WHETHER SHORT-TERM EXPERIENCE CAN ENHANCE PERCEPTUAL-MOTOR LEARNING IN A MOVING (VEHICULAR) GAP INTERCEPTION TASK

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Abstract

Background: Accurate perceptual judgment and skilful movement coordination are required to perform sports specific or everyday perceptual-motor tasks. In ball catching, for example, a catcher must judge the spatial and temporal aspects of the flying ball and adjust his locomotion according to the changing situation. Likewise, an everyday perceptual-motor task that requires perceptual accuracy and skilful movement coordination is to intercept a gap between moving vehicles as a pedestrian (i.e., road-crossing). Purpose: Experience (both short-term and long-term) is important in learning to perform such everyday perceptual-motor skills. The purpose of this study was to investigate the effects of short-term experience on pedestrians' perceptual decisions and movement coordination in an experimental road-crossing task. Methods: Twenty-two young adults of Kunsan National University participated voluntarily in the experiment and performed a moving gap interception task (road-crossing) in the virtual environment. Results: Participants' perceptual decisions improved and movement coordination during gap interception enhanced with short-term experience. Conclusion: this study concluded that perception and movement coordination can be calibrated with experience even in short-time scale. Also, perceptual accuracy and enhanced motor-ability is important to increase pedestrians' safety in road-crossing and in other similar everyday perceptual-motor tasks.

Key Words: Perceptual-Motor Tasks, Gap Interception, Pedestrian, Virtual Environment

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1. Introduction

Motor learning is an interdisciplinary approach that involves multiple fields of physical education, kinesiology, and cognitive psychology. The target of motor learning research is to understand how individuals learn and perform motor skills in sports and in everyday activities as well. Learning to perceive accurately and experienced control of movement is essential for good coordination to perform everyday perceptual-motor activities. For example, perceptual learning and control of movement involves in the duration of walking, cycling, reaching, catching, throwing, kicking, writing, and the like skills.

How do perceivers learn to couple the perception with action/movement and fine tune this process of perception-action coupling? Individuals learn to couple perceptual information to the action and fine tune these processes with experience. Learning means that an individual is becoming perceptually adapting to the consequences of different action possibilities within the available environment structure (Fitch & Turvey, 1978). Those possibilities to perform an action are called affordances (Gibson, 1979/2014) that are available in the environment where an action to be performed. Motor skills require different control of action according to the nature of the task. The simple/fine motor skills do not require much adaptation in behavior usually involving the coordination of hands and fingers with the eyes. However, interceptive actions and adaptive movements such as avoiding collision with moving objects, which have drastic after-effects, require actors to learn from the consequences of previous action and to control the self-movement accordingly. The present study focused on the role of experience in learning to perform an everyday activity (road-crossing) that might have dangerous consequences in case of misjudging the affordance of the vehicular gap to cross and/or moving inadequately.

1.1. Intercepting a Moving Gap

Dynamic interceptive actions require the actors to adapt their behavior adequately according to the changing environmental information to carry out an action successfully. More specifically, humans can modify their behavior in a constructive way to fulfill requirements of the ongoing task. For instance, catchers should keep adjusting their movement while catching a flying ball in such a way that they can intercept/catch the ball at the right time and at the right place (Oudejans, Michaels, Bakker, & Dolne, 1996). This notion of perceiving/moving at the right time and right place is also applicable to another everyday activity that is intercepting a gap between moving vehicles (i.e., road crossing). How such interceptive actions can be performed successfully. In this respect, Savelsbergh and Bootsma (1994) suggested that when individuals need to perform a dynamic interceptive action effectively, they require; i) making sure that they contact or avoid the object at the appropriate moment, ii) moving with the required velocity and force, iii) intercepting the object at the required spatial and temporal orientation. So, it can be established that all dynamic interceptive actions require becoming skillful in perception-action coupling keeping in view the spatial-temporal aspects of the moving objects.

As described in the aforementioned example of fast ball sports, interceptive actions become more constrained as such actions require quick and accurate perceptual-motor responses (Ranganathan & Carlton, 2007). Thus, perception-action coupling become more crucial when to intercept a vehicular gap because movement is to be synchronized in response to a rapidly changing traffic environment with increased spatial-temporal demands.

Crossing the road between moving traffic is a dynamic interceptive task that can provide researchers an insight into studying the human perceptual-motor behavior. Besides, the movement data from the crossing action can be served as an ongoing understanding of perception-action processes of the human system. In specific, intercepting a moving vehicular gap serves as an example of a functional perception-action coupling, and provides a collaborative link between the actor and the environment (Davids, Renshaw, & Glazier, 2005; Dicks, Davids, &

Araujo, 2008). As such, moving gap interception task require a pedestrian to be fully informed with task demands in the changing environment. Thus, the perceptual accuracy and experienced movement coordination plays an important role in performing such everyday activities.

To date, several studies have been carried out investigating that how pedestrian perceive and make decisions to cross the road between moving vehicles. For example, studies found that perceptual judgments can be differed based on participants' age when they make decisions to cross the road in a virtual environment (Lobjois & Cavallo, 2007, 2009; Oxley, Ihsen, Fildes, Charlton, & Day, 2005; Simpson 2003). In addition, a study worked on the effects of long-term experience on pedestrians' perception-action adaptation in the gap interception task (O'Neal et al., 2018). While short-term experience can also play important role in learning the already learned skills such as cyclists' navigating through the busy road intersections (Plumert, Kearney, Cremer, Recker, & Strutt, 2011). However, we found not a single study relating to the effects of short-term experience on perceptual accuracy and movement coordination in pedestrian road-crossing task.

Perceptual-motor learning over a short time scale in the road-crossing task may be described in terms of enhanced perceptual judgment, movement timing, and walking speed. The present investigation, therefore, aimed to examine the influence of short-term experience regarding changes in the two aspects of pedestrian behavior (i.e., perception accuracy and movement coordination) in the road-crossing. Short-term experience may help enhancing pedestrians' ability to differentiate crossable/not crossable gaps and to synchronize their self-movement with the movement of vehicles during crossing action. Thus, we hypothesized that short-term experience with the pedestrian road-crossing task may improve individuals' perceptual accuracy in terms of deciding crossable/not crossable gaps and movement coordination regarding the timing of movement and walking velocity.

2. Methods and Materials

2.1. Participants

In total, twenty-four healthy young adults (undergraduate students) with an age range between 20-28 years (*M* = 22.95, *SD* = 2.28 yrs.) participated in the experiment. All the participants had normal or corrected to normal vision and with no injury history within previous six months. In the recruitment process, undergraduate students were contacted through a social media network of the Kunsan National University, South Korea using a convenience sampling technique. Prior approval of the experiment was obtained from the local Research Ethics Committee, and the written informed consent was provided to each participant.

2.2. Apparatus and Task

A high-fidelity interactive pedestrian simulator (Azam, Choi, & Chung, 2020) was used to conduct this experiment. The experimental set-up comprised of a PC Intel (3.30 GHz with 8.00 GB RAM), an Oculus Rift DK 2 (Oculus VR LLC, US) incorporated with a mobile phone (LUNA TG L800S), a data encoder device (Arduino Uno), and an actual corridor (10 m long) outside the Motor Behavior Laboratory situated in Physical Education and Sports Sciences department of KNU.

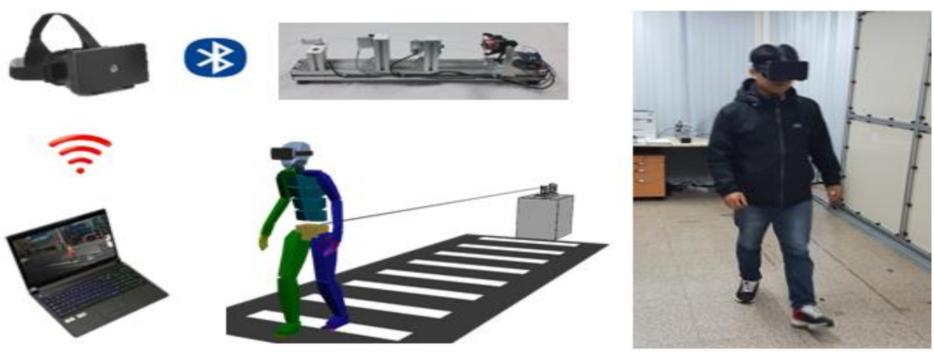

Figure 1: A schematic view of the pedestrian simulator

The crossing task required from participants first to perceive the crossable gap and then to go between two cars while avoiding collision with the lead vehicle (LV) or rear vehicle (RV). Participants could move forward in the virtual environment while adjusting their locomotion speed.

2.3. Procedure and Design

Each of the participants was instructed about the task like that; do not move before the experimenter gives you verbal ‘ready’ and ‘go’ signal, and upon ‘ready’ you should be prepared for moving. At the ‘go’ signal, you have to look left immediately for watching the vehicles and walk to cross if you think the upcoming gap is crossable, and do not cross if you think it is not crossable. Before starting the experiment the participants were provided a few familiarization trials. The purpose of those trials was to make them familiar with the task and VR system.

The experimental session consisted of two blocks considering block 1 as a practice block and block 2 as a test block. In a block, we manipulated 6-time gaps between two vehicles (2s, 2.5s, 3s, 3.5s, 4s, and 4.5s), and two vehicle speeds (i.e., 36 km/h or 55 km/h). Thus, it became 12 experimental conditions multiplying 6 temporal gaps and 2 vehicle speeds in a block. Therefore, a participant had to perform 24 trials (12 practice trials + 12 test trials) in total to complete the experiment. The trials were randomized for each participant in both practice and test block. The whole experiment was completed within 30 minutes providing participants with a brief rest (5 min) between the two blocks of trials.

2.4. Data Analysis

The two aspects of pedestrians’ behavior were recorded and analyzed.

2.4.1. Perceptual Accuracy

Perceptual accuracy was analyzed in terms of gap acceptance thresholds and perceptual decisions. Gap acceptance thresholds were calculated both for practice and test blocks to see the changes in perceiving and accepting crossable gaps. Gap acceptance thresholds could be calculated depending on the percentage/probability of participants' gap crossing data (to cross/not to cross decisions). Participants' performance outcomes were prepared based on a dichotomous scale 'YES' for success and 'NO' for the other two categories (failure, collision). Binomial logistic regression analysis through SPSS software (version 21) was used to calculate the probability of gap acceptance at each gap time.

Improvement in perceptual decisions was analyzed depending on the frequency of perceptual errors in the practice and test blocks separately. Perceptual errors could be defined as the number of collisions that occurred at each gap time. A collision was considered as a perceptual error because a pedestrian must differentiate whether the available gap affords crossing or not in real-world crossing situations and decide to cross accordingly. Chi-squared analysis was used to compute the number of perceptual errors for both blocks.

2.4.2. Movement Coordination

Movement coordination was analyzed in terms of participants' time of interception (TOI) to see how their crossing position regarding interception time deviates from the center of gap (COG) between two vehicles. Time of interception (TOI) can be defined as the "temporal difference between the times at which participant crossed the interception point and the time at which the center of gap arrived at the crosswalk/interception point" (Chung, Choi, & Azam, 2020). The values of TOI were calculated taking the COG as a reference, TOI value resulted in zero if a pedestrian crossed toward the COG, less than zero if a pedestrian crossed before COG and more than zero if a pedestrian crossed after COG, respectively.

Secondly, participants' walking velocity (m/s) at each time point over the given time gap/distance was recorded by the simulation during the gap interception. Note that the target distance for a participant was 3.5 m that was the width of single lane of the road. We averaged walking velocity data into 1-second segments starting from initiation to end of interception as done in previous studies (Chihak, Grechkin Kearney, Cremer, & Plumert, 2014; Chung et al., 2020). The purpose of averaging velocity into 1-second intervals was to see whether participants learn to regulate their walking speed according to the available time/distance up to the interception point in a single experimental session. The process of averaging walking velocity into 1-second intervals was completed using MATLAB software (version R2011B). Then, the segmented data were statistically analyzed in SPSS software (version 21).

Consequently, the data analysis involved three types of statistical analyses; binomial logistic regression analysis to compute the probability of gap crossings, chi-squared analysis to count the frequency of perceptual errors, and analysis of variance (ANOVA) to compare the mean TOI and walking velocity of pedestrians respectively. The significance level was set at 0.05 for all the above-mentioned statistical analyses.

3. Results

3.1. Perceptual Accuracy

Perceptual accuracy was analyzed based on the probability of gap acceptance and frequency of perceptual errors at each gap time.

3.1.1. Gap Acceptance Thresholds

To find transition points and thresholds, a binomial logistic regression analysis was performed based on participants crossing choices at each gap time grouping data for practice and test blocks. The logistic model was statistically significant for practice block, χ^2 (3) = 115.850, $p < .0001$, and $R^2 = .369$ (Cox and Snell), and also for the test block, χ^2 (3) = 181.565, $p < .0001$, and $R^2 = .513$ (Cox and Snell).

The transition from not cross to cross occurred at a lower point for the test block than that of the practice block. Table 1 represents the transition points and thresholds for both blocks.

Table 1: ***Transition points and thresholds for practice and test blocks***

Block	Velocity	Transition Point (in seconds)	Threshold (in seconds)
Practice block	36km/h	2.93	0.40
	55km/h	2.91	0.43
Test block	36km/h	2.57	0.63
	55km/h	2.52	0.71

3.1.2. Perceptual Errors

The frequency of perceptual errors was compared using a Chi-squired test with the purpose to analyze the perceptual attunement from the practice to test block. Perceptual errors were the number of collisions computed separately for the practice and test blocks entering 2 vehicle speeds (36km/h, 55 km/h) x 6 gap times (2 s, 2.5 s, 3 s, 3.5 s, 4 s, 4.5 s) in a chi-squired test. The vehicle speeds and gap times included in the test because we wanted to compare how many collisions occurred at each vehicle speed and gap time across blocks. The results of chi-squared test were significant for practice block (χ^2 (1) = 17.00, p < .0001), and for test block (χ^2 (1) = 9.538, p < .002). The numbers of perceptual errors (collisions) at each gap time are given in Table 2.

Table 2: ***The number of perceptual errors (collisions) at each gap time***

Block	Gap Time					
	2 s	2.5 s	3s	3.5 s	4 s	4.5 s
Practice block	20	16	18	7	1	2
Test block	13	12	0	1	0	0

3.2. Movement coordination

3.2.1. Time of Interception

The time of interception (TOI) for successful trials was analyzed using a repeated-measures ANOVA entering 2 (blocks: practice, test) x 2 (vehicle speeds: 36km/h, 55 km/h) x 5 gap times (2.5 s, 3 s, 3.5 s, 4 s, 4.5 s). 2-s gap excluded from this analysis because no one succeed to cross it. A Bonferroni pairwise comparison was included in the ANOVA. Pairwise comparisons showed that there was a significant difference of TOI between two blocks *F* (1, 281 = 9.907, $p < .002$, $\eta^2p = .034$. The mean TOI indicated that participants time to cross became smaller after short-term experience (test block = 0.09 ± 0.025 s) compared to before experience (practice block = 0.25 ± 0.028 s). Here, the smaller value meant that the crossing time tends to COG and the greater value means that the crossing time is getting away from the COG. Also, we found a main effect of vehicle speed on TOI *F* (1, 314) = 8.026, $p < .005$, $\eta^2p = .028$. The mean TOI was significantly smaller when vehicle speed was 36 km/h (0.08 ± 0.027 s) compared to when vehicle speed was 55 km/h (0.25 ± 0.026 s). There was a significant interaction between blocks and gap times ($p = .043$), however, there was no significant interaction between block and vehicle speed.

3.2.2. Walking Velocity

Participants' averaged velocity based on the segmented data was statistically analyzed entering 2 blocks (practice vs. test) x 2 vehicle speeds (36km/h vs. 55 km/h) x 5 gap times (2.5 s, 3 s, 3.5 s, 4 s, 4.5 s) in a repeated-measures ANOVA. The results revealed that the mean walking velocity at each segment significantly differed for both blocks *F* (1, 213) = 7.92, $p < .005$, $\eta^2p = .036$. No other main effects or interaction was found.

Mean walking velocity per segment showing that participants' velocity was calibrated after a short practice. The participants' mean walking velocity (Figure 2) is depicting that their speed smoothly increased with no or fewer adjustments till the end of interception in practice block, whereas they learned to made adjustments in their walking speed according to the vehicle speed after having short experience (in test block). Increased walking velocity in the first segment of the test block showed that pedestrians calibrated their walking speed in accordance with the vehicle speed.

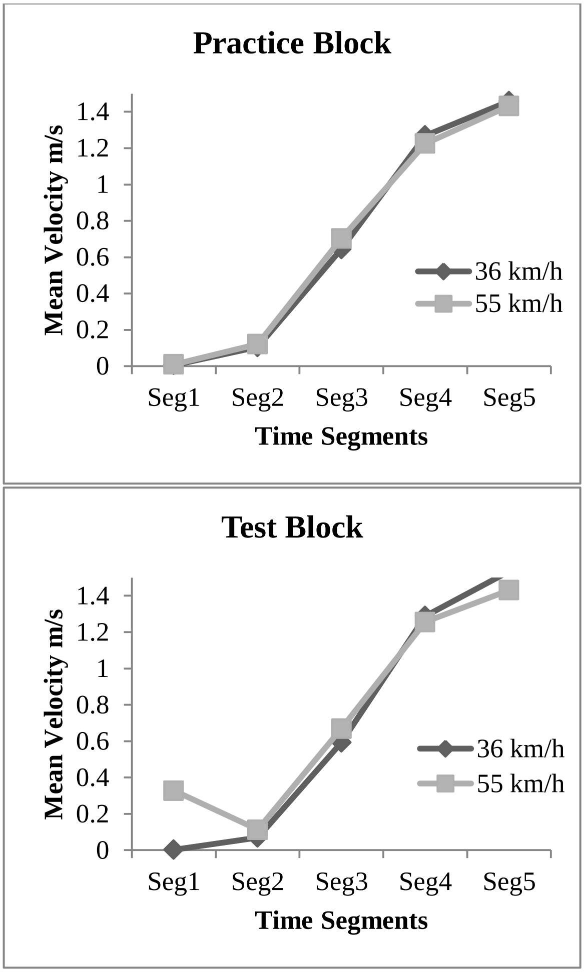

Figure 2: Pedestrians' mean walking velocity profiles from practice to test block. The approach velocity was averaged into 1 s segments (1 s, 2 s, 3 s, 4 s, 5 s) from start to end of interception time.

4. Discussion

The present study examined the effects of short-term experience on individuals' perceptual-motor learning in road crossing task. The results of this study clearly revealed changes in perception and movement behavior over the single experimental session. Participants' probability of gap acceptance on shorter gaps increased after short practice that eventually caused the occurrence of transition points (where decisions change from not cross to cross) at lower time point in the test block. Also, they learned to differentiate crossable/not crossable gap after short-term experience that helped them to decrease collision rate in the test block. Further, they learned to control their movement timing/walking according to the available time/distance towards the gap interception after short-term experience.

4.1. Perceptual-Motor Learning

Perceptual-motor learning, in this study, can be described by two features of pedestrians' behavior. On the perceptual side, participants' probability of gap acceptance on the shorter gaps was increased due to which the transition points were occurred at lower points and the frequency of perceptual errors at each gap was decreased from the practice to test block. The number of perceptual errors (collisions) on the shorter gaps (2 s, 2.5 s) was decreased and approximately came to zero on the larger gaps (3-4.5 s). Apparently, the short-term experience helped them to cross gaps in a more sensible way that resulted in occurrence of the transition from not cross to cross at the lower point and decreased perceptual errors. The increased probability of gap acceptance and the decreased perceptual errors (collisions) revealed that the participants' perception of gap affordance was improved and they were inclined to less risk-taking behavior when they had short-term experience with the crossing task.

On the motor side, participants' action relevant components (i.e., TOI and walking speed) were improved with short training. The results relating to time of interception revealed that TOI was shortened from practice to test block which benefitted them more time to spare in front of the rear vehicle or tendency of crossings towards the COG. Perhaps, they walk fast in the test block to clear the gap and/or they entered quickly behind the lead vehicle that resulted in shortened time during interception. Entering swiftly behind the lead vehicle also seems from our results of walking velocity, participants learned to calibrate their walking speed relative to the characteristics of the traffic environment. In this regard, the first segment of walking speed in the test block was the indication of calibration.

In sum, our results indicated changes in both aspects of pedestrian behavior i.e., perception and action. According to Gibson's (1979) ecological approach, we cannot decouple perception from the action or vice versa, therefore those instances are the account of perceptual-motor learning in this gap interception task.

5. Conclusion

Although the task (to cross the virtual road) presented to the participants was not a new to them, still they have exhibited considerable changes in their perceptual-motor behavior with the short-term experience. Thus, the study concluded that long-term training is not always necessarily important to improve the perception-action coupling. Else, a short-term practice/training may also be considered for improving one's ability to use perceptual information accurately and to enhance the control over movement.

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