Riding the Emotional Roller-Coaster: Using the Circumplex Model of Affect to Model Motorcycle Riders’ Emotional State-Changes at Intersections

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Abstract

This study uses Russell’s Circumplex Model of Affect to examine whether motorcycle rider emotion is contingent on the environment and behavior. If it is contingent then it becomes predictable. If it is predictable it becomes potentially usable for innovating new ways to improve the safety and utility of this important transport mode. Eighteen motorcyclists took part in a 15km on-road study during which they were videoed, tracked via GPS, and followed by a ‘chase vehicle’ as they negotiated intersections, all the while providing a concurrent verbal commentary. The verbal commentary was content analysed using a novel method for mapping the verbalized emotional themes to the Circumplex Model. Network analysis was then used to explore the state changes between affective zones in the model. Riders’ emotions at intersections were found to vacillate between negative and positive affect, demonstrating high degrees of emotional dynamism. Many of these transitions occur in and out of the dominant positive state of calmness, with non-calm states appearing to be aversive and those which riders were seeking to avoid. Knowing this brings forward interesting new approaches for safe intersection design.

Keywords

Motorcycles riding, circumplex model of affect, intersection, emotion, verbal protocol
1. Introduction

Motorcycle riding is often reported to be a physically risky and cognitively challenging road activity (Sexton, Hamilton, Baughan, Stradling, & Broughton, 2006; Chen and Chen 2011; Regan, Lintern, Hutchinson, & Turetschek, 2014). Many of the studies which illustrate this are focused on observable behaviours like filtering, speeding, and gap acceptance, more often than not focusing on risk and accident mitigation. Very few studies report on how riders’ affective attributes influence this behaviour (Williams & Hoffmann, 1979; Preussner, Williams, & Ulmer, 1995; Mulvihill, Salmon, Fitne, Lenné, Walker, Cornelissen, & Young, 2013; Simpson, Wilson, & Currey, 2015; Ivers, Sakashita, Senserrick, Elkington, Lo, Boufous, & de Rome, 2016). Even when the emotional aspects of motorcycle riding are reported it is mostly from a cognitive or recreational riding perspective (Walker, Stanton, & Salmon, 2011; Salmon, Lenne, Walker, Stanton, Fitne, 2014; Broughton, 2008; Broughton & Walker, 2009). Clearly this is a gap in our understanding which requires further insight.

1.1. I ‘Feel’ Therefore I Am: Affect in Motorcycle Riding

Rather than following the well-trodden cognitive path of “I ‘think’ therefore I am – [or behave]” (Muennig et al., 2008) this paper examines the possibilities of the alternative: “I ‘feel’ therefore I am [or behave]” (Ratcliffe, 2008). Riding a motorcycle is a highly skilled activity in which there is an interaction between the rider, the motorcycle, and its changing operational environment (Mclnally, 2003; Walker, Stanton & Young, 2007). This interactive relationship is responsible for the dynamic way in which the motorcycle is manipulated, controlled and handled. Studies have shown that errors and violations leading to risks of motorcycle crashes support this interactive systems approach (Özkan, Lajunen, Doğruyol, Yıldırım, & Çoymak, 2012; Elliott, Baughan, & Sexton, 2007; Stedmon, 2008). An important dimension in this interaction could be the rider’s affective state, with the assumption that riders’ emotion is shaped by the happenings, constraints and challenges they are cognitively aware of while interacting with the various elements in the system (Walker, Stanton, & Young, 2007; Walker et al., 2011; Broughton & Walker, 2009). This position is borne out in the wider literature. The environment in which people find themselves is capable of eliciting a varied range of emotions (Mehrabian & Russell, 1974; Russell & Snodgrass, 1987; Zimring, Joseph, & Choudhary, 2004). There is no conceptual reason why road environments should not be capable of doing the same: they too are not ‘emotion free’ (Hu, Xie & Li, 2013; Jeon, Walker & Yim, 2014; Mesken et al., 2007). Elements of the road environment, ranging from road debris and intersections, to an accident scene or a roadside advert, have already been reported to induce emotional responses in road users (Mégias, Maldonado, Catena, Di Stasi, Serrano, & Cândido, 2011; Serrano, Di Stasi, Mégias, & Catena, 2014 and Tay, Choi, Kattan, & Khan, 2011). The need to describe the nature of these emotional states is important (Norman & Ortony, 2003; Van der Meer, Horváth, van der Vegte, & Ohta, 2007) yet it remains an area in need of further study (Mesken, 2003).
The reason for a research focus that has traditionally favoured cognition over emotion seems to lie in the use of rational choice-based models, such as the Theory of Planned Behaviour (TPB; Ajzen, 1991). In such models intentions and behaviour are strongly based on what is perceived. Fishbein and Ajzen (2010) clearly state that TPB was not limited to “cognitive” behaviors, for example, the attitude construct consists of both instrumental and experiential attitudes. This subtlety is often missed, leading to a rather limited view in the face of cognitive-affective frameworks (Mischel and Shoda, 1995; Bargh, 1994) Cognitive Affective Theory (CAT) is premised on the knowledge that actors engage multiple levels of awareness and automaticity in dealing with cognitive and emotional encoding of information in their environment (Bargh, 1994). The theory explains the process of transforming cognitions and affects into ‘stable, meaningful patterns of social action in relationship to situations’ (Mischel and Shoda, 1995). In other words, events in the external environment activate ‘a set of internal reactions’ in people which are not just cognitive but also affective in nature (Mischel & Shoda, 1995). This internal affective transformation among road users, especially motorcyclists, is still a field of research that needs to be explored. (Gatersleben & Uzzell, 2007).

It is possible that in a dynamic road system riders concentrate their cognitive resources on arising constraints which, at times, can cause their emotional state to change from one state to another (Ekman, 1992). Riders, like drivers could at different points feel happy or sad, confident or nervous. They will enact certain types of riding behavior to move themselves from one state to another (Hu, Xie, & Li, 2013). Also established is that people enact behaviours to avoid ‘aversive states’ (Mehrabian & Russell, 1974; Russell & Lanius, 1984). By knowing the affective state of the rider and its contingent relationship on their behavior could be rendered more predictable. Knowing one it becomes possible to influence the other. In other words, it could become possible to design road environments which present particular hazards to motorcyclists, such as intersections (Haque, Chin, & Huang, 2008), in a way that influences emotion and, by extension, indirectly influences behavior.

1.2. The Circumplex Model of Affect

A number of affect models exist to express various affect dimensions of arousal, valence and power, but one that is often used in relation to experiences from environments is the two dimensional circumplex model of affect by Russell (1980). The arousal dimension indicates the degree of intensity of affect, ranging from high or active arousal to low or passive arousal. The valence, or pleasure dimension, reflects the positive or negative nature of the affect (Pereira, 2000; Cowie and Cornelius, 2003; Schröder, 2004). The model contends that affective dimensions are interrelated rather than independent, and they change from one category to the other due to their transient nature (Ekman, 1992). It also describes people’s affective state by studying the cognitive interpretations of sensations based on what is happening around the individual (Posner, Russell, & Peterson, 2005). When used to explain how emotions are distributed, the circumplex model shows that emotional attributes ‘cluster’ around the two main dimensions of pleasantness or arousal (Russell, 1980) as shown in Figure 1. In this paper the model is used to describe the possible emotional state riders can find themselves in as they interacted with the road environment.
Fig. 1. The Emotion Circumplex Model (Russell, 1980)

1.3 The Current Study

Studies on road users (especially drivers') emotional attributes are relatively common. Studies which examine motorcycle rider affect are comparatively few (Grimm, Kroschel, Harris, Nass, Schuller, Rigoll, & Moosmayr, 2007; Eyben, Wöllmer, Poitschke, Schuller, Blaschke, Färber, & Nguyen-Thien 2010; Bañuls & Montoro 2001). This is despite motorcyclists representing a useful sample given their exposure to the environment and feedback from their machine, all of which seem likely to evoke strong responses (e.g. Walker, Stanton & Salmon, 2011). One study linked rider's skills to the emotions, which in turn make them engage in an enjoyable riding experience or 'flow' (Broughton & Walker, 2009). Whilst insightful, the data collection method poses a challenge as riders may not be able to give accurate descriptions of past emotional states during the interview. Tradeoffs such as these demonstrate the challenges involved in measuring emotion. It is possible to evoke emotions in controlled laboratory settings using a variety of techniques. These include recall of previous experiences, reading passages of emotion evoking texts or images (Roidl, Frehse & Höger, 2014; Lu, Xie & Zhang, 2013; Lobbestael et al., 2008). It is also possible to measure emotions indirectly and post-hoc using subjective measures (e.g. self-assessment techniques; Bradley & Lang, 1994; Deffenbacher et al., 1996), or directly in the moment (e.g. using physiological data as proxy measures). The method chosen for this study is concurrent verbal protocol. This has the benefit of being able to easily capture emotional experiences as they are happening on-road without the need to artificially evoke them.

Emotional states are "the end product of a complex interaction between cognitions" (Posner et al., 2005). External environments can induce different emotions (Mischel & Shoda, 1995). These emotions are semantically distinctive and can be expressed through people's language and words (Bann & Bryson, 2012; Schröder, 2004; Cowie & Cornelius, 2003). Indeed, the stronger the emotion the more fulsome the
A possibility to study how motorcycle rider’s emotions transit from one state to another exists in the form of analyzing their recorded concurrent verbal protocols (i.e. thinking out loud) to identify ‘emotion denoting words’, and mapping them on to Russell’s circumplex model of affect (Posner, Russell, Gerber, Gorman, Colibazzi, Yu, & Peterson, 2009; Kring, Barrett, & Gard, 2003). By these means the distribution of riders’ emotional states can be examined. This study suggests the possibility that motorcycle rider affect will be dynamic, rather than static, and that transition from certain states will be more commonplace than transitions from others. Given the novelty of the study, the hypotheses remain couched at an exploratory level, the goal being to describe the phenomena of emotional dynamics at intersections and reveal a new and potentially useful research agenda.

2. Method

2.1. Design

The participants, data and materials used in this study are part of large scale research on Distributed Situation Awareness and intersection safety. It involves motorcyclists, pedestrians, cyclist and drivers, the results of which are published in Salmon et al., (2013, 2014), and Mulvihill et al., (2013). The data has not so far been used to study the affective attributes of motorcycle riders. Intersections were the focus of this work because of a wider aim to increase motorcycle safety in such locations. Intersections also represent a ‘negotiated’ road space and a rich environment for interactions with other road users to occur and, by extension, transitions from one emotional state to another.

2.2. Participants

The participants comprised 17 males and 1 female rider with a mean age of 45.5 years (SD = 12.87). This is an imbalanced sample and an acknowledged challenge. It arises from the opportunity sampling method, and the fact male motorcyclists are significantly more common than females. Riders had between 3 and 47 years’ riding experience (Mean = 22.1 years; SD = 17.62) and were exposed to between 2 and 22 hours of riding time per week (Mean = 7 hours; SD = 5.19) or between 80 and 600km per week (Mean = 281.6km; SD = 167.38). The vehicles themselves were all owned and operated by their regular rider and were full size motorcycles (not mopeds or scooters) with engine capacities in excess of 125cc. The participating motorcyclists were required to have taken a specific National and/or State mandated riding test in order to be granted the full motorcycle license. The study was approved by the Monash University Human Research Ethics Committee.

2.3. Materials

The site for the on-road study was a 15 km urban route located in the south-eastern suburbs of Melbourne, Australia. The route comprised a mix of arterial roads (50, 60 and 80 km/h speed limits), residential roads (50 km/h speed limit), and university
campus private roads (40 km/h speed limit). The study reported in this paper focuses on the emotional transitions which occurred at the intersections within the study area. The route was chosen to maximize riders’ exposure to intersections, with the mix of other roads providing the most efficient way for riders to encounter them. It is also worth noting that the non-intersection parts of the course involved riding in a largely steady-state ‘vehicle following’ manner. Intersection zones were defined from from approximately 100m before and after the intersection itself. The intersections required riders to make left turns, right turns, or proceed straight ahead. The intersections comprised a mix of fully signalized (i.e. all turns controlled by traffic lights), partially signalized (i.e. some but not all turns controlled by traffic lights) and non-signalized intersections.

Fig. 2. The 15km experimental route was located in the south eastern suburbs of Melbourne, Australia, and included 15 intersections of differing types.
An Oregon Scientific ATC9K portable camera was fixed either to the handle bar or the front headlamp assembly of the participant motorcycles. This captured the visual scene, speed and distance travelled (via GPS). A voice recorder captured the rider’s concurrent verbal commentary for the duration of the trip. The Monash University on Road Test Vehicle (ORTEV) was employed as the chase vehicle in which a similar camera was fitted as part of its instrumentation suite (Figure 3).

2.4 Procedure

The first stage of the study required participants to receive a full experimental debrief on the study aims. The need to ride safely to the conditions and in compliance with all road rules was emphasized as part of the formal risk assessment. A consent form was signed, a short demographic questionnaire completed to obtain information on age, experience and riding background. Following this they were given a verbal protocol analysis (VPA) training session in which they received a description of the VPA method and instructions on how to provide concurrent verbal protocols. They were then taken to a desktop driving simulator where they were asked to complete a test drive whilst providing a verbal protocol. An experimenter monitored the drive and provided feedback to the participant regarding the quality of their verbal protocol. Following the VPA training, participants were shown the study route and were given time to memorise it. Whilst participants were practicing the VPA method and familiarising themselves with the route, a technician fitted the ATC9K camera to their motorcycle or helmet. When comfortable with the VPA procedure and route, participants were taken to their vehicle and asked to prepare themselves for the test.
In order to control for traffic conditions, all tests took place at the same times on weekdays. These times were derived from pilot testing prior to the study and represented non-peak hours for the area. When ready, the motorcycle rider set off with a chase-vehicle following at a safe distance behind. The chase vehicle used their indicators to help guide the rider around the course; a standard procedure in many motorcycle riding tests (Tseng & Cheng, 1998; Dase, Falcon, & MacCleery, 2006). While following at a safe distance, a camera fitted to the chase vehicle dashboard captured the riders’ movements ahead and any pertinent contextual observations which may impact on the type and quality of VPA provided (Salmon et al., 2013, 2014).

2.5 Data Analysis

**Step 1: Coding Method.** Participants’ verbal protocols were transcribed verbatim using a professional third party transcription service. The transcripts were then subject to a theme-based content analysis in order to extract emotion-denoting statements consistent with the circumplex model of affect. Paper versions of the circumplex model of affect that were divided into four Zones were produced, with a horizontal axis corresponding to valence and a vertical axis corresponding to arousal. The content analysis approach was novel in that it involved the coder moving their pen across the four Zones of the circumplex model while reading the transcript. For example if a rider said ‘Oh what a crazy slow fellow, because of him I missed the green light’ the pen is moved into Zone 1 (High Negative Affect), and if the rider later says something like ‘wow! Feels great riding today’, the pen is moved into Zone 2 (High Positive Affect). This continues until the last emotion denoting statement identified in that particular transcript is mapped. Each time a desired theme emerged from the transcript the pen was moved (without it leaving the paper) into the respective Zone. At the end of the transcript the start and end point of the continuous line was marked (see Figure 4).

![Circumplex Model](#)

**Fig. 4.** A sample of the paper based versions of the circumplex model (Russell, 1980) in which four Zones were derived and coders moved their pen into corresponding regions of the model as they read the transcript.
This approach is somewhat different to a more straightforward coding method in which a numerical score might be written. The more conventional coding approach typically requires more pauses as each theme is encountered. This breaks the smooth trajectory of emotional state changes, and tends not to encourage initial responses from the coders. The alternative method proved highly effective in encouraging the coder’s initial reactions to the emotion denoting words, making the method quick to apply whilst preserving the ‘trajectory’ or dynamics of the emotions being described: a key research aim. This step was repeated for all 18 rider transcripts, using one circumplex model template for each rider.

Step 2: Emotional State Transitions. The data was further reduced by examining the number of occasions an emotional state crossed from one quadrant of the circumplex model to another. Every time this happened a value of 1 was added into the appropriate cell of a pre-prepared data matrix. So for example, if the line went from Zone 1 to Zone 2, a value of 1 was entered into the ‘1 to 2’ cell for that participant. If the line then went from Zone 2 to Zone 3, a 1 value was added to the ‘2 to 3’ cell, and so on. If the line crossed back to a previously visited Zone the value in that cell of the matrix was increased by 1. The process of incrementing the values every time a particular emotion transited ‘from Zone x to Zone y’ was repeated until the whole transcript was complete. The sum and mean of each Zone to Zone transition was calculated.

Step 3: Inter Rater Reliability. Two further analysts were given three samples of the transcribed verbal protocols each (a total of six). Using the same strategy as above the analysts produced a set of matrix results that were compared to the lead analyst’s outputs and Cronbach Alpha calculated. Coder 1 achieved $\alpha = 0.69$ and coder 2 achieved $\alpha = 0.87$. The mean value achieved was $\alpha = 0.78$. According to $\alpha$-value heuristics this is deemed a satisfactory level of reliability.

Step 4: Emotional Network Analysis (ENA). Having produced a data matrix showing the transitions that occur between different quadrants of the circumplex model it then becomes possible to subject it to network analysis. Network analysis is a tool to model relational changes in a system (Adamic, Buyukkokten, & Adar, 2003; Walker et al., 2011; Veltri, 2012). The data matrix produced for this study is expressive of an Emotional Network, and subjecting this network to formal network analysis leads to a novel approach we label Emotional Network Analysis (ENA). Network analysis allows numerous network metrics to be calculated from the data matrix. These, in turn, provide insights into dominant emotional nodes in the emotional network and other important features of the network’s topology and functioning.
3. Results

An on road study was performed in which the emotional states of 18 motorcycle riders were studied as they entered and exited selected road intersections in Melbourne, Australia. Intersections were the focus of this study because they are both an emotionally rich, 'negotiated' road space but also because of a desire to extend the results to the design of future intersections. Rider's verbal protocol transcripts were content analysed to determine the category of emotions displayed and how they transited from one Zone of affect to another within Russell's (1980) circumplex model. This section presents and discuss the results of the analysis.

The method of analysis enables us to explore not just the type of emotional change but also its rate. The logical, if not wholly realistic, null hypothesis is that motorcycle riding is emotion free and static. This would mean the number of emotional transitions a rider experiences as they traverse the route is zero. In this study the mean was actually 8.22, with a standard deviation of 2.90 (Table 1). This supports a central theme of the paper: motorcycle riding is not ‘emotion free’ and neither is it static.

Table 1. Descriptive Statistics

<table>
<thead>
<tr>
<th>Number of Emotional transitions during route</th>
<th>*Time taken to travel route (Minutes)</th>
<th>Reported Hours per week</th>
<th>Reported Km per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (M)</td>
<td>8.22</td>
<td>33.39</td>
<td>7</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>2.90</td>
<td>3.01</td>
<td>5.19</td>
</tr>
<tr>
<td>Minimum (Min)</td>
<td>4</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Maximum (Max)</td>
<td>14</td>
<td>38</td>
<td>22</td>
</tr>
</tbody>
</table>

When the data were analysed on the basis of distance travelled per week and compared with the number of emotional transitions made, riders who covered more distance (above 400km/week, or approximately 1 SD above the Mean) showed more transitions in their emotions. The reverse seemed to be true for riders who reported less weekly mileage (approx. 115km/week, or approximately 1 SD below the mean). Both relationships were not, however, statistically significant.

The reported weekly riding hours of the participants correlated significantly with the dynamics of their emotional transitions ($\rho = 0.55$, $p < 0.05$). In other words, riders with lower weekly riding hours (two hours or less) indicated a general tendency for fewer emotional transitions at the intersections and vice versa. This is in line with studies which have associated emotional stress with time spent driving (Gulian, Glendon, Matthews, Davies, & Debney, 1990).
3.1. Riders Emotional Distribution

The emotion denoting words used by riders, when plotted into the circumplex model, showed how riders transit from one emotional state to another. The transition matrix shown in Table 2 is based on Stanton & Baber (1996) and specifies Undesirable (U), Desirable (D) and Neutral (N) states. Again, it can be posited that riders will not be intentionally seeking undesirable or aversive emotional states, and will tend to be propelled into them by external environmental features such as other traffic or a particular roadway design (Megías et al., 2011). They will then perform certain behaviours in order to move themselves from these aversive states to more positive states. This hypothesis is largely supported by the Emotional Network Analysis (ENA) presented later. Zone 4 (Low Positive Affect e.g. calm, contented) and Zone 2 (High Positive Affect e.g. excitement, enthusiastic) were reported as desirable emotional states for riders, although Zone 4 was a more desirable state than Zone 2 (Table 2). Zone 1 (High Negative Affect e.g. jittery, nervous) and Zone 3 (Low Negative Affect e.g. sluggish, tired) are not desirable. Within a total of 148 emotional transitions recorded, 54% are to desirable emotions in Zones 2 and 4, while 46% are towards undesirable emotions in Zones 1 and 3 (Table 3). This again supports the notion that riders transit towards desirable emotional states, while avoiding aversive or undesirable state (Mehrabian & Russell, 1974; Russell & Lanius, 1984).

**Table 2.** The state transition matrix (left hand) defines emotional state transitions into Undesirable (U), Desirable (D) and Neutral (N) categories

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>N</td>
<td>D</td>
<td>U</td>
</tr>
<tr>
<td>Zone 2</td>
<td>U</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>Zone 3</td>
<td>U</td>
<td>D</td>
<td>N</td>
</tr>
<tr>
<td>Zone 4</td>
<td>U</td>
<td>D</td>
<td>U</td>
</tr>
</tbody>
</table>

**Table 3.** Data matrix of Riders' Emotional Transitions

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td>Zone 2</td>
<td>10</td>
<td>5</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Zone 3</td>
<td>12</td>
<td>6</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>Zone 4</td>
<td>13</td>
<td>17</td>
<td>17</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>34</td>
<td>33</td>
<td>46</td>
</tr>
</tbody>
</table>
3.2 Emotional Network Analysis (ENA)

The findings so far revealed a correlation between emotional state and riding exposure. They also revealed a pattern and rate of transitions suggestive of high dynamism between aversive and desirable emotional states. While the nature of these behaviours is the subject of future research, it remains that rider’s emotions are in a continuous and expressive dynamic state (Megías et al., 2011). The final part of the analysis presents an Emotional Network Analysis (ENA) to specify more formally the transitional relationships discovered. Based on the data matrix shown in Table 3, an emotional network (Figure 5) was drawn to show the Zones and how they link to each other.

![Emotional Network Diagram](image)

From the network it is visually apparent that riders seek to move themselves from less favourable Zones (e.g. 1 and 3) to more favourable Zones (e.g. 2 and 4). Interestingly, Zone 4 (Low Positive Affect e.g. content, calm) is particularly densely interconnected with riders somehow favouring this ‘calmer’ Zone over other Zones considering the number of transitions that are made into or out of it. Visual inspection of the diagram grants a certain degree of insight that can be extended more formally by applying a number of network metrics. Table 4 presents the outcomes of this analysis showing the relative prominence of emotional nodes in the network based on the riders’ emotional state transitions.

Table 4. Emotional Network Analysis Metrics (highest values shown in bold).
### Affect Zone

<table>
<thead>
<tr>
<th>Affect Zone</th>
<th>Weighted In-degree</th>
<th>Weighted Out-degree</th>
<th>Determination Degree</th>
<th>Emission Degree</th>
<th>Reception Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (Jittery/Nervous)</td>
<td>11.7</td>
<td>11.3</td>
<td>0.3</td>
<td>34.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Zone 2 (Excited/Enthusiastic)</td>
<td>11.3</td>
<td>9.7</td>
<td>1.7</td>
<td>29.0</td>
<td>34.0</td>
</tr>
<tr>
<td>Zone 3 (Sluggish/Tired)</td>
<td>11.0</td>
<td>12.7</td>
<td>-1.7</td>
<td>38.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Zone 4 (Content/Calm)</td>
<td>15.3</td>
<td>15.7</td>
<td>-0.3</td>
<td>47.0</td>
<td>46.0</td>
</tr>
</tbody>
</table>

#### 3.2.1. Determination Degree

Determination degree provides a measure of whether an emotional Zone in a network is dominated or influenced (positive value) or dominant and influencing (negative value). It is given by:

\[
\text{Determination degree} = \sum_i W_{i,j} - W_{j,i}
\]

Where:

- \( W \) is the connections between emotional zones weighted according to their frequency
- \( i \) and \( j \) are individual emotional zones

By this measure we see that Zone 4 (content/calm) is the dominating emotional state. While this does not imply causation, more of the emotional changes originates or end in this Zone indicating that it is the preferred one. The network analysis also shows that Zone 2 (excited/enthusiastic) is the most dominated or influenced emotional Zone, meaning that riders will only transit to this Zone by the influence or input they receive from other Zones. Thus it is the emotional state most dependent on the happenings in other emotional Zones, and riders will get excited or happy only as other emotional states allow.

#### 3.2.2. In-Degree (and Reception)

This metric measures how often an emotional Zone is chosen, desired or transited to by riders. It is given by:

\[
\text{Reception} = \sum_j W_{j,i}
\]

By this measure we see that Zone 4 (content/calm) is the dominating emotional state. While this does not imply causation, more of the emotional changes originates or end in this Zone indicating that it is the preferred one. The network analysis also shows that Zone 2 (excited/enthusiastic) is the most dominated or influenced emotional Zone, meaning that riders will only transit to this Zone by the influence or input they receive from other Zones. Thus it is the emotional state most dependent on the happenings in other emotional Zones, and riders will get excited or happy only as other emotional states allow.
From the study, Zone 4 (content/calm) has the highest In-Degree value (15.3). Riders are attracted to, or more regularly move into this emotional state from others. This emotional state seems linked to road users who desired to be alert and focused. Even in non-riding contexts, performance is improved in actors performing under this state (Isen, Rosenzweig, & Young, 1991; Grimm et al., 2007). The next is Zone 1 (jittery/nervous), which is an aversive emotional state riders, especially when it is triggered by unanticipated happenings during the riding process. Zone 2 (excited/enthusiastic) and Zone 3 (sluggish/tired) were the least transited into. That there were appreciable transitions into negative emotional Zones, however, poses a challenge to riding where the default state expected is for riders to avoid this undesired state as much as they can. This also corresponds with the reception degree result which is the sum of the weighted emotional activity one Zone receives from other Zones in the network. The more attractive or popular a Zone is, the more emotional activity it will attract from all other Zones. As has already been noted, riders prefer Zone 4 and the feelings of contentment and calmness associated with it. By implication, interventions design seeking to enhance riders’ safety should focus on encouraging this emotional state. For example, the road environment could be designed to elicit this emotional response, or at least help riders to avoid the less preferred states (such as Zone 2).

3.2.3. Out-Degree (and Emission)

This metric measures how often riders transits from a particular emotional Zone into other Zones in the circumplex model. It is given by:

\[ \text{Emission} = \sum_j W_{i,j} \]

Once again, the weighted network metric shows that Zone 4 (content/calm) has the highest Out-Degree (15.7) and Emission values (47). This means riders do not remain in Zone 4 emotional states of calmness. They are buffeted by factors in the external environment such that transitions out of Zone 4 are common. This seems to be supported to some extent in the wider literature (Grimm et al., 2007). Indicative of the emotional transitions which return riders to favourable ‘Zone 4’ states are the transitions out of Zone 1 (jittery/nervous) and Zone 3 (sluggish/tired). Riders found themselves transiting from these ‘undesirable’ emotional states more often than they transited into them. The Emission Degree metric, which is the sum of the weight of emotional activity initiated from individual Zones, shows a corresponding behaviour.

4. Conclusions

This study analysed the role of affect during motorcycle riding. It did so by analyzing concurrent verbal protocols provided by riders as they approached and transited intersections. With Russell’s circumplex model of affect acting as the theoretical basis for the study, the results showed which emotional Zone(s) were more important in the model than others; how strong the influence of each Zone(s) was; and the
readiness of riders to embrace or rescind a transition into other emotional Zones. It was also reported that riding exposure relates to emotional dynamism, with greater experience correlating with a greater number of emotional state transitions. The findings also show that affective state is not static. The majority of transitions occur in and out of a dominant state of calmness. The implications of the findings are intriguing. Firstly, rider affect has not previously been the topic of extensive study yet it is clearly a contingent factor in motorcycle riding. In other words, emotions change in structured and predictable ways depending on the environment and what the rider is doing. More fundamental is the demonstration that motorcycle riding is not the exclusive domain of cognitive processes like hazard perception and situational awareness, as the majority of literature might suggest (Slovic & Peters 2006; Salmon et al., 2013). The continually changing and contingent emotional state of riders could open up innovation in safe riding interventions. Could infrastructure be purposely designed to elicit desirable affective states and consequently reduce risky riding behaviours like speeding and filtering? Could rider training emphasise mindsets, emotional control, and strategies for avoiding aversive emotional states? These, and more, are tantalizing possibilities which this research helps to demonstrate a case for.

4.1 Limitation and Further Studies

Having established the potential role of emotional state changes in motorcycling, and how they could be used to aid the design of safer intersections, it is possible to identify areas that future studies could build upon. The first such area is to achieve greater gender equality in future samples. This is a criticism that can be rightly levied at the transportation research domain in general, and in this case arises from a marked iniquity in how many males ride a motorbike compared to females. The second area is to extend the analysis of emotional dynamism beyond the intersection to a wider range of road environments. In focusing on intersections the paper meets its own particular aim but it must be acknowledged that intersections may embody a particular emotional tone or characteristic pattern of state transitions. Broadening the analysis will establish whether different patterns emerge, and whether they too could prove useful in road design more broadly. The third area centers on the process of mapping emotions to the circumplex model. Naming emotions can be a potentially challenging task, and it is possible that this may mask true emotional states not captured using a verbal method. Tools such as EEG may assist in overcoming such practical limitations but of course bring additional challenges in mapping physical measures to affective states. Future studies for which greater accuracy is required may consider both verbal and EEG approaches simultaneously. Further work is required into practical intersection design and testing against these new emotional criteria even if at simulation level. Further studies are already underway mapping emotional states to actual riding behaviours, and expanding the study to include non-intersection riding. In the future it becomes possible to create emotional road maps to provide an alternative way of prioritizing improvements or better understanding rider behavior across a broader area. It is the authors’ opinion that understanding the changing emotional state of riders’ is a good place to start from.
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6. References


