Measurement of Situation Awareness on Pedestrians: An exploratory study

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Abstract

Walking is an everyday activity. This automatic behavior triggers pedestrians to perform secondary activities, such as operating a mobile phone. Operating mobile phones while walking can cause cognitive impairment as well as reduced situation awareness (SA). Low SA can increase unsafe behavior among pedestrians. With the increasing dynamics of the pedestrian environment, pedestrians will be more susceptible to injury than other road users. Measurement of SA on pedestrians is one of the efforts to control pedestrian safety. This research is an exploratory study that examines the effect of secondary activities on pedestrians and the appropriate measurement method to assess SA in that condition. The result is a proposed combination of more than one method as the method that is effective to match different characteristics of pedestrian environments. It is hoped that multi-methods will be able to find out what occurs to attention and motor demands on pedestrian secondary activities in order to control safety in the pedestrian environment.

Keywords
Dual activities, Measurement, Pedestrians, and Situation Awareness.

1. Introduction
In carrying out daily activities, walking is the most basic mode of transportation (Lin and Huang 2017). This activity is generally repeated every day, so pedestrians can do it without much cognitive consideration. Walking is an automatic behavior that requires little or even no attention to the surroundings (Harms et al. 2019). In the future, as road users are increasing, the pedestrian environment will be more complicated. Each road user has their own perception of their environment (Walker et al. 2011, Salmon et al. 2013). Differences in perception have the potential to cause conflicts between pedestrians and other road users (Tong et al. 2018). While not being equipped with personal protection, pedestrians are more prone to injury than other road users (Lin and Huang 2017).

Automatic behavior when walking causes pedestrians to feel able to perform secondary activities. In practice, secondary activities will distract people from their walking activity (Harms et al. 2019). Meanwhile, along with the development of cellular technology, various features on smartphones make users more productive even when they are traveling (Pizzamiglio et al. 2017). These devices allow users to engage in social networking, games, video streaming, and various other mobile applications (Lin and Huang 2017). A survey conducted by the American Academy of Orthopedic Surgeons (2015) with 2000 respondents concluded that one third of the respondents claimed to have done dual activity such as using a smartphone while walking. Meanwhile, 85% of all respondents said they had seen pedestrians doing non-verbal activities with their smartphones. In fact, operating smartphones while walking can cause cognitive impairment as well as reducing SA (Lamberg and Muratori 2012, Lim et al. 2015). A low SA can increase unsafe behavior among pedestrians (Nasar and Troyer 2013), for example, when crossing the road (Nasar et al. 2008) or maintaining path direction (Kao et al. 2015).

SA means knowing what is going on around us and understanding the meaning of the perceived information now and in the future (Endsley 2000). The role of SA becomes an important construct as the basis for decision making and performance achievement. A person with good use of SA will be more likely to make the right decisions and perform well in dynamic systems (Endsley et al. 2003). The SA study on pedestrians is one of the efforts to control pedestrian safety (Lim et al. 2015). Therefore, SA measurement needs to be carried out to determine the effect of dual activity on pedestrian SA. By knowing what occurs to attention and motor demands on pedestrian secondary activities, effective education can be designed to prevent the use of smartphones or other dual attention-grabbing activities while walking (Lin and Huang 2017).

Studies of SA measurement in the context of the pedestrian environment is still limited (Salmon et al. 2012). Previous researchers tend to only use one of the measurement methods (Lim et al. 2015, Lin and Huang 2017, Sheik-nainar et al. 2015, Lu and Lo 2018, Pielot et al. 2010) or be only based on the subjects' ability to recognize or read an object (Harms et al. 2019). The current SA measurement methods have their strengths and weaknesses (Salmon et al. 2009). However, weaknesses in one measurement method can be overcome by the strengths of other measurement methods. Online and offline measurements have been shown to complement each other in measuring SA by utilizing different cognitive processes (Cak et al. 2020). The combination of multiple SA measurement methods is possible and has the potential to lead to appropriate actions in measuring pedestrian SA levels.

Thus, based on the tendency of pedestrians to perform dual activity and the need for an appropriate measurement method to assess SA in that condition, an exploratory study is needed to assess the measurement of SA in the pedestrian environment. The research area explored is illustrated in Figure 1.

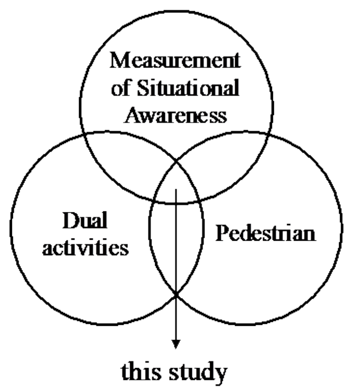

Figure 1. The research area

1.1 Objectives
This study aimed to explore the methods of measuring SA in pedestrians who perform dual activities.

1.2 Research Questions
Based on the research area, the research questions formulated in this study are:
RQ1 : What are the dual activities in the pedestrian environment that have the potential to reduce SA?
RQ2 : How to assess the effect of dual activity on the pedestrian SA with multiple SA measurement methods?

2. Literature Review
Studies exploring the effect of dual activity on pedestrians are still limited. There has not been found literature that discusses the measurement of SA in pedestrian environment. Only one article in 2016 evaluated the effect of mobile phone distraction on pedestrians. The article states that the method commonly used to measure pedestrian performance is to evaluate postural performance. Results of the review stated that previous studies tried to evaluate the effect of mobile phones when performing posture tasks, such as standing or walking (Nurwulan and Jiang 2016). Meanwhile, the operation of mobile phones has also been shown to cause cognitive impairment and reduced SA (Lamberg and Muratori 2012, Lim et al. 2015). Thus, this study evaluates the effect of dual activity in the pedestrian environment on SA and how to assess the effect of dual activity with the appropriate measurement method.

3. Methods (12 font)

This study explores the SA measurement methods in the pedestrian environment using the Systematic Literature Review Methodology (SRM), namely the Cochrane method. This approach is based on specific stages to ensure the quality of the articles explored with the following steps.

3.1 Keywords

Keywords combined to explore related articles are "situation awareness" AND ("pedestrian" OR "walking") AND ("secondary task" OR "multitask" OR "dual task").

3.2 Database

The source of the articles used is Google Scholar within a time span of 2010 to 2020.

3.3 Selection Criteria

Articles were selected in two stages. In the first stage, articles were selected based on abstracts, conclusions, and similarity of titles. After that, in the second stage, articles were selected based on the entire contents. Articles that were considered not relevant were eliminated. Only articles with experimental-based studies were included as part of this study. Studies based on observational and historical data were not considered. As a result, there were 24 articles related to the topic of SA measurement in the pedestrian environment.

4. Data Collection

A search of the Google Scholar database within the time span of 2010 to 2020 showed 1200 related articles. Based on the selection criteria, the number of articles to be reviewed can be seen in Table 1.

Table 1. Result of selection

Stage	Filter	Number of articles	
		Inclusion	Exclusion
1	Similarity of titles, abstracts, conclusions	239	961
2	contents	24	215

Finally, the 24 articles that discuss the SA measurement in the pedestrian environment were chosen to be studied further.

4.1 Year of Publication

The first publication discussing SA measurement in the pedestrian environment was in 2008. The article presents the results of military operation simulation experiments to measure the effect of cognitive and physical workload while walking on a treadmill on SA. However, until early 2010, the topic was still limited and there were only three articles found until 2014. A significant increase occurred in 2015 until 2020 where the publication reached 21 articles. Therefore, this topic is considered to have the potential to be studied further.

4.2 Secondary Activities

Walking while doing secondary activities makes pedestrians have to detect and identify more visual information. The process requires attention and interferes with the performance of the main task, walking.Operating a mobile phone is the most secondary activity done by pedestrians. Operating mobile phones can be grouped into several types of activities, namely texting, talking, browsing, dragging, listening to music, and gaming. Another secondary activity that is also widely used by previous researchers is visual tasks. In addition, there are also other secondary activities in the form of navigation tasks, passing through obstacles, crossing, and auditory working memory. The percentage of each type of activity is shown in Figure 2.

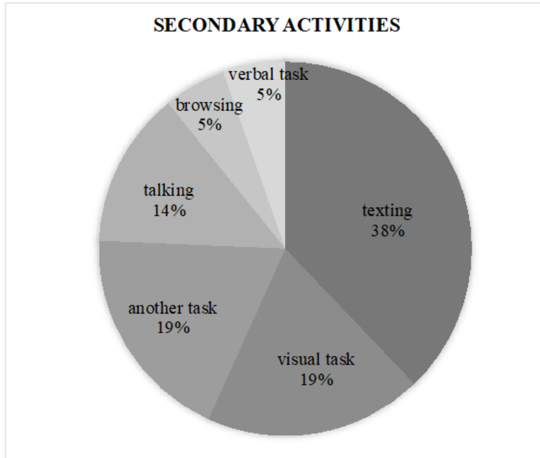

Figure 2. Secondary activities

4.3 Procedure

Based on the results of the review, experimental procedures are generally carried out indoors. The procedure is considered to have several advantages including reducing uncontrollable disturbances such as air and noise pollutions; minimizing pedestrian and vehicle density; and reducing potential hazards when carrying out dual activity. To describe the condition of the pedestrian environment, the subjects walked while listening to a video showing the pedestrian environment. Other than that, there are several studies that used virtual reality to describe more real conditions.

Indoors, walking on a treadmill is the activity most widely used by previous researchers to simulate pedestrian activities. In the procedure of using a treadmill, the subjects always walked at a constant speed. The speed of the treadmill was usually determined by each subject. The average speed of the treadmill used was 0.946 ± 0.074 m/s. However, there are also studies that did not use a treadmill with the consideration that the use of a treadmill does not support secondary activities.

Meanwhile, there are also several studies that conducted experiments outdoors that are close to actual conditions. The procedure was carried out with certain considerations and requirements to ensure the safety of the subjects when carrying out dual activity. The percentage comparison of procedures performed indoors and outdoors is shown in Figure 3.

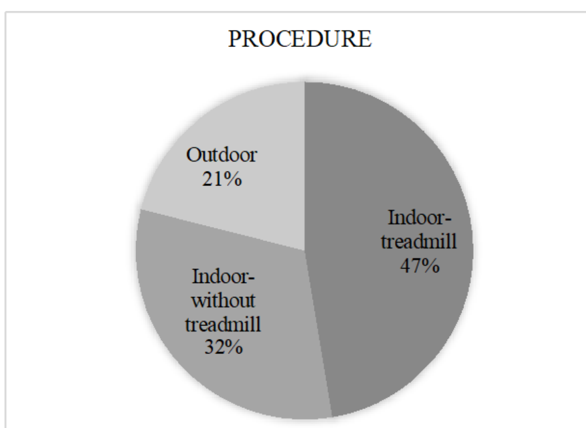

Figure 3. Procedure of experiment

5. Results and Discussion

5.1 The Effect of Dual Activities on Pedestrians

This section reviews dual activity and its effect on SA. The main focus of this section is to examine the influence of SA in previous studies, both explicitly and implicitly. The results of the review show that in general, previous studies suggest that secondary activities performed while walking are associated with increased cognitive demands and decreased AS. The findings in the six articles relating to cognitive and SA-lowering demands from the review are presented in Table 2.

Tabel 2. The effect of dual activities on pedestrians

Author	Secondary Activities	Findings
Lim et al. 2015	Texting Visual task	- The magnitude of the loss of SA depends on the nature of the visual information provided on the secondary task. - The loss of SA occurs concurrently with a decrease in secondary task performance. - As much as 48.3% of visual information in the environment is not perceived by the subjects when typing messages on a mobile phone while walking.
Lin and Huang 2017	Dragging Texting Reading	- The secondary activity of reading news on the mobile phone screen causes a higher workload and interferes with the SA compared to typing messages or scrolling the screen.
Lamberg and Muratori 2012	Talking Texting	- Decreased SA on dual activity, characterized by decreased ability to extract spatial and temporal information in the environment, interferes with working memory and affects gait to the point of endangering the subject's safety. - The ability of pedestrians to avoid obstacles, maintain the direction of the road, and cross safely while doing secondary activities will be the focus of new studies in the future.
Harms et al. 2019	Visual task	- SA is not a prerequisite for avoiding obstacles when on foot. The absence of SA does not mean that there are no cognitive and perceptual processes. - Walking without awareness does not always result in risk because walking has become an automatic activity for some people.
Lu and Lo 2018	Texting	- The risk associated with impaired visual attention is higher when typing messages while walking. - Meanwhile, SA, hearing, and walking speed have no significant effect on that condition.
Sheik-nainar et al. 2015	Visual task	- Knowledge and understanding of navigation tasks support better SA.

Thus, even though walking is a common activity that is done without certain skills, it is necessary to pay attention to the effects caused by secondary activities carried out while walking, especially when pedestrians are in an unfamiliar environment. Although it does not always affect SA, dual activity can also interfere with the physical and mental conditions of pedestrians.

5.2 Assessment of the Effect of Dual Activities with SA Measurements

Based on the results of a review of previous studies, SA measurement methods, meaning the various measurement techniques, have been used to evaluate the effect of dual activity on pedestrians. However, the measurement of SA is not the main focus of this study. A summary of the results of the review is presented in Table 3.

Situation Awareness Rating Technique (SART) is a self-rating technique that is carried out after a subject has completed a task. SART assesses SA based on three main dimensions, namely demand on attentional resources, supply of attentional resources, and understanding of the situation provided. This subjective SA measure is related to measures of performance and workload (Endsley and Jones 2011). The results of the SA measurement with SART show that the subjects tend to feel a significant decrease in SA when doing secondary activities with a high workload such as reading the news on a mobile phone. On the other hand, the measurement using the eye-tracking approach are used to visually detect each secondary activity. The results of eye-tracking measurements show that subjects take longer when walking while reading and texting than dragging (Lin and Huang 2017). The SART method is easy to use and analyze, does not interfere with the main task, and can be applied in various domains without the need for complex adjustments (Raza et al. 2019, Kaber et al. 2016). However, the results of the SART measurement are considered too correlated with workload (Endsley 2019). In addition, the measurement accuracy is still in doubt because it depends on the reliability of the observer to himself (Raza et al. 2019, Kaber et al. 2016).

Tabel 3. Measurement of SA

Author	Secondary Activities	Measurement Technique			
		Freeze	Real-time	Post-rating	Process indices
Lin dan Huang 2017	Dragging, texting, reading			SART	eye tracking
Harms et al. 2019	Visual task			Verbal response	
Lim et al. 2015	Texting, visual task			Verbal response	
Sheik-nainar et al. 2015	Visual task	SAGAT			
Sheik-nainar et al. 2015	Navigation task		real-time probe		
Pielot et al. 2010	Visual task		SPAM	SART	
McKendrick, et al., 2016	Visual task, auditory working memory			Yes-no questions	eye tracking
Pizzamiglio, et al. 2017	Texting				EEG
Courtemanche et al. 2019	Texting				EEG
Han, 2019	Browsing, texting				EMG

SA measurement based on verbal responses can be done in real-time or post-task. Measurements carried out by post-task are conducted by remembering or recognizing an object. Measurement results based on verbal responses are important to be observed carefully to monitor responses that sometimes appear implicitly (Harms et al. 2019). This measurement is easy to apply. The acquisition of the subjects' verbal responses can be programmed using a device such as Matlab (Lim et al. 2015).

Based on the results of the review, the Situation Awareness Global Assessment Technique (SAGAT) measures SA as the dependent variable to assess the operator's mental model formulation. With this method, the accuracy of the operator's recognition of his environment, the relationship of these conditions with the goal, and predictions of future conditions can be measured to describe the control strategy of each operator that is affected by dual activity. The verbal nature of the SAGAT query is considered interfering with the performance of navigation tasks, especially instruction-based tasks. Therefore, more objective measures, such as eye movements, are needed to find out what the operator observes during the navigation tasks (Sheik-nainar et al. 2015).

Measurements using the real-time technique are performed by asking questions related to SA while the subjects are performing their tasks, either directly or through a simulation (Endsley 1995). Based on the results of the review, the Situation Present Assessment Method (SPAM) is used as an SA assessment by asking questions during the main task. The assessment requires the subjects to describe an ongoing situation and rate how well the progress is made based on the initial plan. Accuracy and response time are parameters for this measurement. Supported by the results of subjective measurements using SART, the SA assessment in the experiment results in an effective design for presenting the location of objects on the display of the device it designs (Pielot et al. 2010).

Based on the results of the review of various SA measurement methods, it is known that each method has limitations. However, weaknesses in one measurement method can be overcome by the strengths of other measurement methods. Various measurement techniques have proven to be complementary in measuring SA (Pielot et al. 2010), namely by utilizing different cognitive processes (Cak et al. 2020). Thus, this study proposes the need for a combination of multiple SA measurement methods to establish appropriate measures to measure pedestrian SA levels and address the limitations of previous measurement methods. However, it is necessary to further study the combination of effective multi-methods for each characteristic of the pedestrian environment to be measured. Multiple methods that match the characteristics of the pedestrian environment will be able to see what occurs to the attention and motor demands of pedestrian secondary activities and find out the design of effective education to avoid unsafe behavior in the pedestrian environment.

6. Conclusion

Automatic behavior when walking causes pedestrians to feel able to perform secondary activities. In practice, secondary activities will divert attention from the walking activity, for example, when walking while operating a mobile phone. Dual activity can cause cognitive impairment and reduce situation awareness (SA). The exploratory study on various SA measurement methods in this study proposes a combination of more than one method as the method that is effective to match different characteristics of pedestrian environments. It is hoped that multi-methods will be able to find out what occurs to attention and motor demands on pedestrian secondary activities in order to control safety in the pedestrian environment.

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