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Using ecological momentary assessment to understand a construction worker's daily disruptions and decisions

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Abstract

Capturing the momentary decisions and actions made by construction workers in response to workflow disruptions is challenging because, until now, there has not been a minimally-disruptive data collection method that allows workers to identify their decision process "in the moment." However, an Ecological Momentary Assessment (EMA) method – designed to capture momentary work experiences in natural settings – can provide researchers with detailed information about the daily challenges experienced by workers during the course of performing their tasks. An explanation of the method is provided, along with examples of the types of research questions that can be addressed and appropriate analysis techniques. The EMA method is being used on a federally-funded research program in the United States that is investigating how construction workers adapt to workflow disruptions by improvising their decisions and actions. Consequently, this article demonstrates the use of the method by presenting an idiographic study of William, an electrical construction worker. The evaluation of William's disruptions, decisions, and actions elucidated an important relationship: *every one* of William's disruptions required an improvisational action in order to continue working. The EMA method opens the door to the development of new theories about rapid decisions and subsequent actions on construction sites.

Key Words: Construction worker, research methods, decision making, workflow

1. Limitations to our knowledge of construction worker disruptions and decisions

Workflow disruptions create turbulent conditions on construction jobsites, resulting in difficulties in managing and controlling the work (Menches and Hanna 2006, Mitropoulos and Nichita 2010). While new tools and technologies continue to improve companies' abilities to manage large-scale disruptive events (Sacks, Treckmann and Rozenfeld 2009), such as late delivery of equipment or customer indecision, the *daily disruptions* that occur at the worker level have not been well-studied. In fact, on the *vast majority* of construction projects, trade workers experience daily (and sometimes hourly) disruptions that significantly impede the progress of their work, and these disruptions occur for a number of reasons. For example, a masonry crew might begin working in exactly the same location as an electrician thus preventing the electrical worker from completing a scheduled task. A physical obstruction might also impede work, such as materials or debris that is occupying the assigned workspace and that prevents a task from being completed. Or, a task might require two people but only one worker is available, who cannot complete the task alone. Or, a worker might not have the materials or tools needed to complete a scheduled task. Consequently, when a disruption occurs, a worker must take immediate action in order to minimize the impacts on productivity. What happens next – that is, how a worker makes a decision to overcome the task disruption and what specific actions the worker decides to take – is not well known because capturing momentary decisions and actions poses significant research challenges. While observational methods can inform researchers about specific actions taken by workers in response to specific precursor events, a researcher will not be able to determine what a worker was thinking or how a worker made a decision to take a particular action because simple observation cannot capture such cognitive detail. An interview can be used by the researcher to augment observations and to question a worker about an observed action, but two additional problems emerge: (1) if the interview is conducted on-the-spot, the researcher risks becoming the source of disruption, or (2) if the interview is conducted at a later time, a worker may experience recall bias, which occurs when a worker has difficulty recalling accurate information about an earlier disruption (Raphael 1987). As a result, a data collection method that is minimally disruptive to workers but allows workers to identify their decision process "in the moment" is needed to circumvent these research problems. Such a method makes it possible to investigate a vast array of phenomenon experienced by a worker during the course of performing daily work, thus opening the door to the development of new theories about rapid decision making and subsequent actions that influence workflow on construction sites.

One key purpose of this article is to report on a well-established momentary research method that has been used broadly in other fields, especially psychology and mental health, but has never been applied to the field of construction. The method – called the Ecological Momentary Assessment method – is designed specifically to capture momentary work experiences in natural work settings, thus providing researchers with rich, detailed information about the daily challenges experienced by construction workers during the course of performing their tasks. Furthermore, a second key purpose of this article is to demonstrate the use of this novel research method by reporting the results of an idiographic study of William, an electrical construction worker, and how William responds to daily workflow disruptions.

2. Introduction to the Ecological Momentary Assessment (EMA) method

A powerful way to collect data “in the moment” and in a natural setting is by implementing an Ecological Momentary Assessment (EMA) methodology. An EMA approach aims to assess daily work experience by obtaining a representative sample of thoughts, decisions, and actions throughout the day in a participant’s natural work setting (i.e., the jobsite). Workers complete real-time brief momentary assessments of their decisions and actions on a digital device at random times throughout the workday. As a result, the EMA method has significant advantages over standard methods that ask participants to report their thoughts and behaviors retrospectively, where recall bias becomes a significant concern. Hence, given that retrospective reports seriously limit our ability to accurately characterize and understand behavior in actual work settings – and they miss the dynamics of workflow changes experienced minute by minute and hour by hour – an EMA method allows workers to systematically and repeatedly report on their experiences in real-time and in jobsite settings, over time and across contexts (Shiffman, Stone and Hufford 2008).

The use of EMA methods represents a shift from research that treats thoughts and behaviors as stable and unchanging over time to an approach that emphasizes patterns and changes throughout the day and week (Teuchmann, Totterdell and Parker 1999), thus allowing researchers to identify, for example, patterns of disruptions and decisions that impact daily productivity. Disruptions occur frequently on the jobsite and workers’ reactions to these disruptions vary with the event; consequently, an EMA method makes it possible to capture these unplanned-for events and subsequent decisions and actions “in the moment.”

2.1. Brief history of the EMA method

The EMA method has evolved out of an idiographic psychology tradition that emphasized the study of individuals rather than the study of general populations. The modern use of EMA methods (also known as the Experience Sampling Method (ESM)), which involves collecting momentary data using digital devices, began in the 1970s (Csikszentmihalyi 1975) and has been used widely to study positive psychological states (e.g., happiness) as well as clinical psychological conditions (e.g., depression) (Haworth, Jarman and Lee 1997, Myin-Germeys *et al.* 2009, Trull and Ebner-Priemer 2009, Ben-Zeev and Young 2010). In the 1980s, its acceptance as a reliable research method for capturing patient experiences resulted in its widespread use to investigate a growing number of medical conditions, including addiction, eating disorders, self-esteem, and exercise, to name a few (Larson and Csikszentmihalyi 1983, Larson, Csikszentmihalyi and Freeman 1984, Kimiecik and Stein 1992, Oorschot *et al.* 2009).

However, the use of EMA methods for examining behaviors in *work settings* has occurred only very recently. It has been used to study a range of work-related topics, including workaholism (Snir and Zohar 2008), work demand and time pressure (Teuchmann, Totterdell and Parker 1999), job satisfaction (Ilies and Judge 2004), and productivity and mood (Zelenski, Murphy and Jenkins 2008). Shiffman, Stone, and Hufford (2008) have written an excellent detailed account of the extended history of EMA and its predecessors and variations.

The EMA method has never been used to study the decisions and actions of construction workers but, given its well-documented success at capturing actions "in the moment," it shows particular promise at capturing the experience (i.e., reactions, decisions, and actions) of workers who become disrupted throughout the workday.

2.2. Phenomena that can be studied using EMA

The two most common applications of EMA methods include (1) studying the properties of *situations* and (2) studying the properties of *persons* (Larson, Delespaul and Devries 1992). Questions about *situations* address comparisons between different work contexts, such as:

1. Actions of workers when disrupted versus actions when not disrupted
2. Safety behavior of workers when working around other people versus safety behavior when working alone
3. Productivity of workers on projects that have implemented Lean principles versus productivity on traditional (non-Lean) projects
4. Time pressure experienced by workers at the beginning of the project versus time pressure experienced at the end of the project

A specific situational research question might address how the safety behavior of a worker changes when the individual is working with (and is influenced by) other workers rather than when the individual is working alone (and is not influenced by other people). Or, the research question might address how the mood, productivity, and stress level of a worker change as the worker experiences an increase in time pressure. Nearly all situations that can be differentiated by "moments in time" can be investigated using an EMA methodology. It is important to note that situational research questions do not make comparisons between groups of people but instead compare moments in time within individuals.

Questions about *differences in persons*, however, can be addressed by making comparisons between groups of people, particularly groups that differ in specific traits, such as:

1. Role (foreman, journeyman, or apprentice)
2. Gender (male or female)
3. Personality type indicator (extrovert or introvert)
4. History of injuries (has experienced an injury or has not experienced an injury)

A specific between-persons research question might address how the ability to adjust to a task disruption differs between foremen and journeymen. Or, the research question might address how the safety behavior differs between those workers who have experienced a previous injury versus those workers who have never been injured. Hence, between-persons research questions focus on making comparisons between different groups of people.

Because EMA methods allow the researcher to collect multiple data points from a single person and at the same time to collect data from multiple people, both situations and persons can be investigated in a single study, but it is important to clearly define the situational (within-person) research questions and the between-persons research questions prior to designing the study. For example, a single study can investigate the phenomenon of safety behavior by addressing the situational question of how the safety behavior of a worker changes when the workers is with other crew members compared to when the worker is alone. The same study can simultaneously address the between-persons question of how the safety behavior systematically varies between those workers who have experienced a prior injury and those who have not.

2.3. Data Collection Devices

The choice of the method used to collect the data essentially consists of two options: (1) a paper-and-pencil method or (2) a digital method (Hektner, Schmidt and Csikszentmihalyi 2007). Each method has benefits and drawbacks that must be considered during the study design.

The paper-and-pencil method involves using a paper-based booklet with enough surveys contained within each booklet to permit the participant to complete the pre-determined number of surveys each day. At designated times of the day, the participant will receive an alarm on a separate alarming device that signals the participant to stop what they are doing and complete a survey contained in the survey booklet (Hurlburt and Akhter 2006). Consequently, the participant must carry and keep track of the alarm device, the booklet, and the writing instrument. One particularly positive aspect of the paper-and-pencil method is the flexibility in the types of questions that can be asked. Both scaled questions and open-ended questions can be asked in a single survey because the paper format permits the respondent to write more extensively about what they are working on, how they are feeling, who they are with, and how they reacted to a particular phenomenon. Hence, greater specificity is possible when using the paper-and-pencil method. But the biggest drawback to the method is the need to code and transcribe the responses after they have been collected and then convert them to a computerized format for data analysis (Csikszentmihalyi and Larson 1987). Coding the data and entering the data into a computerized database is time consuming and can introduce errors into the process, and while the data collection instruments are relatively inexpensive (paper booklets, a pen, and an alarm), the cost to hire an individual to code and enter the data can be expensive.

An alternative to the paper-and-pencil method is the digital method in which participants enter their responses directly into a digital device (Stone, Kessler and Haythornthwaite 1991). The device – typically a personal digital assistant (PDA) or smart phone – is pre-programmed with the survey questions (Le, Hat and Beal 2006). Then, at specified times of the day, the device emits an audible and vibratory alarm to remind the participant to stop what they are doing and complete a digital survey. The responses are stored directly on the device and are downloaded into a computer database at the end of the data collection period, thus eliminating the need to code and transcribe the data. Hence, using a single self-contained device to send the alarm, record participants' responses, and store the data is perhaps the biggest benefit of using a digital "diary" rather than using a paper-and-pencil diary. However, the biggest drawback is the loss in specificity of the responses because respondents must typically select from a fixed number of pre-determined answers that have been coded into the device (Conner *et al.* 2009). Because the answers are entered directly into the digital device, the most efficient way to ask questions is using a scaling system, where respondents supply scaled answers, such as yes/no, low/high, rankings, or categorical responses. Some devices may permit the entry of open-ended answers, but the amount of time required to type a lengthy response on a small keypad limits the utility of this technique. In fact, the difficulty in using the digital device to record open-ended responses has been a major reason why some researchers continue to use the paper-and-pencil method (Hektner, Schmidt and Csikszentmihalyi 2007).

2.4. Signaling Protocols

A hallmark of any EMA method is the use of alarms to signal participants at various times throughout the day to stop what they are doing and fill out a brief momentary assessment form. Such a methodology permits the nearly instantaneous recording of participants' location, activities, thoughts, and moods. This momentary assessment increases the possibility of capturing the phenomenon of interest, such as a deviation from the planned course of work, as well as the worker's step-by-step cognitive and behavioral response to the phenomenon. The likelihood of identifying decisions and actions made in such an environment (such as when deviating from the planned task) is significantly greater than if taking retrospective reports at a later time in which recall bias is more likely to interfere with the participant's ability to accurately remember the sequence of decisions and actions.

Hence, a fundamental consideration when designing the signaling protocol is whether the phenomenon-of-interest occurs as a discrete episodic event (such as a near-miss safety incident) or whether it occurs continuously (such as mood or concentration) (Stone *et al.* 2007). Discrete episodic phenomena can be captured using an event-based signaling method, in which the participant is asked to respond to a survey each time a pre-defined event occurs (e.g., they experience a near-miss safety incident). Hence, the event itself becomes the cue or signal for recording their reactions on the survey (Stone *et al.* 2007). For example, a participant may be asked to respond to a survey each time they encounter an obstruction that disrupts their flow of work. Thus, the worker can respond to questions about their location, the nature of the obstruction, how long their work was interrupted, and how the obstruction was dealt with (i.e., moved it, worked around it, eliminated it, etc.).

Alternatively, a phenomenon-of-interest that is continuous (or nearly so, such as mood or concentration) has no natural trigger, thus requiring the researcher to capture random moments of the incident throughout the day. A signal or alarm can be sent to a participant at regularly scheduled intervals (called interval-contingent signaling), such as every two hours, or at random intervals (called random signaling) to capture instances of the phenomenon "in the moment." For example, if a researcher is interested in investigating how a worker's perception of time-pressure changes throughout the work day, the worker can be signaled four times per day with the signal occurring (1) every two hours at exactly the same time each day (interval-contingent signaling), or (2) at random moments within four two-hour blocks of time each day (random signaling).

Hybrid signaling techniques are also possible, where event-based responses are combined with interval or random signals to capture the phenomenon-of-interest. Likewise, daily diaries (where surveys are completed at the beginning of the day, at the end of the day, or both) can be combined with momentary assessments to intentionally capture prospective or retrospective accounts that can augment momentary assessments of specific phenomenon. Stone et al. (2007) provide an excellent detailed discussion of the different signaling techniques, including when and how they can be applied to various research questions.

2.5. Survey questions

The EMA method is an especially powerful way to collect data on phenomena that cannot be directly observed (e.g., perceptions, pain, hallucinations) or phenomena that fluctuate over time (e.g., mood, attitude). To collect data on such phenomena, the questions selected for inclusion in the survey should be grounded in a set of research objectives constructed from a strong underlying theory about the phenomenon-of-interest. While many excellent resources are available to guide the survey development process, Schwarz (2007) has provided an insightful discussion of survey design, appropriate (and inappropriate) questions, and biases inherent in surveys within the context of the EMA method.

EMA methods are often designed to capture both external and internal dimensions of experience (Hektner, Schmidt and Csikszentmihalyi 2007), where external dimensions include date and time signaled, physical location at the moment signaled, physical activities at that moment, and other persons the participant is with. These questions form the *context* for the particular phenomenon-of-interest and could technically be observed by the researcher or a third party. The internal dimensions of experience, on the other hand, are measured by questions about the participant's thoughts, feelings, perceptions, and decisions as the participant performs various work activities and/or interacts with other people (Nielsen and Cleal 2010). These internal dimensions cannot be observed by a researcher, per se, and as a result, the researcher relies on the participant to accurately perform a self-assessment and report the results of their assessment on the EMA survey. For example, if an electrical worker is angry about a stack of bricks that is located exactly where the worker needs to work, thus causing a delay in completing the planned electrical task, a researcher could observe the electrician moving the bricks out of the way but might not be able to document that the electrician is angry and "feeling rushed" because their task has been delayed. This is exactly the key benefit of the EMA method – the electrician can document on the EMA survey that their work was disrupted by a misplaced pile of bricks and that they had to spend time relocating the bricks so that the planned electrical task could be completed; and, the electrician can report that they were feeling angry and rushed because of the delay in their work and that the incident caused an increase in their stress level. All of these internal thoughts can be documented by the worker almost exactly at the moment they were experienced.

While the external dimensions of experience (i.e., context) are typically measured by the four standard questions identified previously (date/time, location, activities, and companions), the internal dimensions of experience are highly flexible, with the number and content of the items on the survey varying widely from study to study depending on the subject-matter of the study and the particular research questions being addressed. For example, Teuchmann, Totterdell, and Parker (1999) investigated the impact of sustained periods of intense time pressure on reported stress levels of members of an accounting team by asking questions about time pressure, perceived control, negative mood, and emotional exhaustion. Similarly, Zelenski, Murphy, and Jenkins (2008) investigated the theory that positive emotions are strongly related to worker productivity by asking questions about various facets of "happiness," job satisfaction, and productivity. In contrast, Delespaul, Devries, and Van Os (2002) investigated the frequency of hallucinations experienced by patients diagnosed with a psychotic disorder by asking questions about the number and intensity of hallucinations, the type (visual or auditory), their mood state, and their activities. Consequently, the EMA method can be adapted to nearly any research study that investigates the internal thoughts, emotions, and subjective experiences of individuals over time.

2.6. Data analysis methods

Perhaps one of the biggest benefits of the EMA method is its ability to be adapted to a variety of sample sets and a variety of sample sizes. The method has been used on a data set that consisted of as few as seven participants (Teuchmann, Totterdell and Parker 1999) and as many as 199 (Ben-Zeev, Ellington, Swendsen and Granholm 2011). Furthermore, the use of an EMA method facilitates both qualitative and quantitative analysis. As a qualitative research tool, the EMA method informs us – in the participant's own words – what they are doing, thinking, and feeling (Hektner, Schmidt and Csikszentmihalyi 2007), which can be transcribed, word-for-word, by the researchers to derive a deep understanding of the participant's experiences. Furthermore, the volume of numeric data produced by using an EMA method creates an avenue for conducting both simple and complex statistical analyses on nearly all aspects of the participant's reported experiences as measured by multiple items over multiple points in time and across multiple contexts (Hektner, Schmidt and Csikszentmihalyi 2007). Typically, the within-person analysis occurs at the response level; that is, the sample to be analyzed consists of a collection of moments in time for each individual. Hence, each entry into a database consists of a row of data that represents a single self-assessment completed by a single participant in response to a single alarm. These within-person responses can be analyzed primarily using qualitative data analysis techniques to understand the experiences of a single participant. In contrast, the between-persons analysis focuses on the larger sample of individuals; that is, the sample to be analyzed consists of data that are aggregated within each participant so that comparisons can be made across persons.

The within-person data can be qualitatively analyzed by developing, for example, (1) graphs depicting the frequencies of categorical variables (such as frequency of activities performed), (2) tables listing mean ratings of a variable along a continuous, ordinal, or nominal scale (such as ratings of how much time pressure a worker feels at various moments in time), and (3) time series plots that link specific instances of a variable to specific moments in the participant's day or week (such as specific activities performed at precise moments in time). While limited within-person *quantitative* analysis may be used by the researcher, such as correlations between within-person variables, it is important to keep in mind that a within-person inferential analysis technically violates the assumption of independence of observations since all observations come from a single participant. This assumption must be met in order to validly infer from a sample to a population; *however, a within-person analysis does not typically attempt such inference*. Furthermore, it should be noted that, although the within-person data are not technically independent because many responses come from a single participant, the data do, in fact, come from different points in time, thus creating a non-standard type of independence of responses (i.e., responses from independent points in time) (Hektner, Schmidt and Csikszentmihalyi 2007).

The between-person analysis can be conducted using a variety of traditional strategies as well as a few complex methods. Traditional analysis methods include those based on ordinary least squares linear models, including t-tests, analysis of variance, or linear regression techniques. However, before these techniques can be used to make comparisons between participants or between groups of participants, the within-person variables must be aggregated. For example, 50 self-reported ratings of "amount of time pressure felt" by an individual across a week should be aggregated into a single mean value of time pressure felt by that individual for the week, and then that mean value of time pressure for that individual can be used in further between-persons comparisons. To overcome many of the aggregation problems associated with traditional techniques, researchers have turned to multilevel modeling (MLM). In MLM, the units of analysis are typically individuals (at a lower level) who are nested within contextual units (at a higher level). Consequently, EMA data have a natural nested structure to it, with a varying number of repeated measures spread unequally over time and nested within persons, making it ideal for use in MLM analysis. MLM can address the nested structure of EMA data by conducting a two-stage analysis that first involves modeling the relationship within each participant's set of data points. Then, MLM can test whether those within-person patterns are the same or different across participants. If differences are found, MLM can test whether other between-persons variables (e.g., role, gender) might account for that variance (Conner *et al.* 2009). Similar to ordinary least squares regression, MLM produces a coefficient that describes the direction and magnitude of the relationship between a predictor and an outcome variable. However, this coefficient describes a within-person relationship (e.g., how changes in a worker's tasks are associated with changes in that worker's feelings of time pressure).

2.7. Limitations to the EMA method

The previous sections identify *how* and *when* to use EMA as well as many of the benefits of using the method, but there are also limitations that must be noted. Perhaps the biggest drawback of using EMA is the reliance on self-reporting. Response rates may vary among participants, with some individuals making a greater effort to respond than others. One potential way to increase response rate is to call the participant at random times during the study to encourage them to respond to the alarms. Another significant drawback is the disruptions that the alarms cause to participants, especially individuals in a work setting. Specifically, a random signaling protocol may not be appropriate for workers that perform tasks under hazardous conditions, such as road construction (on roadways in use) or steel erection. In such instances, the researcher should consider using an end-of-day self-reporting protocol or an interview, which may introduce recall bias but the bias is expected to occur to a lesser degree than conducting interviews at the end of the week. Yet another drawback is the self-selection bias, which occurs when participants are volunteers. A self-selection bias may result in certain types of participants being over-represented (i.e., they are more willing to participate) while others are under-represented (i.e., they are less willing to participate). One way to increase participation by all desired study subjects is to pay the subjects to participate. Typically, gift cards of a modest value are appropriate, where the value of the gift card is large enough to attract volunteers but is not the primary reason the individual agrees to participate.

The digital device data collection tool tends to be more convenient for the participant to use, but it has limitations that may make a different research method more attractive. Typically, digital devices are limited to closed questioning using scaled responses, which limits the quantity (and perhaps quality) of data collected. An EMA method, for example, might not be the most suitable choice during the early stages of theory building, where qualitative data obtained through interviews or open-ended written responses might provide greater insight about a phenomenon thus leading to hypothesis generation. In fact, one of the main benefits of using an EMA technique is the ability to collect quantitative data and to test new theories. Furthermore, an EMA technique results in collecting multiple data points from a single individual, but if multiple data points are not required or desired, then an alternative method should be selected, such as a single survey, observations, an interview, or a combination of other methods.

3. Demonstrating the use of EMA: An idiographic study of a construction worker's daily disruptions and subsequent decisions and actions

The experience of a construction worker is formed by the hour-to-hour tasks that fill their day. In order to understand the flow of activities that fill a worker's day – and *why and how* a worker reacts and adapts following a disruption – it is essential to identify and evaluate their subjective internal experience (i.e., judgments, emotions, and decisions) as well as their planned and improvised activities (i.e., external experience) in response to unexpected task disruptions. Unfortunately, much of the research on construction workers' activities and productivity has been conducted through a restrictive lens that documents the worker's internal and external experiences *retrospectively* (e.g., through retrospective surveys and interviews) but fails to fully capture the complex nature of a construction worker's *momentary* experience – that is, *what* they think, *why* they react, and *how* they feel "in the moment" while they are performing their work. Thus, the methodological difficulties in capturing an individual's momentary experiences limit our ability to fully understand construction workers' daily "work experience" (i.e., how they internally and externally experience their workday).

Yet, as early as the 1930s, researchers called for more novel methods to capture and document the complex nature of human experience (Allport 1937). One technique that emerged as a viable way to study "within-person" phenomena was the *idiographic* technique. An idiographic approach emphasizes personal uniqueness and focuses on examining the relationship between different traits *within a single person* (Pelham 1993), such as the relationship between an individual's daily activities and the individual's specific mood states. This approach has also been referred to as a single-case analysis method. In contrast, the traditional "between-persons" analysis of generalized human traits is referred to as a *nomothetic* approach (Allport 1937) and might, for example, study the relationship between general work activities of construction workers and average mood states of a population of workers. Idiographic methods "aim to identify patterns of behavior, thought, and emotion within an individual over time and contexts, rather than to strictly identify patterns of differences between individuals, as is the case with standard nomothetic approaches" (Conner *et al.* 2009). The EMA method, consequently, permits researchers to address their study topic *both* idiographically *and* nomothetically.

While nomothetic research approaches (i.e., between-persons analyses) have been used extensively in the construction industry to study a broad array of phenomena, the use of idiographic approaches to study changes in traits within a single person *over time* – and *why or how* such changes occurred – has been limited. Yet, there may be times when a researcher would like to identify and understand phenomena that occur over time and across contexts at the individual person-level, such as how a particular type of disruption impacts a worker's decisions and actions across a workweek. Hence, an idiographic approach using the EMA method was selected for the study reported in this article because it effectively demonstrates how to address questions about *how and why* a construction worker reacts and adapts to task disruptions during the workday and workweek. The remainder of this article demonstrates the use of the EMA method – emphasizing its utility as a novel idiographic research approach – for addressing questions about how and why an individual construction worker reacts to task disruptions and how that worker often improvises decisions and actions in order to work productively.

3.1. Sample design and participant selection

The idiographic study presented in this paper was extracted from a large federally-funded research program designed to investigate how workers adapt to daily workflow disruptions by improvising their decisions and actions. Over the course of the study, the researchers anticipate collecting data from 33 electrical foremen, 66 electrical journeymen, and 33 electrical apprentices, thus providing data that captures the experience of three distinct groups of workers, each with some unique and some similar work tasks. For example, the foreman often performs supervisory, administrative, and installation tasks. The journeyman performs primarily installation tasks. And, the apprentice often performs installation, material handling, and cleanup tasks.

Data was collected from electrical construction workers located in the Chicago metropolitan area of the United States. The researchers advertised their study through the local trade association, called the Electrical Contractors' Association of Chicago. In addition, the researchers sent personal e-mails to company executives who have previously participated in research studies. Data collection was expected to last 18 months, and at the time of this article, the data collection effort had been in progress for four months. Two pilot studies were completed prior to launching the full data collection effort in order to test the data collection devices (PDAs), evaluate the survey questions, and incorporate feedback from workers on how to improve the study. Thereafter, data was collected from at least two workers, but not more than four workers, per data collection cycle (i.e., every two weeks). The reason the researchers limited the number of participants per cycle was because the pilot study revealed that collecting data from more than four people at one time did not allow the researchers to conduct exit interviews in an efficient way that limited the disruptions to the workers.

The first phase of the full data collection (Jan-May 2012) began by meeting with company executives to solicit and secure their participation in the research and to select specific weeks that the company would participate in the data collection effort. The companies selected crews, largely at random, to participate in the study based on whether the crew contained at least one journeyman and one apprentice. Data collection was scheduled to occur every two weeks and followed a rigorous two-week cycle that involved: (1) meeting with the foreman and electrical workers on Monday morning of Week 1 before work began to train the workers on the procedures for collecting data during the one-week period, and then launching the data collection effort; (2) responding to any problems or questions throughout the data collection week or replacing defective devices when necessary; (3) retrieving the devices on Friday afternoon after the work week ended; (4) downloading the data over the weekend and removing the data from the devices; (5) reviewing the data as a research team on Monday afternoon of Week 2 and scheduling an exit interview for later in the week; and, (6) conducting exit interviews (typically on Thursday or Friday morning of Week 2) to question workers in greater depth about their experiences and responses to the questions.

3.2. Training the participants

Because the data collection involved the use of digital devices, the researchers had to train the workers on how to use the devices as well as on what to do if the device failed. The training also involved describing the purpose of the study, familiarizing the participants with the questions on the digital device, and answering any questions the workers had about the research.

The training typically occurred on Monday morning of Week 1 just prior to the start of work (around 6:30 AM). Two researchers met with the two workers who would participate, with one researcher explaining the procedures while the other researcher demonstrated the operation of the device. The workers received a package that contained a baseline assessment that they were instructed to fill out at home and a set of training instructions. The training instructions described (1) the purpose of the study, (2) what to expect during the week (i.e., response procedures), (3) how to know if they've been disrupted (i.e., definitions and examples), (4) what they might do in various situations (i.e., scenarios), and (5) the digital survey questions. The researchers explained all of the procedures, provided examples of disruptions, discussed some of the scenarios that might occur during the workers' day, and then asked the workers to complete one trial survey on the digital device. As the workers conducted the trial run, the researchers explained each question and demonstrated how to make their selection from among the multiple choice questions. The workers were given an opportunity to ask questions following the training.

3.3. Protocol for sampling a worker's daily disruptions

Following the training, the workers placed the PDA in a carrying case, attached the carrying case to their belt, and went to work. In order to balance temporal resolution, statistical reliability, and reporting burden, a block design was used in which participants were reminded to complete a self-report momentary assessment form once every 90 minutes at a random moment in time during the 90-minute block, which is customary for EMA research. As a result, the devices were programmed to send five alarms per workday to the workers between the hours of 7:30 AM and 3:00 PM. An alarm was programmed to beep at a random moment within five 90-minute windows (7:30-9, 9-10:30, 10:30-12, 12-1:30, and 1:30-3). The alarm sounded for five minutes to give the workers enough time to complete their task, determine whether it was safe to respond, and then respond to the survey. At the end of each day, the workers returned the devices to the construction office, where they were plugged into an electrical source to be charged overnight. The next morning, the workers retrieved their device and continued responding to alarms. At the end of the week, a researcher returned to the site to collect the devices from the workers.

3.4. Responding to the survey questions

The digital survey was designed to permit the worker to respond to all of the questions in three minutes or less. Consequently, the questions included only multiple choice answers with no open ended responses. The survey consisted of five sections, including (1) context questions, (2) questions when disrupted, (3) questions when not disrupted, (4) state of mind questions, and (5) end of day questions. The PDA was programmed so that the workers only answered the “questions when disrupted” if they responded that they had, in fact, been disrupted since they were last alarmed. If they indicated that they had not experienced a disruption, the PDA was programmed to present only the “questions when not disrupted.” Likewise, after 1:30 PM each day, one final alarm was received, and this triggered the “end of day questions,” which were only presented once per day at the end of the day.

The context questions asked the workers about their location, who they were with, whether they experienced time pressure or turbulence, and whether their work had been disrupted since they were last alarmed.

The “questions when disrupted” asked the workers about whether the disruption caused them to change their location, task, or work method (i.e., did they have to improvise). If they answered yes to any of these questions, they were prompted to identify who made the decision to change their work conditions (themself or their supervisor), how much time was spent on making the decision, and how much thinking (i.e., cognitive effort) was necessary to make the decision. Workers were also asked to identify the type of task they were working on before and after the disruption, the cause of the disruption, the severity of the disruption, and the impact of the disruption on their productivity. Similarly, the “questions when not disrupted” were nearly identical to the “questions when disrupted” but were asked under the assumption that any deviation from the planned location, task, or work method was essentially voluntary. As a result, these questions were framed either as “no change to the work condition” or as “unspecified changes to the work condition” rather than changes caused by a disruption.

The state of mind questions asked workers about their positive and negative emotions as a result of the disruption or at the moment they received the alarm. Two questions asked workers to rate their negative reaction to a disruption or negative emotion at the moment of the alarm. Likewise, two questions asked workers to rate their positive reaction or positive emotion.

Finally, the end-of-day questions were asked once per day after 1:30 PM. These questions were designed to assess the impact of disruptions (or lack of disruptions) on the workers’ perceived ability to work productively and complete their assigned tasks.

3.5. The exit interview

On Friday afternoon of Week 1, a researcher retrieved the PDAs from the workers and downloaded the data for review by the research team. The following week, the researchers conducted exit interviews to discuss the results of the data collection effort with the workers. Each worker was interviewed separately and was asked to describe in richer detail one or more disrupted work incident. The exact date and time of specific momentary assessments were presented to the worker, and they were asked to recall the specific disruptive incident and "describe what happened." Their responses were recorded for later transcription. These exit interviews provide a rich source of anecdotal data and provide further context for understanding how workers react to workflow disruptions and how they adapt their activities accordingly.

4. Demonstrating EMA analysis: Results for the idiographic study of a construction worker's daily disruptions, decisions, and actions

The study aimed to identify how a worker reacts and adapts to workflow disruptions by evaluating the worker's subjective internal experience (i.e., judgments, emotions, and decisions) as well as their planned and improvised activities (i.e., external experience). To better understand how a worker reacts to disruptions on the jobsite, the idiographic study addressed the following within-person questions:

1. How do the decisions and actions of a worker differ when the worker has been disrupted versus when the worker has not experienced a disruption? Specifically, does the worker make more improvisational decisions and take more improvisational actions when they have experienced a disruption as opposed to when they have not been disrupted?
2. How do disruptions influence a worker's state of mind throughout the day? Specifically, do mood states change following a disruption?

The results of the idiographic study of a construction electrician are presented below.

4.1. Idiographic study of William, a journeyman electrician

Background and demographics. William is a 28-year old journeyman electrician with more than five, but less than 10, years of work experience as an electrician. He has a four-year college degree and has completed an apprenticeship program that lasted longer than four years. At the time of the data collection effort, he was working on a hospital renovation project, which he characterized as being moderately complex and highly turbulent. However, he stated that during the week of the data collection, the amount of turbulence experienced was less than it had been in previous weeks. He indicated in his baseline assessment that he felt confident that he had the skills needed to complete routine and complex work tasks and that he prefers to try to solve problems himself rather than ask his supervisor to solve the problem. He also indicated that his supervisor encouraged him to solve problems independently when possible. William enjoys the challenge of solving complex problems and seeks out opportunities to increase his skills and knowledge.

Response rate and types of disruptions. During the week, William received 25 alarms and responded to 18 of them, for a response rate of 72%. Typical reasons for missing the alarm include not hearing the alarm or not being in a safe condition to respond. In one instance, he reported being on a break. Of the 18 alarms that he responded to, he reported being disrupted seven times and not being disrupted 11 times, resulting in being disrupted 39% of the time that he responded. During the week, he worked on installing electrical conduit and did not report working on any other task. The types of disruptions he experienced included:

- Someone (another trade, co-worker, or supervisor) interrupted his work: 6%
- Materials, tools, trash, or workers were in his way: 17%
- He lacked materials, tools, or equipment needed to perform the task: 6%
- He lacked information, directions, or communication needed to complete the task: 6%
- Other: 6%.

Figure 1 presents a time series plot that identifies exactly when he experienced each of the disruptions during the week. Disruptions experienced Monday through Wednesday were primarily caused by materials, tools, trash, or other workers occupying his workspace thus preventing his task from being completed as planned. Disruptions experienced on Thursday and Friday consisted primarily of a lack of materials, tools, equipment, or information that he needed to complete the work.

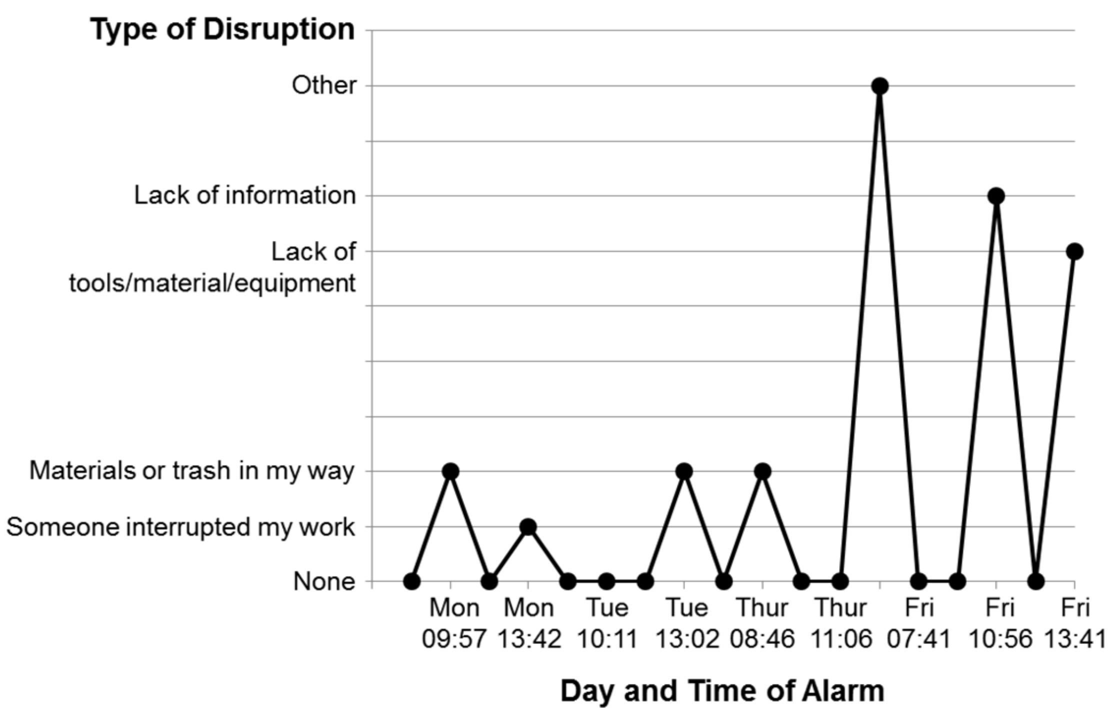

Figure 1. Disruptions experienced during the week

How disruptions influenced his decisions and actions. To investigate how William's decisions and actions differed when he had been disrupted versus when he had not been disrupted, the researchers analyzed his responses to the following questions:

1. (When disrupted) How different is your new task (following the disruption) from your planned task?
2. (When not disrupted) How similar is your current task to your planned task?

The possible answers to these questions included: (1) I am performing the *same* task in the *standard* way, (2) I am performing the *same* task in a *non-standard* way, (3) I am performing an *entirely different* task in the *standard* way, and (4) I am performing an *entirely different* task in a *non-standard* way. These questions and responses explored how significantly the disruptions (or lack of disruptions) impacted William's ability to complete his assigned tasks. The underlying assumption is that the decision to select a new task that requires a creative (i.e., non-standard) method for completing the task (Response 4) is more improvisational than simply working on the same task as planned and performing that task using the typical methods (which requires no improvisational decisions or actions) (Response 1). Hence, the ordering of the responses reflects the increasing degree of improvisational decisions and actions that might be taken either involuntarily (e.g., when disrupted) or voluntarily (e.g., when not disrupted) in order to remain productive, where the ordering of improvisation can be thought of as no improvisation (Response 1), minor (Response 2), moderate (Response 3), and major improvisation (Response 4).

By stating the questions and responses in this way, it is possible to identify an association between William's experience of being disrupted and his need (or choice) to make a fast (i.e., improvisational) decision to select a different task or different method in order to work productively. An examination of the frequencies of the responses to the questions identified above demonstrated the following:

- During 100% of William's disrupted experiences, he *improvised a new task* (i.e., he performed an entirely different task in a standard or non-standard way) or he *improvised his work method* (i.e., he performed the same task in a non-standard way); that is, every time William experienced a disruption, he improvised a whole new task or improvised a new method for completing his disrupted task.
- Likewise, in 100% of the instances when William was *not* disrupted, he *did not* improvise his task or his work method – that is, he did not improvise his decisions or his actions – but rather, he performed exactly the same task that he was scheduled to work on and he performed it in the usual way.
- Furthermore, a within-person correlation between William's disruptions and his degree of improvisational decisions and actions resulted in a very strong positive correlation between being disrupted (yes/no) and degree of improvisational decisions and actions (none/mild/moderate/major) ($r = 0.929$, $p = 0.000$).

Therefore, in response to the question, "Did William make more improvisational decisions and take more improvisational actions when he experienced a disruption as opposed to when he was not disrupted?" – the answer is yes.

How disruptions influenced his state of mind throughout the day. To investigate how William's state of mind (i.e., emotions) differed when he had been disrupted versus when he had not been disrupted, the researchers analyzed his responses to the following questions:

1. Rate how annoyed you felt as a result of the disruption (or how annoyed you are feeling right now)?
2. Rate how motivated you felt as a result of the disruption (or how motivated you are feeling right now)?

The possible answers to these questions included: (1) not at all, (2) a little, (3) moderately, (4) quite a bit, and (5) extremely. These questions and responses explored how significantly the disruptions (or lack of disruptions) impacted William's negative and positive emotional states. Two specific emotions (annoyed and motivated) were evaluated.

To evaluate whether William's emotions state changed after he experienced a disruption compared to when he did not experience a disruption, the researchers superimposed his responses to the questions above onto two time series plots that identified his disruptions during the week. The first plot (Figure 2) shows that William reported an increase in his level of annoyance in six out of the seven moments when he was disrupted (86%), and that he reported being *at least* moderately annoyed five times (71%) following a disruption. His average rating of annoyance following a disruption was 3.0, whereas his average rating of annoyance when not disrupted was 1.8. The second plot (Figure 3) shows that William reported a decrease in his level of motivation in five out of the seven moments when he was disrupted (71%), and that he reported being *less than* moderately motivated two times (29%) following a disruption. His average rating of motivation following a disruption was 3.0, whereas his average rating of motivation when not disrupted was 4.9. Furthermore, a within-person correlation between William's disruptions and his level of annoyance resulted in a strong positive correlation between being disrupted and feeling annoyed ($r = 0.662$, $p = 0.004$). And, the correlation between William's disruptions and his level of motivation resulted in a strong negative correlation between being disrupted and feeling motivated ($r = -0.707$, $p = 0.002$). These findings suggest that William experienced a strong negative swing in emotions when he was disrupted and his motivation also declined following a disruption.

Therefore, in response to the question, "Did William's emotional states change following a disruption?" – the answer is yes. William experienced an increase in his level of annoyance and a decrease in his level of motivation following most of his disruptions.

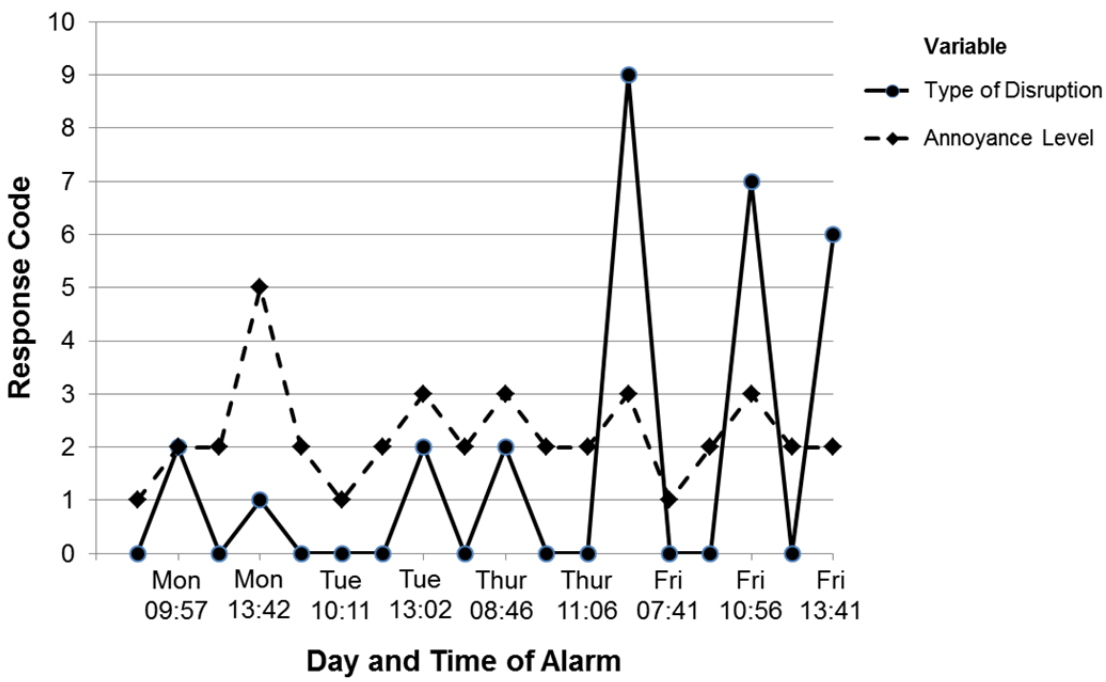

Figure 2. Variation in annoyance level when disrupted

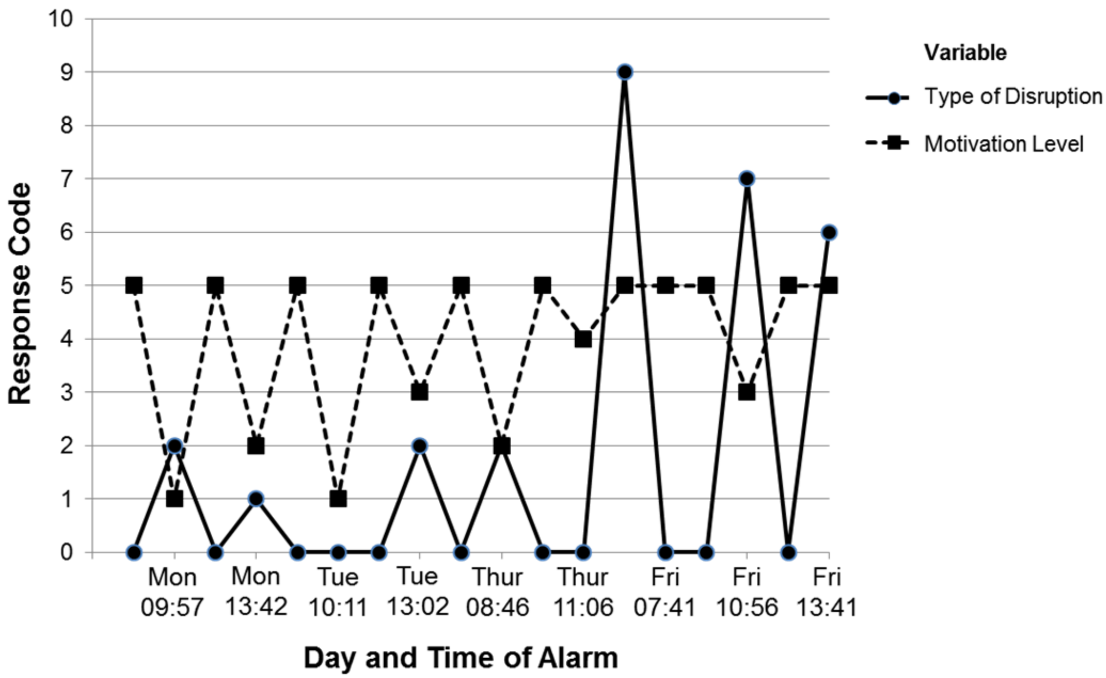

Figure 3. Variation of motivation level when disrupted

Understanding "what happened" as described in William's own words. The researchers conducted an exit interview with William to learn more about his experiences during the week that he responded to the alarms. Although William experienced seven recorded disruptions, he was asked to explain "what happened" during only one of the disruptions. The disrupted experienced occurred on Monday, February 13, 2012. William reported that he was disrupted and that he had to set up a totally different set of tools in order to keep working following the disruption. Just prior to the disruption, William was installing a rack that would eventually support the electrical conduit. He stated that he was working efficiently, but then his supervisor asked him to stop his current task and go to a different floor to work on a "hot job." The hot job involved running flexible electrical conduit and wire to the ceiling juncture boxes so that permanent lighting could be installed and the temporary lighting could be removed. This request for permanent lighting was made by the general contractor, and, in order to maintain positive relationships, the electrical foreman (i.e., William's supervisor) complied by pulling William off his planned task (i.e., installing racks) and had him switch to an improvised task (i.e., install flexible conduits). In order to implement the improvised task, William had to put away all of the tools and materials for his planned task, locate the freight elevator, wait until another trade finished using the freight elevator, load a new set of tools and materials onto the freight elevator, and take his new tools and materials to his new work location. The transition from stopping his planned task to starting his new task took 45 minutes. This disruption significantly increased William's level of annoyance, which he rated as 5 ("extremely annoyed"), and significantly lowered his level of motivation, which he rated as 2 ("a little motivated"). As the interview was being conducted, William was able to show the researchers the flexible conduits he had installed and indicated that none of the permanent lighting had subsequently been installed – so the "hot job" must not have been so "hot" after all.

William reflected on his experience and indicated that he might have taken a different approach if he was the supervisor: he stated that he would have negotiated with the general contractor to install the flexible conduit the next day rather than interrupting the current day's planned tasks. William also reflected on how his week went overall, stating, "I had a very calm week…everything (I did) was roughing in conduit…I did the same thing the whole day and really the whole week, and it makes for a productive week."

5. Conclusions

This paper reported on a novel research method that has made it possible to transition from studying the phenomenon of workflow disruptions at a project level to studying this phenomenon at an individual worker level. Specifically, previous studies of workflow disruptions have identified how disruptions impact the progress of the work, the cost of the project, the amount of turbulence, and the overall impact on productivity levels (Finke 1998, Eden *et al.* 2000, Thomas *et al.* 2003, Mitropoulos and Nichita 2010). These approaches often document the worker's external experience captured through a largely observational lens but fail to capture the construction worker's subjective experience – that is, what they think and how they feel as they react and adapt to disruptions. Of particular interest is how workers adjust their decisions and actions "in the moment" – that is, how they improvise -- in response to unexpected task disruptions. These improvisational decisions and actions are believed to be an important but little-studied phenomenon that may help or hinder efforts to reduce the impacts of workflow disruptions on progress. Consequently, through the use of idiographic (within-person) and nomothetic (between-persons) techniques, the researchers have engaged in a process of theory testing, revision, and re-testing to derive a better understanding of how and under what conditions some workers use improvisational decision-making effectively to overcome barriers to progress on the jobsite. This theory testing and revision process has become possible through the use of an Ecological Momentary Assessment (EMA) methodology that can capture workers' decisions and actions in near-real time following a disruption.

The idiographic case of William, the electrical construction worker, which was presented in this paper, has helped elucidate important relationships between disruptions and the worker's reactions. Specifically, in the case of William, every disruption required an improvisational action – either selecting a totally different task to work on or changing the method used to complete the planned task. These rapid adaptations appear to have made a positive difference over the course of the week as evidenced by William's comment that he felt that he had a calm and productive week overall. The study also noted negative emotional changes (i.e., greater annoyance and lower motivation) following each of the disruptions, which may have had only a *brief* negative impact on his productivity. As noted by Zelenski et al. (2008), workers who experience greater *positive* emotions tend to be more productive and, at the same time, workers tend to experience their greatest levels of productivity when they experience positive mood states. Hence, the ability of the worker to quickly recover their positive mood following a disruption may be an important resiliency factor that will be investigated as the research progresses.

In fact, the rich dataset that will be collected by using an EMA method will make it possible to compare individual workers to one another in order to understand their *unique experiences* and also to compare groups of workers to identify *overall trends* in the phenomena of making fast decisions following a disruption to the workflow. The EMA research method provides an avenue to systematically advance a theory of how workers adapt to chronic disruptions through improvised decisions and actions on the jobsite.

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