



# Elderly pedestrians' self-regulation failures and crash involvement: The development of typologies

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## ABSTRACT

The present study aims to identify, study, and develop typologies based on cases of elderly pedestrian collisions with vehicles where the pedestrians subjectively ascribe the collision at least in part to their own self-regulation failures. Semistructured interview surveys were conducted with 18 elderly people who had experienced a crash with a vehicle as a pedestrian aged 65 years or older. Personal construct theory is adopted as the theoretical underpinning, and it is assumed that pedestrians have their own subjective ways of making sense of the crashes they are involved in. It was found that 11 of the 18 participants ascribed the crashes at least in part to their own self-regulation failures. Cognitive maps of the 11 participants had a common structure, and the associated 11 incidents were classified with respect to the following dimensions: (a) self-regulation type, (b) self-regulation motivation, (c) cause of self-regulation failure, and (d) characteristics of the collisions that occurred after the self-regulation failure. Based on these findings, practical implications are found, and corresponding interventions that may reduce elderly pedestrian–vehicle crashes of this type are discussed. Specifically, this study demonstrates the necessity of education or other intervention that goes beyond informing elderly pedestrians of what is right and wrong in traffic environments. Another critical result—the need to motivate elderly pedestrians to respect and adhere to their own highly personal self-regulation, even if it is not against the social norms—is also presented and discussed.

## 1. Introduction

Self-regulation, or the act of transcending immediate temptation(s) in favor of achieving long-term goal(s), has attracted the attention of scholars in general psychology. Psychologists have explained an extensive range of societal problems with respect to self-regulation failure, including crime, teen pregnancy, alcoholism, drug addiction, venereal disease, educational underachievement, gambling, and domestic violence (Baumeister and Heatherton, 1996). In order to explain why people cause such problems by so frequently failing to regulate themselves, many models have adopted the dual-process view (Chaiken and Trope, 1999; Epstein, 1994; Smith and DeCoster, 2000; Lieberman, 2007; Metcalfe and Mischel, 1999; Strack and Deutsch, 2004), in which the failure is explained as stemming either from an overactive impulsive system (e.g., emotional and visceral influences, reward saliency, habitualness) or a deficient reflective system (e.g., alcohol consumption, being under high cognitive load) (Huberts et al., 2014). More recent studies, however, cast doubt on that view and focus instead on the role the reflective system plays in the justification for setting aside long-term goals as a reason for self-regulation failure. Six different types of justification-based self-regulation failure are studied and proposed in the review by Huberts et al. (2014).

In the road safety literature, the self-regulation of elderly drivers is regarded as a promising strategy to simultaneously attain elderly mobility and traffic safety; the amount of research on this topic has significantly increased over the past few years (see Molnar et al. (2013) for the latest comprehensive review). In this specific context, self-regulation is usually described as a driver's adjustment of his or her driving patterns by driving less or intentionally avoiding situations considered to be challenging to compensate for age-related declines in driving ability (Molnar et al., 2013; Baldock et al., 2006; Ball et al., 1998; D'Ambrosio et al., 2008; Molnar and Eby, 2008; Stalvey and Owsley, 2000; Hakamies-Blomqvist and Wahlstrom, 1998; Sullivan et al., 2011). Although such studies seldom refer to the general psychology literature, self-regulation as understood by safety researchers is consistent with how it is defined in general psychology. In fact, elderly drivers who self-regulate transcend the immediate temptation to drive, as they used to when they were younger, in an attempt to satisfy their long-term goal of not causing or being involved in crashes. Additionally, some earlier studies have considered the age-related awareness of one's reduced functional abilities and frailty in the street to be an important element of self-regulation that may help older people to adjust their behavior accordingly (Tournier et al., 2016). This age-related self-awareness includes walking speed reductions (Bernhoft and Carstensen, 2008),

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declining eyesight (Holland and Rabbitt, 1992), and impaired postural control (Legters, 2002).

Although there are many studies on the *failure* of self-regulation in general psychology, to the best of the author's knowledge, no road safety studies have ever considered the possibility that self-regulation *failure* is associated with elderly pedestrians' crash involvement. Thus, considering the extensively recognized seriousness of pedestrian collisions all over the world and the necessity to reduce them (e.g., Zegeer and Bushell (2012), the National Highway Traffic Safety Administration (2012), Cabinet Office of Japan (2019), and several others), this study intends to investigate elderly pedestrian-vehicle collisions that occur after a pedestrian's self-regulation failure. Specifically, the goals of this study were: (I) to identify cases of elderly pedestrian crashes in which the pedestrians subjectively and either partly or totally ascribed the crashes to their self-regulation failures and (II) to develop typologies of the identified cases with respect to (a) the content of the self-regulation, (b) the motivation of the self-regulation, (c) the cause of the self-regulation failure, and (d) the characteristics of the collisions occurring after the self-regulation failure. The ultimate goal of the research was to use the results of I and II to (III) get an overview of the commonalities and variations across such pedestrian traffic incidents. Since pedestrian self-regulation failure is barely investigated in the traffic safety literature, it was considered appropriate to conduct in-depth interviews with a relatively small number of research participants. The consequent typologies and overview of the commonalities and variations should serve as a basis for further quantitative investigations, such as the identification of the types of self-regulation that are more likely to induce elderly pedestrian-vehicle collisions.

The present study's focus on pedestrians seems to be validated considering the fragility of pedestrians in crashes. According to Cabinet Office of Japan (2019), the fatality rate for pedestrians involved in crashes (= the number of fatality divided by the number of those injured \* 100) was 2.6%, which was more than six times larger than the percentage for those in vehicles (i.e., 0.4%). Furthermore, it is estimated that the burden of injury on survivors, as defined by the years lived with disability, is the highest when they are pedestrians (Weijermars, Bos & Stipdonk).

Note that the present study focused on *elderly* pedestrians rather than pedestrians in general. This focus is warranted by the breakdown of pedestrian fatalities by age, which shows that the recent trend of fatal collisions is more problematic for older adult pedestrians. In the U.S., pedestrians aged 70 years or older made up 9% of the entire population but 16% of the pedestrian deaths in 2007 (Chang, 2008). In the Netherlands, almost 50% of the pedestrian fatalities involve people older than 65 (Hummel, 1998). In Japan, about 70% of the pedestrians in fatal accidents are older than 65 years old (Cabinet Office of Japan, 2016). Additionally, even if elderly people survive from crashes, they are known to experience severer after-effects than younger people (e.g., Haukeland, 1996; Weijermars et al., 2016). Adoption of self-regulation failure as a theoretical lens through which to analyze elderly pedestrians seems to be a promising strategy, because the ability to self-regulate is known to decline with age. For example, von Hippel and Ronay (2011) argue that inhibitory mechanisms play the crucial role in self-regulation, and that it is often caused by cortical limitations as a result of old age.

## 2. Background theory and assumption

To investigate the types of elderly pedestrian self-regulation failures and subsequent crashes, the present study utilizes cognitive mapping (Eden, 1992; 2004). A cognitive map is the representation of a person's subjective understanding of how he or she makes sense of the world by seeking to manage and control it. Typically drawn based on information gathered in interview surveys, it usually takes the form of nodes representing ideas that are connected by arrows representing causal relationships. As Eden (2004) stressed, cognitive maps are not simply

“word and arrow” diagrams, because cognitive mapping is a formal modeling technique with rules for its development. Its basis is derived from personal construct theory (Kelly, 1955), which the present study also relies on for its theoretical underpinning. The theory posits that individuals act on their perceptions of the objective world as filtered through their constructive systems rather than passively perceiving the environment (Reger and Huff, 1993). It also posits that bipolar constructs are the primary mechanism individuals use to organize, simplify, and interpret the objective world throughout such a process.

The cognitive mapping technique is often adopted by scholars of problem structuring methods, where it has been shown to be an effective strategy in achieving consensus among diverse groups addressing a problematic situation with “swamp conditions” (Rosenhead, 1992, 2006). Cognitive mapping enables the visualization of different stakeholders' perspectives on what the problem is and how it should be formalized.<sup>1</sup> The present study adopts cognitive mapping for the same reason. As scholars of problem structuring methods take interest in the causal mechanisms behind problematic situations that can be interpreted in multiple ways, the present study deals with the possible causal linkages between vehicle-pedestrian collisions and pedestrian self-regulation failure, which are formed through the pedestrians' subjective interpretation of the incidents. The interpretations are subjective in the sense that the same incidents could have been interpreted in different ways by other stakeholders, such as the vehicle drivers, road administrators, courts, and insurance companies. Representing such subjective interpretations in cognitive maps and finding topological similarities or differences among the maps enable us to develop typologies of crash incidents, as perceived from the standpoints of the involved pedestrians.

It should be noted that the present study deviates from earlier studies on pedestrian-vehicle collisions by adopting personal construct theory as a theoretical underpinning. Previous research on pedestrians focused on risky pedestrian behaviors, e.g., violating a red light traffic signal (Paschalidis et al., 2016; Fu and Zou, 2016), crossing during the clearance phase (i.e., when “Don't Walk” is flashing) (Zhuang et al., 2018), violating traffic safety laws (Ding et al., 2015), and reckless or careless midblock crossing (Holland and Hill, 2010; Dommers et al., 2012; Lobjois and Cavallo, 2009; Oxley et al., 2005; Avineri, 2012) where there is no crosswalk or island. It is true that the present study may also discuss such behaviors as those earlier studies did. However, this research only tangentially touches on risky behaviors—insofar as elderly pedestrians had perceived the necessity of avoiding these behaviors in advance and had retrospectively and subjectively ascribed their crash involvement at least in part to their failure to avoid it. Taking such a peculiar theoretical perspective has the merit of enabling one to shed light on behavior that is well above reproach but may increase the chances of crash involvement as well as behavior that is widely regarded as problematic and risky in the literature.

## 3. Method

### 3.1. Data collection

Interview surveys were conducted with 18 participants who satisfied all the following conditions:

- 1) He or she experienced a crash at the age of 65 or older as a pedestrian, either on the road or in a public space, such as the parking

<sup>1</sup> Ackoff (1979) created the following example to demonstrate how a single problematic situation could be framed in multiple ways: a doctor may see the incapacity of an elderly woman as a result of her weak heart; an architect, as deriving from the fact that she must walk up three flights of steep stairs to the meager room she rents; an economist, as due to her lack of income; a social worker, as a consequence of her children's failure to “take her in,” and so on.

lot of a supermarket.

- 2) The police of the Kochi Prefecture of Japan was notified of the crash.
- 3) He or she was injured in the crash, regardless of whether the crash was treated as a bodily injury accident or damage accident by the police.
- 4) At the time of the interview, fewer than five years had passed since the crash occurred.

Data were collected in the Kochi Prefecture, Japan. Kochi is considered a typical Japanese prefecture. It is located far from the major cities in Japan, such as Osaka, Kyoto, and Tokyo, and it struggles with various social problems, like aging, population decline, and low regional economic growth. Its population stood at 759,700 as of 2017. While it has a major city, Kochi City, with a population of 337,200, forests cover nearly 84% of the total area of the prefecture, and there is an abundance of rural areas.

The recruitment strategy for the study was as follows. In each of the 17 police stations in the Kochi Prefecture of Japan, one staff member is dedicated to the traffic safety of elderly people, both as drivers and pedestrians. Upon the author's request, the specialized staff members visited elderly pedestrians whose traffic accident situations satisfied the aforementioned conditions and asked whether they were willing to accept information from the author regarding the research project. If the answer was positive, the author called the elderly pedestrian, explained the research objective, and invited him or her to participate in the study. The interviews were conducted either in the homes of the participants or in meeting rooms in nearby hotels. Each interview lasted 1.5 to 2 h. Each participant was given 5000 yen for his or her contribution to this research. The interviews were recorded and transcribed verbatim. More than 600 transcribed pages resulted from the 18 interviews.

The interviews were semistructured and gathered the following information:

- 1) The starting point and planned destination of the trip during which the participant was involved in the crash
- 2) The date, time, and location of the crash
- 3) The purpose of the trip
- 4) The car and pedestrian trajectories toward the position of the collision
- 5) Injury sustained by the participant and its effect on his or her life thereafter
- 6) Whether the participant passed through the area on the day of the crash differently from how he or she did regularly

This study was approved by the Ethical Committee of the Kochi University of Technology in the fiscal year of 2014 (reference number: N8-2).

### 3.2. Qualitative data analysis

For each of the 18 interviewees, phrases representing the interviewee's behavior as a pedestrian or events perceived by the interviewee as direct or indirect causes of his or her crash involvement were extracted from the transcriptions. Then a cognitive map of each of the interviewees was drawn, in which the identified phrases were selected as nodes, and the node-to-node connections were made, with arrows representing causal relationships perceived by the interviewees.

One important characteristic of the cognitive map is that the meaning of each phrase extracted from a transcription as a node is represented, along with its contrasting ideas (Eden and Ackermann, 2004) when possible. This strategy stems from personal construct theory (Kelly, 1955), which considers bipolar constructs to be the primary mechanism individuals use to organize, simplify, and interpret the objective world throughout such a process. For example, (1) "Decision to cross a road at intersection A" might be contrasted with (2) "Decision

to cross a road at intersection B" or (3) "Decision to cross a road at the midblock." This example demonstrates how a contrasting idea effectively articulates the meaning of the original idea. In fact, when contrasted with phrase (3), phrase (1) takes on the meaning that the pedestrian has successfully overcome the temptation to adopt a risky route; such a meaning does not emerge when (3) is contrasted with (2). Although the original and its contrasting ideas are conventionally linked with the sign "..." in each node in the literature, the present study connected them with "*rather than*," for the convenience of readers who are not familiar with cognitive maps.

After drawing the 18 cognitive maps, the following procedure was applied:

- 1) Maps including nodes representing the self-regulation failure were identified.
- 2) Nodes in such maps were differentiated based on how they represented (a) the content (type) of the self-regulation, (b) the motivation to self-regulate, (c) the cause of the self-regulation failure, and (d) the characteristics of the subsequent crashes.
- 3) For (a) to (d), typologies of the nodes were developed.
- 4) The merged cognitive map (Eden & Ackermann, 2004) was developed.

In the cognitive map merging process in step 4), similar nodes from different individual cognitive maps are integrated, and new nodes are defined for the merged map. The causal relations among these new nodes are also defined to the extent that similar relations are identified in two or more cognitive individual maps. Thus, the merged cognitive map represents a common structure in the individual cognitive maps; however, this does not imply at all that each individual cognitive map is completely consistent with the merged map. Therefore, the merged cognitive map represents both commonality (*i.e.*, the basic path from the node of the self-regulation failure toward that of crash involvement) and variations (*i.e.*, with respect to the four aspects) among the crash incidents identified in 1). Obtaining the merged map is equivalent to achieving the goal of the present study (*i.e.*, item (III) in the Introduction section).

### 3.3. Text mining

Pedestrians who ascribe their crashes at least in part to their own self-regulation failure are expected to narrate their crash experiences in a different manner from that of others. Specifically, the former may well emphasize the subjective aspect of the crash incident (*i.e.*, their own inner process), whereas the latter may well emphasize the objective aspect of the crash incident (*i.e.*, the motions of the vehicles and themselves as objects). Thus, the following hypothesis can be hypothesized:

**Hypothesis:** We define that a "key verb" for a pedestrian is a verb that he/she utilizes while referring to his/her own motion at the moment of the crash in the interview survey. We also define that a "document" is a series of words stated by a pedestrian in the interview that is not interrupted by the voice of the interviewer. Further, the probability that a pedestrian's key verb in a document is accompanied by the Japanese verb "omou" (*i.e.*, think, believe, feel, and expect) in the same document is higher when a pedestrian ascribes his/her crash at least in part to his/her own self-regulation failure.

We calculate the overall probabilities for the two pedestrian groups (*i.e.*, those who ascribe their crashes at least in part to their self-regulation failure and the rest) and test whether these probabilities are distinct from one another using the chi-squared test of independence. The verification of this hypothesis will partially support the validity of the author's judgment in determining whether each participant ascribed his/her crash experience at least in part to his/her own self-regulation failure.

**Table 1**  
List of participants.

Name	Gender	Age <sup>1</sup>	Location category <sup>2</sup> (Population density)	Month of crash	Time of crash	Rainy Weather	Location of crash	Pedestrian's Behavior <sup>3</sup>	Pedestrian's Injury
A	Female	73	Urban (1079/km2)	April	Evening (After sunset)	No	Midblock	Crossing a road	Fracture of spine
B	Female	80	Rural (379/km2)	April	Afternoon	No	Signalized intersection	Crossing a road	Cervical contusion <sup>4</sup>
C	Female	72	Rural (51/km2)	January	Afternoon	No	Parking lot	Walking along a passage	Head bruise
D	Female	77	Rural (379/km2)	December	Evening (Before sunset)	No	Parking lot	Walking inside parking lot	Fracture of spine
E	Female	73	Urban (1079/km2)	July	Around noon	Yes	Midblock	Crossing a road	Fracture of right wrist
F	Female	74	Rural (51/km2)	September	Around noon	No	Signalized intersection	Crossing a road	Bruise of left leg and ribs
G	Female	66	Urban (1079/km2)	May	Around noon	No	Unsignalized zebra	Crossing a road	Bruise of left and right knees
H	Male	77	Rural (47/km2)	December	Morning (Before sunrise)	No	Unsignalized intersection	Crossing a road	Cervical contusion
I	Female	76	Rural (51/km2)	January	Afternoon	No	Parking lot	Walking inside parking lot	Head bruise
J	Male	85	Urban (1079/km2)	December	Late at night	Yes	Midblock	Walking along a road	Bruise of left and right knees
K	Female	73	Rural (289/km2)	October	Morning (After sunrise)	No	Parking lot	Getting out of a car	Fracture of the big toe
L	Male	83	Urban (1079/km2)	August	Afternoon	Yes	Signalized intersection	Crossing a road	Bruise of waist
M	Female	81	Urban (1079/km2)	October	Evening (After sunset)	No	Unsignalized intersection	Crossing a road	Fracture of left toes
N	Female	66	Rural (289/km2)	April	Morning (After sunrise)	No	Midblock	Sitting at the edge of the path	Bruise of waist
O	Female	69	Rural (50/km2)	October	Evening (Around sunset)	No	Midblock	Walking along a path	Cracked spine and hipbone
P	Male	68	Rural (50/km2)	August	Night	No	Unsignalized zebra	Crossing a road	Fracture of ribs
Q	Male	68	Urban (1079/km2)	September	Around noon	No	Sidewalk	Entering into a lunch vendor	Bruise of waist
R	Female	75	Rural (379/km2)	April	Evening (Before sunset)	No	Midblock	Walking along a road	Bruise of right arm

Participant	Driving License <sup>1</sup>	Driving Habit	Remarks
A	Unknown	No	
B	Unknown	No	
C	Yes	Yes	
D	Unknown	No	
E	Possibly No	No	There was a statement "I know nothing about cars".
F	Unknown	No	
G	Unknown	No	
H	Unknown	No	
I	Yes	No	He has a license of motor bikes, but it is not clear if he has a car license.
J	Yes	Yes	
K	Yes	Yes	
L	Yes	Yes	
M	Yes	Yes	
N	Yes	Unknown	
O	Unknown	Unknown	He has a license of motor bikes, but it is not clear if he has a car license.
P	Yes	Yes	
Q	Yes	Yes	
R	Unknown	No	

Notes. 1: Age of participants when they encountered crashes. 2: It is tentatively defined that the locations of crashes are urban if the locations are in the municipalities with the population density of 1000 people/km2. 3: Pedestrian's behaviors at the moments of the crashes. 4: Head bruise with a sequela due to the brain damage.

Note. 1: This refers to the licence of cars rather than motor bikes, unless otherwise stated.

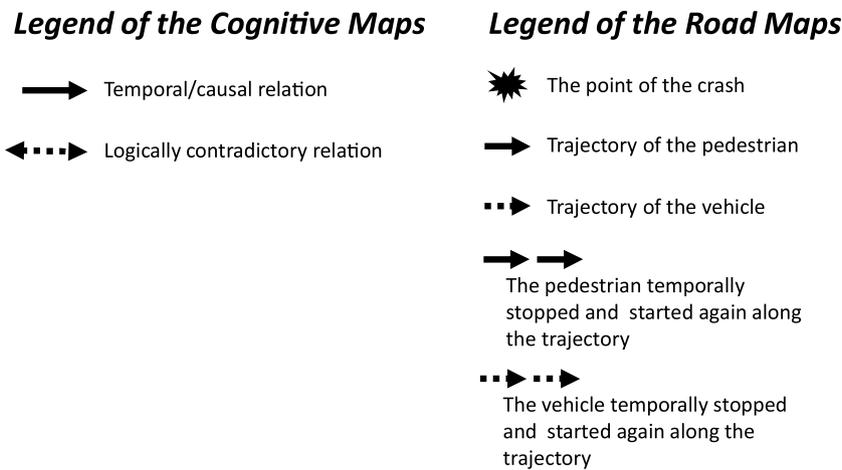


Fig. 1. Legends of Figs. 2 to 7.

#### 4. Results

Data were collected from 18 participants. They were named Participant A to Participant R. Each participant had experienced a single crash incident. The 18 crash incidents are summarized in Table 1. The mean and the standard deviation of the ages of the 18 participants were 74.2 and 5.6, respectively. The population densities of the municipalities where the 18 crashes occurred ranged between 47 and 1079 people/km<sup>2</sup>, thus suggesting that data were collected from diverse areas, *i.e.*, from rural to urban. Table 1 (continued) presents data on whether or not the participants had driving licenses and had the habit of driving at the time of the interview. The cognitive maps of the 18 participants are shown in Figs. 2–6, where nodes are labeled by combining the participant names (A to R) and numerals (*e.g.*, the nodes of Participant A were labeled as A1 to A12). Legends of the figures are shown in Fig. 1.

Eleven of the 18 participants (A to K) ascribed their involvement in the crash at least in part to their own self-regulation failures. The labels of the nodes representing the pedestrian self-regulation failure are A9, B11, C7, D6, E6, F7, G10, H11, I6, J3, and K5. For the other seven incidents (L to R), the perceived causes were the vehicle driver's lapse in attention (L8, M5, N5, O5, P6, Q4, R6) or the pedestrian's own behavior, which the pedestrian considered to be usual and unproblematic when he or she was involved in the crash (M4, N2).

The analytic procedure described in subSection 3.2 was applied to the aforementioned 11 participants to develop typologies and establish the merged map.

##### 4.1. Typology based on the self-regulation type

Each participant possessed and violated self-regulation when the crash occurred; the type of the self-regulation varied and is summarized in Table 2. While nine of the 11 participants' self-regulation (participants A to I) types were location specific, the others (J and K) were general; the latter two were general because they were based on adopting specific transportation modes (not being a passenger of drivers of a similar age (J4) and only taking trams to a specific destination when going home (K1)<sup>2</sup>). The types of self-regulation for participants A to I were further classified into two groups: avoiding crossings at specific locations (A3, B5, C3, D4, E3, and F5) and avoiding specific ways to make crossings at specific locations (G5, H6, and I3) (Tables 3–5).

<sup>2</sup> This rule was applied when participant K went home from the city center. Regardless of the stops, he took trams. Thus, this rule was considered location specific.

##### 4.2. Typology based on the motivation for self-regulation

The reasons the participants possessed self-regulation also varied. Ten out of the 11 participants practiced self-regulation for the sake of their own safety, while the remaining participant (participant K) did so for transportation convenience. The latter was considered an exception among the participants, and thus was not included in the development of the typology. The motivation for the remaining ten to self-regulate was classified into three groups: the perception of one's own physical decline (A2, D3, and K1), local knowledge on the crash risk in familiar places (B1, C2, D3, F4, G1, H4, and I2), and pressures from family members or others (D2, E2)

##### 4.3. Typology based the cause of self-regulation failure

Following Huberts et al. (2014), the cause of self-regulation failure was classified into unjustified failure (H11 and J2) and justified failure. Furthermore, the present study classified the latter into two sub-categories: justification based on the pedestrian's judgment that the goal of traffic safety had been guaranteed or complemented even without adhering to self-regulation (A7, B8, E4, G10, and I6) and justification due to the decision to prioritize goals other than traffic safety, such as time efficiency (C6, E4, F6, and K3). Consistent with the literature suggesting that the reflective process is much more responsible for self-regulation failure than it was previously believed to be (Huberts et al., 2014; Rawn and Vohs, 2011), the present study found that in a non-negligible number of crash incidents, justified self-regulation failure led to crashes. This finding has an important practical implication and will be discussed later.

##### 4.4. Typology based on the characteristics of the subsequent crashes

As explained earlier in Section 4.1, some participants possessed their own self-regulation as pedestrians, which suggests that they clearly anticipated specific types of crashes they could be involved in and would like to avoid. This enables us to classify the crashes according to whether they were *expected* in advance by the pedestrians (B12, C9, F7, G10, and H13) or *unexpected* (A10, D7, E8, I8, J4, and K8). It should be noted that this distinction has some ambiguity; although crashes are classified as unexpected, it does not mean that they were totally unexpected. For example, in the case of participant A, she was aware in advance of the possibility that a dangerous crossing at the midblock would lead to a crash. Indeed, she encountered a crash while crossing at the midblock. What made this crash unexpected for her was that the vehicle involved in the crash was a motor bike; it was more difficult for a pedestrian to recognize than a car.

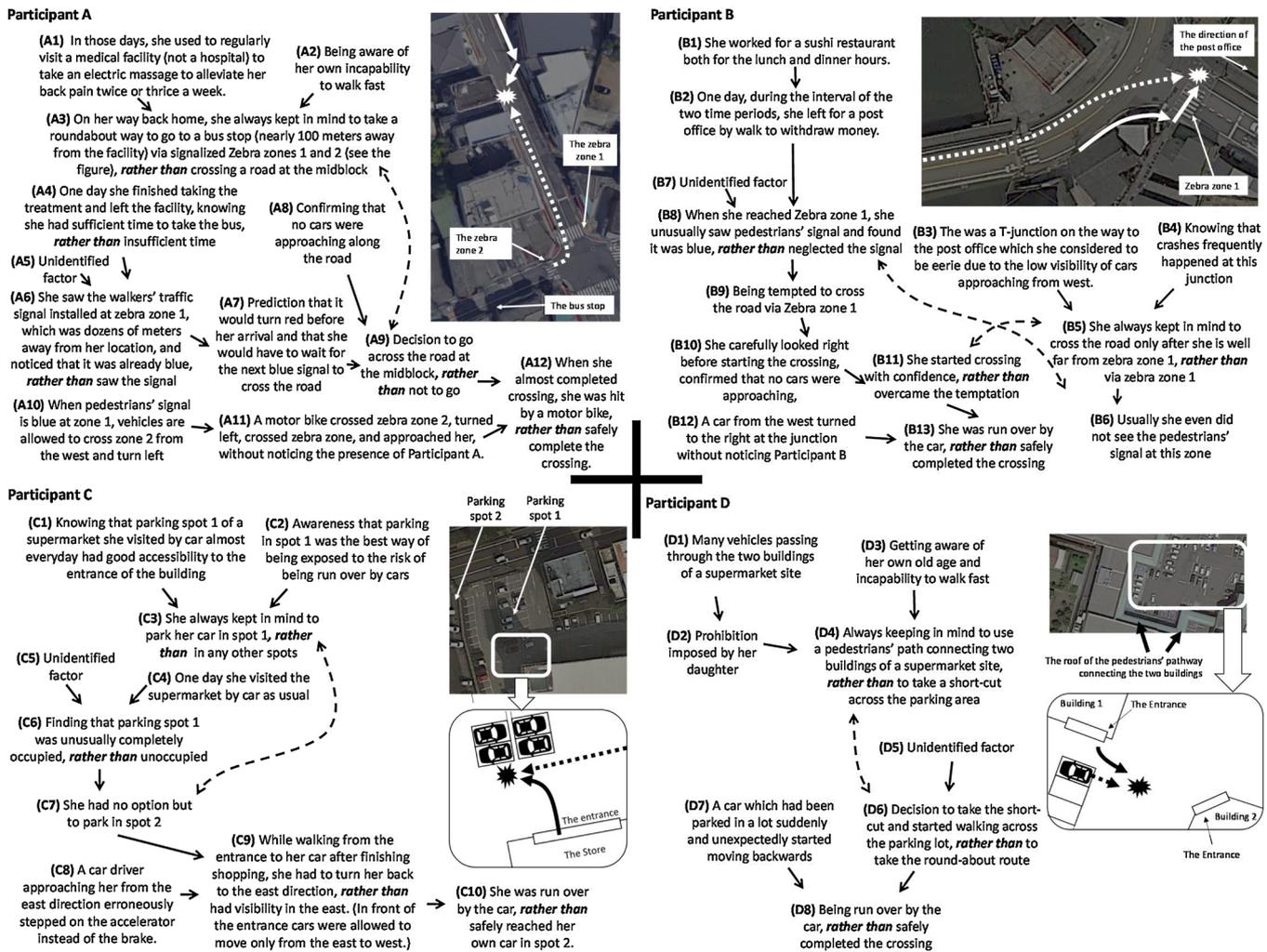


Fig. 2. Cognitive maps of participants A to D.

4.5. The merged cognitive map

The 11 cognitive maps of participants A to K were merged into a single map in Fig. 7 that shows the commonalities and varieties among the participants explicitly. In doing so, the typologies developed in subSections 4.1 to 4.4 are fully considered. Specifically, the merged map consists of two fundamental causal/temporal flows: from the variety of reasons to self-regulate (b) to the possession of different types of self-regulation (a), and from the variety of motivation to self-regulate (c) to the two types of subsequent crashes (d). These two causal/temporal flows are related in that the elements of (a) contrast with those of (c). The elements in category (a), (b), (c), and (d) are derived from the typology developed in subSections 4.1, 4.2, 4.3, and 4.4, respectively.

The links from (c) to (d) indicate the 11 participants' perception that unjustified or justified self-regulation failure is a cause of their crashes. At the same time, item (11) "Unexpected appearance of a careless vehicle driver" indicates that the external factors also influenced the crashes for all 11 participants. However, a considerable variety exists associated with the extent to which such external factors contribute to the crash occurrence (and thus the extent to which the pedestrian blames the vehicle drivers); this variation is not represented in Fig. 7 for technical reasons. In fact, while some participants believed vehicle drivers were almost totally at fault for the crashes (e.g., participants G and H), others believed they (the pedestrian) were totally at fault (e.g., participants A and J). Participant A even felt sorry for involving the vehicle driver in the crash, though the midblock at which the

participant crossed was not designated as a noncrossing zone.

Further, one important thing should be noted. The extent to which a pedestrian blames himself/herself is dependent not only on the perceived contribution of the external factors but also on the frequency in which he/she has violated self-regulation. For example, the extent to which the participant H believed he/she is to blame was very small. It was not only because the driver was totally at fault from a legal viewpoint but also because the frequency that the participant H had failed to self-regulate (i.e., to look around while crossing) was so high in winter times that the violation was almost normal for him/her.

4.6. Text mining result

First, the key verb (i.e., the verb a participant uses while representing his own motion at the moment of the crash) was identified in each of the 18 transcriptions. The verb "wataru" (i.e., cross over) was identified for the participants A, B, C, E, F, H, L, P, and Q, the verb "tooru" (i.e., pass through) was identified for the participants G and M, the verb "aruku" (i.e., walk) was identified for the participants O and R, the verb "deru" (i.e., go out) was identified for the participants D and I, the verb "iku" (i.e., go) was identified for the participant J, the verb "oruru" (i.e., get off (a vehicle)) was identified for the participant K, and the verb "suwaru" (i.e., sit down) was identified for the participant N.

Second, the frequency of (i) the key verbs, (ii) the verb "omou" (i.e., think, believe, feel, or expect), and (iii) the co-occurrence of the key verb and the verb "omou" were estimated (Table 6). Note that Table 6

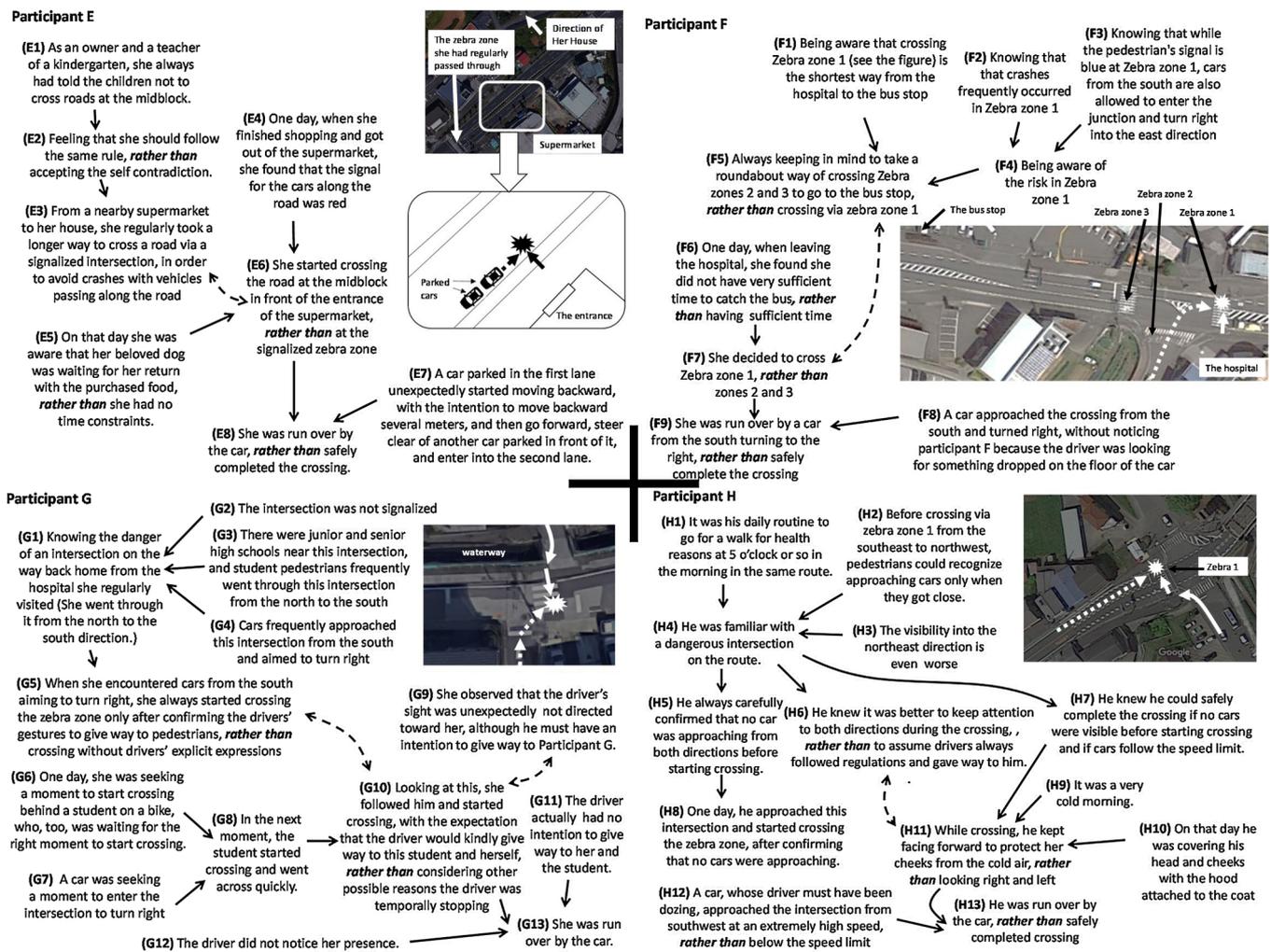


Fig. 3. Cognitive maps of participants E to H.

also reports the Jaccard index for each participant. In the context of the present study, this index represents the extent to which the two sets of documents<sup>3</sup>, including (i) and (ii), overlap and takes a value between 0 and 1. The larger the score, the larger will be the extent.

Third, the numbers obtained in Table 6 were aggregated. The frequencies of the key verbs (i) accompanied by “omou” and (ii) not accompanied by “omou” were specifically calculated for groups of participants (A–K and L–R). The probabilities that the key verbs are accompanied by “omou” were 32.6% and 17.3% for groups A–K and L–R, respectively. The chi-squared test of independence revealed that this difference was significant at the 0.1% level. Thus, the hypothesis in the Method section was verified.

## 5. Discussion

Although several studies reported on elderly driver self-regulation as a means of avoiding crashes, to the best of the author’s knowledge, no studies have ever reported that elderly pedestrians also self-regulate. The present study is the first to do so. Our most important contribution to the literature on elderly road user safety lies in identifying cases of pedestrian–vehicle crashes that pedestrians subjectively ascribe to be at

least in part due to a violation of their self-regulation, which they had possessed for their own safety and other purposes. Although statistics derived from a qualitative study with a limited sample size cannot be generalized, the finding that self-regulation failure was perceived to be a cause of the crash in 11 of the 18 cases suggests that the percentage is not negligible.

Two things should be noted regarding the findings. First, with regard to the self-regulation type, it was found that some of our participants avoided road crossing in a specific manner at a specific location, while others avoided a specific transportation mode. It is interesting to compare this result with those found in the literature on the self-regulation of elderly people who *drive*. Molnar et al. (2013) classified elderly driver self-regulation into strategic regulations (*i.e.*, occurring during the general planning stage of a trip, such as mode of transit, driving route, and conditions under which to drive) and tactical regulations (*i.e.*, actual maneuvers drivers make in traffic, such as in the speed choice, passing, and using the radio, which may be distracting). Considering these classifications, a pedestrian’s avoidance of a specific transportation mode can be considered a strategic regulation, while a pedestrian’s avoidance of road crossing in specific manners at specific locations can be considered a tactical regulation. A pedestrian who avoids road crossings at specific locations can be seen as falling between these two types. This said, there is a critical difference between the elderly driver and pedestrian self-regulation. It is true that the literature on elderly driver self-regulation and the present study consistently referred to some elderly drivers and pedestrians who were cautious in driving or walking at specific locations. However, while the

<sup>3</sup> Frequency of the term or the pair of two terms as measured by the number of documents at which it appeared. A document is defined to be a series of words stated by the interviewee that was not interrupted by the interviewer’s voice.

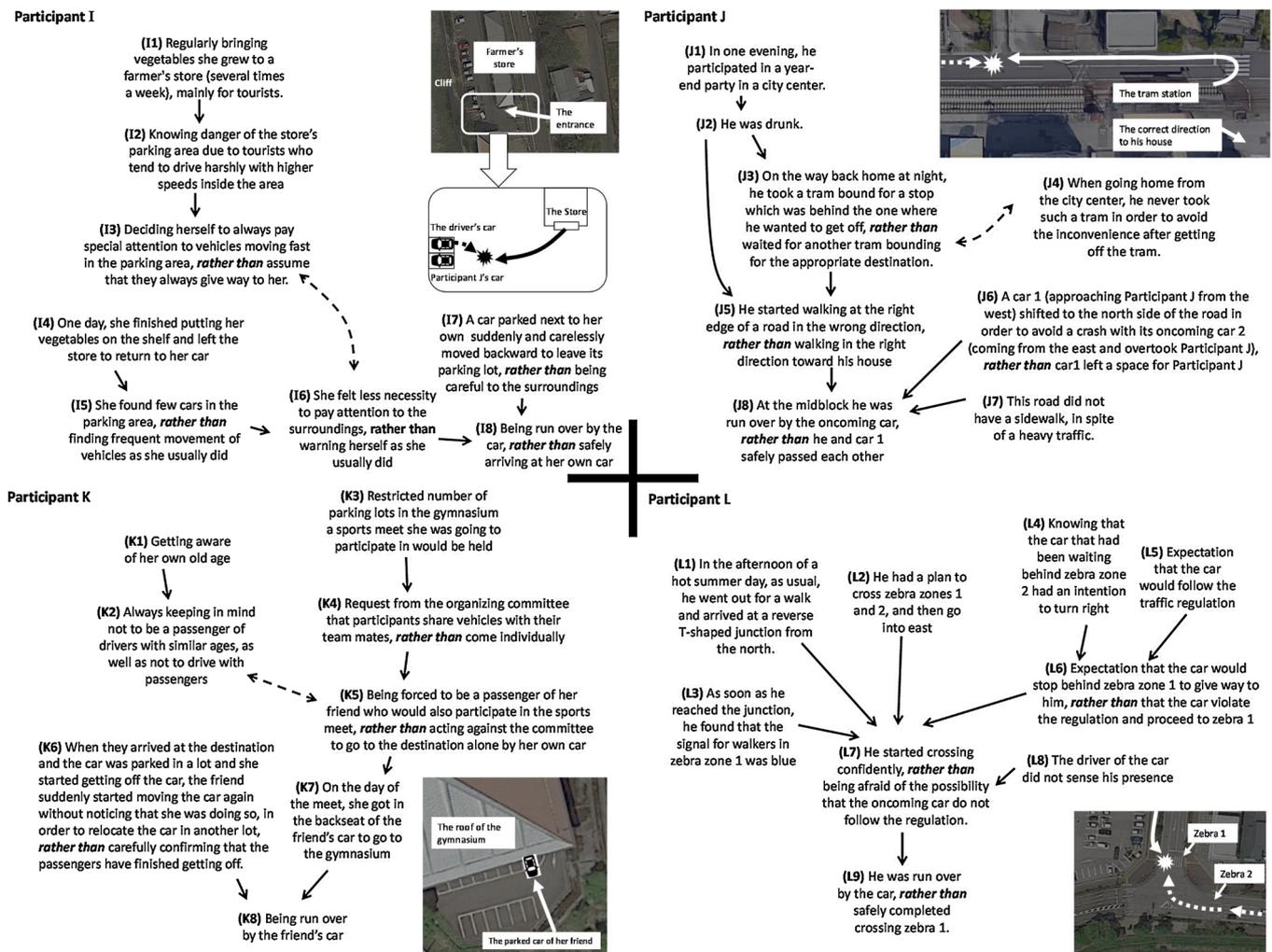


Fig. 4. Cognitive maps of participants I to L.

former tended to focus on a small number of typical locations (e.g., areas unfamiliar to drivers, areas requiring right turns, freeways, high-traffic roads, traffic circles, tunnels (D'Ambrosio et al., 2008; Sullivan et al., 2011)), possibly with the expectation that different elderly drivers are similarly unwilling to drive in locations with common characteristics, the present study found that the characteristics of the locations where pedestrians became cautious varied, e.g., from a supermarket parking lot (Participant C of this study) to an “eerie” T-junction (Participant B of this study), thus suggesting that a location that seems dangerous for an elderly pedestrian may not seem so for other pedestrians. This subjectivity has important practical implications, which will be discussed later.

Second is regarding motivation to self-regulate. Studies on elderly drivers consistently argue that elderly drivers self-regulate not only due to age-related decline but also due to changes in preferences or lifestyle, such as a general feeling of discomfort (Molnar et al., 2013), disliking or feeling insecure about driving in particular situations (Meng and Siren, 2015), having fewer activities to engage in (Meng and Siren, 2015), and family pressure (although this may well be the consequence of the age-related decline) (Peel et al., 2002; Adler and Rottunda, 2006; Choi, Adams and Mezuk, 2006). The present study identified both age-related decline and other factors as the reasons pedestrians self-regulate. However, a major difference between elderly drivers and pedestrians should be noted. Regarding age-related decline, while the literature on driver self-regulation has identified a variety of factors, including physical, cognitive, and visual ones (e.g., Rudman et al., 2006), the present study identified only the decline in the ability to walk quickly as a factor.

The present study reveals five important strategies for reducing elderly pedestrian crash involvement while taking into consideration that pedestrians may subjectively ascribe their crash involvement at least in part to their own self-regulation failures. First, in the literature on pedestrian safety, it seems to be widely agreed that educational measures teaching pedestrians how to cope in a traffic environment are an essential component of any strategy (e.g., Duperrex, Bunn, and Roberts, 2002a). In fact, many studies on educational programs for pedestrians measure the extent to which knowledge acquisition, attitudes, and behaviors are widely recognized as correct (see Duperrex, Roberts, and Bunn (2002a) and Duperrex, Bunn, and Roberts (2002b) for reviews of such studies). Although these kinds of interventions seem meaningful, especially for child pedestrians, the present study suggests that they are not sufficient. We also need interventions for elderly pedestrians who already possess such knowledge and attitudes but nevertheless engage in risky behaviors they personally believe is incorrect when they are tempted to behave differently.

Second, as noted in Section 2, earlier studies on elderly pedestrian crashes have focused on pedestrian behavior that is widely recognized as dangerous, such as violations of the red light indication, crossing during the clearance phase, violation of road traffic safety laws, and reckless or careless crossing at the midblock. The present study enlarges the scope of interest and sheds light on correct behavior that pedestrians ascribe their crashes to, such as crossing signalized crosswalks during the blue light indication.<sup>4</sup> We do not demonstrate that such

<sup>4</sup> See cognitive maps of participants B and F.

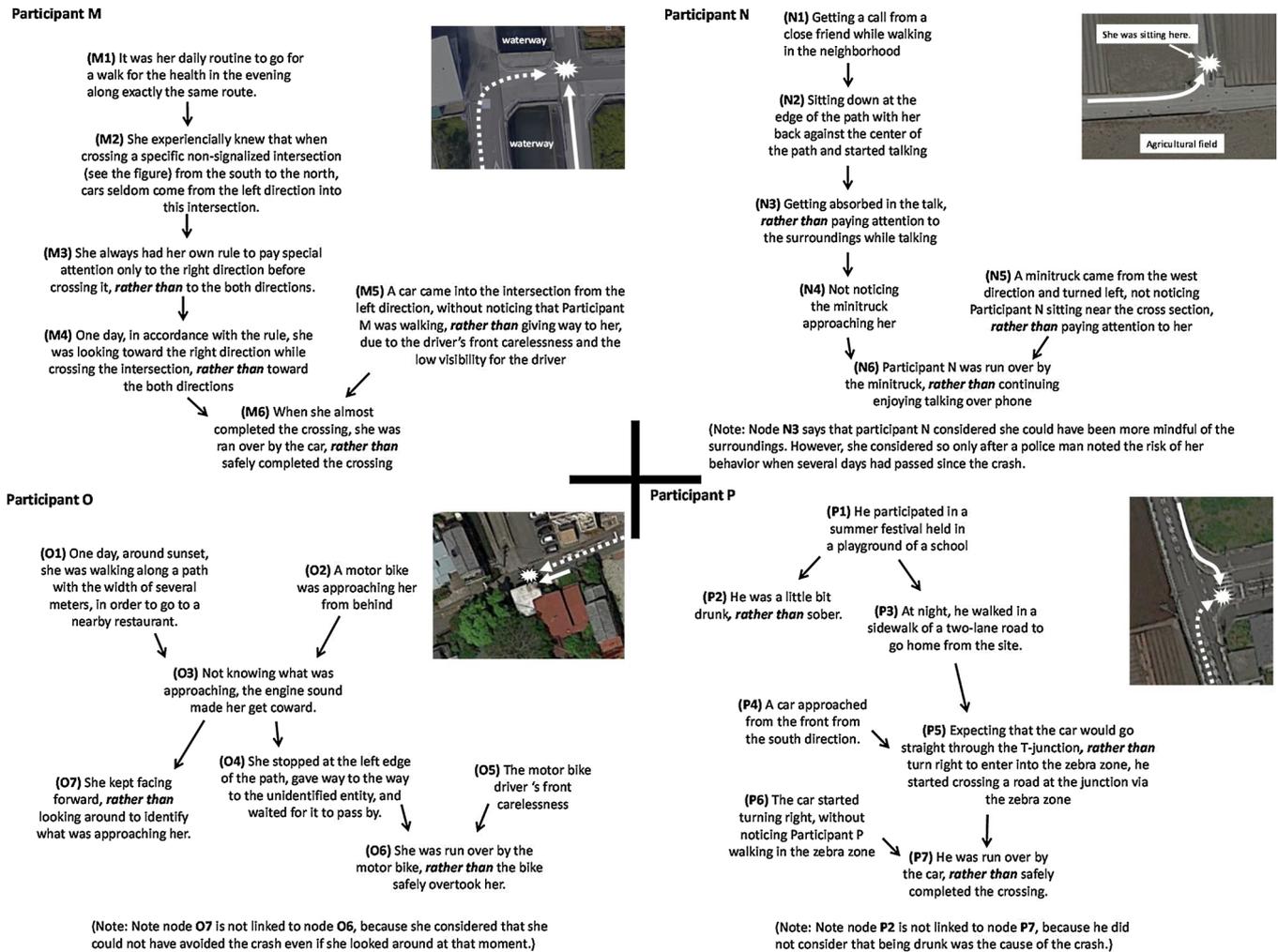


Fig. 5. Cognitive maps of participants M to P.

behavior is problematic. Rather, it demonstrates that despite the soundness of such behavior from legal and ethical viewpoints, correct behavior can be the target of interventions aiming to prevent elderly pedestrian-vehicle crashes. This unique practical implication is the consequence of adopting the personal construct theory as the present study's theoretical underpinning.

Third, the present study found that in a non-negligible number of crash incidents, self-regulation failures leading to crashes was justification induced rather than impulse induced. In such incidents, the reflective system of the pedestrian must be active when he or she decides to violate his or her self-regulation. Thus, the pedestrians “still have the capacity to self-regulate” (Huberts et al., 2014; p. 134). This suggests

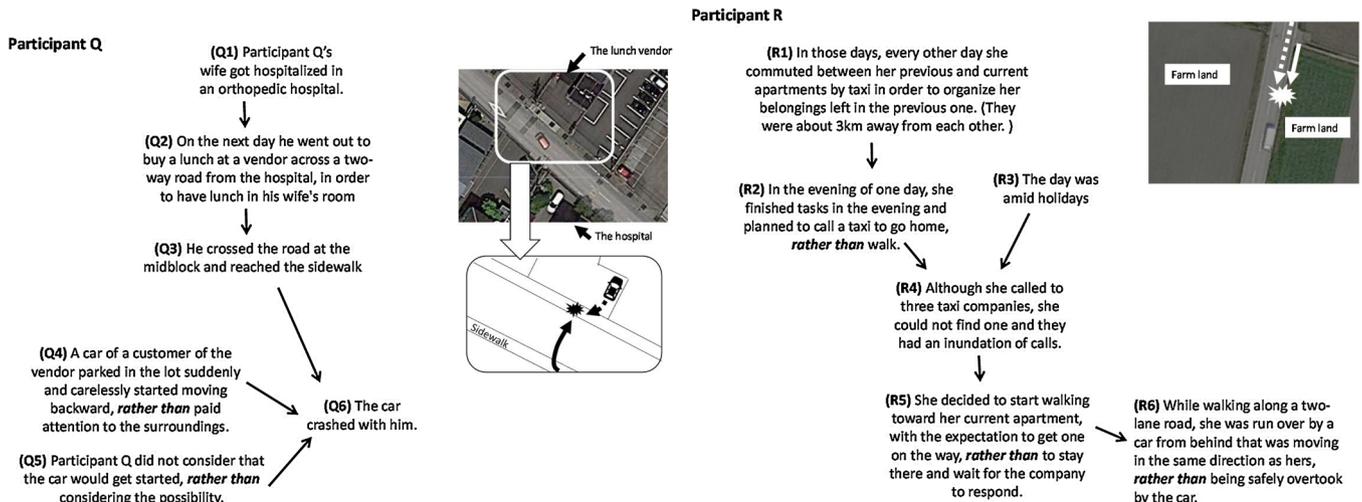


Fig. 6. Cognitive maps of participants Q to R.

**Table 2**  
The contents of self-regulation.

Participant	Self-regulation content (Corresponding cognitive map node number)	Type of the self-regulation		
		(I) To avoid a dangerous crossing at a specific location	(II) To cross in a specific manner at a specific location	(III) To avoid a specific trans-portion mode
A	Not to cross a road at a specific midblock (A3)	✓		
B	Not to cross a road through a specific signalized crosswalk (B5)	✓		
C	To park at a specific area near a supermarket (C3)	✓		
D	Not to take a short-cut to cross the parking lot of a supermarket (D4)	✓		
E	Not to cross a road at a specific midblock (E3)	✓		
F	Not to cross a road through a specific signalized crosswalk (F5)	✓		
G	To cross at a specific non-signalized intersection only after waiting for vehicle drivers to show confirming gestures (G5)		✓	
H	To keep attention on vehicles while crossing a specific non-signalized crosswalk (H6)		✓	
I	To keep attention on vehicles in the parking lot of a specific market (I3)		✓	
J	To take direct trams to go home from the city center (J4)			✓
K	Not to be a passenger in cars driven by elderly persons (K2)			✓

**Table 3**  
The motivations to self-regulate.

Participant	The motivation to set and adhere to self-regulation (corresponding cognitive map node number)	Type of the motivation to adhere to self-regulation			
		(I) Physical decline	(II) Local knowledge	(III) Social pressure	(IV) Other
A	It was risky to cross at the midblock because she could not walk fast (A2)	✓			
B	She knew crashes frequently happened at the location (B1)		✓		
C	To minimize the risk while walking from the car to an entrance (C2)		✓		
D	It was risky to take a short-cut because she could not walk fast (D3) /Her daughter had strongly recommended her not to do so (D2)	✓	✓	✓	
E	As a kindergarten owner, she always told children not to cross at the midblock (E1, E2)			✓	
F	She knew crashes frequently happened at the location (F4)		✓		
G	She knew crashes frequently happened at the location (G1)		✓		
H	He knew the visibility is not very high at the location (H4)		✓		
I	She knew crashes frequently happened at the location (I2)		✓		
J	To avoid transfers after getting off the tram (J4)				✓
K	She believed elderly drivers had higher crash risk (K1)	✓			

**Table 4**  
The causes of the self-regulation failure.

Participant	Cause of the failure (corresponding cognitive map node number)	Type of the cause of the failure	
		(I) Unjustified failure	(II) Justified failure (a) Perceived complemented goal of safety (b) Prioritizing goals other than safety
A	The tempting phase of the traffic signal (A7)		✓
B	The tempting phase of the traffic signal (B8)		✓
C	No available parking spots in the accustomed area near the supermarket (C6)		✓
D	Not knowing what tempted her to violate her self-regulation (D5)		
E	The tempting phase of the traffic signal (E4)	✓	✓
F	Feeling that she did not have enough time to catch the next bus (F6)		✓
G	Optimistically assuming the vehicle driver intended to give her the right of way (G10)	✓	
H	To look around seemed uncomfortable in the very cold morning (H11)	✓	
I	Let her guard down because only a few vehicles were moving (I6)	✓	
J	Being drunk prevented him from making a rational choice (J2)	✓	
K	Being prohibited from going to the destination individually due to the lack of parking spots (K3)		✓

that justification-induced self-regulation is “more amenable to change, and therefore creates opportunities for interventions” (*ibid.* p.134) when compared with impulse-induced self-regulation. Thus, scholars and practitioners should consider how the reflective systems of elderly pedestrians contribute to the avoidance of self-regulation rather than to

the justification of self-regulation. Although we cannot provide a complete answer to this difficult problem, sharing the narratives of pedestrians who experienced crashes and regretted their self-regulation failures, such as the ones collected in the present study, seems to be a promising strategy.

**Table 5**  
The characteristics of the subsequent crashes.

Participant	Consequence of the self-regulation failure (corresponding cognitive map node number)	Type of the consequent crash	
		(I) Expected	(II) Unexpected
A	Crashing with a motor bike while crossing a road at the midblock (A10)		✓
B	Crashing with a car while crossing the signalized crosswalk (B12)	✓	
C	Crashing with a car while walking in a parking lot in an unfamiliar direction (C9)	✓	
D	Crashing with an unmarked parked car that unusually and quickly started backward while she was crossing a parking lot (D7)		✓
E	Crashing with an unmarked parked car that unusually started backward while she was crossing at the midblock (E8)		✓
F	Crashing with a car while crossing the signalized crosswalk (F7)	✓	
G	Crashing with a car while crossing the unsignalized crosswalk (G10)	✓	
H	Crashing with a car while crossing the unsignalized crosswalk (H13)	✓	
I	Crashing with an unmarked parked car that suddenly started backward, while walking to her own parked car (I8)		✓
J	Crashing with a car while walking in the wrong direction (J4)		✓
K	Run over by the friend's car when she almost got out of it (K8)		✓

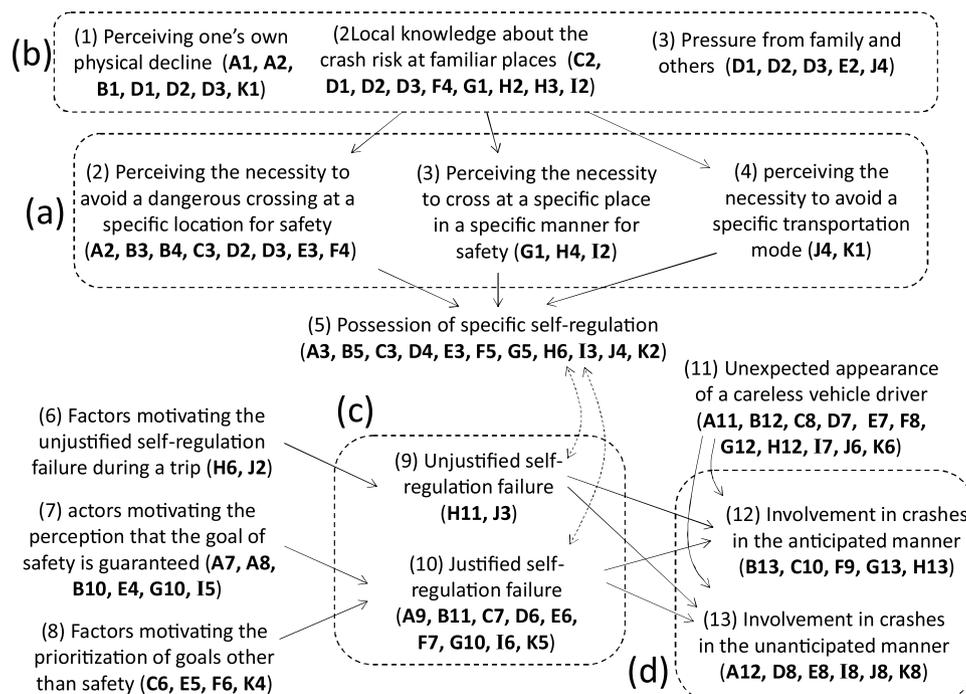
Fourth, the present study found in subSection 4.4 that while some self-regulation failure led to the types of crashes pedestrians had anticipated in advance, other failure led to unanticipated crashes. This suggests that pedestrian self-regulation could contribute to the avoidance of crashes the pedestrian does not anticipate. In other words, the benefit of sticking to self-regulation can be larger than the pedestrian believes it to be. Making pedestrians aware of this may be another strategy for enabling pedestrians to activate their reflection systems to protect their self-regulation.

Finally, the findings of the present study suggest that elderly pedestrians exercise caution and set their self-regulation in a variety of locations for subjective reasons. Thus, while it is possible for scholars to develop typologies of pedestrian self-regulation, such as the typologies the present study developed, it seems difficult to prepare a comprehensive list of types of self-regulation, such as the ones proposed by studies of elderly driver self-regulation (e.g., D'Ambrosio et al., 2008; Sullivan et al., 2011). Practitioners should keep in mind that an elderly pedestrian can identify his or her own self-regulation by carefully reflecting on what he or she thinks is safe in each location as a pedestrian rather than by simply letting the pedestrian choose a self-regulation from a comprehensive list of possible self-regulation types. People

around the elderly pedestrian, such as family members and practitioners, can only encourage him or her to be aware of his or her personal self-regulation (or encourage him or her to define self-regulation if he or she does not knowingly possess it yet) and regularly remind him or her of the importance of not violating it.

To summarize, this study results in five practical strategies for the prevention of vehicle-pedestrians crashes caused by pedestrian self-regulation failures. It demonstrates the necessity of interventions that extend beyond merely informing elderly pedestrians what behaviors are right and wrong in traffic environments. The interventions should motivate the pedestrians to cherish their highly personal self-regulation methods, even if violating it is not against the social norm. Suggesting the possibility that their own self-regulation is more beneficial in terms of safety than they believe is one of several promising strategies to prevent the justification-induced failure of self-regulation. Intervention to motivate pedestrians to avoid temptation-induced failure is also required and is likely to be a more challenging task.

This study has two important limitations. First is on the clarity of the concept of self-regulation. As suggested in the case of participant H (see footnote 3), some pedestrians fail to self-regulate more frequently than others. If the frequencies are too high, it seems inappropriate to



**Fig. 7.** The merged cognitive map. The meanings of the notations (a)–(d) are as follows: (a) the content (type) of the self-regulation, (b) the motivation to self-regulate, (c) the cause of the self-regulation failure, and (d) the characteristics of the subsequent crashes.

**Table 6**  
Text Mining Result.

Participant	A) The verb representing the participant's action at the moment of the crash	(B) Frequency <sup>1</sup>			C) Jaccard Index
		The verb listed in (A)	"Omou" (i.e., presume)	Co-occurrence	
A	"wataru" (i.e., cross over)	83	137	49	0.29
B	"wataru" (i.e., cross over)	73	81	31	0.25
C	"wataru" (i.e., cross over)	13	32	0	0.00
D	"go out" (i.e., go out)	25	64	11	0.14
E	"wataru" (i.e., cross over)	20	46	9	0.16
F	"wataru" (i.e., cross over)	68	30	7	0.08
G	"tooru" (i.e., path through)	35	59	20	0.27
H	"wataru" (i.e., cross over)	26	15	0	0.00
I	"deru" (i.e., go out)	32	49	0	0.00
J	"iku" (i.e., go)	41	13	7	0.15
K	"oriru" (i.e., get off (a vehicle))	10	25	5	0.17
L	"wataru" (i.e., cross over)	13	20	0	0.00
M	"tooru" (i.e., path through)	27	64	0	0.00
N	"suwaru" (i.e., sit down)	11	37	0	0.00
O	"aruku" (i.e., walk)	8	73	2	0.03
P	"wataru" (i.e., cross over)	4	11	1	0.07
Q	"wataru" (i.e., cross over)	10	33	3	0.08
R	"aruku" (i.e., walk)	37	65	13	0.15

Note. 1: Frequency of the term or the pair of two terms as measured by the number of documents where it appeared. A document is defined to be the series of words stated by the interviewee that was not interrupted by the interviewer's voice.

regard such pedestrians as possessing self-regulations. However, the present study did not define what should and should not be called a self-regulation. It is important in the future to enhance the clarity of this concept. Second, this study did not obtain any meaningful findings for vehicle-pedestrian crashes where pedestrians a) ascribe the crashes either to vehicle drivers' carelessness and risky behaviors or b) to their own (pedestrian) behaviors that they believed were not unusual or problematic rather than to their self-regulation. In the present study, seven of the 18 cases were of this type. To better understand such incidents, it should be necessary to collect narratives from both the vehicle drivers who collided with the pedestrians and the pedestrians.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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