Risk perception and risk communication

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Methods for documenting the personally constructed reality of risk

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ABSTRACT: To document an individual's longitudinal construction of risk is a logistically intensive task. To identify a logistically feasible approach, we review existing agent-based experience documentation approaches within the context of a specified risk source – performance of a transportation network. The most promising documentation method, GPS tracking, was then tested in a four month pilot study. This study found that while GPS tracking documents an individual's activities in extreme detail, the psychological context of these activities is missing. To contextualize this data, the feasibility of applying three different hedonic psychology research methodologies is assessed. From the perspective offered by this pilot study, it is believed a daily survey documenting the individual's observed key experiences combined with a focused survey qualifying recent GPS documented experience variances shows potential for being a comprehensive and logistically feasible methodology for documenting an individual's longitudinal construction of risk.

1 INTRODUCTION

1.1 *Context*

When a risk manager conducts a risk analysis, he employs the level of risk acceptable within the respective industry to determine the required safety and operational changes to ensue the risk source operates in an 'acceptable' manner. A citizen from the risk source's community forms a personal construction of risk from his exposure level and experience with the risk manager's 'acceptable' risk source. From this personal construction of risk, the general citizen forms his own acceptable level of risk. The resulting key question is: How does the risk manager's 'acceptable' level of risk compare to the general citizen's 'acceptable' level of risk? (Fig. 1)

Figure 1. Acceptable level of risk: Relating the risk manager's usage and the general citizen's construction.

If the risk manager's acceptable level of risk is more conservative than the general public's acceptable level of risk, a lack of public support and funding for the risk manager's decisions can be the result. On the other hand, when the public's acceptable level of risk is more conservative than the risk manager's acceptable level of risk, the public's safety expectations can be left unfulfilled by the risk manager – potentially jeopardizing the public's trust in the risk management. Finally, when the risk manager's acceptable level of risk is in close agreement with the public's acceptable level of risk, a publicly supportive environment can be produced.

To improve the probability of achieving a close agreement between the risk manager's and the public's acceptable levels of risk, one should document representative individuals' personal constructions of risk.

To document the continually refining and redefining process of an individual's construction of risk is logistically intensive if not altogether impossible. Logistically feasible documentation methodologies must be identified if such risk reconstructions are to enter risk analysis. We begin this identification process by assessing existing agent-system documentation methods, testing the most promising method and evaluating approaches for qualifying and contextualizing this data.

1.2 *Normative evaluation*

From the field of psychology, one can observe an individual employs their senses (sight, sound, touch, and smell) to assess their environment interactions (Mahoney 2003). From these assessments, the individual forms mental constructs – discrete relative mental concepts of their environment (Kelly 1955). The individual then employs these existing constructs to frame and evaluate their future experiences (Kahneman 2003). Where environmental changes are either unconsciously or consciously observed, the individual is spurred to determine if the change correlates with a previous construct, whether the change is positive or negative and if any reaction is required (Bargh and Chartrand 1999, Slovic et al. 2002). The individual then employs these future interactions to refine or redefine, where warranted, their personal constructs to ensure they reflect their experienced reality (Kahneman 2000, Kelly 1955). The end result is a unique construction of reality for each individual. This construction of reality is a product of the intensity, range, and sequence of the individual's environmental interactions (Glasersfeld 1996).

1.3 *Defining the risk construction documentation requirements*

From these observations, we defined an individual's construction of risk as a function of the individual's uncertainty with a risk source and how the individual's risk source experience varies with respect to his pre-established norms. Therefore, to reconstruct the individual risk construction, one must document in detail an individual's temporal interaction with a given risk source. Potential participant environmental documentation approaches must be identified and evaluated if such reconstruction approaches are to enter risk analysis.

A risk environment, in this case a public transportation system, is selected in which the participant is required to frequently interact with during the course of their daily activities. This risk environment was chosen for it has been documented to produce a cognitive risk assessment process which is predominately an unconscious and automated decision process rather than an active and pensive decision process (Birdsall & Brühwiler 2006b). This test environment will assist in evaluating potential participant risk construction research methodologies.

2 PARTICIPANT-SYSTEM INTERACTION DOCUMENTATION METHODOLOGIES

To reconstruct an individual's risk construction one must first document the individual's daily interactions with the risk source and the resulting induced impact on the individual. Within a public transportation system, this documentation process includes recording time, location, performance, and induced affective aspects. We define 'interaction' as the direct personal usage of a public transportation system. All secondary and tertiary exposure venues (learning about public transportation risk issues from the media or from talking with colleagues) are actively ignored for it is assumed the individual's personal and frequent usage of the system will outweigh external influences. Through consulting the field of transportation engineering, it can be seen there are already a number of time, location and performance documentation methodologies (Table 1) including: (1) self-administered travel surveys, (2) human-system interaction documentation, (3) passive and active cellular signal tracking, and (4) global positioning system (GPS) tracking.

Table 1. Participant-system documentation methodologies.

Method	Aspects (limitations)
Travel survey	Manually record date, start & end locations (incorrect documentation common)
Human-system interaction	Automatically records time at start, end & other key waypoints (system requirements) (data of insufficient detail)
Passive cellular signal	Movement through cellular network (anonymously recorded)
Active cellular signal	GPS receiver in cell phone broadcasts location (USA only)
GPS tracking	GPS receiver documents location & time multiple instances a minute (limited battery & data storage)

2.1 *Self-administered travel survey*

Self-administered travel surveys are the most simple of location documentation approaches. In this approach, respondents are asked to document the date and the start and end locations of their daily trips taken within a transportation system. Providing this information is relatively simple and non-time intensive task for a participant and it can therefore be easily applied to longitudinal studies involving a large number of respondents. From such a study, one can ascertain the frequency and range of the participant's travels (Axhausen et al. 2002).

While this methodology documents the location and date of the various interactions, it fails to document the individual's micro (how long a station stop lasted) or even global temporal experienced performances (how long the entire trip took). Furthermore, as this methodology asks participants to document

their daily trips, short trips and multiple location trips are commonly either non-documented or documented incorrectly (Wolf 2004).

2.2 *Human-system interaction documentation*

In the human-system interaction documentation approach, a participant's interaction with a system is documented at key points, commonly at entry, exit and waypoints. This methodology is commonly integrated within the given system and such systems have been used to establish customer preferences, to document participant movements and even to rate a participant's likelihood to commit a crime (Cho et al. 2002, Landfried & Teufel 2006).

The completely integrated nature of this approach has the potential to be ethically questionable as was recently the case in the United States (CNN 2006), and therefore it is essential to actively obtain and document a participant's permission to use such collected information. Furthermore, as this method only documents the individual's interactions at key points, the individual's experiences at intermediate points may not be able to be determined. As an individual's risk construction is a continuously refining and redefining process, this discrete documentation methodology does not adequately document an individual's interactions.

2.3 *Passive agent cellular signal tracking*

Passive agent cellular signal tracking is essentially an adaptive human-system interaction documentation methodology in which the cell phone towers serve as the waypoints. The methodology is as follows: take a person carrying a cell phone, at any point in time the cell phone is connected to one or more cell towers. As the cell phone moves through a cellular network, the cell phone's signature is passed from one cell phone tower to the next. Through signal analysis and triangulation, a cellular service provider can determine the location and speed of a cell phone carrier. This methodology has already been tested in a number of countries to anonymously monitor traffic speeds (Smith et al. 2003, Ygnace et al. 2000).

To effectively implement such a documentation approach, one needs to actively engage the cell phone service providers and to address the cell phone customer privacy issues. The current approach employed by cell phone providers is to 1) issue limited term access to cell phone signature data (extending from a few days to many months) and 2) remove all identifying customer data prior to releasing the cleansed data to a third party (Fontaine & Smith, 2004). The anonymous nature of passive cellular tracking negates its applicability to documenting an individual's set of experiences for one is unable to match an individual with their respective experiences.

2.4 *Active agent cellular signal tracking*

In 1999, the United States Federal Communication Commission (FCC) started a phased implementation of requiring cell phone providers to be able to provide a cell phone's location in the event an emergency phone call (911) was placed (FCC 2006). The required accuracy has resulted in most service providers building a global positioning system (GPS) receiver into each new cell phone. In the event of an emergency, the service provider can query this GPS receiver (Charles 2006).

Currently within the United States of America there are approximately 100 million GPS capable phones in operation but only one company, Nextel, permits customers to have direct access to this usually encrypted capability. With this access and an inexpensive program, Nextel users can broadcast their location and speed every 15 seconds to a server or website (Mologogo 2006). While this capability is readily available in the United States, to the authors' knowledge, such capabilities and access have not yet been introduced in Europe.

While this documentation approach is ideal for documenting an individual's experience within a transportation system, given the requisite permission, it has not yet been introduced into the European market. Therefore other documentation methods will have to be employed until this capability arrives.

2.5 *Global positioning system (GPS) tracking*

The global positioning system (GPS), established in 1993, is a system of 24 geostationary satellites. Each satellite, using an atomic clock for reference, continuously broadcasts its location and time. These broadcasts are received by a GPS receiver which computes the distance to each satellite from the delay between sent and receipt times. The GPS receiver then employs triangulation to determine its location to an accuracy of 10 meters (Garmin 2006).

GPS receivers have been applied in many different civilian settings including navigation, trip documentation, and physical training (Wikipedia 2006). To employ a GPS receiver to document movement, one must first turn on the unit, permit the unit to calibrate its position (an approximately 30 second process) and finally manually start data acquisition. While this is a rather lengthy process, it is believed that by requiring the participant to manually initiate data acquisition, the researcher can ensure a participant has active control over and full knowledge of the collection of their personal data. During active data acquisition, the GPS receiver automatically records time, location, and speed data approximately every five seconds.

While GPS tracking currently offers the most promise in documenting a participant's interactions within a transportation network, the limited battery

life and data storage capability (both under 30 hours) requires the participant to daily charge and download the recorded data. These additional tasks can potentially compromise the feasibility of this documentation methodology.

In the absence of the active agent cellular signal tracking, GPS tracking, with a 10 meter accuracy and full-day experience documentation capability, is currently the most promising participant-system documentation approach.

3 GPS-BASED RISK CONSTRUCTION PILOT STUDY

3.1 *Pilot study overview*

To further explore the feasibility of documenting the construction of risk, a four month pilot study was launched. In this study, the participant documented their daily interactions within a public transportation system with a Garmin Forerunner 205 GPS receiver, a wrist-mounted GPS unit originally designed for triathlon training. To improve the accuracy of the collected GPS data, the participant was encouraged to turn on and calibrate the GPS unit prior to each use.

Additionally, the participant was asked to complete an 8-question semi-focused survey each day. This 8-question survey asked the participant to list three positive and three negative events that occurred during their day and to rate the intensity, between 10 and 0 and −10 and 0 respectively. Additionally the participant was asked to list two events that occurred during their day's travels and to rate the events' intensities between −10 and 10. While it is fully understood that intensity ratings can be extremely contextually sensitive, even to extremely minor events (Schwarz 1987), the participant is asked to list and rate events from their daily experiences to document what individual is focused on and perceives as changing in their daily lives. To improve survey response frequency, the participant was encouraged to fill in the survey at the same time each day. The GPS and survey data was submitted by the participant each day.

3.2 *Raw GPS documentation*

During the pilot study, over one-hundred thousand data points detailing the individual's location, speed, and acquisition time were collected. These data points detailed 220 distinct trips. This data was then classified into different trip types, 25 in all, using the start point, end point and general location. An example trip and the associated experienced speeds as a function of distance are presented in Figures 2 and 3 respectively. From these figures, one can observe the GPS location and speed measurement detail. From the Figure 3, one can also observe the calibration induced error immediately

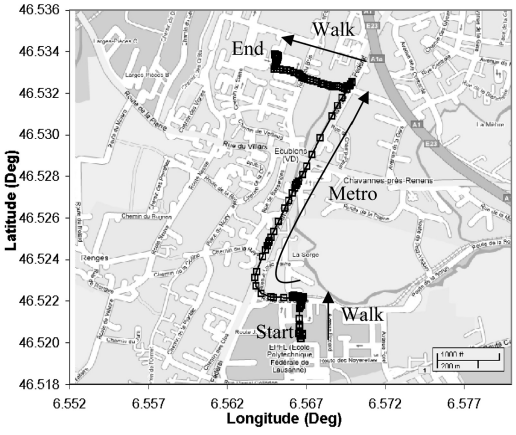

Figure 2. An example trip – EPFL to a shopping center.

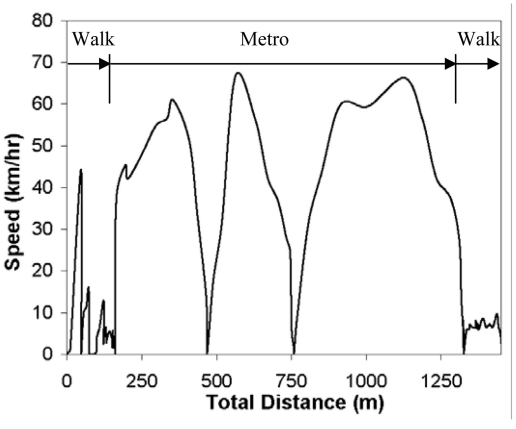

Figure 3. Trip speed as a function of trip distance.

adjacent to distance 0, the significant speed differences between walking and riding the metro and even the two intermediate stops on the metro.

In the detail presentation of this GPS documentation, Figure 4, the location of each data point is represented by a square. At higher speeds, such as when the participant is riding the metro, the data points are more spread out, but when the participant moves at slower speeds the data points are more closely spaced providing a detailed automated documentation of the individual's activities.

3.3 *Analyzing the GPS documentation*

The experience of additional trips along the same path can be relative assessed by comparing the obtained GPS data for each trip. One such method is by overlaying a subsequent trip on top of a previous trip and

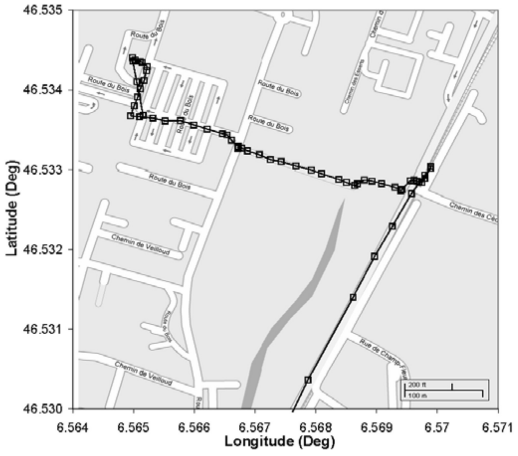

Figure 4. Detailed view of GPS documentation.

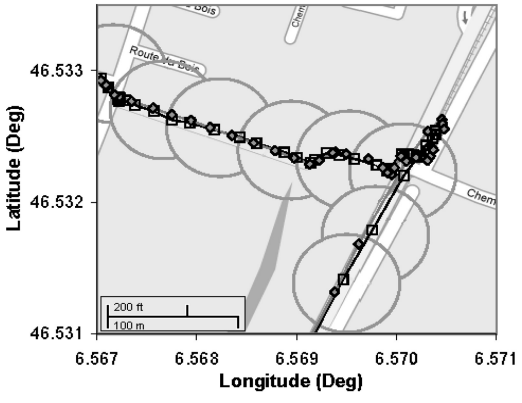

Figure 5. Contextual analysis using influence circles.

computing the time required to exceed a predefined range of movement.

Figure 5 presents such an analysis. In this figure, one can observe that a subsequent trip is overlaid on the trip presented in Figures 2–4. 80 meter diameter influence circles, defining the referenced range of movement, are then sequentially added to the initial trip data points. The center of each circle coincides with a data point not contained with a preexisting influence circle. The time required for the individual to move from the center of a given circle to its perimeter is then calculated. The process of assigning unbounded data points to the preexisting influence circles is then repeated for the subsequent trip and the time required to extend beyond the respective influence circle's perimeter is calculated. These computed parameter crossing times are then compared to determine how the individual's experience has changed between the two trips.

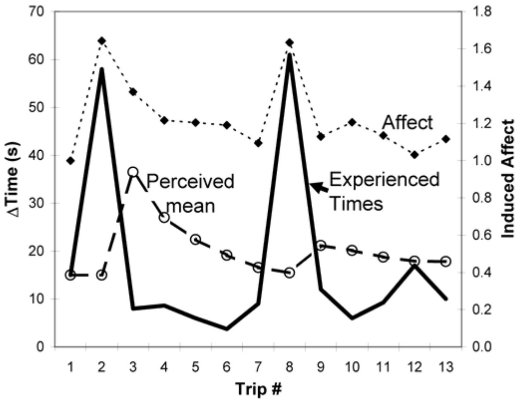

Figure 6. Affect-based assessment – an example analysis.

The impact of this relative experienced change is modeled for demonstrative purposes using the affect-based assessment approach originally developed by Birdsall & Brühwiler (2006a) to model drivers' responses to experiencing congested and non-congested highways. In this approach, the induced affect of an experience is defined as a function of the distance the current experience varies from the preexisting perceived mean experience.

The affect-based assessment for an influence circle within the participant's commute path between home and work is presented in Figure 6. In this figure, one can observe that the individual passed through this influence circle thirteen different times during the studied period. Furthermore, the individual's experienced times varied from a minimum of 4 seconds to a maximum of 60 seconds. The modeled induced affect for each subsequent experience and the resulting perceived mean are presented.

While this affect-based assessment approach can indicate how a given experienced time varies from a previous set of experienced times and how the average perceived experienced time evolves from one trip to the next, it is unable to indicate the motive or instigators behind this modified experienced time. Such increased times, as experienced during trips 2 and 8 presented in Figure 6, may be a product of a negative experience, such as increased traffic slowing the participant down, or a positive experience, such as stopping briefly to talk with a friend. Both events would provide a different contextual experience but both would produce an identical GPS history.

3.4 *Semi-focused survey results and analysis*

During the pilot study, the participant also submitted the semi-focused surveys by email at the end of each day. At the end of the pilot study, this set of surveys were analyzed and coded in bulk. The three

Table 2. Travel event classification.

Classification	Example represented events
Weather-time change	Shortening of the length of the day, changing weather conditions
Personal factors	Personal health and schedule events, work requirements
GPS documentable events	Missing a bus or train, changing of a train schedule
Travel environment	Number of passengers on train/bus, reading newspapers on the train
General environ. changes	Metro station construction, opening of an additional building entrance

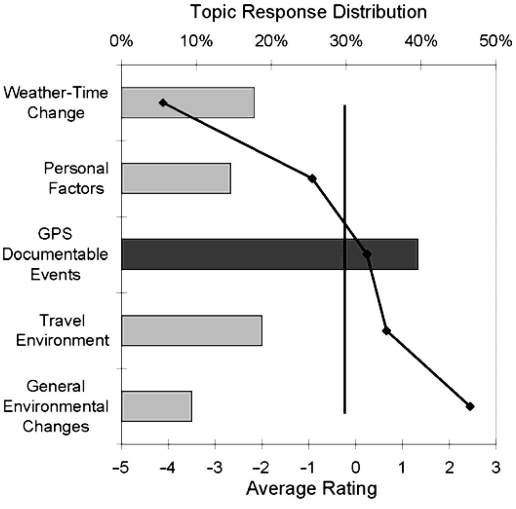

Figure 7. Travel event classification: Response distribution and average rating.

positive and three negative daily event questions were coded into 13 classifications and the two daily travel event questions were initially coded into 18 classifications and then sub-coded into 5 comprehensive classifications. The 5 comprehensive classifications and examples of their represented events are presented in Table 2.

The distribution and the average rating for each comprehensive classification are presented in Figure 7. One can observe that while the GPS documentable events category is the largest comprehensive classification, it still accounts for only 40% of the documented travel events. Furthermore, from the intensity rating responses introduced in Section 3.1, the two most extreme average rating comprehensive categories, weather-time change and environmental changes, are not considered by the GPS documentation approach.

Table 3. Participant survey methods.

Method	Aspects (limitations)
ESM	Portable timer indicates survey time Avoids hindsight bias, multiple surveys per day
EMA	Timer indicated survey, survey data complemented with quantitative data (Intensive analysis)
DRM	Multi-phased event diary, reconstruct previous day (Participant time intensive 45–75 minutes)

From these survey results, one can see that while the GPS documentation does account for a significant portion of the noted events, there are still numerous additional sources contributing to the individual's construction of risk other than those documented by GPS tracking.

3.5 *Pilot study summation*

From this pilot study, one can observe that the GPS tracking approach provides an adequate automated documentation of the individual's movements and interactions within their environments. Likewise, the semi-focused survey provides an insight into what the individual views as a significant event and introduces a perspective of the event topic coverage offered by the GPS tracking.

What is missing from the documentation approaches employed during this pilot study is the detailed psychological context and perspective of the interactions an individual has with their environment. Without this perspective, a researcher cannot differentiate between positive and negative experiences producing identical GPS histories.

4 ADDITIONAL PARTICIPANT SURVEY METHODS

To further complement and contextualize the GPS tracking documentation approach, the feasibility of applying three different survey research methodologies (Table 3) originally developed within the field of hedonic psychology – "the study of what makes experiences pleasant or unpleasant" – are evaluated (Kahneman et al. 1999).

4.1 *Experience sampling method (ESM)*

In the experience sampling method, developed by Csikszentmihalyi et al. (1977), participants employ a portable timer, such as a wrist watch or beeper, to indicate when they should manually or digitally complete a short predefined survey. This process is replicated multiple times during a day and through this approach, researchers are able to collect a detailed in-time

documentation of an individual's experiences while minimizing hind-sight bias. Early studies employed a wrist alarm watch and paper forms. More recently, studies have evolved to using personal digital assistants (PDAs) for both notification and data collection. Furthermore, ESM has been employed to collect an upwards of fifty survey periods per participant within a given week (Csikszentmihalyi & Hunter 2003). The experience sampling method has been used in the psychology, hedonic psychology and human system-interaction research fields (Intille et al. 2003).

4.2 *Ecological momentary assessment (EMA)*

The ecological momentary assessment (EMA) approach is an extension of the ESM where the range of collected data is broadened to include environmental, social, psychological and biological states (Stone et al. 1999). In EMA, the participants are signaled by a timer to manually or digitally fill out a survey detailing their current state and recent previous events. This survey data is then complemented with environmental or participant quantitative data such as documenting participant medical vital signs (Smyth & Stone 2003). By including environmental events, researchers have the potential to study the relationship between various environmental conditions and the resulting impact on the respondent in natural settings. The significant drawback of this research approach is the quantity of collected temporally dependent data. For a researcher or research team to process and analyze this volume of information can be a daunting task but the results are commonly worth the investment.

4.3 *Day reconstruction method (DRM)*

The day reconstruction method (DRM), developed in 2004, is a relatively recent systematic reconstruction documentation methodology (Kahneman et al. 2004). In DRM, the study focus is the reconstruction of the previous day. In the first of three phases, respondents are first asked to provide general background information on emotional, financial and life perspective topics. In the second phase, respondents are asked to write a confidential detailed event-based diary of their previous day's activities. This diary is intended only to assist the respondent in reconstructing the previous day's activities and is not submitted. In the last phase, respondents are asked to employ a provided response form to detail each event in their event-based diary. In particular, the response form addresses topics such as when, what, where, with whom, and how they felt during each episode. Respondents normally invest between 45 and 75 minutes to complete all three phases of the DRM. Thus far, DRM has been employed in the hedonic psychology and medical research fields (Kahneman et al. 2006, Spiegel et al. 2005).

4.4 *Participant survey method critique*

The ESM and EMA participant survey methods offer the ability to gather in-time participant data. Unfortunately moving through a transportation system requires a number of the individual's faculties limiting the feasibility of taking in-time measurements. Furthermore, as the risk construction formation continues for a period after using a transportation system, in-time measurements may miss this post-exposure risk perception reformation.

The DRM offers an extremely detailed analysis of an individual's day. Unfortunately, this approach is extremely time intensive and it is logistically infeasible to apply more than once a month. Therefore this approach, at the most, can be applied monthly or quarterly to gain snapshot pictures of the individual's experiences and risk constructions.

It is believed, a good balance between time applicable survey administration and context qualification of GPS data would be best achieved by having the participant's previous day's GPS data analyzed immediately each morning upon submission and the five most significant event variations presented to the participant in survey format. The participant would then be asked if they remembered anything specific from each of the five GPS documented event variations. If the participant responds in the negative, no further questions would be asked, but if the participant responds in the positive, further qualifying and contextually oriented questions would be asked. This survey would need to be administered after the current semi-structure survey to minimize potential response contamination.

5 CONCLUSIONS AND OUTLOOK

5.1 *Conclusions*

1) We have reviewed existing participant interaction documentation methods to work towards developing a logistically feasible approach to document an individual's construction of risk within the defined risk source of a transportation system. While active cellular signal tracking is the most feasible interaction documentation approach, it is currently only offered in the US. GPS tracking which offers a semi-automated location and time data documentation every few seconds to an accuracy of 10 meters proved to be the most applicable quantitative documentation approach.
2) GPS tracking and a semi-focused daily survey were tested in a four month pilot study. This study showed that the GPS documentation provides an adequate automated documentation of an individual's environmental movements and interactions but misses the individual's event associated psychological context and perspective.

3) To further contextualize the GPS data, three different hedonic psychology research methodologies were assessed. This review found the ESM and EMA methods may prove logistically difficult to implement within a transportation system requiring the attention of the participant. Furthermore, in-time measurements may misrepresent the post-travel risk construct reformation. An alternative approach of immediately analyzing the participant's previous day's GPS history to determine the five most significant event variations, testing whether the participant is aware of these events and administering focused survey questions to further contextually qualify the GPS data was proposed. This combined approach of automated GPS tracking and post-experience significant event confirmation and qualification has potential as a logistically feasible risk documentation approach.

5.2 *Outlook*

When the studied risk source is expanded from the very focused risk source of a public transportation system, the authors suggest similar evaluation processes be employed. In particular, searching and evaluating current research methodologies for an applicable and automated quantitative documentation approach and selecting a contextualizing and quantifying qualitative research methodology. The authors envision that by developing, implementing and analyzing risk construction documentation methodologies, a better understanding of the complex risk construction processes can be developed.

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