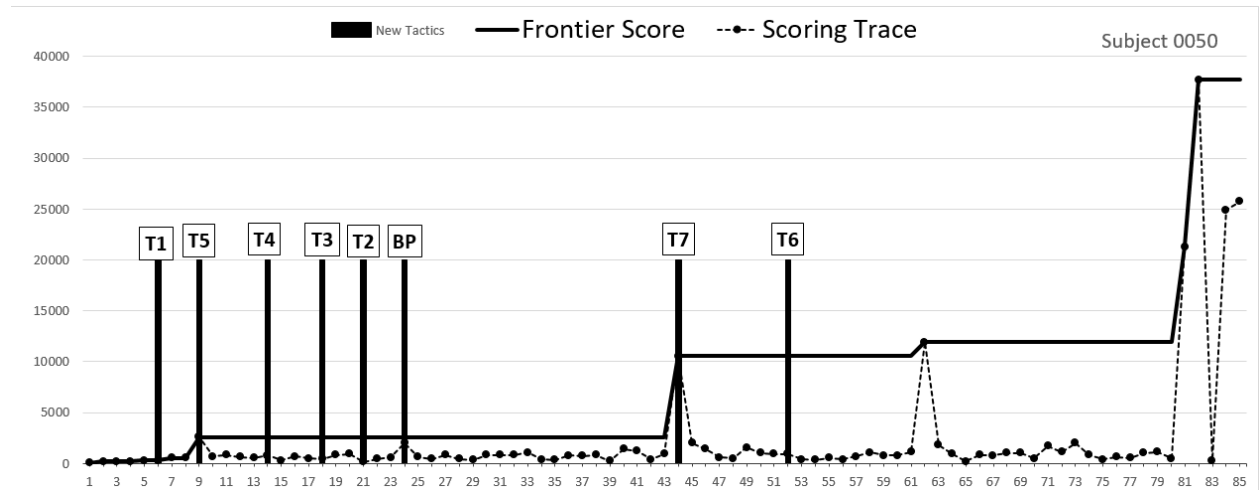


Appendix P: Study 1 – Scoring and Tactical Development Traces

Study 1 – Subject Number 49



Study 1 – Subject Number 50



Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a –EXAMPLE

ILLUSTRATION

In Appendix Q, individual subject scoring traces illustrate scoring performance (y-axis) by trip number (x-axis). Study 2a Subjects were in the “no elective breaks” treatment condition. The scoring trace is represented by the dotted line and progressing high scores (frontier scores) by the solid line. The bars and boxes note first use of a new tactic by trip number and do not relate directly to score.

For instance, subject 1031 below conducted 129 trips in 60 minutes of gameplay. The subjects first score was approximately 50 points. His highest scores on trip 83 earned 2300 points, this subjects overall frontier score. Of the seven focal tactics evaluated in Study 2, only four were discovered and deployed. Tactic 2, for instance, was first used on trip 31. That trip appears to be associated with 450 points.

Tactic Indicators -

T1 = Speed

T2 = Erase

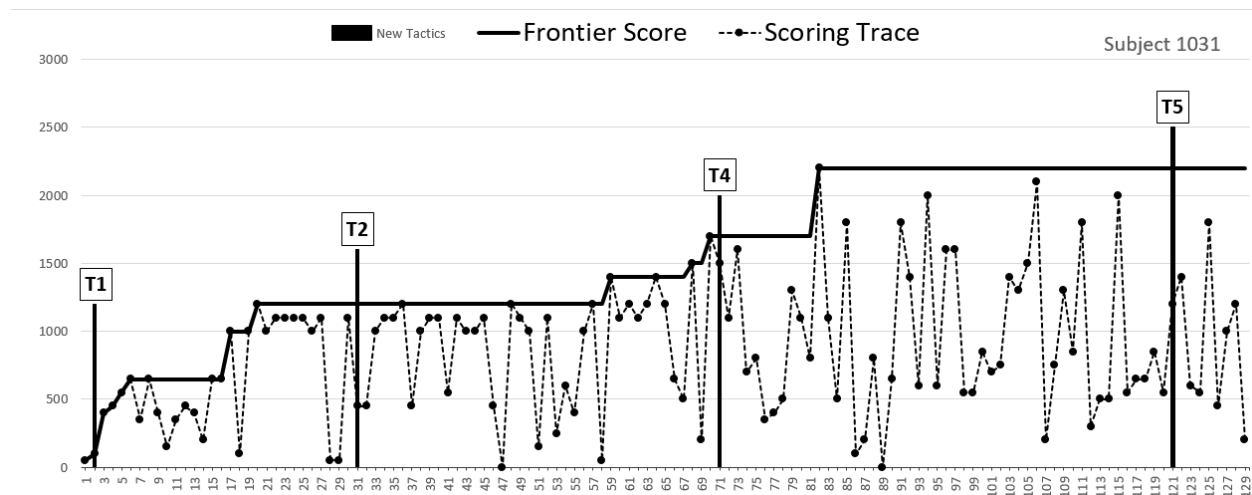
T3 = Discard

T4 = Loop

T5 = Extend

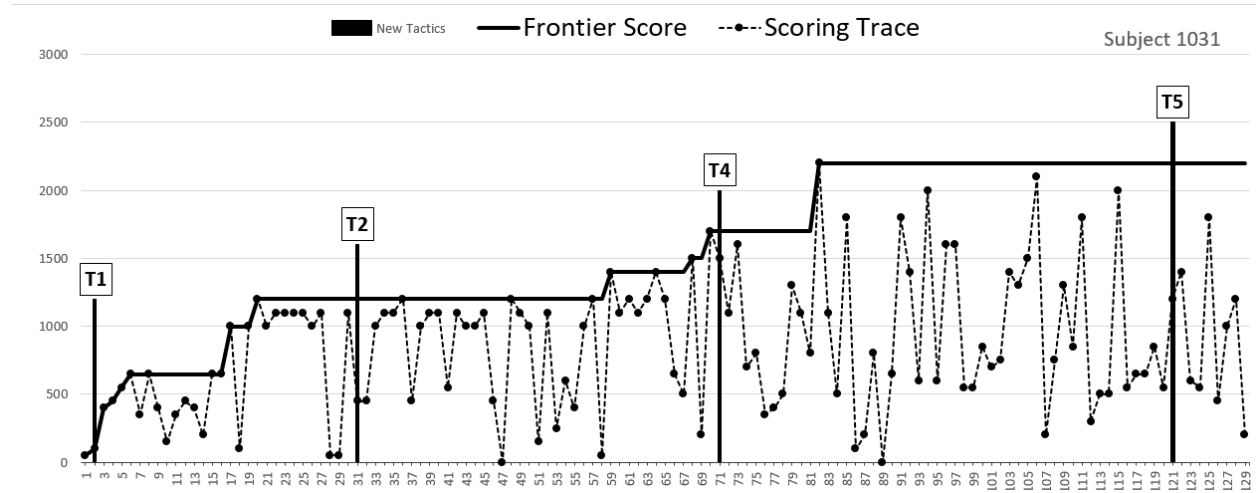
T6 = Play Ahead

T7 = Close Loop

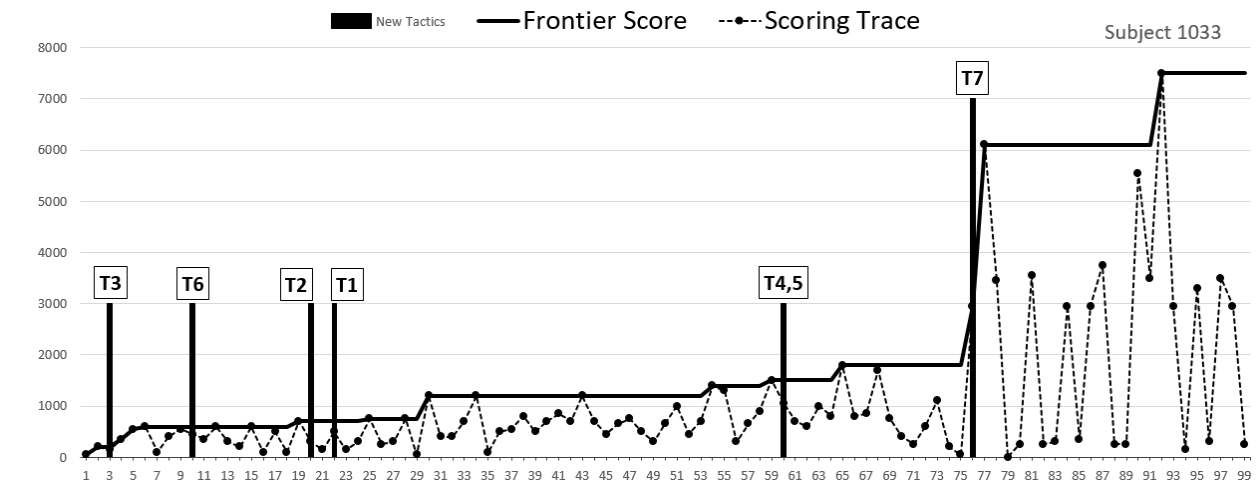


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1031

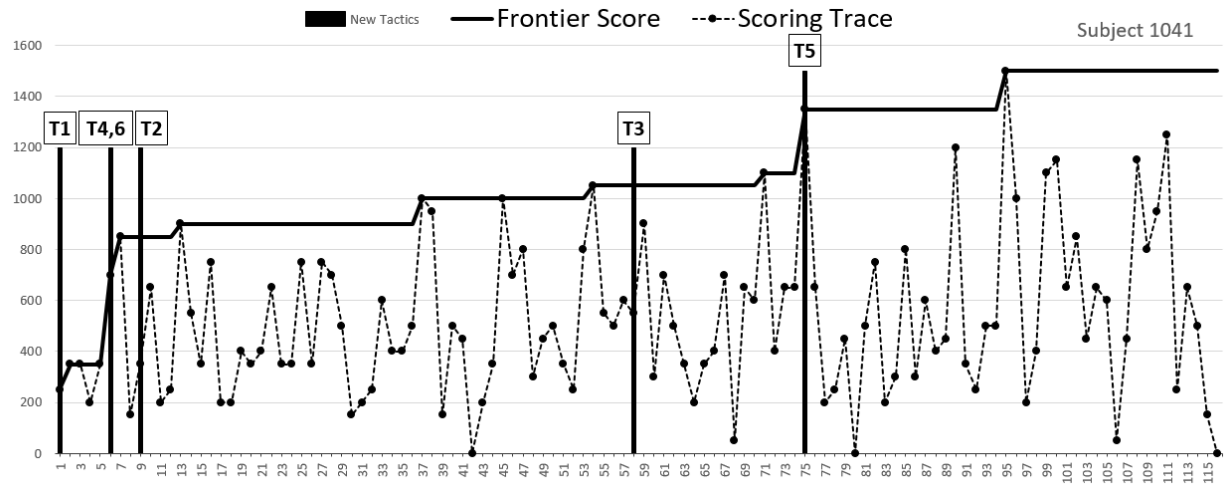
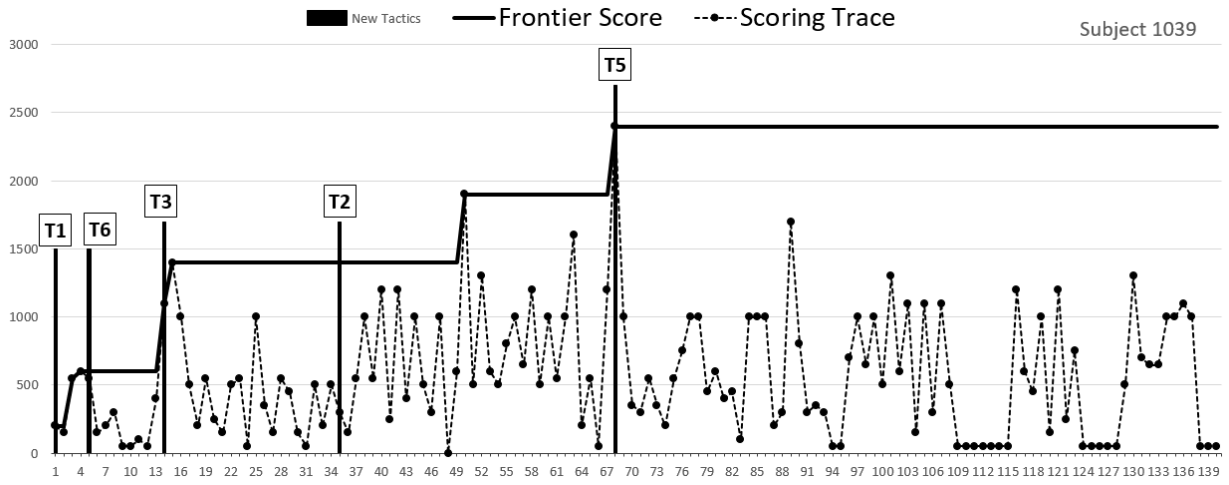


Study 2a – Subject Number 1033



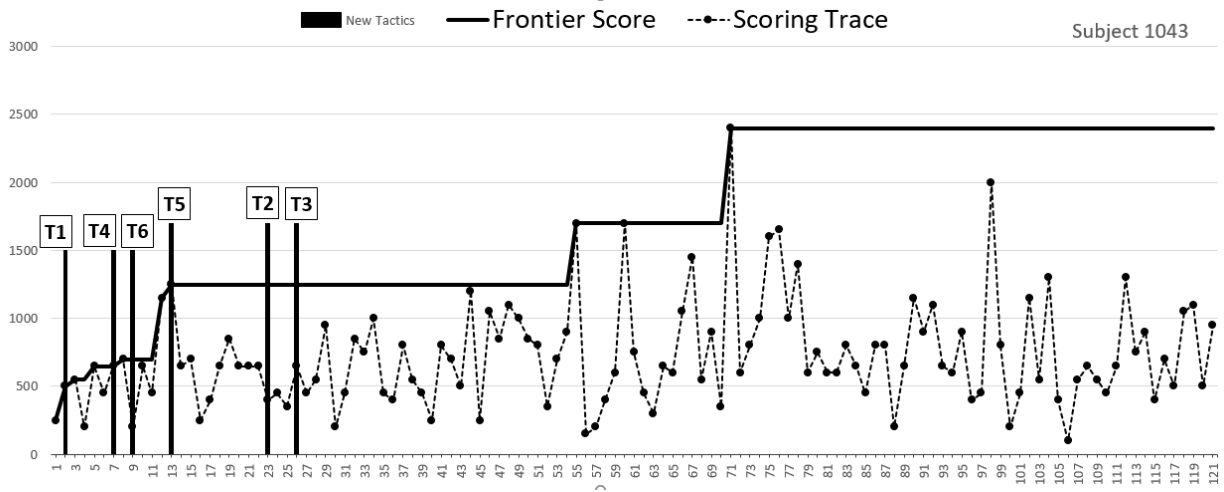
Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1039

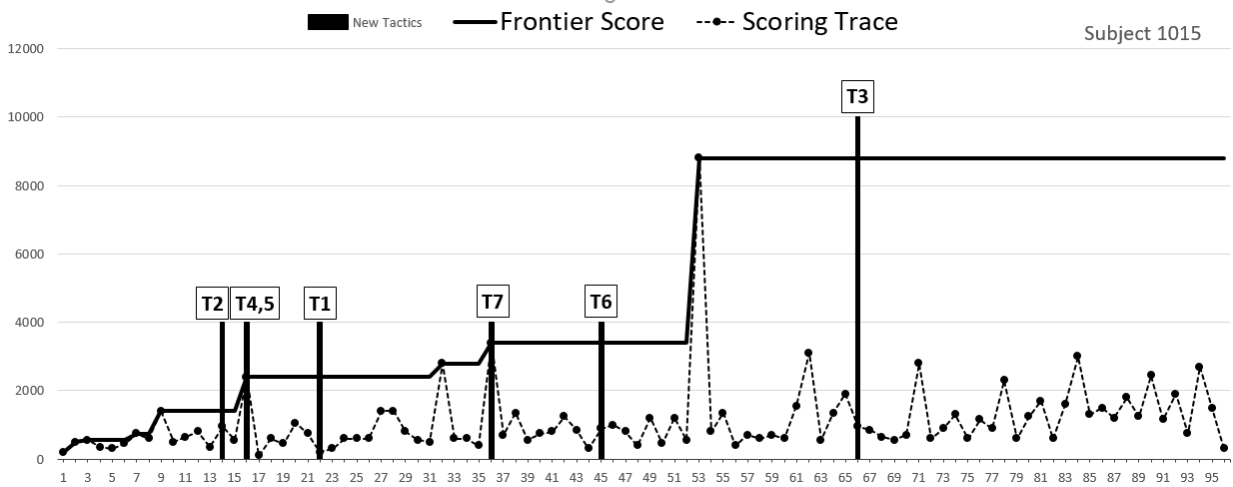


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1043

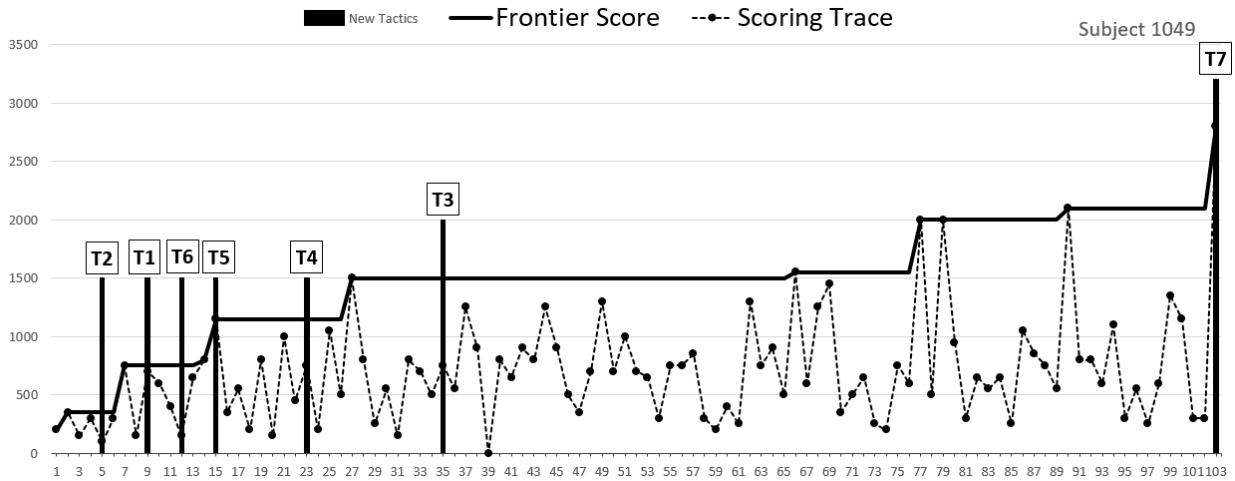


Study 2a – Subject Number 1015

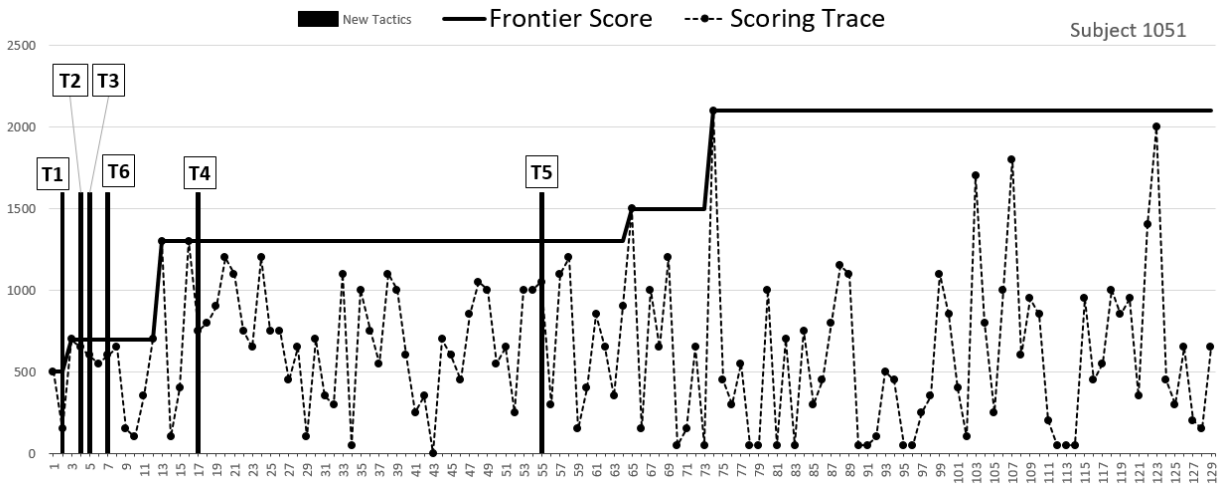


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a - Subject Number 1049

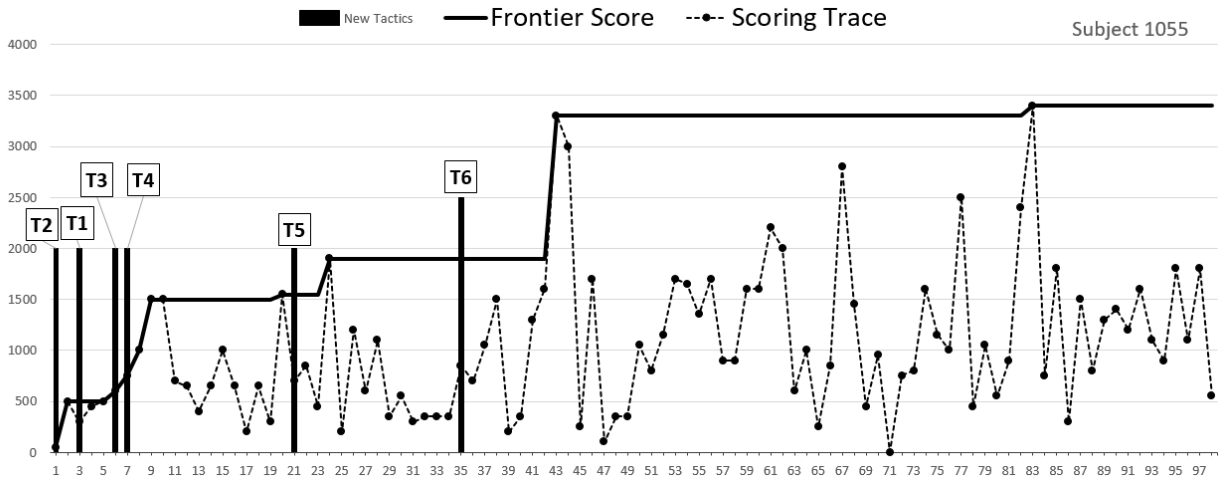


Study 2a - Subject Number 1051

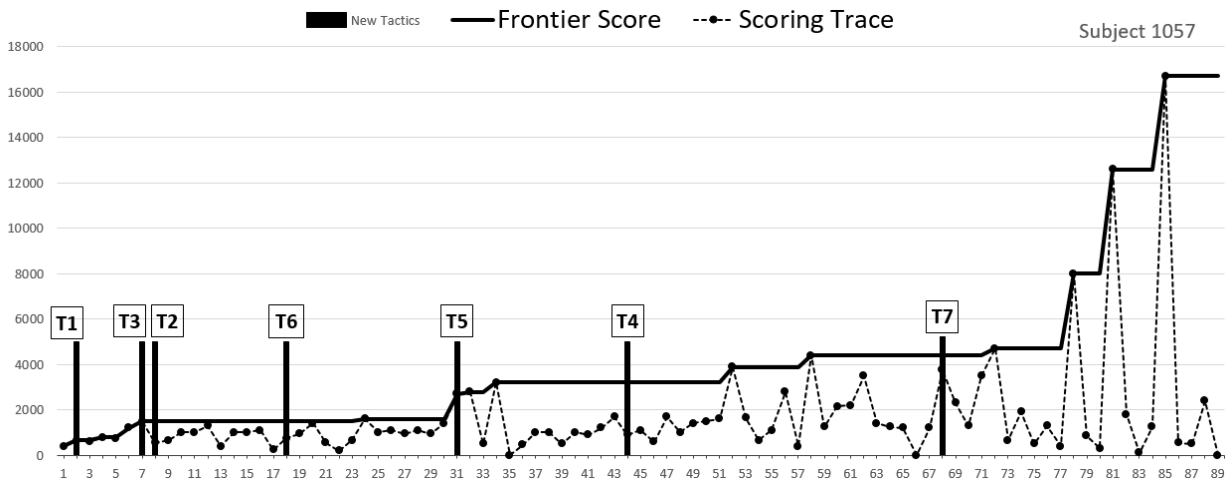


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1055

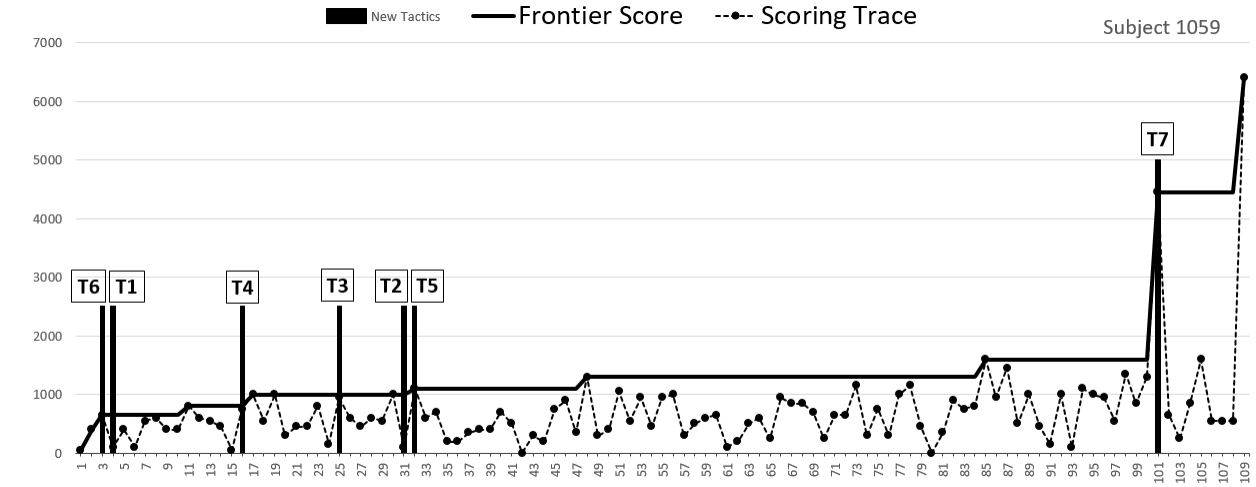


Study 2a – Subject Number 1057

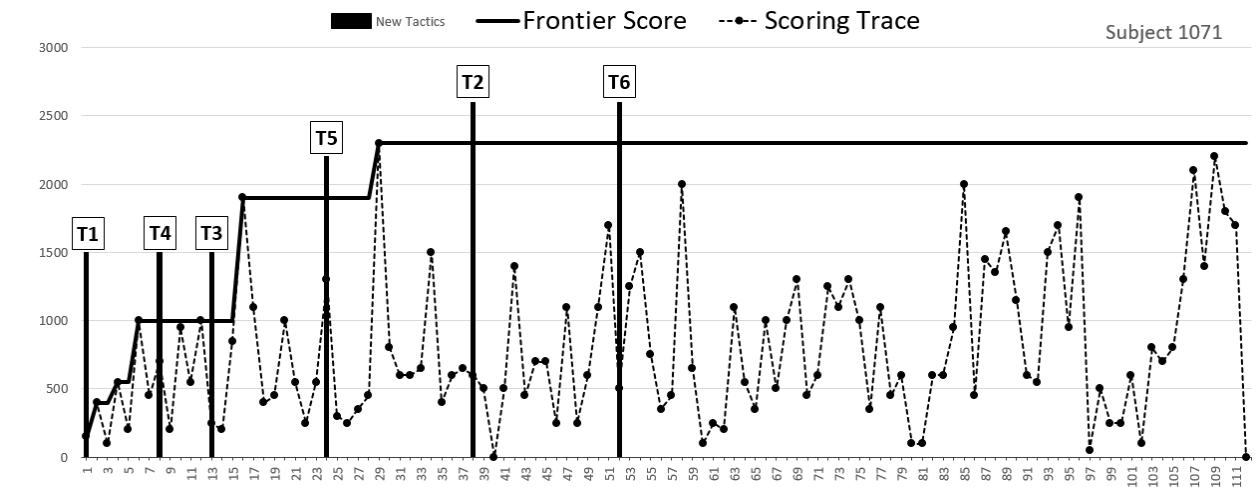


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1059

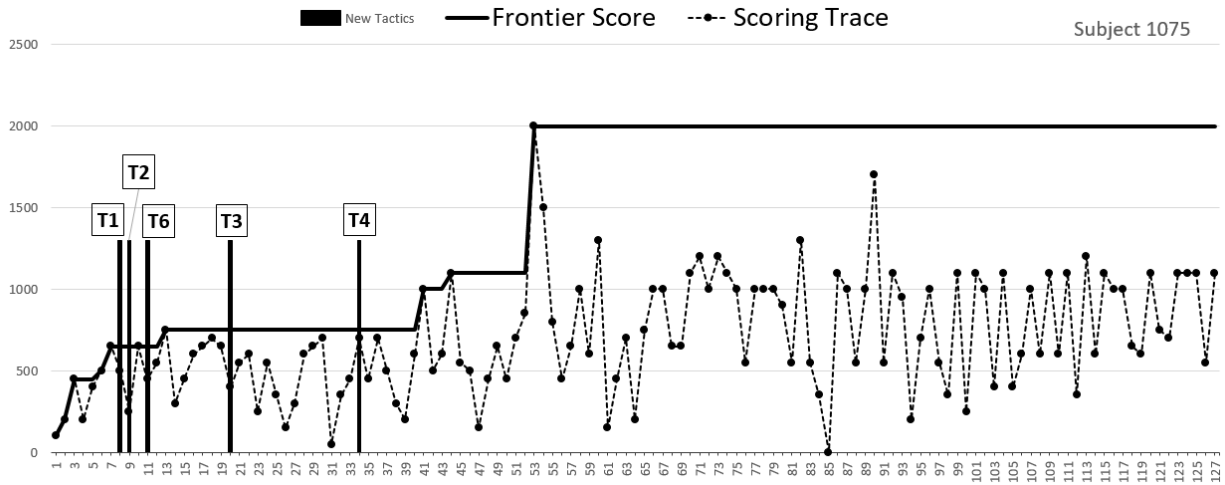


Study 2a – Subject Number 1071

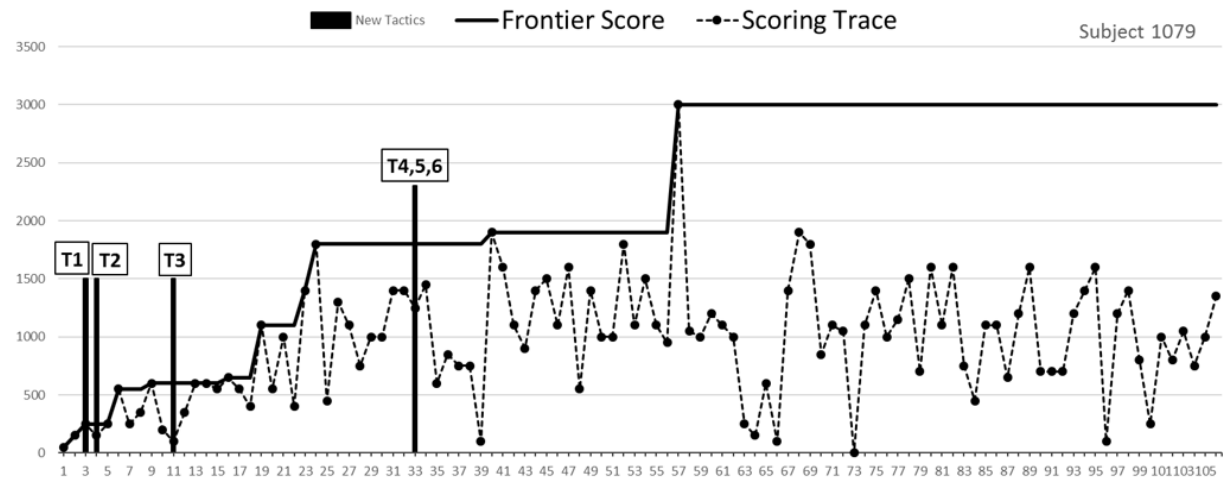


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1075

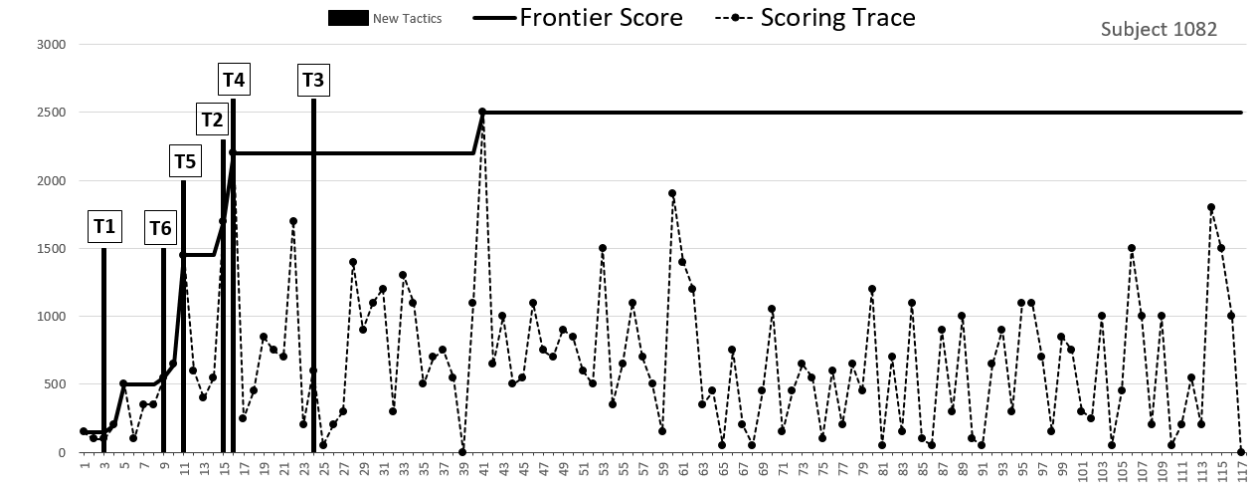


Study 2a – Subject Number 1079

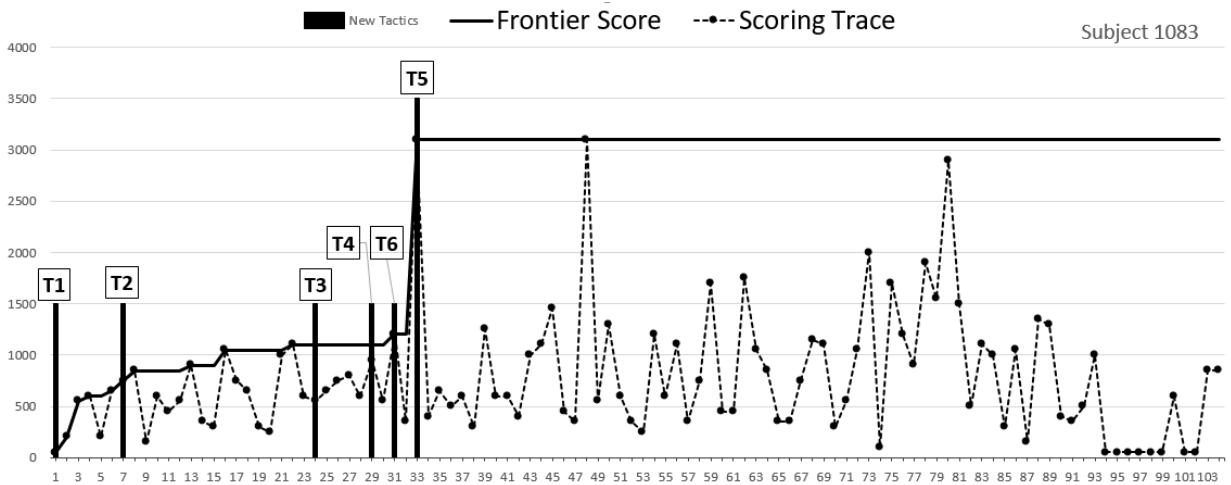


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1082

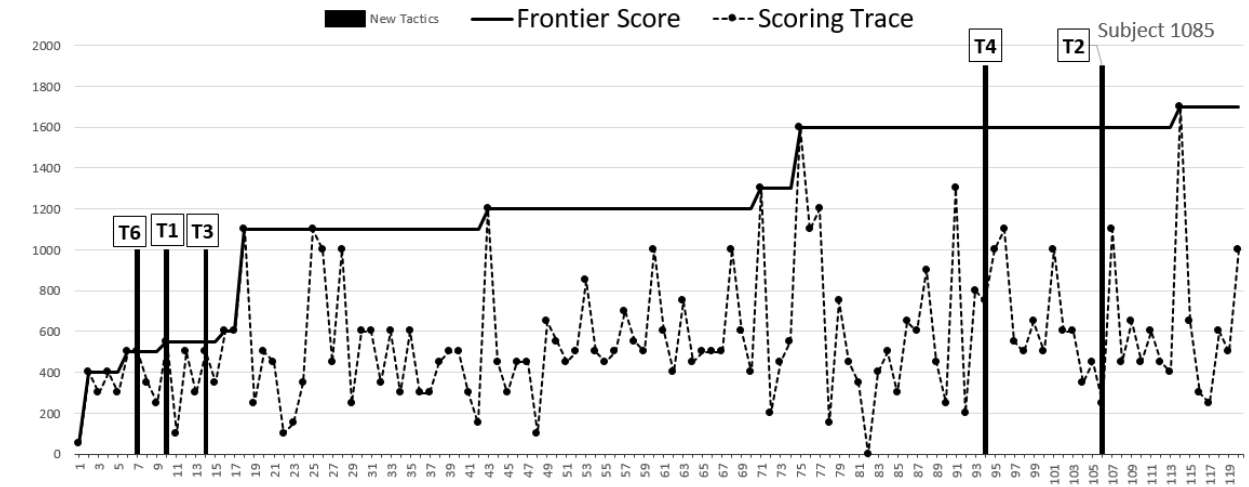


Study 2a – Subject Number 1083

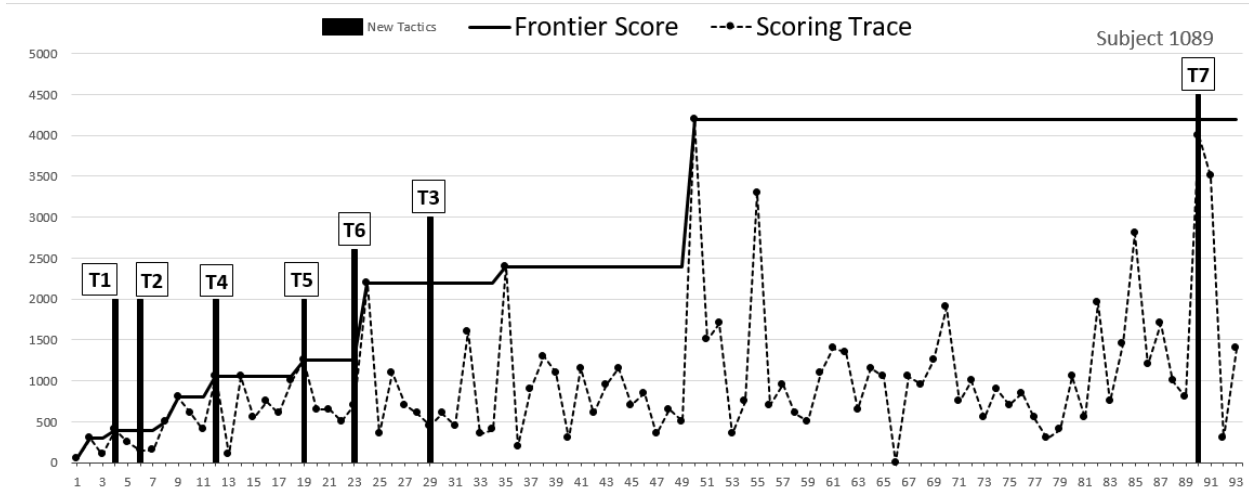


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1085

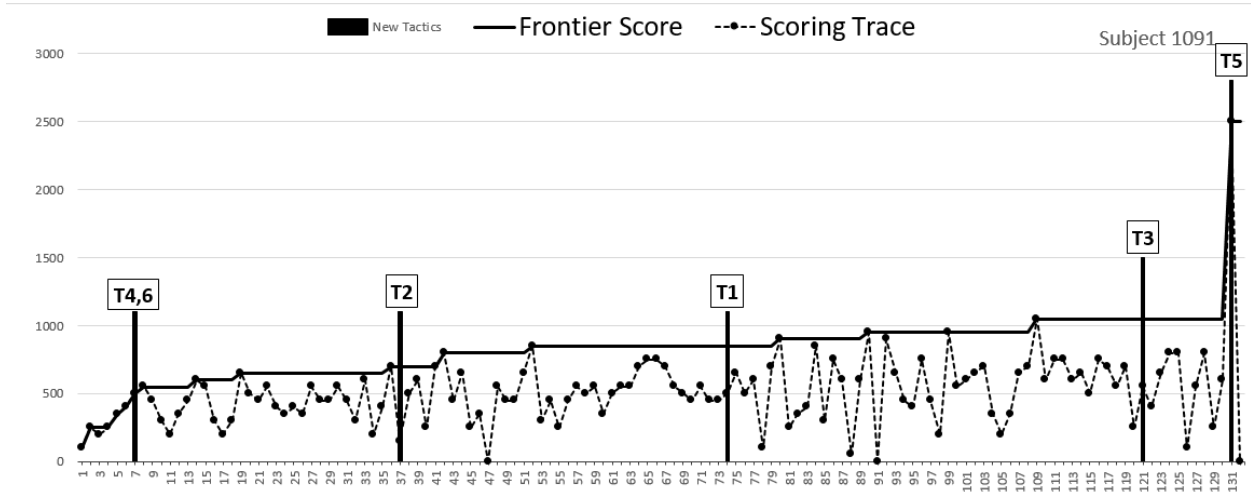


Study 2a – Subject Number 1089

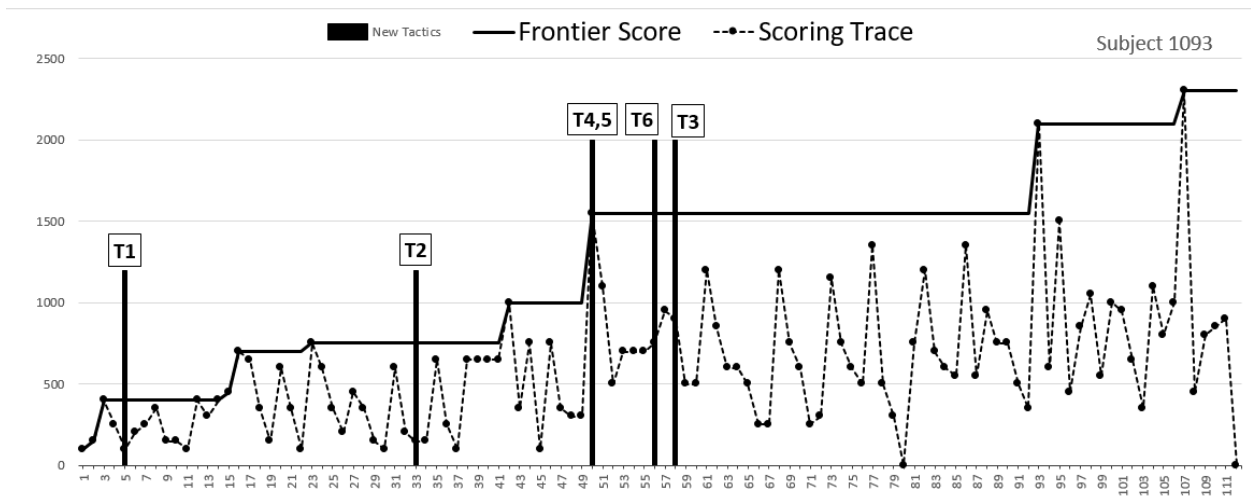


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1091

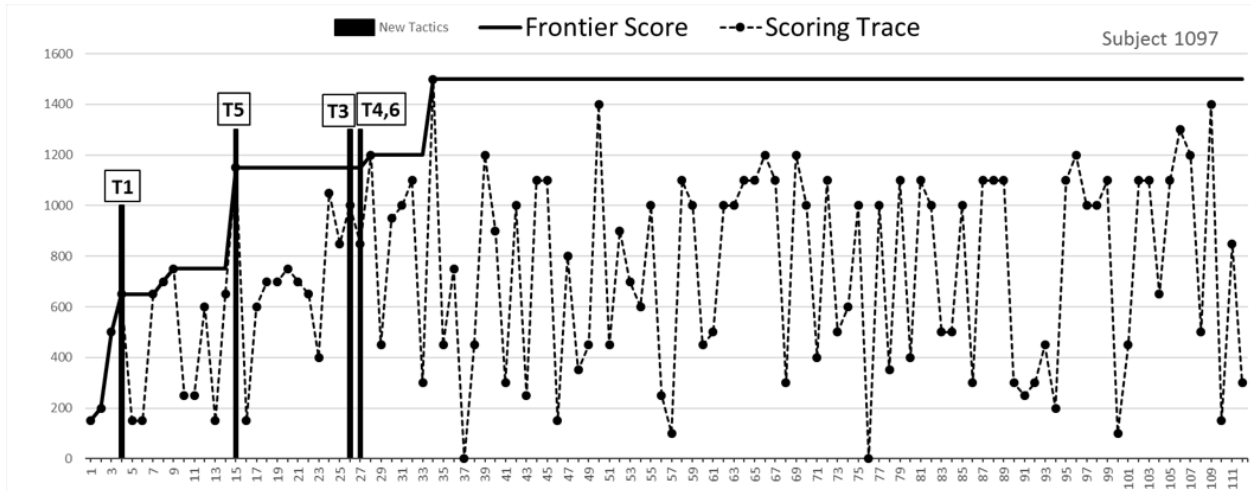


Study 2a - Subject Number 1093

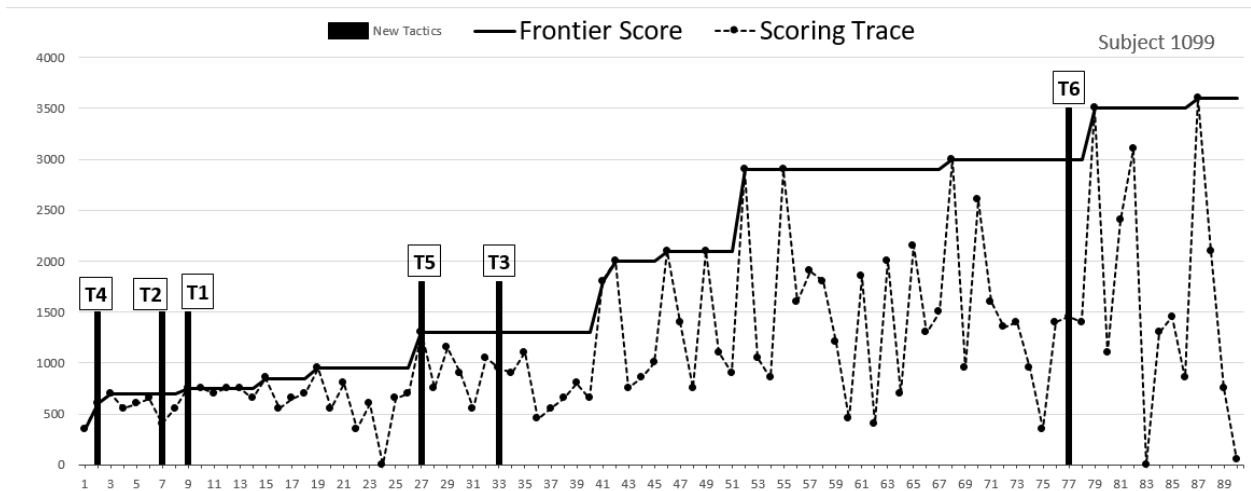


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1097

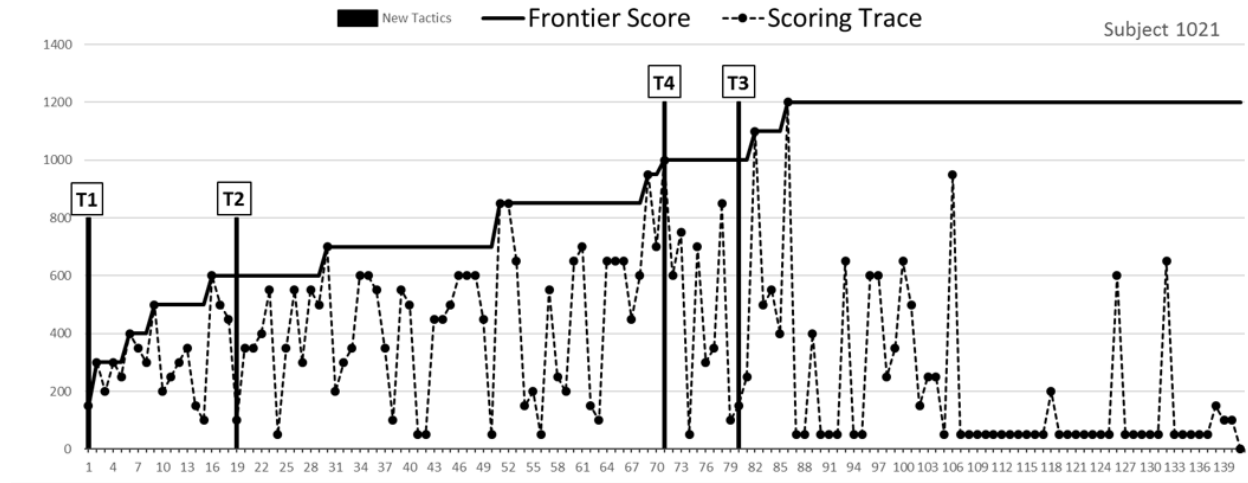


Study 2a – Subject Number 1099

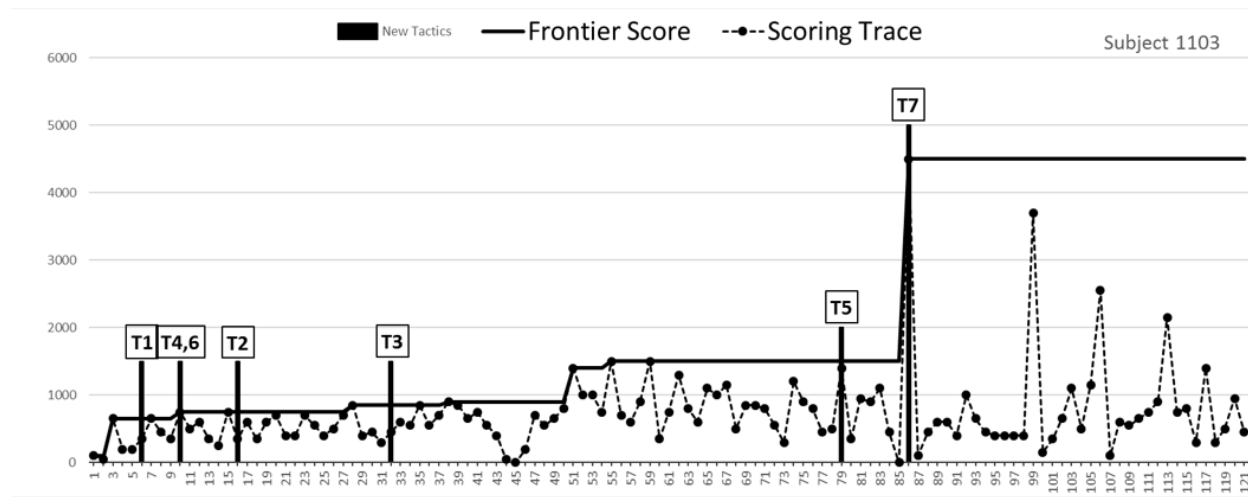


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1021

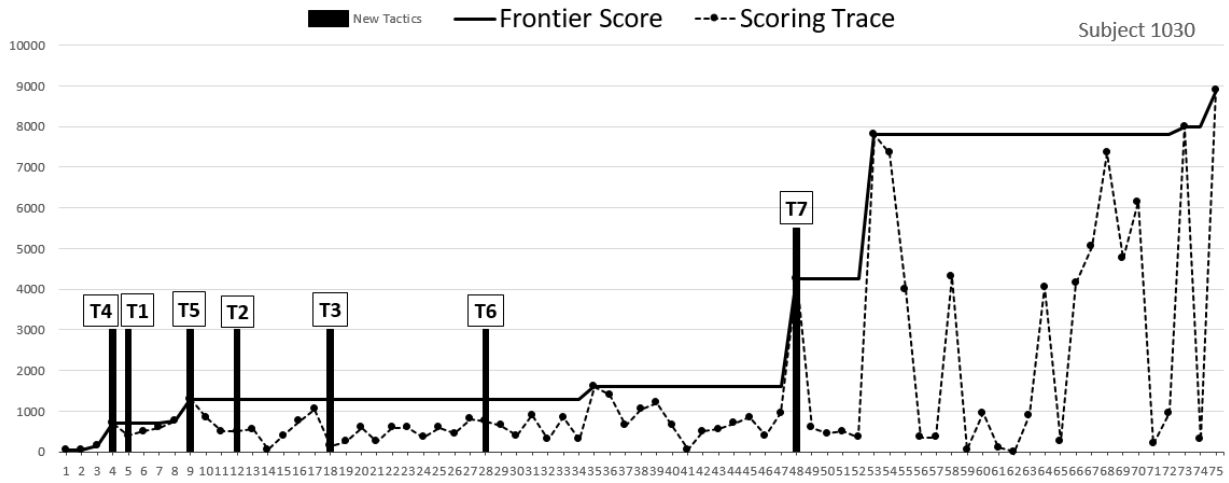


Study 2a – Subject Number 1103

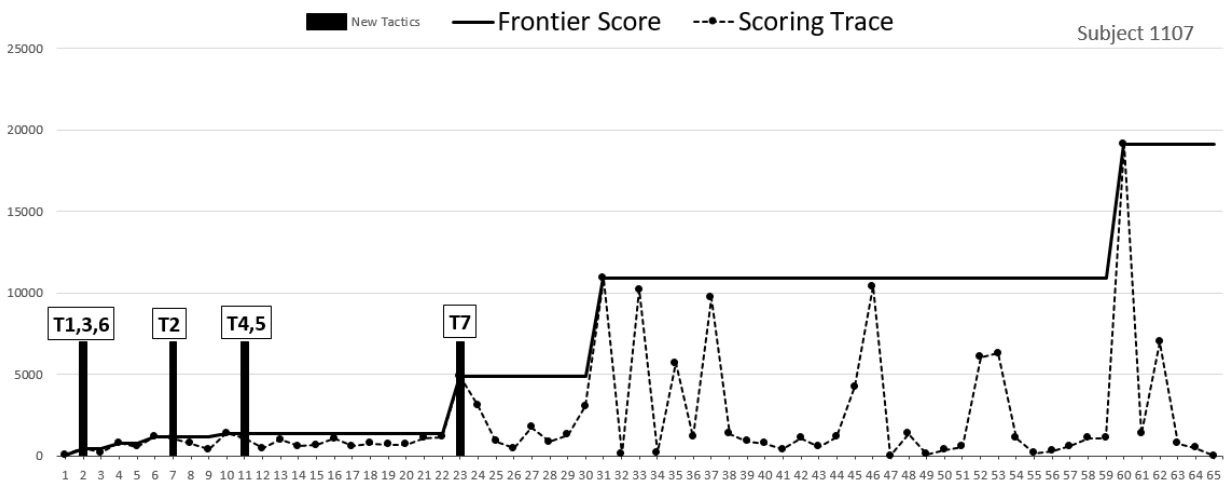


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a - Subject Number 1030

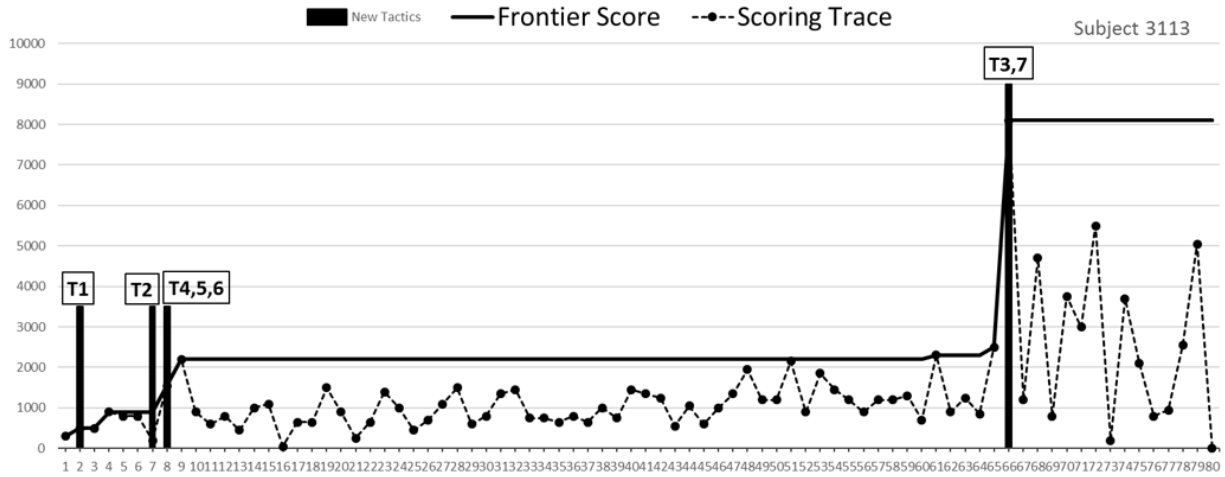


Study 2a – Subject Number 1107

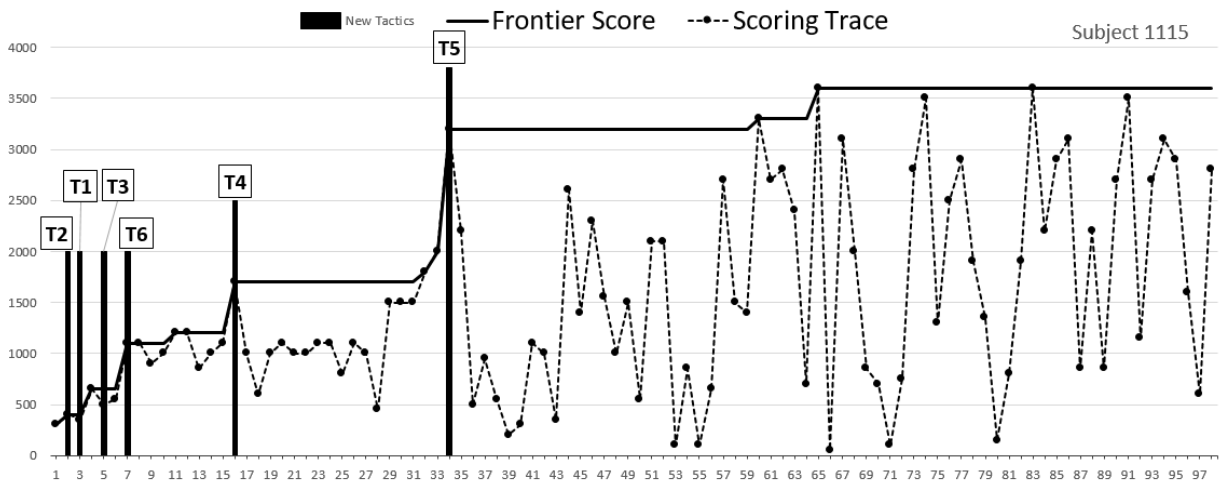


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 3113

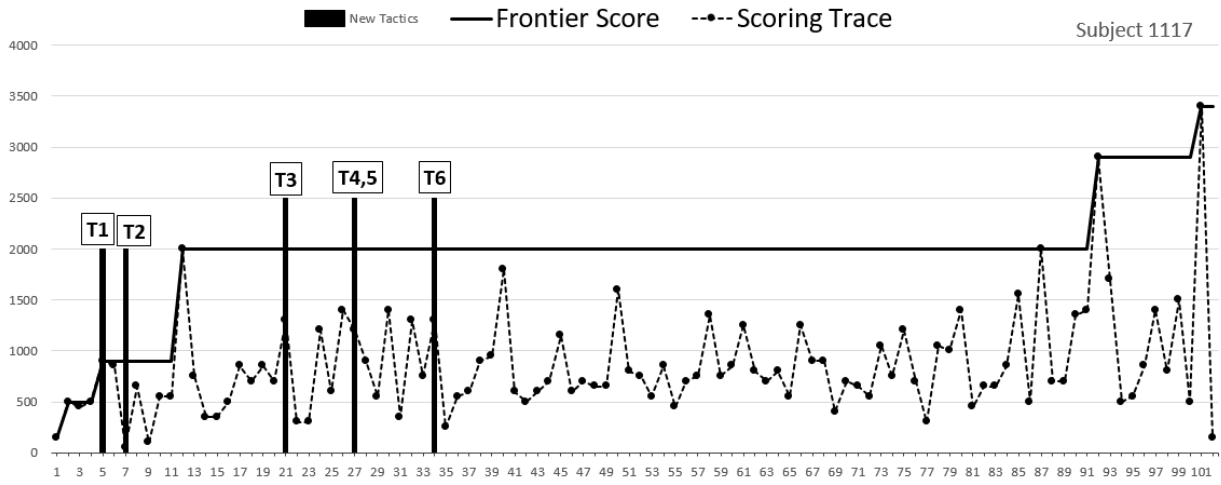


Study 2a – Subject Number 1115

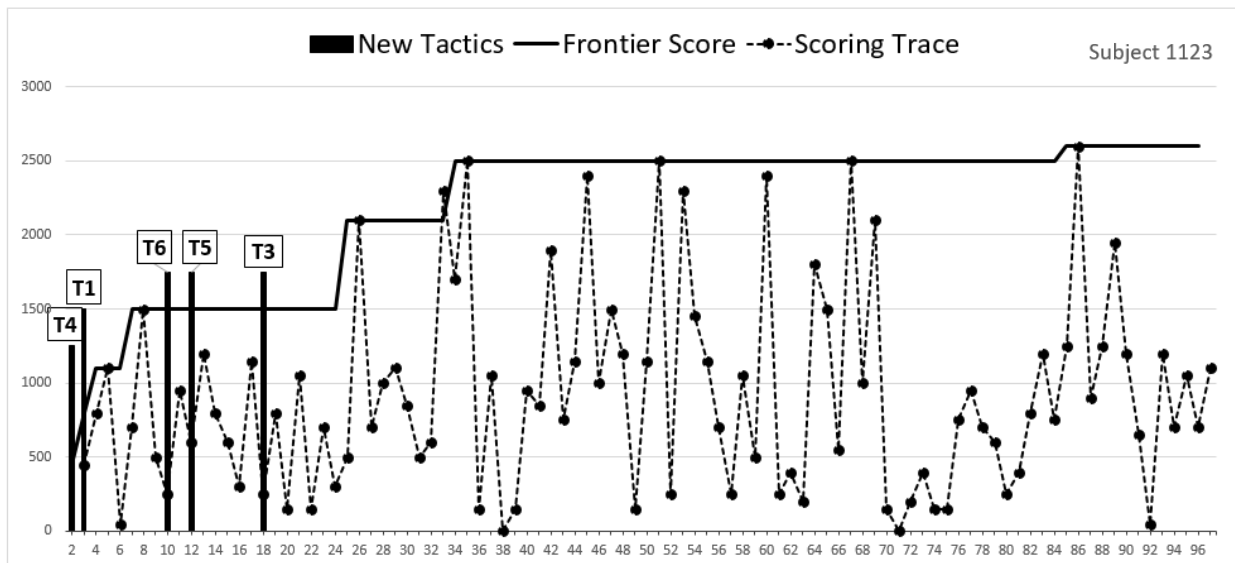


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1117

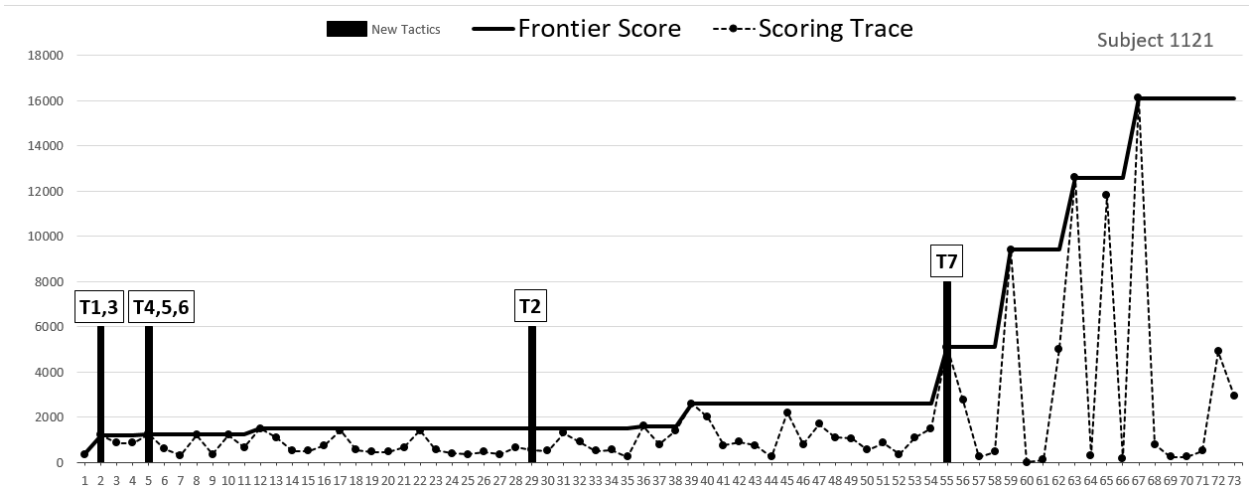


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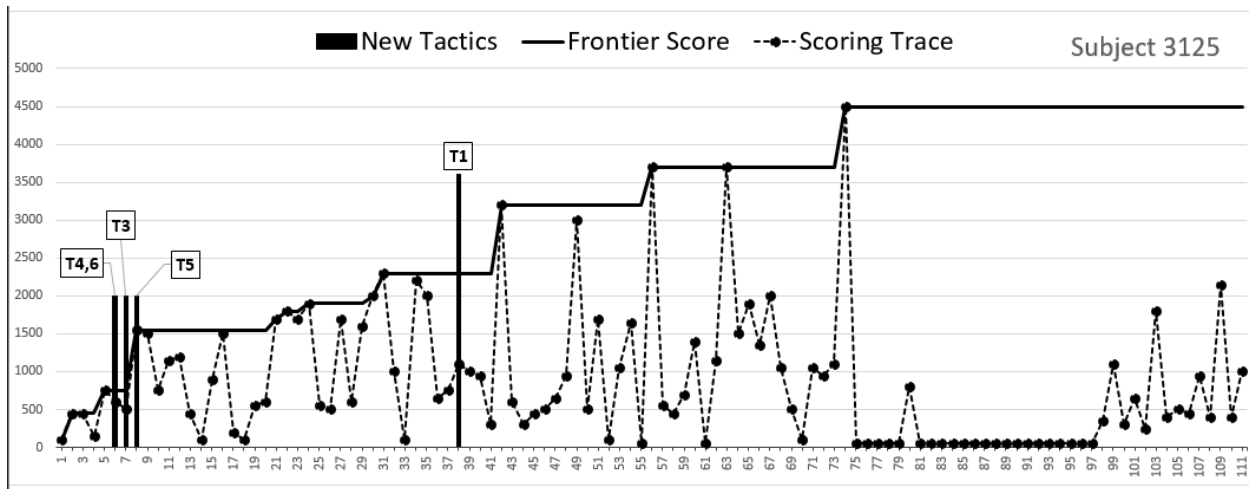


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1121

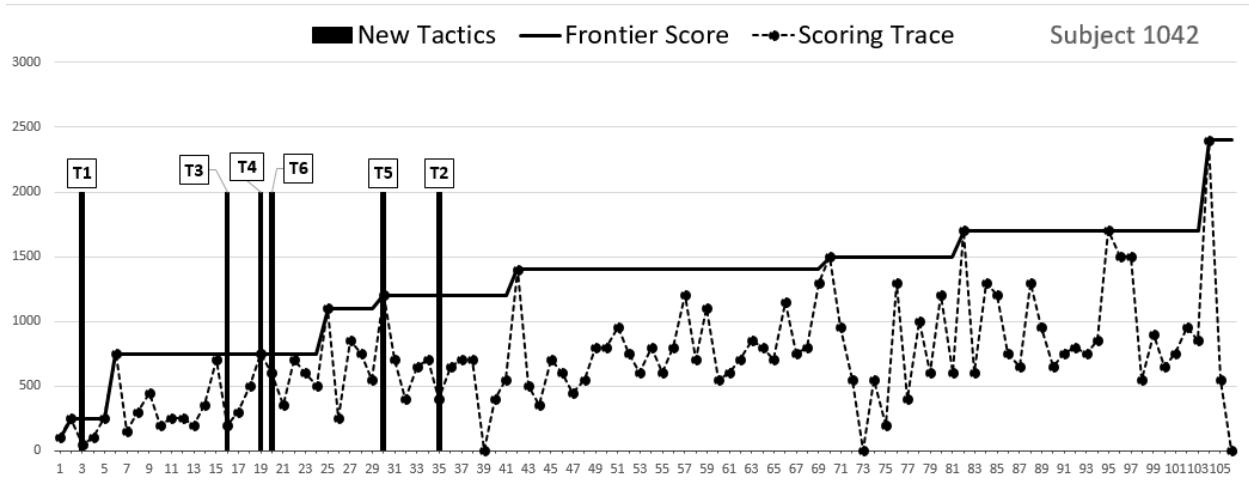


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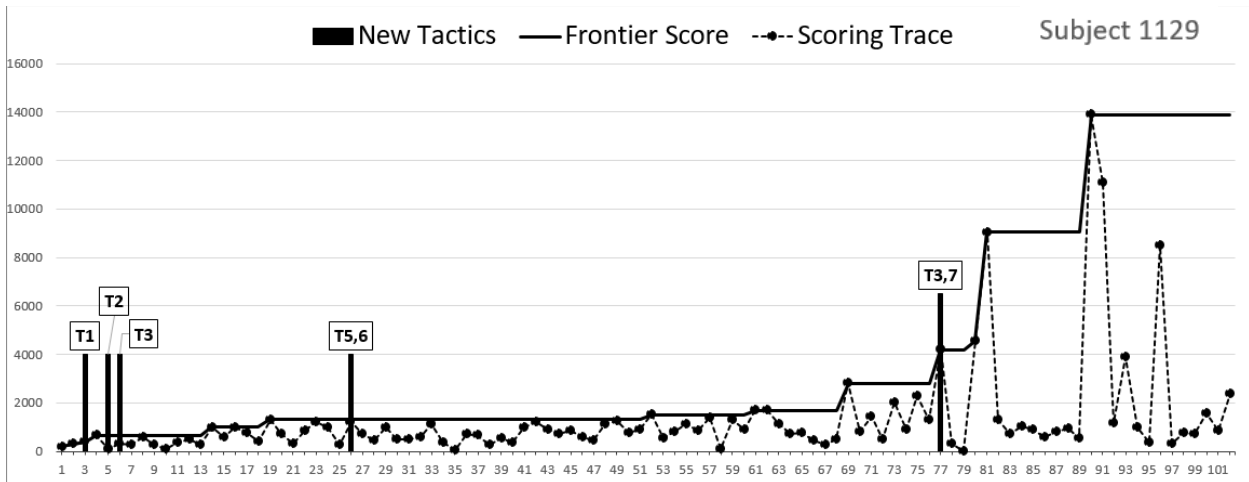


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1042

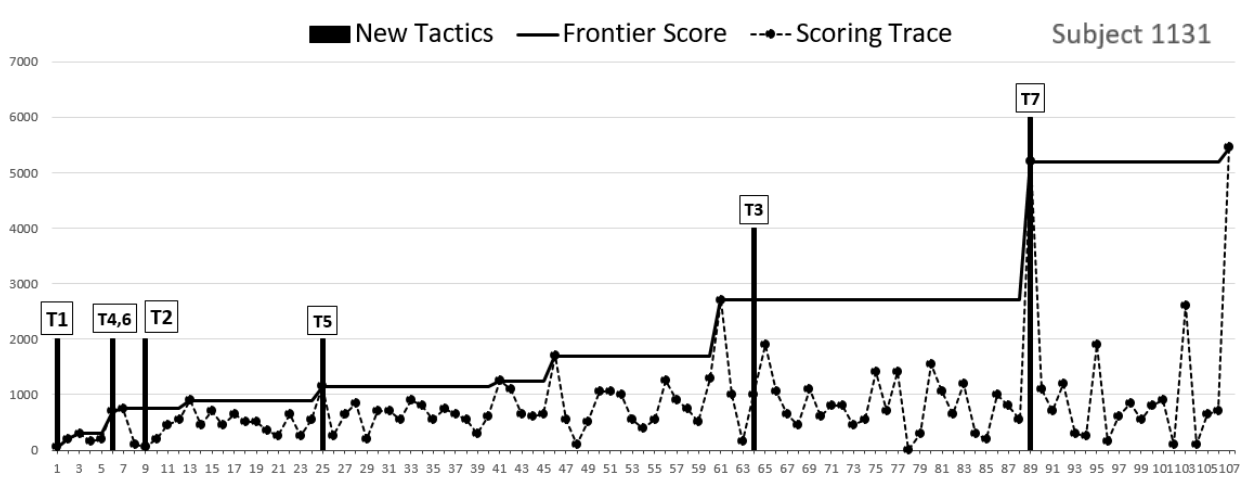


Study 2a – Subject Number 1129

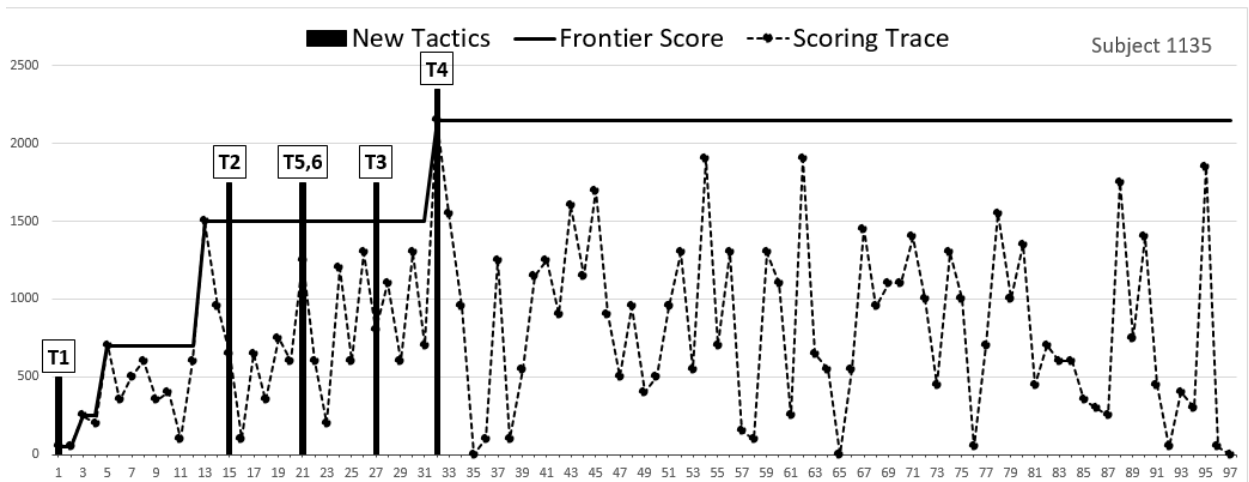


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1131

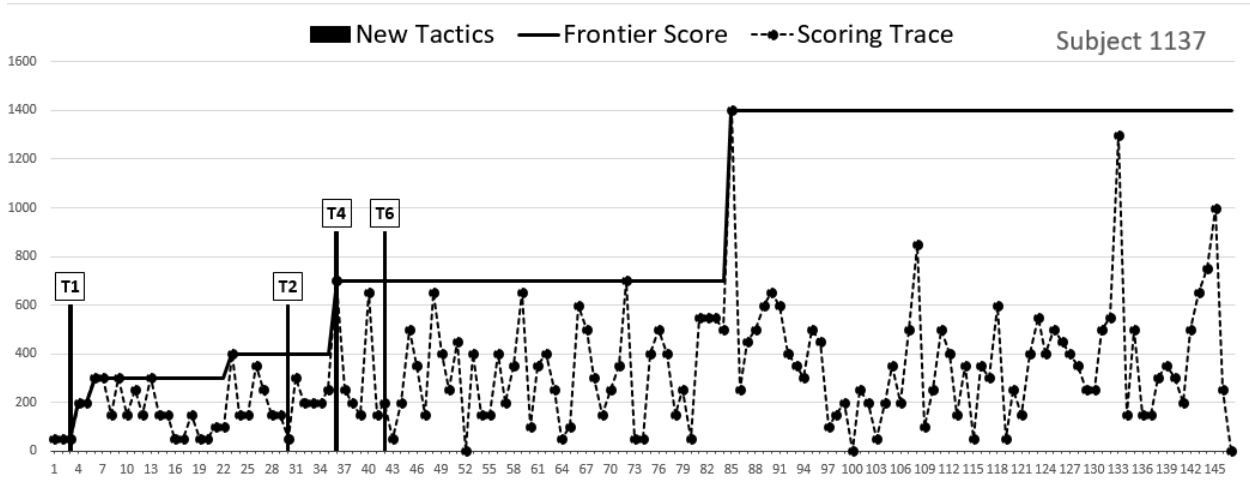


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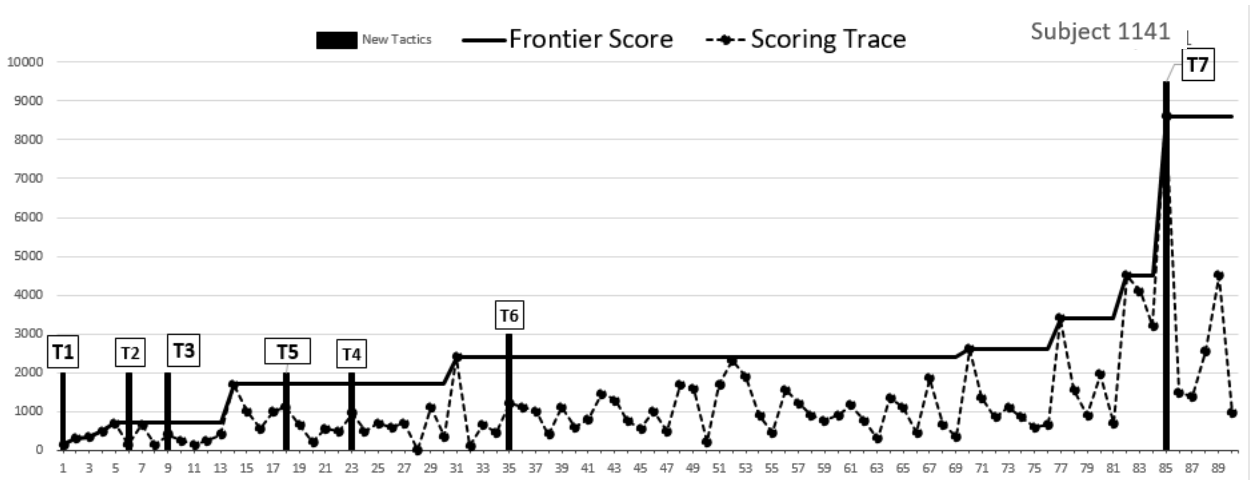


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1137

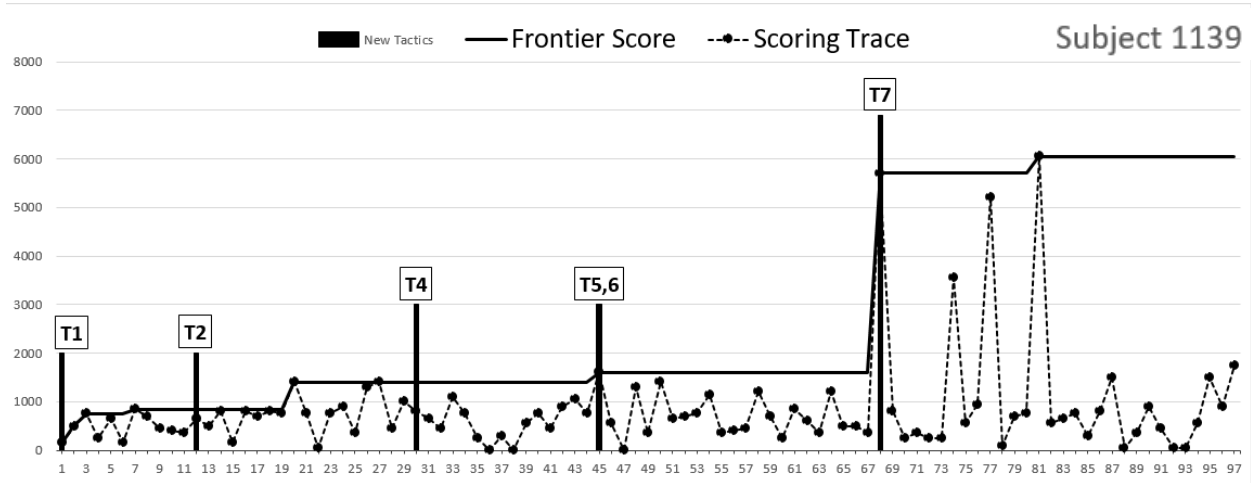


Study 2a – Subject Number 1141

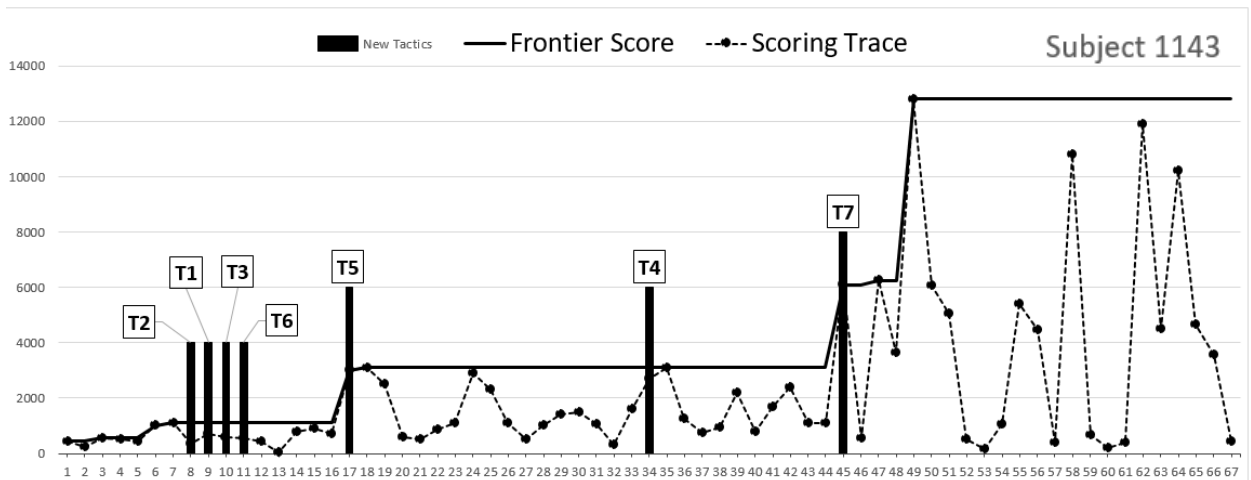


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1139

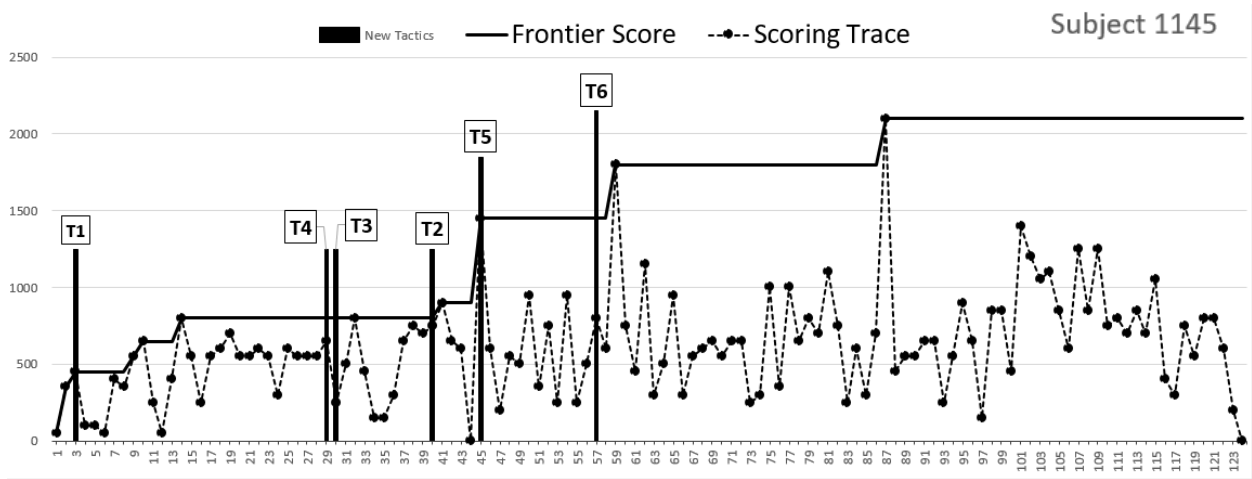


Study 2a – Subject Number 1143

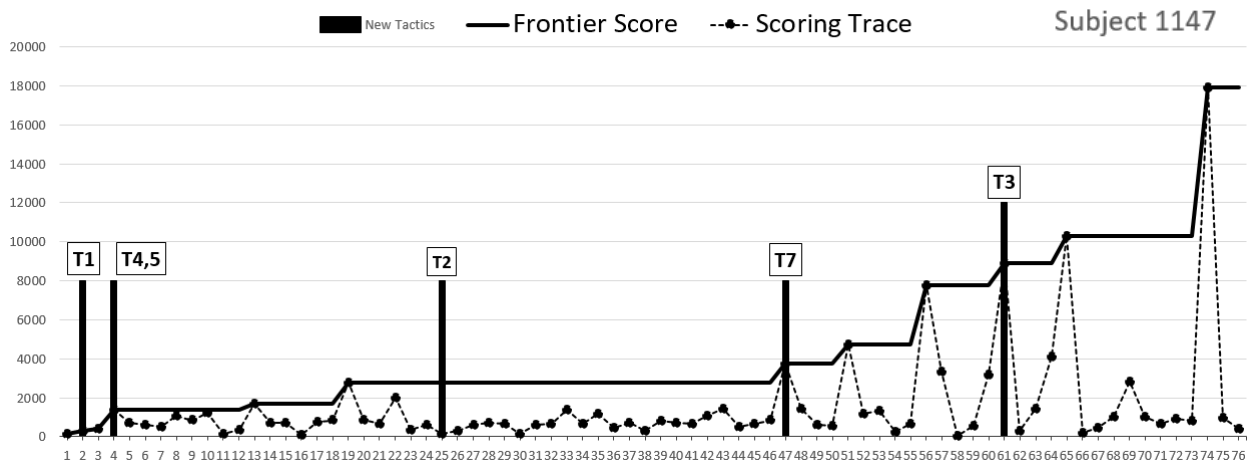


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1145

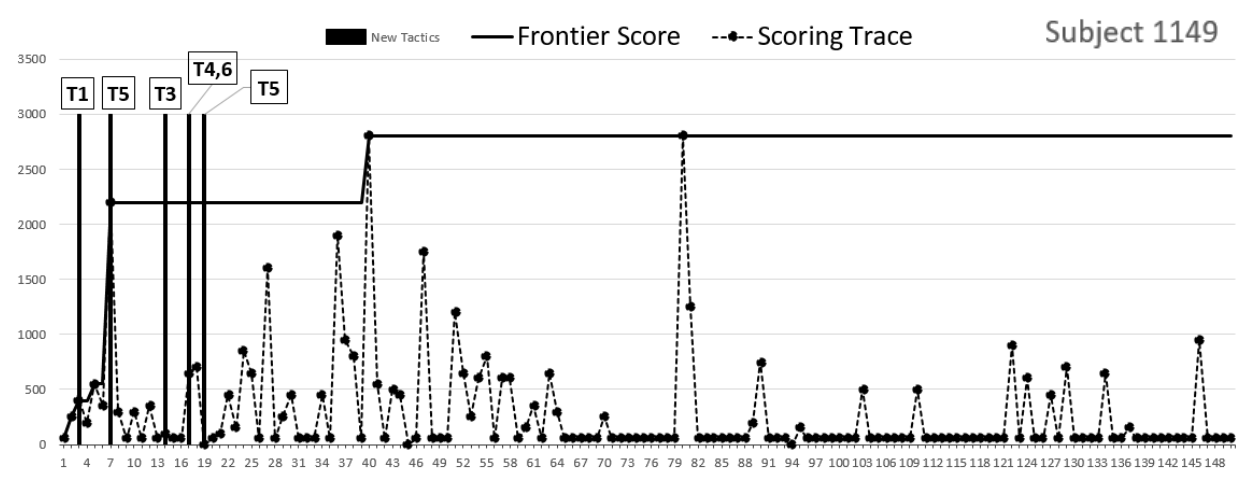


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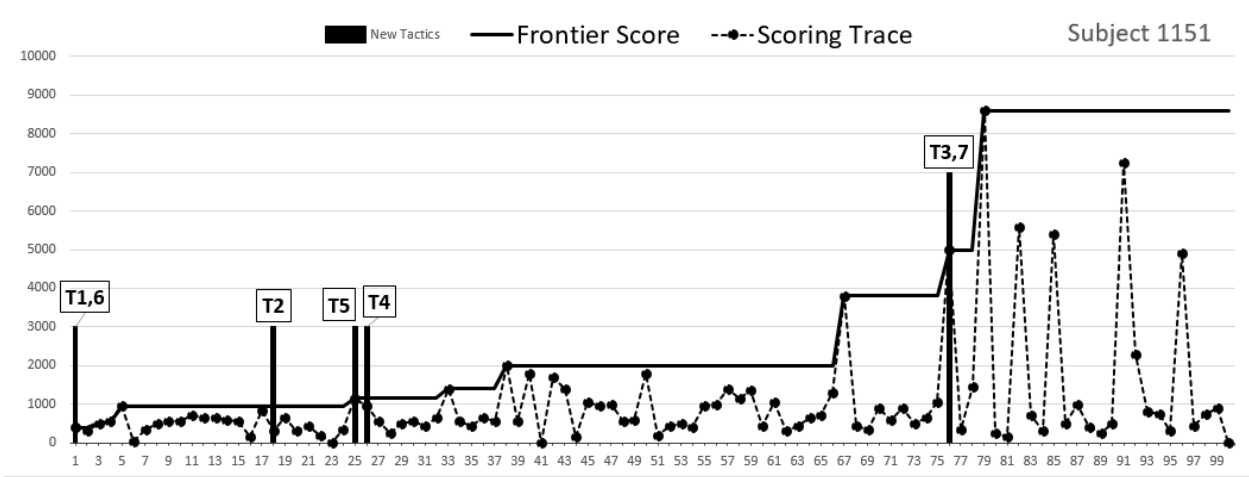


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1149

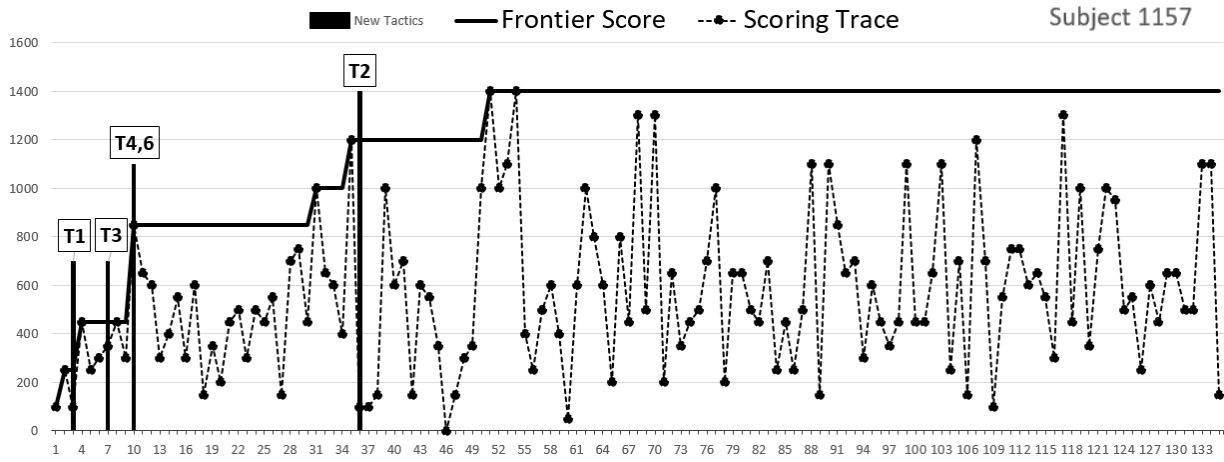


Study 2a – Subject Number 1151

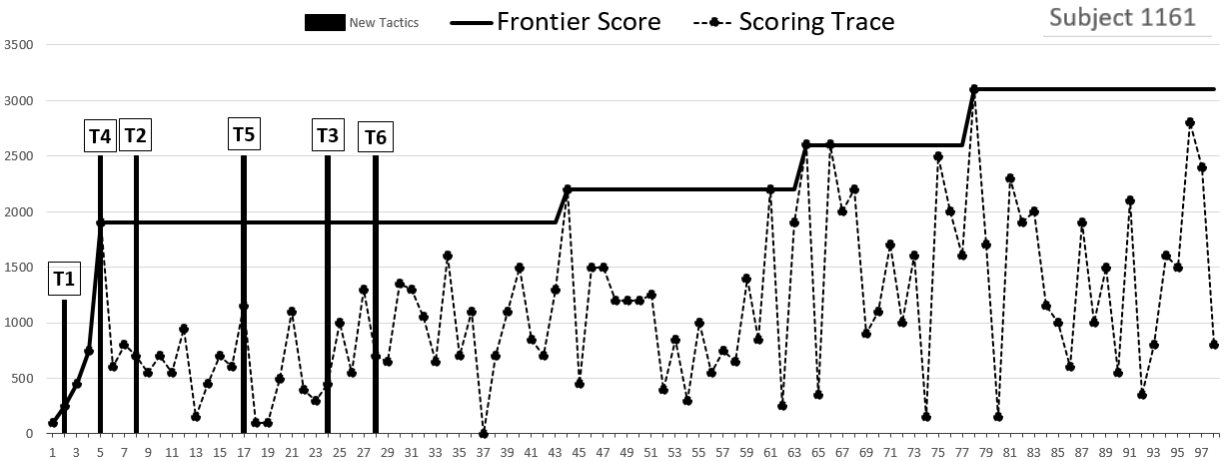


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1157

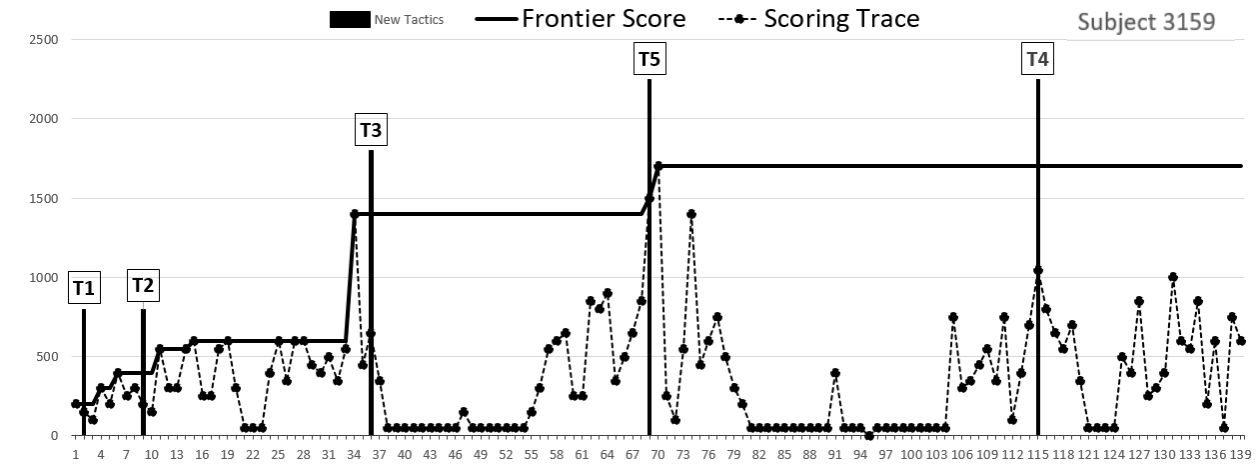


Study 2a – Subject Number 1161

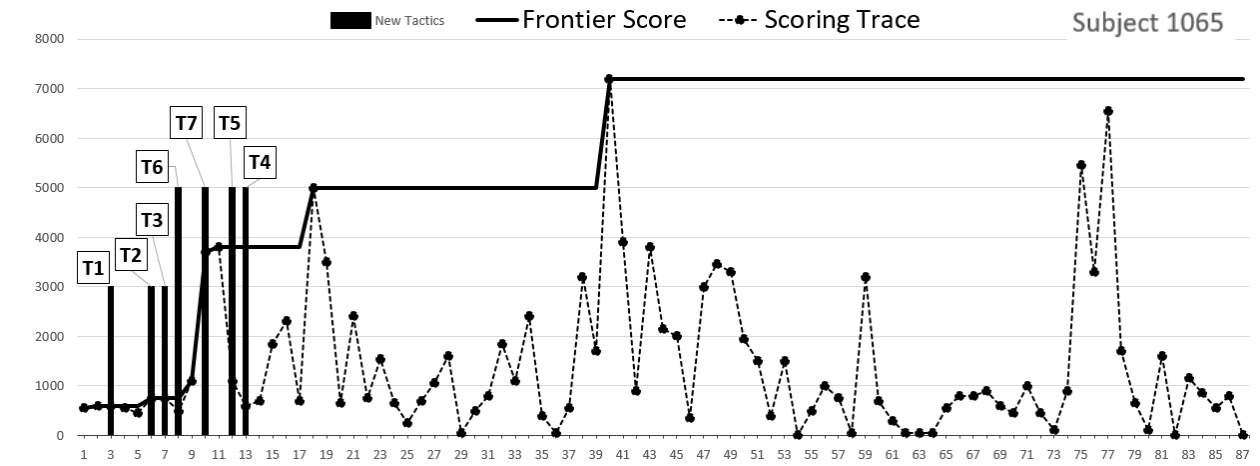


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 3159

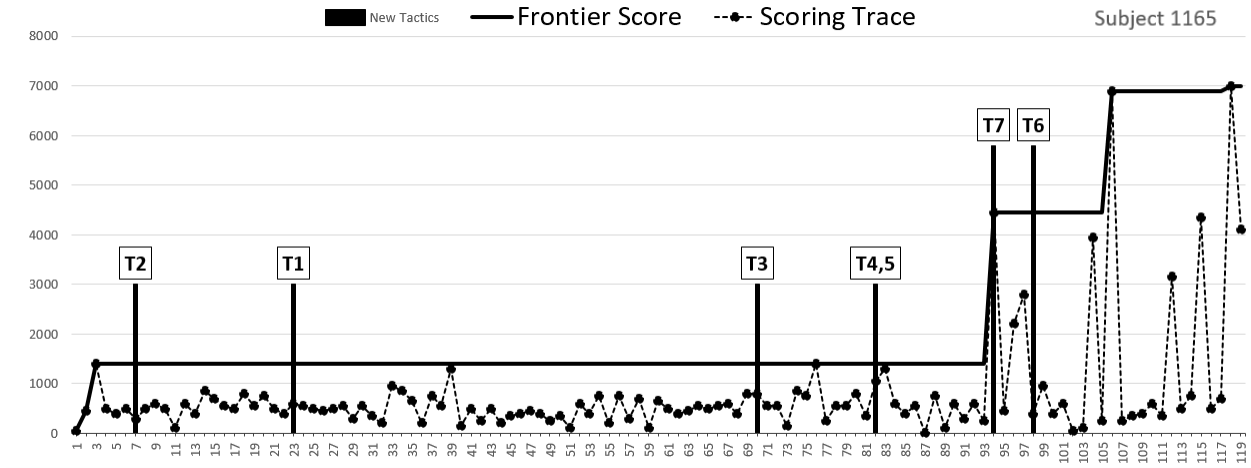


Study 2a – Subject Number 1065

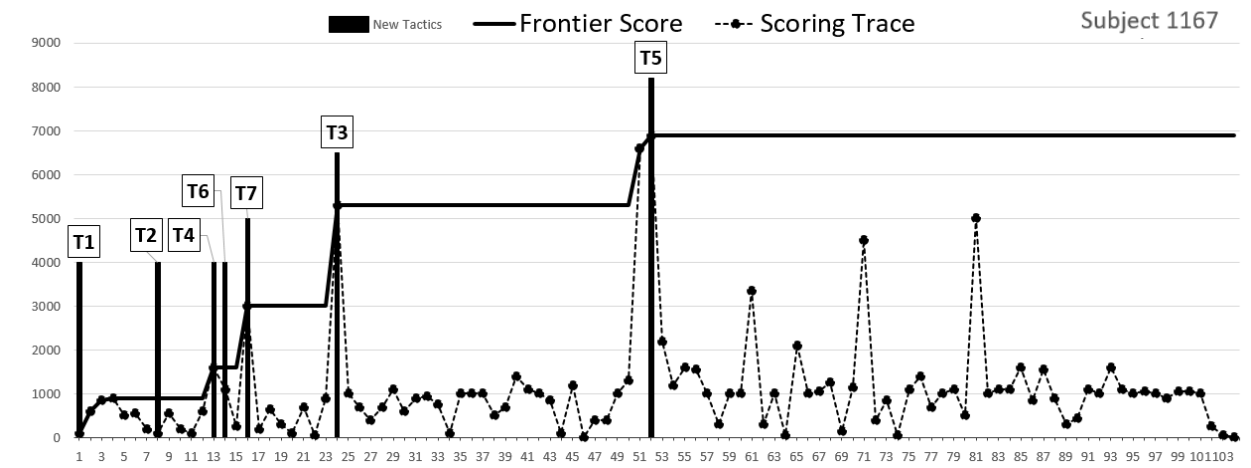


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1165

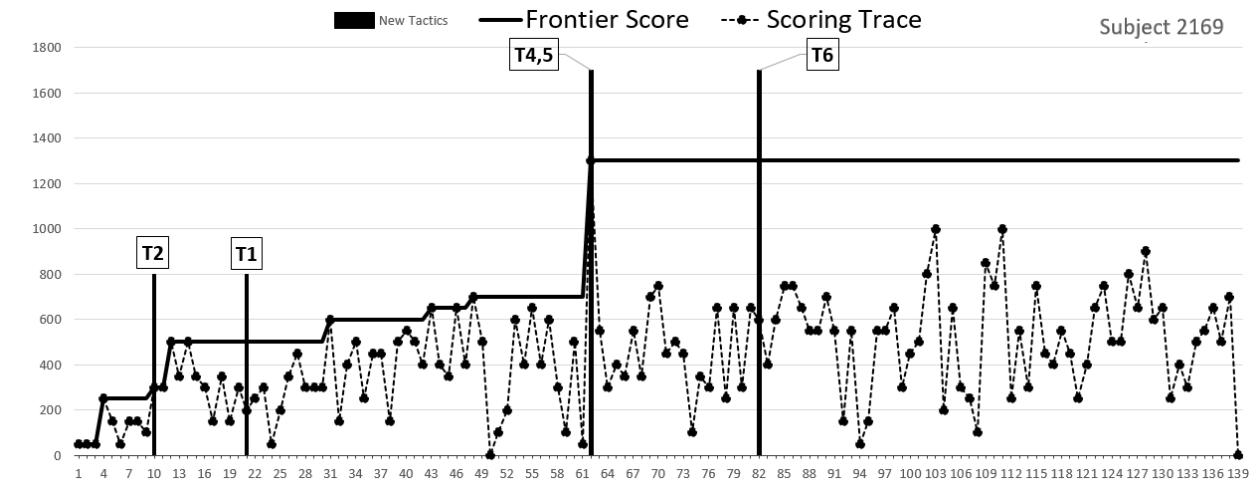


Study 2a – Subject Number 1167

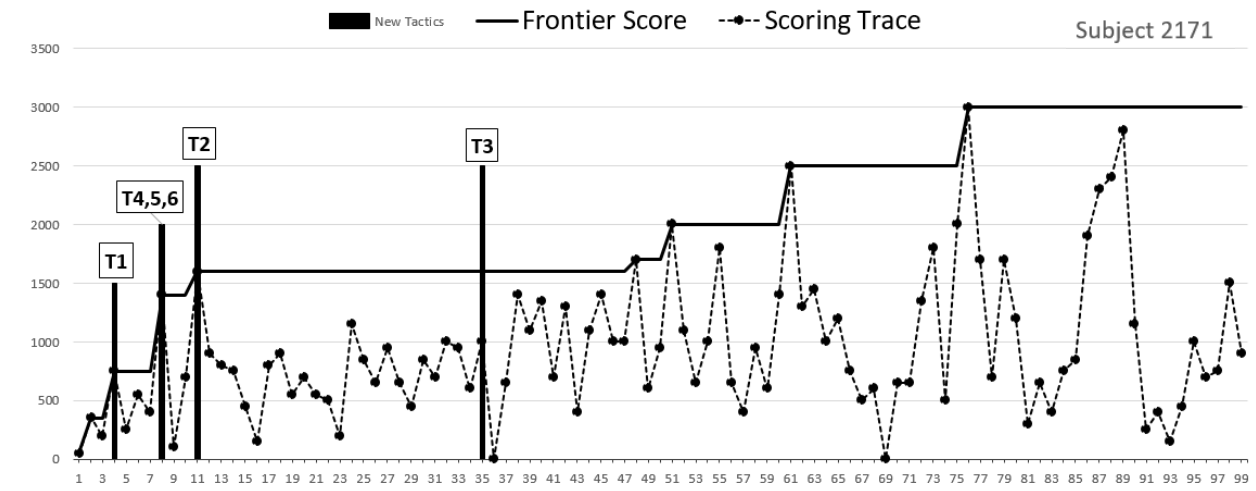


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2169

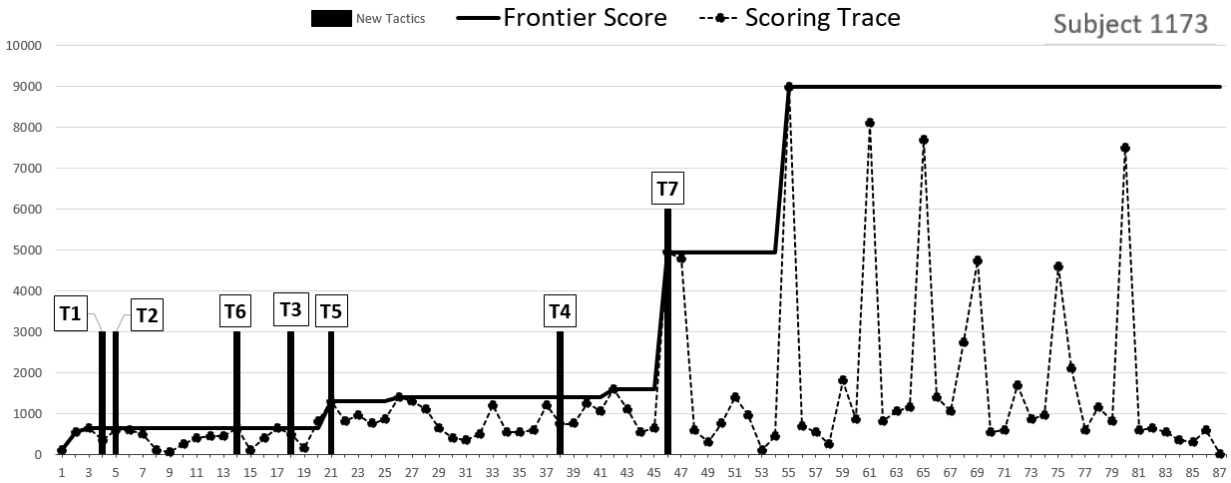


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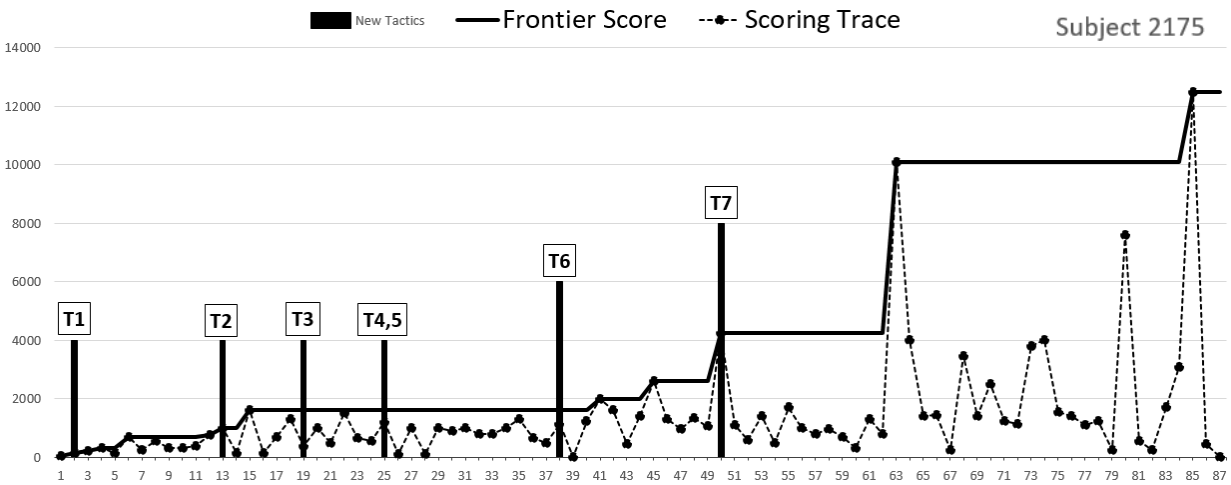


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1173

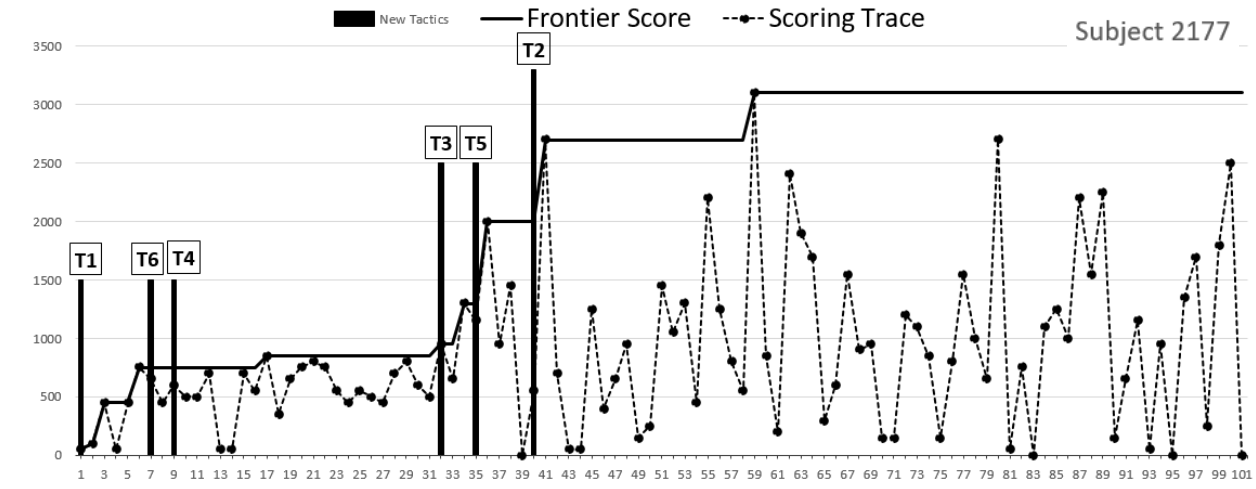


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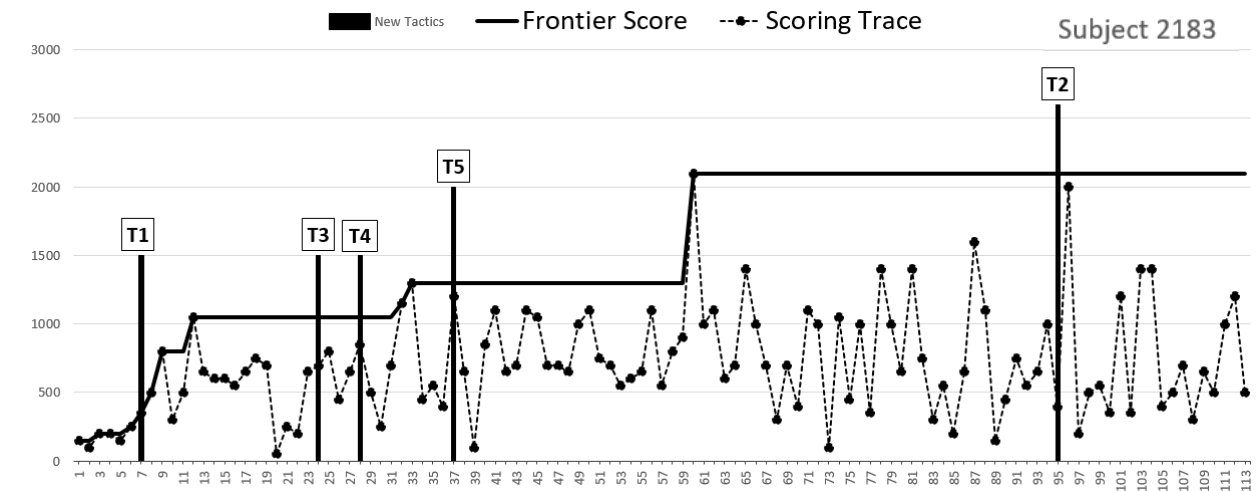


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2177

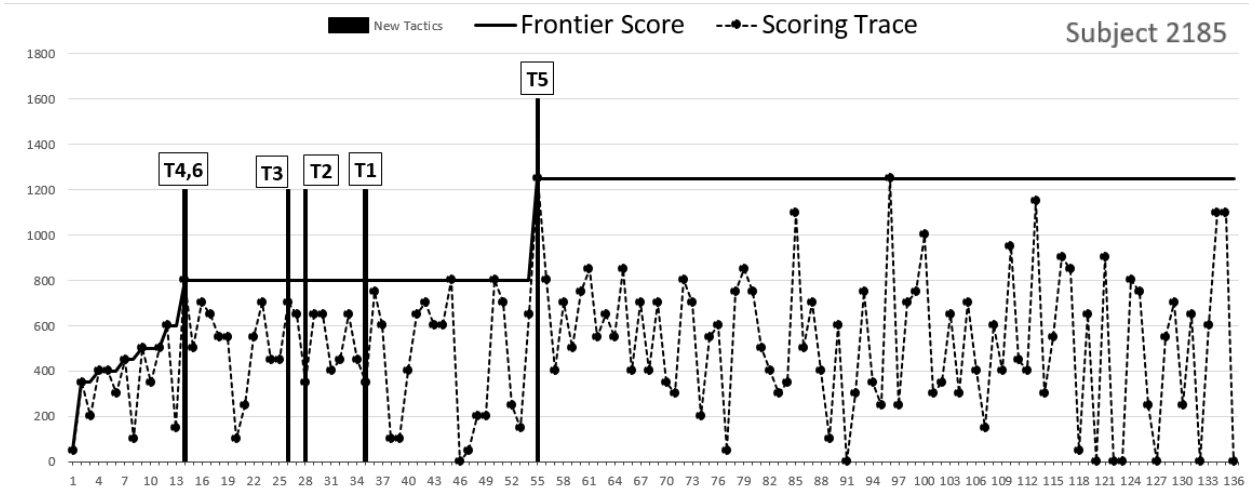


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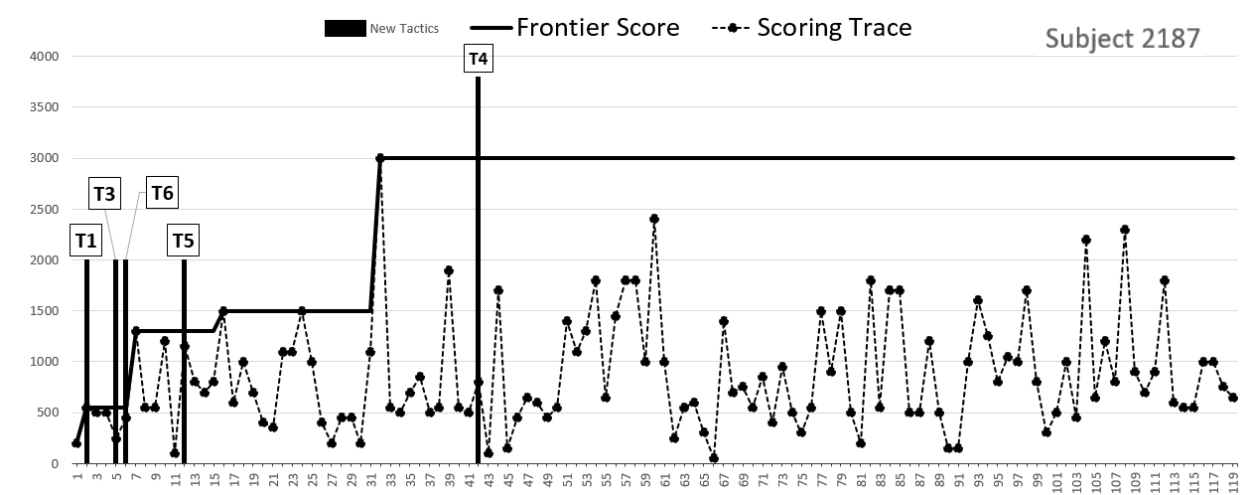


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2185

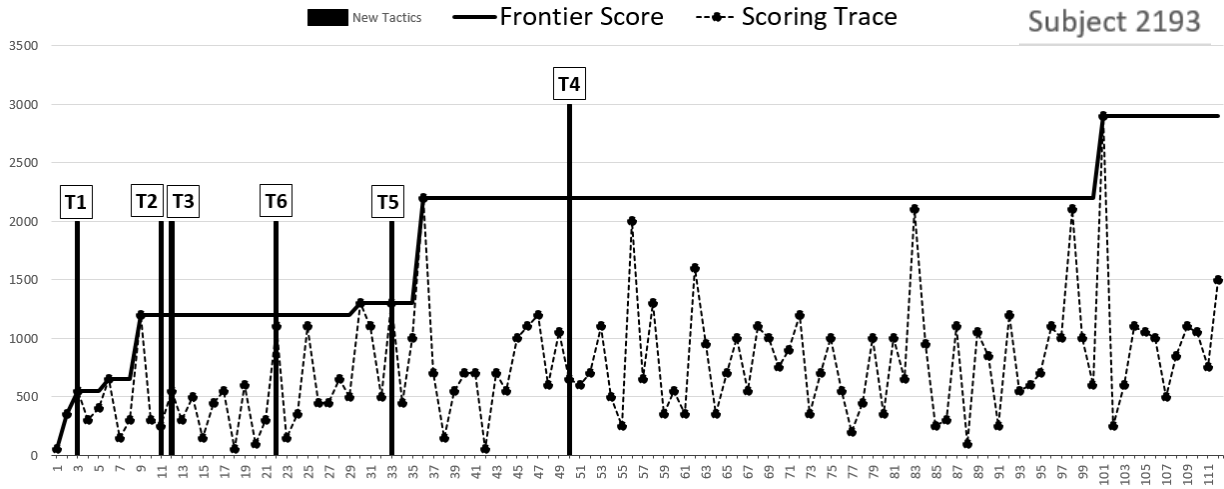


Study 2a – Subject Number 2187

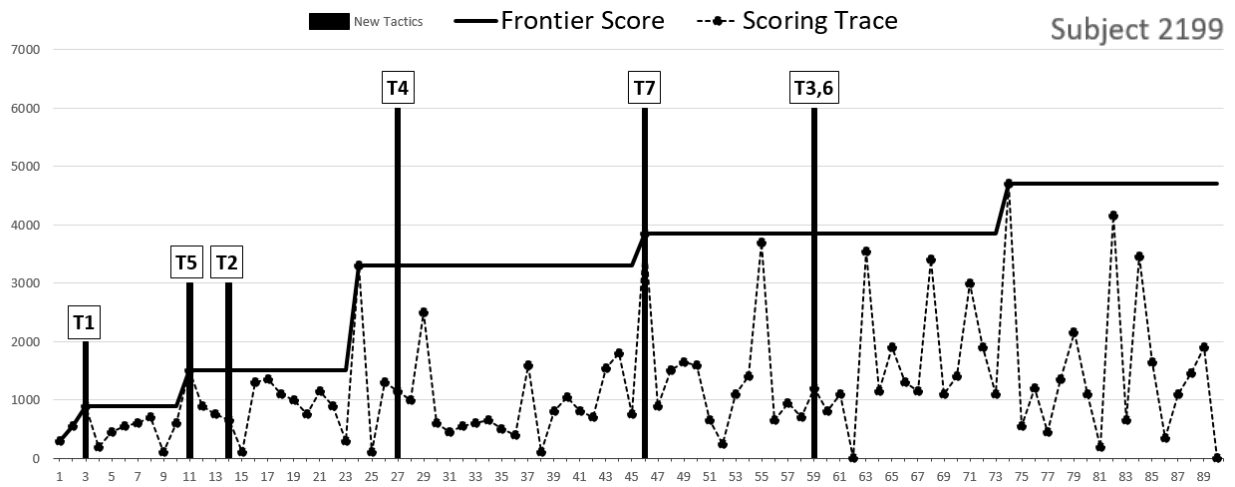


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2193

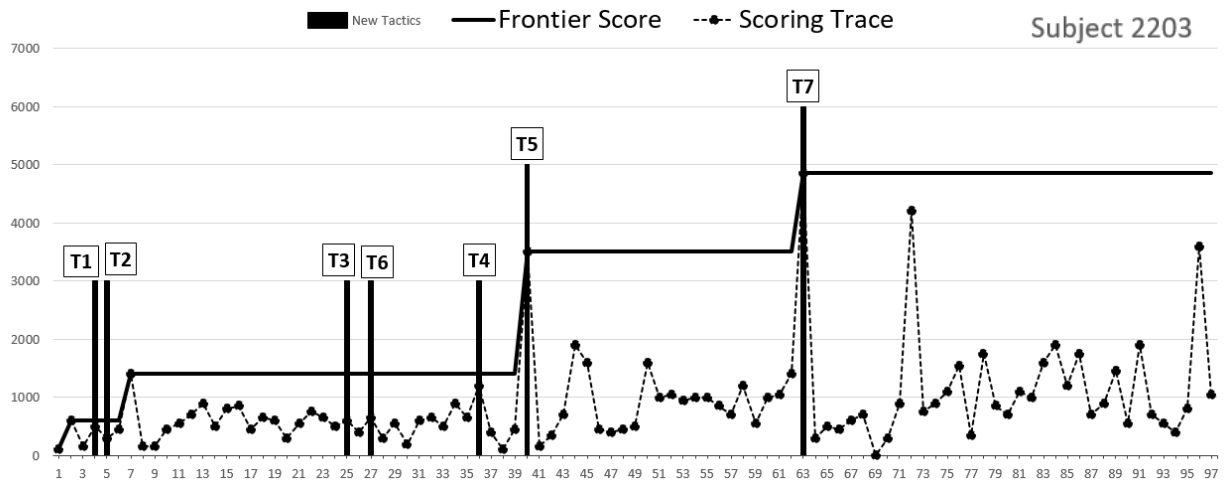


Study 2a – Subject Number 2199

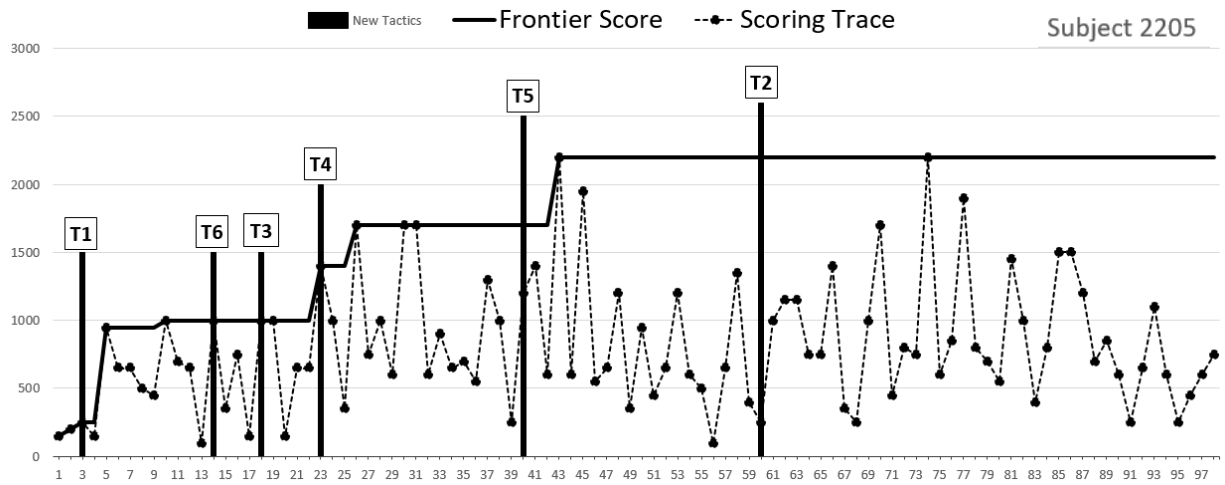


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2203

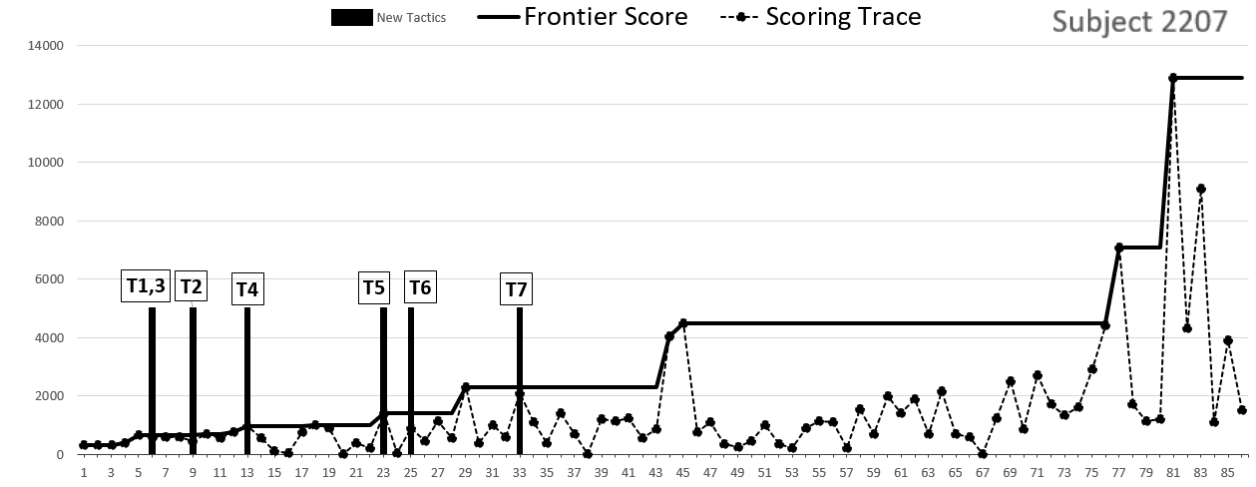


Study 2a – Subject Number 2205

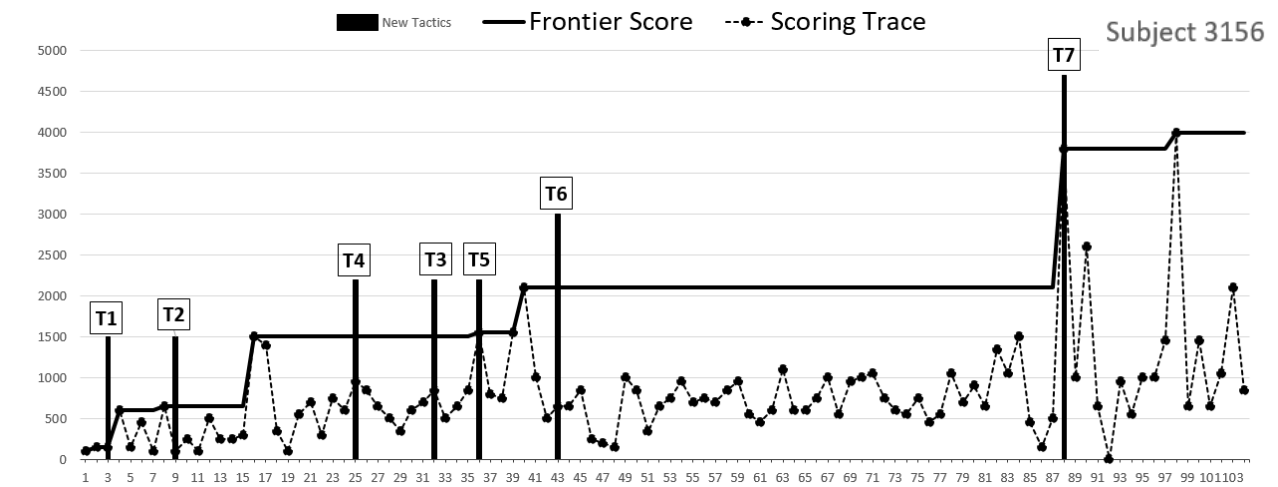


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2207

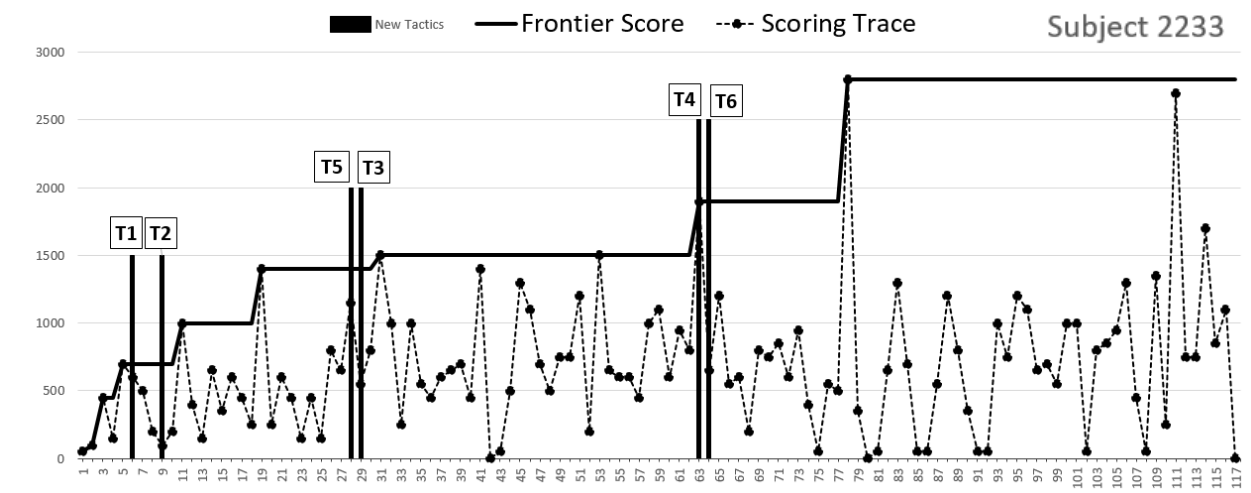


Study 2a – Subject Number 3156

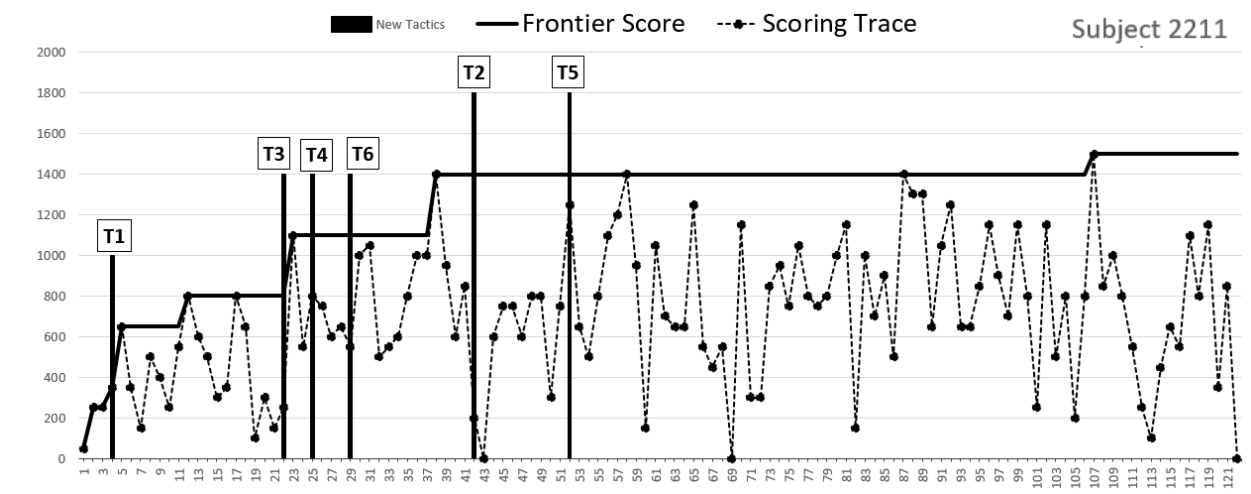


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2233

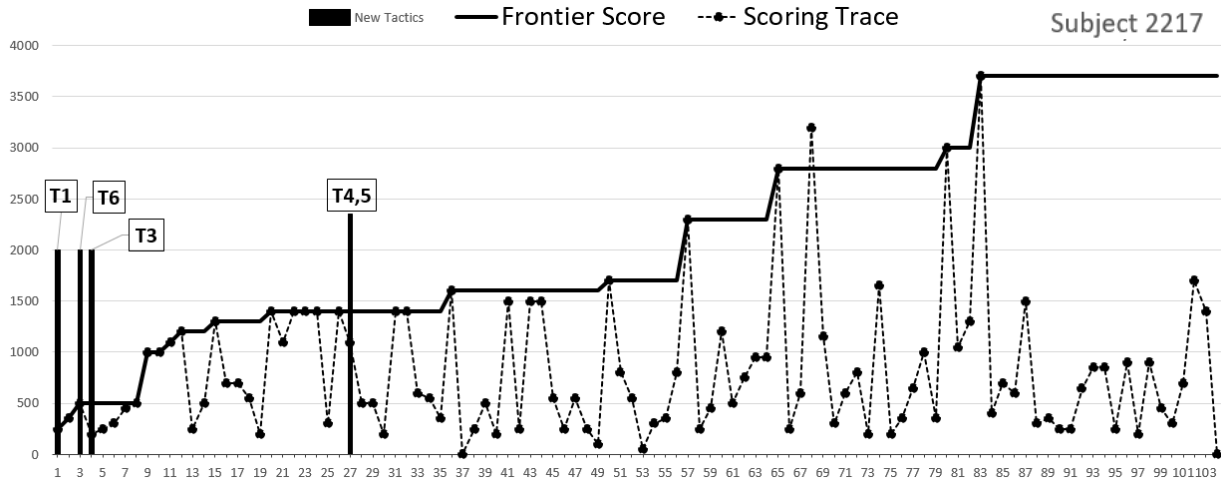


Study 2a – Subject Number 2211

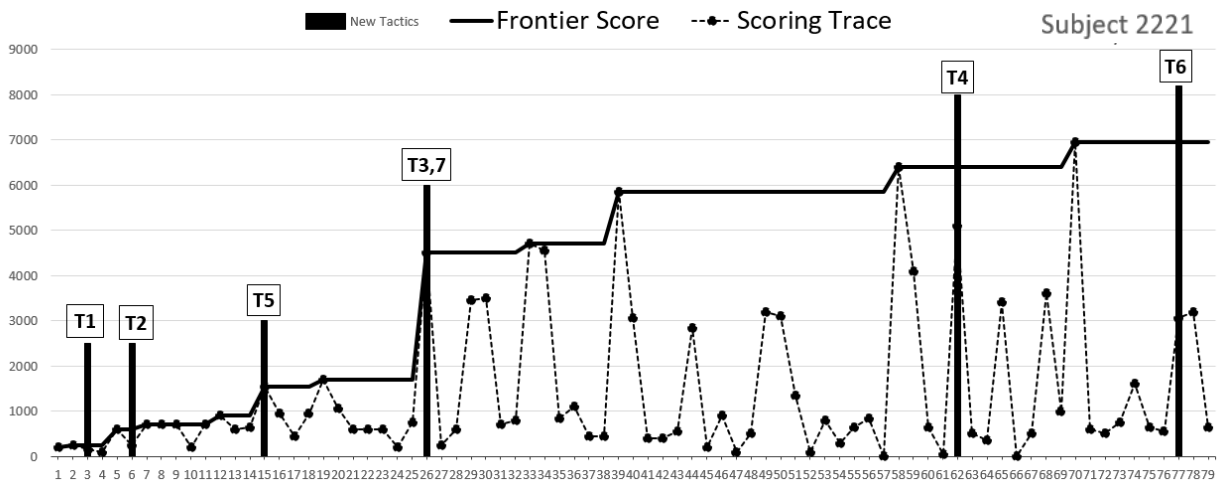


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2217

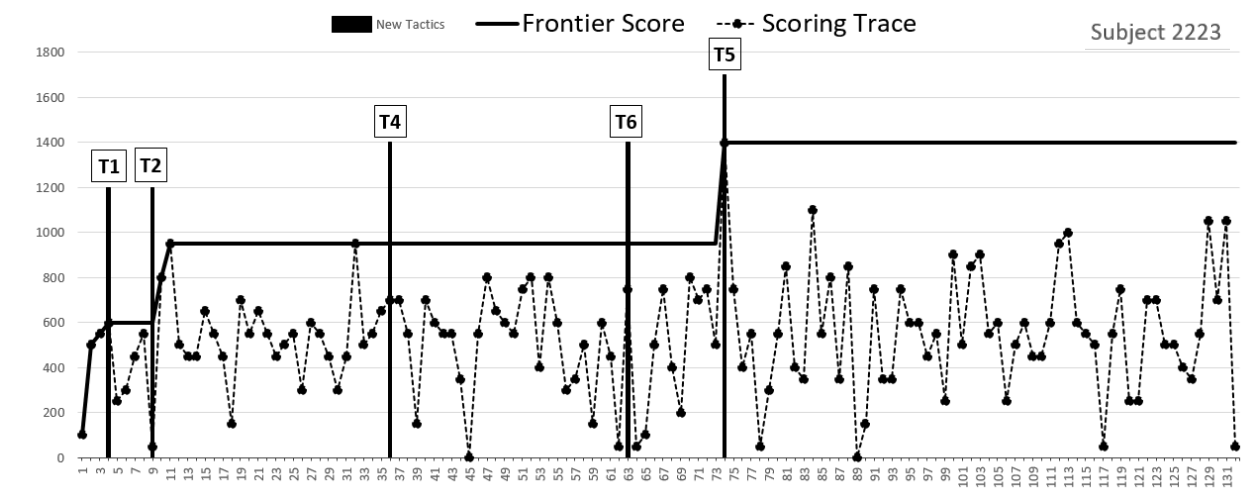


Study 2a – Subject Number 2221

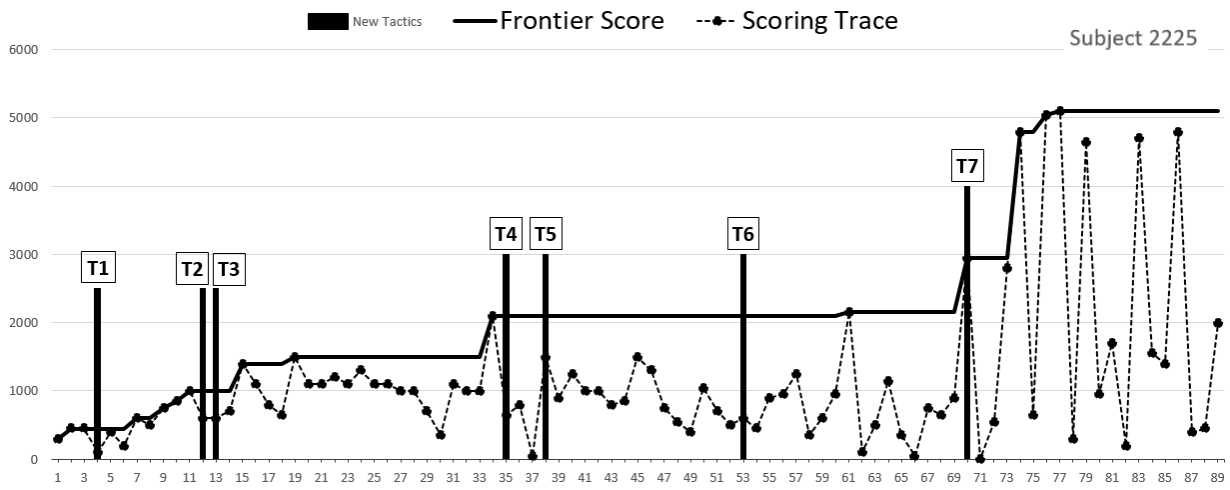


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2223

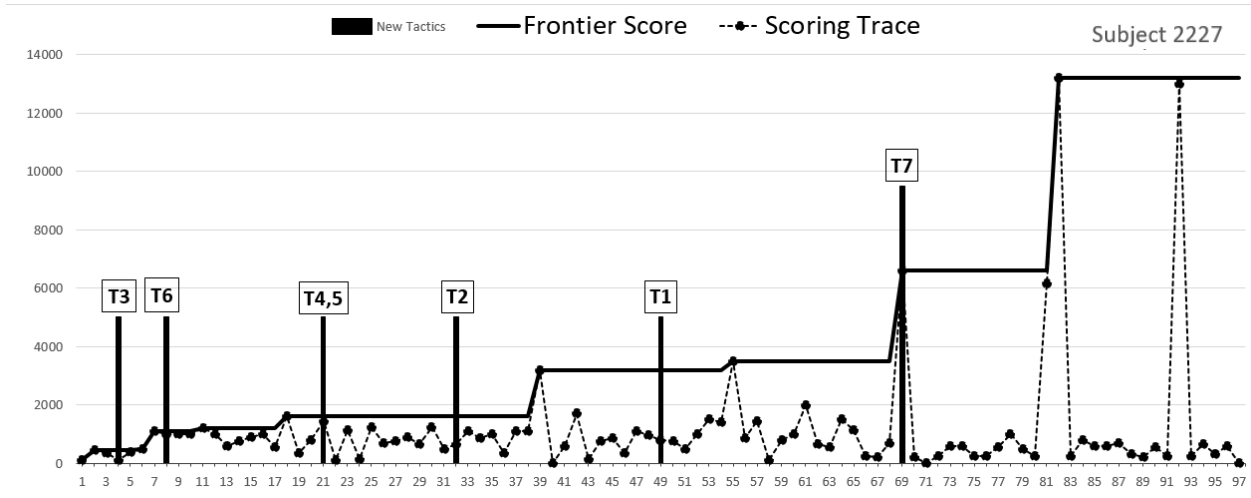


Study 2a – Subject Number 2225

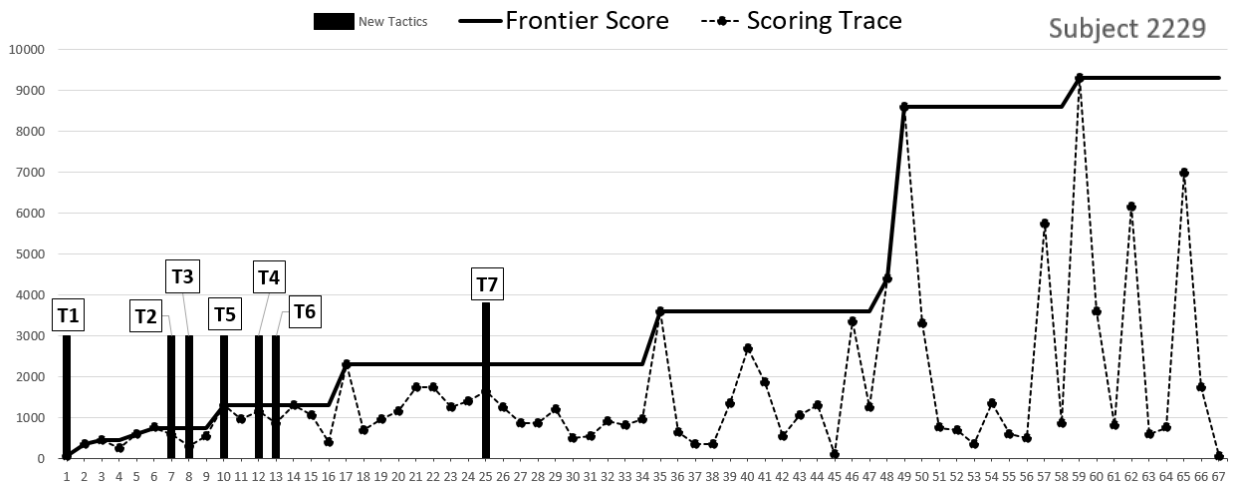


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2227

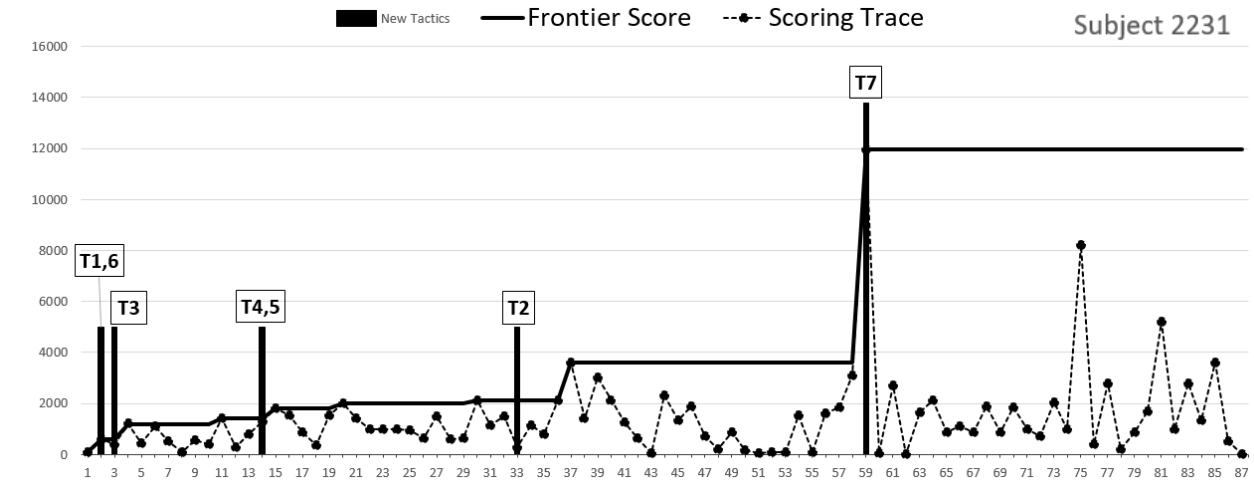


Study 2a – Subject Number 2229

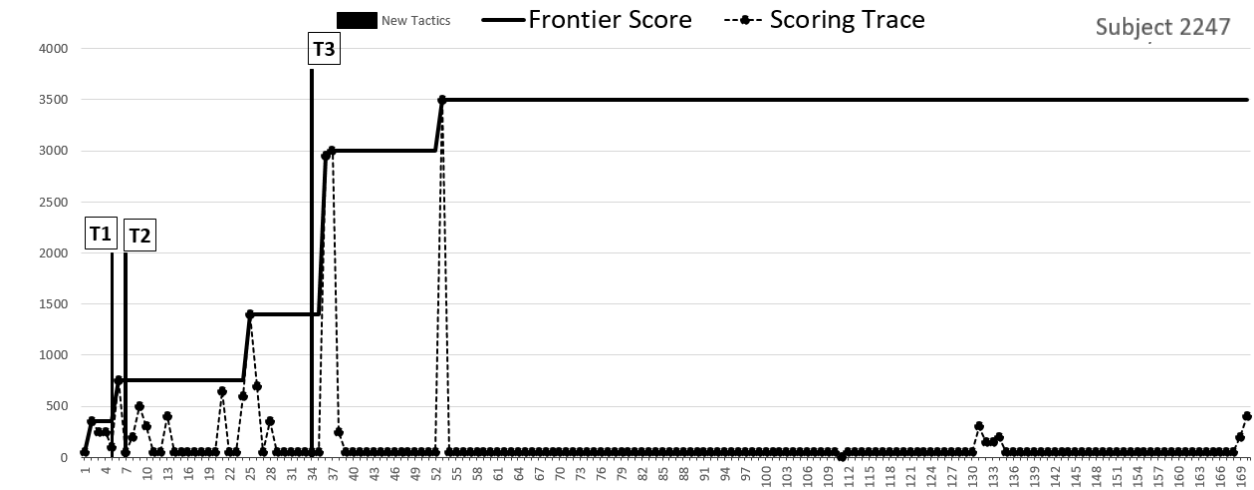


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2231

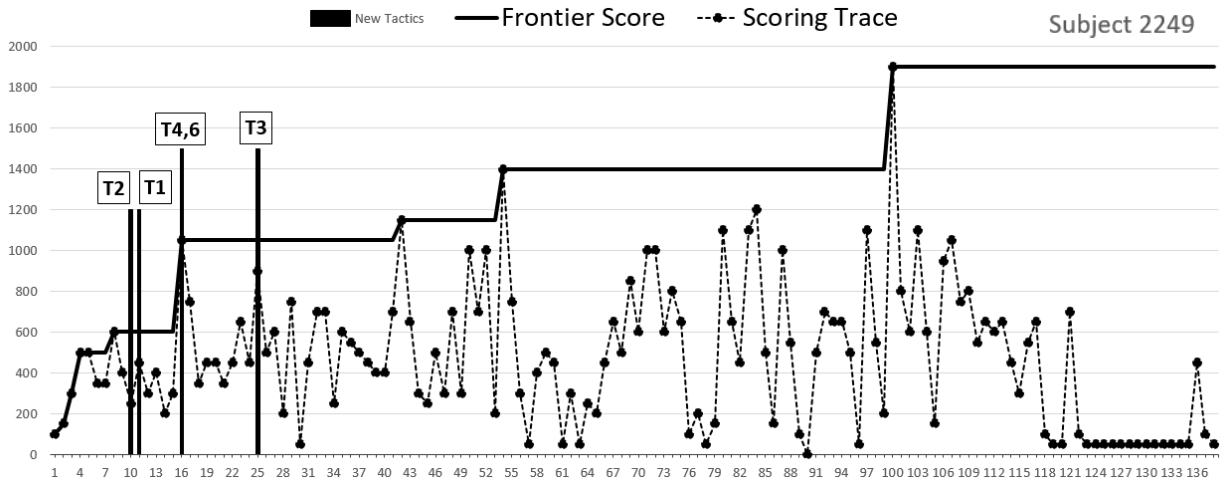


Study 2a – Subject Number 2247

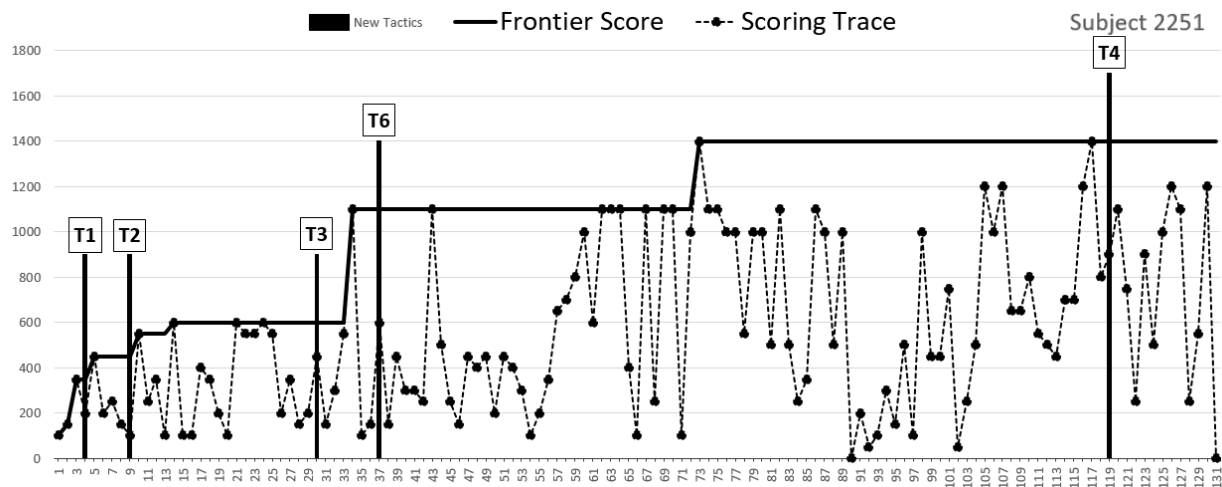


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2249

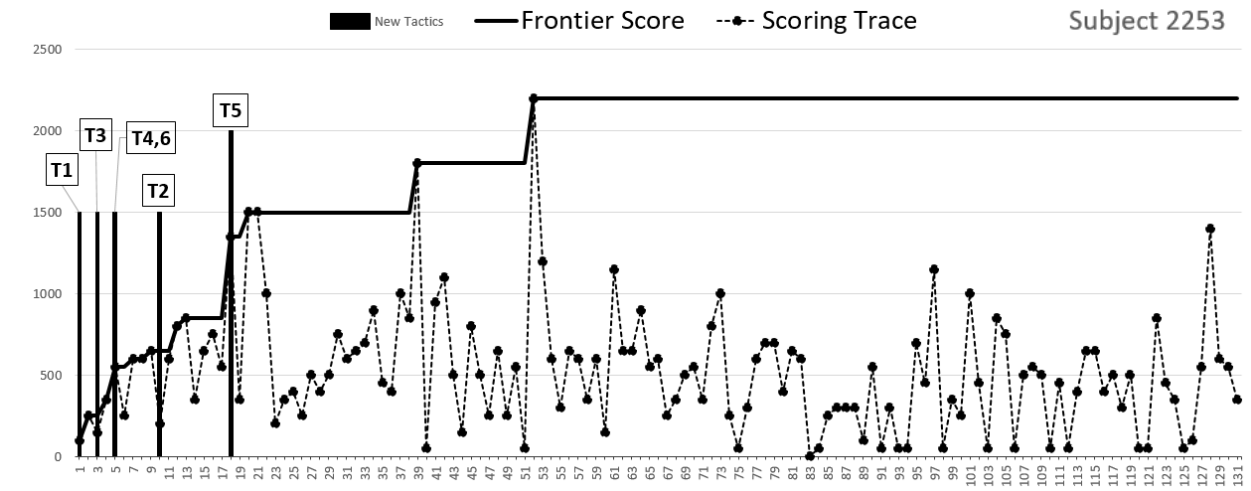


Study 2a – Subject Number 2251

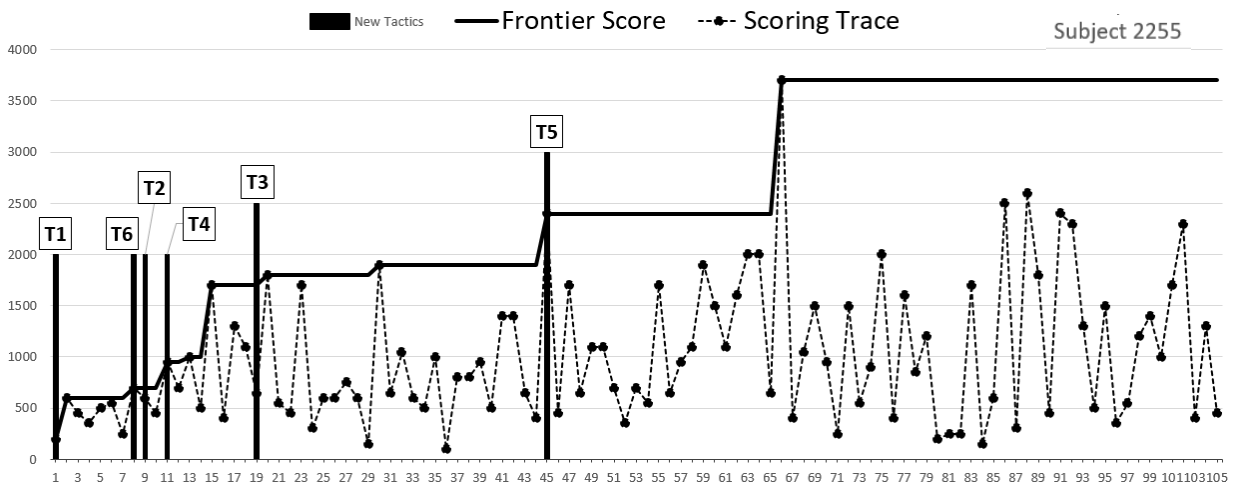


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2253

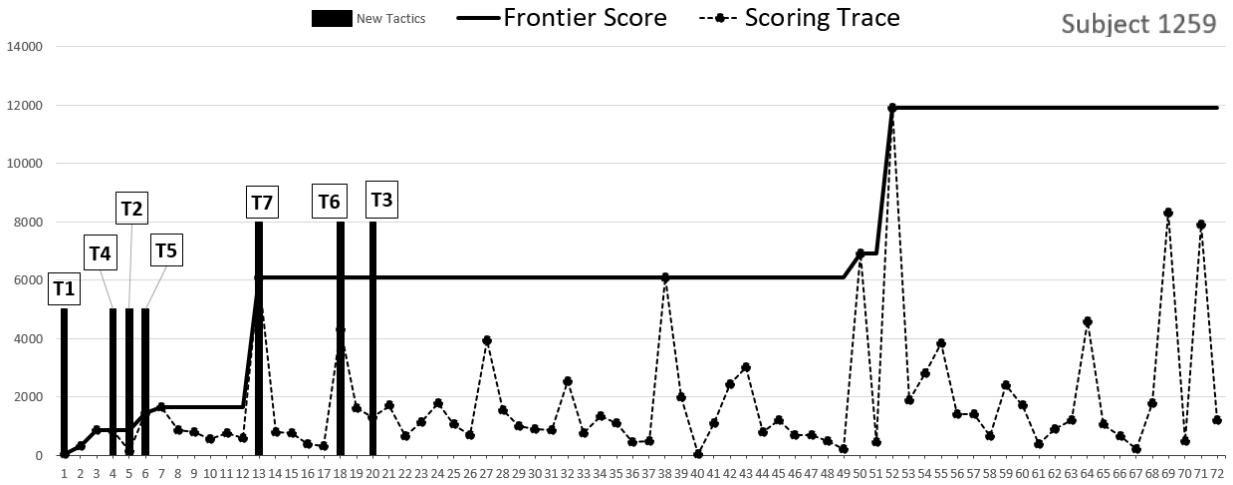


Study 2a – Subject Number 2255

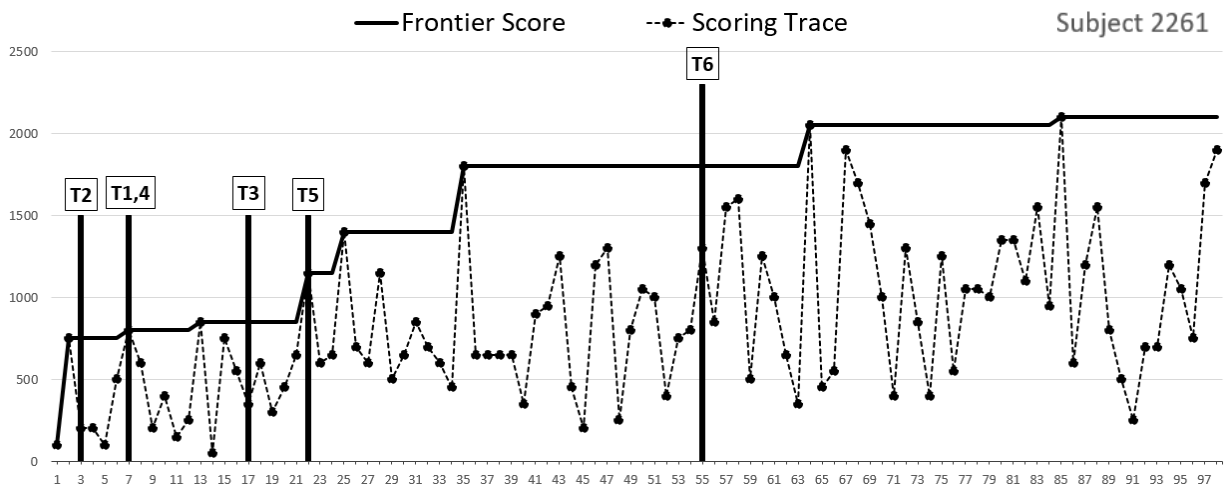


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 1259

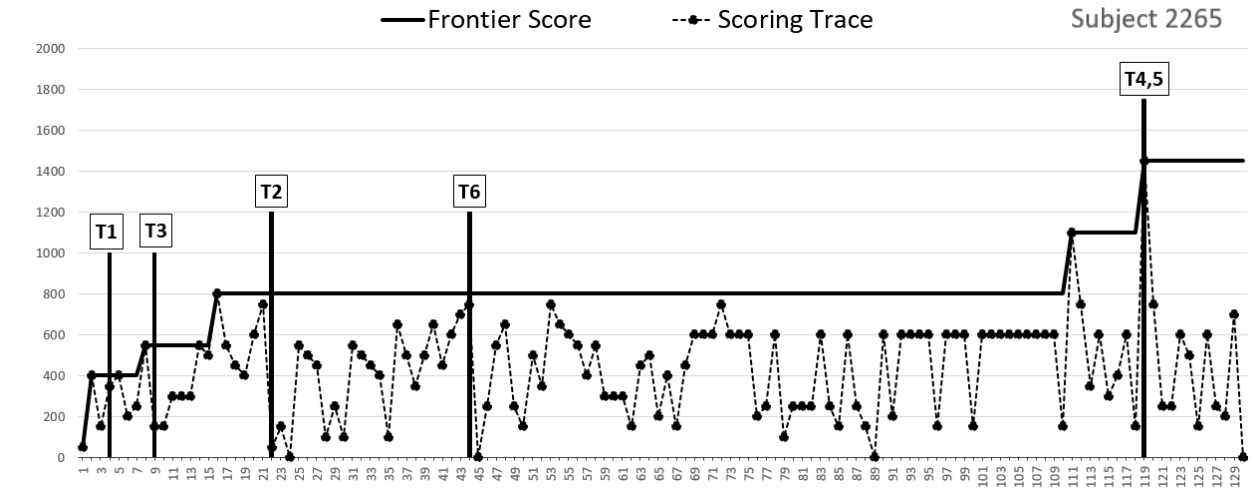


Study 2a – Subject Number 2261

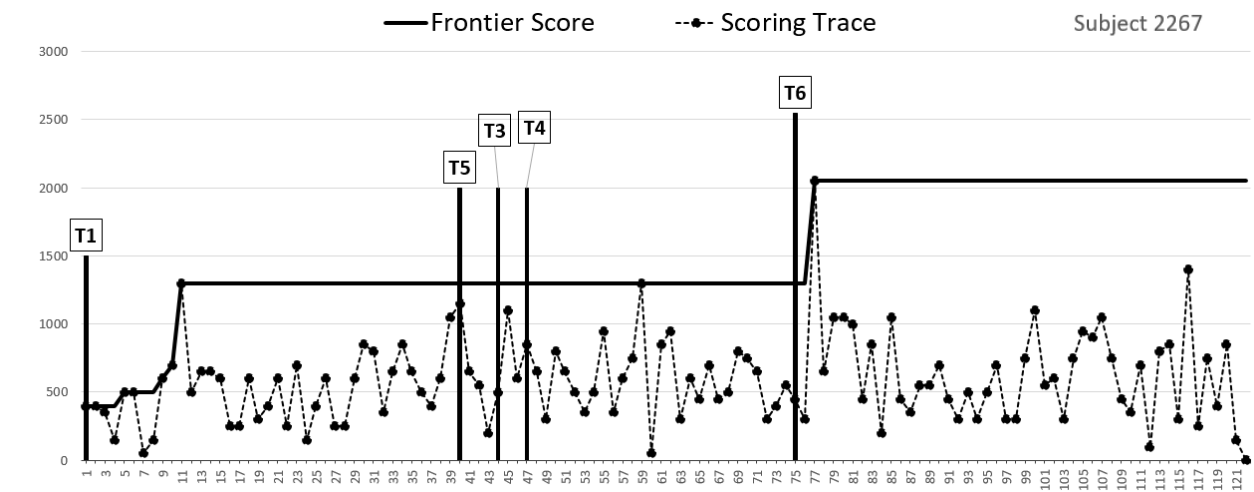


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2265

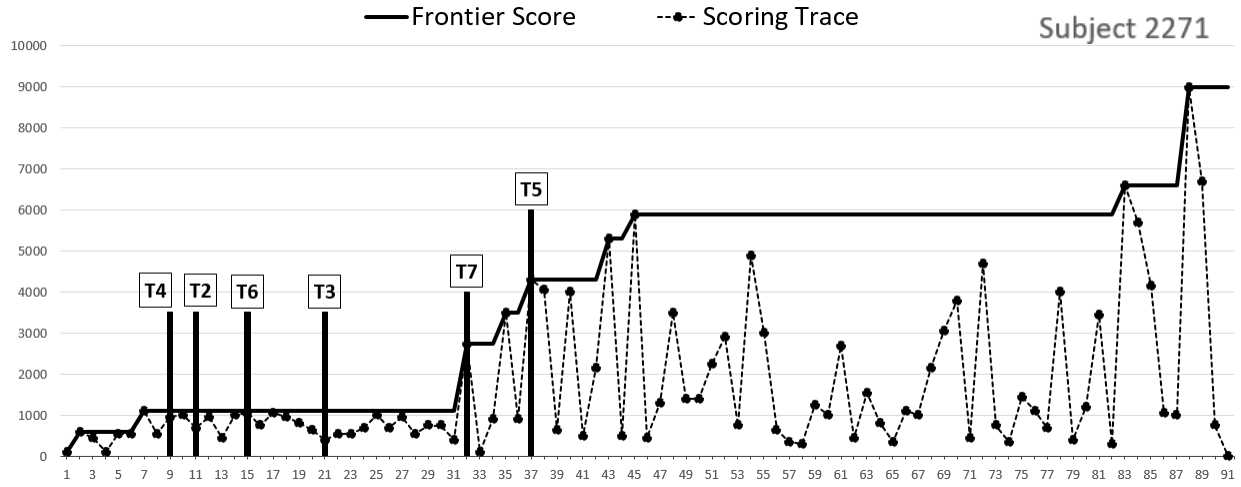


Study 2a – Subject Number 2267

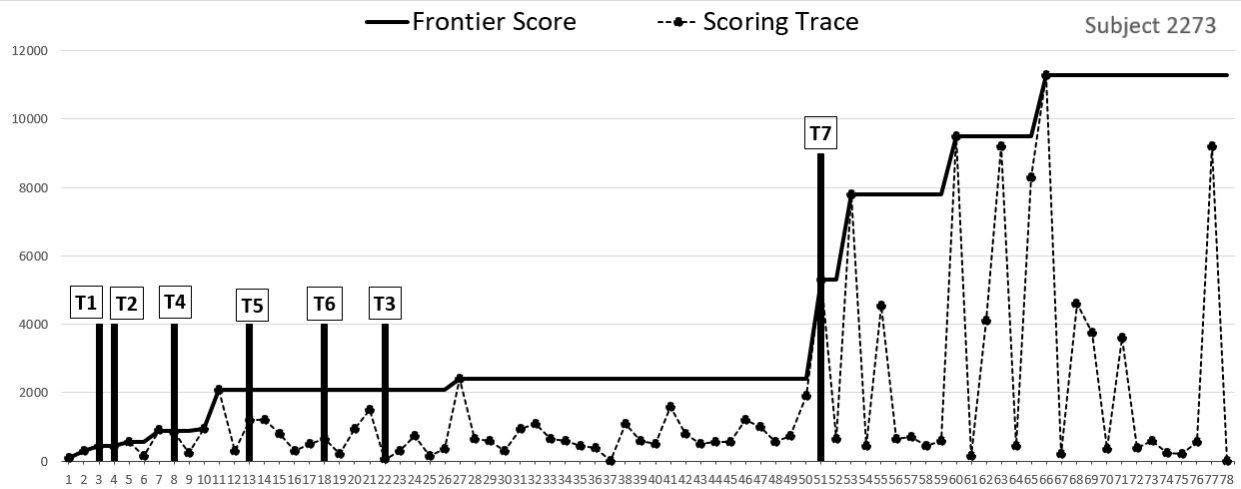


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2271

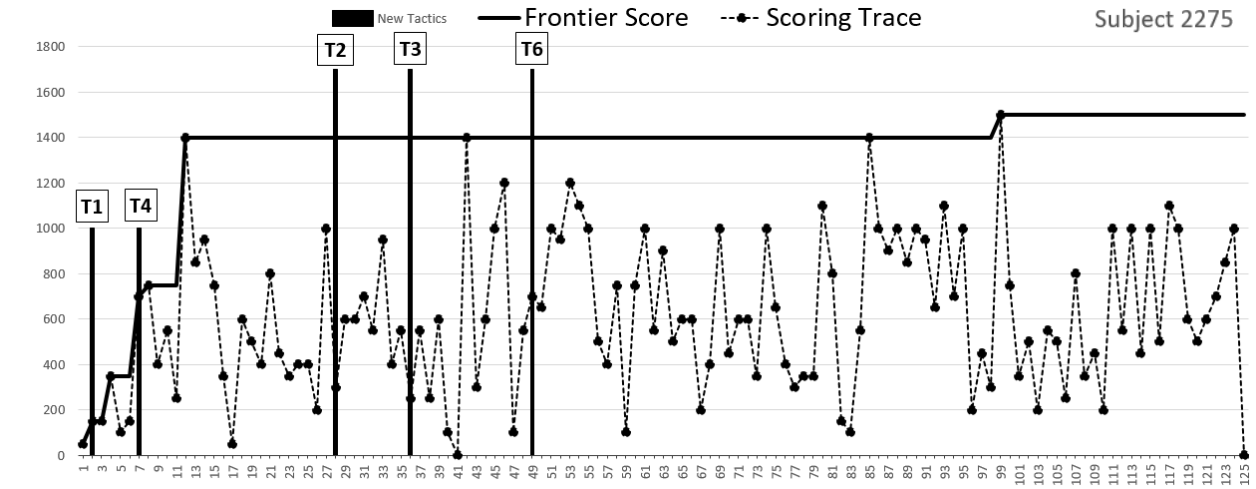


Study 2a – Subject Number 2273

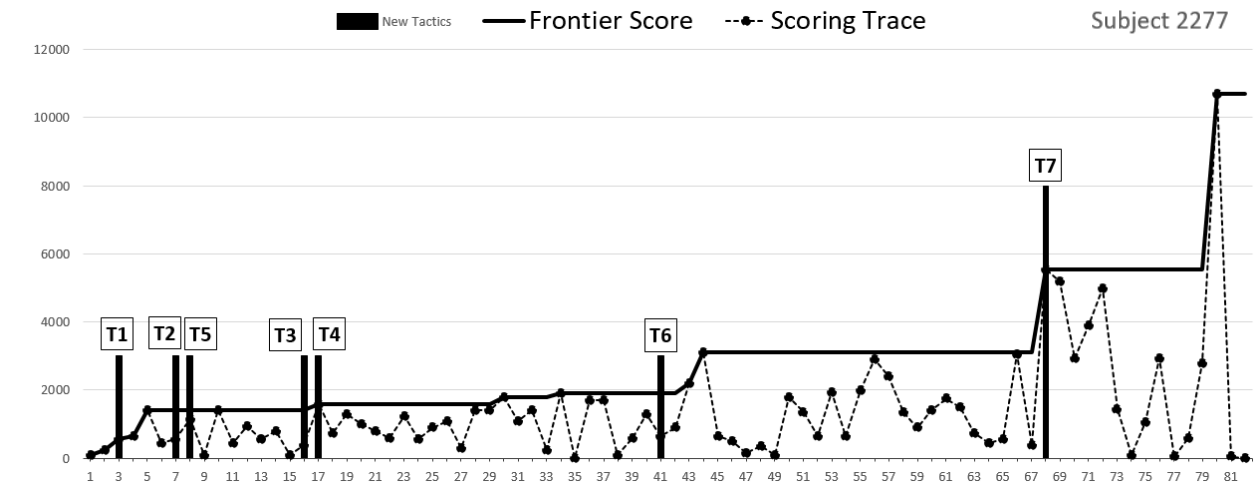


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2275

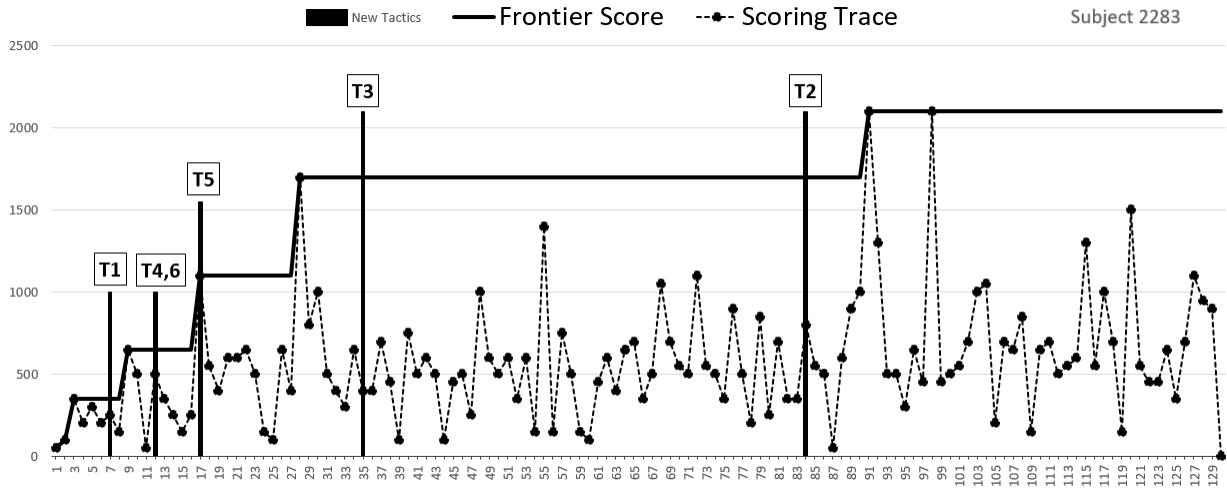


Study 2a – Subject Number 2277

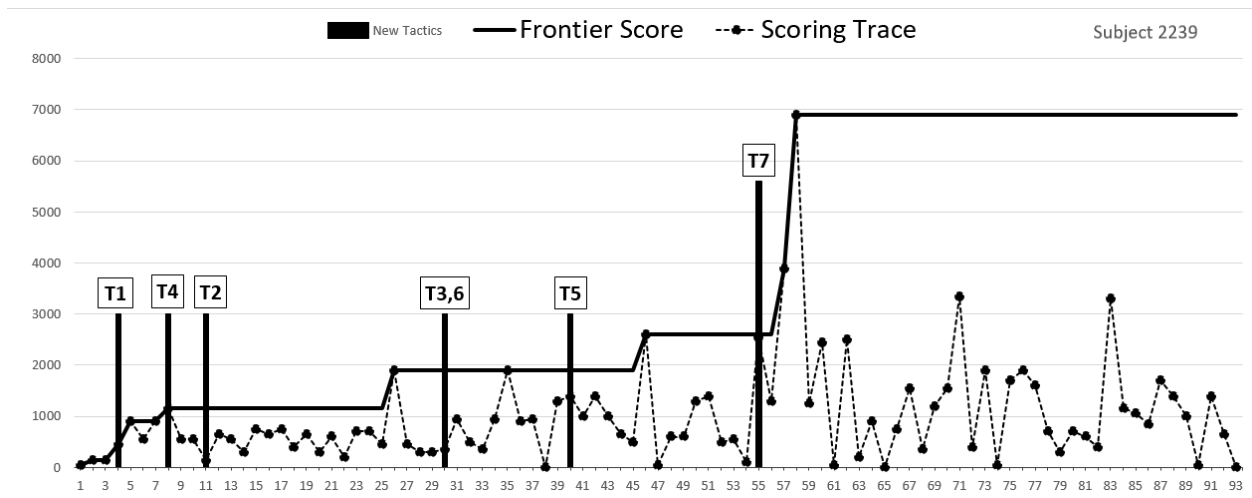


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2283

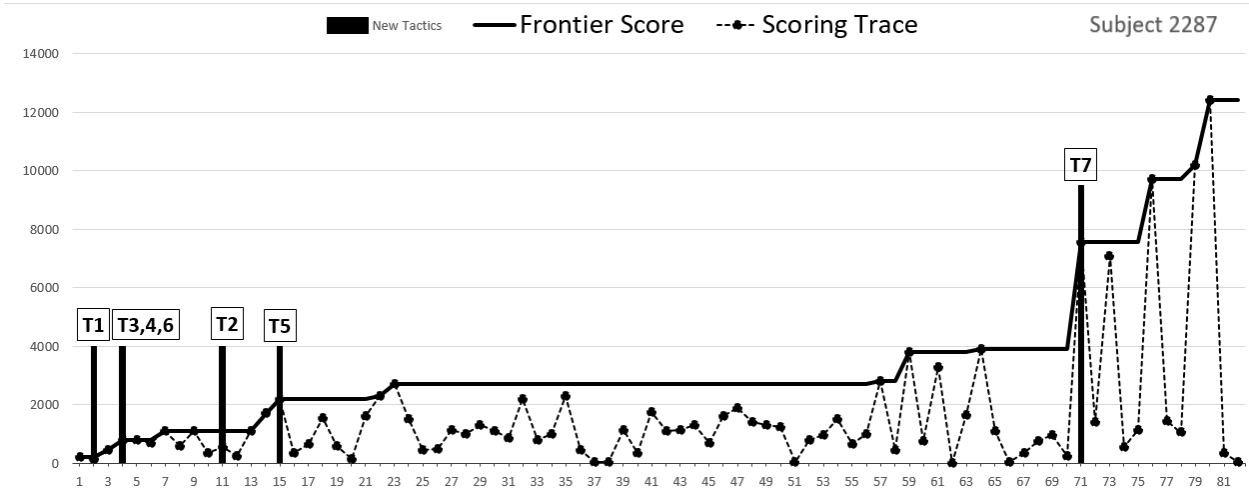


Study 2a – Subject Number 2239

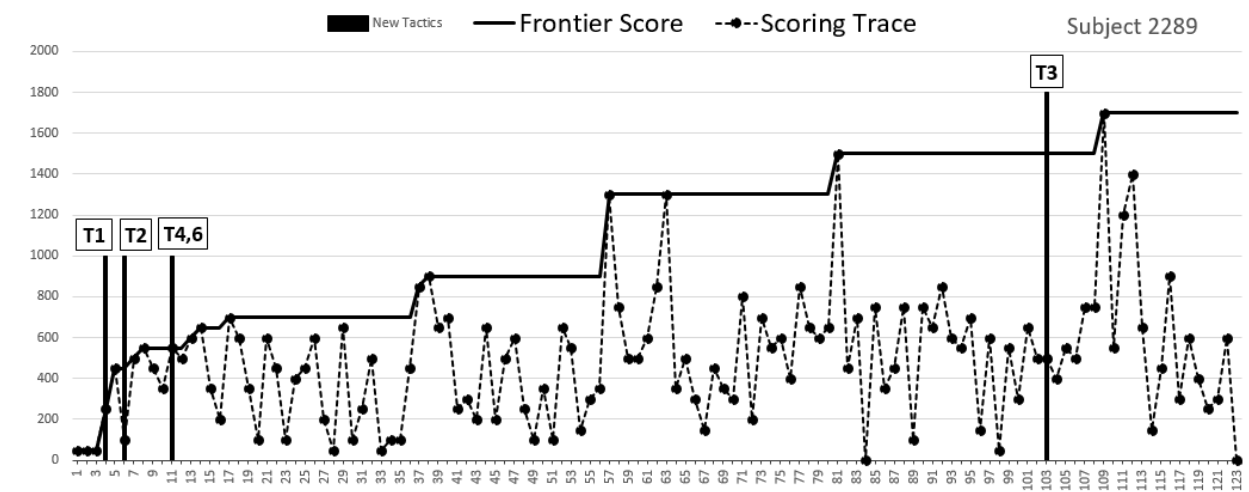


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2287

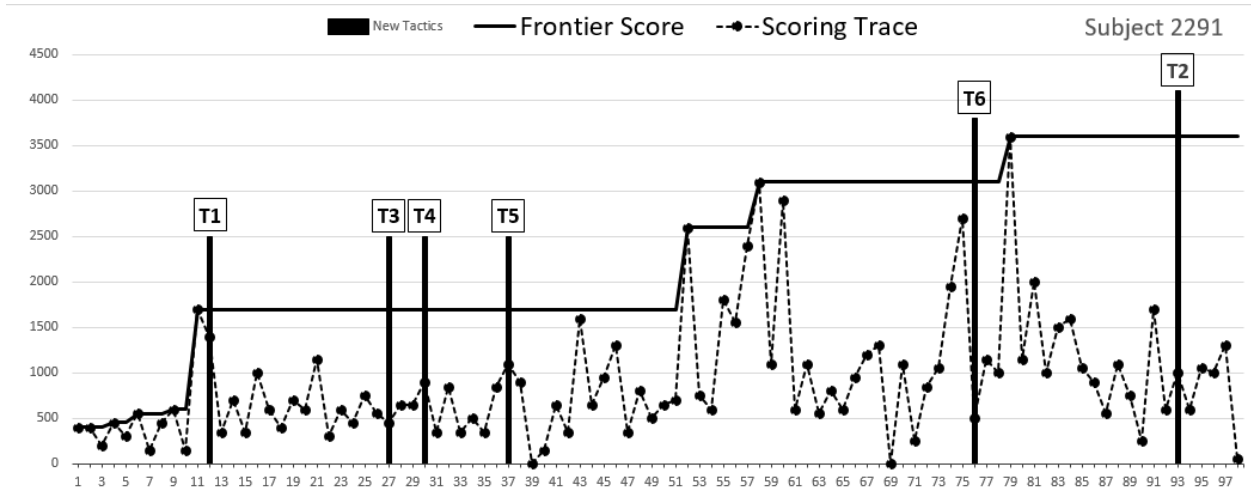


Study 2a – Subject Number 2289

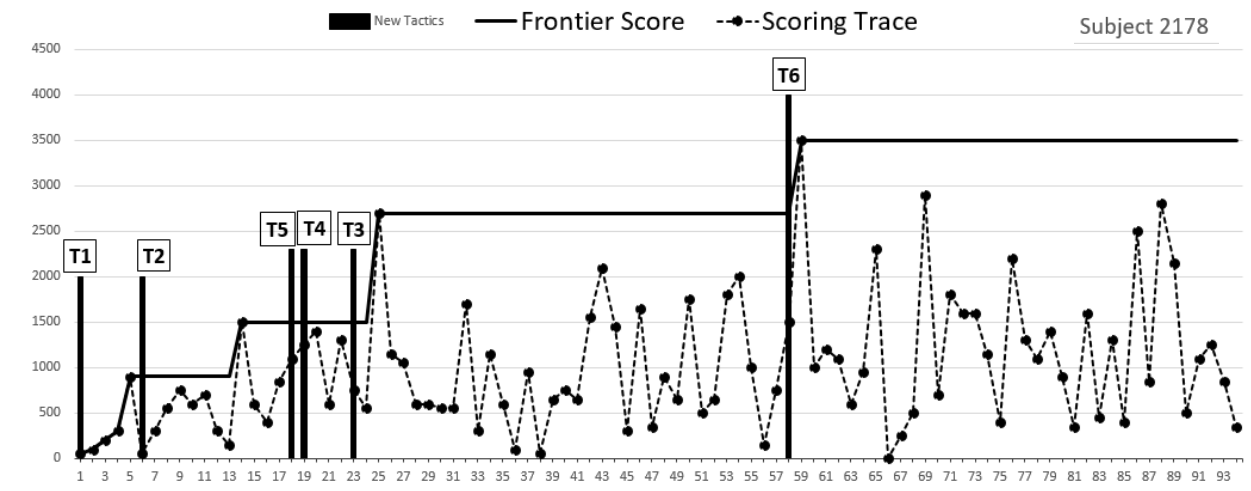


Appendix Q: - Study 2a (n=92) Scoring and Tactical Development Traces

Study 2a – Subject Number 2291



Study 2a – Subject Number 2178



Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – EXAMPLE

ILLUSTRATION

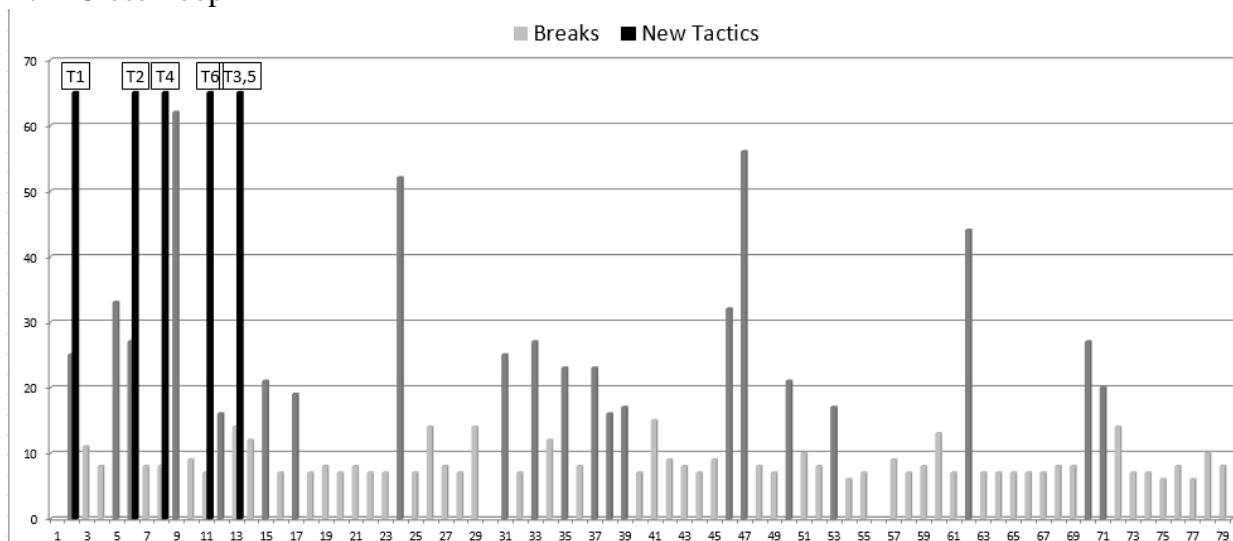
In Appendix R, individual subject scoring traces illustrate scoring performance (y-axis) by trip number (x-axis). Study 2b Subjects were in the “elective breaks” treatment condition. The first graphic is a scoring trace, and is interpreted the same as in Appendix Q.

As Study 2b was associated with the “elective break” treatment condition, a break histogram is positioned below the scoring trace.

The break histogram depicts break time in seconds on the Y axis and trip number on the X axis. Using the example below, the grey bars depict preceding trip breaks, and the black bars are indicators of tactical discovery by trip number, with no explicit vertical height interpretation. Break length is judged “substantive” in the darker grey bars, less so for the light grey bars. Break proximity patterns to tactical discovery are also discernable.

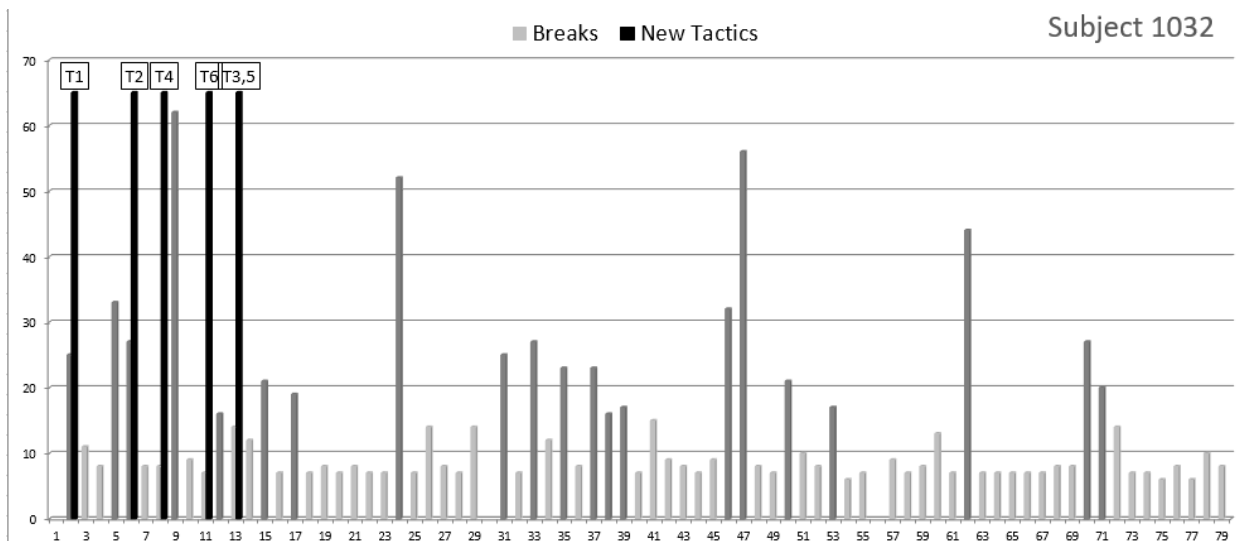
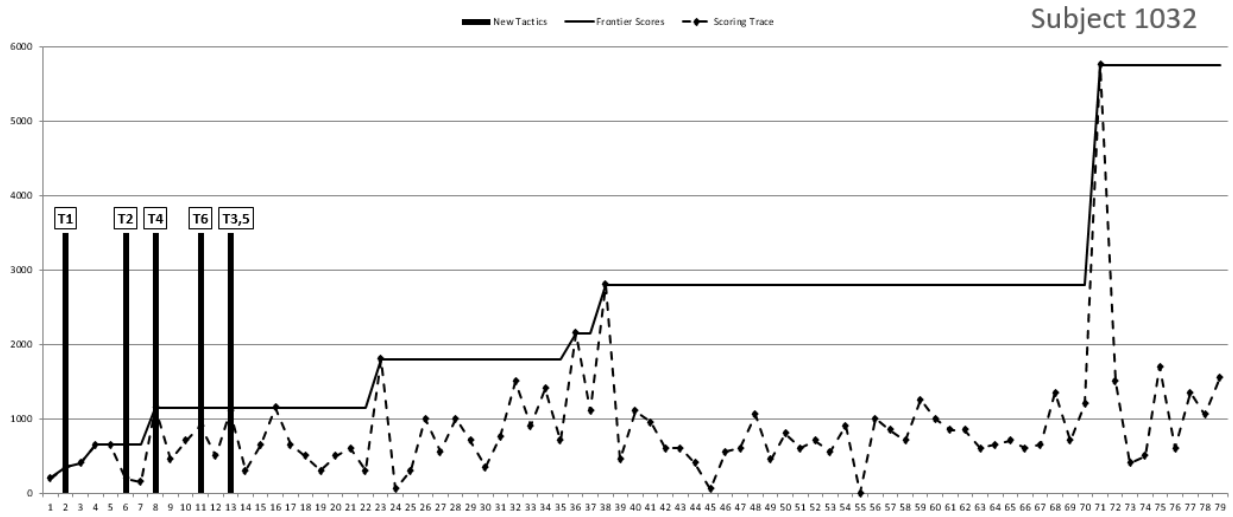
Tactic Indicators:

- T1 = Speed
- T2 = Erase
- T3 = Discard
- T4 = Loop
- T5 = Extend
- T6 = Play Ahead
- T7 = Close Loop



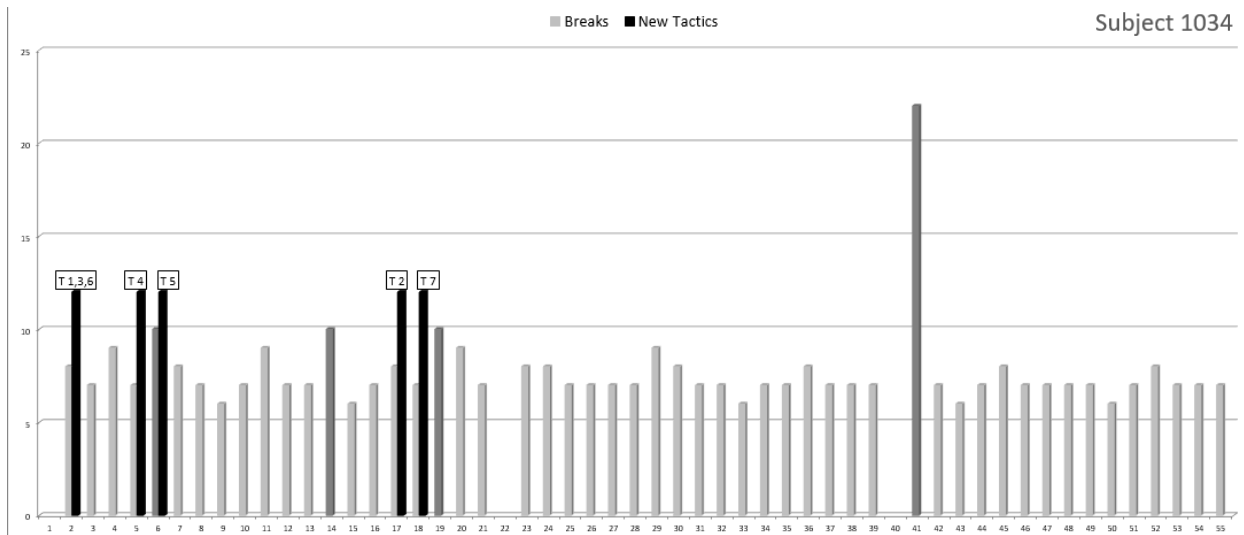
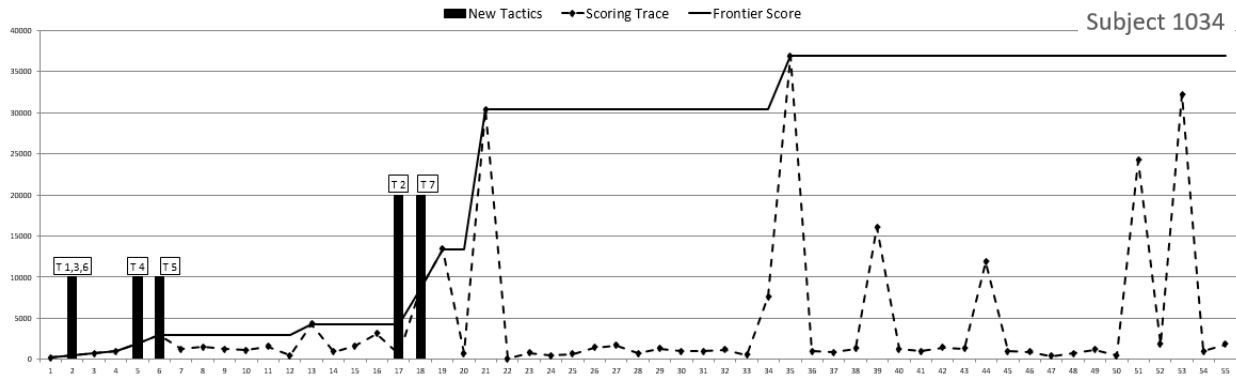
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1032



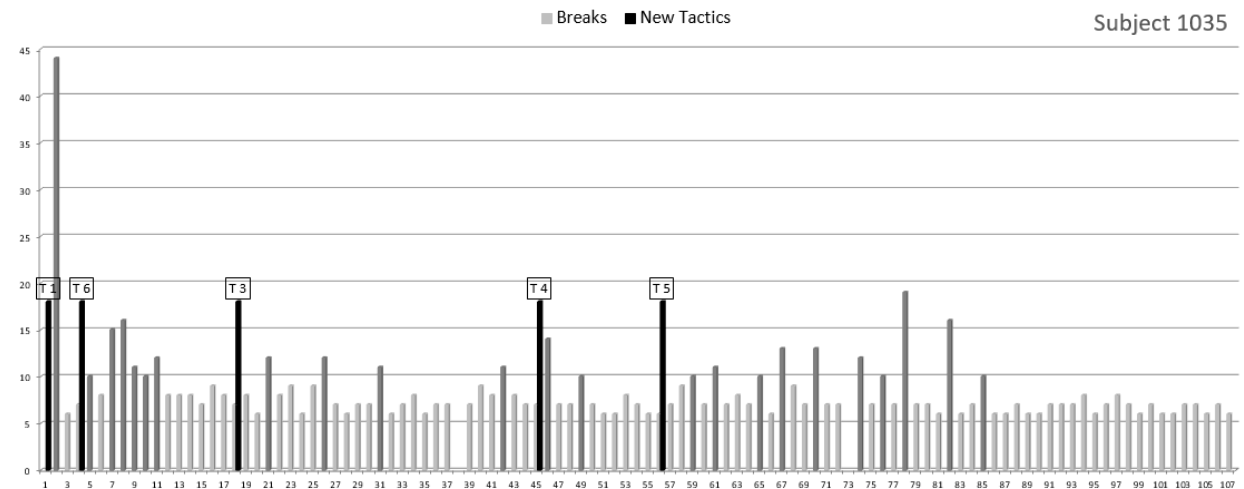
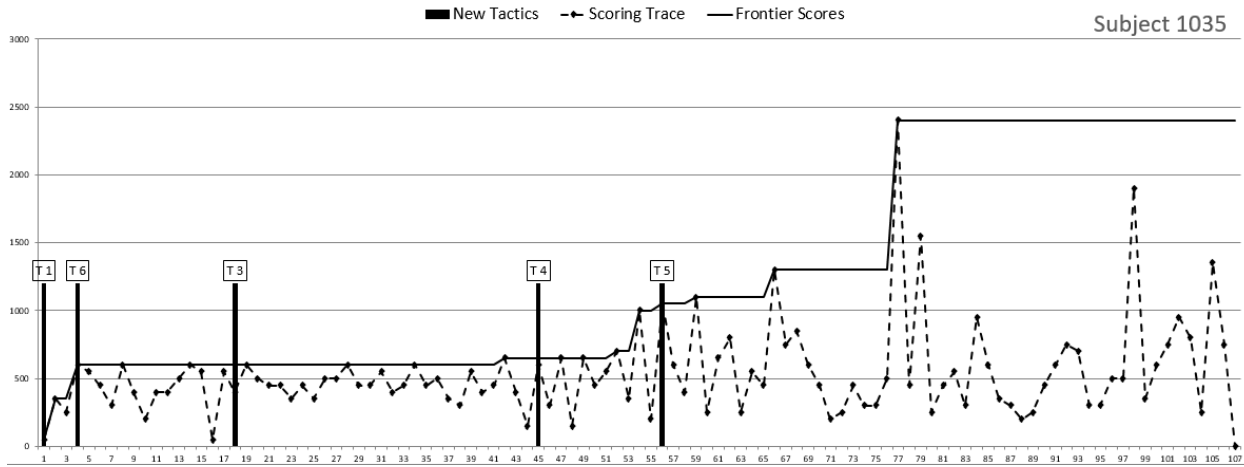
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1034



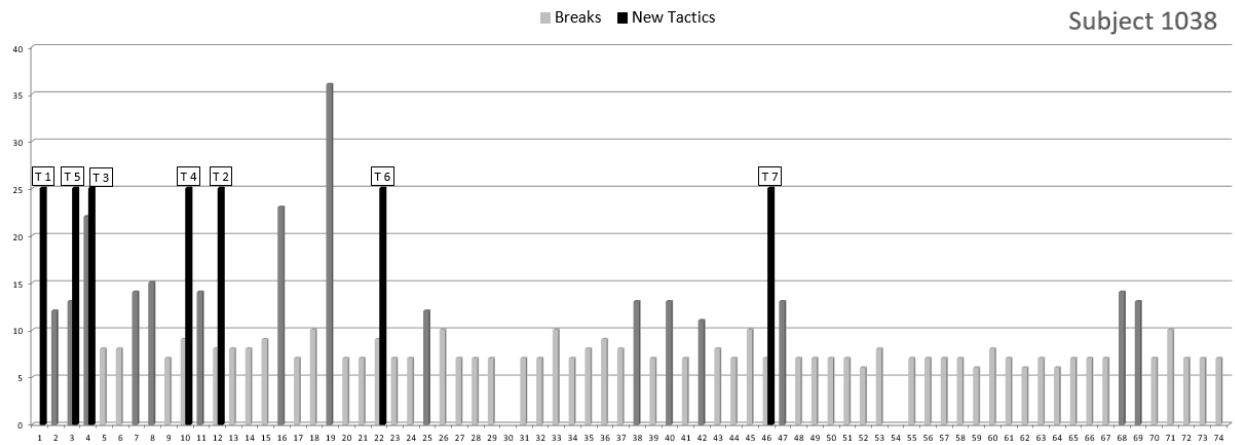
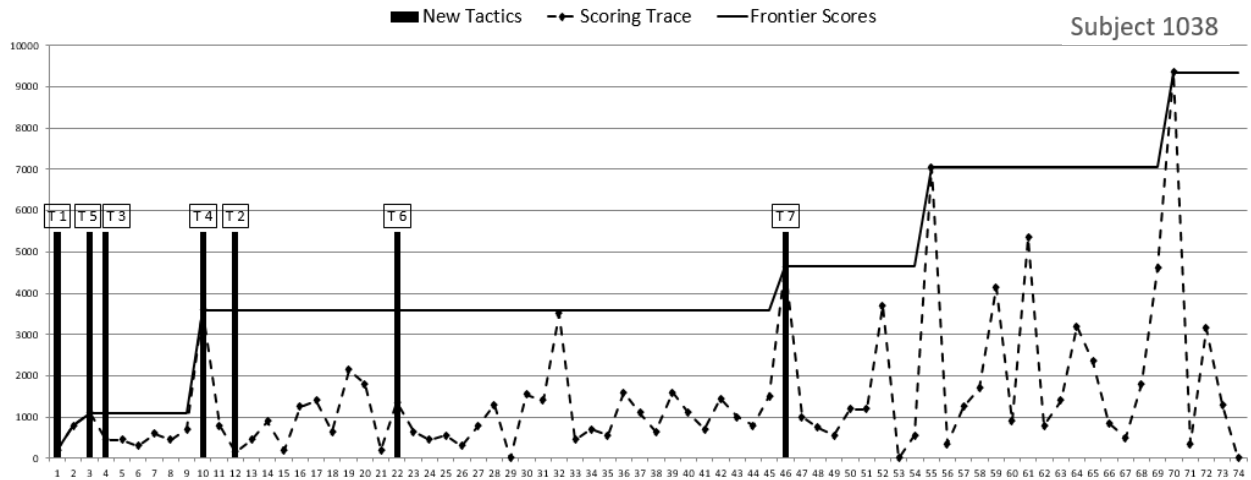
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 1035



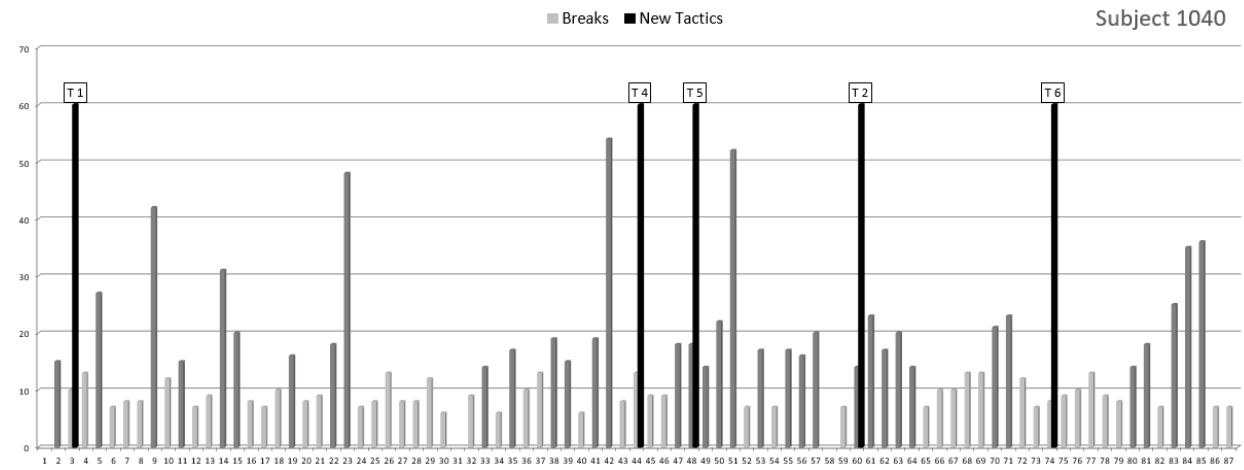
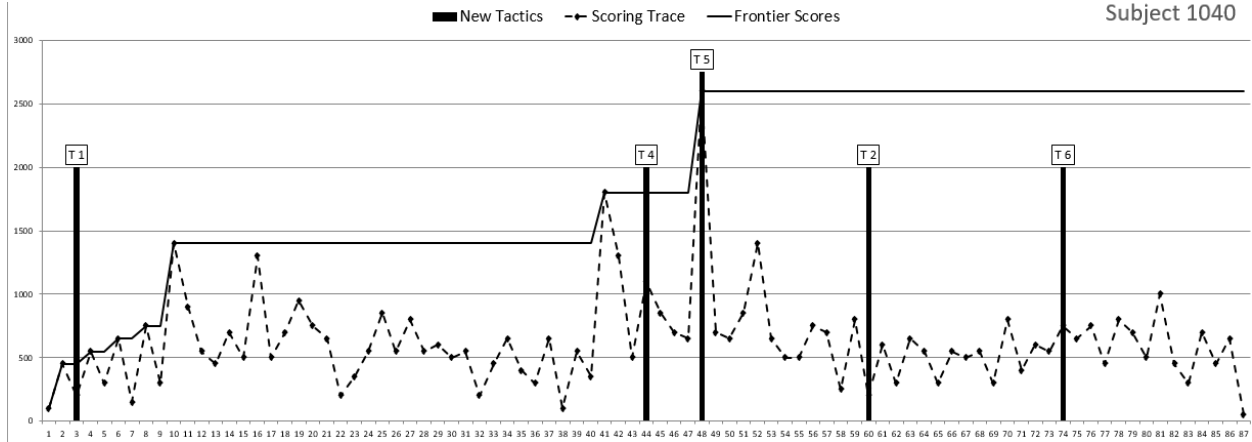
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1038



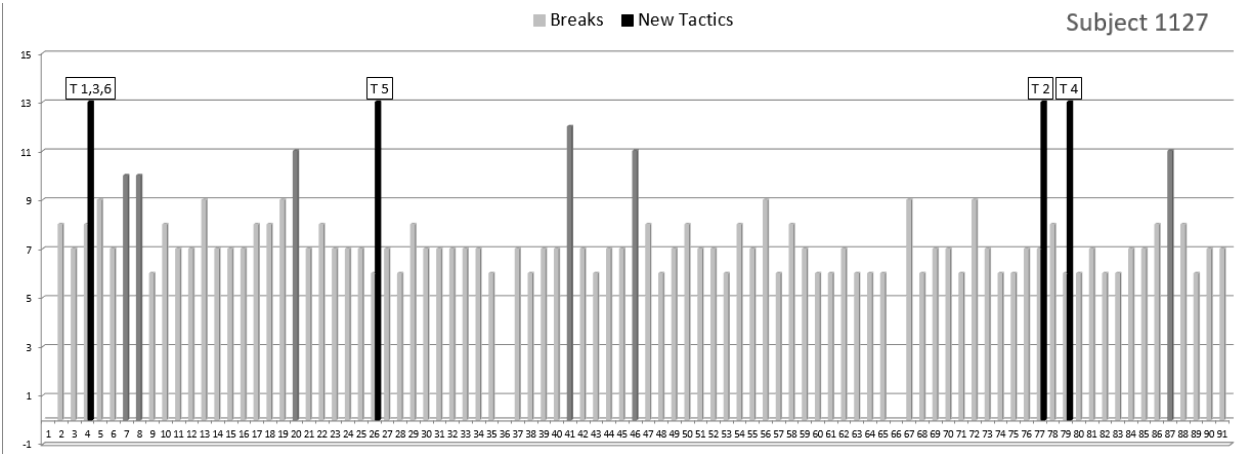
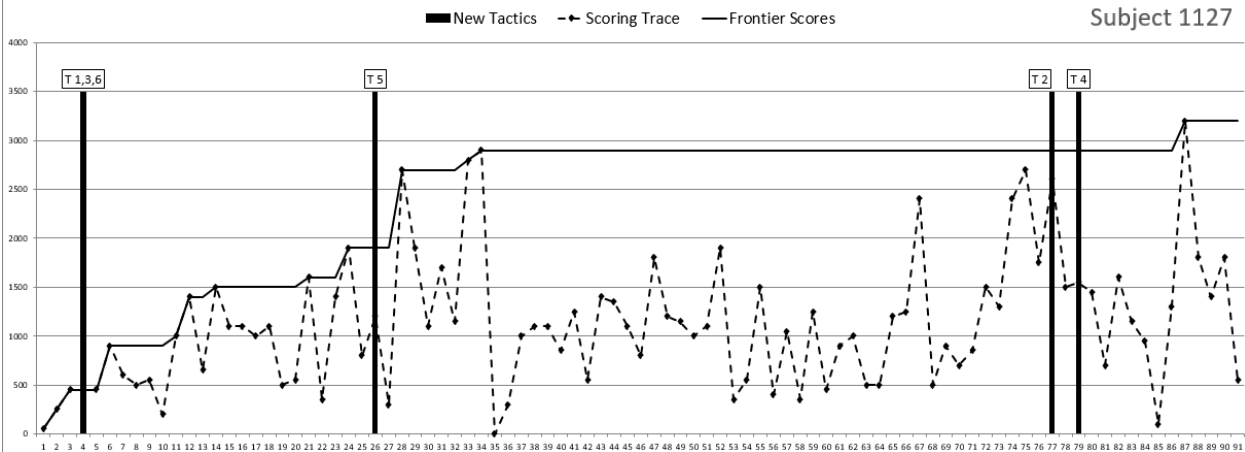
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1040



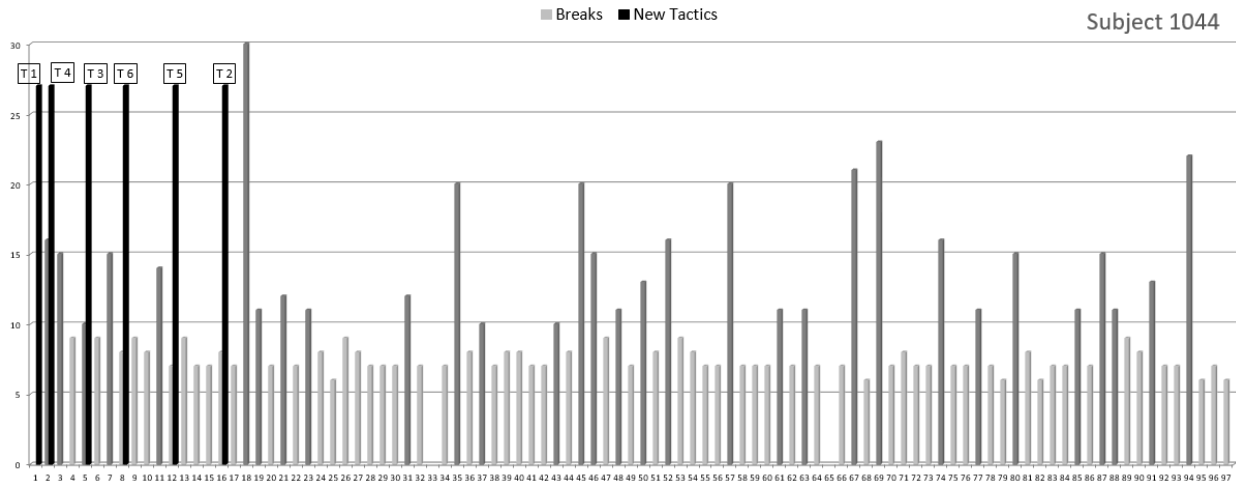
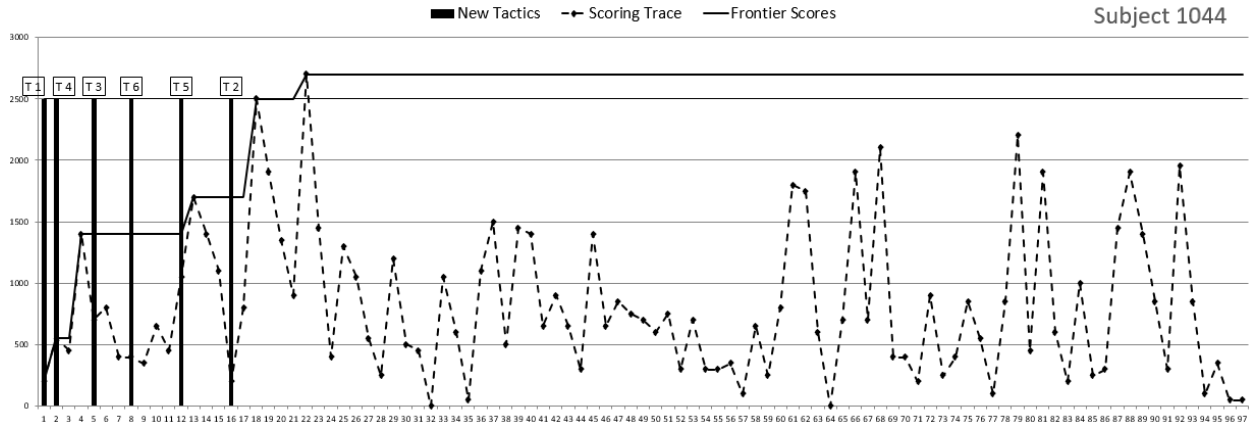
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1127



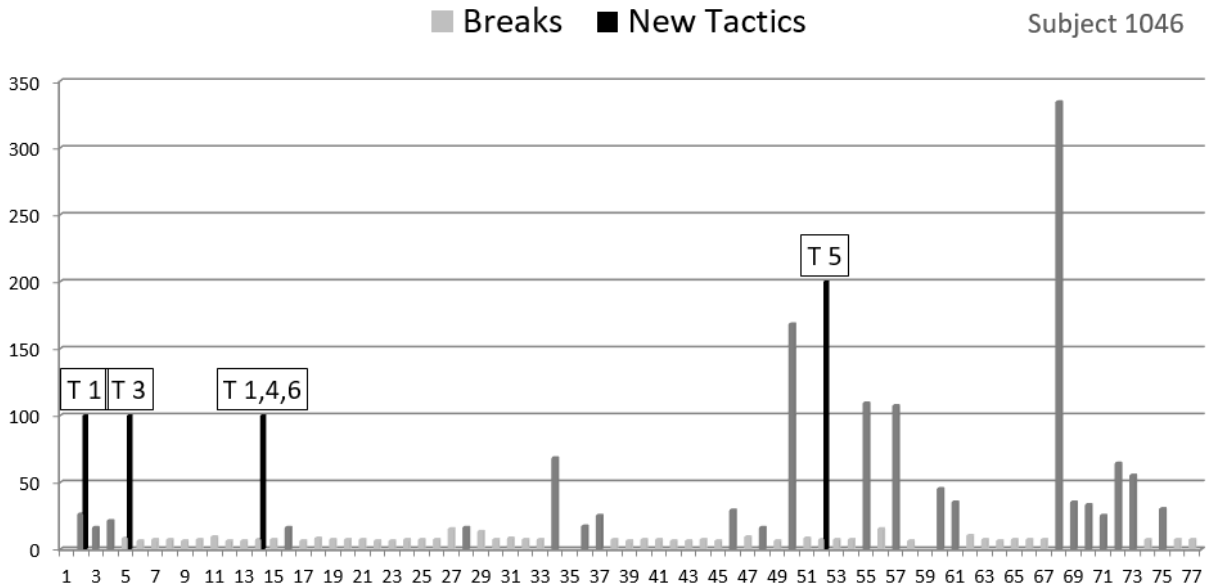
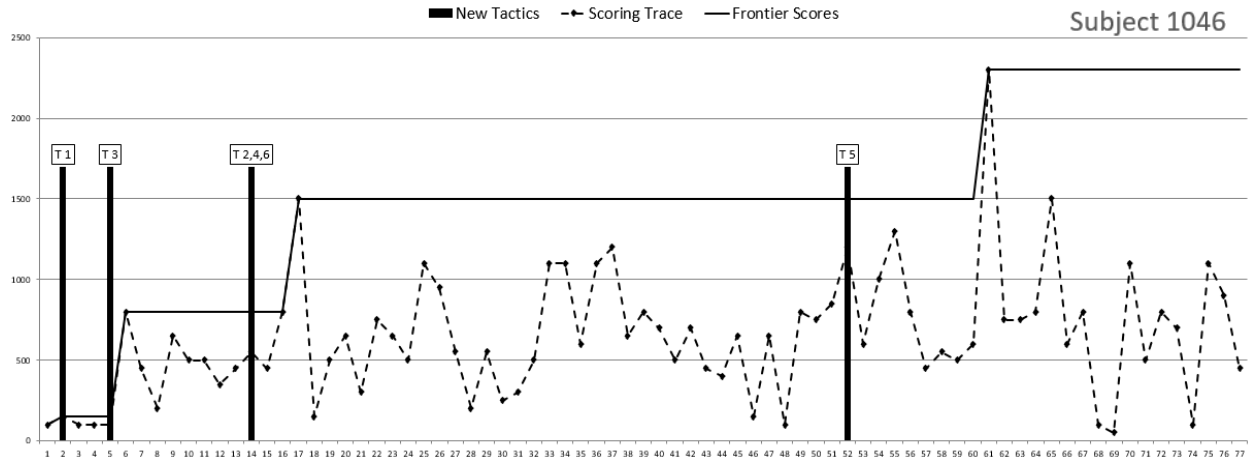
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1044



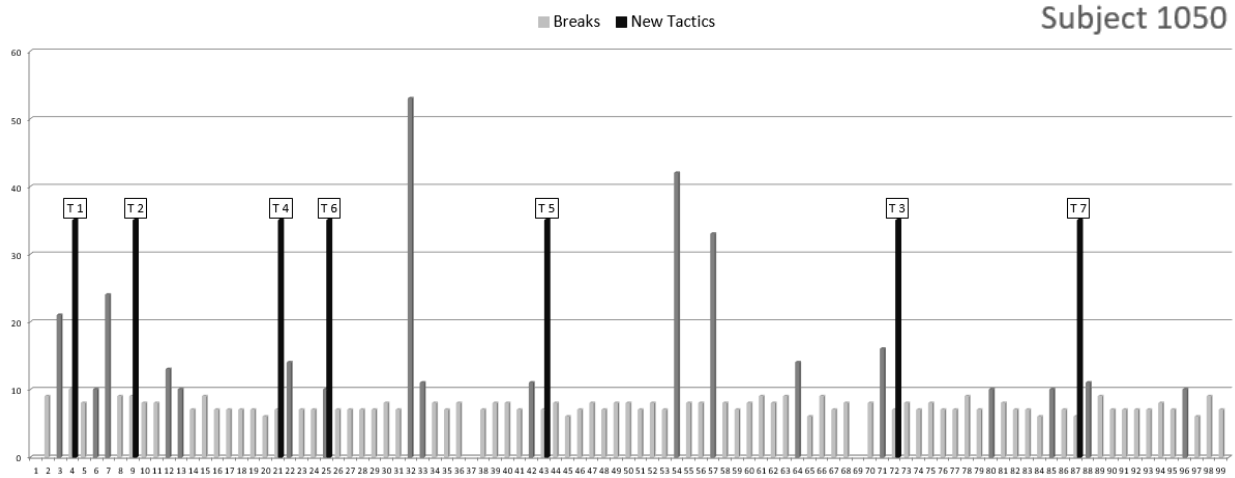
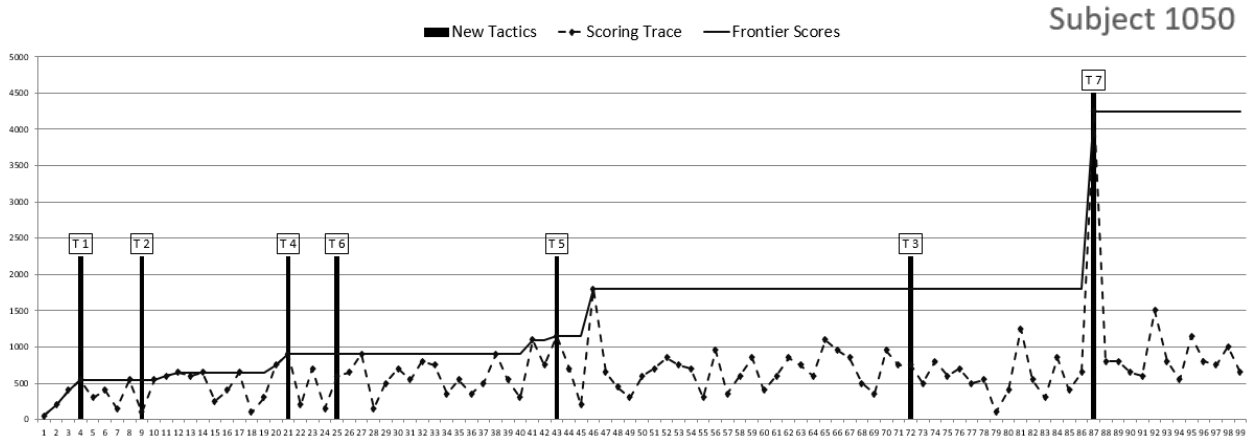
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1046



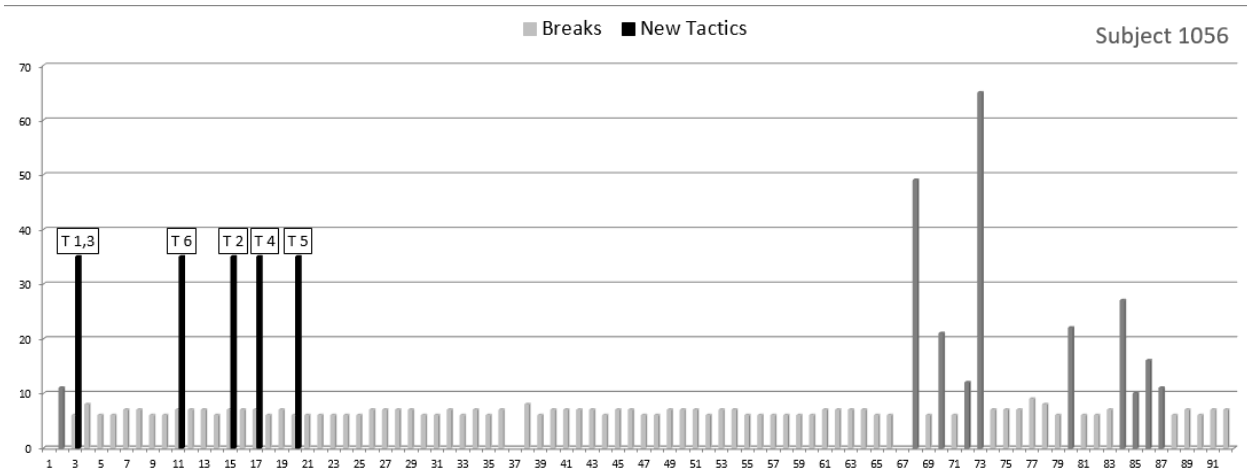
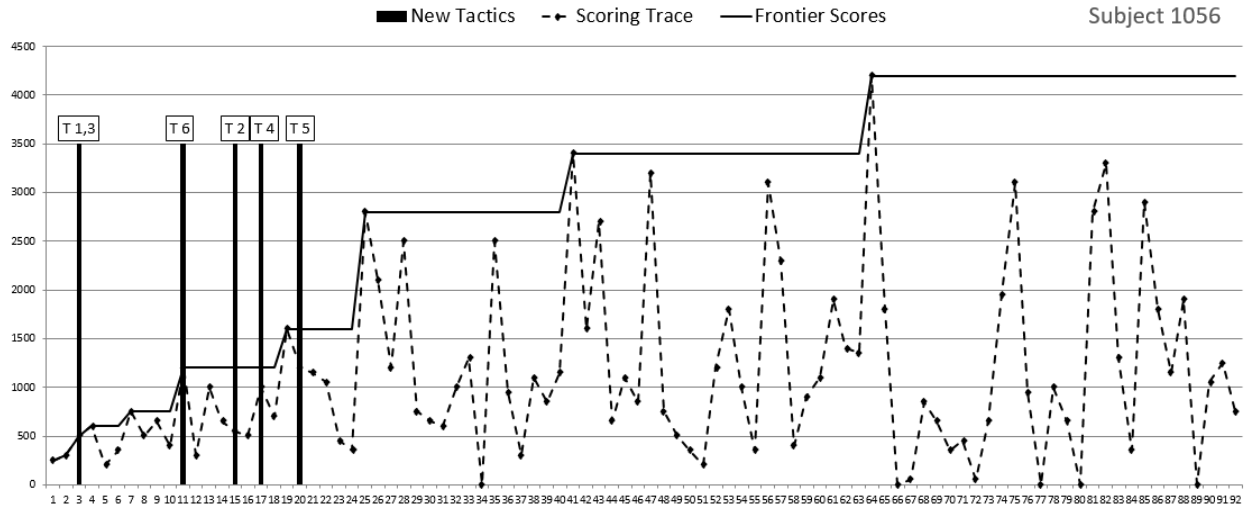
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1050



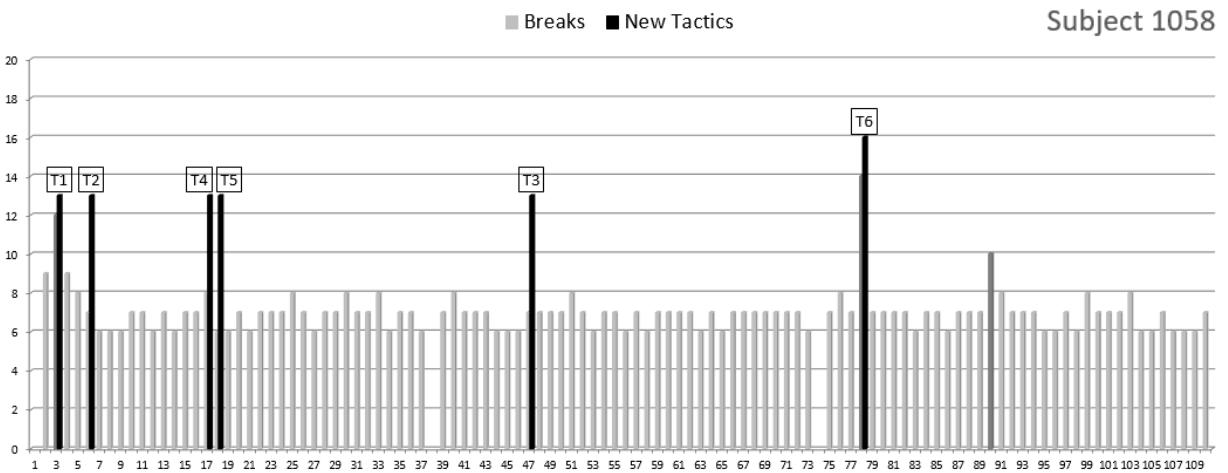
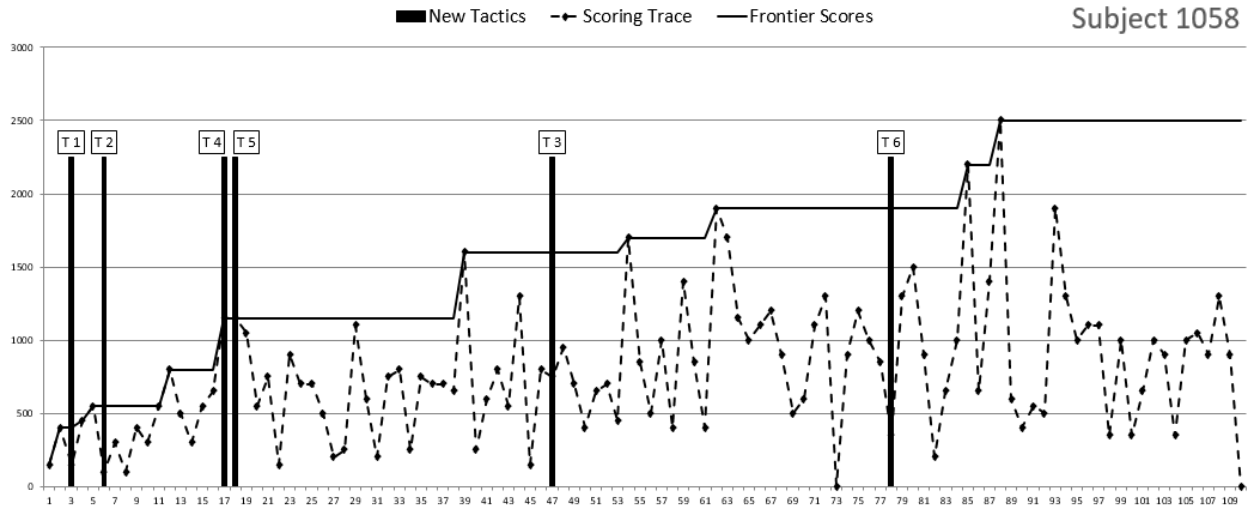
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1056



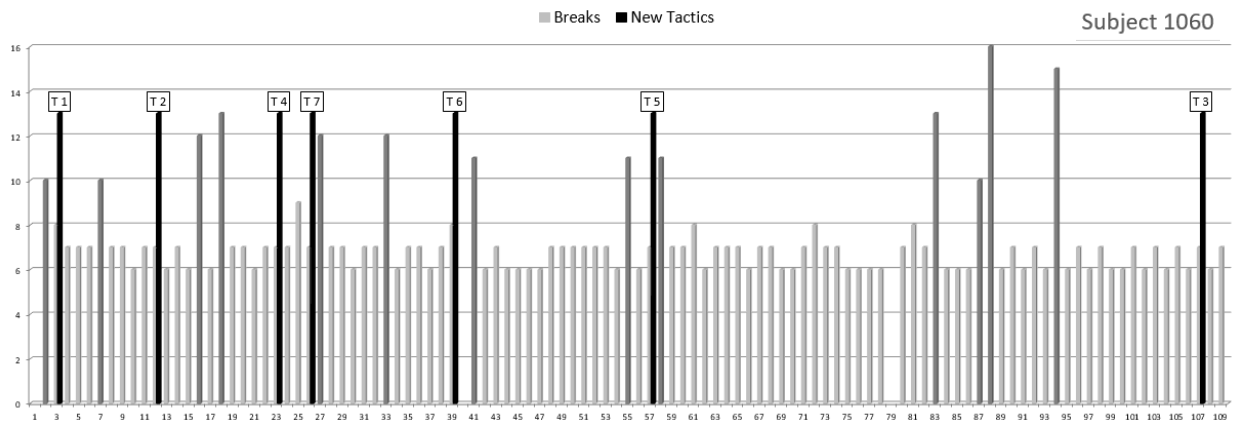
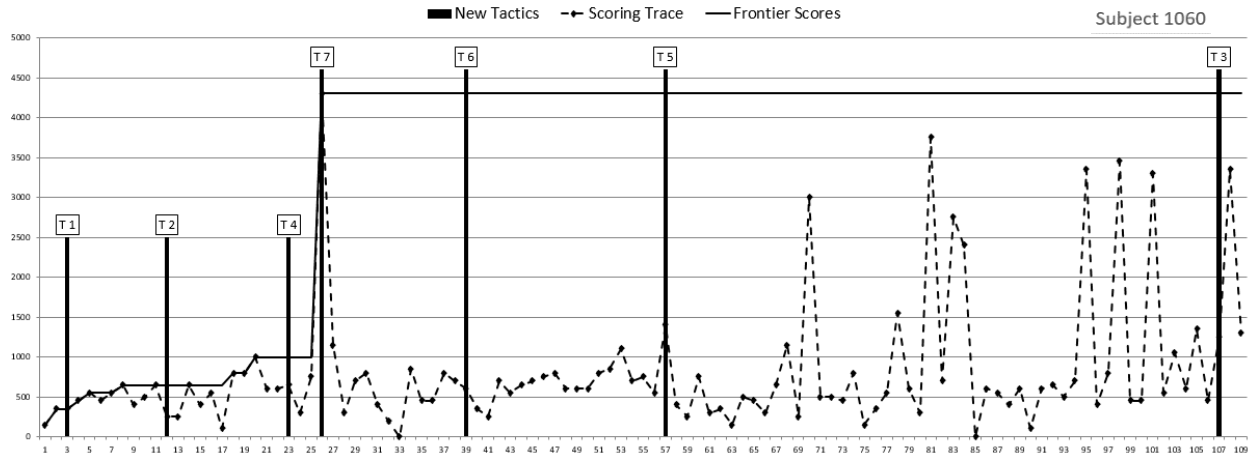
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1058



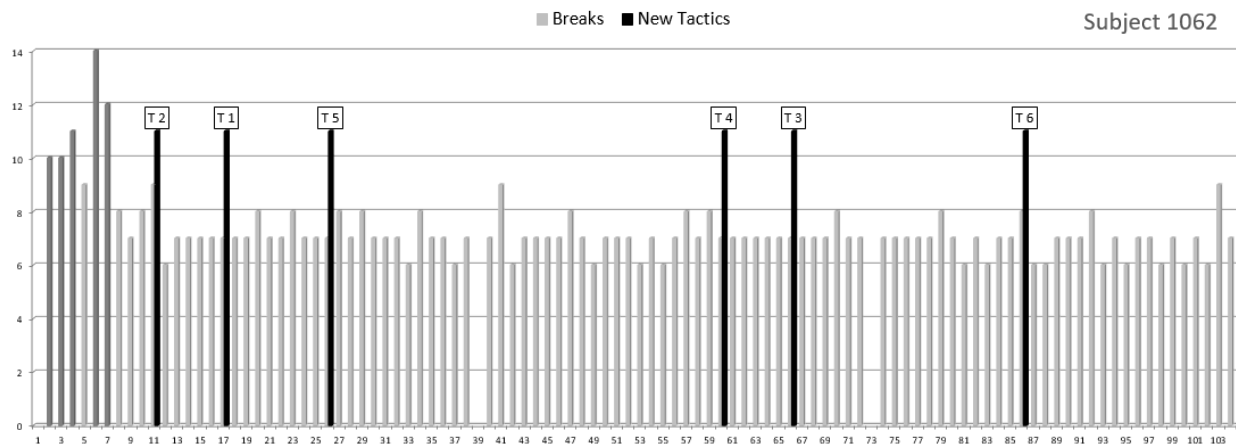
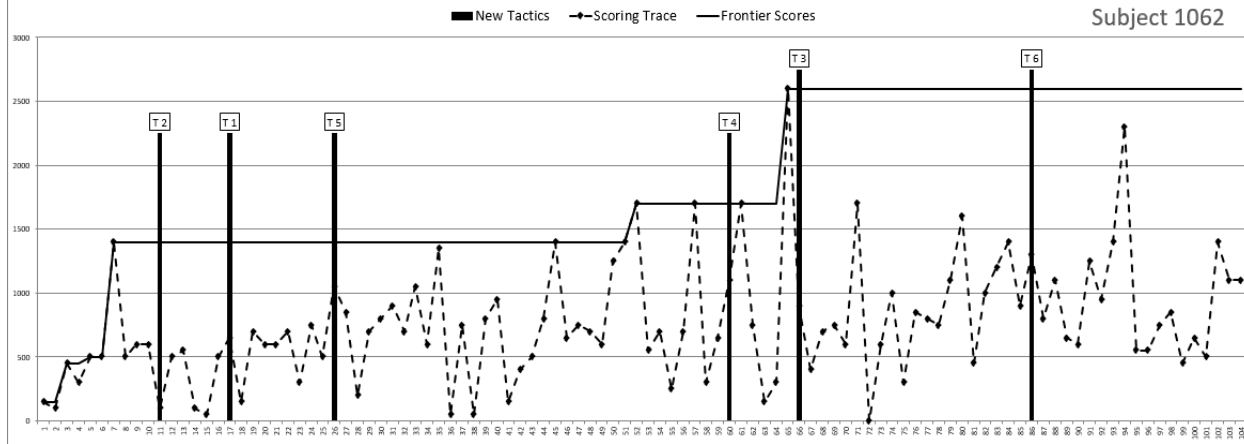
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1060



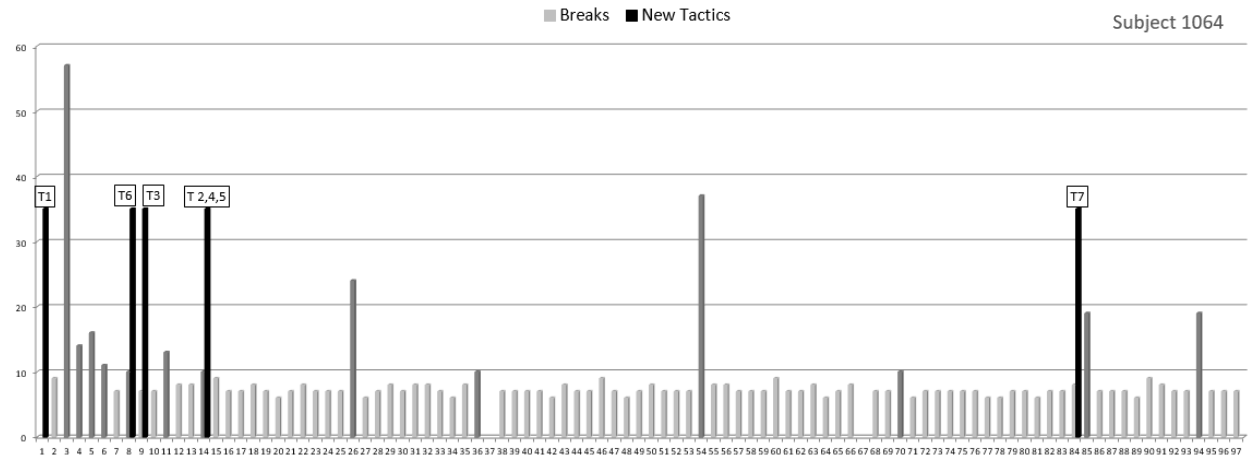
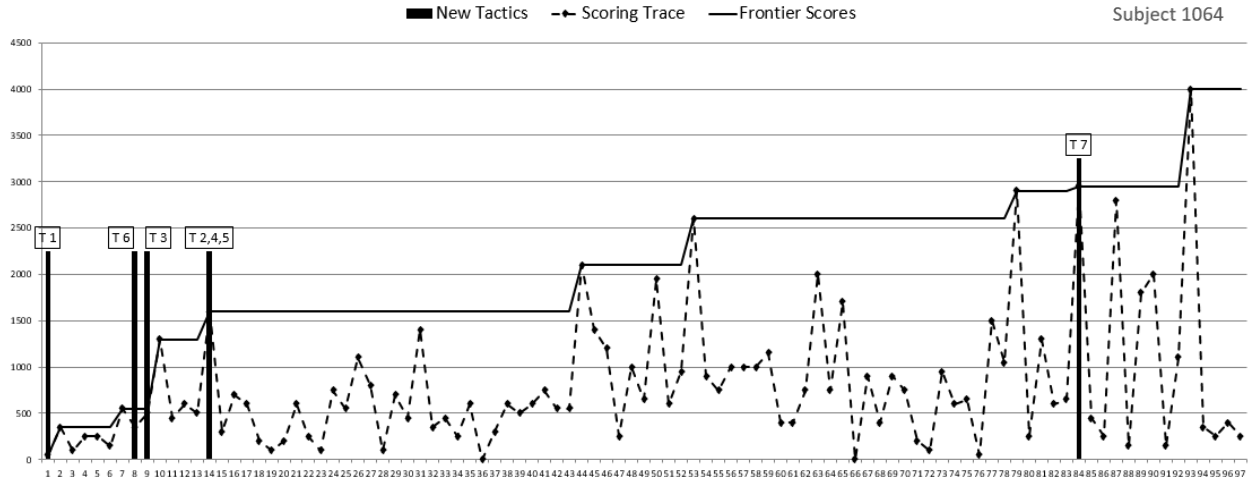
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1062



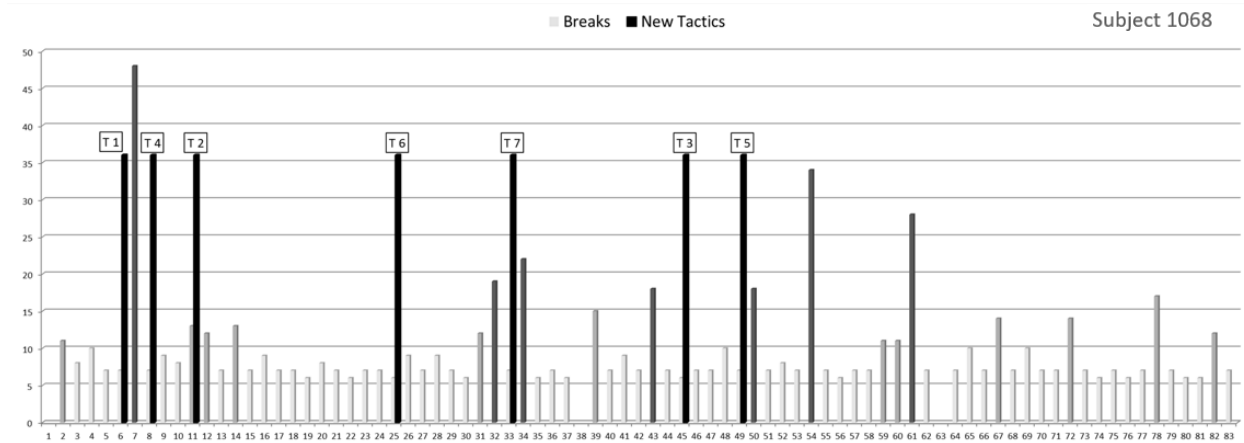
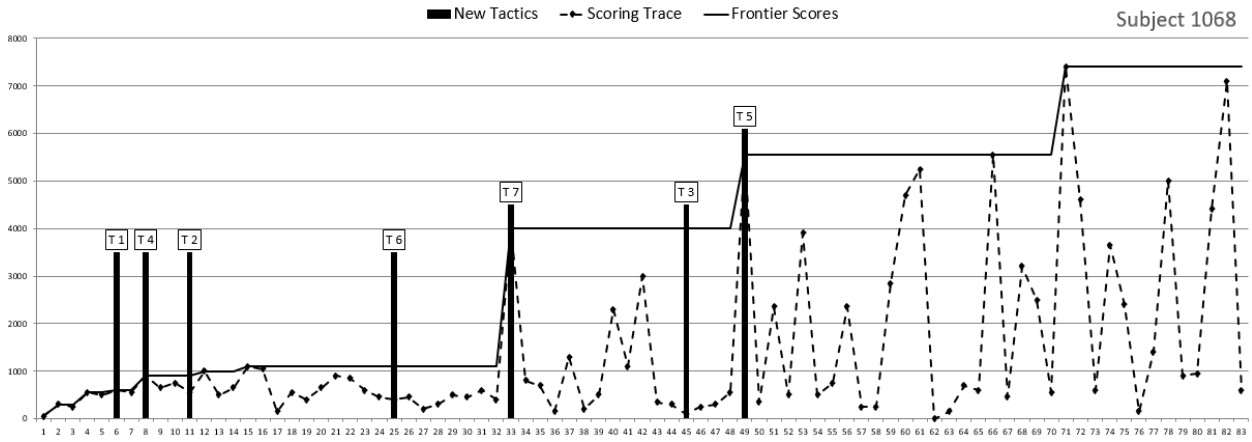
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1064



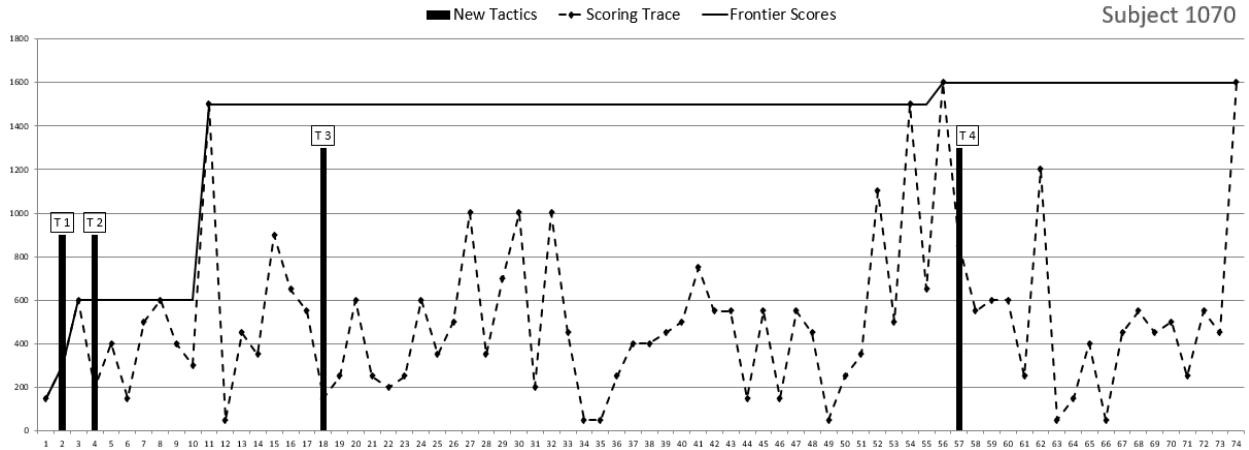
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1068



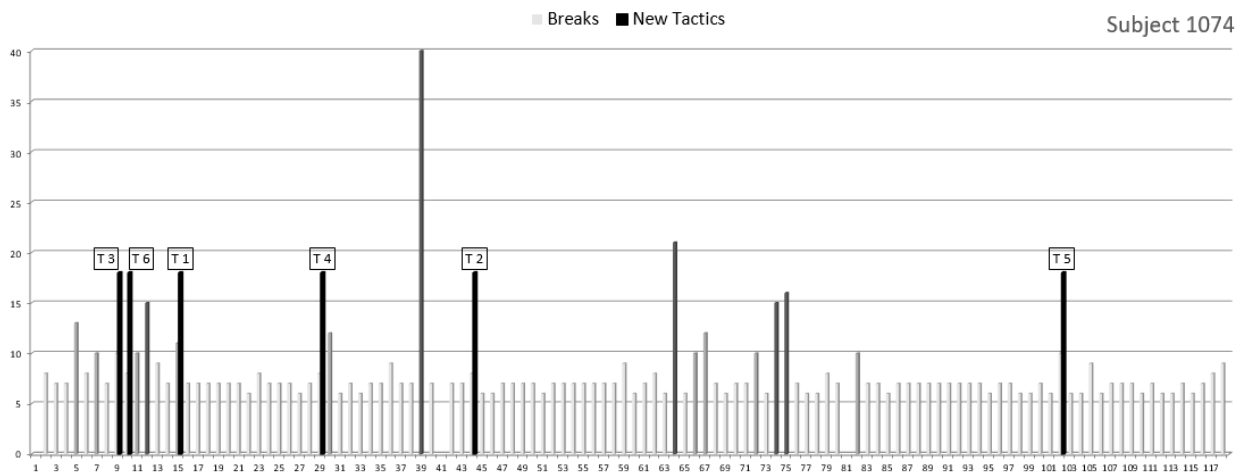
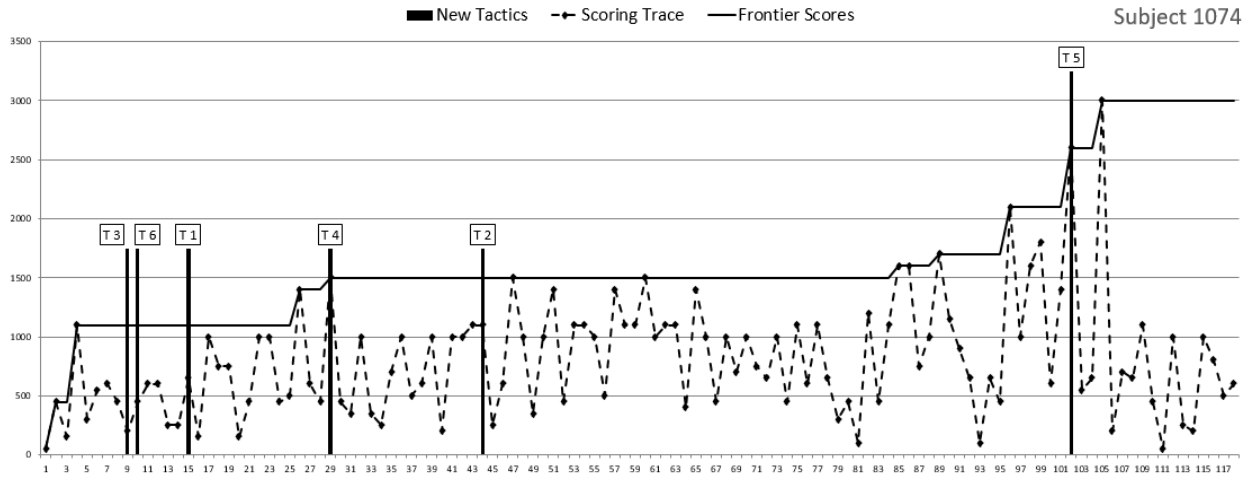
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1070



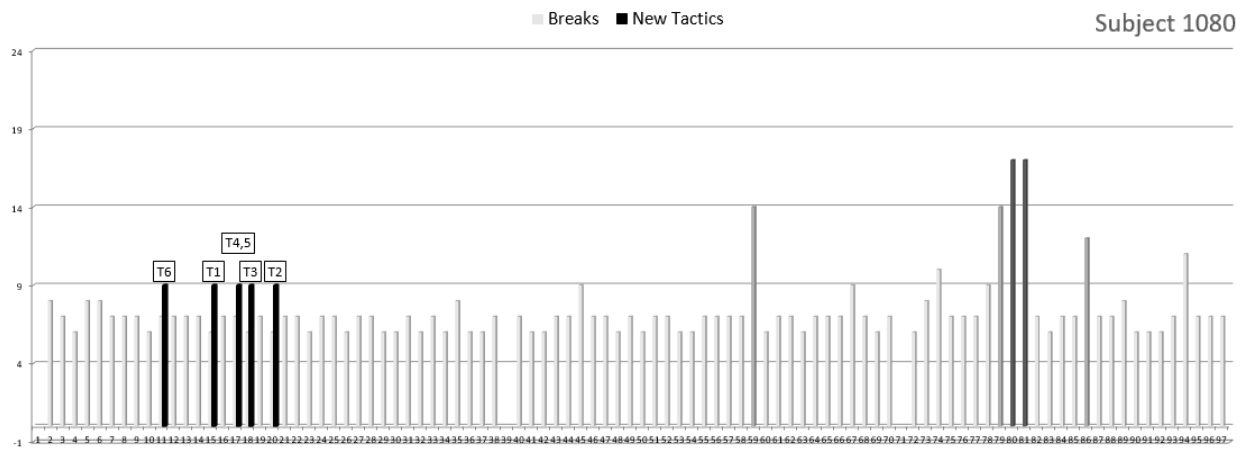
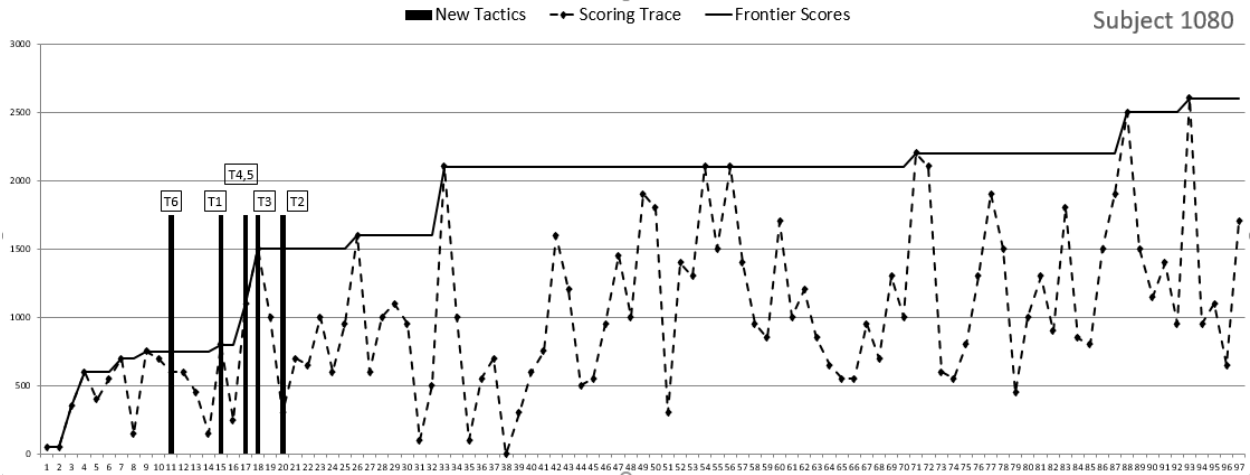
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1074



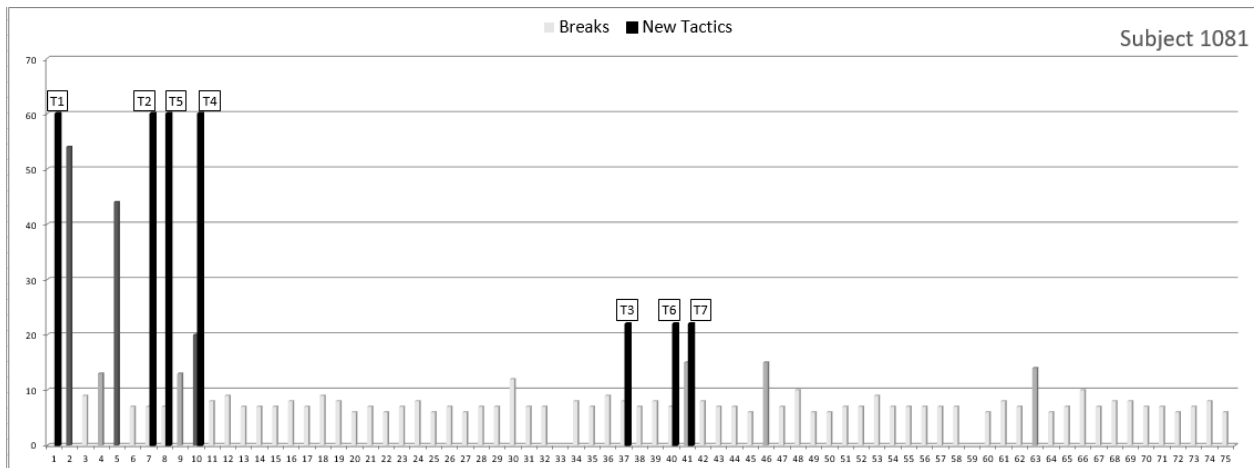
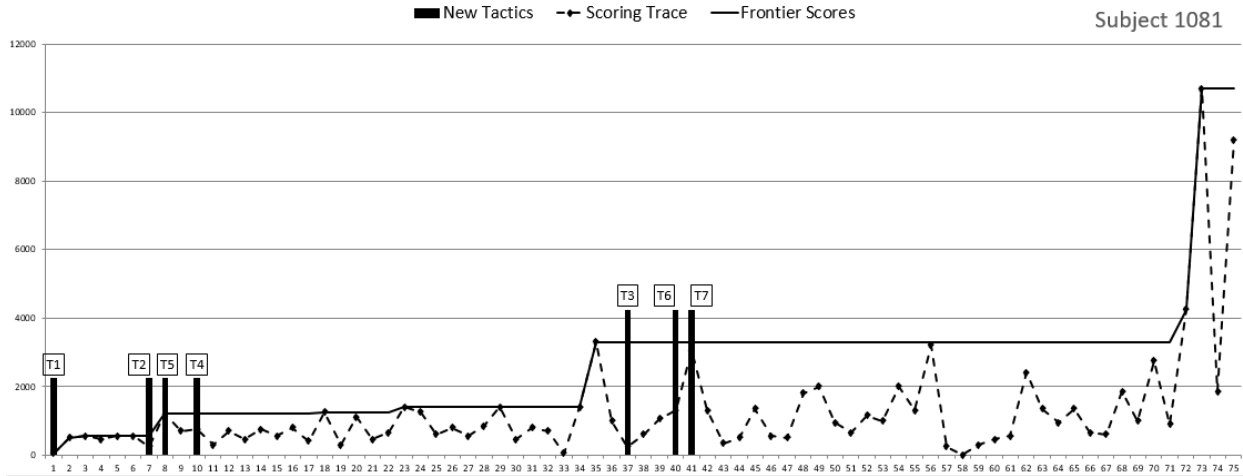
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1080



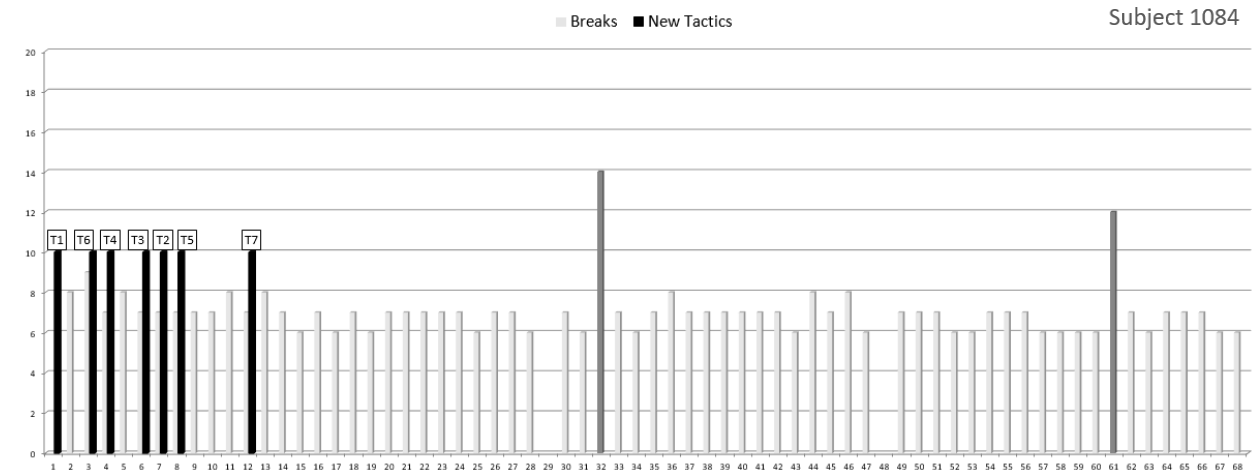
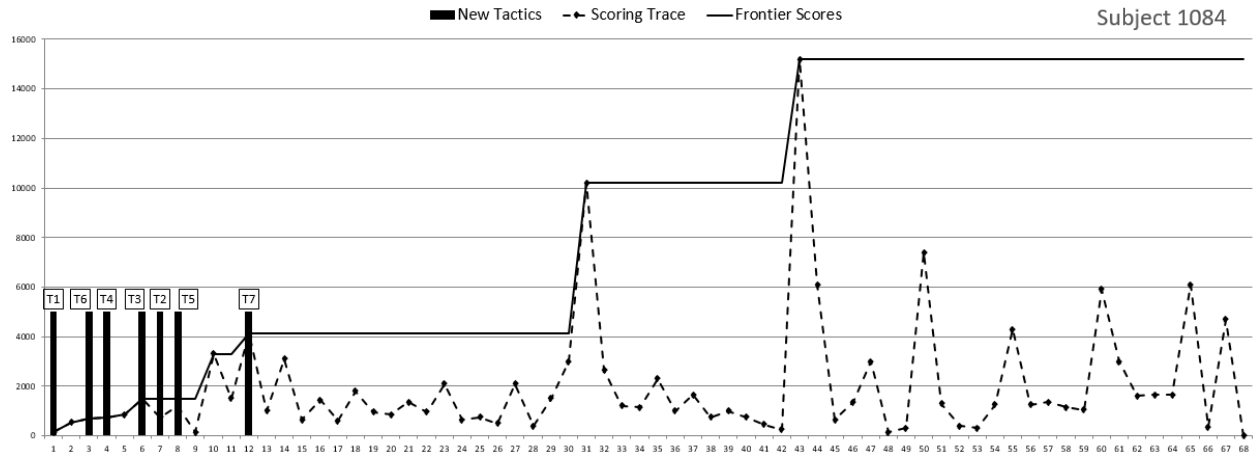
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 1081



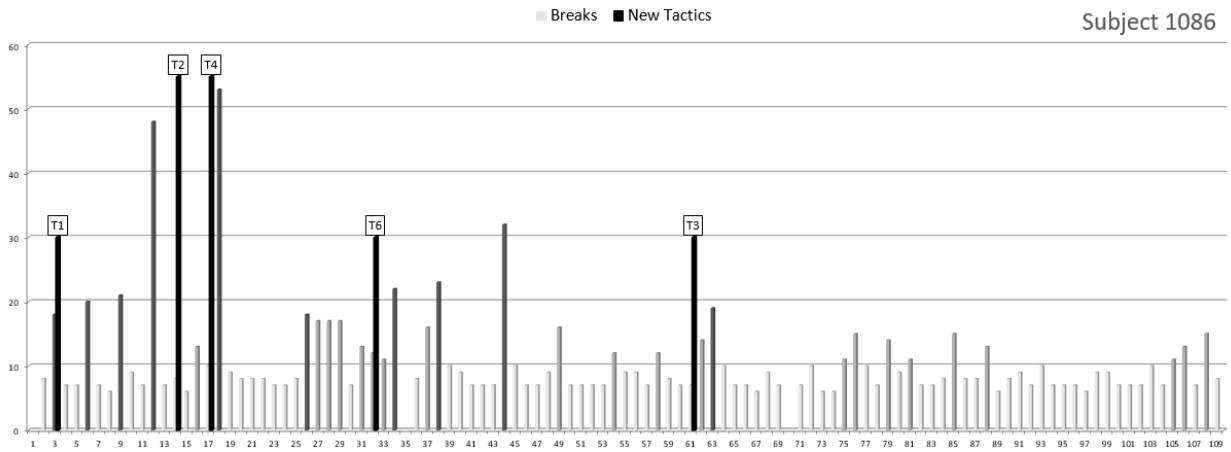
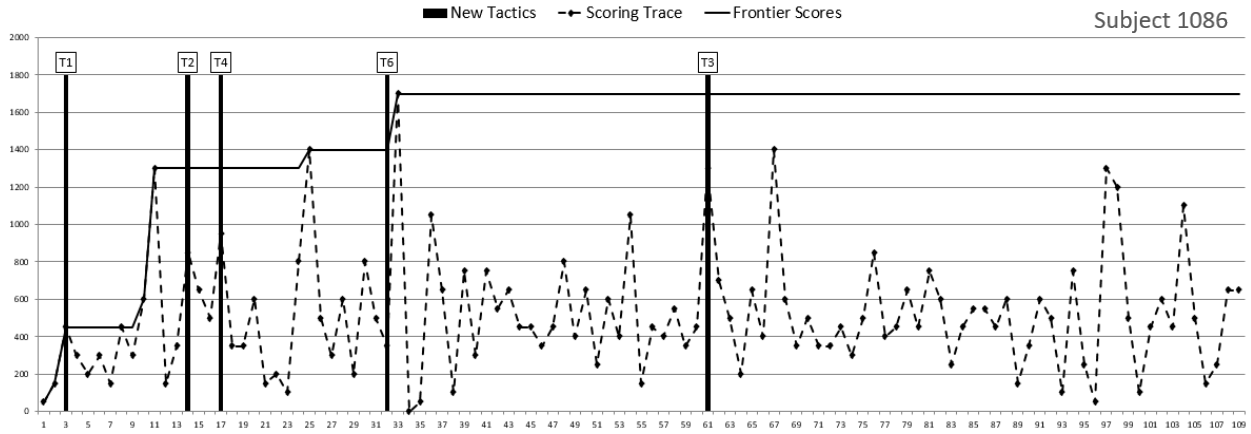
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1084



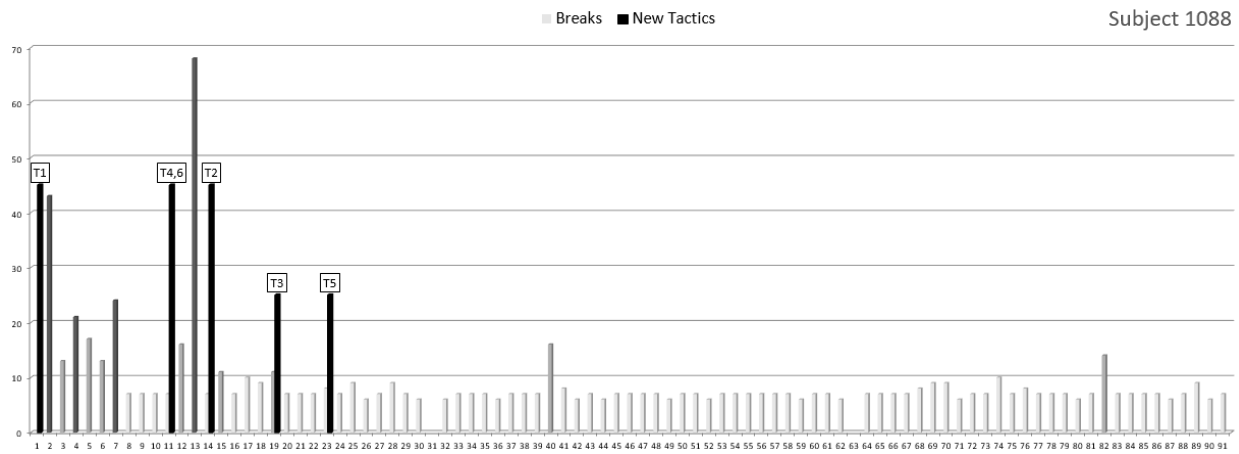
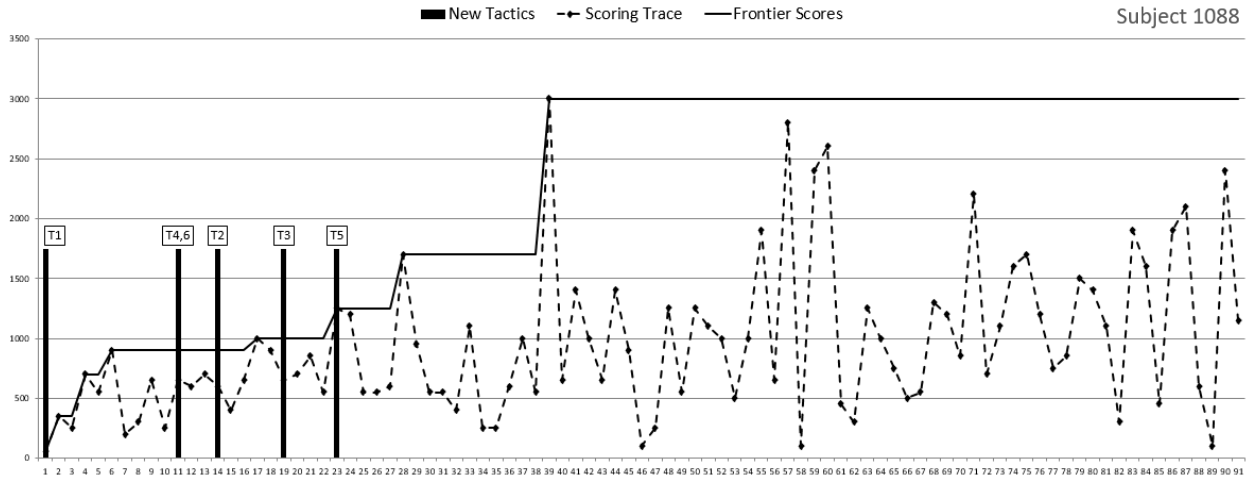
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1086



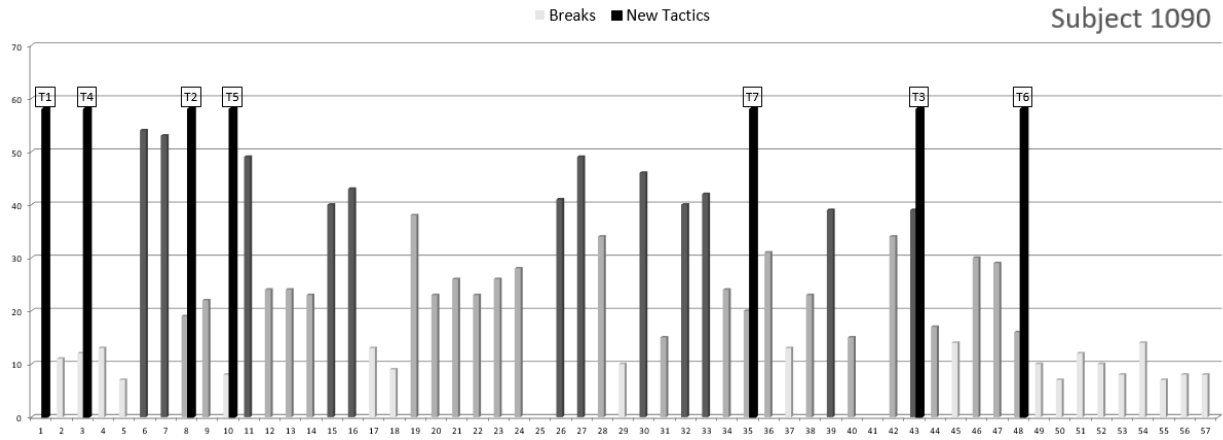
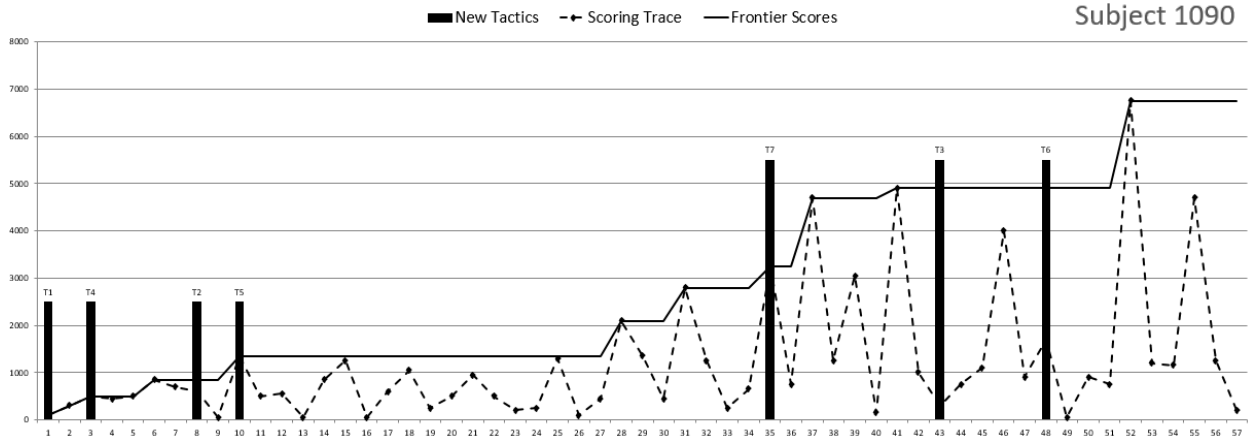
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1088



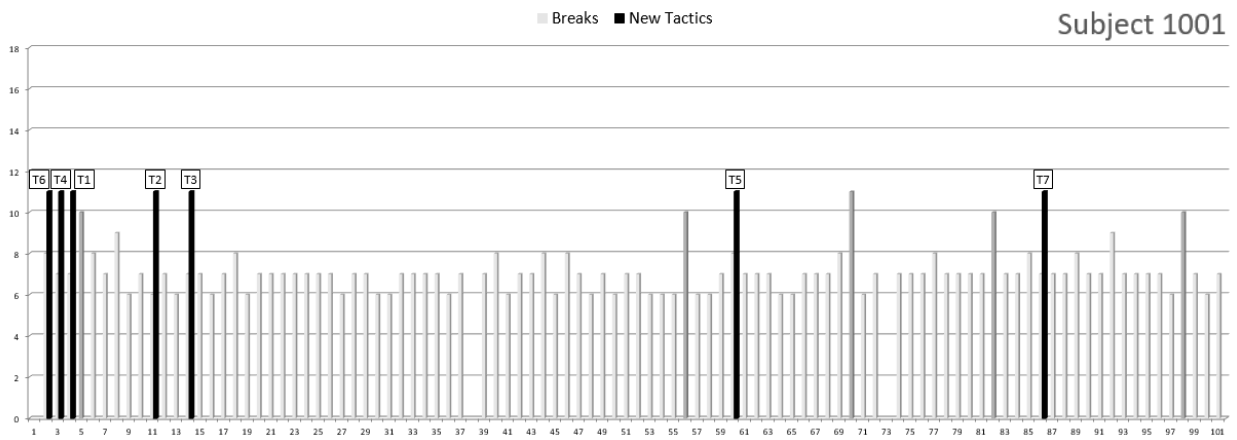
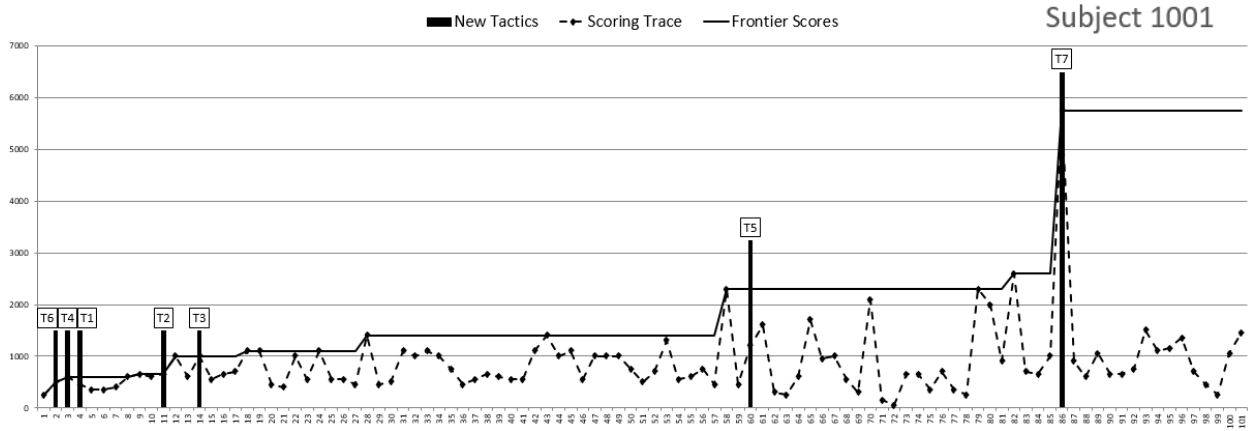
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1090



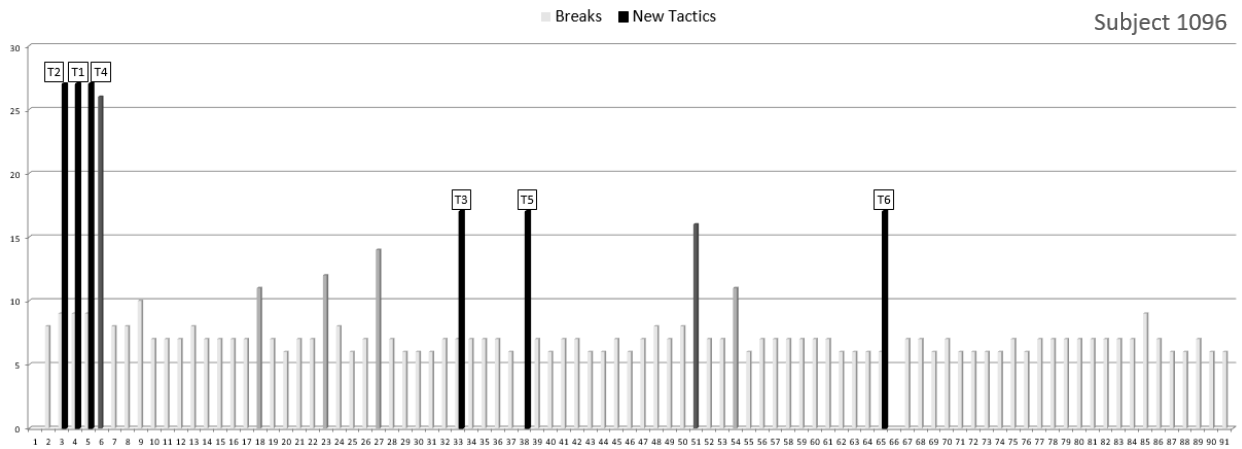
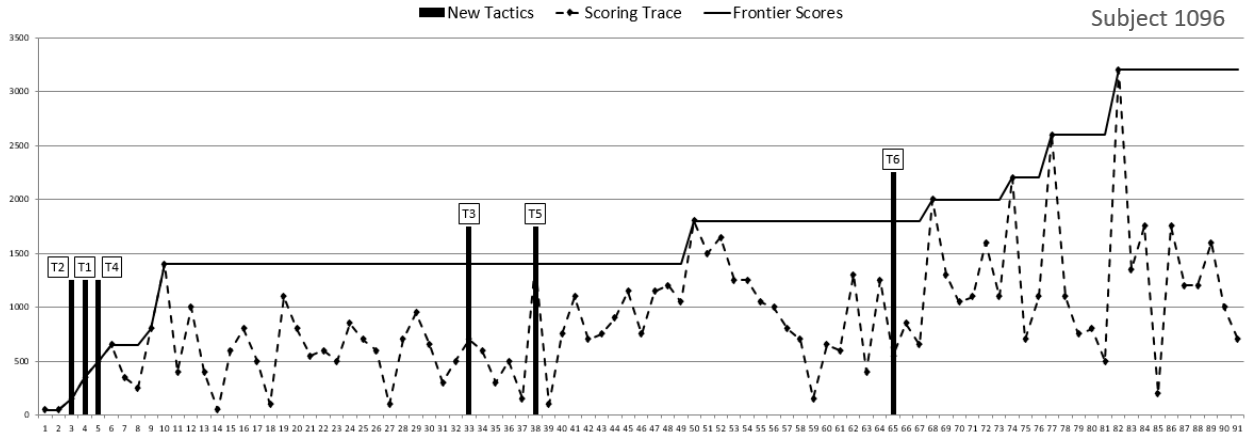
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1001



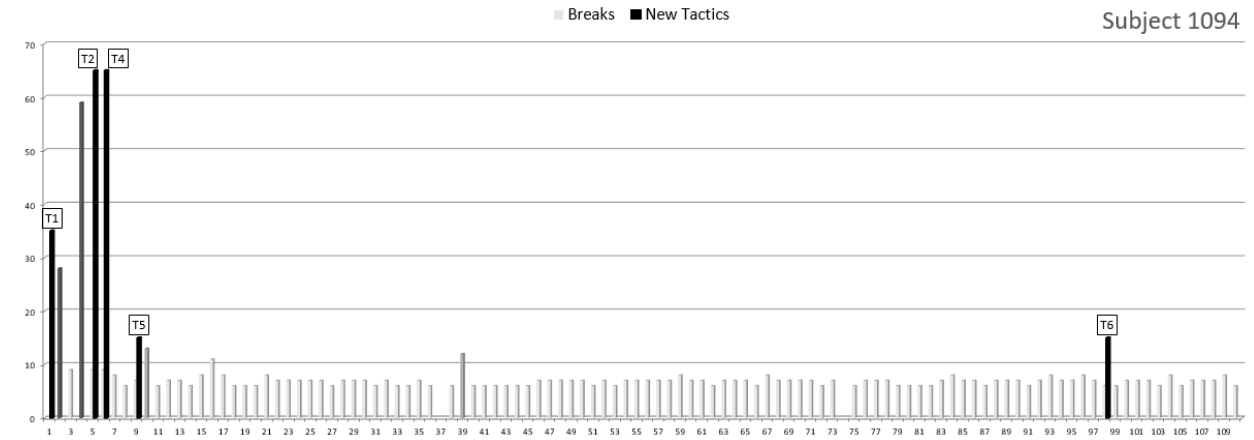
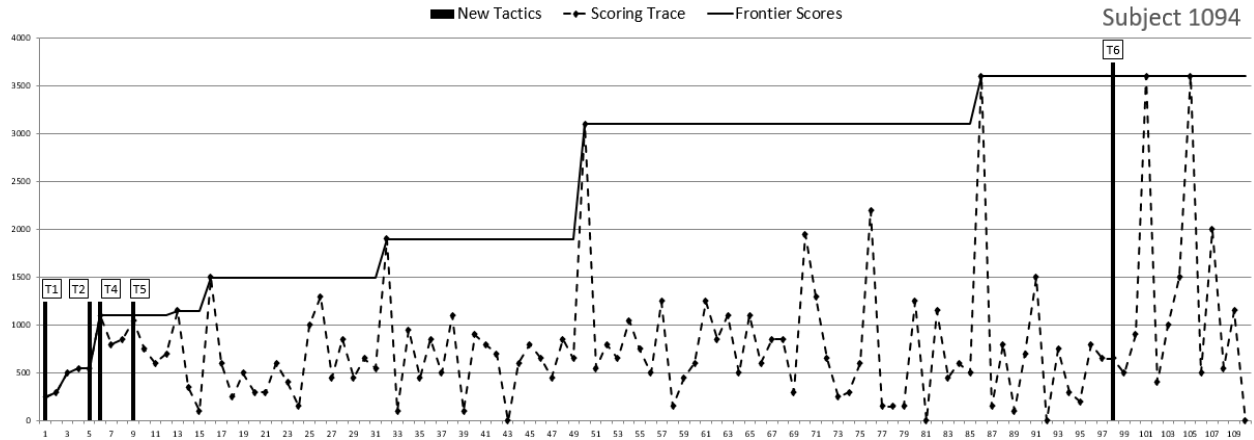
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 1096



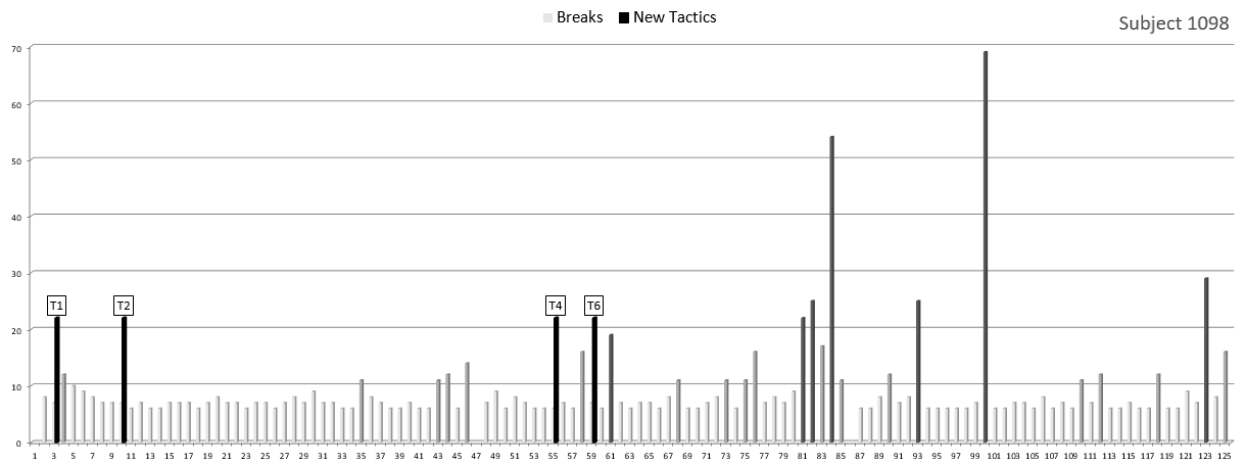
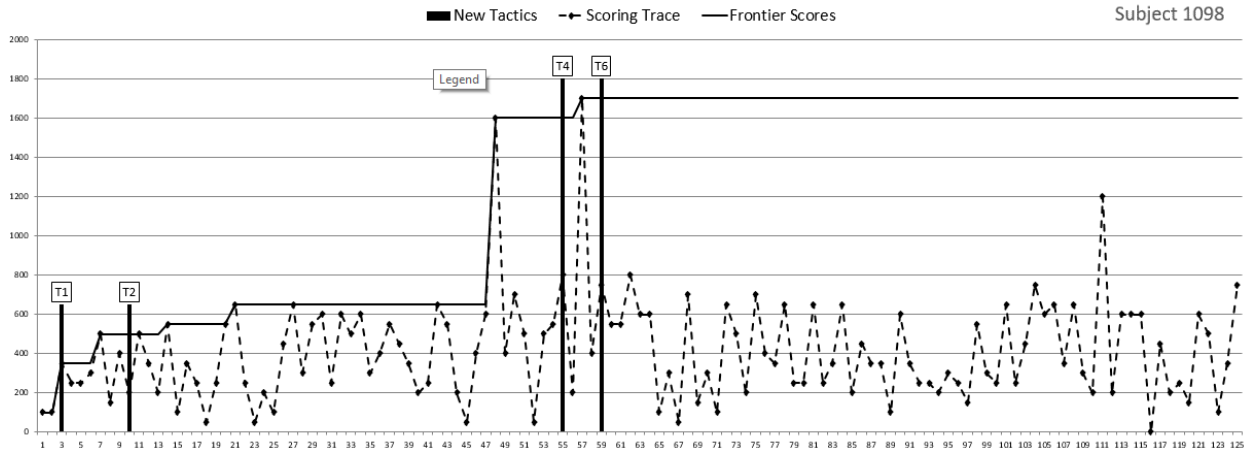
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1094



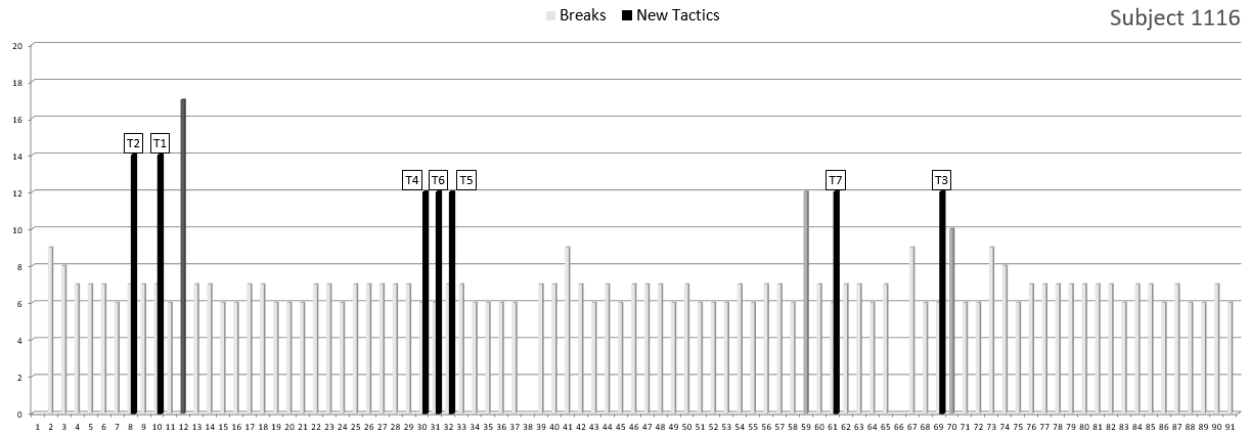
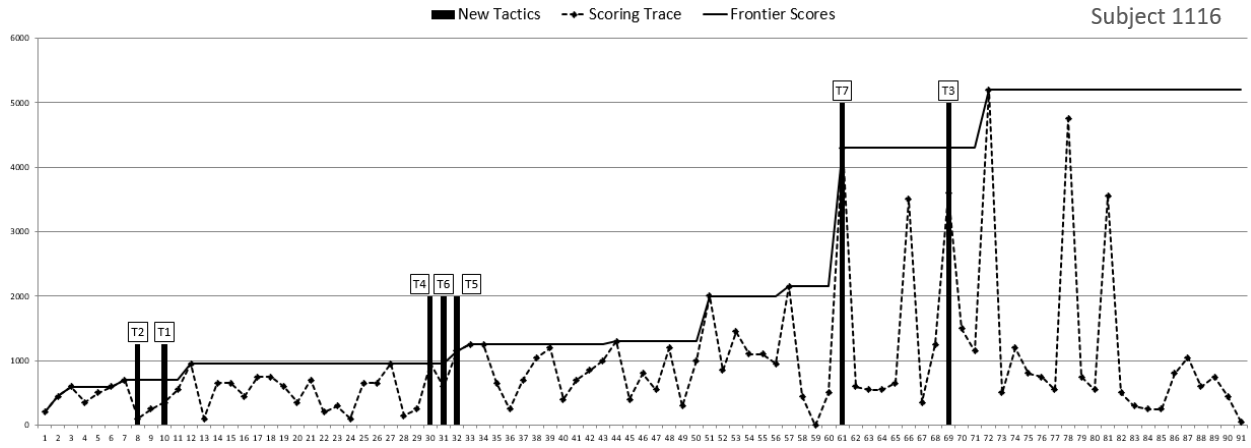
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1098



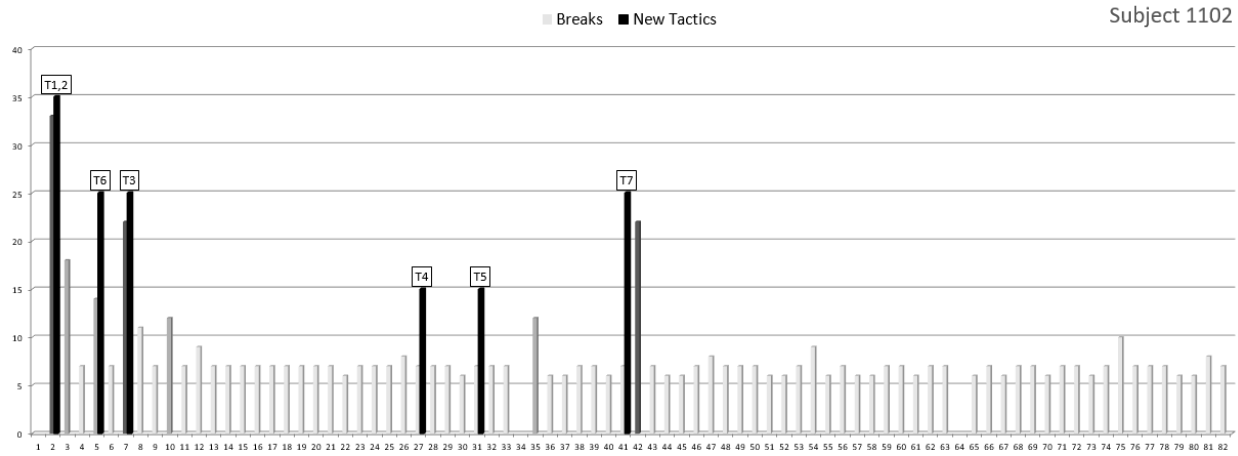
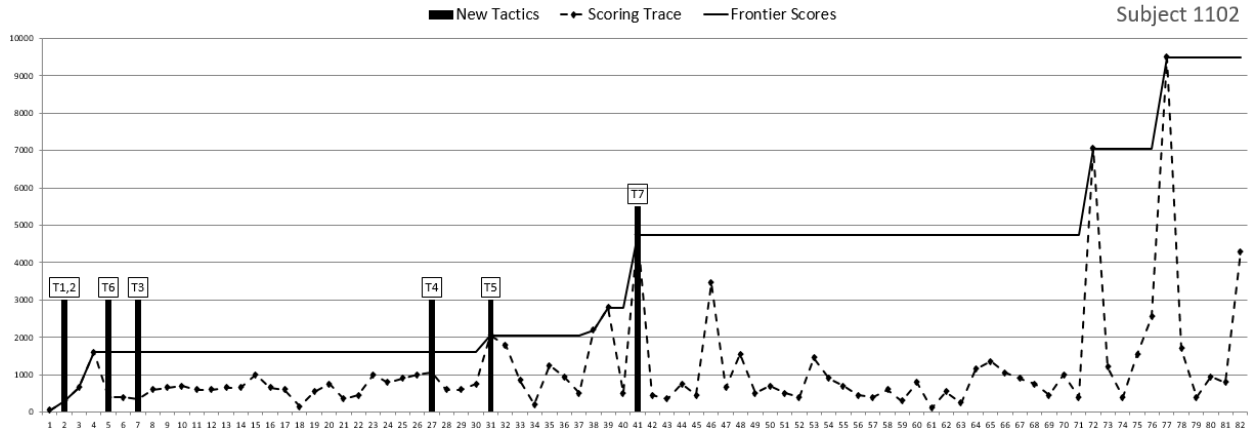
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1116



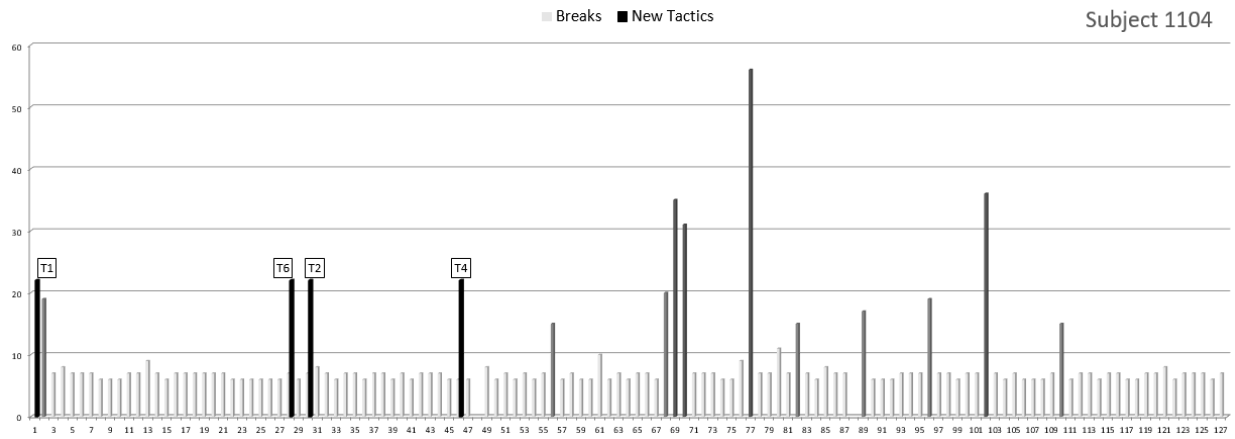
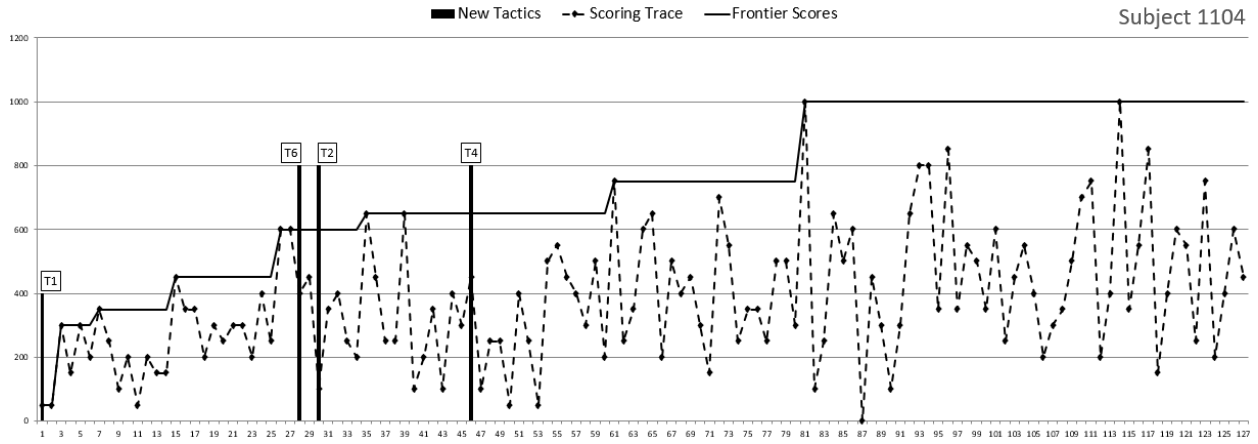
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1102



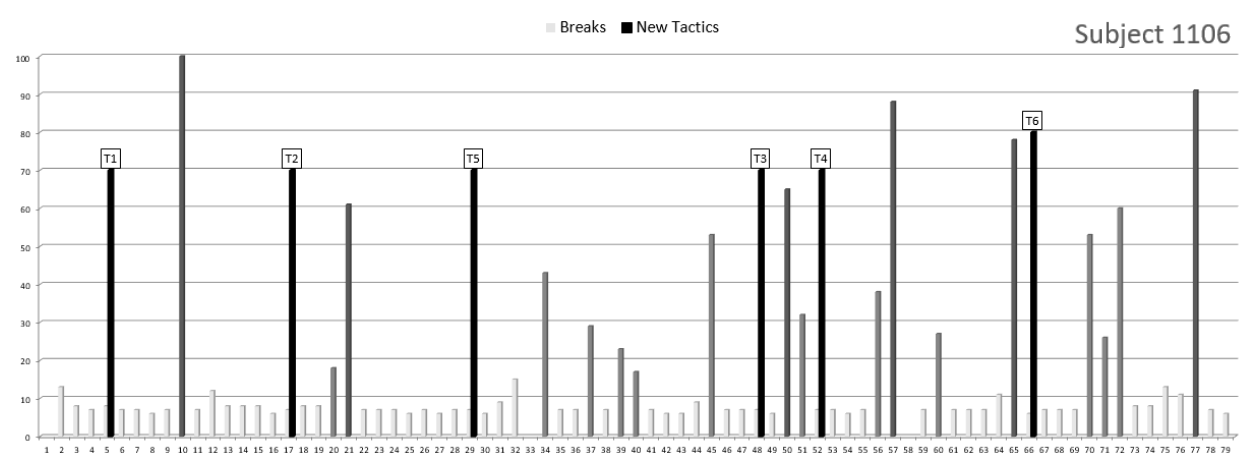
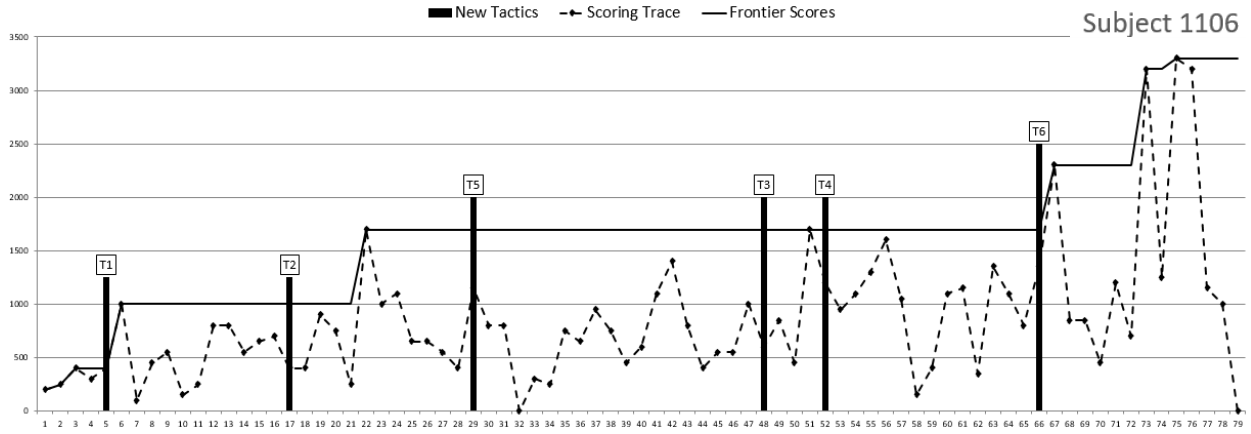
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1104



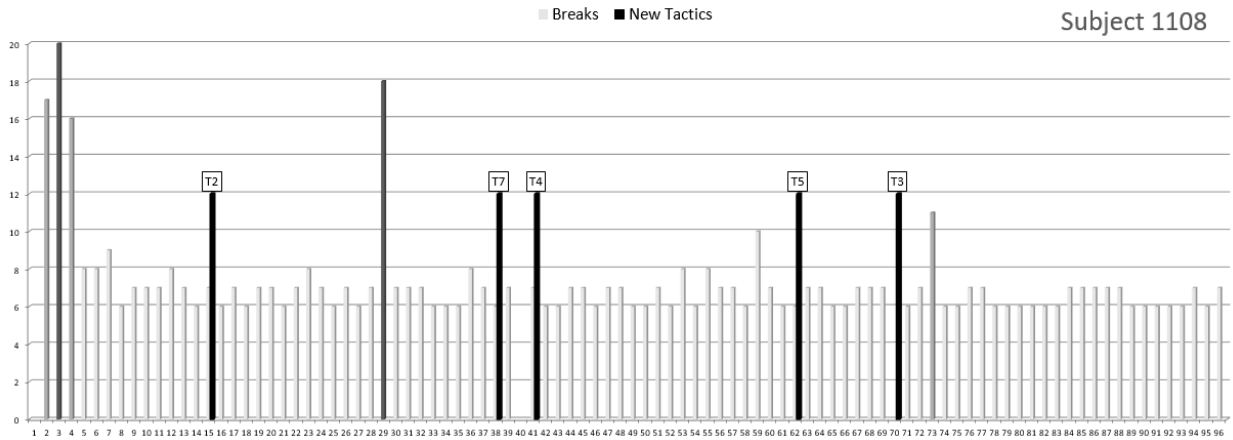
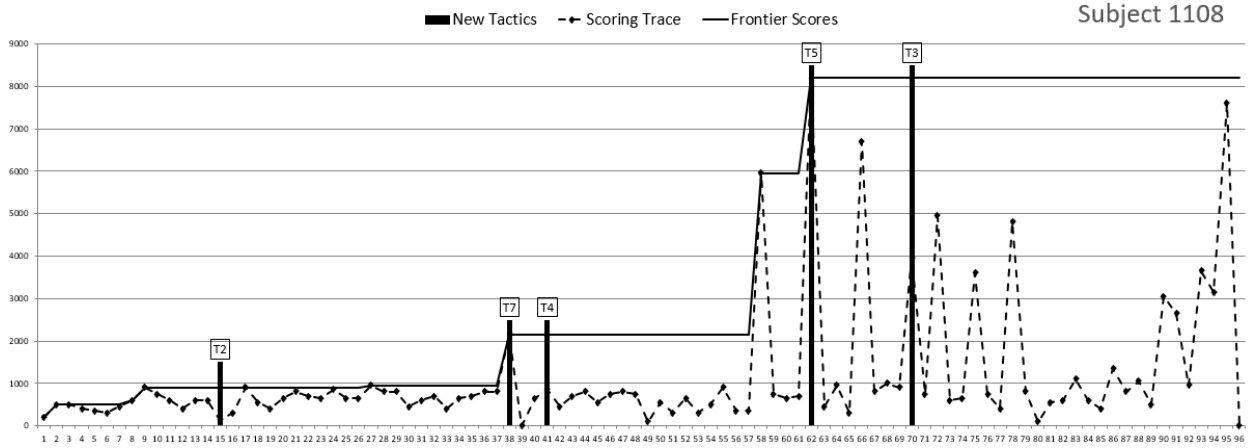
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1106



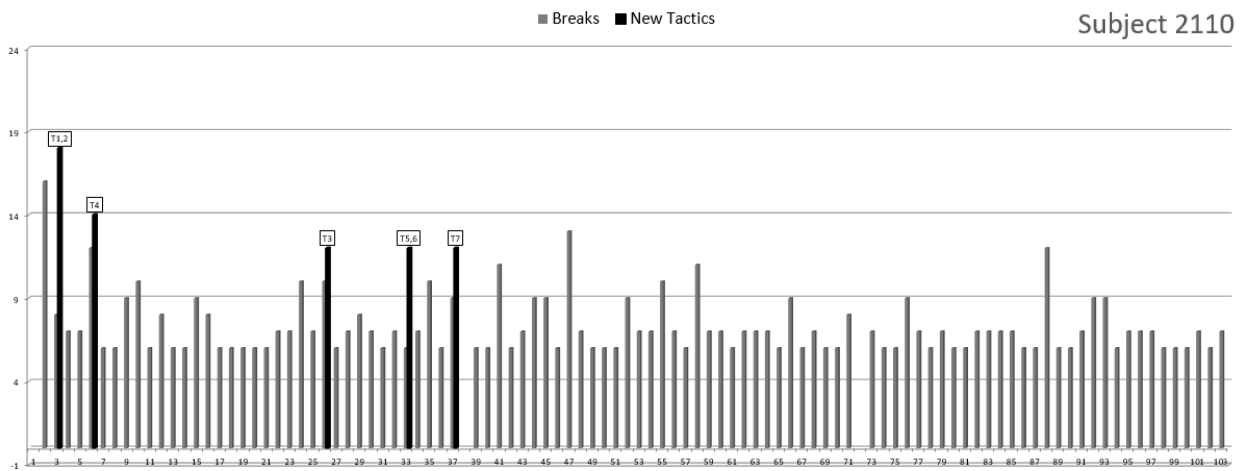
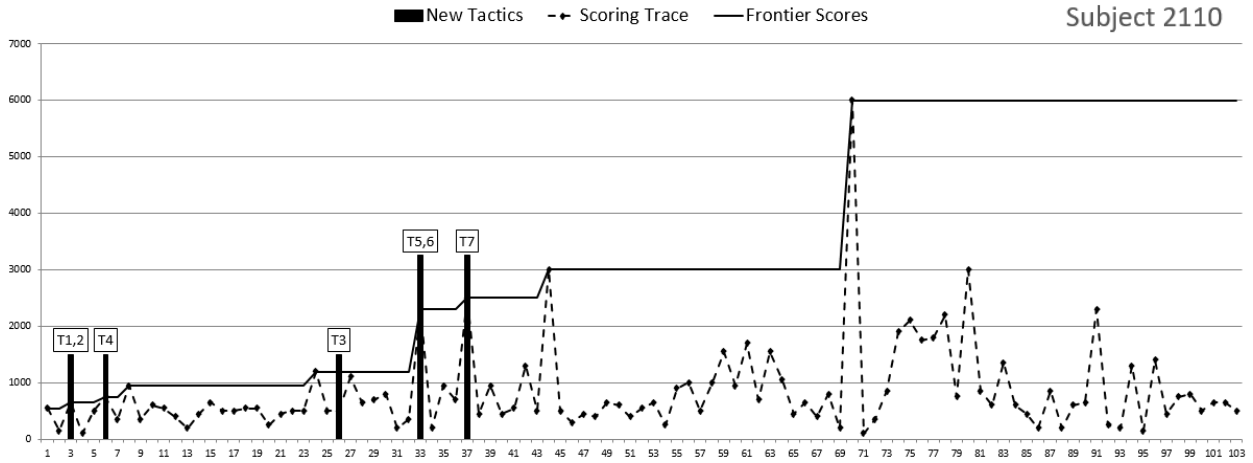
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1108



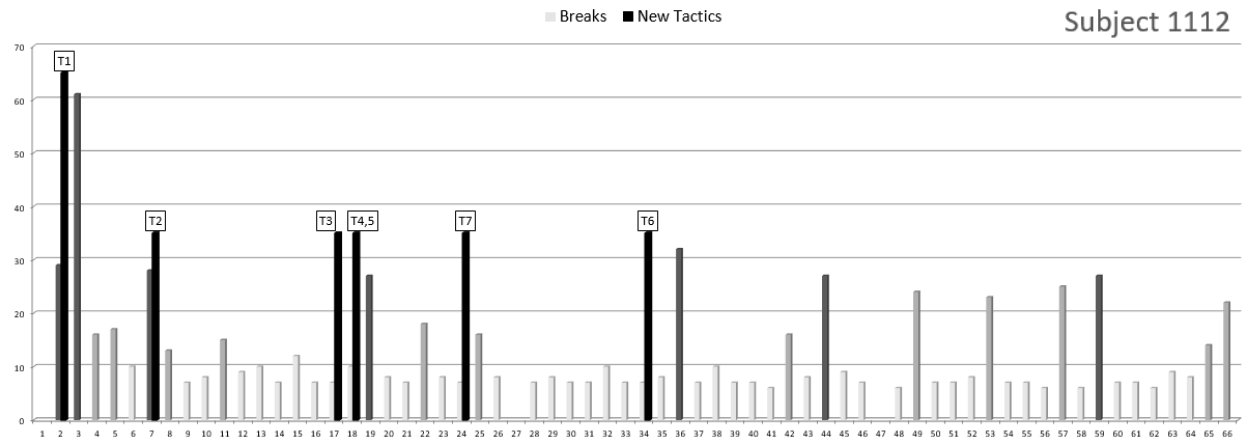
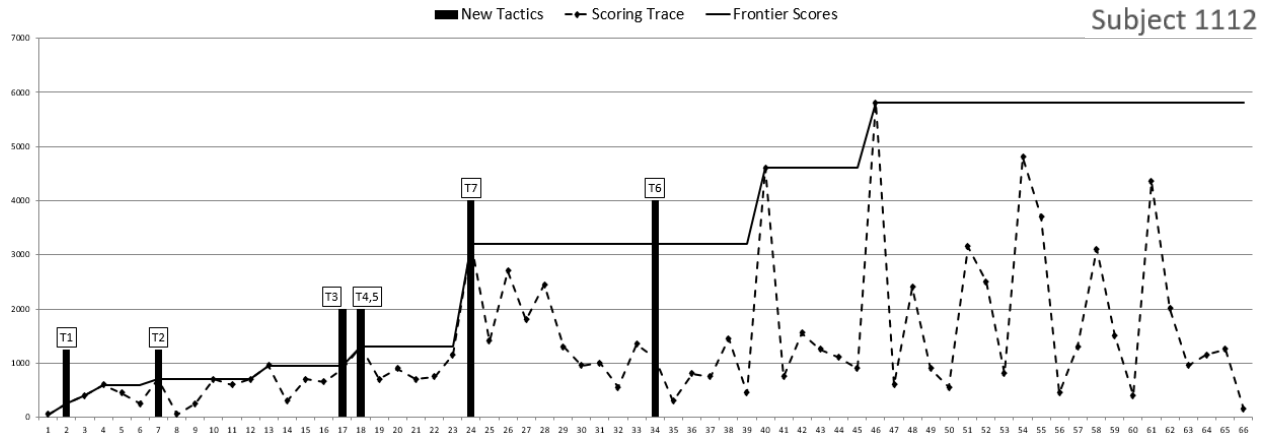
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2110



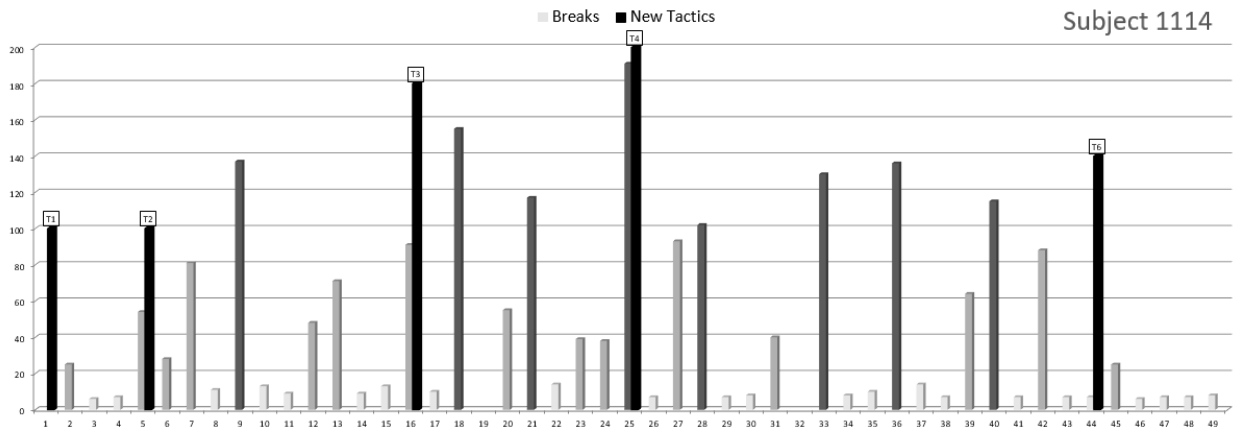
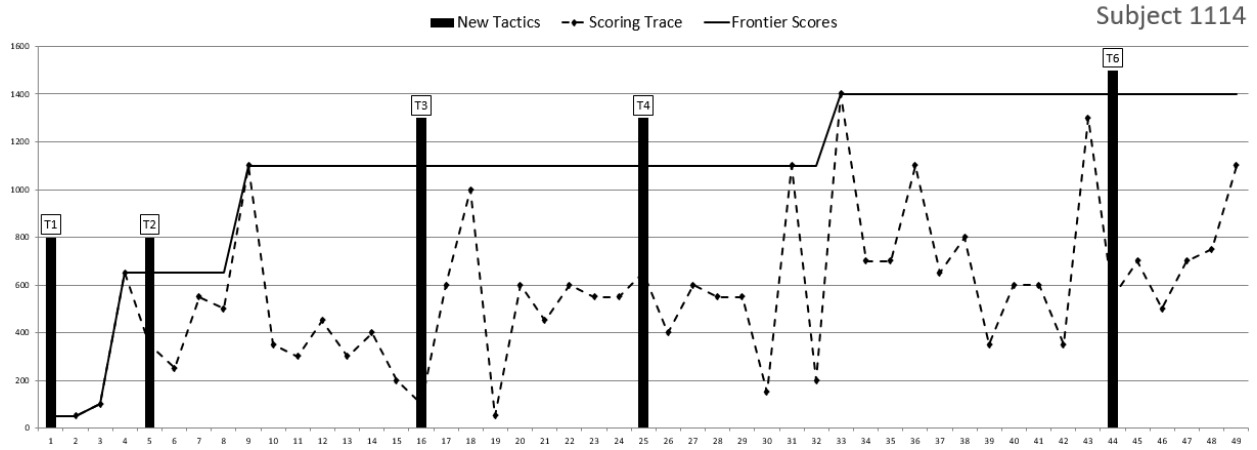
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1112



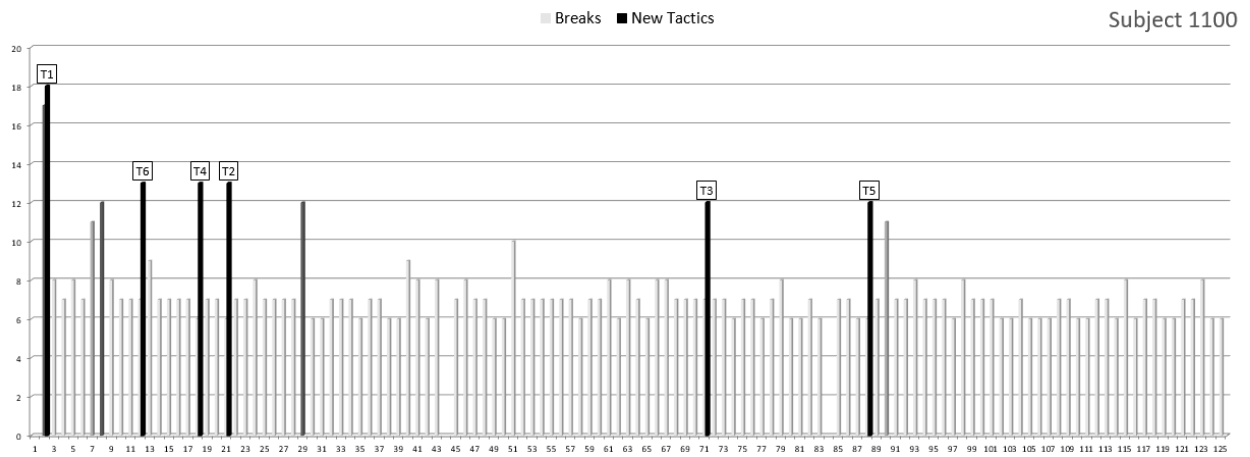
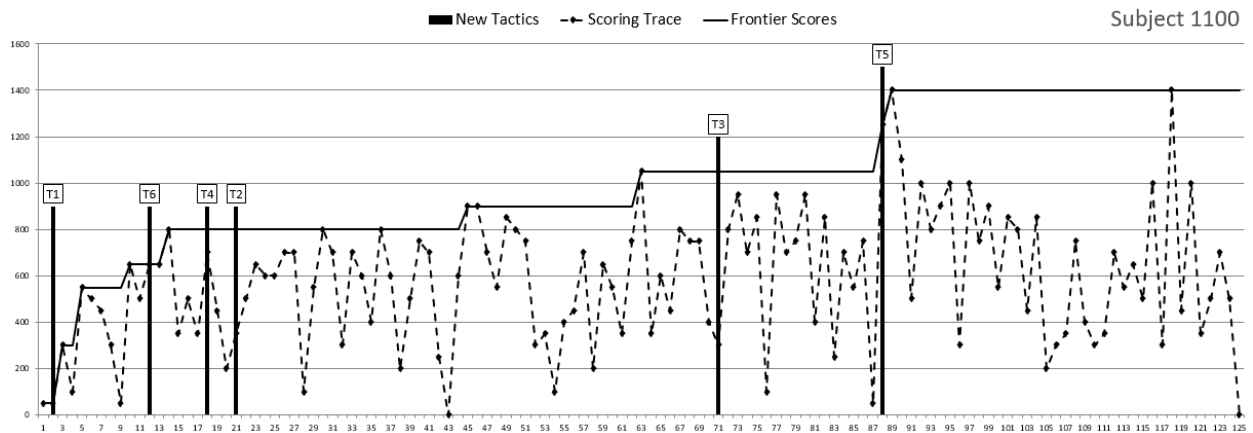
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1114



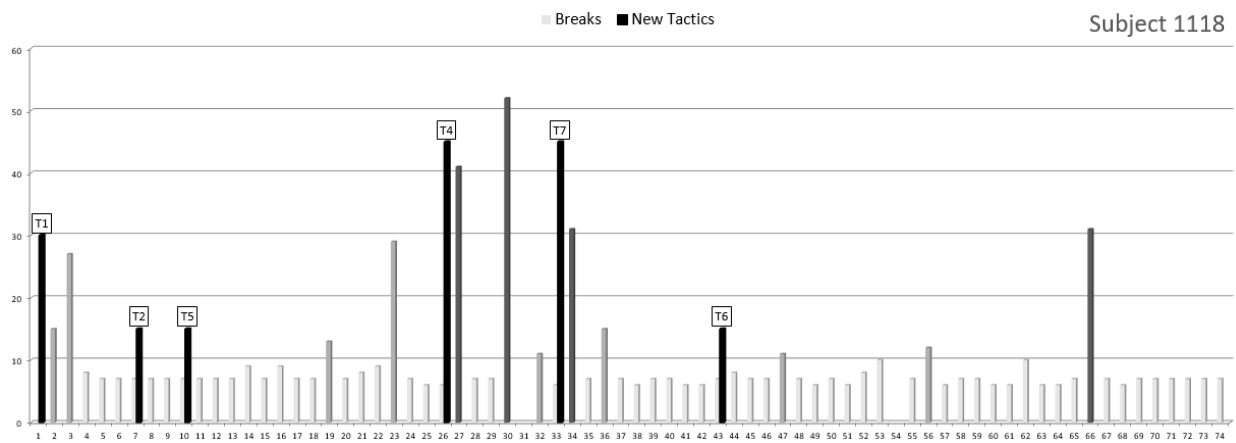
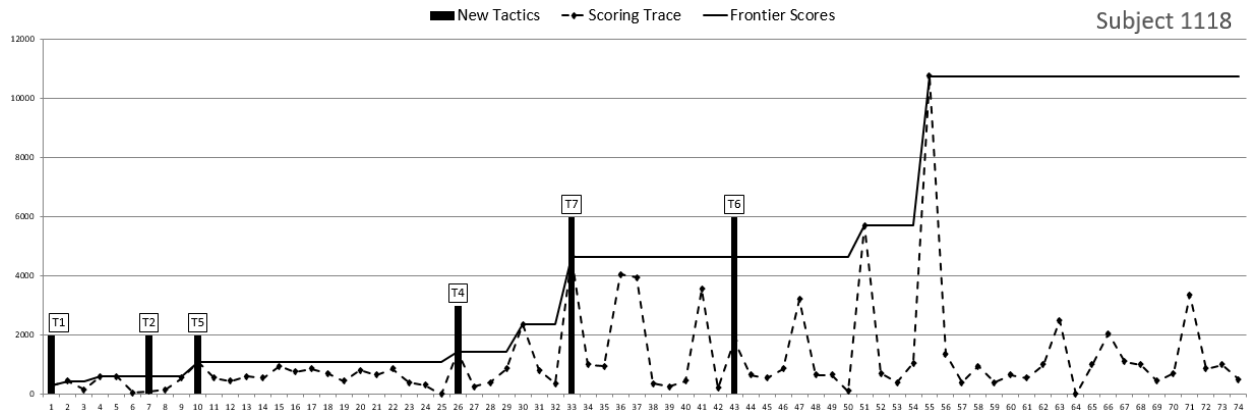
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1100



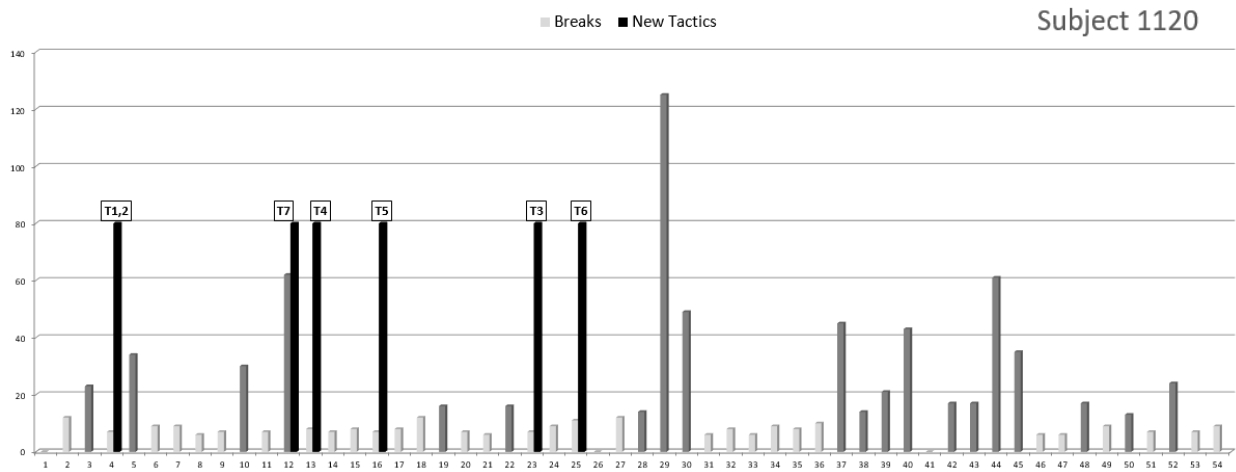
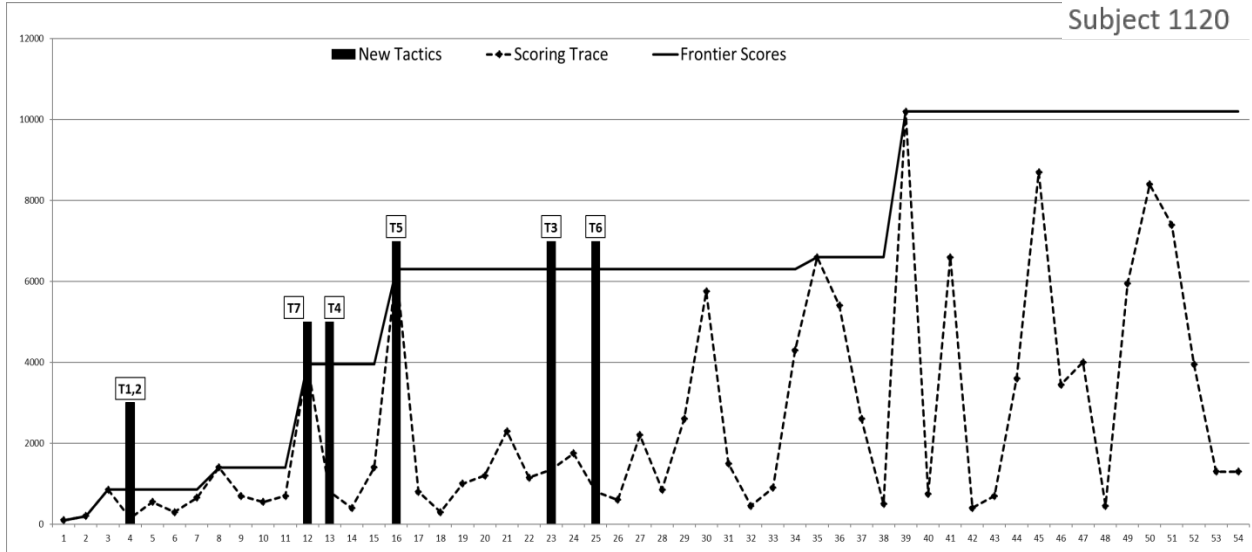
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1118



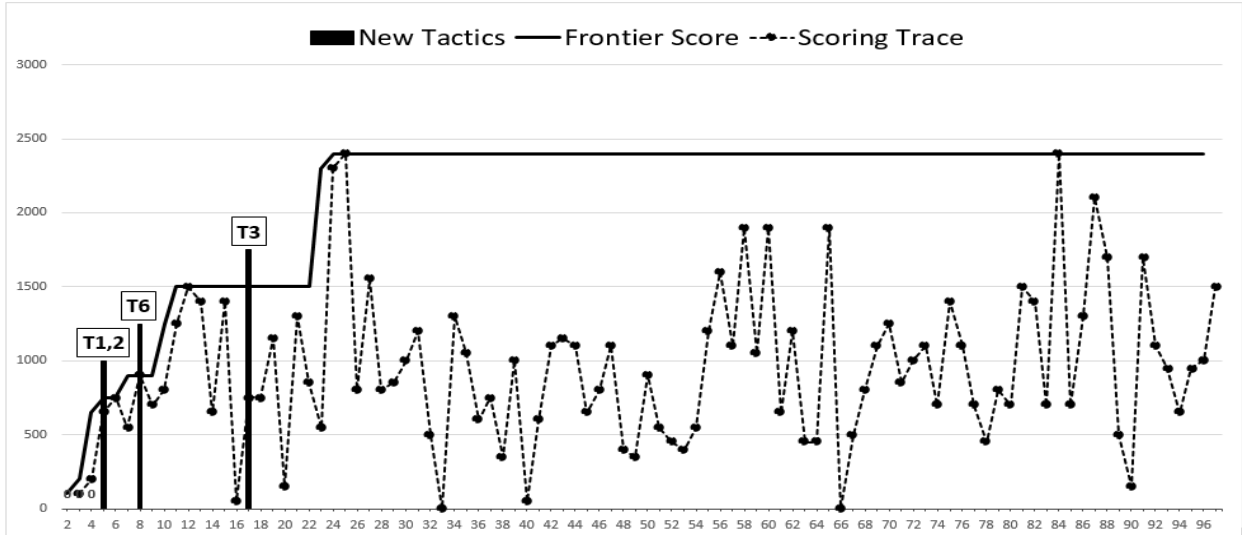
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 1120



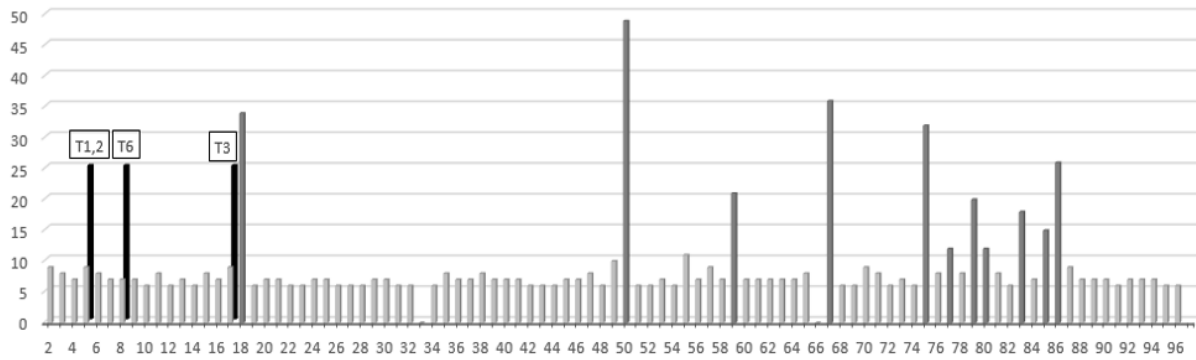
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1126



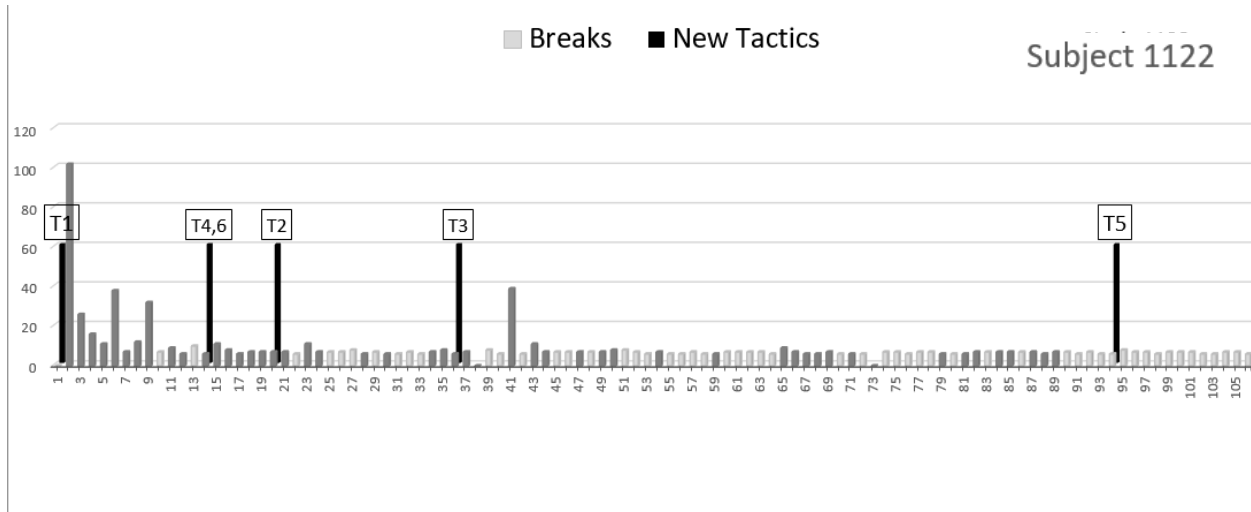
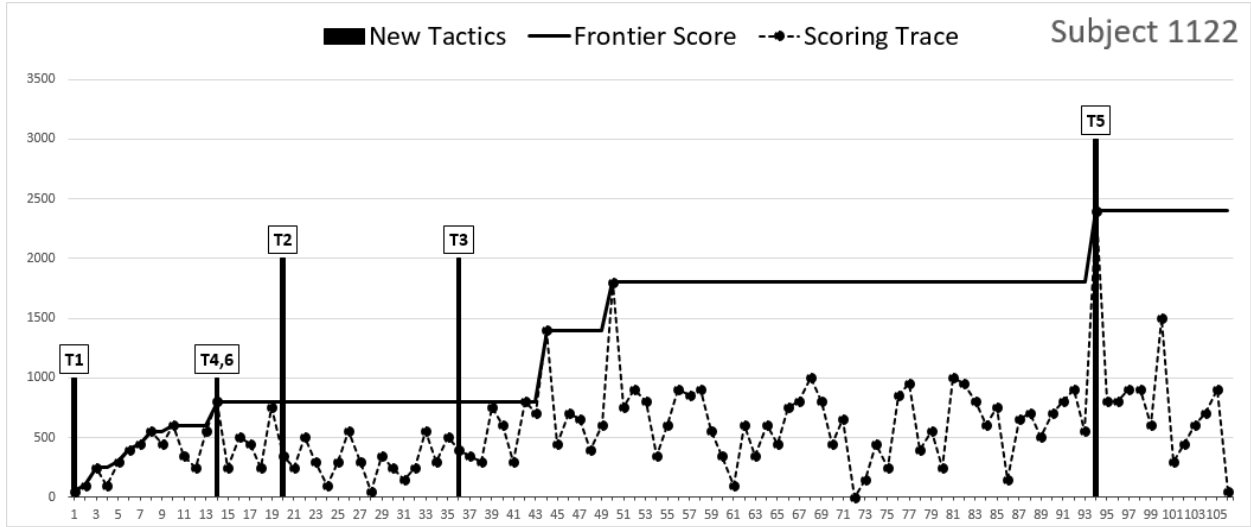
Breaks
 New Tactics

Subject 1126



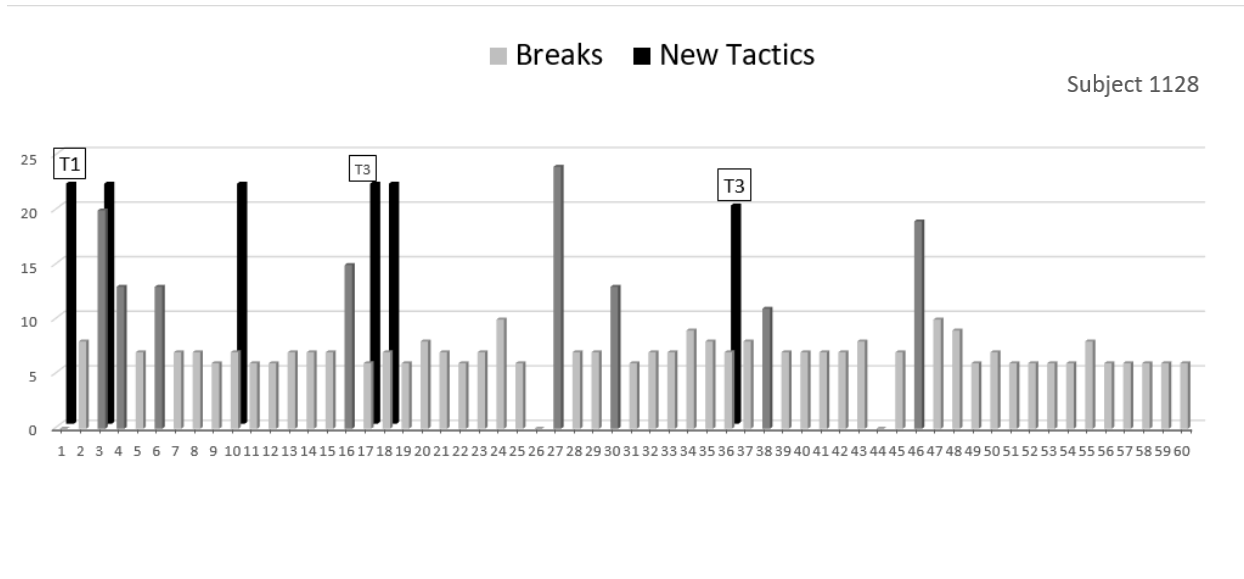
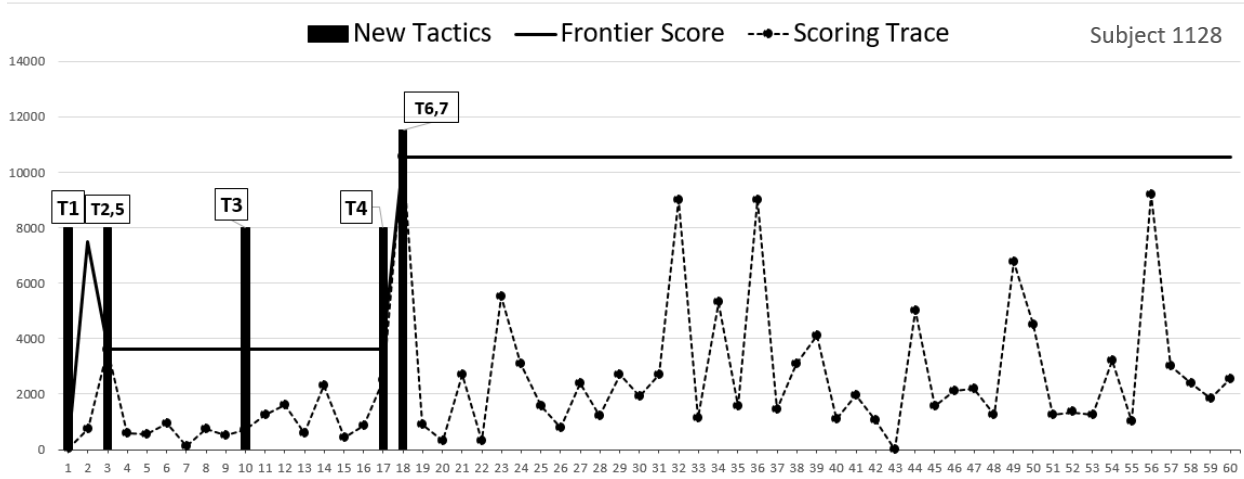
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1122



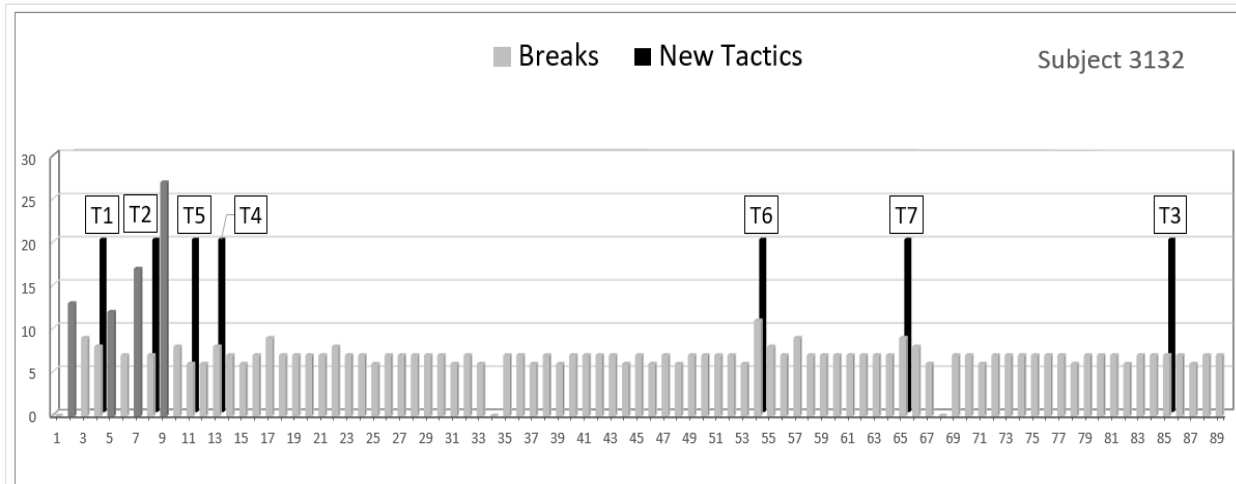
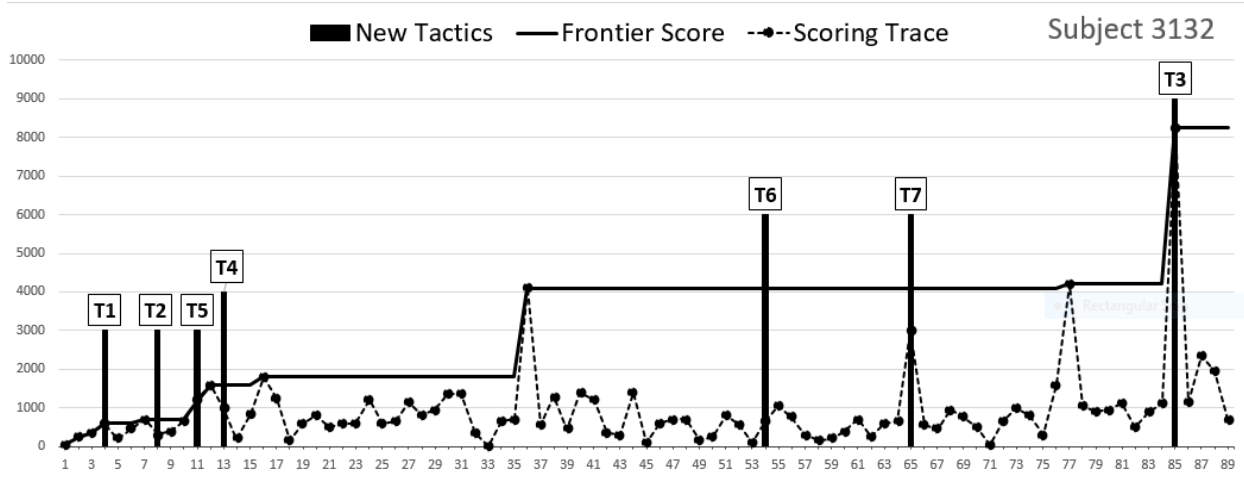
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1128



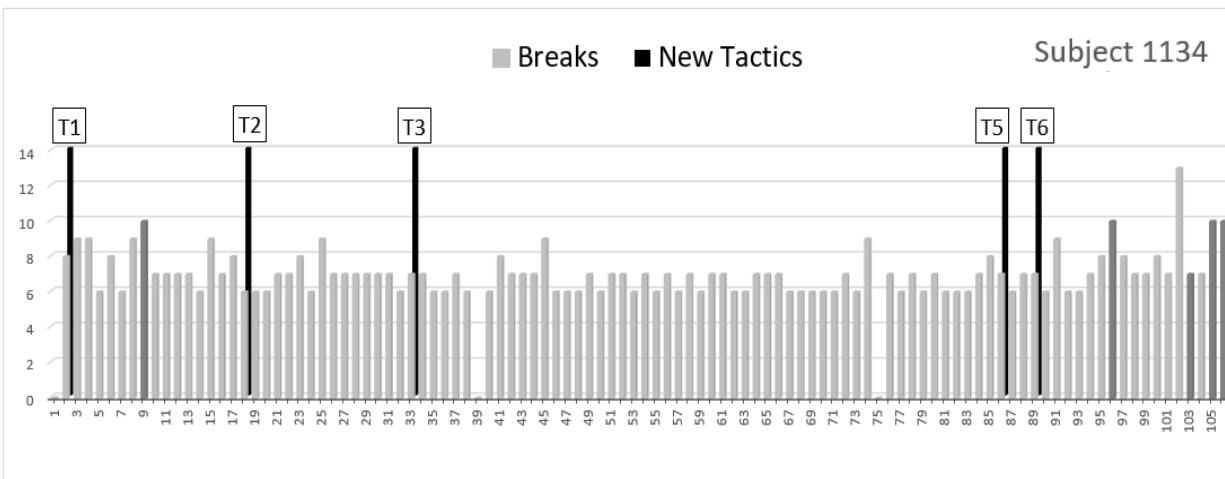
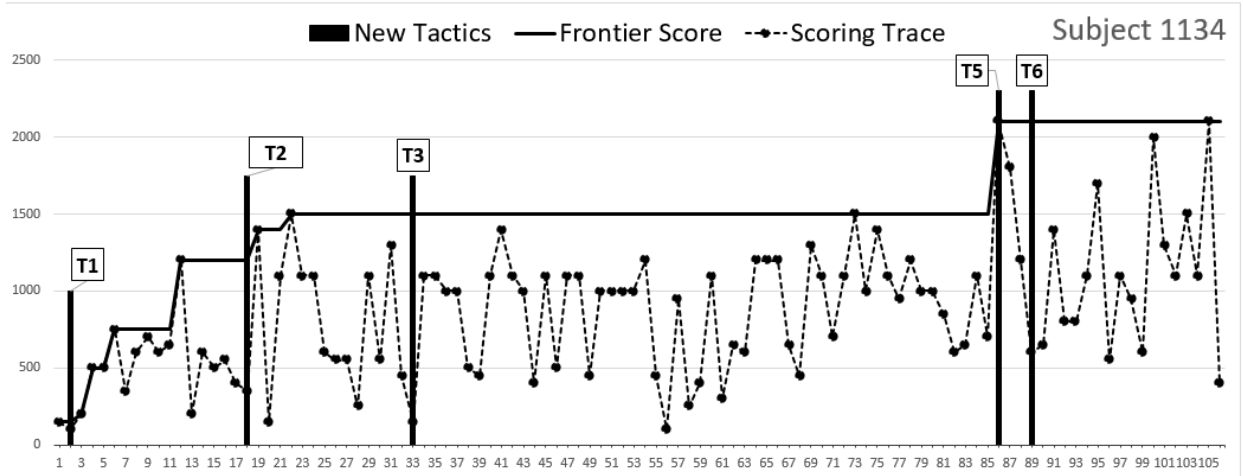
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 3132



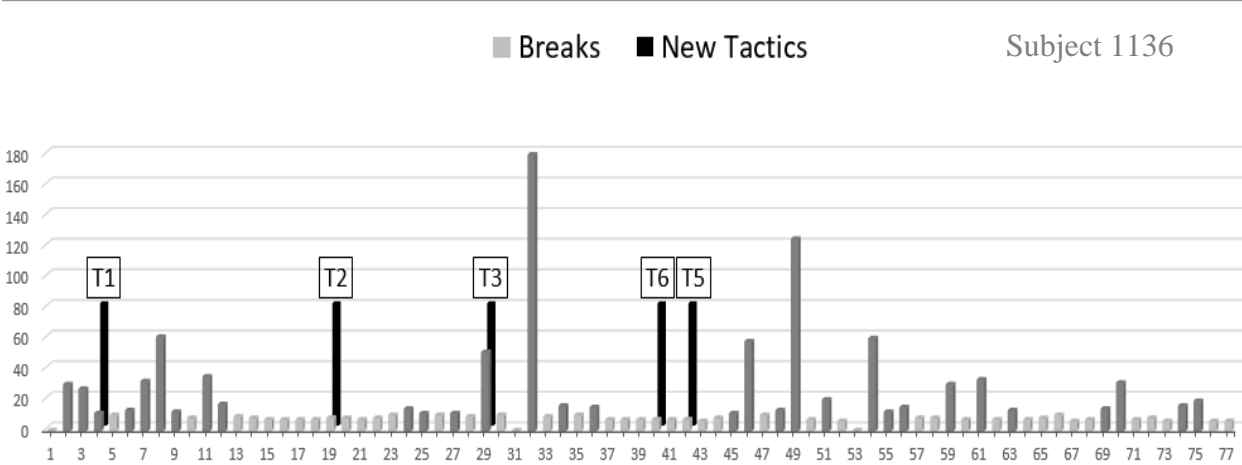
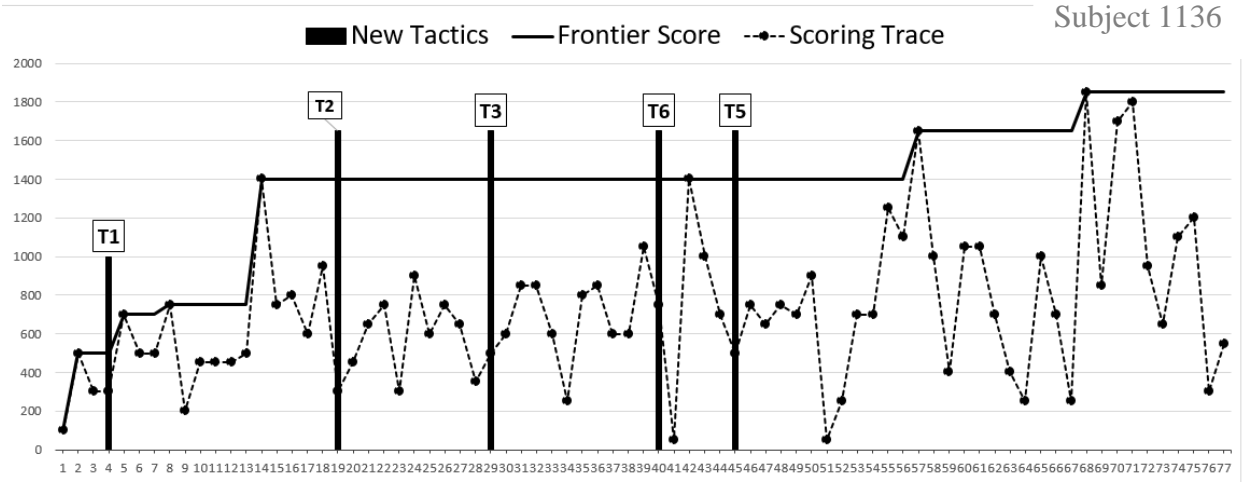
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1134



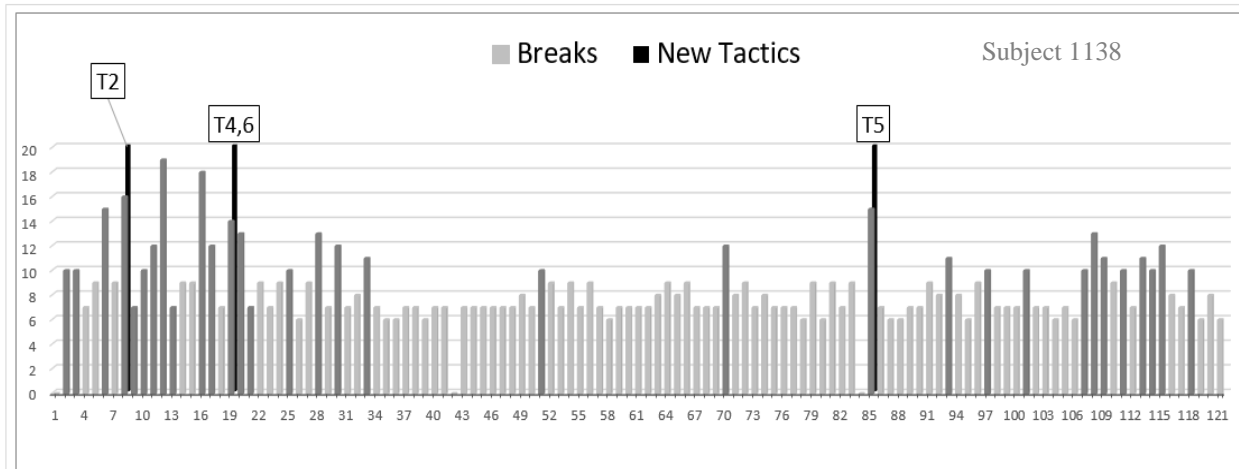
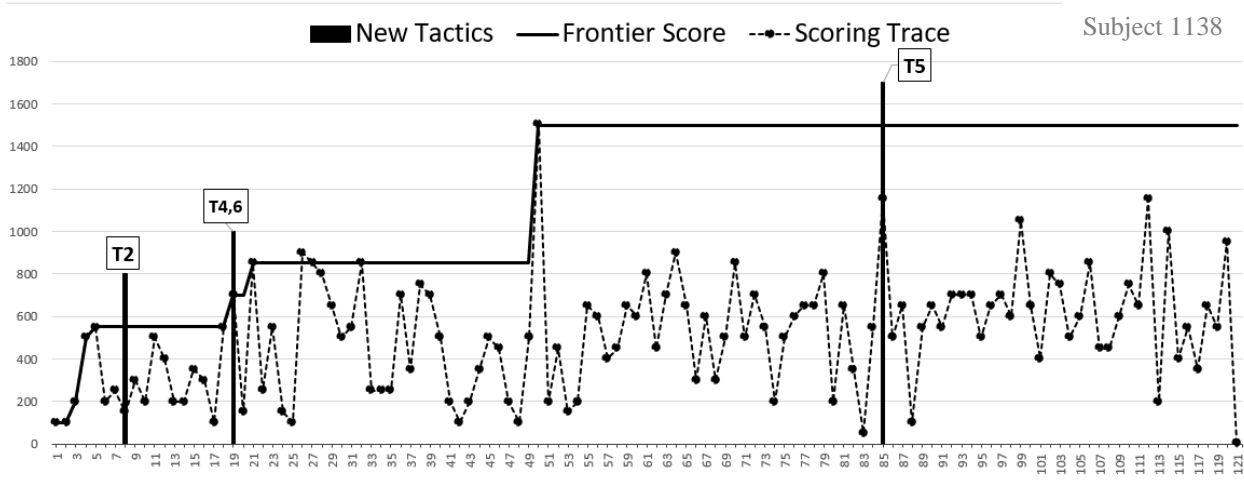
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1136



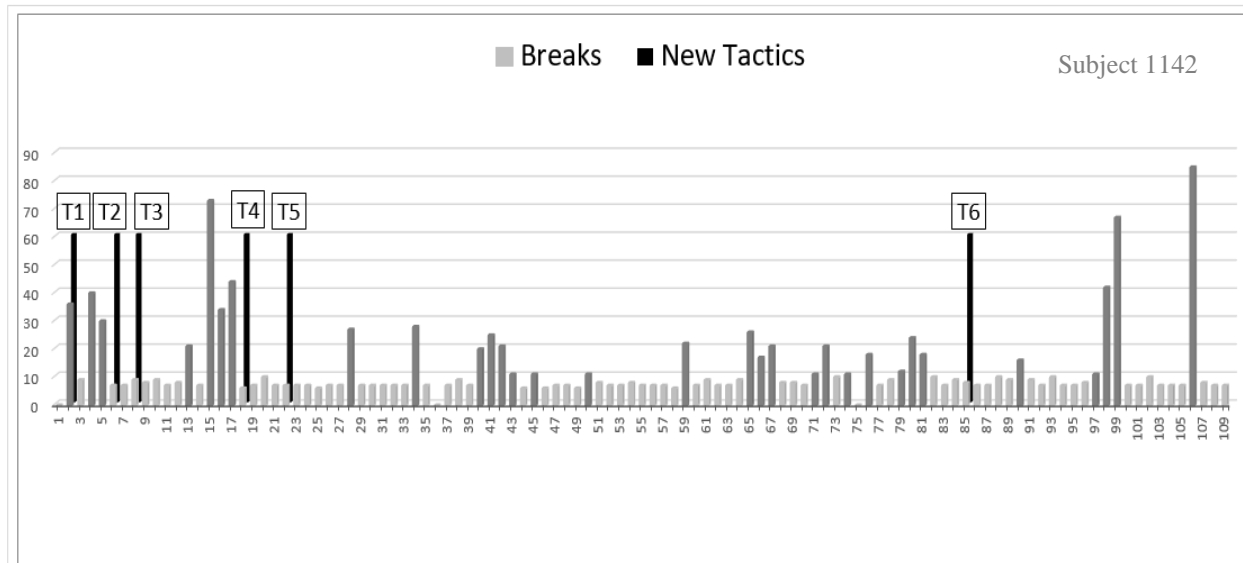
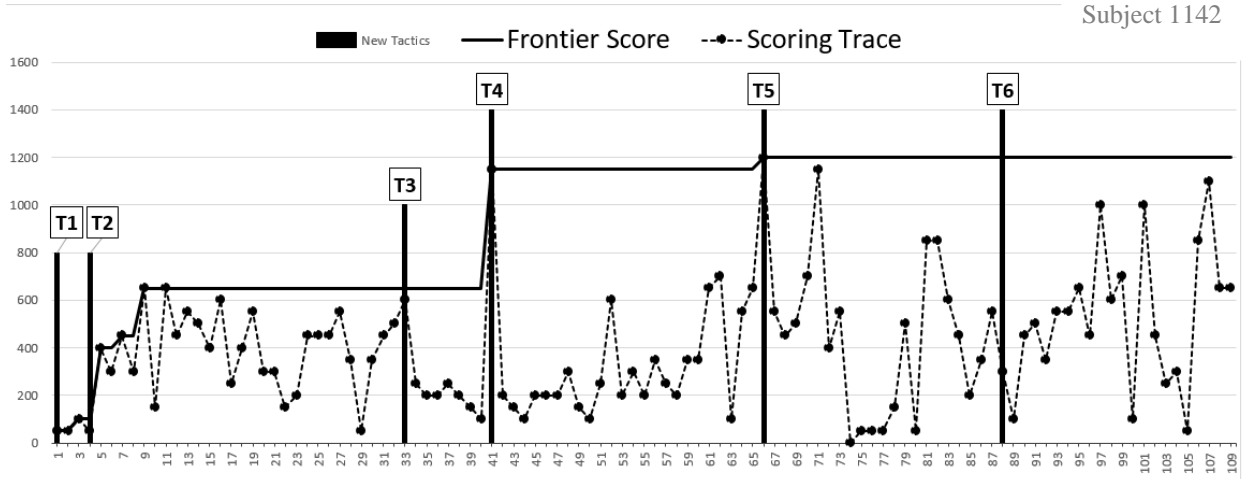
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1138



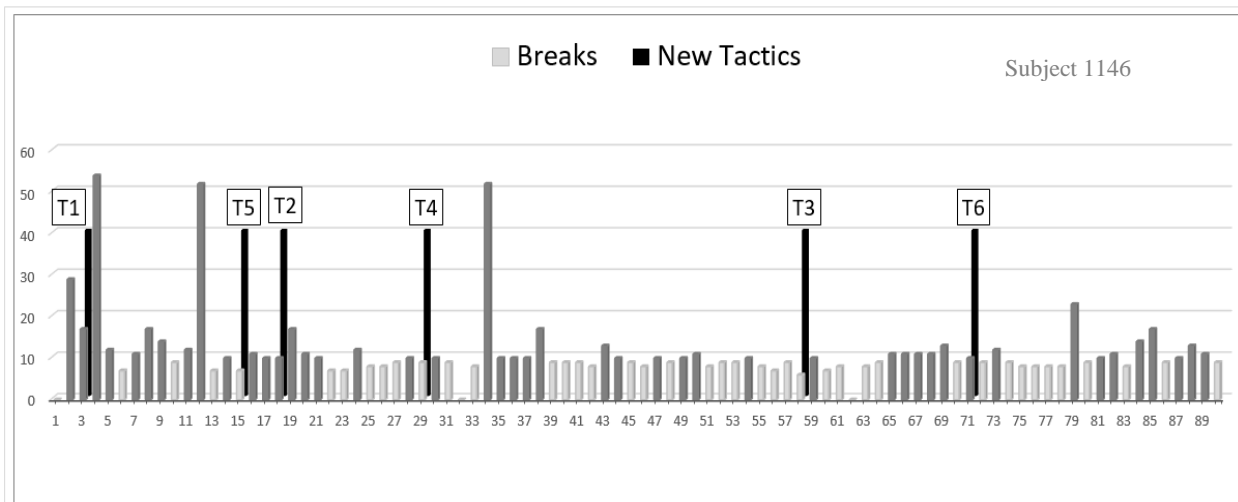
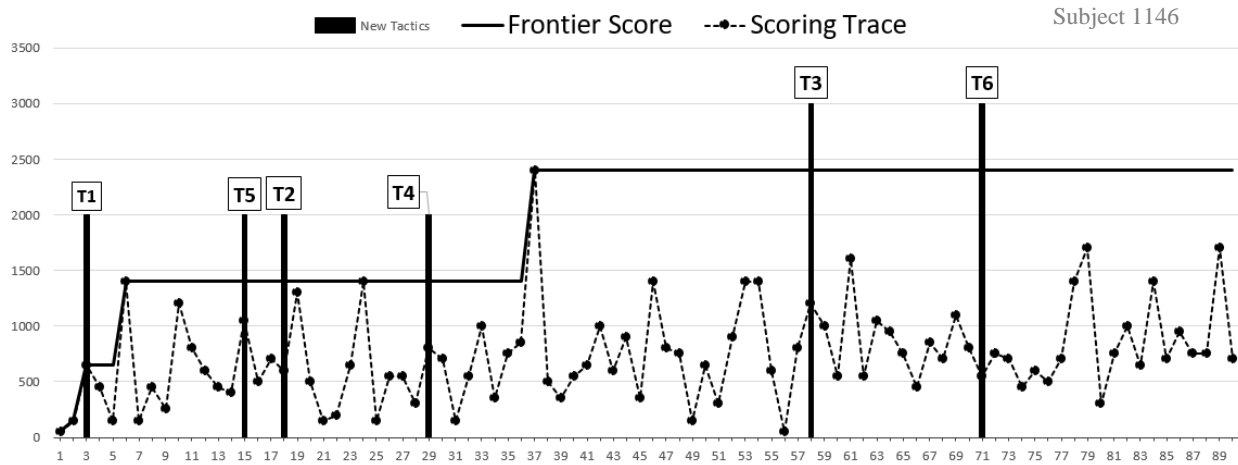
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1142



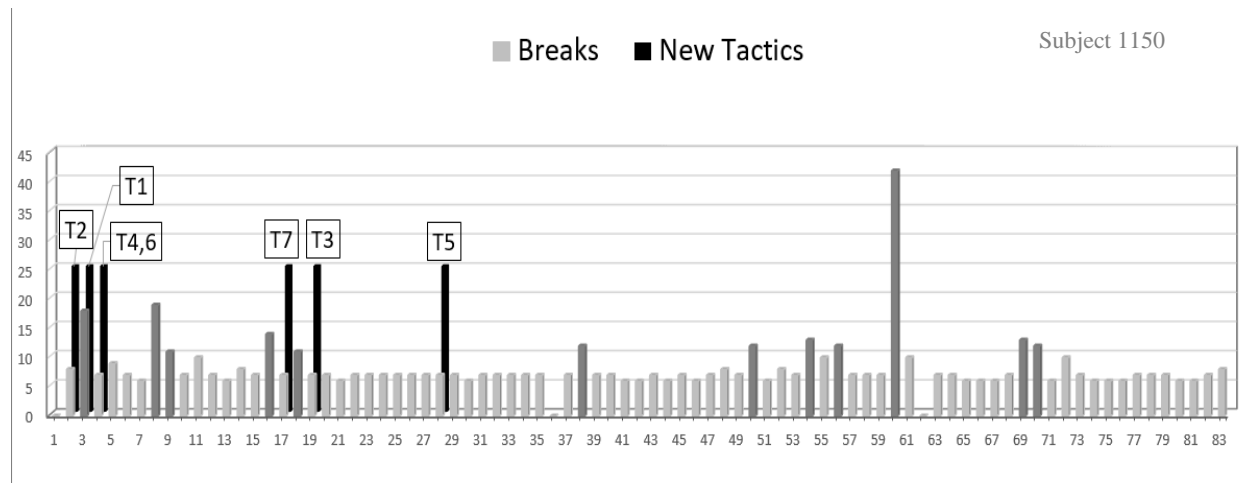
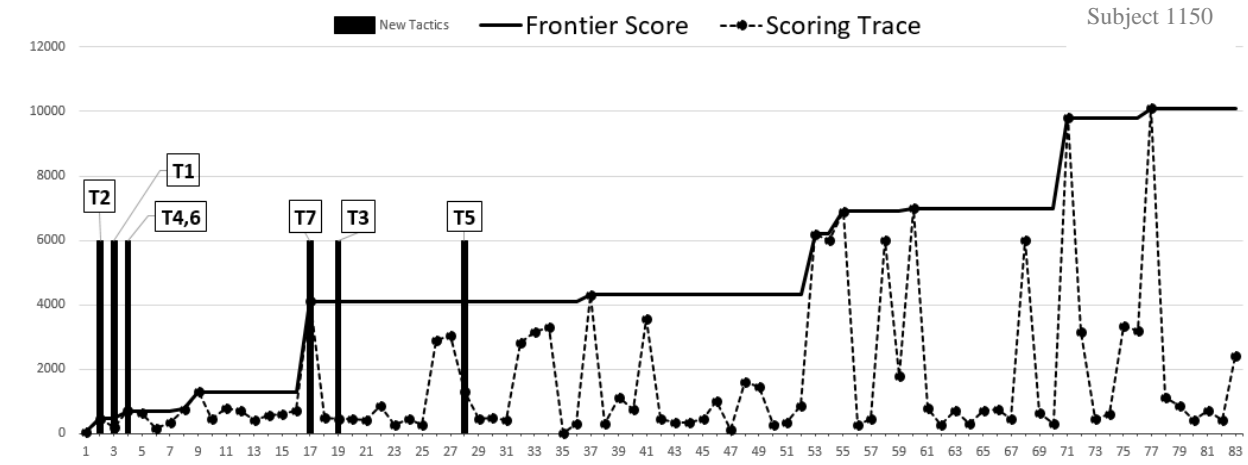
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1146



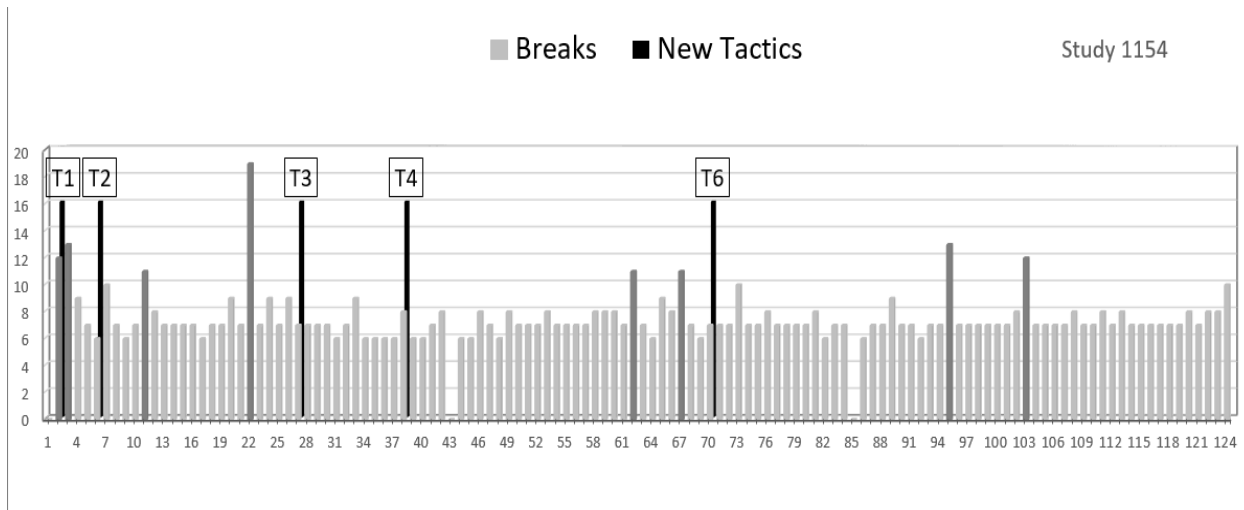
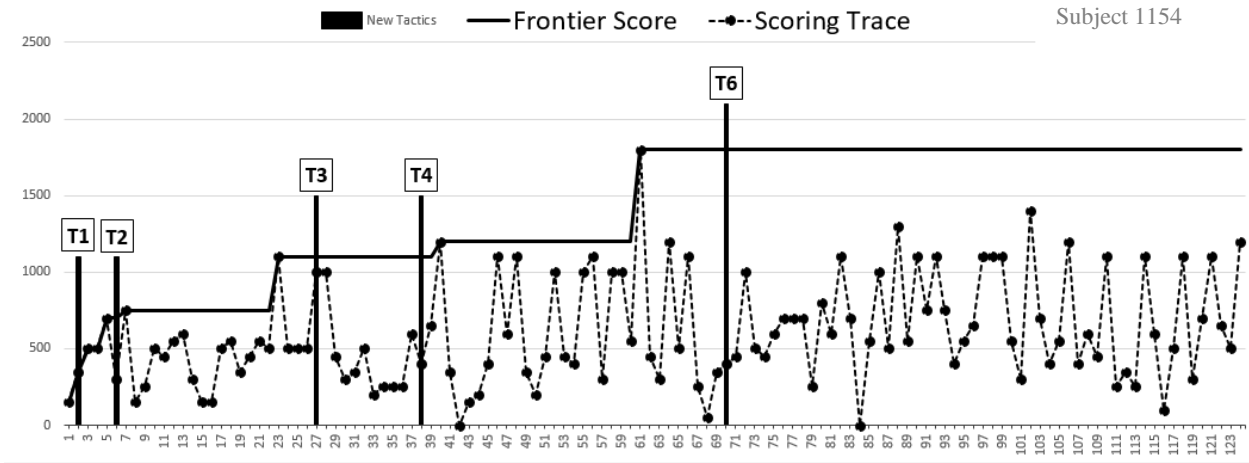
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1150



Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

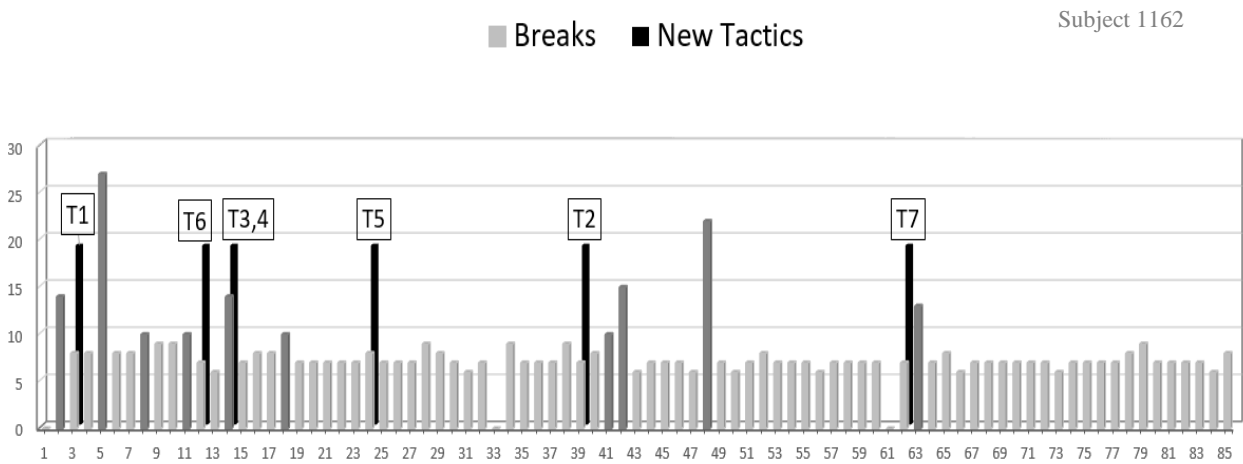
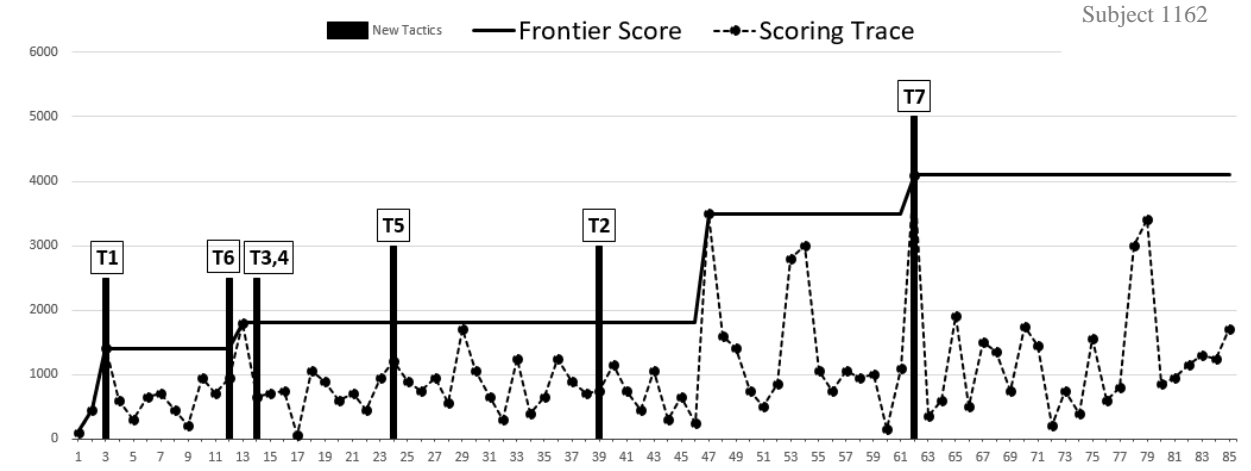
Study 2b – Subject Number 1154



Subject 1154

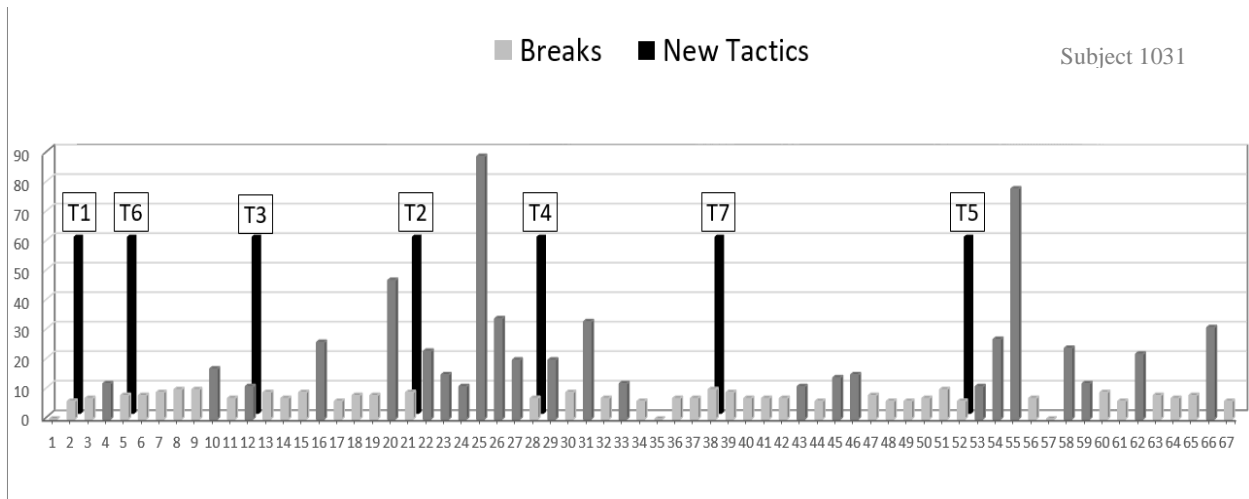
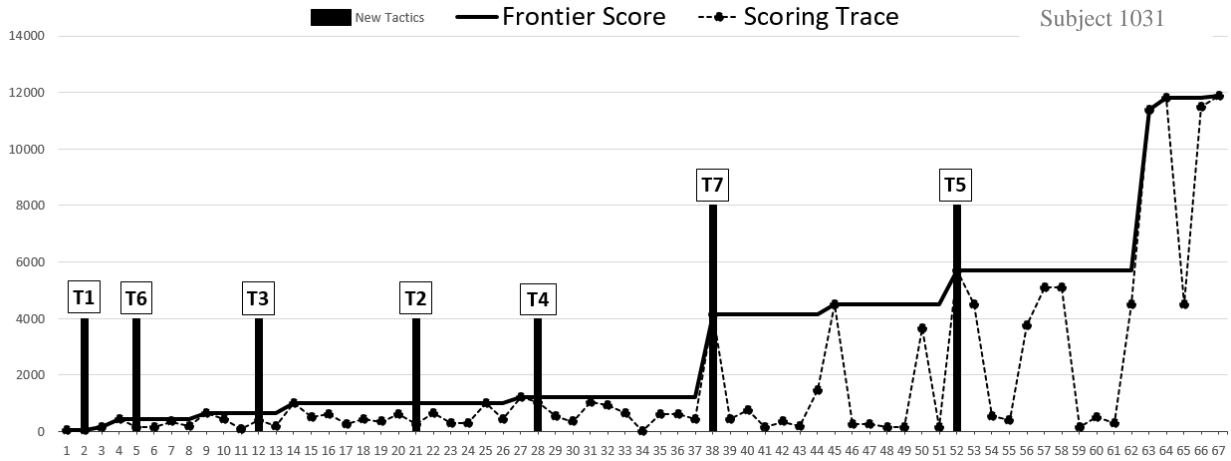
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1162



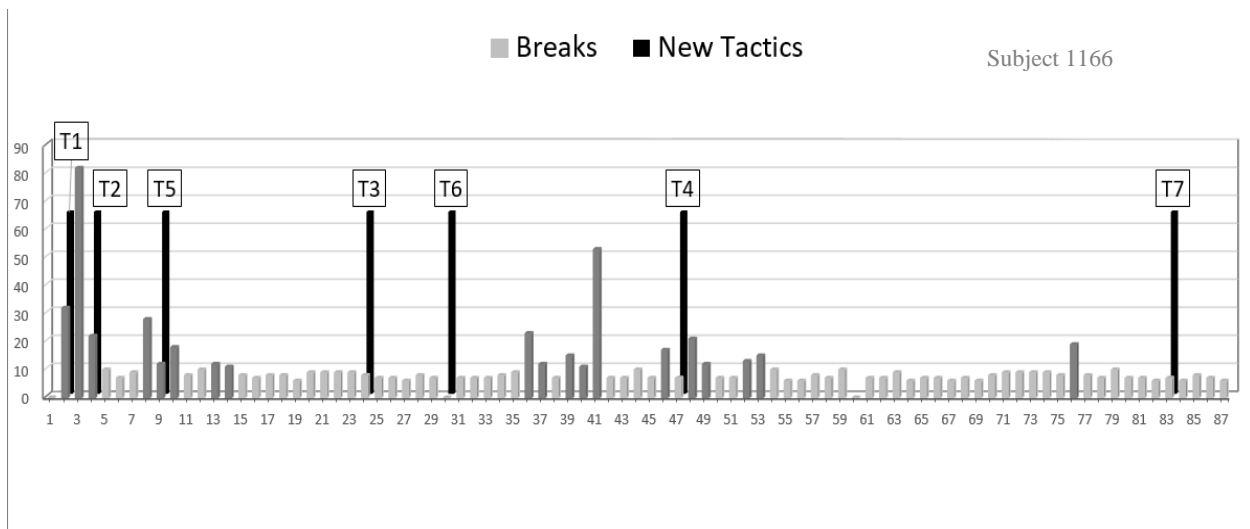
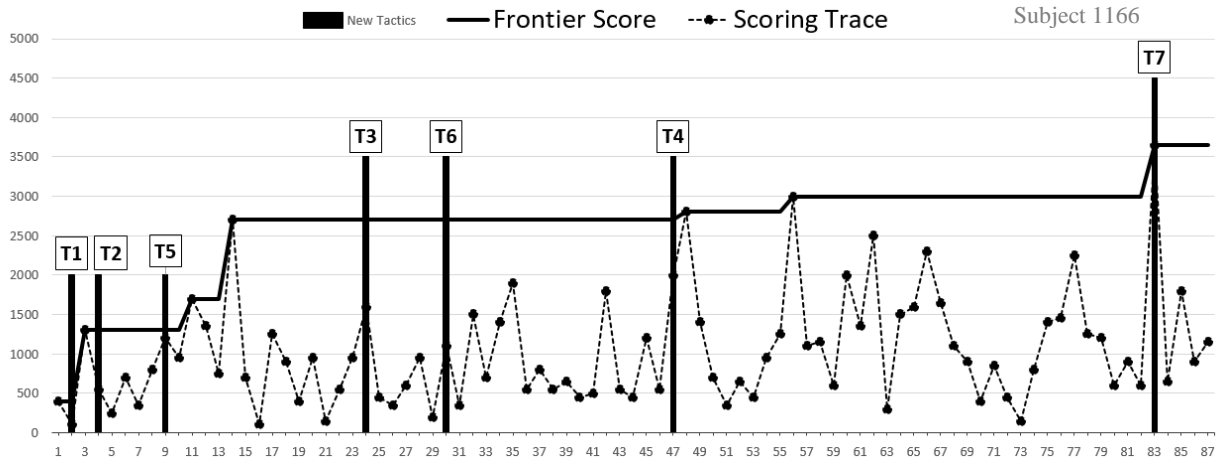
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1031



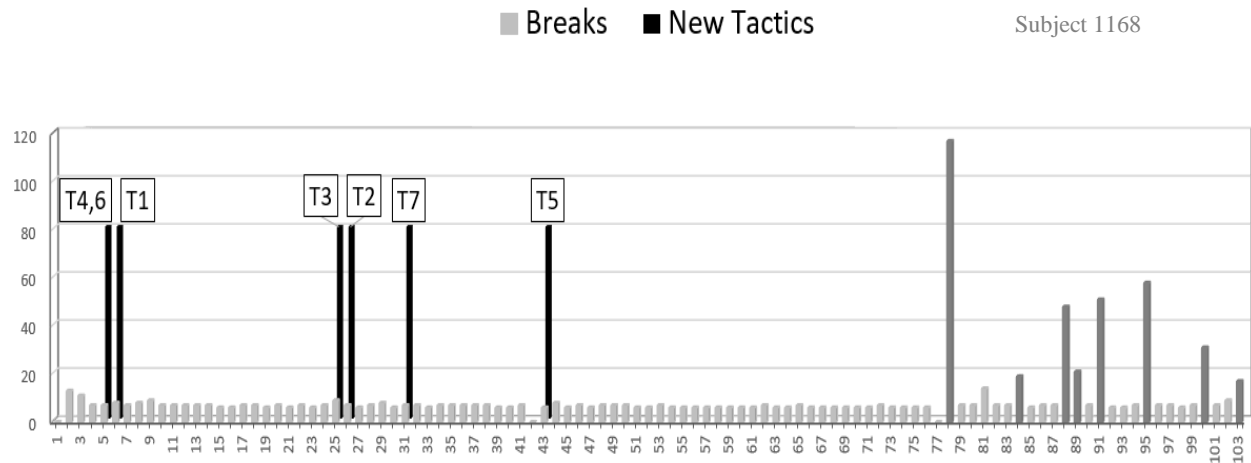
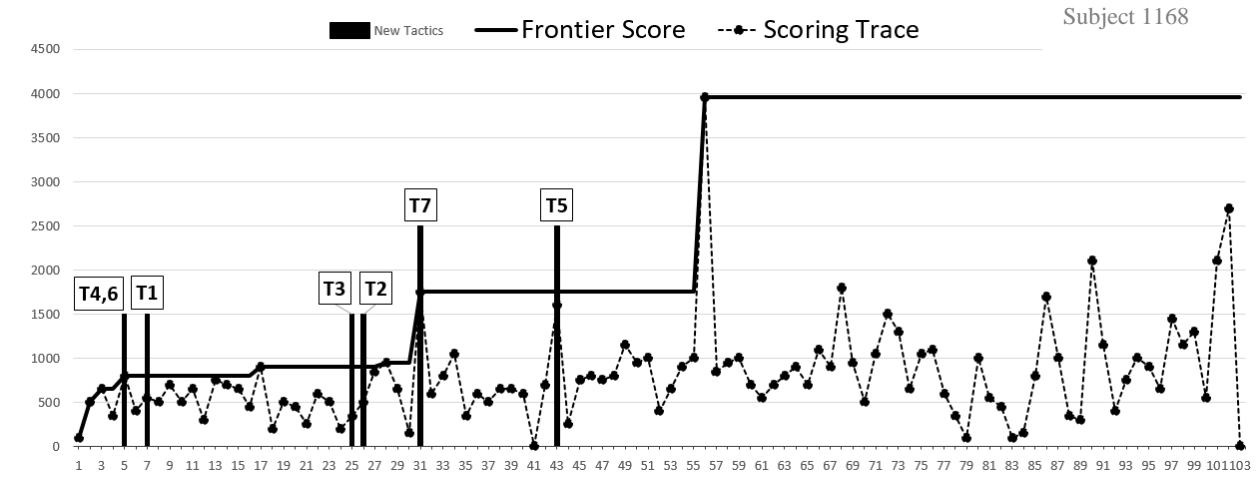
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1166



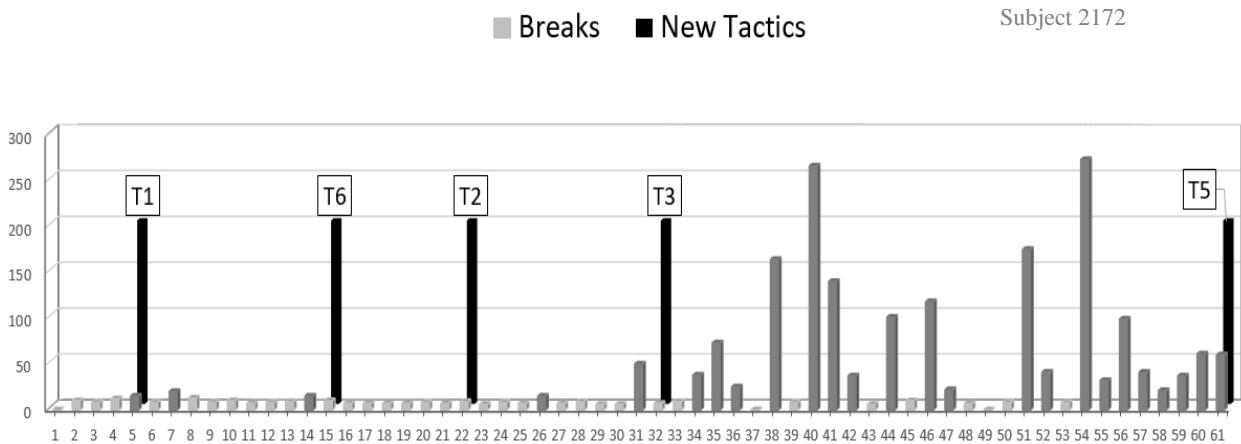
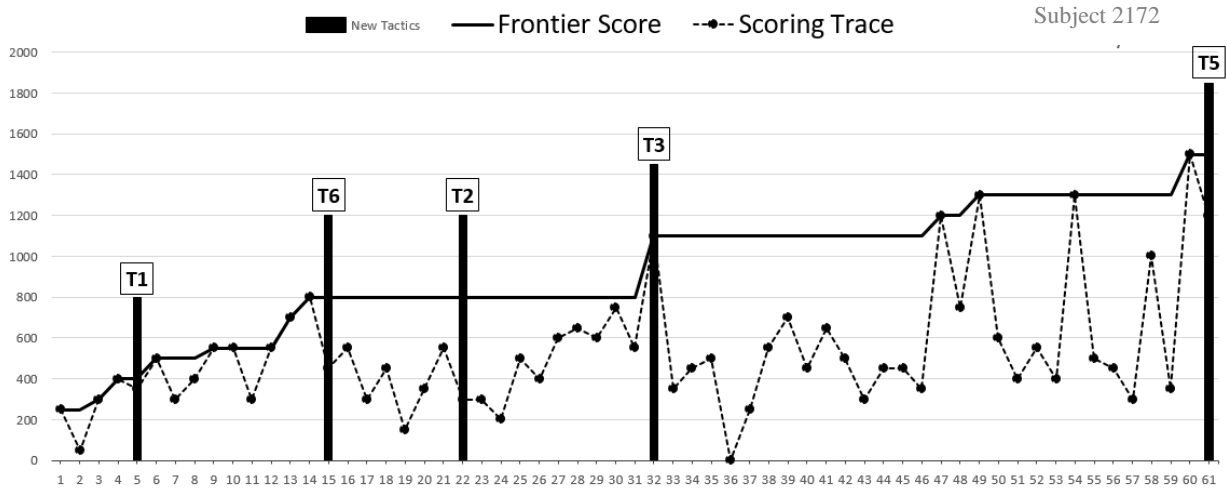
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1168



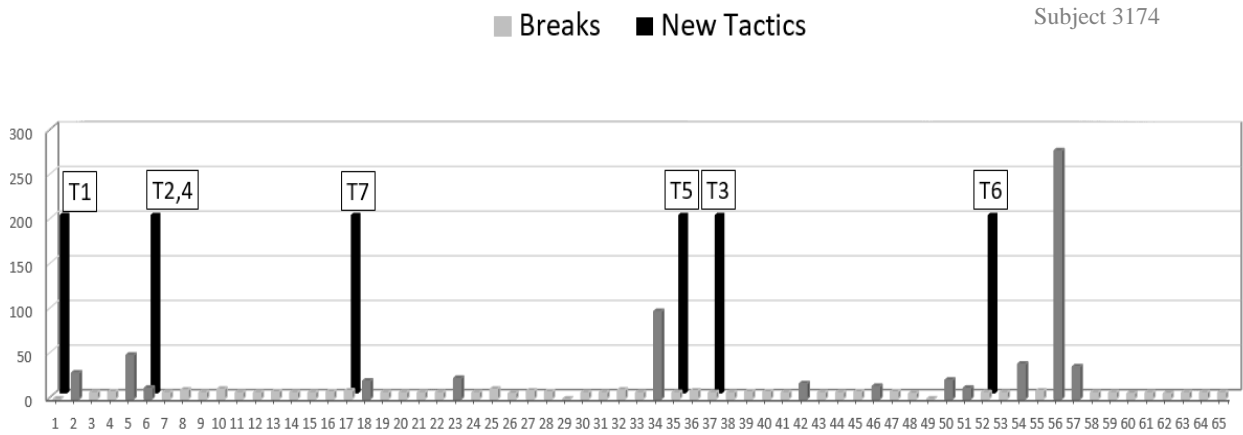
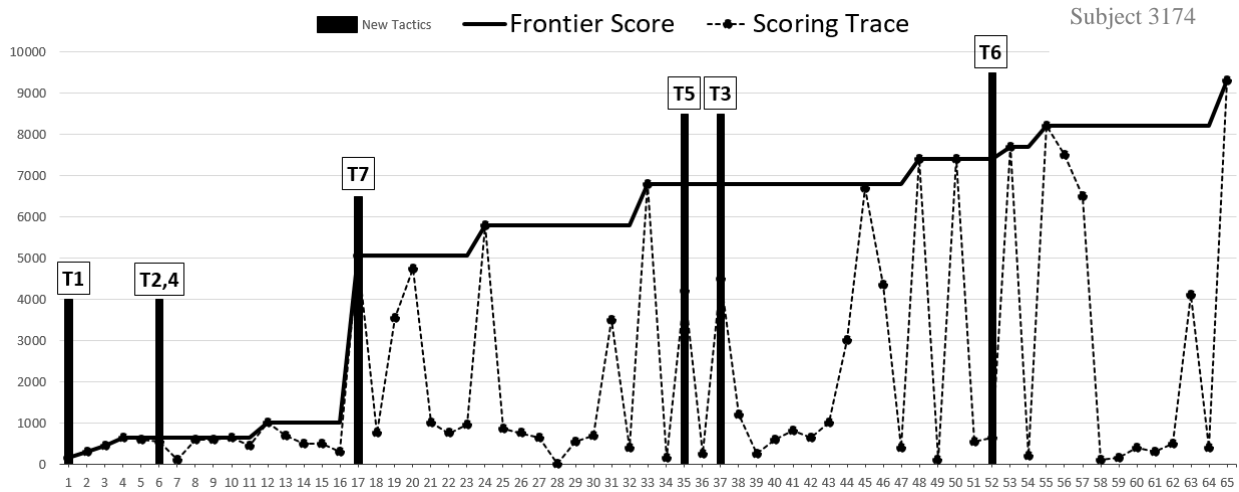
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2172



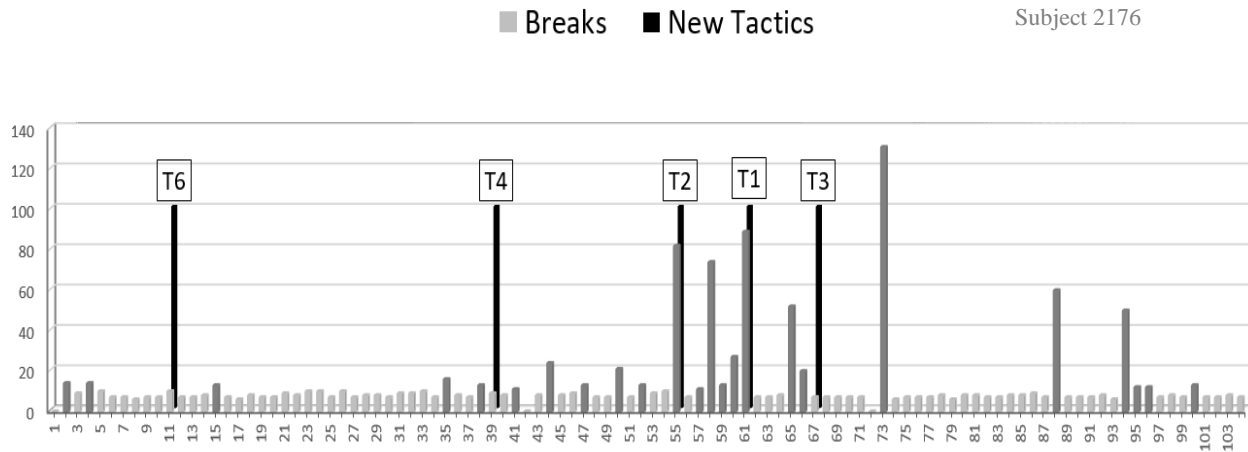
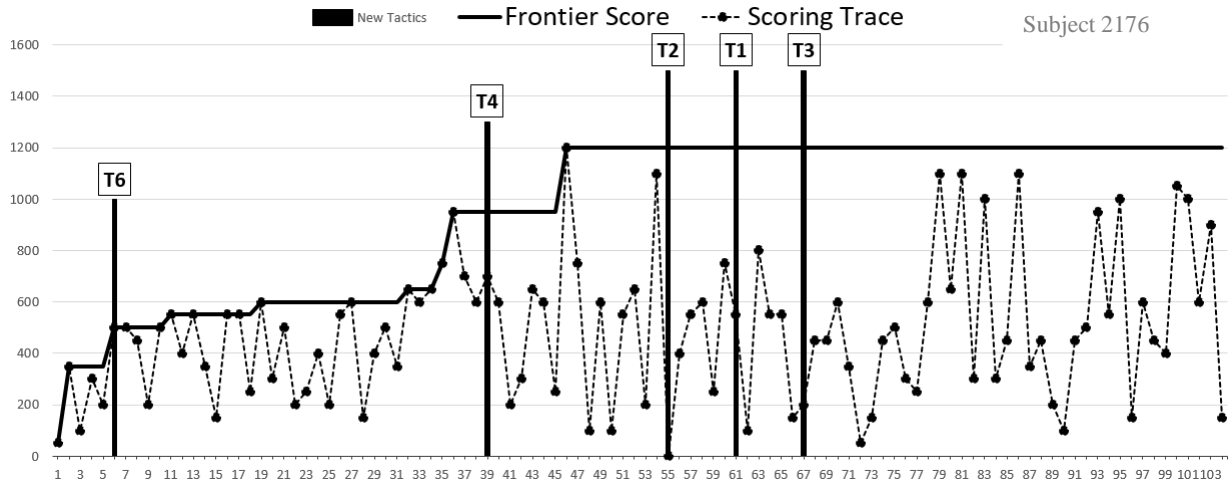
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 3174



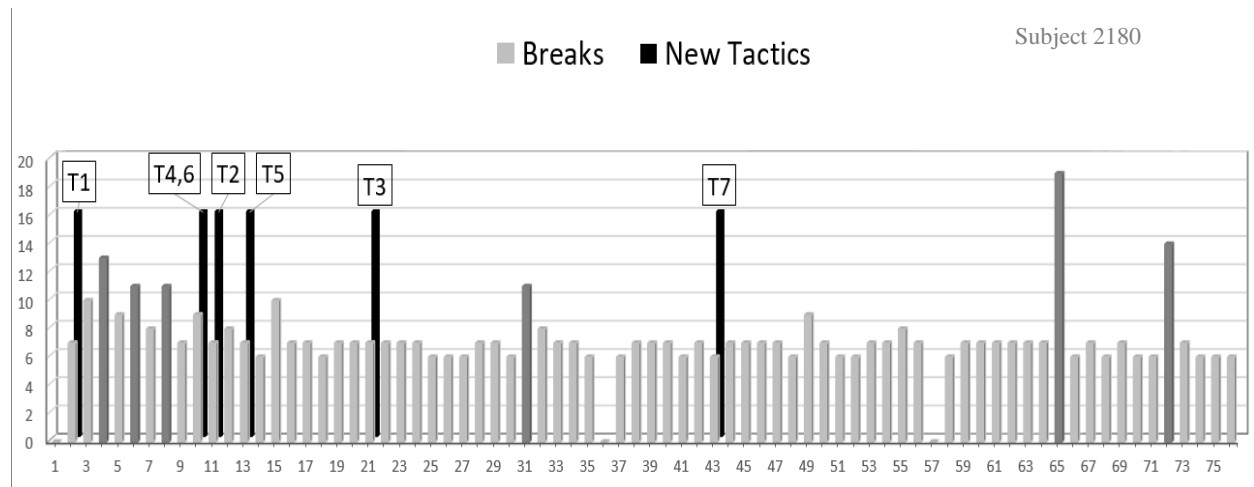
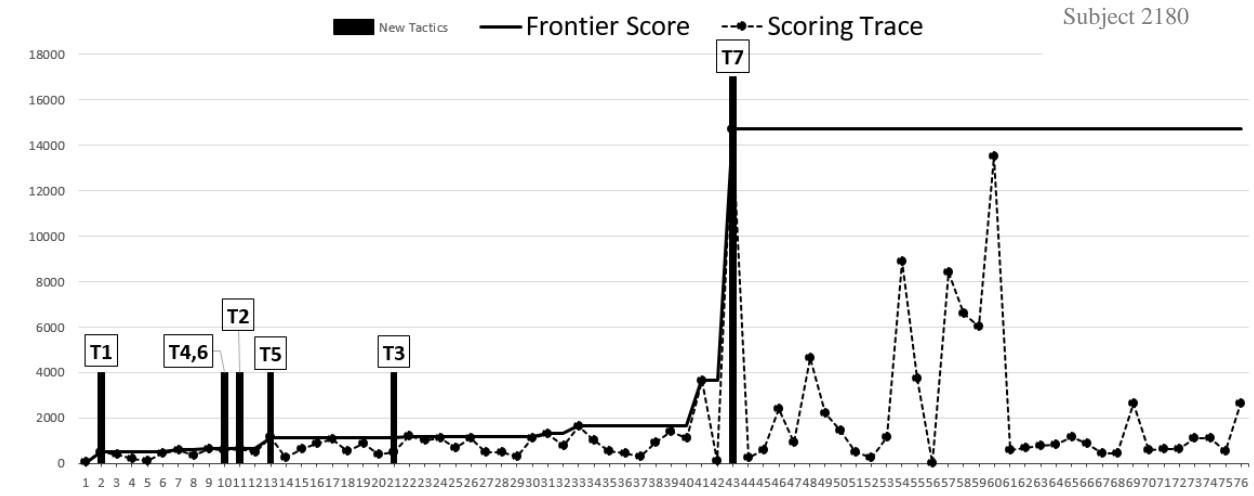
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2176



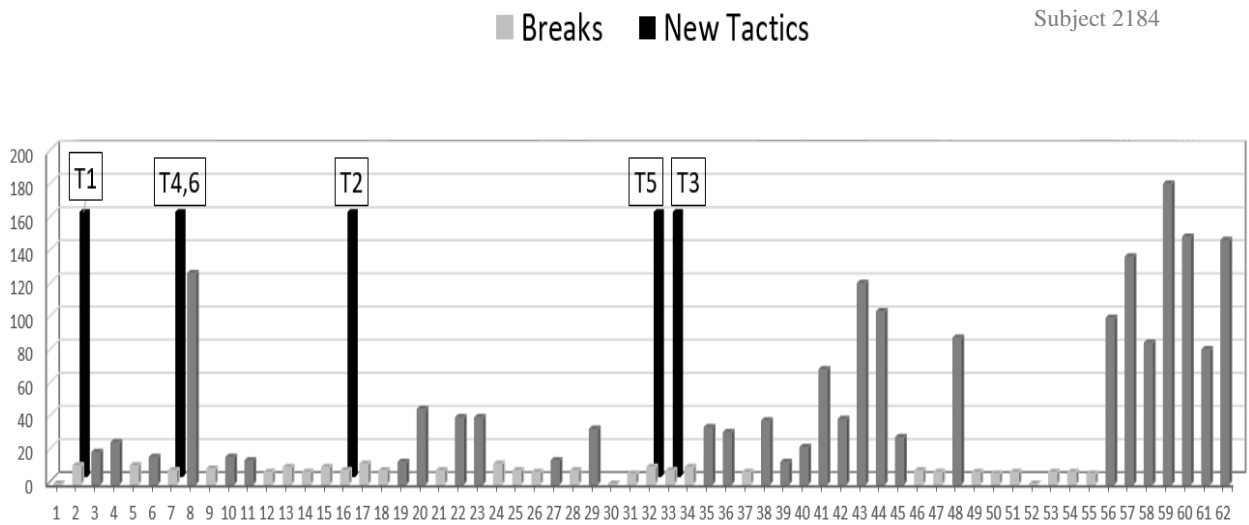
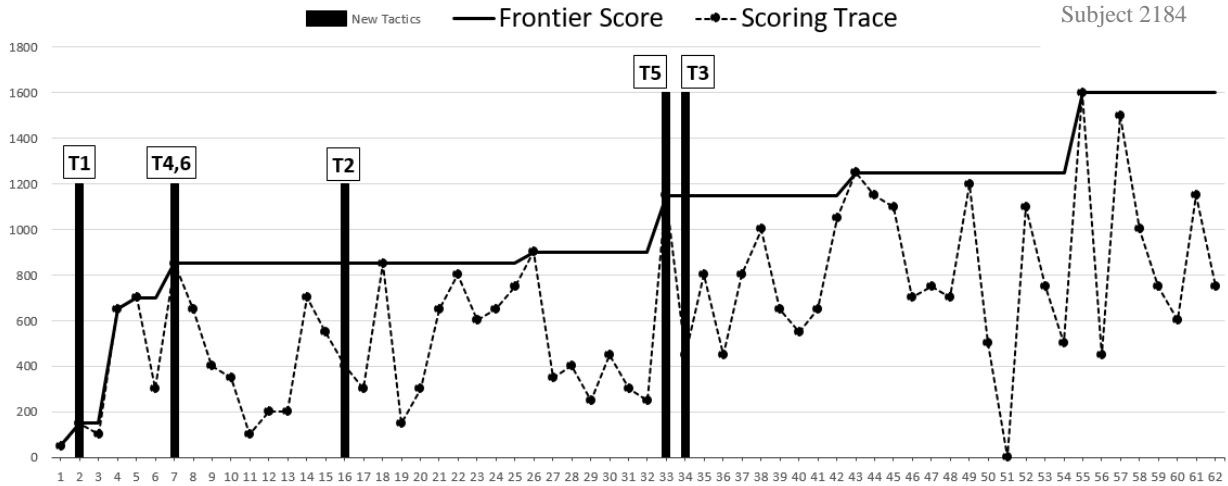
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2180



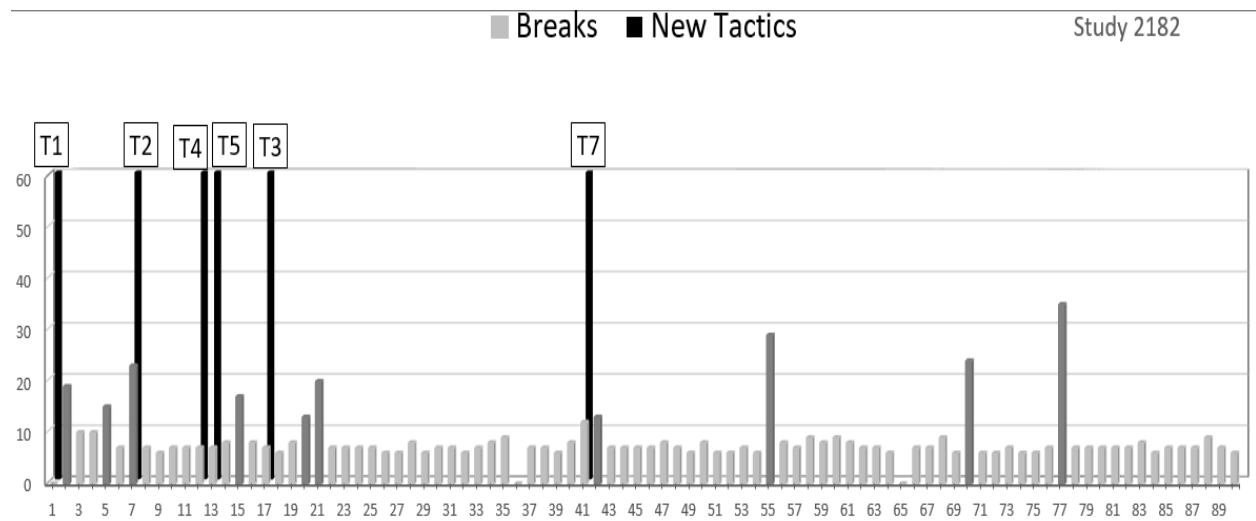
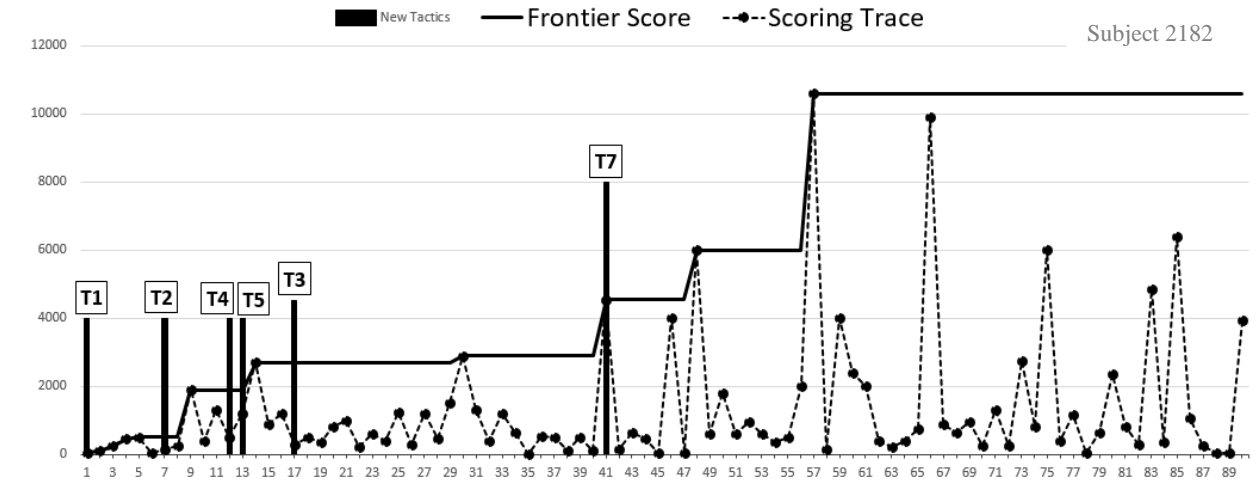
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2184



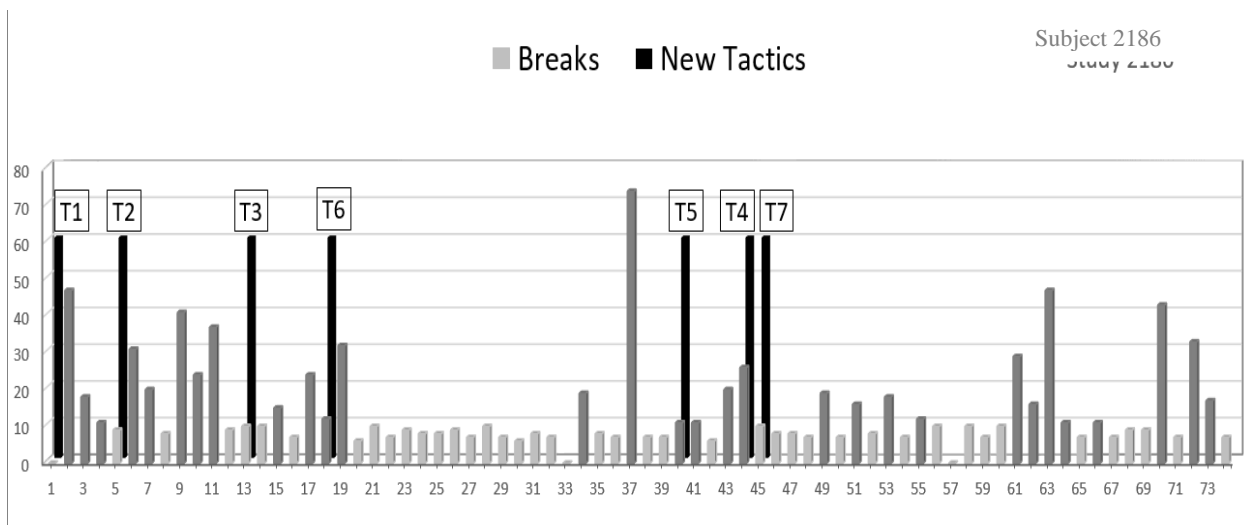
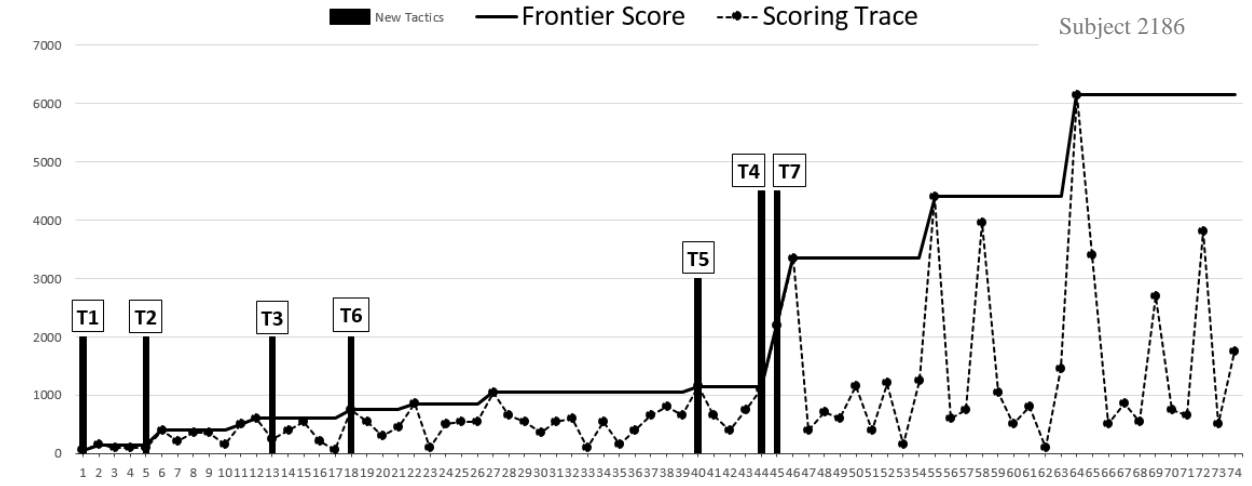
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2182



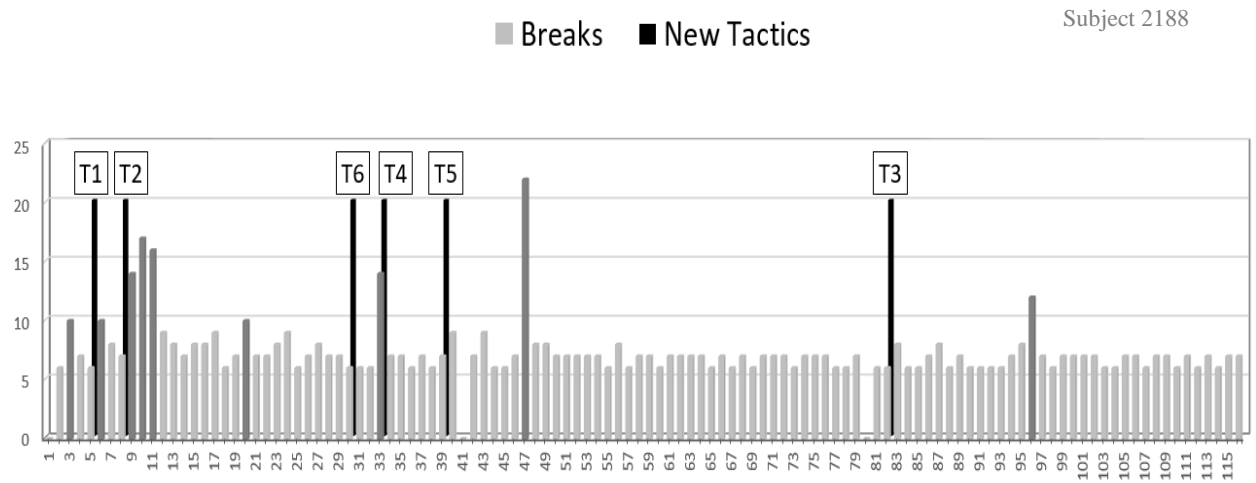
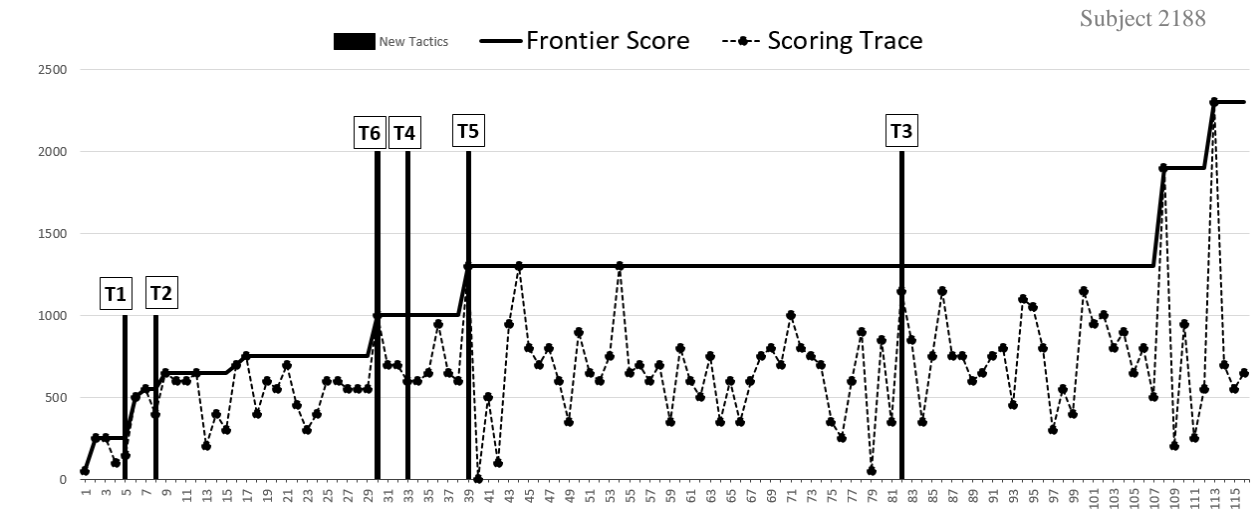
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2186



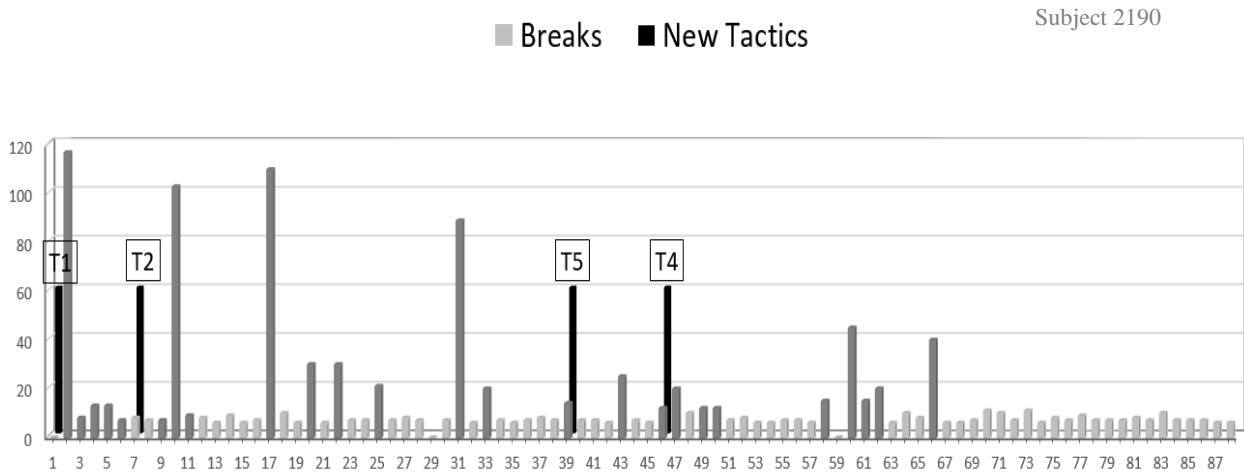
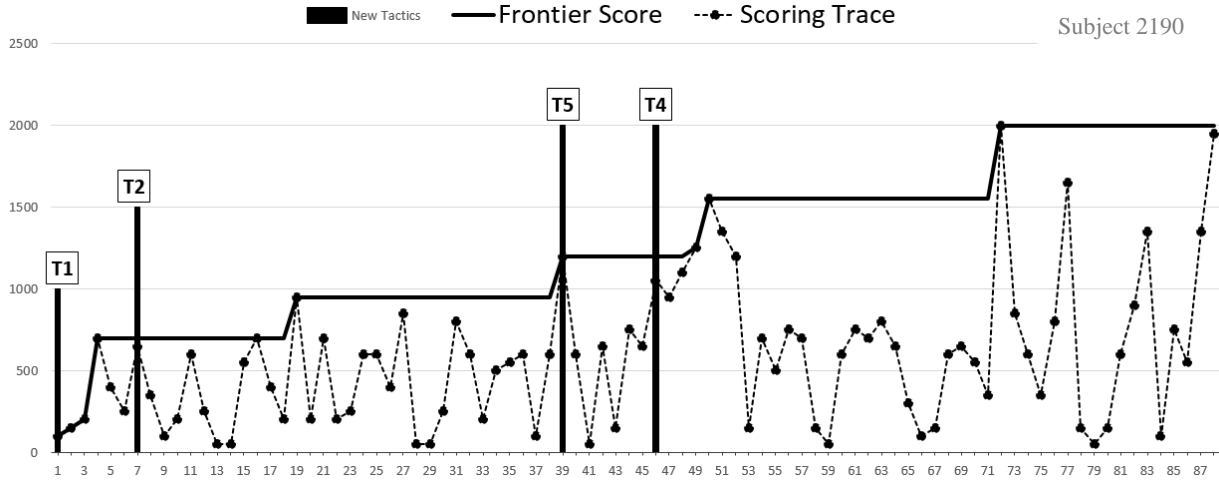
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2188



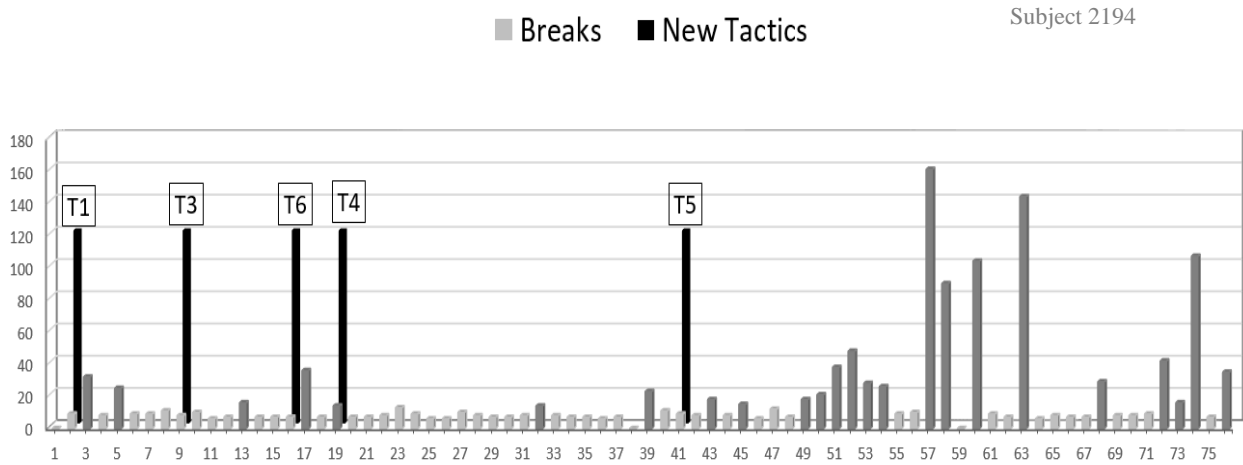
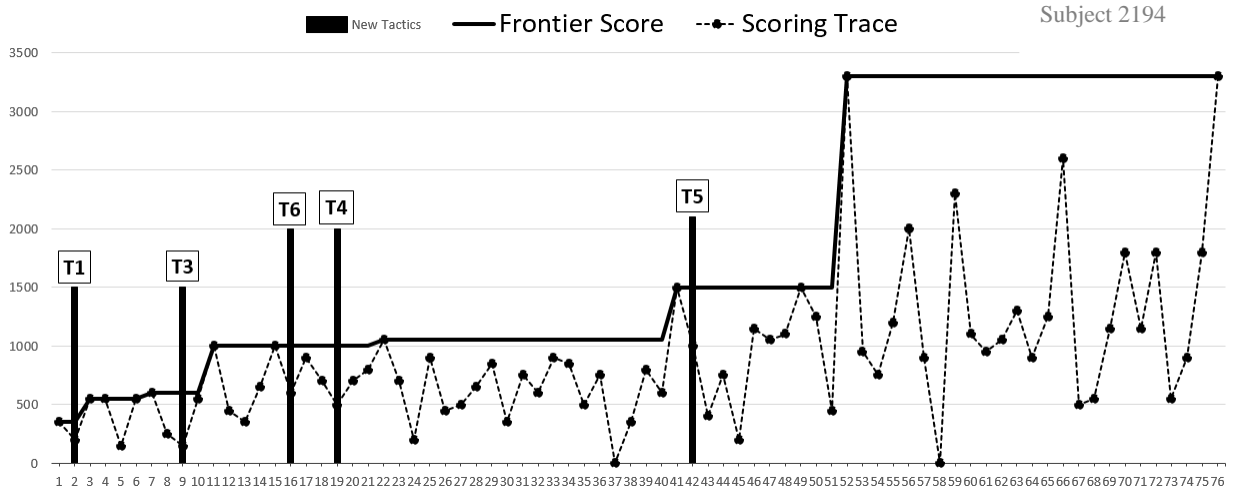
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2190



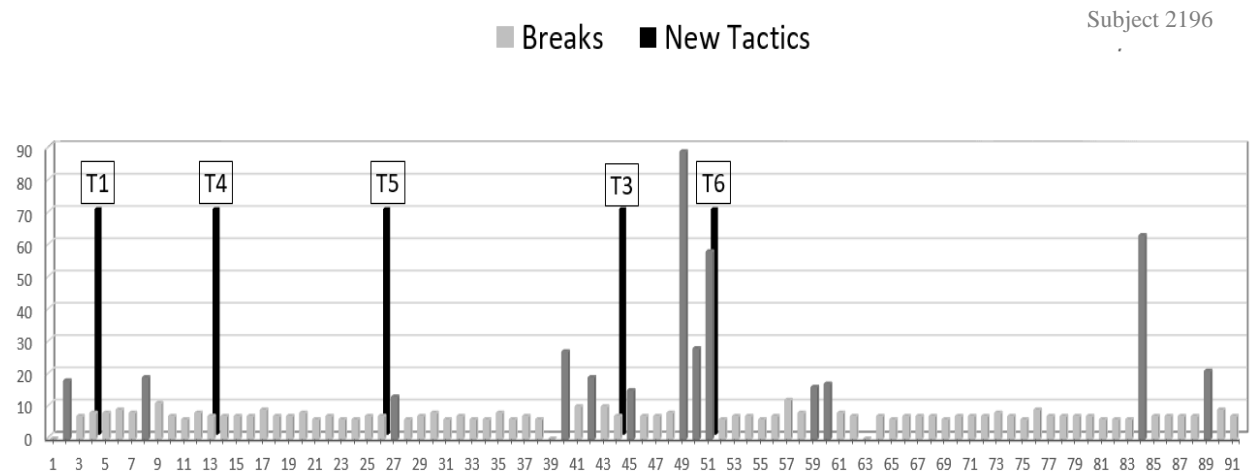
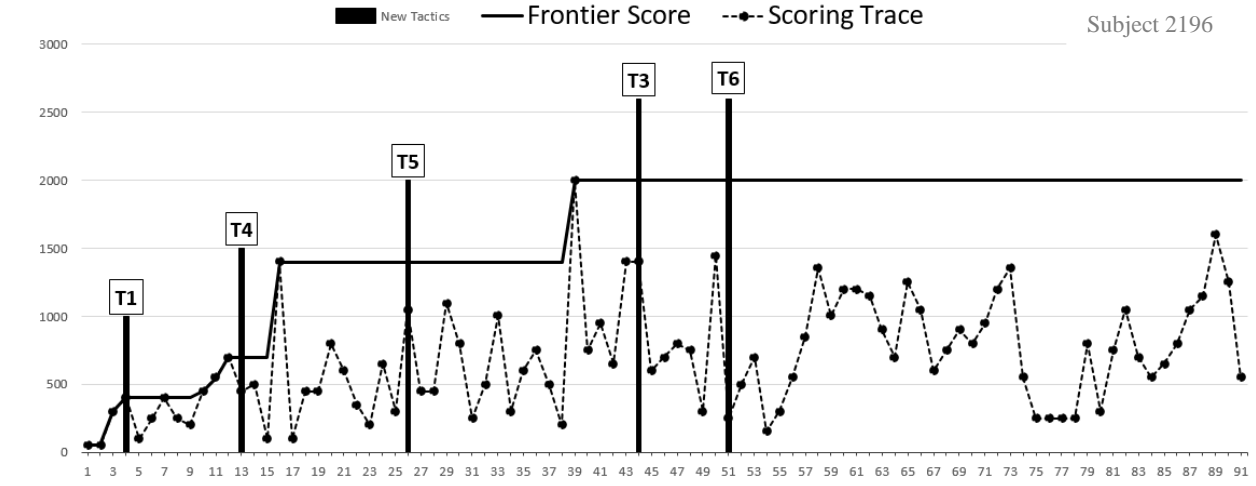
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2194



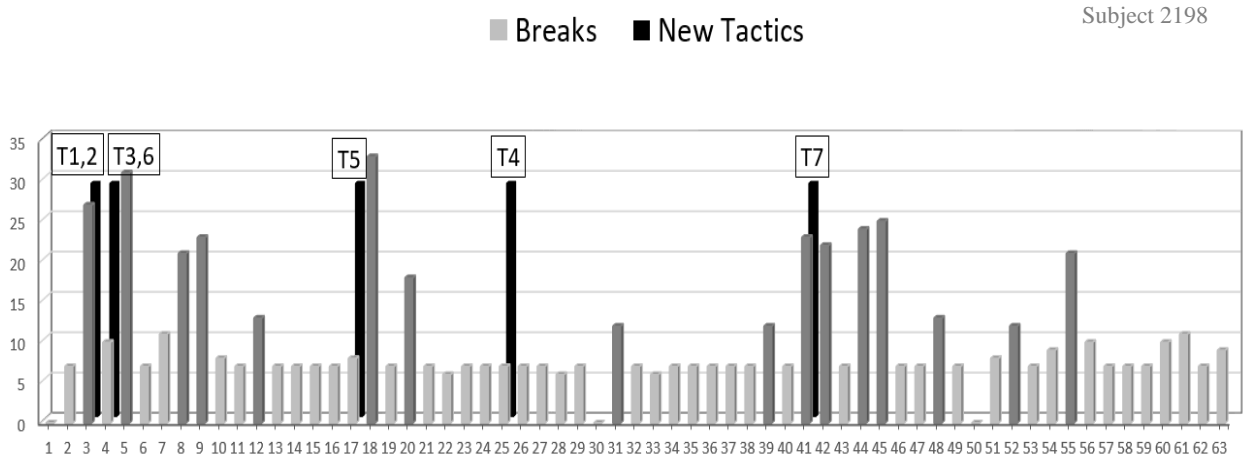
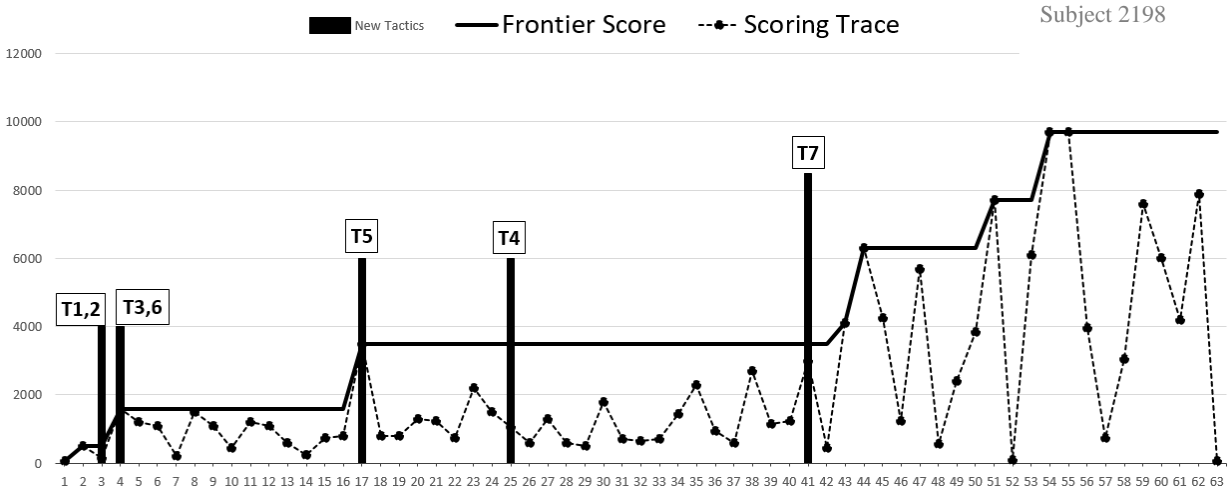
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2196



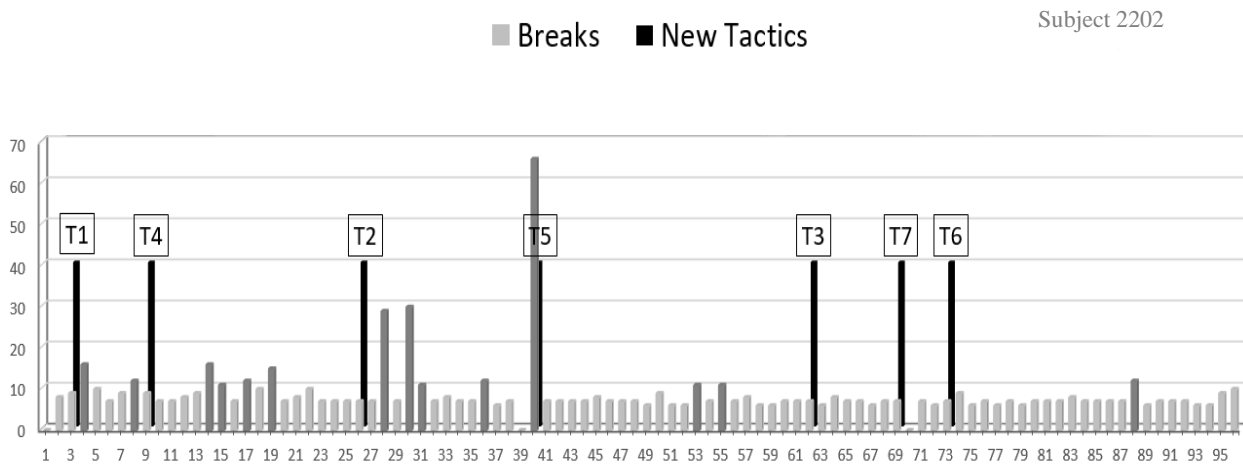
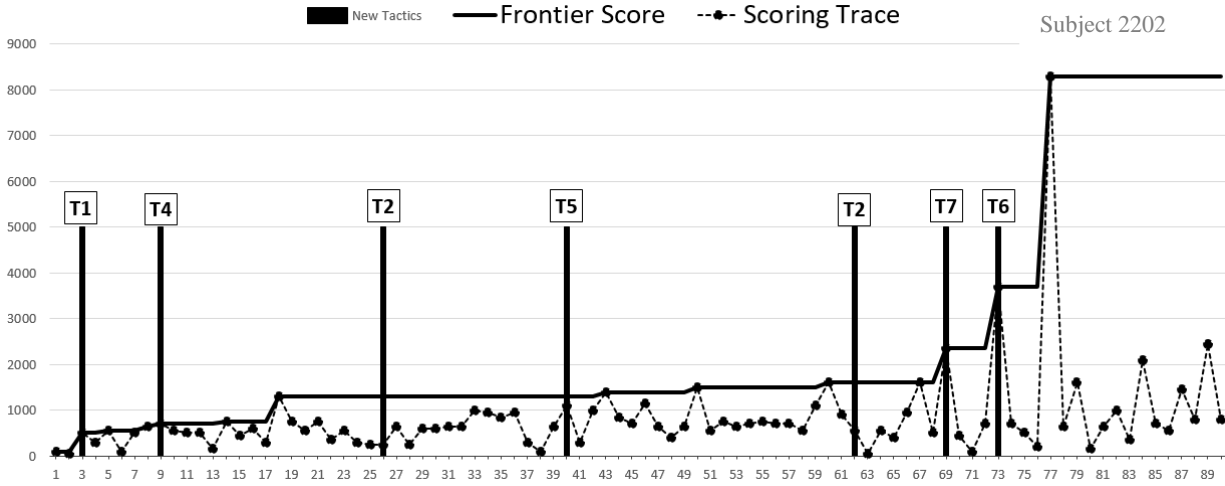
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2198



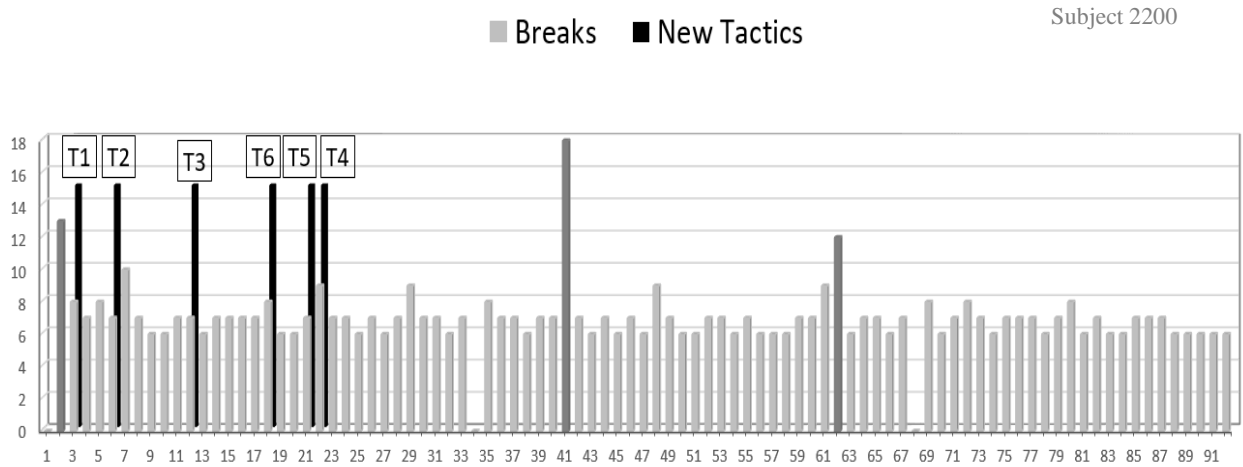
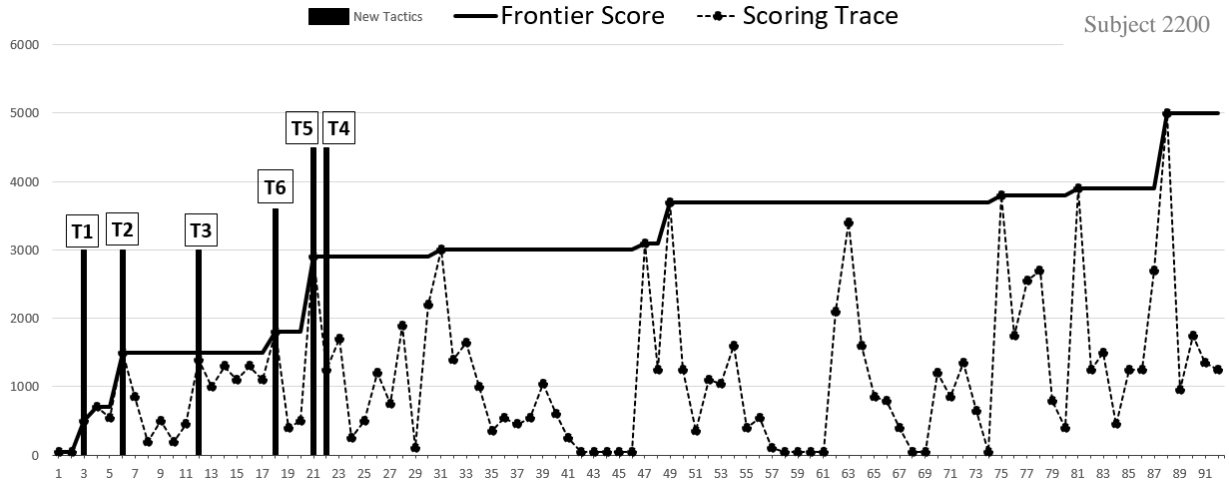
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2202



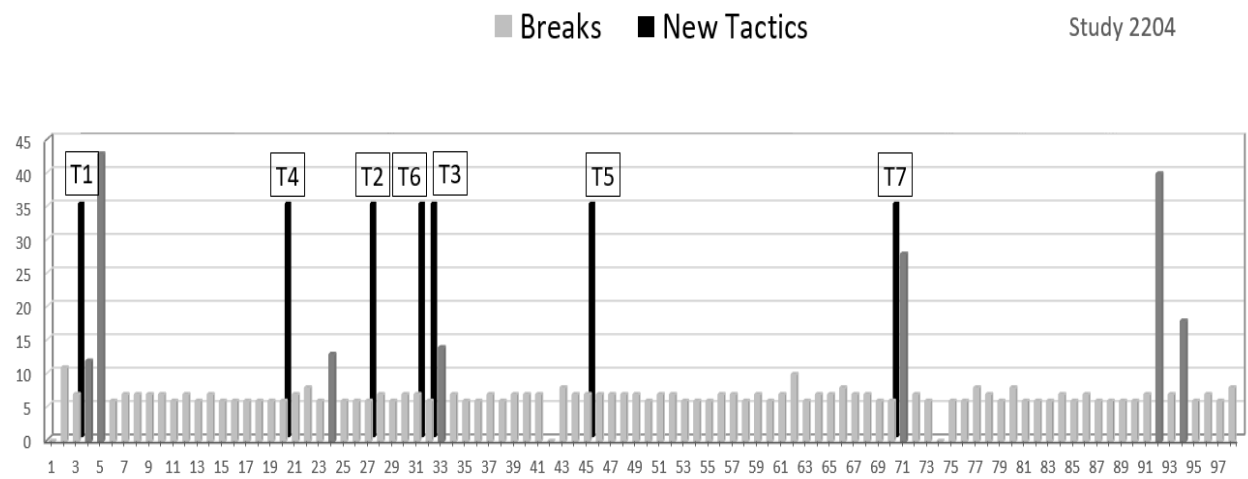
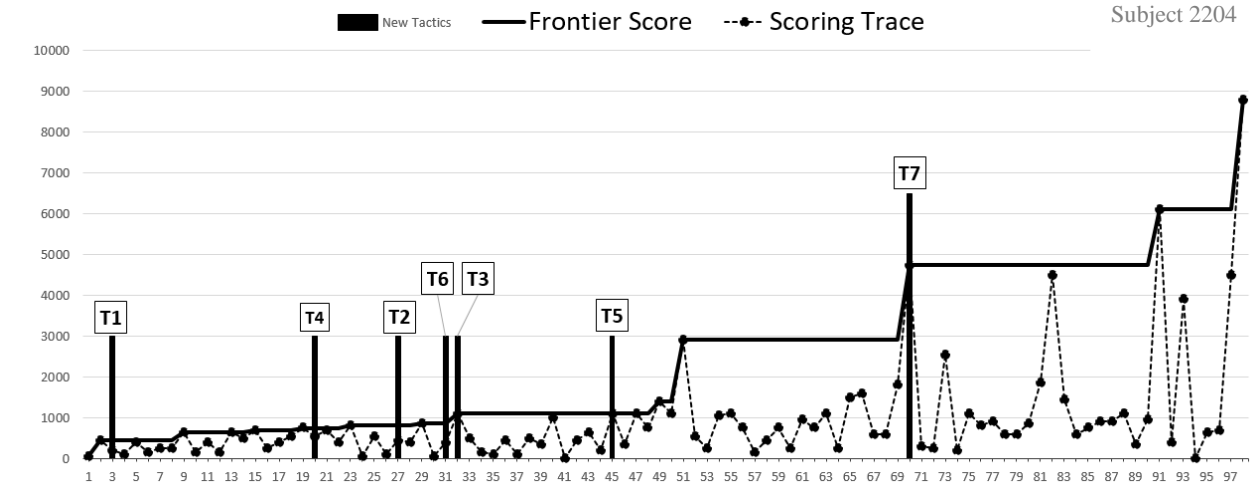
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2200



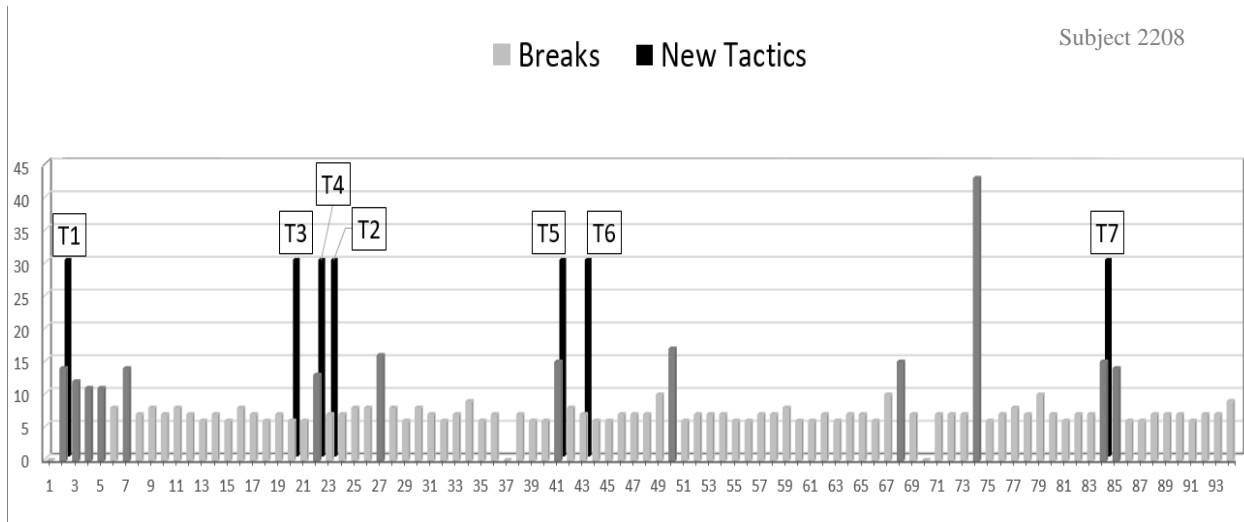
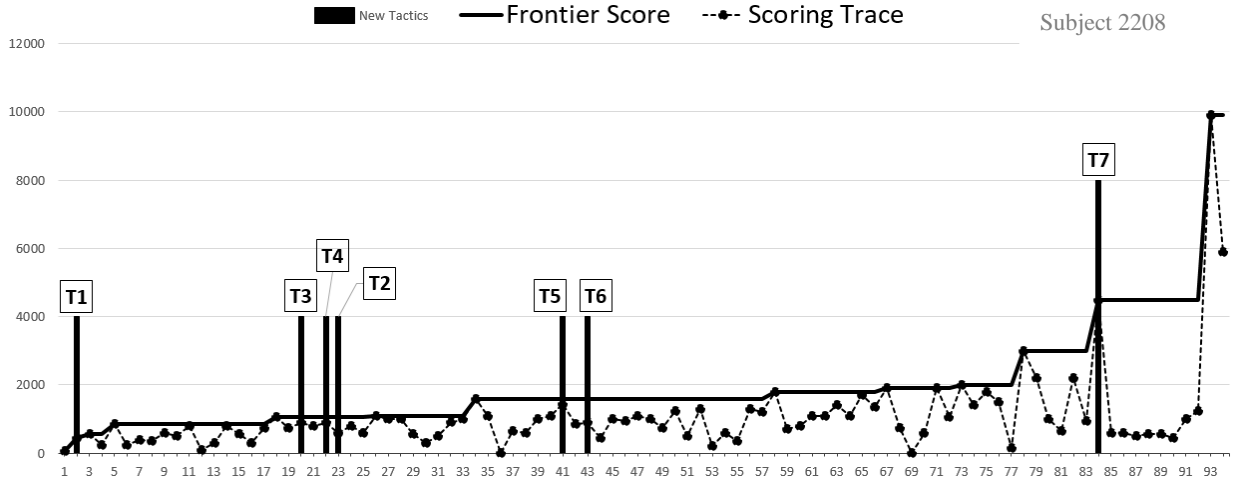
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2204



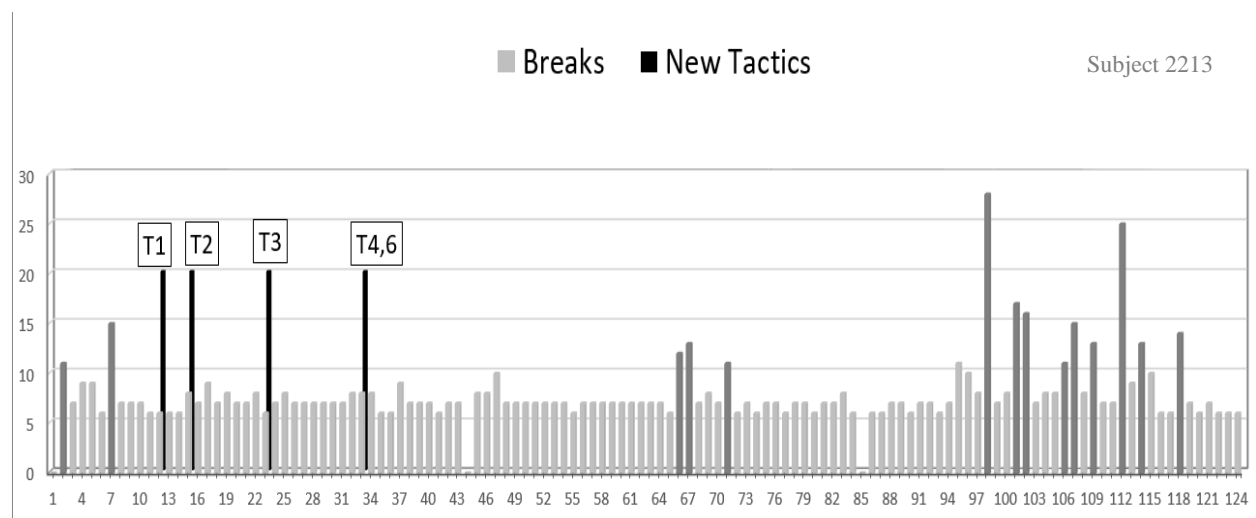
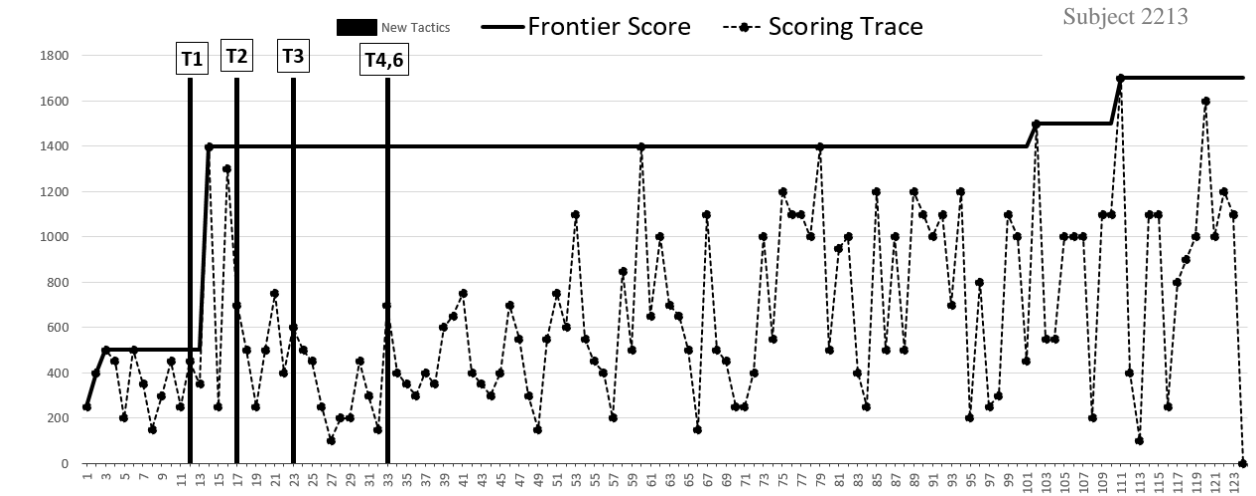
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2208



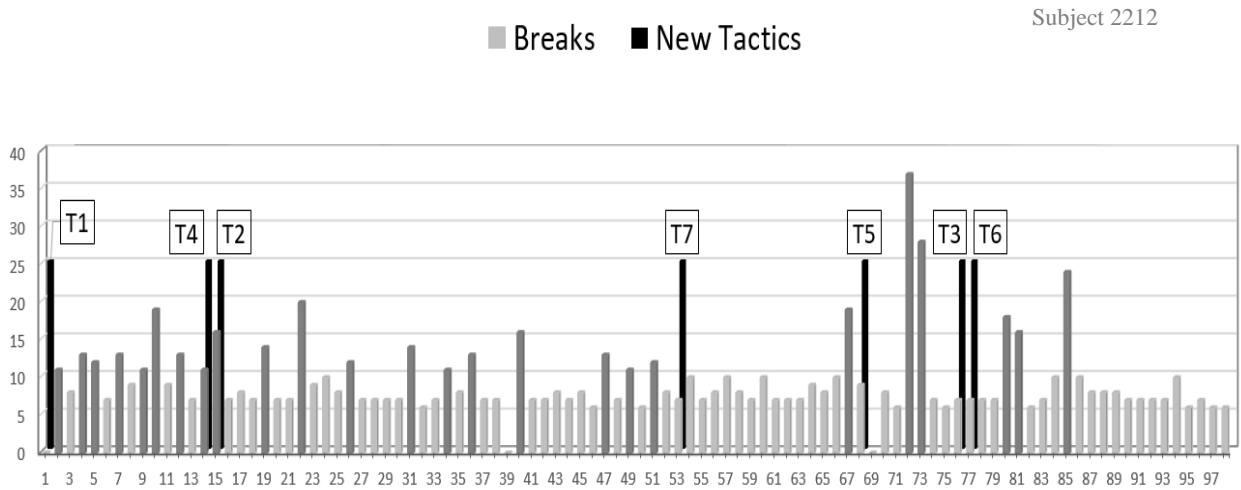
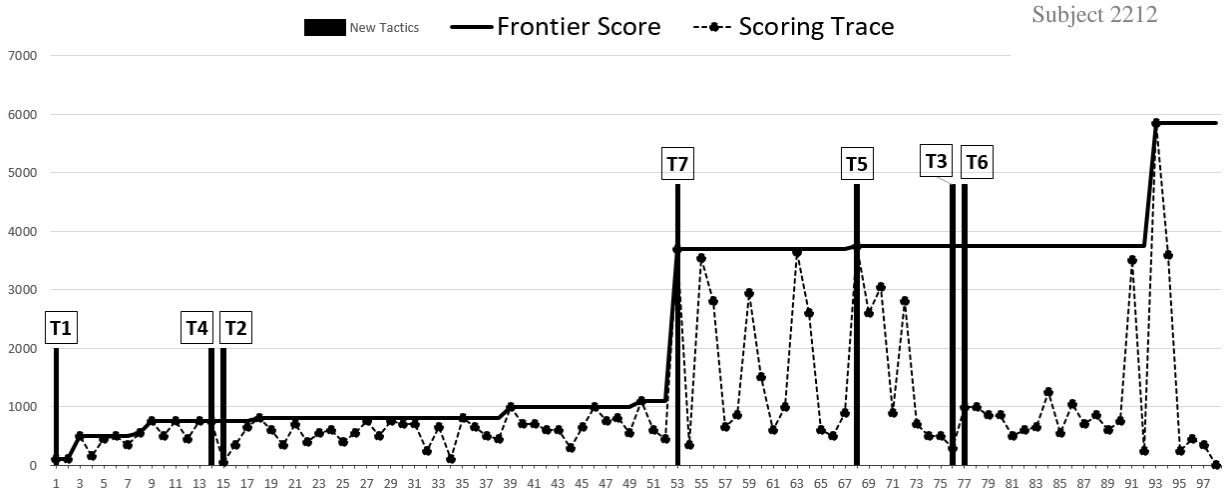
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2213



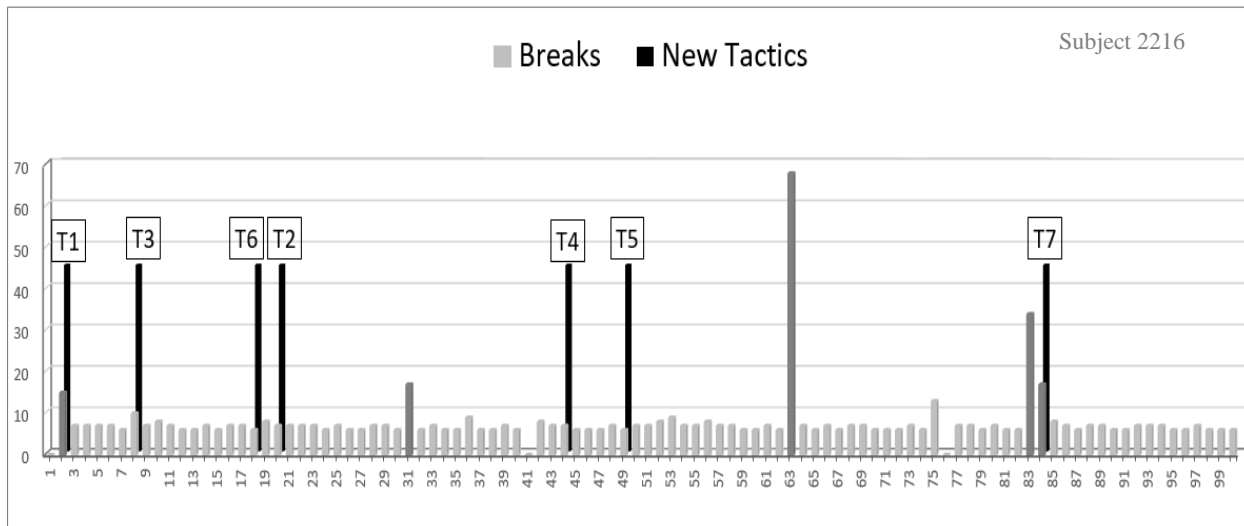
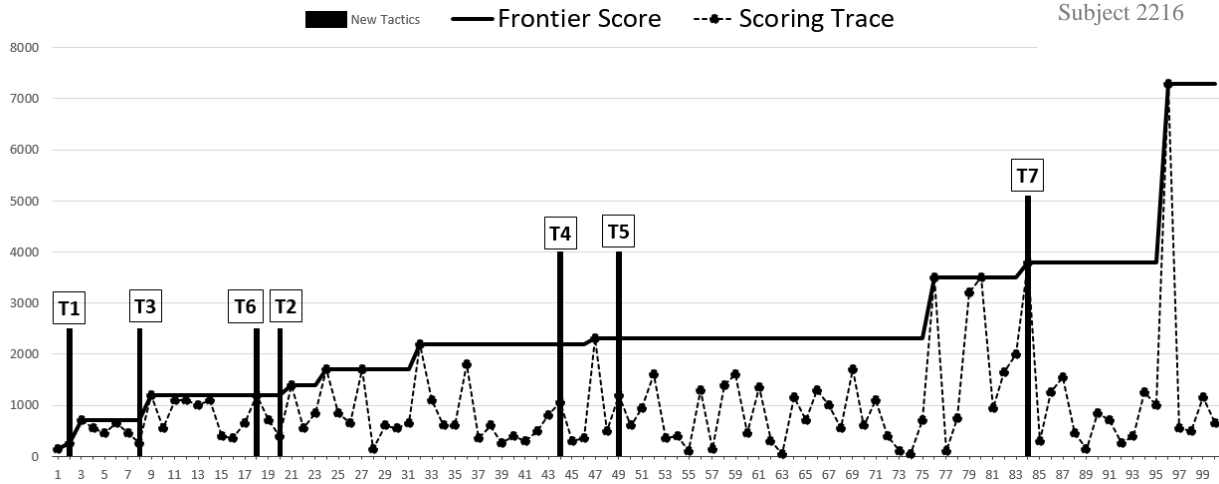
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2212



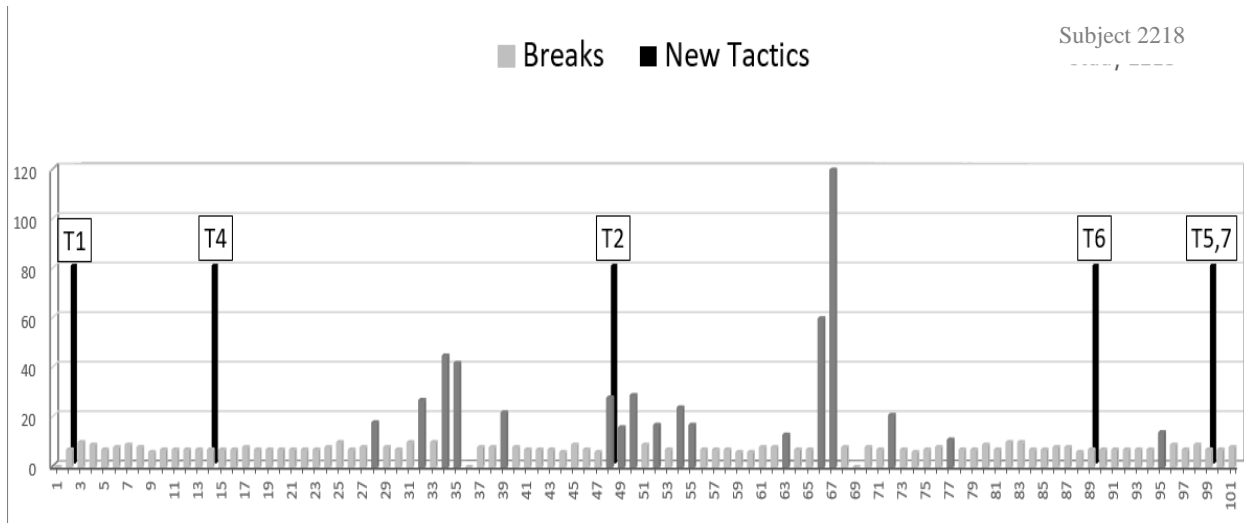
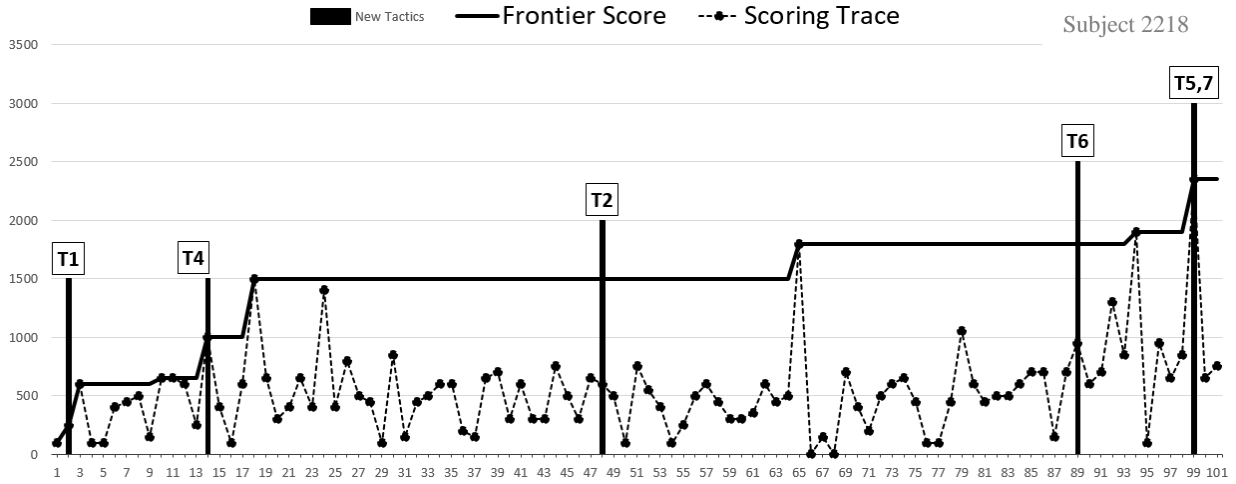
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2216



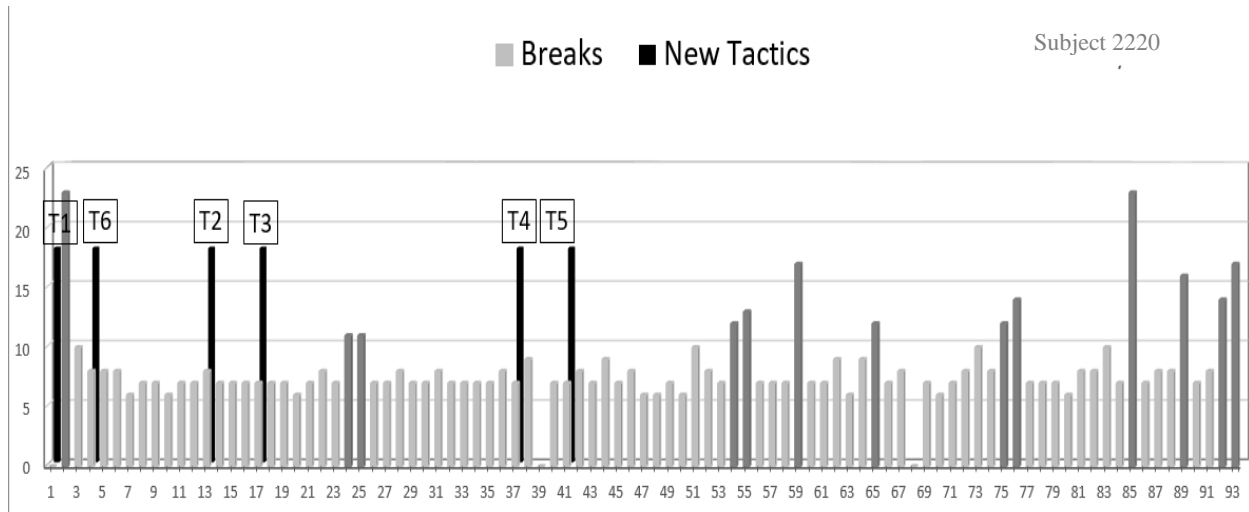
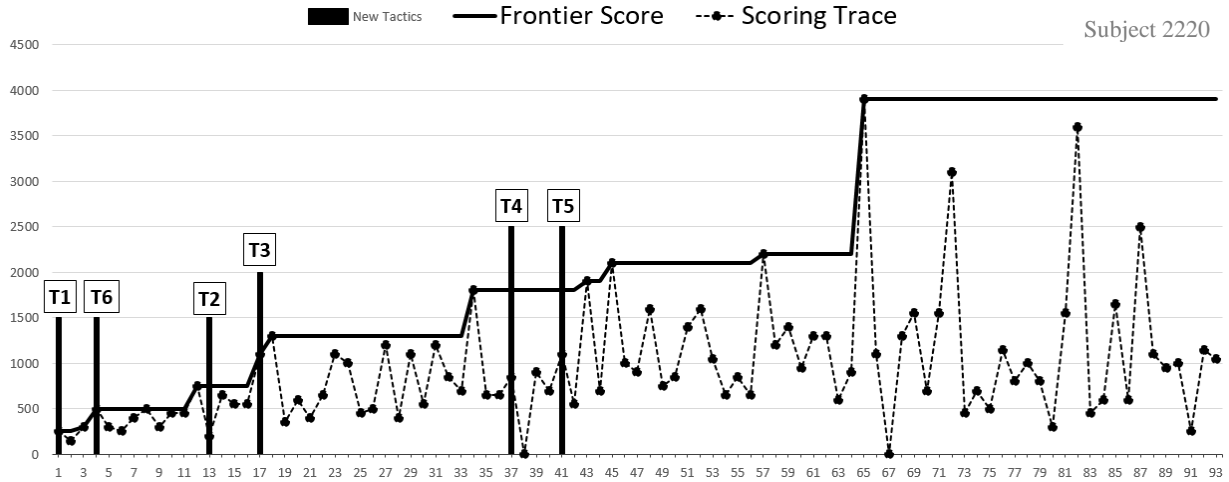
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2218



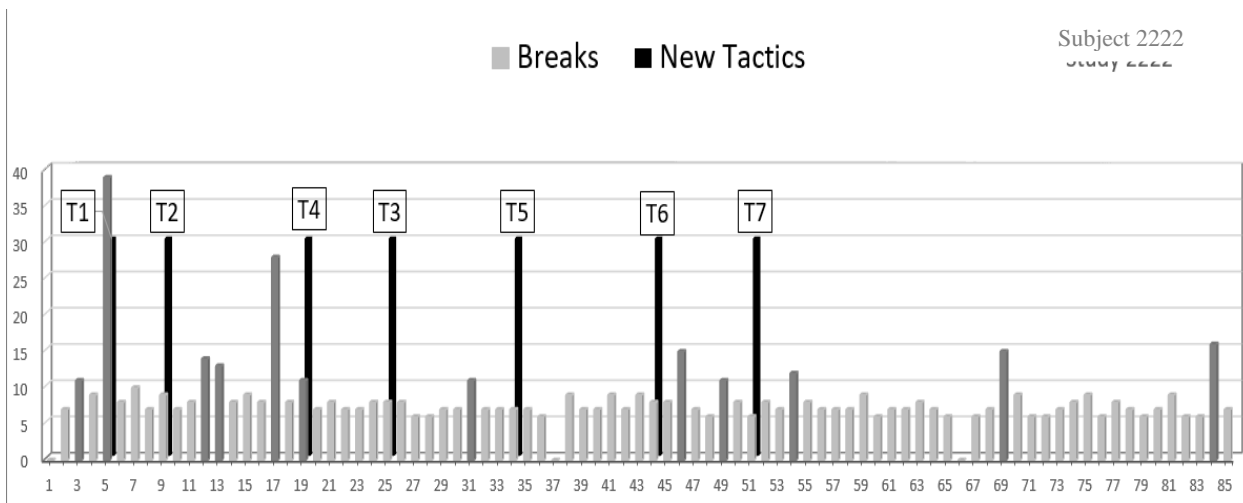
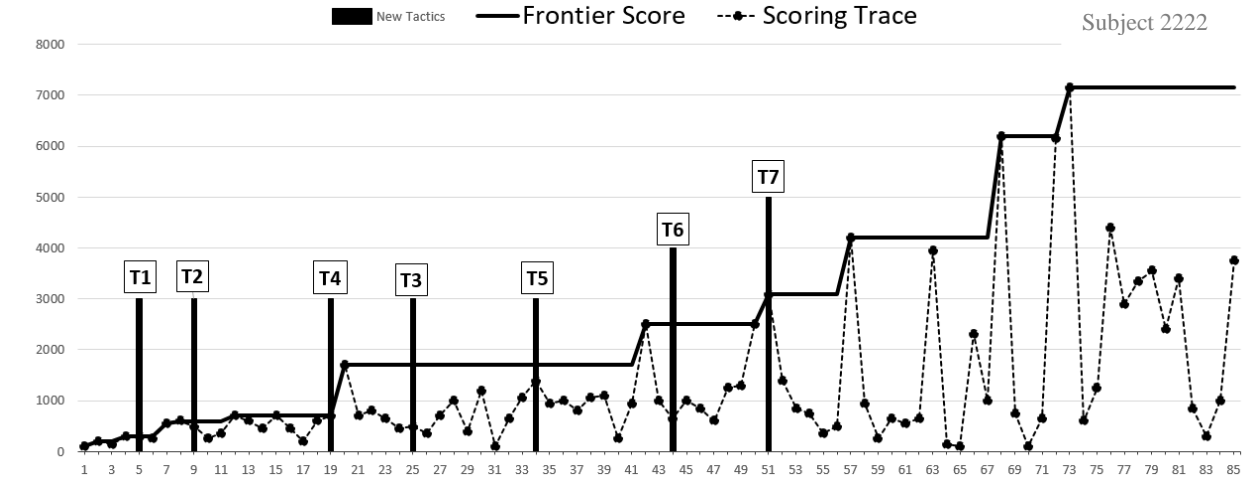
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2220



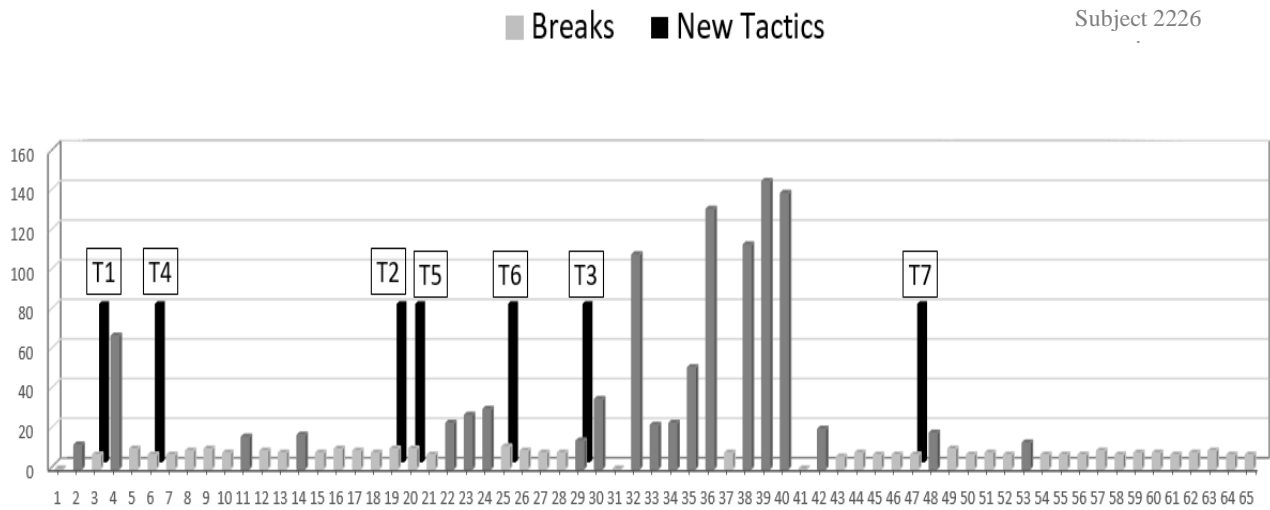
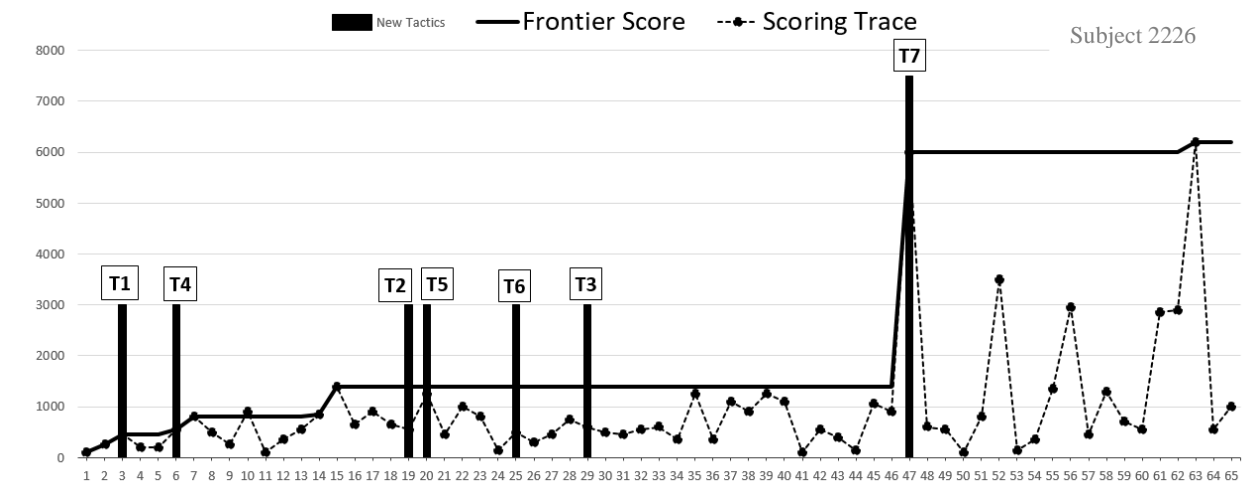
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2222



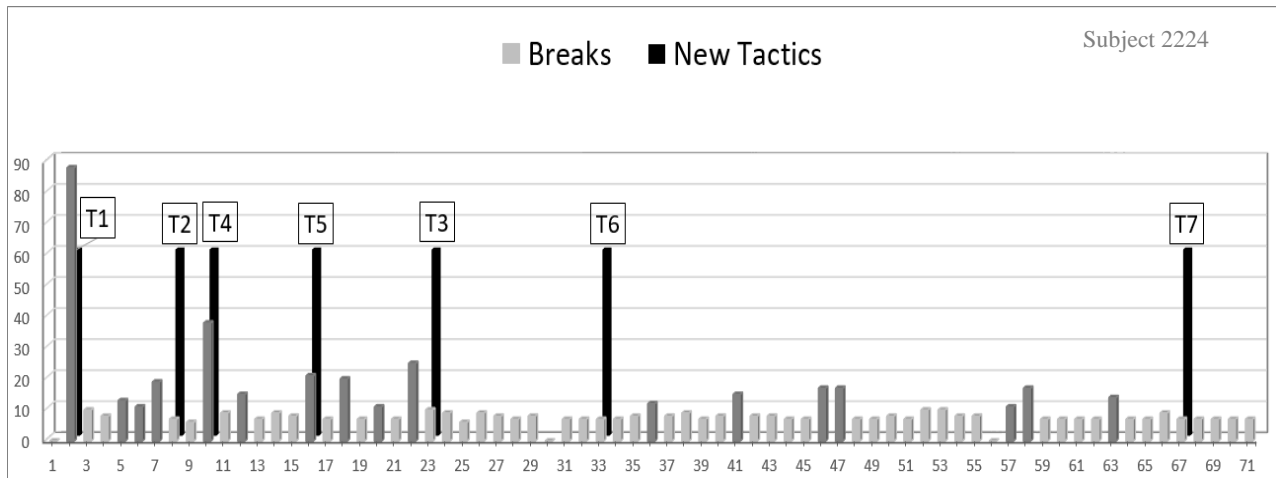
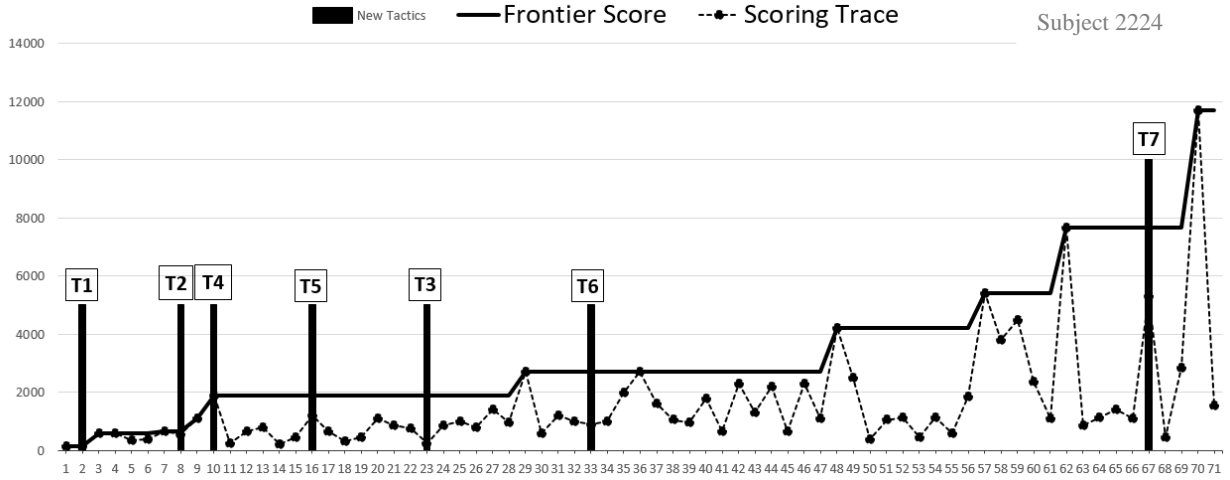
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2226



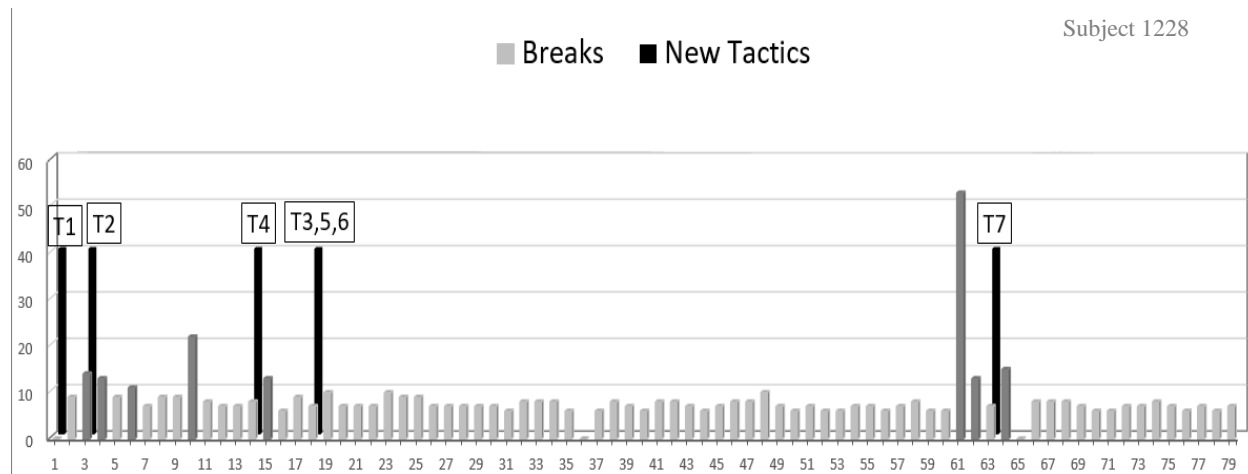
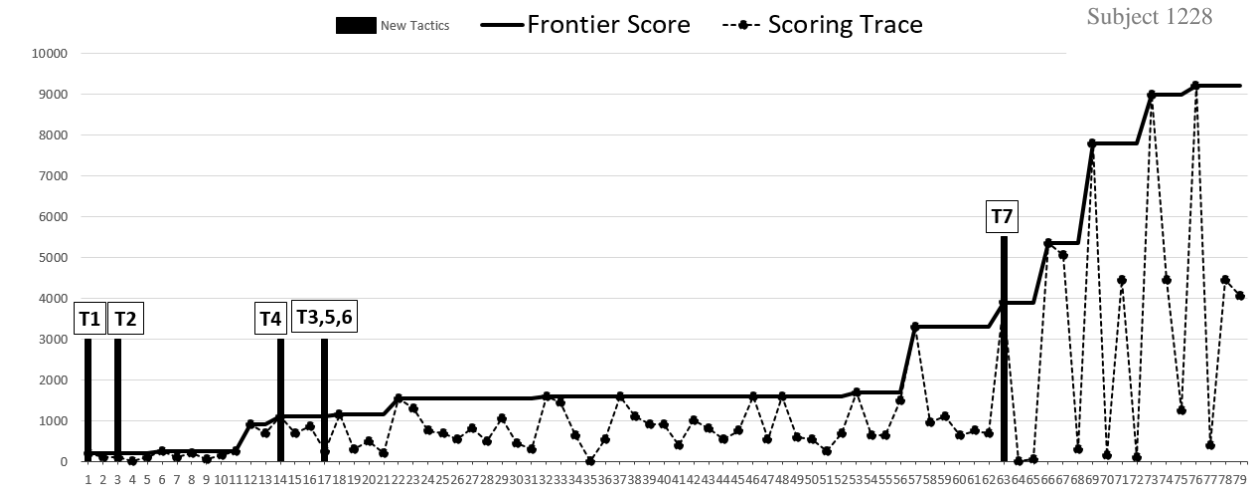
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2224



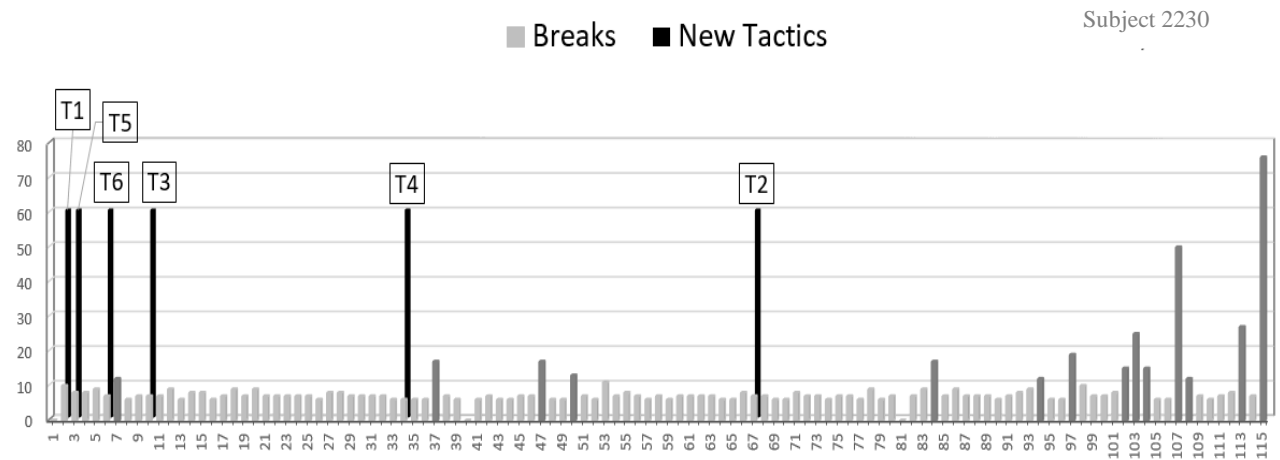
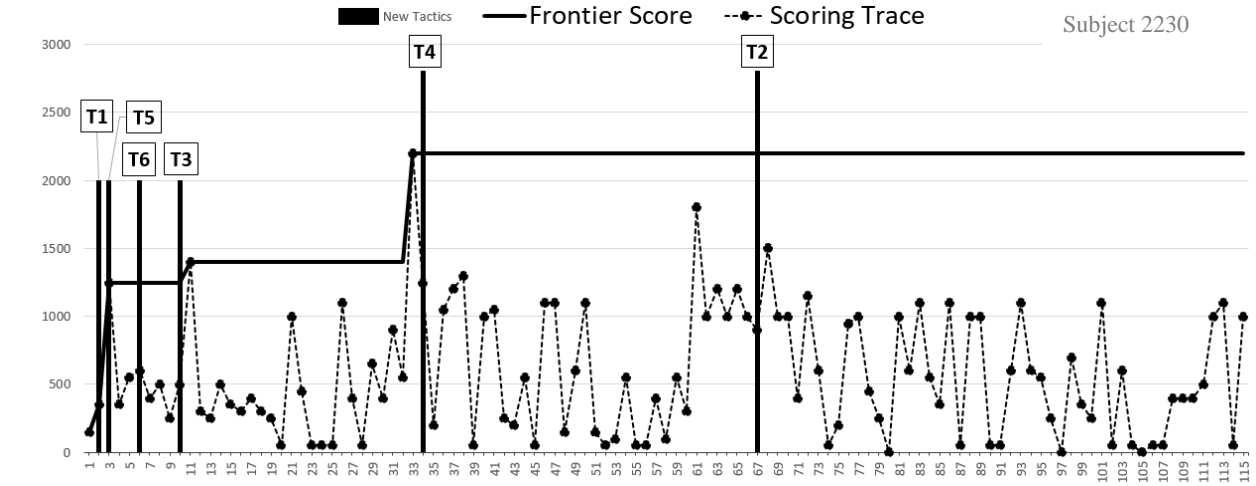
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 1228



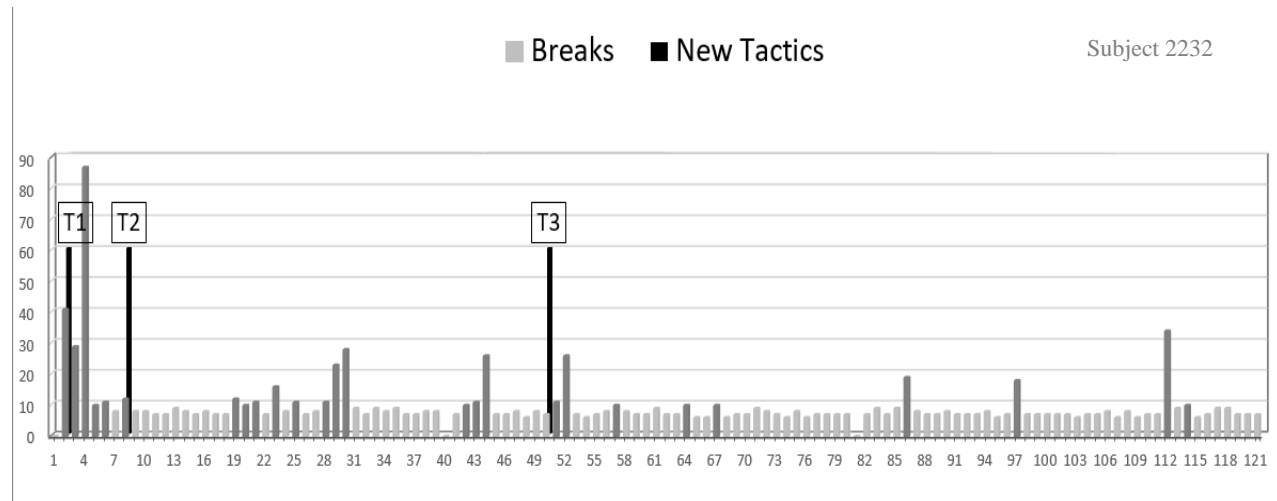
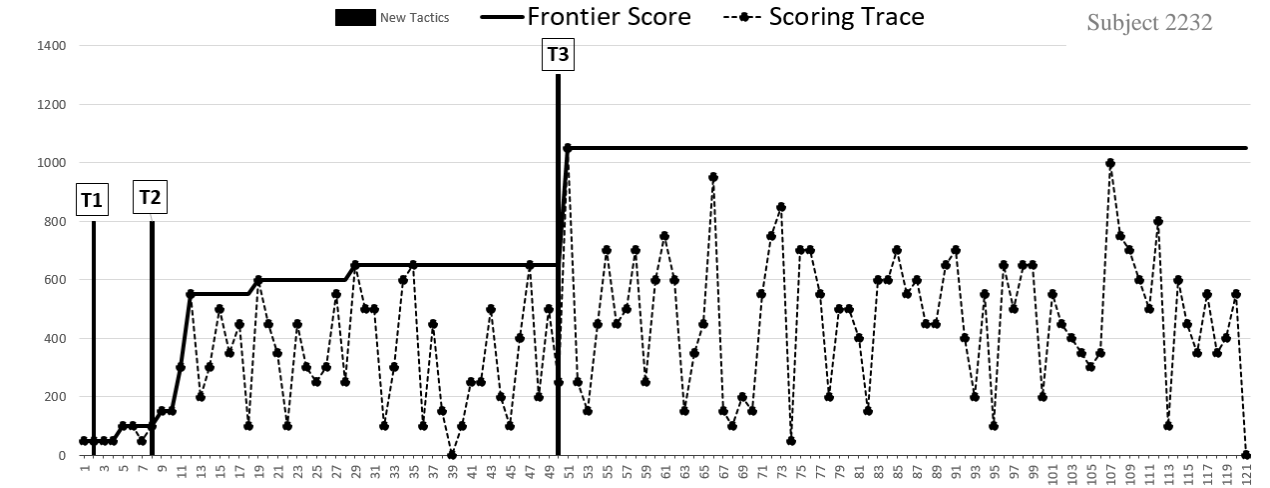
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2230



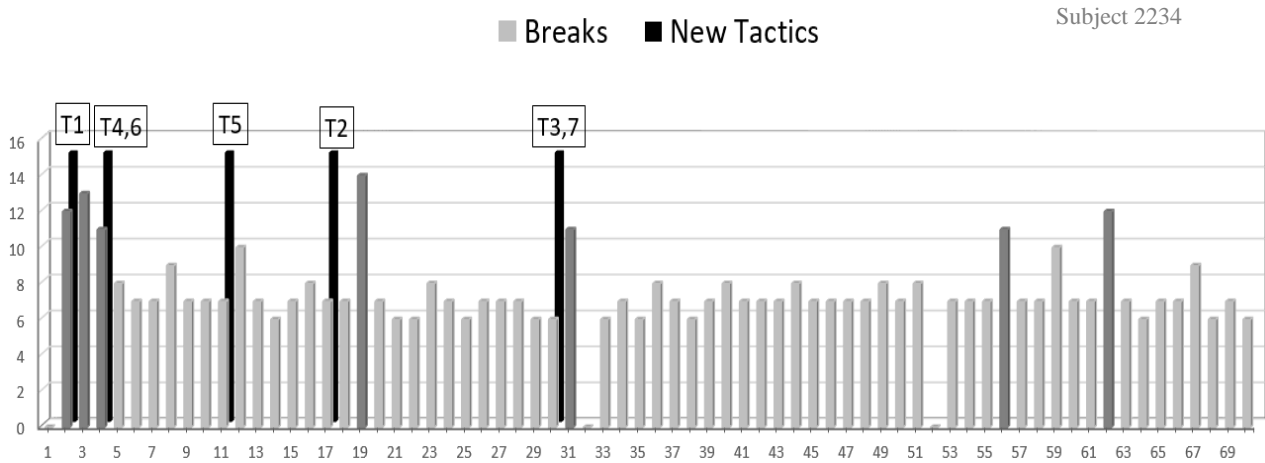
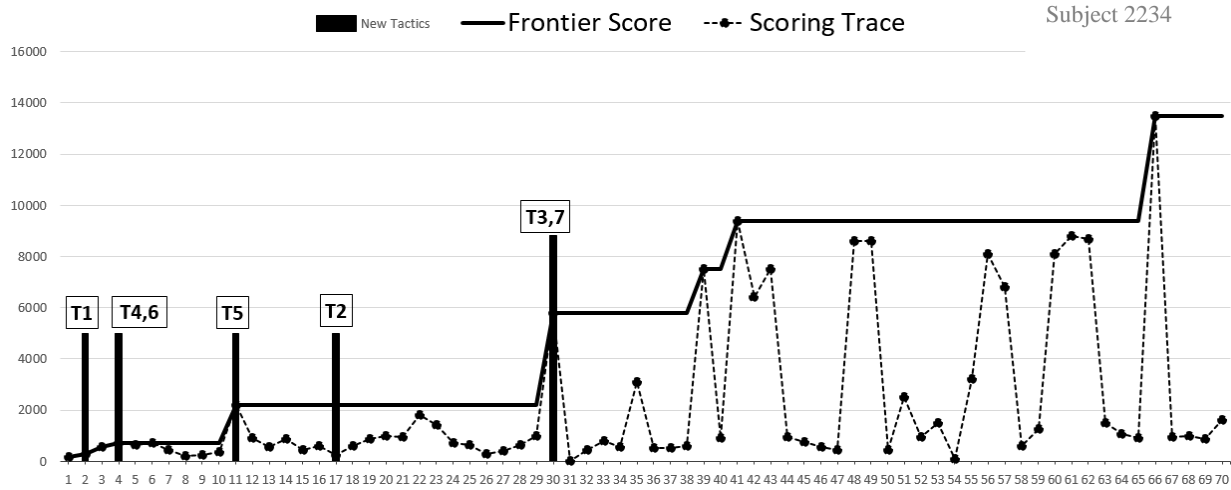
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2232



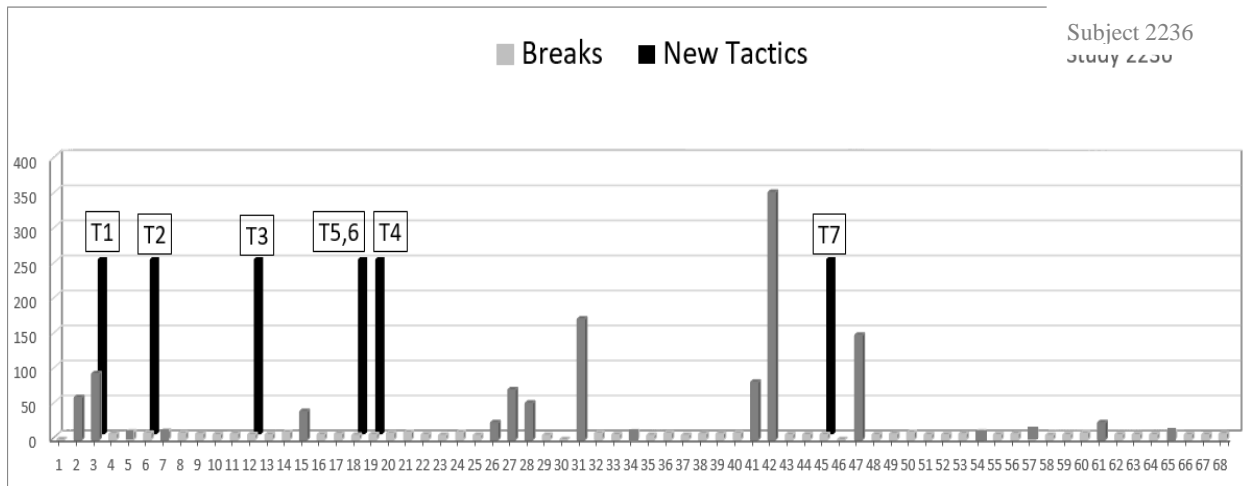
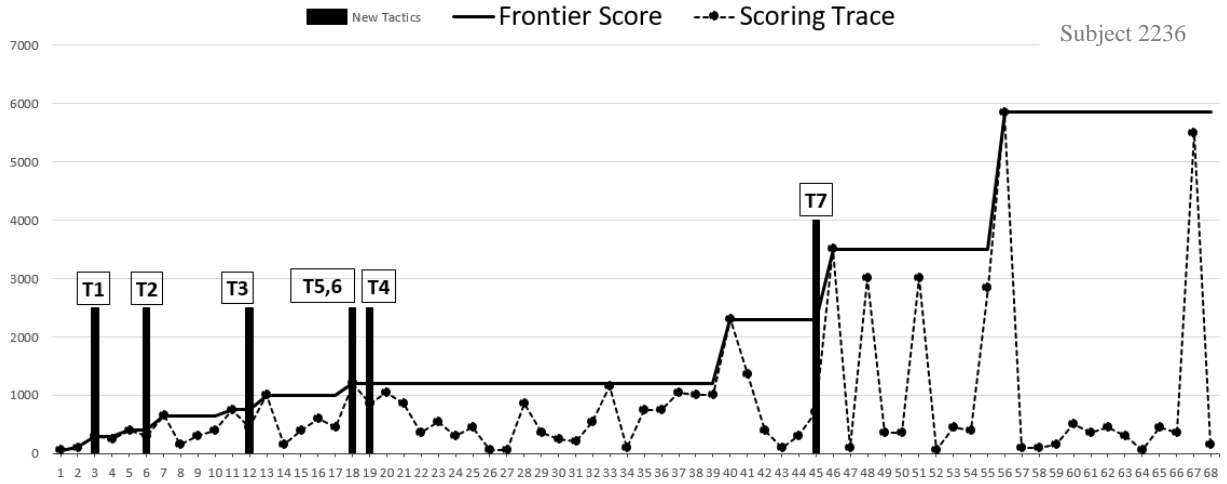
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2234



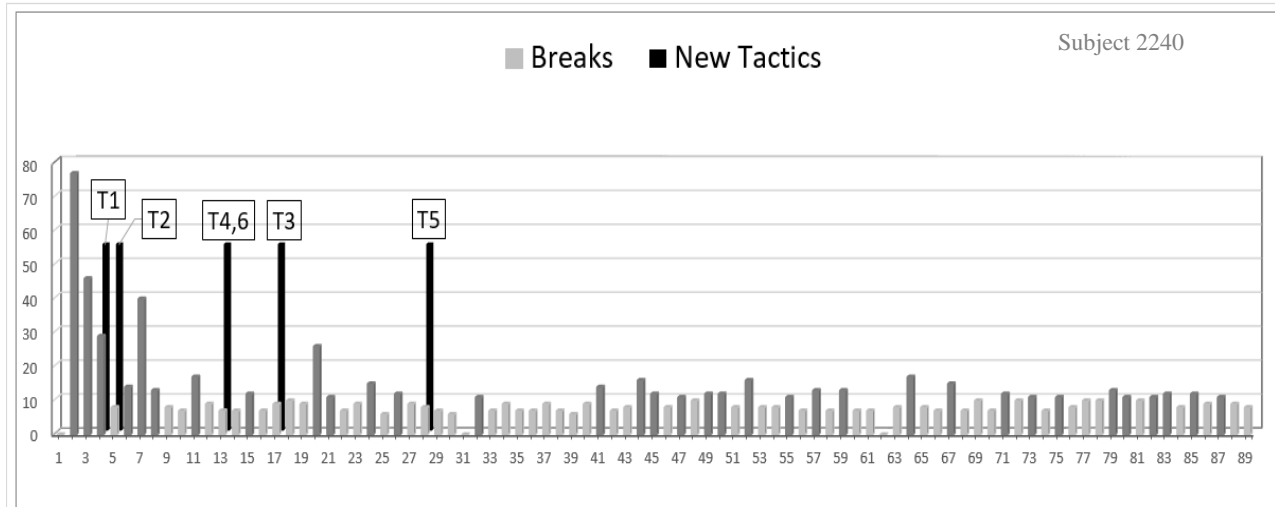
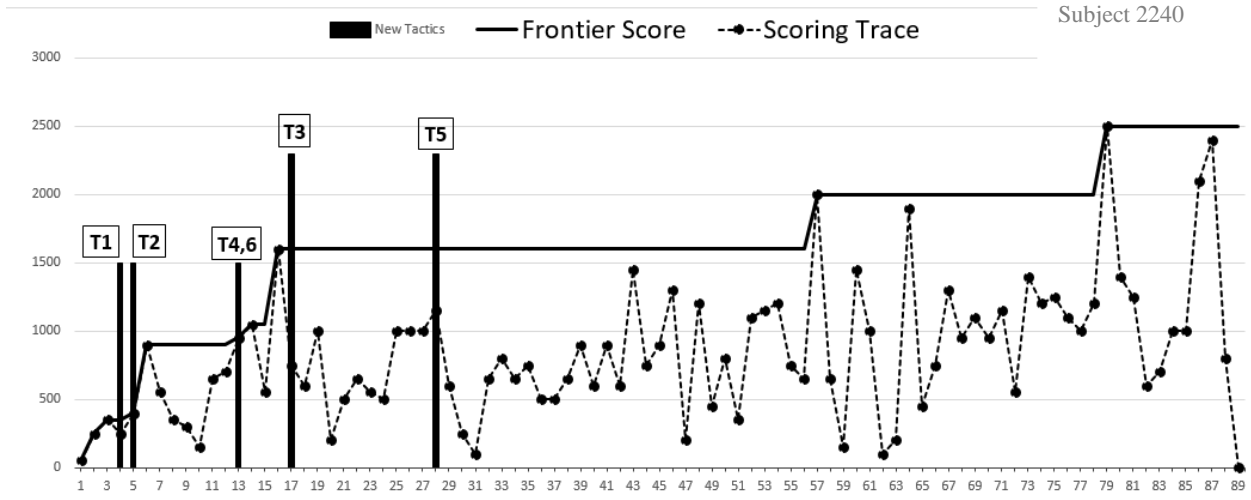
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2236



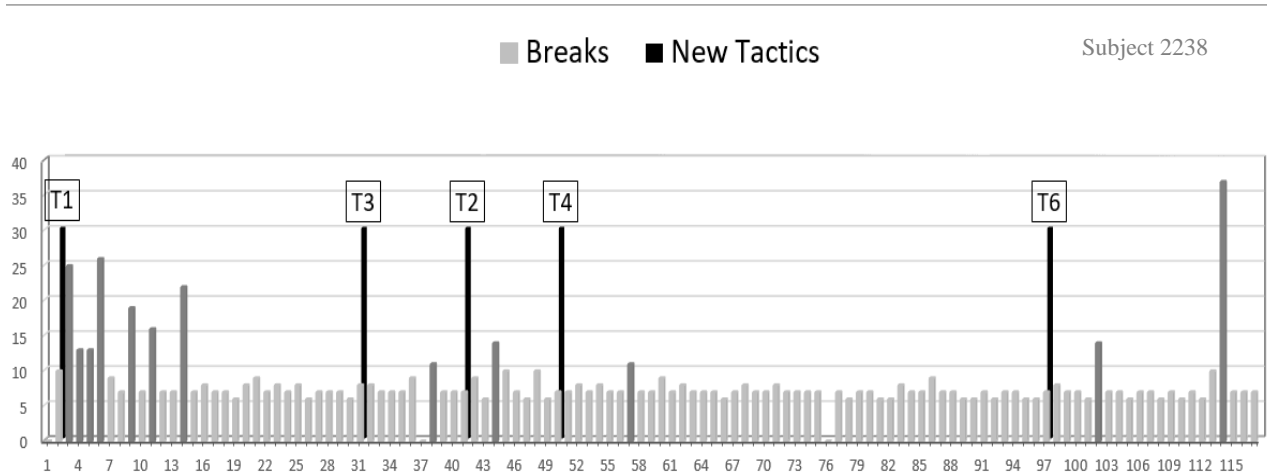
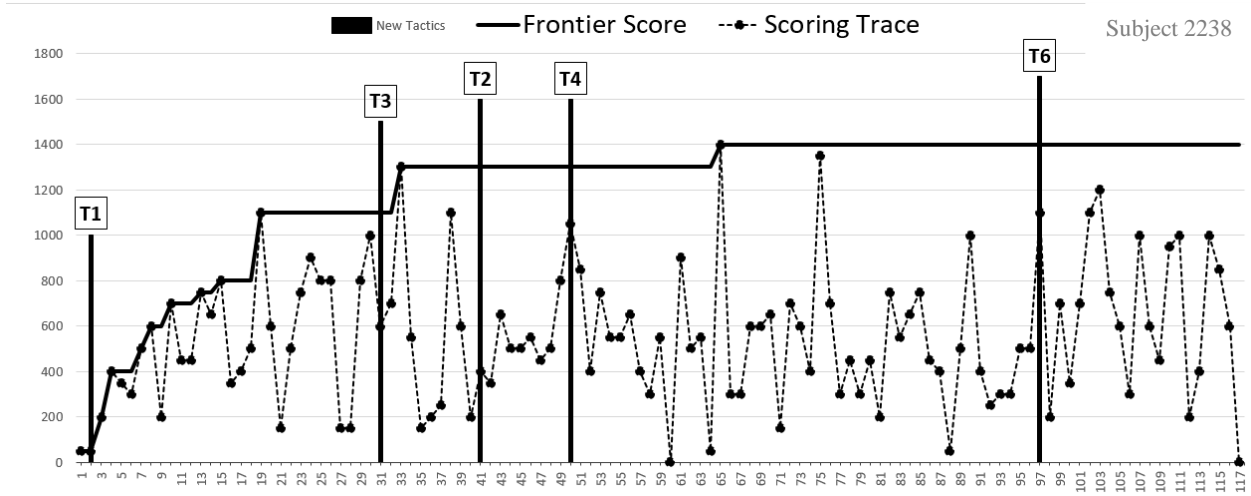
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2240



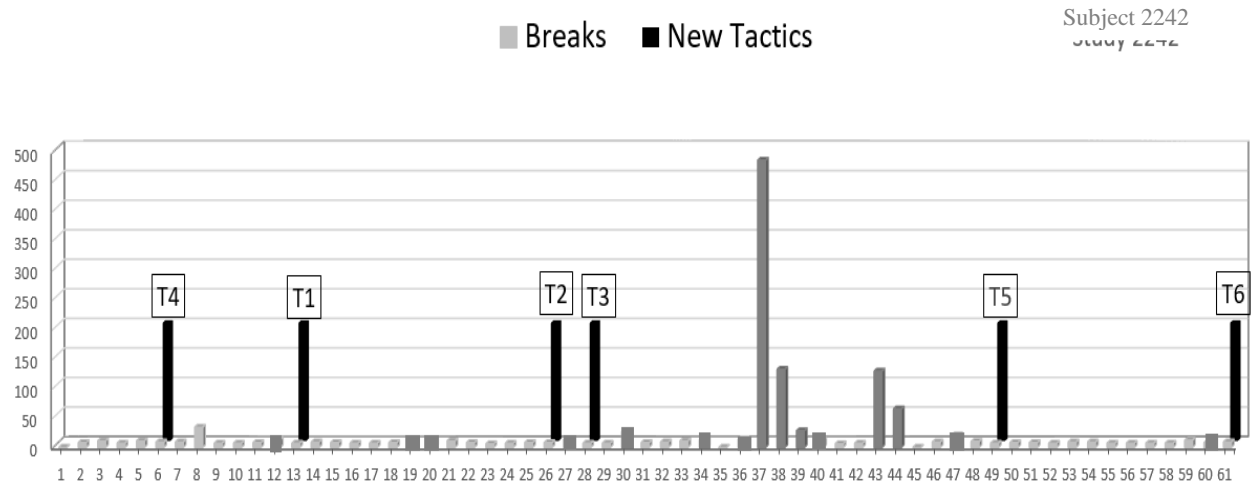
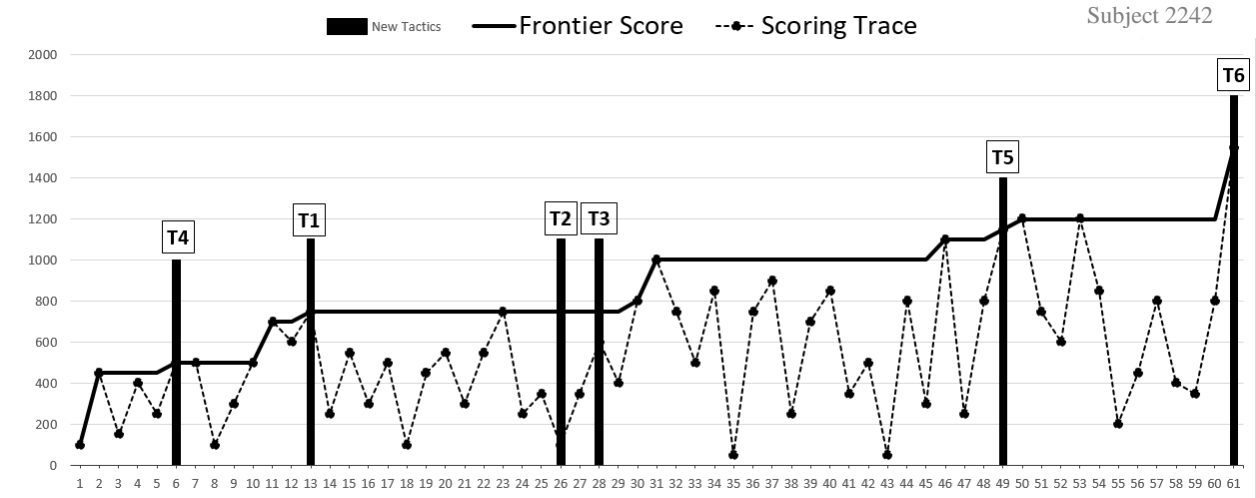
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2238



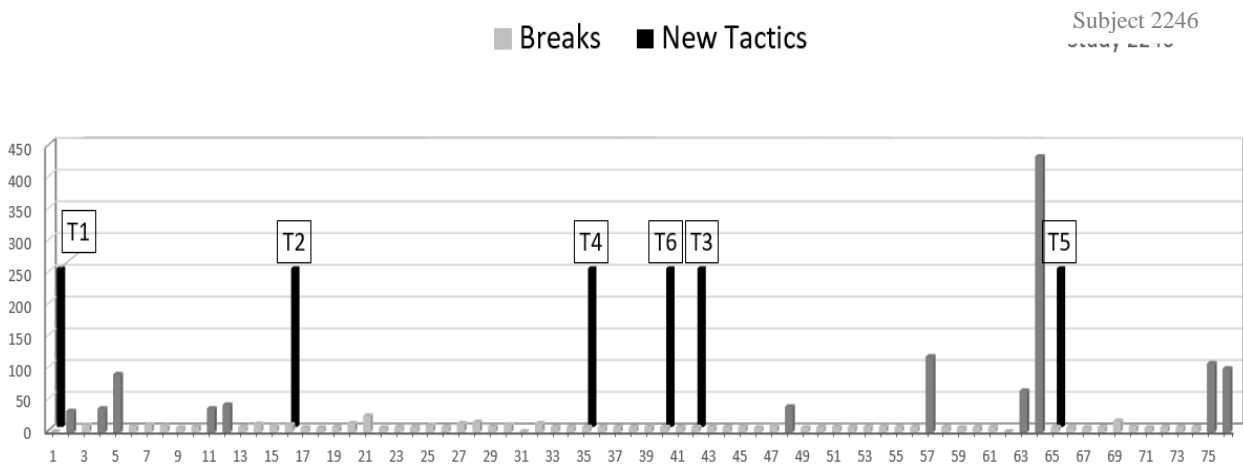
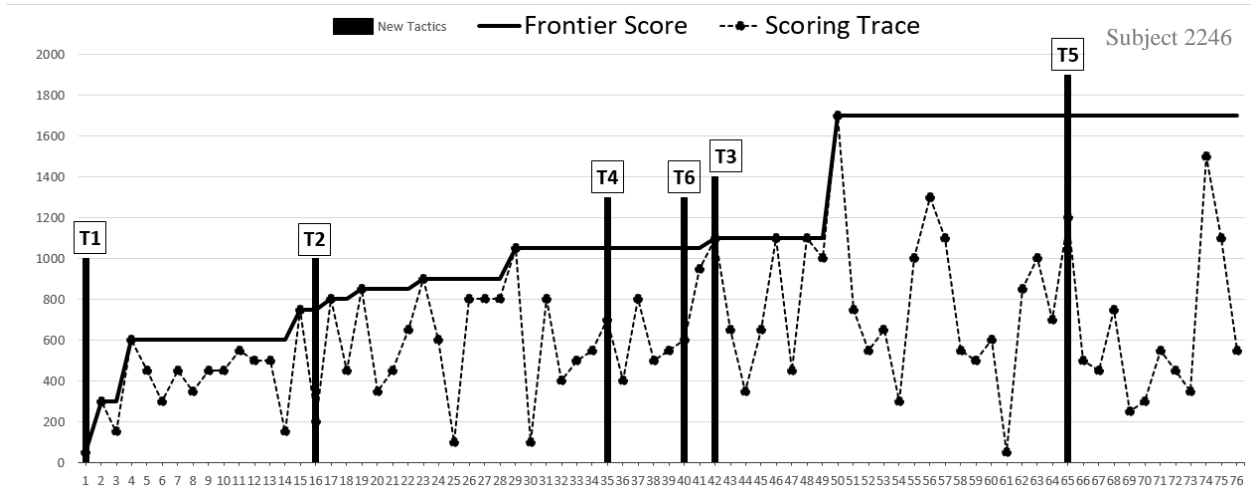
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2242



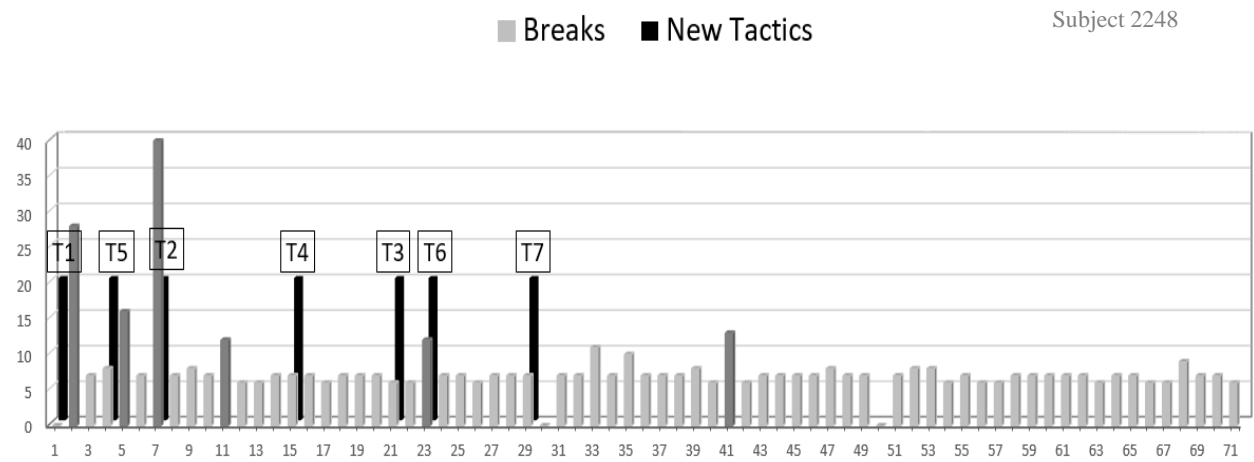
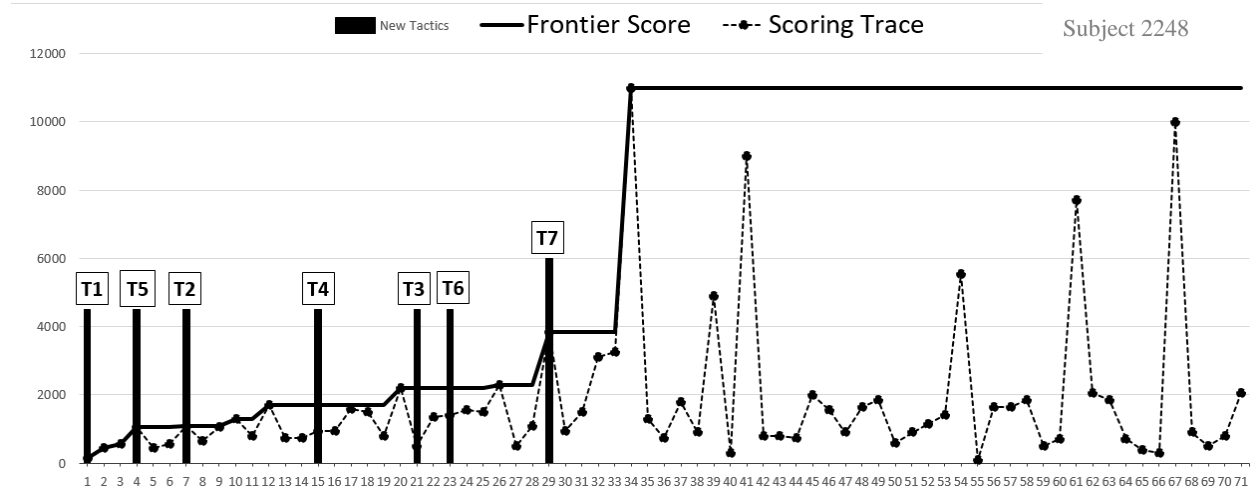
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2246



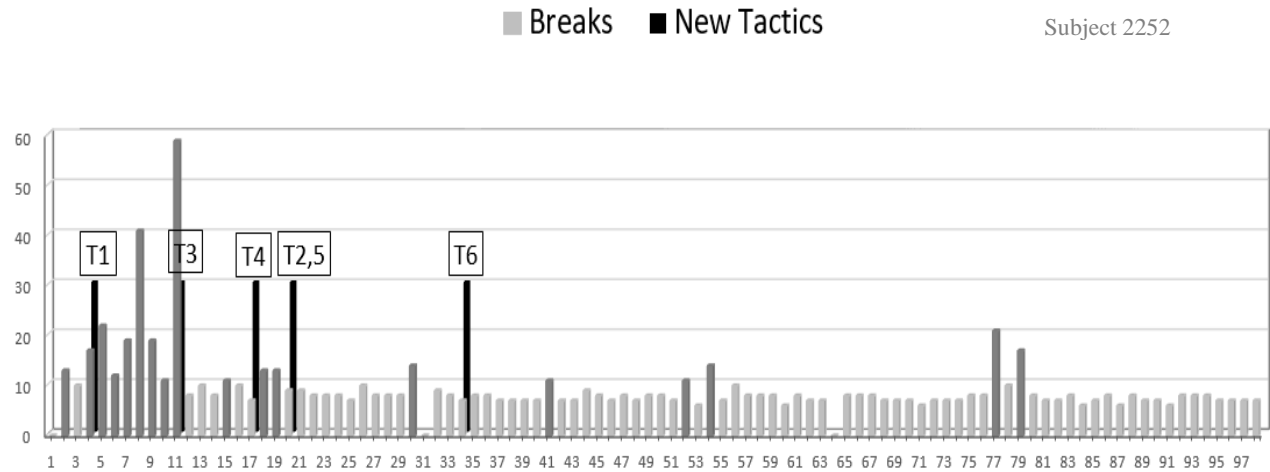
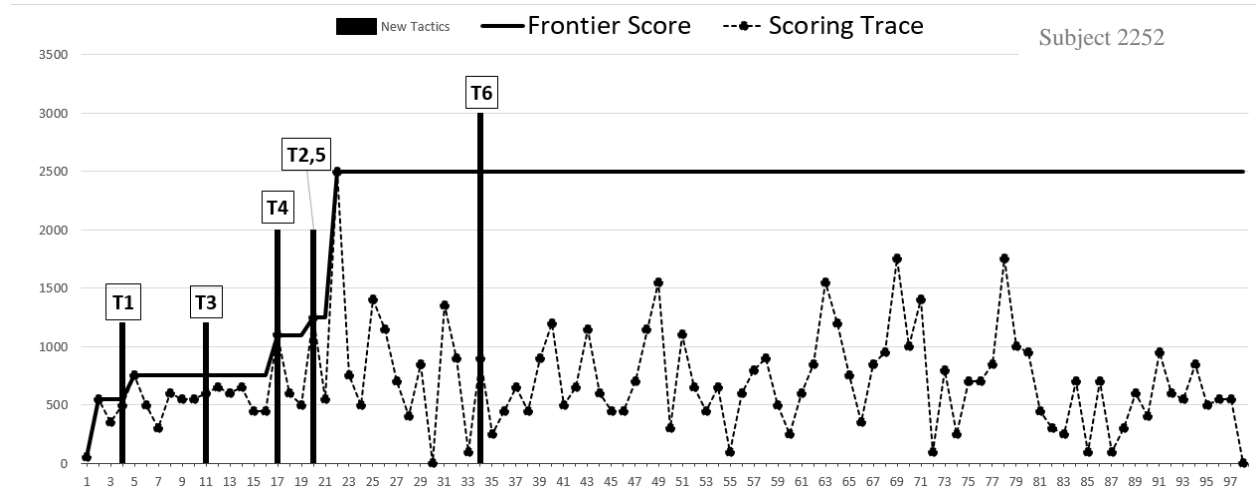
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2248



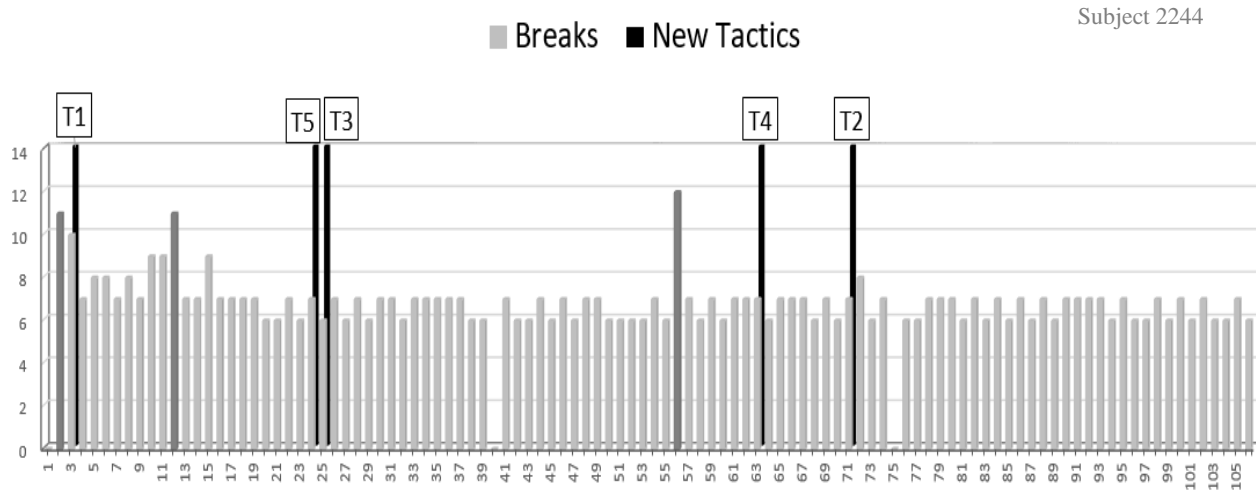
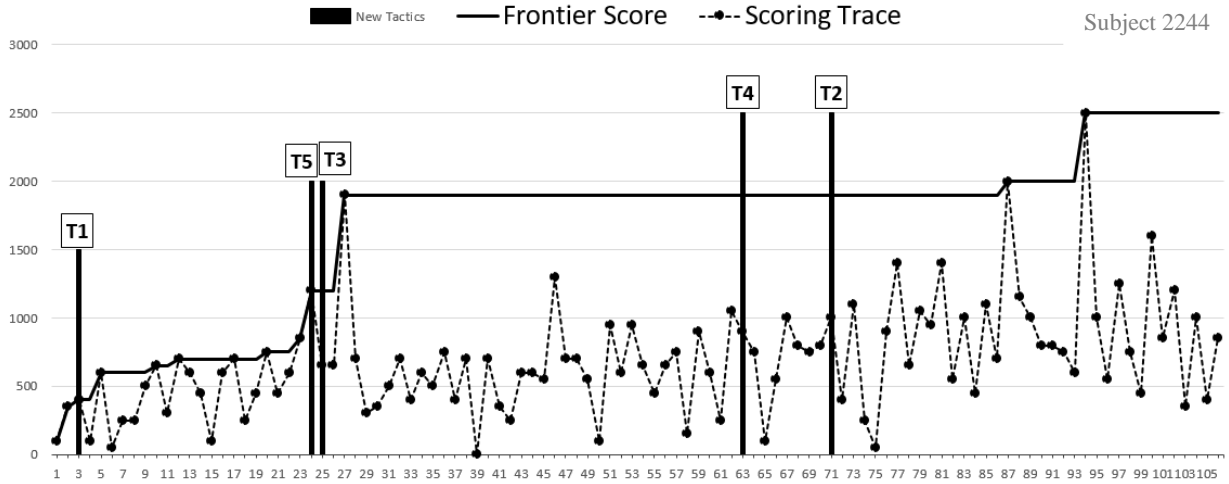
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2252



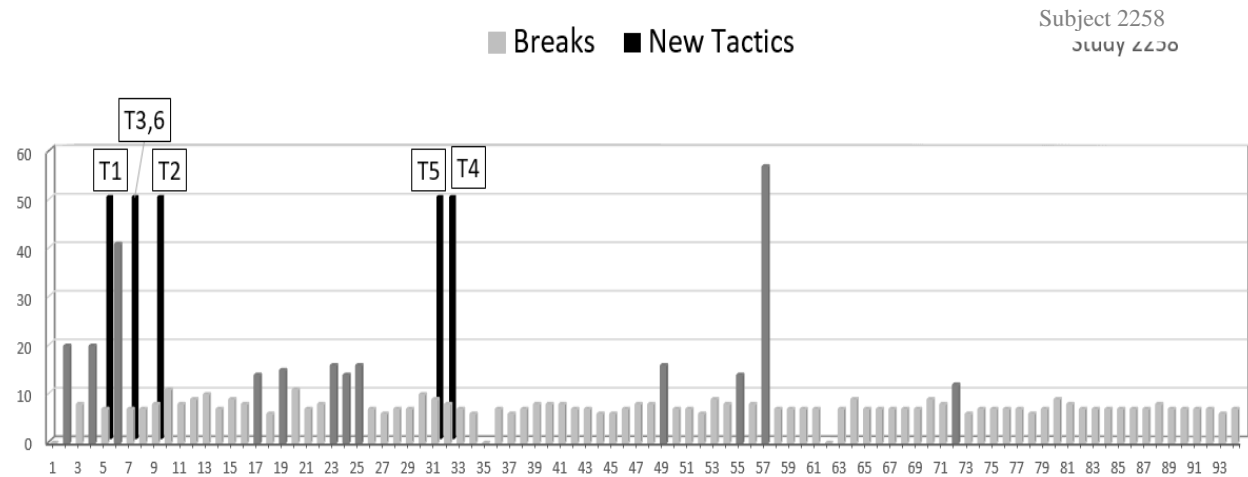
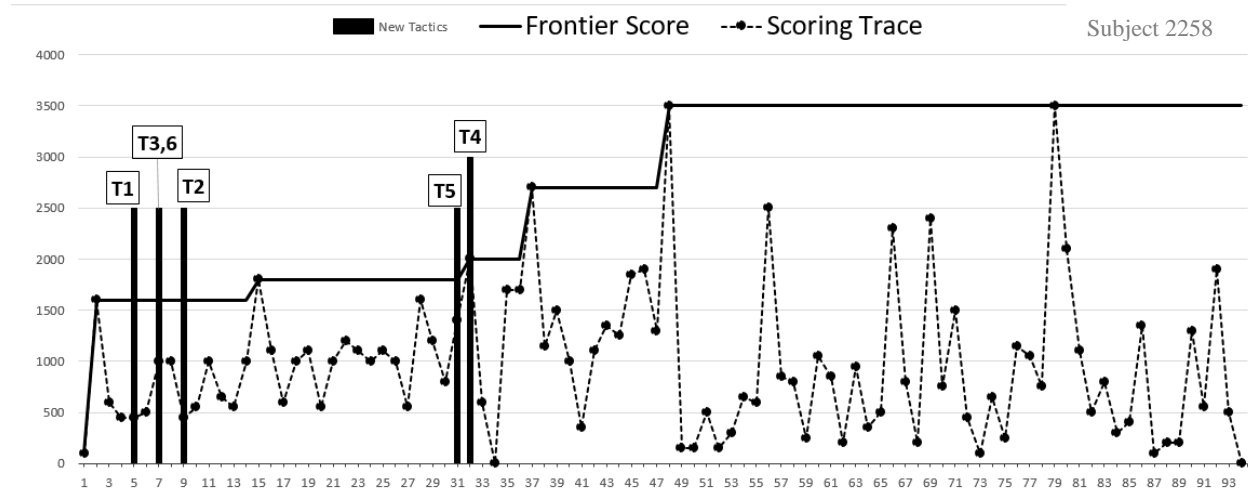
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2244



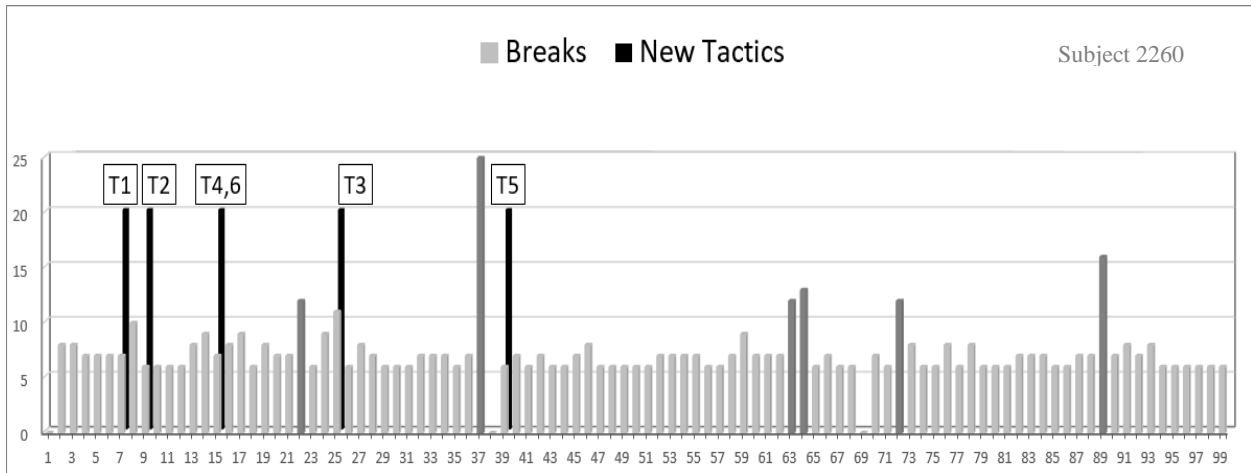
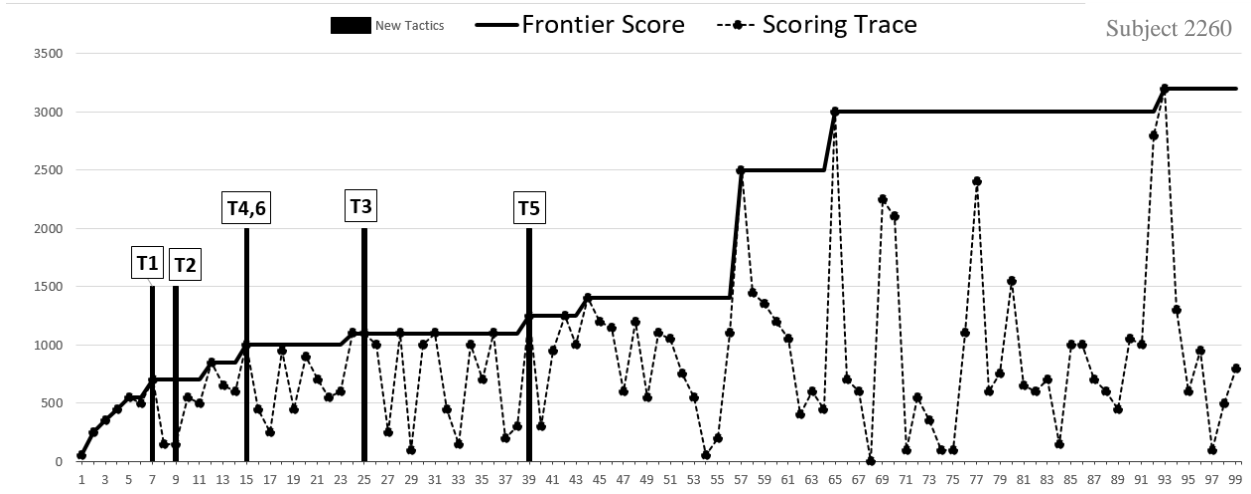
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2258



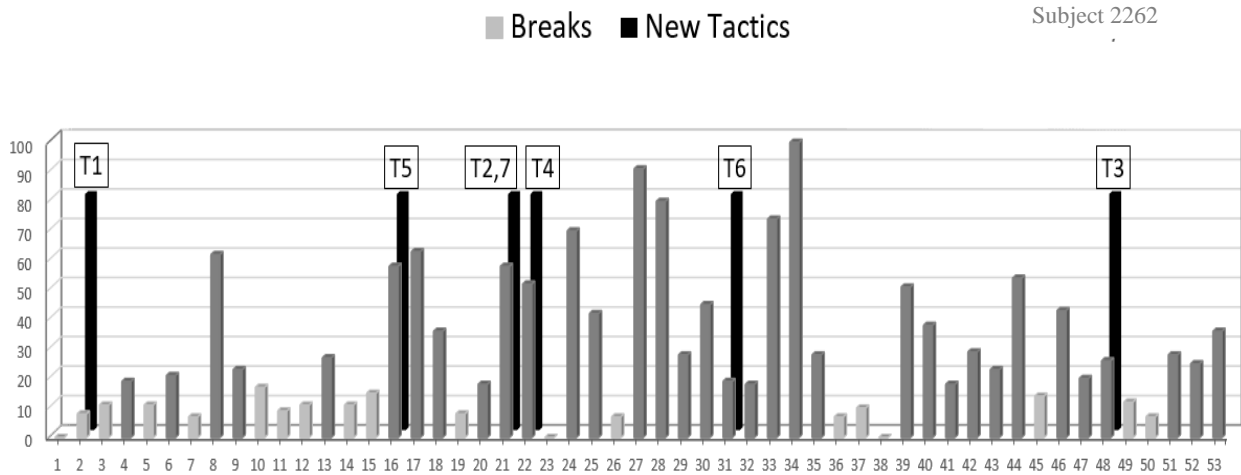
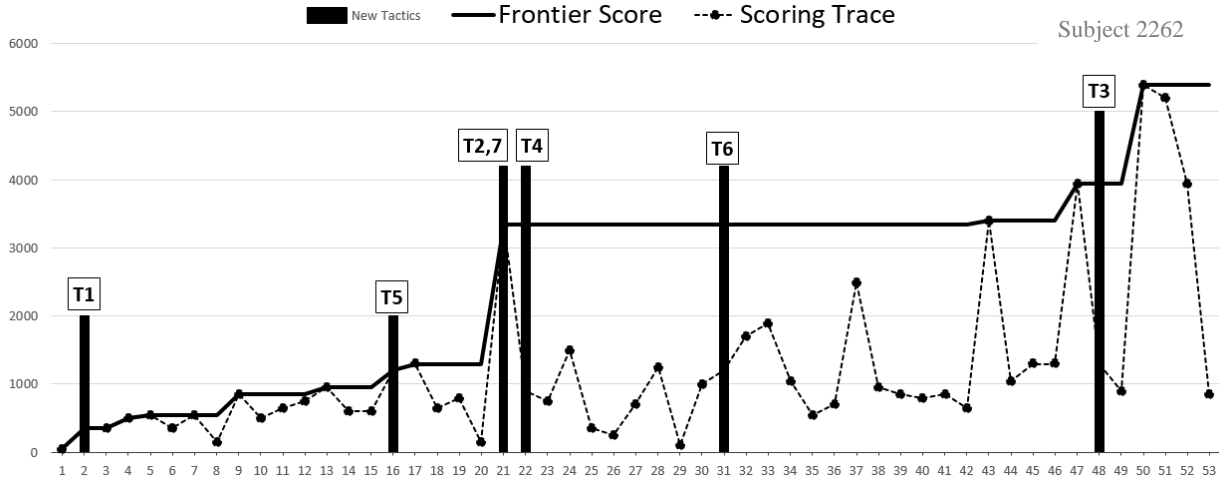
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2260



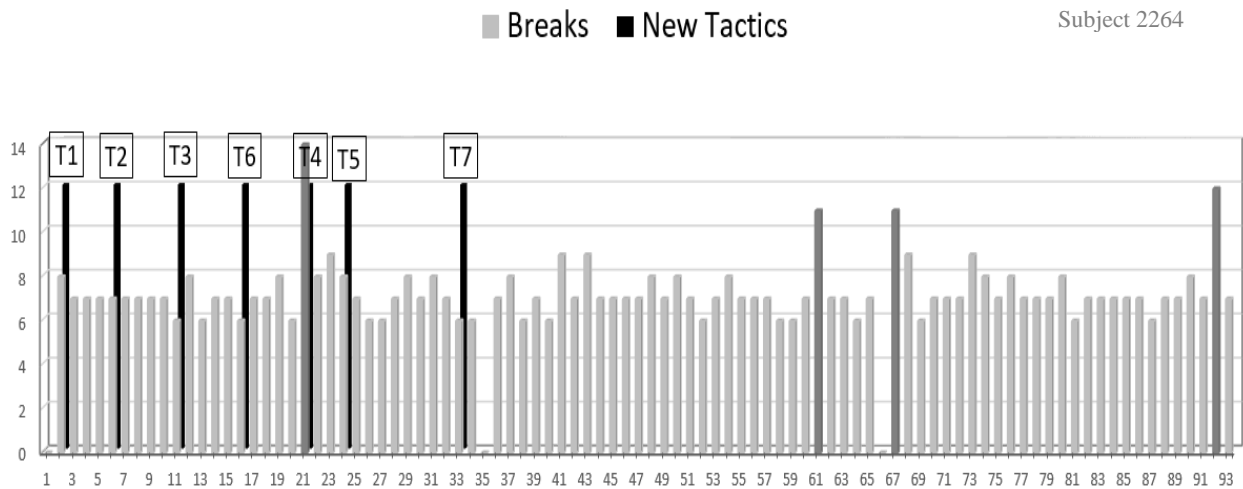
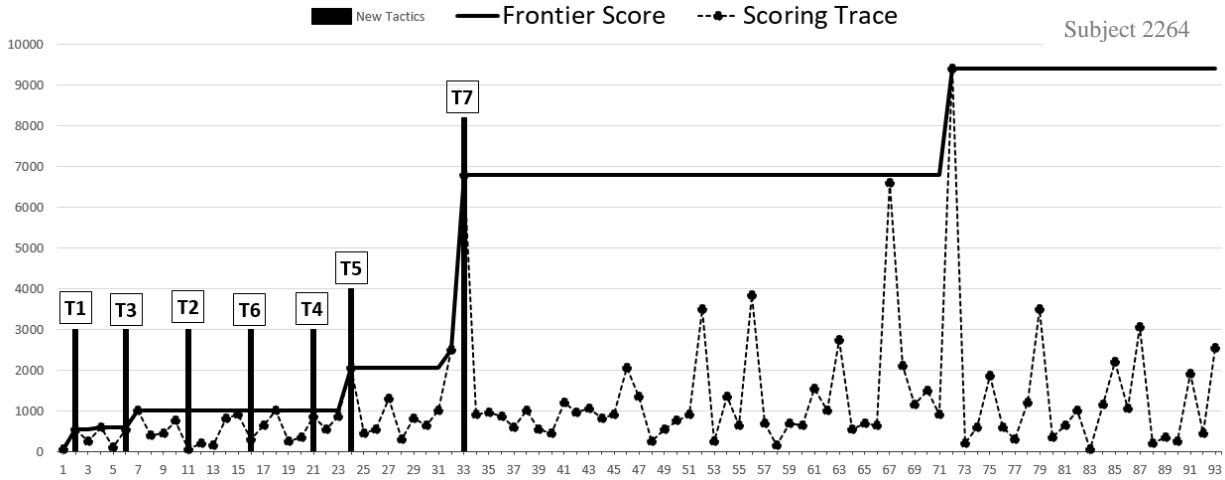
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2262



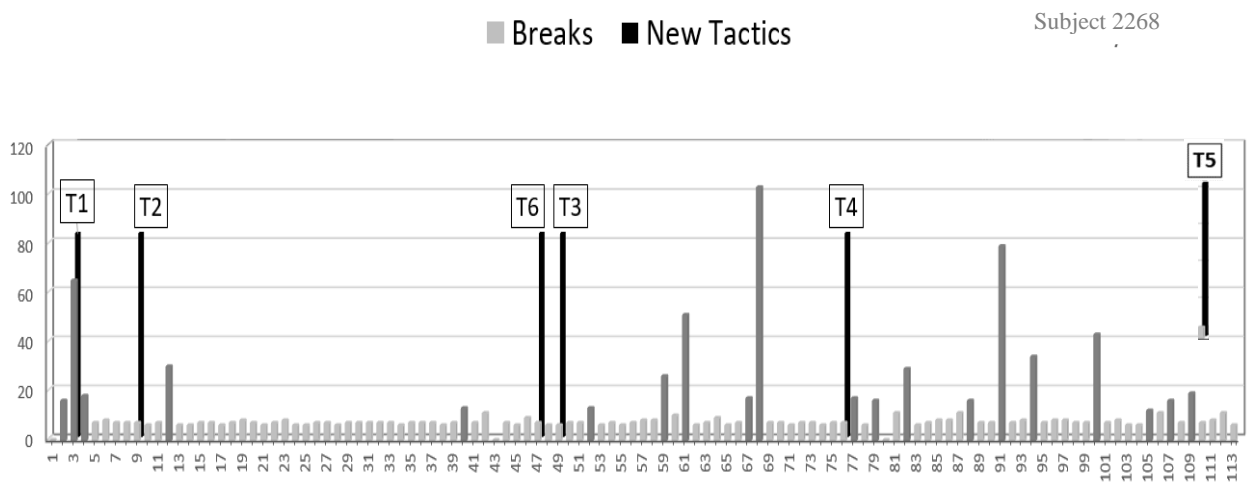
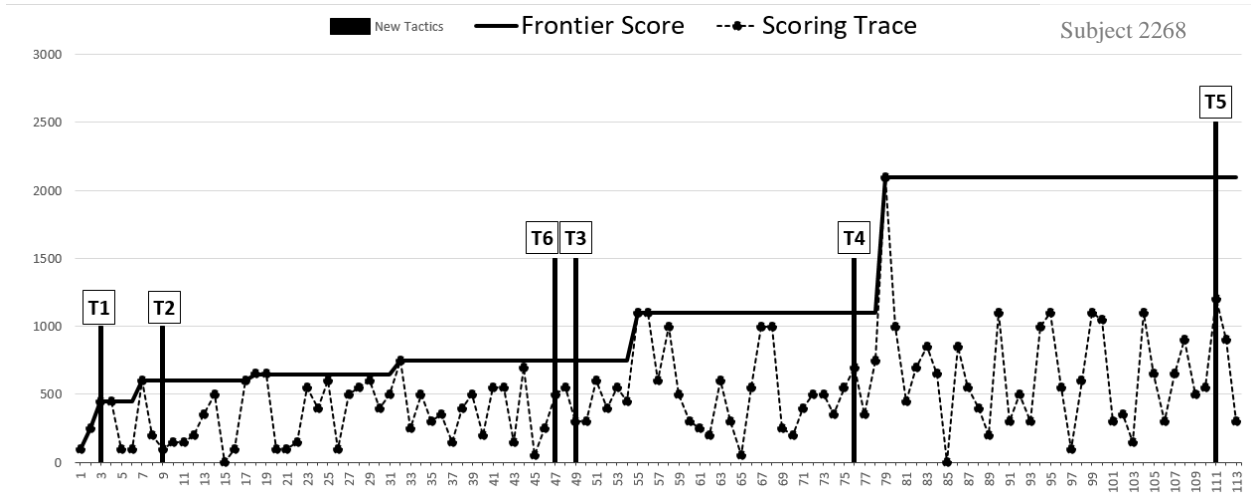
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 2264



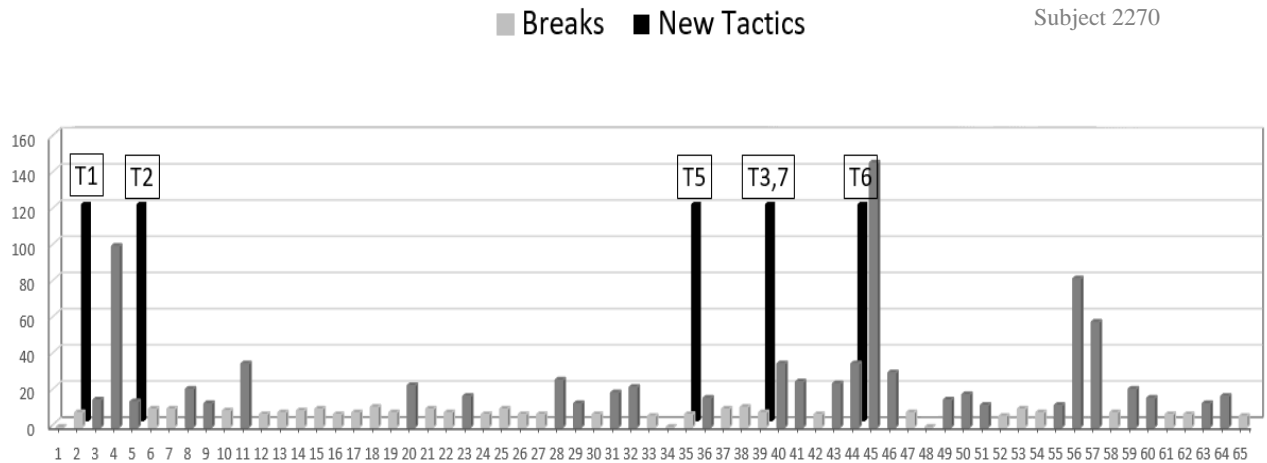
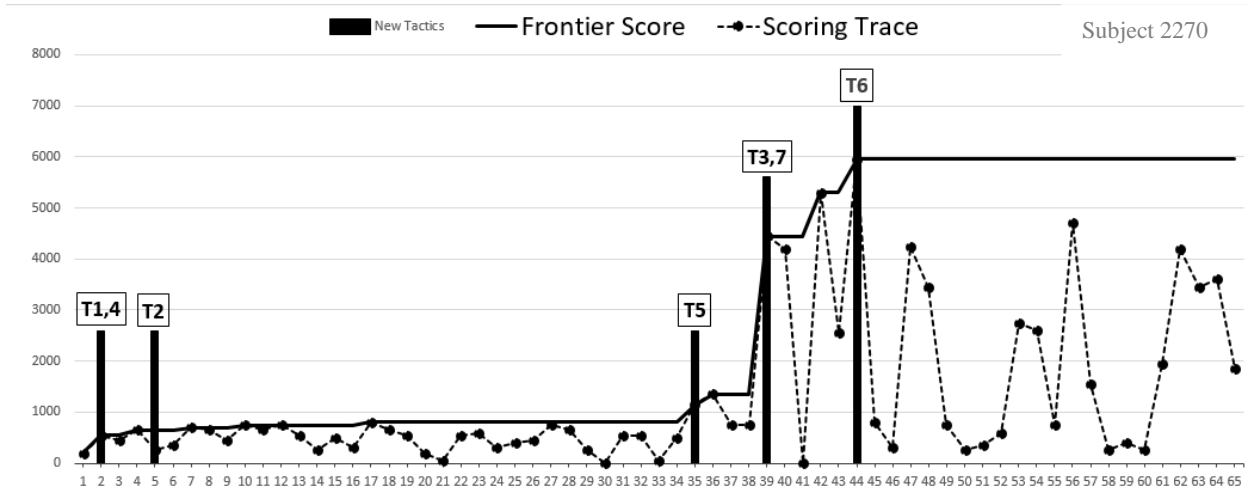
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b - Subject Number 2268



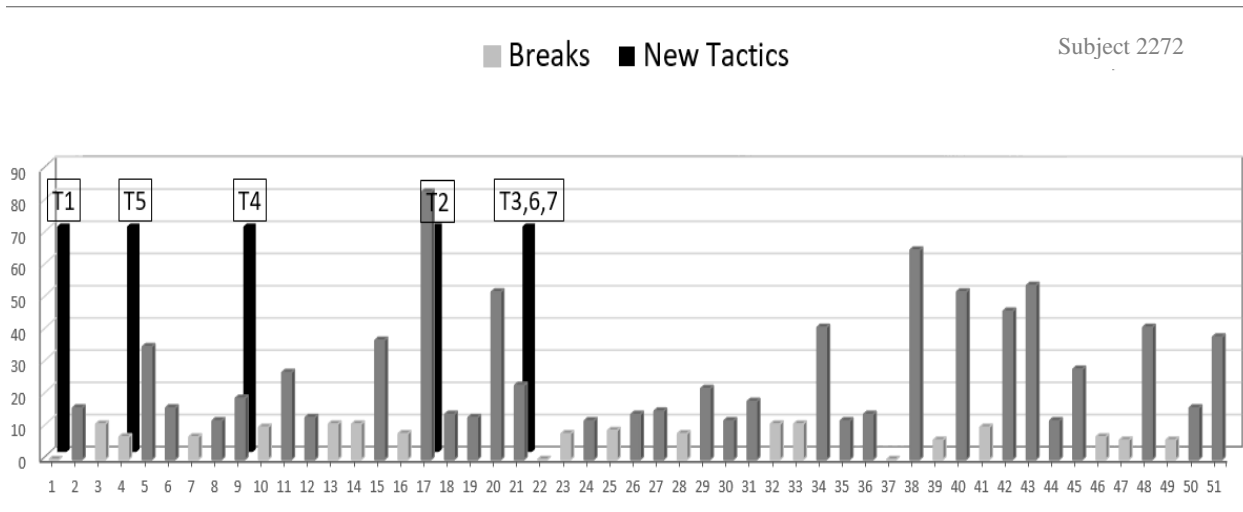
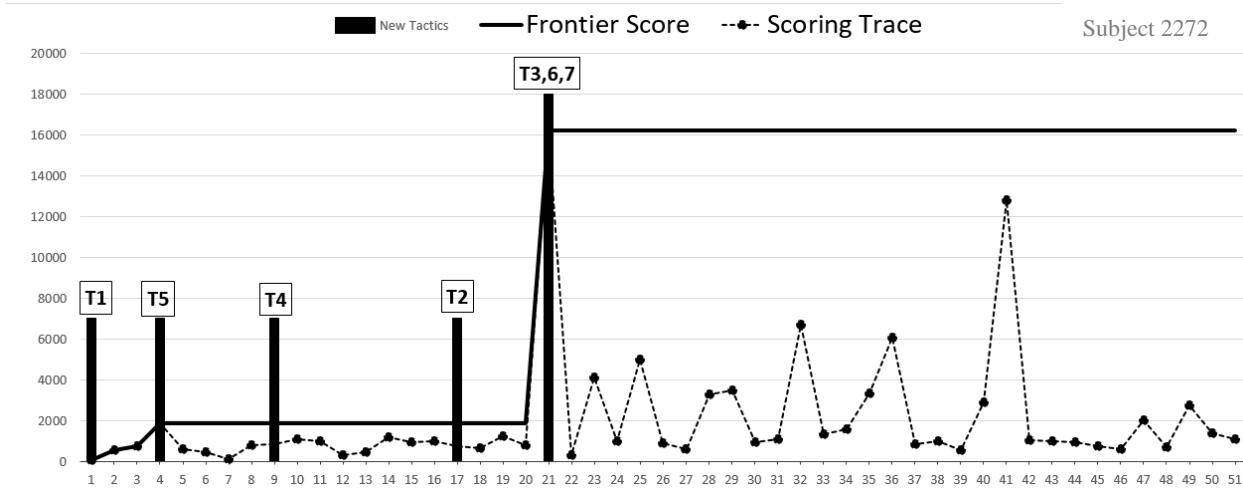
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2270



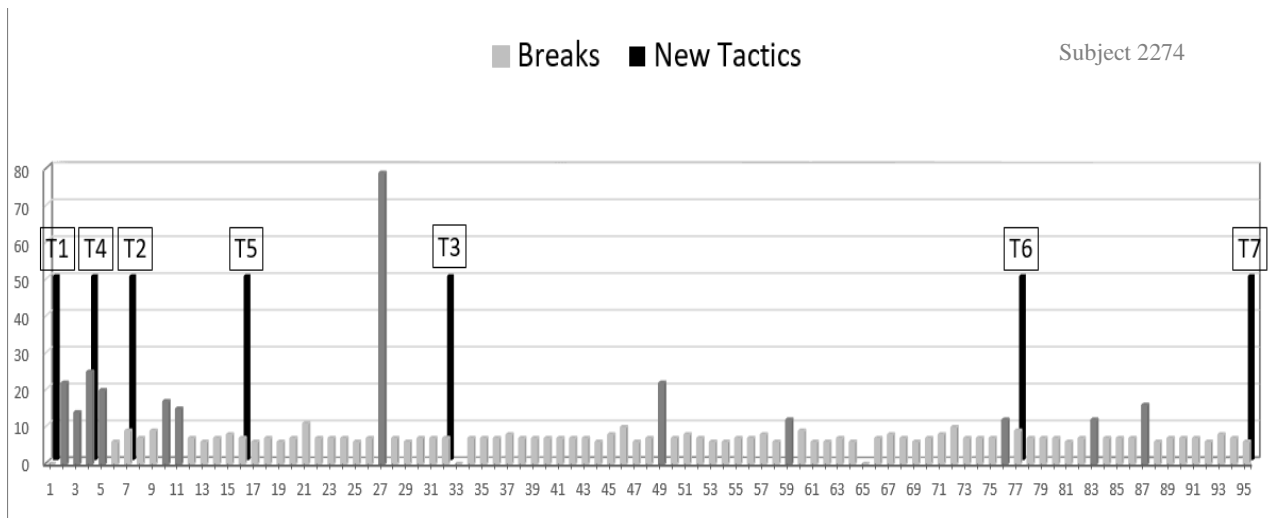
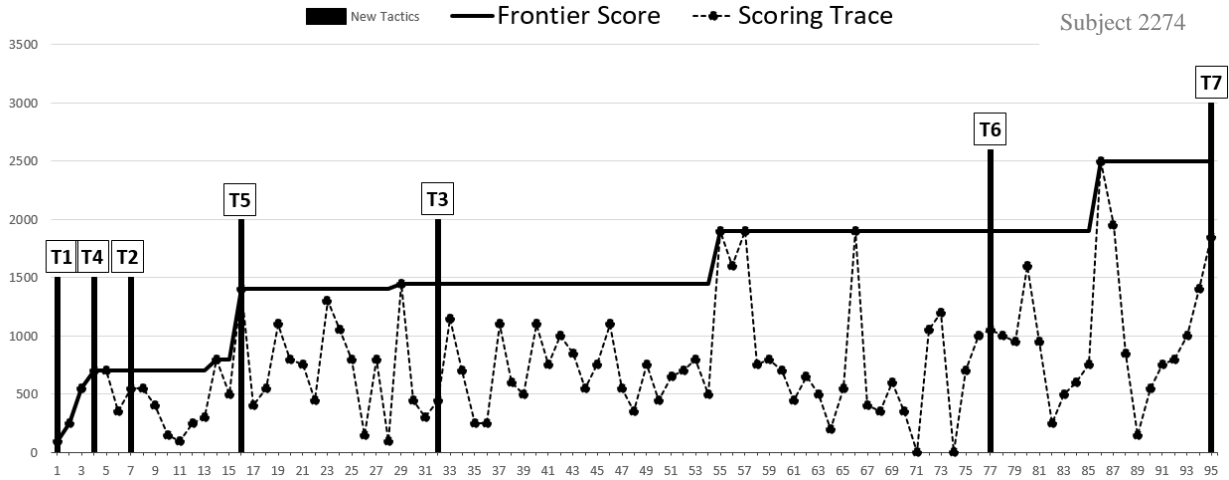
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2272



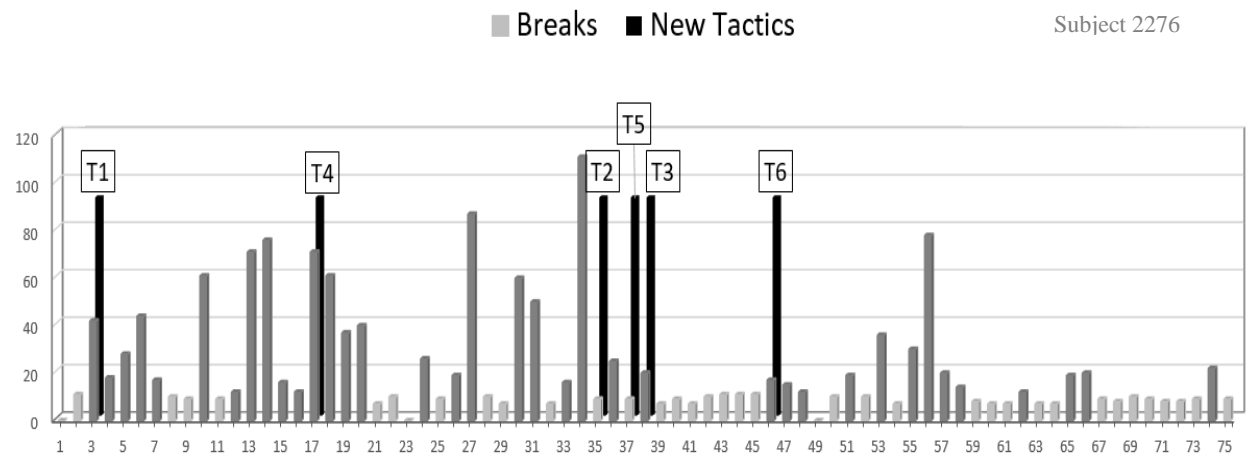
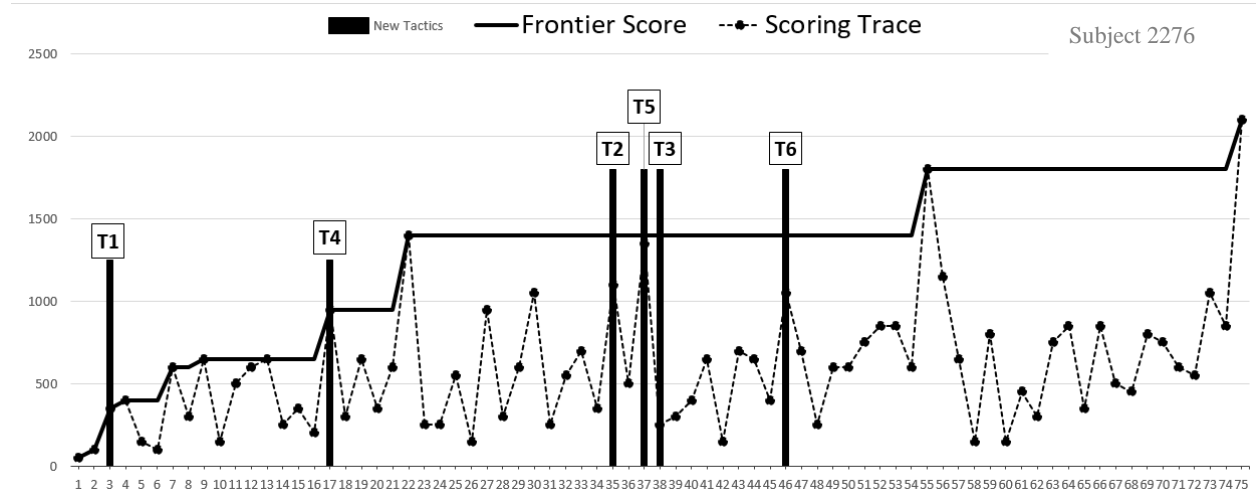
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2274



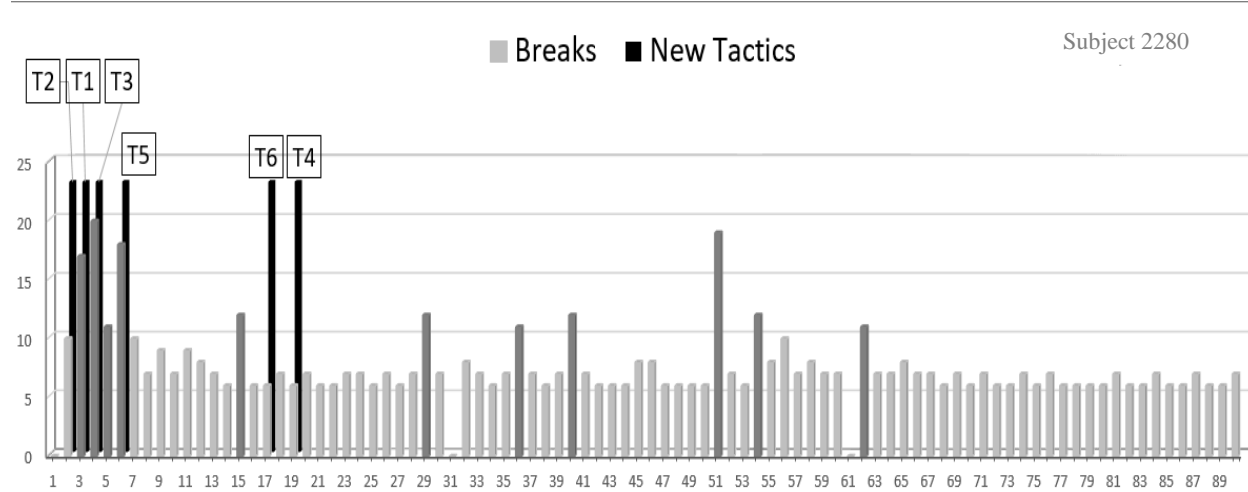
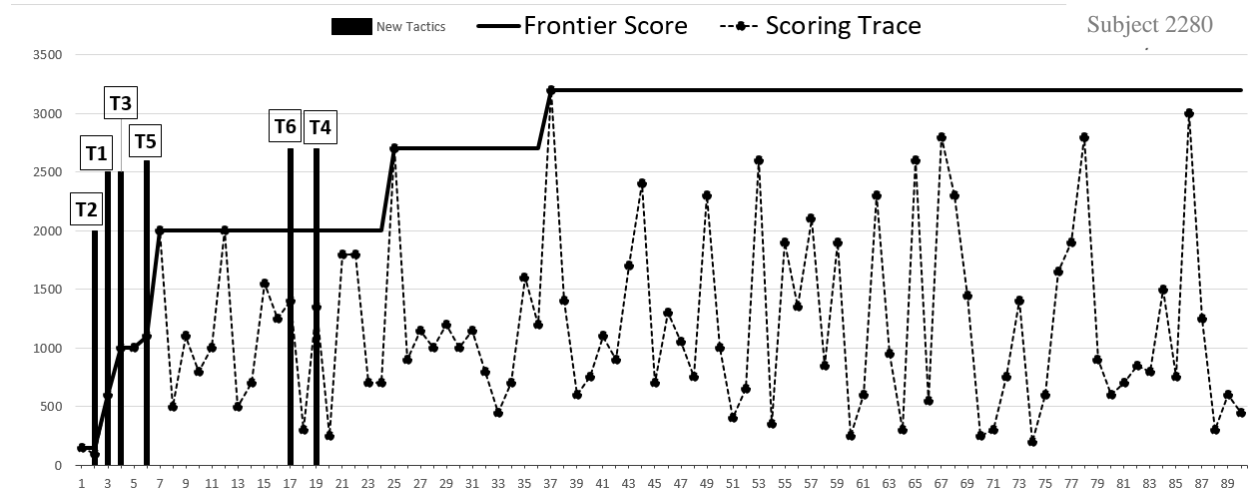
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2276



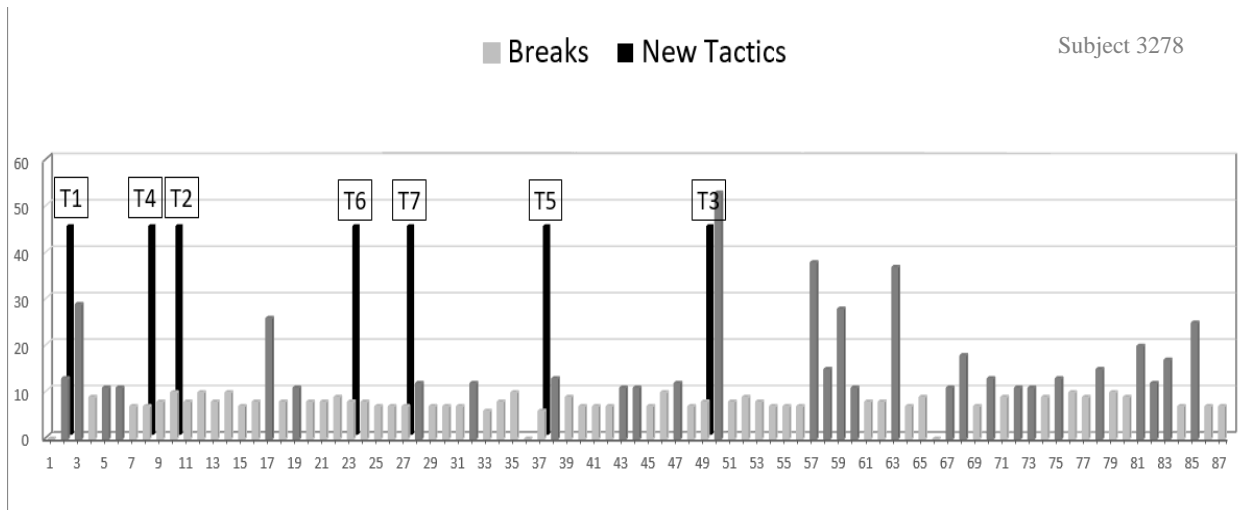
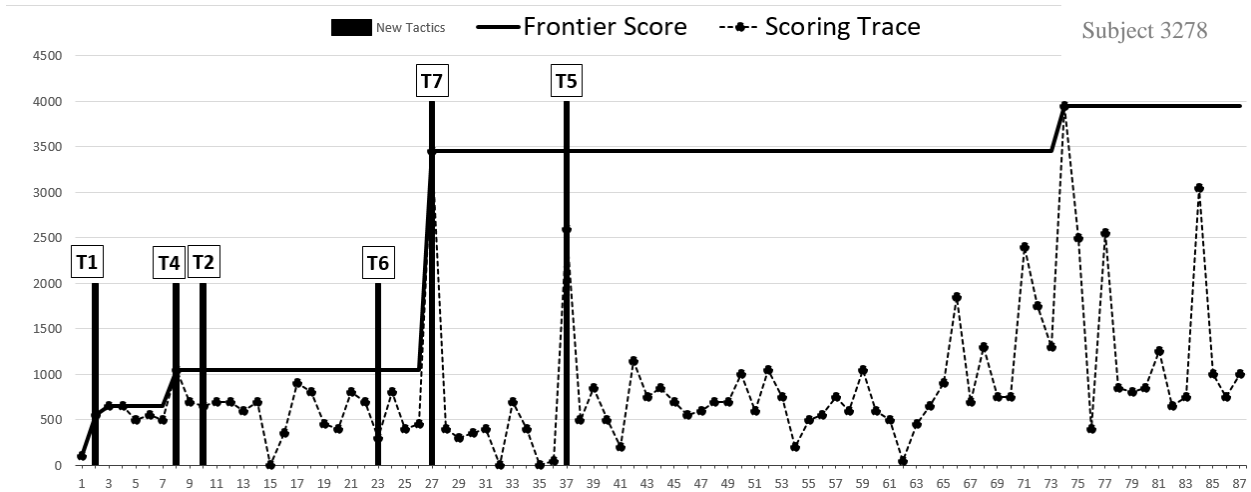
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2280



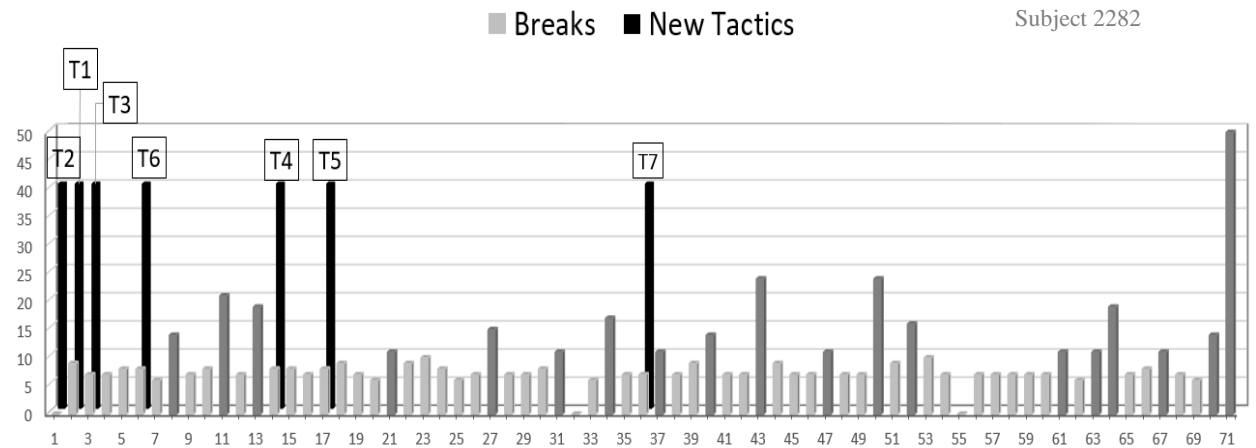
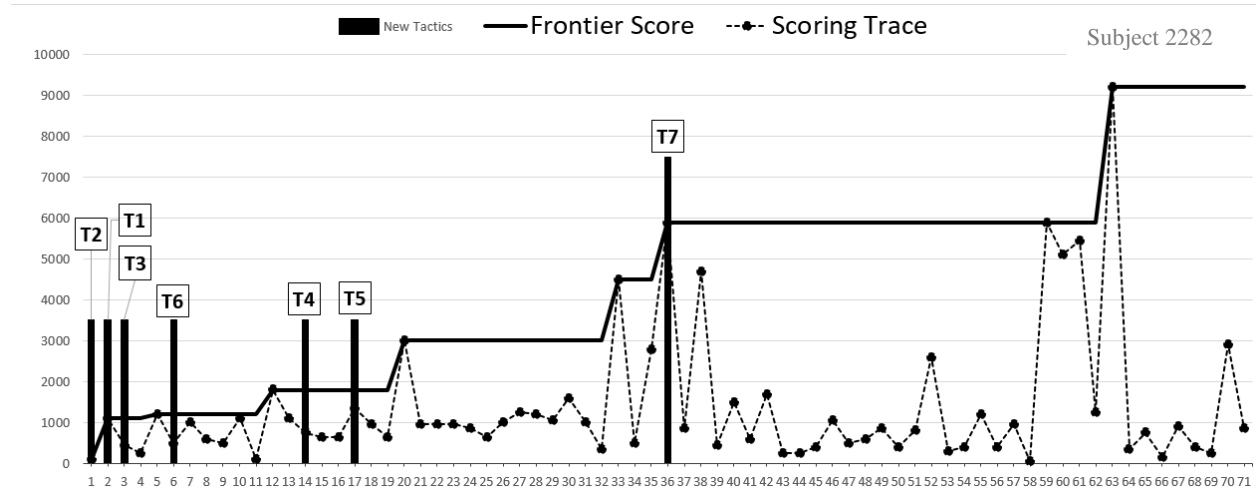
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 3278



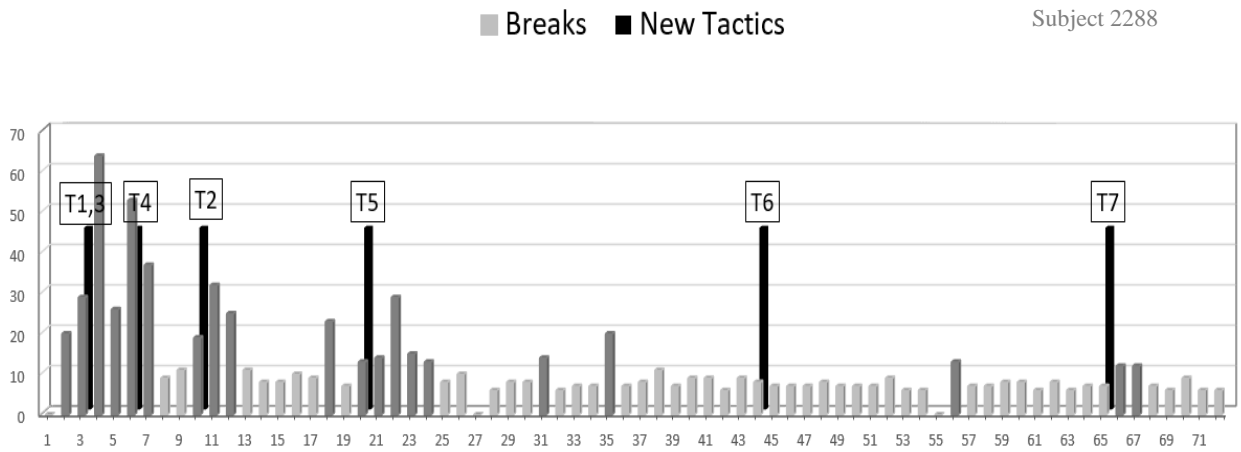
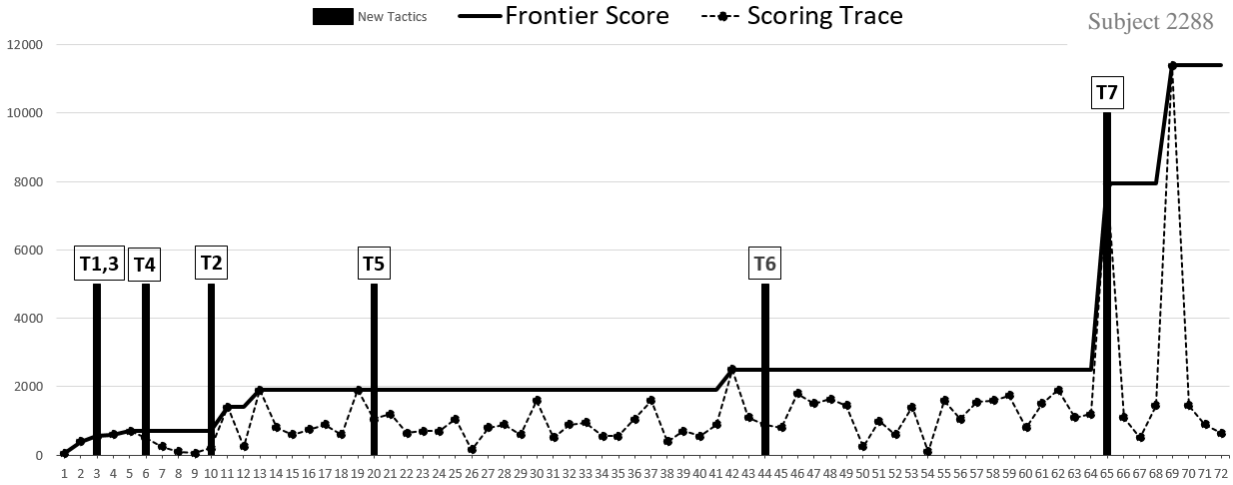
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2282



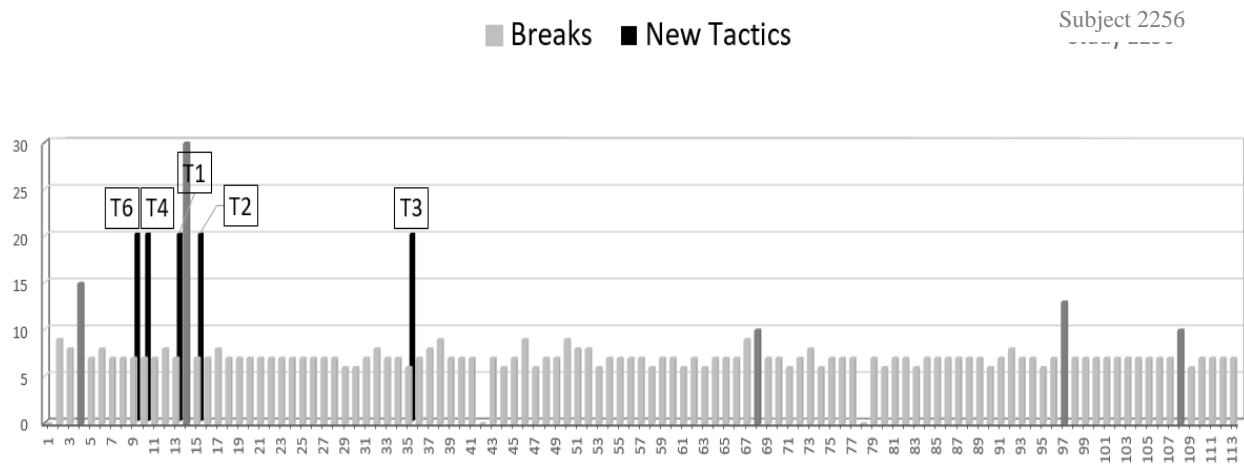
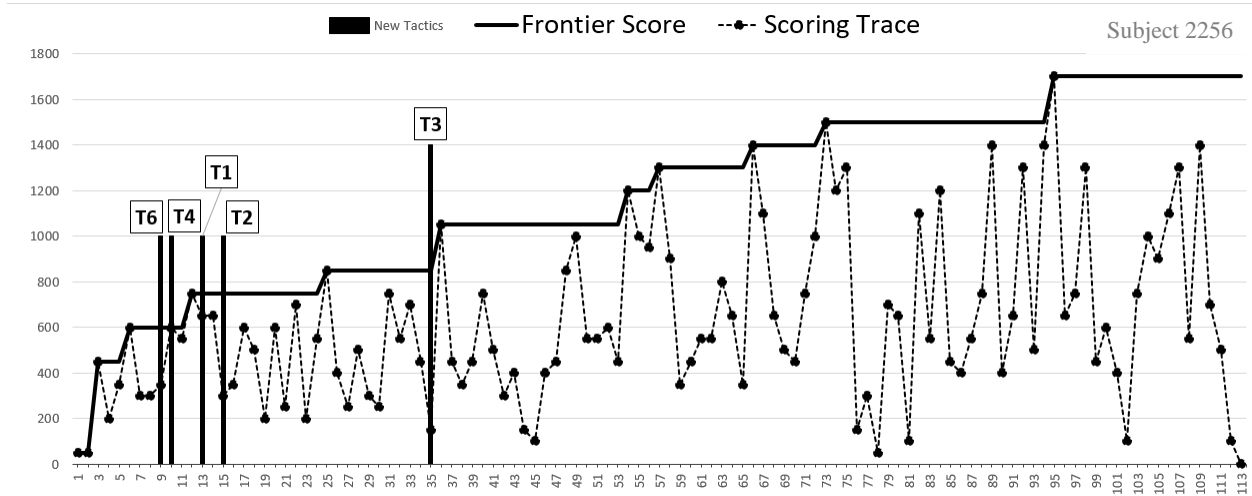
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2288



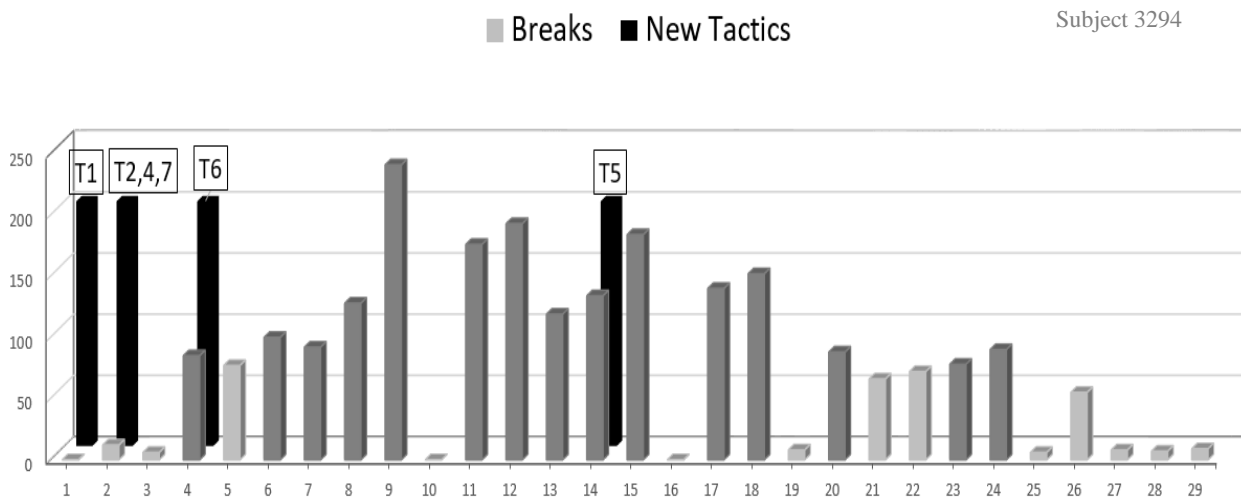
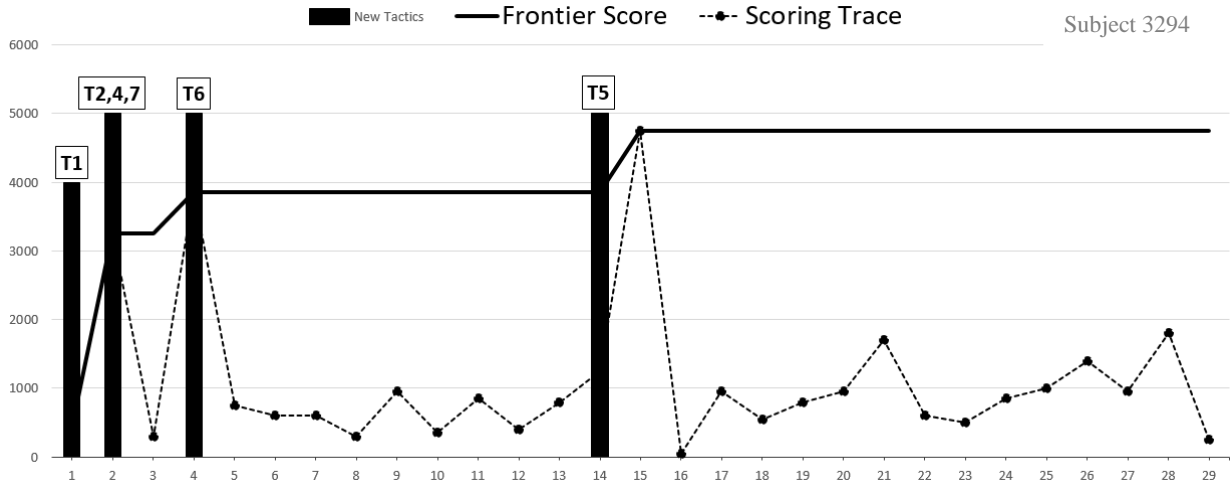
Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 2256



Appendix R: Study 2b (n=102) - Scoring and Tactical Development Traces with Break Histograms

Study 2b – Subject Number 3294



Appendix S

Study 2b (n=102): Standardized Regression Analysis Substituting # Substantive Breaks - DV is Frontier Score

Model / Variables	Mean	SD	Correlation	M1	M2	M3	M4	M5	M6	M7	M8	Ru
DV - Frontier Score (Fs)	5,518.63	4,840.83										
Hypothesized Variables:												
Cognitive Ability	27.20	4.63	.31	.30	.46		.29			.28	.29	.05
# of Substantive Breaks	13.12	9.39	-.16	-.14	.53		-.13			-.12	-.08	.01
Ability X # Substantive Breaks			-.10		-.69						-.04	
Psychological Factors												
Extraversion	3.56	.92	-.21			-.27	-.29		-.26	-.28	-.28	.06
Agreeableness	4.09	.69	.05			.12	.14		.14	.16	.16	.02
Conscientiousness	3.58	.83	.01			-.04	.07		-.01	.08	.09	.00
Neuroticism	2.75	.83	-.29			-.32	-.25		-.24	-.19	-.19	.02
Imagination	3.72	.71	.06			.09	.07		.06	.05	.04	.00
Control Variables												
Gender, 0-M, 1-F	.47	.50	-.26					-.10	-.10	-.09	-.09	.00
Age	20.30	1.74	.03					.03	-.03	-.02	-.02	.00
Videogame Experience	3.26	1.79	.29					.21	.11	.07	.07	.00
Model Summary												
R				.34	.36	.40	.51	.30	.44	.52	.52	
R Squared				.11	.13	.16	.26	.09	.19	.27	.27	

Note. # of Substantive Breaks substituted for Incremental Breaks. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a a subjects trial. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. One outlier with excessive frontier score is retained in the data set (36,900 points; > 3.0 standard deviations from the mean). Ru is calculated using Model 7 combined R value minus Model 7 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M1 thru M8 are regression model numbers.

Appendix T

Study 2b (n=102): Standardized Regression Analysis Substituting Average Break Time - DV is Frontier Score

Model / Variables	Mean	SD	Correlation	M1	M2	M3	M4	M5	M6	M7	M8	Ru
DV - Frontier Score (Fs)	5,518.63	4,840.83										
Hypothesized Variables:												
Cognitive Ability	27.20	4.63	.31	.30	.54		.30			.28	.29	.07
Average Break Time	10.95	4.91	-.08	-.08	.57		-.02			-.03	-.02	.00
Ability X Average Break Time			.01		-.69						-.01	
Psychological Factors												
Extraversion	3.56	.92	-.21			-.27	-.29		-.26	-.27	-.27	.06
Agreeableness	4.09	.69	.05			.12	.14		.14	.16	.16	.02
Conscientiousness	3.58	.83	.01			-.04	.06		-.01	.08	.08	.00
Neuroticism	2.75	.83	-.29			-.32	-.25		-.24	-.19	-.19	.03
Imagination	3.72	.71	.06			.09	.09		.06	.06	.06	.00
Control Variables												
Gender, 0-M, 1-F	.47	.50	-.26					-.10	-.10	-.11	-.11	.00
Age	20.30	1.74	.03					.03	-.03	-.02	-.02	.00
Videogame Experience	3.26	1.79	.29					.21	.11	.07	.07	.00
Model Summary												
R				.32	.33	.40	.49	.30	.44	.51	.51	
R Squared				.10	.11	.16	.24	.09	.19	.26	.26	

Note. Average Break Time substituted for Incremental Break Time. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a a subjects trial. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. One outlier with excessive frontier score is retained in the data set (36,900 points; > 3.0 standard deviations from the mean). Ru is calculated using Model 7 combined R value minus Model 7 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M1 thru M8 are regression model numbers.

Appendix U

Study 2b (n=102): Standardized Regression Analysis, Technique and Tactical Learning Time - DV is Frontier Score

Model / Variables	Study 2b N	Study 2b Mean	Study 2b SD	Correlation with Frontier Score	M14	M15	M16	Ru
Technique and Tactic Learning								
Speed - Technique 1 (seconds)	100	89.11	216.29	-.18	-.11		-.06	.00
Erase - Technique 2 (seconds)	99	522.75	536.87	-.18	-.04		.05	.00
Discard - Technique 3 (seconds)	94	1,012.46	826.90	-.22	-.19		-.17	.01
Loop - Technique 4 (seconds)	99	739.29	606.31	-.33	-.30		-.24	.04
Extend - Tactic 5 (seconds)	92	1,103.62	819.97	-.39		-.31	-.24	.04
Ahead - Tactic 6 (seconds)	96	1,141.23	974.97	-.23		-.10	.00	.00
Close Loop - Tactic 7 (seconds)	50	1,748.16	891.6	-.37		-.28	-.30	.06
Model Summary								
		R			.41	.50	.56	
		R Squared			.17	.25	.32	

Note. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. Ru is calculated using Model 16 combined R value minus Model 16 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M14 thru M16 are regression model numbers.

Appendix V

Study 2b (n=102): Standardized Regression Analyses with Tactics 1 - 7 as Dependent Variables

				M17	M18	M19	M20	M21	M22	M23
				Speed (T1)	Erase (T2)	Discard (T3)	Loop (T4)	Extend (T5)	Ahead (T6)	Close Loop (T7)
n				100	99	94	99	92	96	50
Mean				3.85	15.88	29.33	22.35	32.76	32.05	46.86
SD				6.59	15.09	23.05	17.19	24.31	26.17	23.56
Hypothesized Variables:										
	n	Mean	SD							
Cognitive Ability	102	27.2	4.63	-.04	-.16	-.24	-.14	-.13	-.27	-.15
Incremental Break Time	102	388.06	313.18	.04	.09	.00	.11	.07	.12	-.19
Other Factors										
Extraversion	102	3.56	0.92	-.06	.00	.10	-.07	.04	-.03	-.11
Agreeableness	102	4.09	0.69	.13	.09	-.03	.08	-.05	.03	.15
Conscientiousness	102	3.58	0.83	.10	-.15	.00	-.23	-.01	-.07	.03
Neuroticism	102	2.75	0.83	.09	-.18	-.13	-.10	.04	-.25	.17
Imagination	102	3.72	0.71	.04	.11	.09	.02	.00	.07	-.21
Gender	102	0.47	0.5	.00	.18	-.03	.20	-.02	-.07	.12
Age	102	20.3	1.74	.06	-.07	-.02	.05	-.13	-.17	-.28
Video Experience	102	3.26	1.79	-.08	-.02	-.19	.07	-.06	-.36	-.03
Model Summary										
	R			.25	.31	.34	.30	.23	.47	.50
	R Squared			.06	.10	.12	.09	.05	.22	.25

Note. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. M17 thru M23 are regression model numbers.

Appendix W

Study 2b (n=102): Standardized Regression Analyses with Close Loop (T7) as Dependent Variable

Model / Variables				M24	M25	M26	M27	Ru
	N	Mean	SD					
Technique and Tactic Learning								
Speed - Technique 1 (# trips)	46	2.52	1.71	.15			.19	.02
Erase - Technique 2 (# trips)	46	11.35	8.12	.18			.19	.02
Discard - Technique 3 (# trips)	46	28.3	23.82	-.30			-.19	.00
Loop - Technique 4 (# trips)	46	15	10.95	.29			.30	.05
Extend - Tactic 5 (# trips)	46	26	16.9	.13			-.07	.00
Ahead - Tactic 6 (# trips)	46	26.59	19.63	.48			.36	.04
Hypothesized Variables:								
Cognitive Ability	50	28.12	4.31		-.21		-.22	.02
Incremental Break Time (IBT)	50	343.16	287.42		-.19		-.34	.06
Other Factors								
Extraversion	50	3.41	.95			-.12	-.16	.01
Agreeableness	50	4.04	.80			.25	.24	.02
Conscientiousness	50	3.55	.90			.09	.03	.00
Neuroticism	50	2.62	.91			.28	.20	.02
Imagination	50	3.69	.75			-.25	-.26	.02
Gender	50	.38	.49			.13	.20	.01
Age	50	20.26	1.03			-.27	-.28	.03
Video Experience	50	3.65	1.82			-.07	.12	.01
Model Summary								
		R		.53	.26	.50	.75	
		R Squared		.28	.07	.25	.56	

Note. Four outliers with excessive break time (mean 2191.5 seconds over 3,600 second trial, with range of 2,109 to 2,326 seconds) were removed from the data set. Ru is calculated using Model 27 combined R value minus Model 27 R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M24 thru M27 are regression model numbers.

Appendix X

Study 2a (n=92): Standardized Regression Analysis; Technique and Tactical Learning, Hypothesized and Other Variables - DV Frontier Score

Model / Variables	Study 2a N	Study 2a Mean	Study 2a SD	Correlation with Frontier Score	M9a	M10a	M11a	M12a	M13a	M14a	Ru
Technique and Tactic Learning											
Speed - Technique 1 (# trips)	91	6.26	10.75	-.01	.09		.20			.20	.02
Erase - Technique 2 (# trips)	86	19.08	20.78	-.23	-.22		-.26			-.25	.03
Discard - Technique 3 (# trips)	88	26.16	22.45	-.20	-.22		-.08			-.05	.00
Loop - Technique 4 (# trips)	90	27.32	26.08	-.19	-.17		.13			.07	.00
Extend - Tactic 5 (# trips)	82	32.8	25.95	-.38		-.32	-.35			-.24	.02
Ahead - Tactic 6 (# trips)	87	26.33	22.66	-.19		-.13	-.17			-.09	.00
Close Loop - Tactic 7 (# trips)	38	56.66	26.79	-.24		-.11	-.20			-.26	.03
Hypothesized Variables:											
Cognitive Ability	92	26.99	4.22	.21				.21		.05	.00
Incremental Break Time (IBT)	-	-	-					-		-	
Other Factors											
Extraversion	92	3.39	.85	.02					.04	-.05	.00
Agreeableness	92	4.07	.67	-.08					.06	.17	.01
Conscientiousness	92	3.78	.77	-.17					-.05	-.08	.00
Neuroticism	92	2.64	.83	-.06					-.05	.03	.00
Imagination	92	3.77	.68	.12					.00	.01	.00
Gender	92	0.55	0.5	-.24					.07	.12	.00
Age	92	20.43	3.2	-.04					-.05	.05	.00
Video Experience	92	3.16	1.77	.42					.47	.36	.05
Model Summary											
R					.35	.42	.51	.21	.44	.59	
R Squared					.12	.17	.26	.05	.19	.35	

Note. Study 2a is limited to subjects without the ability to elect Incremental Break Time. Ru is calculated using Model 14a combined R value minus Model 14a R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M9a thru M14a are regression model numbers.

Appendix Y

Study 2a (n=92): Standardized Regression Analysis with Frontier Score (DV)

Model / Variables	Mean	SD	Correlation with Frontier Score	M1a	M3a	M5a	M6a	M7a	Ru
Hypothesized Variables:									
Cognitive Ability	26.99	4.22	.21	.21				.16	.02
<i>Incremental Break Time (NA)</i>									
Psychological Factors									
Extraversion	3.39	.85	.02		.06		.04	.05	.00
Agreeableness	4.07	.67	-.08		-.09		.06	.06	.00
Conscientiousness	3.78	.68	-.17		-.14		-.05	-.06	.00
Neuroticism	2.63	.83	-.06		-.07		-.05	-.03	.00
Imagination	3.77	.68	.12		.10		.00	-.00	.00
Control Variables									
Gender	.55	.50	-.24			.06	.07	.11	.00
Age	20.43	3.22	-.04			-.04	-.05	-.04	.00
Videogame Experience	3.16	1.77	.42			.46	.47	.47	.14
Model Summary									
R				.21	.22	.43	.44	.46	
R Squared				.05	.05	.18	.19	.22	

Note. Gender is measured at 0 = male; 1 = female. Frontier score: The highest trip score attained over a subjects trial. Ru is calculated using Model 7a combined R value minus Model 7a R value without the respective factor included in the model. This provides a measure of the unique contribution of the respective factor to the overall R value of the model. M1a thru M7a are regression model numbers.