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Transfer of Learning on a Spatial Memory Task between the Blind and Sighted People

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ABSTRACT

The purpose of this study was to analyze the effect of two different types of feedback on a spatial memory task between the blind and blindfolded-sighted participants. Participants tried to estimate the predetermined distance by using their dominant hands. Both blind and blindfolded-sighted groups were randomly divided into two feedback subgroups as »100% frequency« and »10% bandwidth«. The score of the participants was given verbally to the participants as knowledge of results (KR). The target distance was set as 60 cm. Sixty acquisition trials were performed in 4 sets each including 15 repetition afterwards immediate and delayed retention tests were undertaken. Moreover, 24 hours past the delayed retention test, the participants completed 15 no-KR trials as a transfer test (target distance was 30 cm). The results of the statistical analyses revealed no significant differences for both acquisition and retention tests. However, a significant difference was found at transfer test. 100% frequency blind group performed significantly less accurate than all other groups. As a result, it can be concluded that different types of feedback have similar effect on spatial memory task used in this study. However, types of feedback can change the performance of accuracy on transferring this skill among the blind.

***Key words**: spatial memory, blind, transfer of learning, feedback*

Introduction

Spatial memory involves the ability to encode, store and retrieve information about spatial location of objects and body parts (joints configurations). This important cognitive function enables us to remember the locations of objects and configuration of limb segments in our environment[1]. Driving a car with manual transmission can be a good example for the spatial memory. You should learn the location of pedals (clutch, brake, and gas) and gearshift. At the beginning of learning process, you might need to look at the gearshift to change the gear. However, after long hours of practice, you learn the spatial location and do not need to look at the gearshift; you just reach to it and move it into the other position. During the learning of this skill, you encode and store the information about the spatial location of gearshift and joints configurations of the arm to reach it. When you start driving, you retrieve this information and perform this skill efficiently. In the learning of these joints configurations of the arm, sensorimotor information provides information about initial and end positions of arm segments that are needed in movement control system[2]. Sensory information about the internal environment arises from receptors spread more diffusely from the body. Although this is for purposes of spatial processing, the proprioceptive receptors found in the tendons, muscles and joints are among the most important ones[3].

Many previous studies have demonstrated that spatial information can be acquired from non-visual modalities, such as audition, taction, and proprioception[4,5]. Proprioceptive information has a significant role in movement control. Specifically, it provides information about planning and changing internal movement stimulus. During the deceleration phase of reaching movements, this information provides sensory feedback to the system to perform the movement accurately[6]. Proprioception is the major sensory modality used to acquire a spatial map of the body[7].

Both visual and proprioceptive information about the body play an important role for the spatial processes.

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However, Berthoz et al.[8] found that spatial information of the body does not only depend on visual ability. In their study, participants were asked to reproduce passive linear whole-body displacement distances on a specifically prepared robot that the participants used a joystick to control its velocity and distance. The result of this study revealed that participants were able to reproduce both the distance and velocity profiles[8]. This showed that body is not only based on visual sense to detect its place in the space but also proprioceptive information.

Generally, the studies of spatial memory are conducted on detecting objects which have different shapes and different orders. However, as it is mentioned above, the activities that need to detect and learn places of body parts are among the topics that spatial memory cover[5,9].

The eyes are the organ of vision and they have almost 70% of body sensory receptors to detect the stimuli in the environment. Lack of vision or some illnesses in the eyes may cause some problems in detecting the stimuli[10,11]. However, the blind population completes their daily activities with more efficiency and effectiveness as it is the same with the sighted people. This is where spatial memory plays an important role. Moreover, the blind only use their spatial memory for utilizing auditory, tactile and proprioceptive information. When compared with sighted people, blind participants appear to perform better than blindfolded-sighted participants in some of the spatial and sound localization tasks[4,12]. Després et al.[13] found that the blind were more successful than the blindfolded-sighted people in a task with sound signals given from different distances[13]. Gaunet and Rossetti[14] also found that congenitally blind people used egocentric frame of reference while blindfolded-sighted people used exocentric frame of reference in the pointing task. Moreover, they performed similar in the pointing spatial task.

There are some difficulties the blind faced in the processing the spatial knowledge. Lack of vision for the blind people does not impede the ability to process and transform mental images; however, they are significantly poorer in the recall of more than a single spatial pattern at a time than in the recall of the corresponding material integrated into a single pattern[15]. Gaunet and Thinus-Blanc[16] found that the alteration of places between two objects was equally well searched out by blind and blindfolded-sighted people, whereas the alteration of an object in centimeters was not searched out well enough by the congenitally blind. There are very small amounts of studies on the pointing ability of congenitally blind children. It was previously found that early-blind children rely mainly on body-centered coordinates to encode positions whereas sighted children rely on both body-centered and external cues. In a study about imagery abilities among the blind and sighted individuals, Cornoldi et al.[17] found that blind participants performed more poorly than the sighted individuals when they used a spatial mental imagery strategy, whereas the two groups had a similar performance with a verbal strategy.

One of the most important factors that affects the learning a new skill is feedback. Feedback is a general term used to describe the information a learner receives about the performance of a movement or skill. That information can be available from both internal and external sources[18]. Knowledge of results (KR) is one example of feedback from external sources. Traditionally, KR has been thought of as a powerful learning variable and there are many studies supporting this view[19]. Although KR can guide a learner in the correction of performance errors, according to the guidance hypothesis the provision of too much feedback can have a harmful effect on skill acquisition[18].

Many studies mention the positive effect of the reduced relative frequency and bandwidth KR feedback on movement performance in retention tests[20,21]. Sparrow[19] used linear positioning task to examine the acquisition and retention of a motor skills by utilizing different types of feedback or KR. In his study, three experiments were conducted that used participants of blindfolded-sighted people, and different types of KR (100%, 50%, consecutive and request). The results revealed that reduced relative frequency in acquisition did not enhance performance in retention. It was concluded that reduced relative frequency were task specific and not found with linear positioning task.

In daily life, individuals need to adapt to changing circumstances and situations. This requires utilizing the previously learned knowledge on a recent knowledge. Learning new skill or performing an old skill under novel conditions can be influenced by past experiences with another skill or skills is known as transfer. The influence may be positive, negative or neutral (zero)[18,22–25]. Learning is more effective and faster when knowledge of the past and recent conditions is used in similar ways.

As stated by Gaunet and Rossetti[14], in the perception and learning literature very few studies were conducted to test pointing abilities in the blind population. In addition, proprioceptive ability of congenitally blind children has seldom been studied and there is a lack of knowledge about the effect of the KR on the learning of proprioceptive skills among congenitally blind children. It has been stated that proprioceptive ability continues to improve throughout childhood and well into adolescence for the sighted population[26].

In this study, we tried to investigate if this ability differs among the blind and sighted children. Therefore, one of the purposes of this study was to find whether proprioception system is more enhanced in the blind as a result of lack of vision. Additionally, the aim was to find the effect of reduced amount of feedback on learning using the spatial memory task between the blind and blindfolded-sighted children. Finally, the effect of different feedback scheduling on transfer to a new condition was investigated. It has been previously stated that providing feedback after every trial can result in feedback dependency for the sighted people[18]. However, there is no study showing the effect of feedback on the learning process among the blind. Thus, the result of this study may shed some light on designing the learning environment for blind children.

Materials and Methods

Participants

20 blind individuals (10 girls and 10 boys, M_{age}=12.65, *SD*=1.6) from birth or early ages (0–2) and 20 sighted individuals (10 girls and 10 boys, M_{age}=11.85, *SD*=1.4) voluntarily participated in this study. Katić et al.[27] and Pavić et al.[28] stated no sex differences on some motor abilities of elementary school children; thus, we included both girls and boys in our study. None of the participants in both groups had neurological diseases or physical disabilities and all were right handed. All participants were informed about the nature of the task by consent forms. In this study, approval was obtained from the institutional ethical review committee of the Ministry of Education.

Apparatus and task

Model 31202 Linear Movement Apparatus was used to test participants' ability to find a predetermined target in the horizontal plane (spatial memory) that was set as 60 cm during the acquisition and retention tests for the study. This apparatus consists of a sliding cube mounted on a pipe with bearings (Figure 1). The task is to move the cube at a specified distance (60 cm in our study) without external cues. To evaluate the ability of the participants to judge their performance, an LCD readout displays the distance the cube is moved. This cube also has a button connected to the LCD readout with a cable. When the participants feel that they are on the specified target location, they hit the button and we can read the value from the LCD readout. All the readouts were recorded to the computer. The target distance was convenient to reach for the children. In order to find out the target distance, a small pilot test with 5 children was conducted. Three different distances (50, 60, and 70 cm) were applied and the target distance was set as 60 cm considering the response of the children as a convenient reachable distance. For the transfer test, 30 cm target distance was used to test if the children can transfer a learned spatial location to a different location.

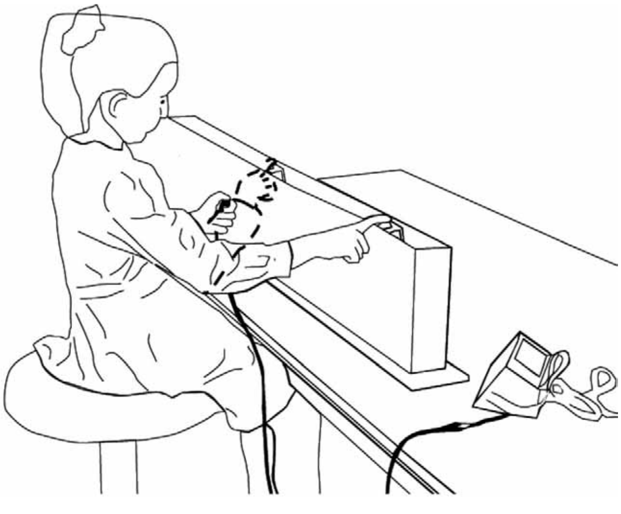

Fig. 1. The schematic representation of experimental apparatus and the task.

Procedure

Before the experimental procedure, the participants in each group were assigned to two KR sub-groups. One group had a relative frequency of 100% KR (on each of trials) and the other group received 10% Bandwidth KR (scores fall outside of 57–63 cm). Therefore, there were two KR groups for both blind and sighted participants. Bandwidth KR was provided as 10% because it was previously found to have better effect on the consistency of task performance[29]. The sighted participants were blindfolded before being exposed to the experimental device and then throughout the experiment. During the familiarization period, the participants were able to freely explore the apparatus with both hands and the location of the target point was presented to them by the following procedure. The participants seated on an adjustable seat were placed at the center of the target point (30 cm). Participants' right index fingers were put on the sliding cube and moved to the target point (60 cm) to the right of the start position (0 cm) passively by the experimenter. The start position of the sliding cube was horizontally located 30 cm away from the midline of the body. The participants were required to move the sliding cube from the right starting position with respect to their bodies to the left target location. After the first three trials, 60 acquisition trials in 4 blocks (in each of them 15 trials) were undertaken, with a 2-minute break between the sets. The participants moved the sliding cube after hearing the command »go« from the researcher and when they arrived at the target point they pushed on the button on their own. After the completion of this movement, the slide was returned to the starting position by the experimenter in preparation of the »ready« command for the next trial.

The score of the participants obtained from the apparatus was given verbally to the participants as knowledge of results (KR) that was previously defined as the distance moved in centimeters in this study. Sixty acquisition trials were followed by a 10-minute break before undertaking 15 no-KR trials in the first retention test (immediate retention). On the following day another 15 no-KR trials were completed as a second retention test (delayed retention). Moreover, 24 hours past the second retention test, the participants completed 15 no-KR trials as a transfer test. In the transfer test, the target point was reduced to 30 cm which was half of their learned distance. In the transfer test, there was no familiarization trial. The participants were not informed that they would be required to perform the tasks without KR during the retention and the transfer tests. The acquisition phase took approximately 30 minutes and retention and transfer tests took about 15 minutes.

Design and analysis

Absolute constant error (|CE|) and variable error (VE) were calculated for each block (average of 15 trials), and these block means were entered into the analysis. |CE|

measures the absolute average error in responding trials in each block. VE is the standard deviation of the 15 trials in each block. Thus, |CE| indicates overall accuracy in responding trials, and VE reveals the trial-to-trial variability of the participants' responses. We also calculated the number of received Bandwidth feedback for both blindfolded-sighted and blind groups to have an idea about their amount of corrective feedback. We applied a repeated measure analysis of variance to this data set with 2 groups (blind and blindfolded-sighted) by 4 Blocks which is treated as repeated measures. The acquisition error scores were analyzed using a factorial repeated measures analysis of variance with 2 (groups; blind and blindfolded-sighted) x 2 (KR types; 100% frequency KR and 10% Bandwidth) by 4 Blocks (of 15 trials) being the last factor treated as repeated measures. The error scores for the two retention conditions (immediate and delayed retentions) were analyzed separately using the same design, except that there was one block (15 no-feedback trials) for each test. Because the đCEđ and VE were calculated for both acquisition and retention blocks, two separate repeated measures analysis of variance were conducted. Finally, a 2 (the blind and blindfolded-sighted) x 2 (KR types) factorial ANOVA was used for the transfer test. Tukey HSD test was used for the post comparison as a follow up test to the ANOVA. The significant level was determined as $p<0.05$ for all analyses.

Results

Acquisition

Initially, we calculated the number of received 10% Bandwidth feedback among the blind and blindfolded-sighted children. As it can be seen in Figure 2, less number of bandwidth feedbacks was given to the blind participants in the first and second blocks but both groups took similar amount of bandwidth feedback in the last two blocks. Even though the averaged number of Bandwidth feedback stayed almost the same for the blind participants, it decreased in the last two blocks for the blindfolded-sighted participants. However, the statistical analysis showed that there was no significant interaction of group (blind and blindfolded-sighted) x block (4 blocks), $F_{(3,16)}=2.31$, p>0.05. In addition, block main effect was also found to be not significant, $F_{(3,16)}=2.92$, p>0.05. That is, the averaged number of Bandwidth feedback provided to both groups did not change between blocks and groups.

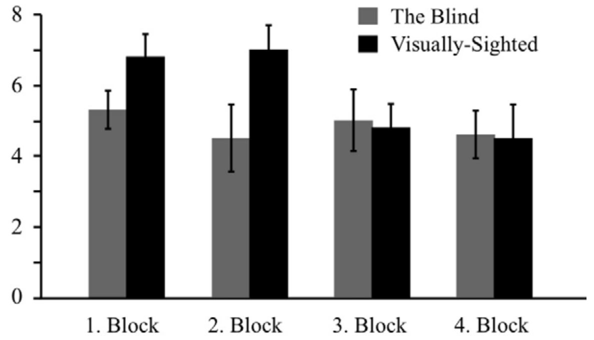

Fig. 2. The number of bandwidth feedback provided to the blind and blindfolded-sighted participants.

The factorial repeated measures ANOVA was conducted to test the effect of different type of feedbacks between the blind and blindfolded-sighted children on the spatial memory task employed in this study. As the |CE| and VE were taken into consideration for the statistical analyses, these two types of measure were analyzed and interpreted separately. |CE| and VE for acquisition and retention tests were graphed in Figure 3 and 4, respectively. The result of the analysis for the |CE| showed that there was no significant interaction between groups (the blind and blindfolded-sighted) and KR types in the 4 learning blocks, Wilks' Lambda=0.76 $F_{(9,82,9)}=1.05$, p> 0.05. Similarly, there was neither a significant group effect by 4 blocks, $F_{(3,34)}=2.75$, p>0.05; nor a significant KR types effect by 4 blocks, $F_{(3,34)}=0.33$, p>0.05. In addition, block effect was also found to be not significant, $F_{(3,34)}=0.92$, p>0.05. This means that both groups with respect to their KR types performed almost with the equal accuracy on finding the predetermined target (60 cm) in acquisition trials in the all 4 blocks. That is, both the blind and blindfolded-sighted children performed the task in the same way and KR types did not make any difference in the learning process.

The result of the analysis for the VE showed that there was no significant interaction between groups (the blind and blindfolded-sighted) and KR types in the 4

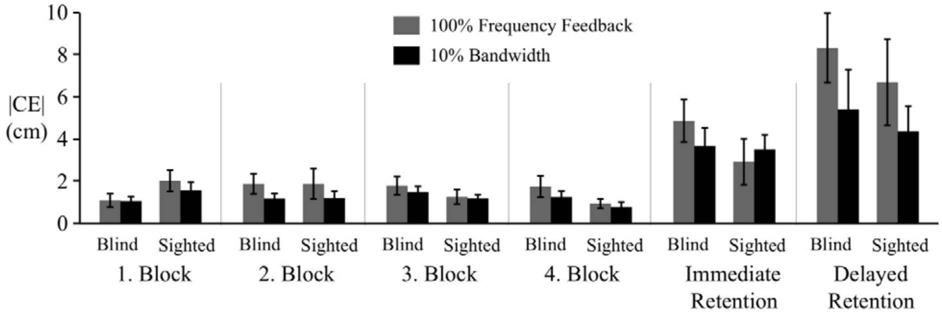

Fig. 3. Absolute constant error of acquisition blocks and retention tests.

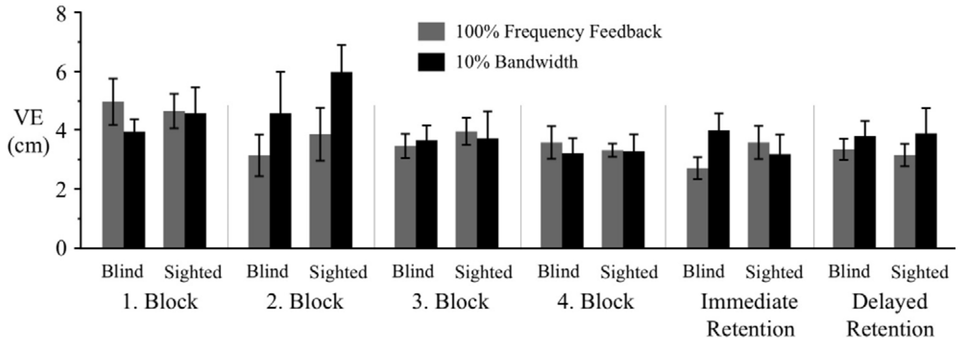

Fig. 4. Variable error of acquisition blocks and retention tests.

learning blocks, Wilks' Lambda=0.74 $F_{(9,82,9)}$=1.16, p> 0.05. Similarly, there was neither a significant group effect by 4 blocks, $F_{(3,34)}$=0.95, p>0.05; nor a significant KR types effect by 4 blocks, $F_{(3,34)}$=2.11, p>0.05. However, block effect was found to be significant, $F_{(3,34)}$=7.01, p<0.05. The post-hoc analysis revealed that VE was significantly higher in the 1st block (M=4.52 cm and SD= 2.12 cm) than in the 3rd (M=3.68 cm and SD=1.85 cm) and in the 4th blocks (M=3.33 cm and SD=1.48 cm). Moreover, VE was also found to be significantly higher in the 2nd block (M=4.37 cm and SD=3.25 cm) than in the 4th block. This result shows that both groups with respect to their KR types performed the task with the equal precision in the all 4 blocks. However, VE across groups and KR types decreased on the 3rd and 4th blocks.

Retention

As it can be seen in Figure 3, |CE| increases from the immediate to delayed retention test for both KR types and groups (the blind and blindfolded-sighted). The result of the repeated measures ANOVA revealed that there was no significant interaction between groups (the blind and blindfolded-sighted) and KR types in the two retention tests, $F_{(3,36)}$=1.05, p>0.05. Similarly, there was neither a significant group effect by retention tests, $F_{(1,36)}$=0.04, p>0.05; nor a significant KR types effect by retention tests, $F_{(1,36)}$=2.90, p>0.05. However, the effect of time from immediate to delayed retention tests was found to be significant, $F_{(1,36)}$=13.01, p<0.05 (M=3.71 cm and SD=2.88 cm vs. $\bar{X}$=6.16 cm and SD=5.44 cm). Participants were less accurate in the delayed retention test than in the immediate retention test. However, both groups with respect to their KR types performed the task with the equal accuracy in the retention tests.

The statistical analysis for VE showed that there was no significant interaction between groups (the blind and blindfolded-sighted) and KR types in the two retention tests, $F_{(3,36)}$=1.55, p>0.05. Similarly, there was neither a significant group effect by retention tests, $F_{(1,36)}$=0.03, p>0.05; nor a significant KR types effect by retention tests, $F_{(1,36)}$=0.10, p>0.05. In addition, the effect of time from immediate to delayed retention tests was also found to be not significant, $F_{(1,36)}$=0.92, p>0.05. Therefore, both the blind and blindfolded-sighted children from two different KR types groups performed the task on the two retention tests with the same precision.

Transfer

The averaged scores of the transfer test for the |CE| and VE were displayed in Table 1. The result of 2 (the blind and blindfolded-sighted) x 2 (KR types) factorial ANOVA analysis for |CE| showed a significant interaction, $F_{(3,36)}$=4.53, p<0.05. Post hoc analysis of the group means for đCEđ revealed that 100% frequency blind group performed significantly less accurate than all other groups, none of which significantly different (Table 1). However, the result of the factorial ANOVA for VE did not show a significant interaction between groups and KR types, $F_{(3,36)}$=1.55, p>0.05. Furthermore, a significant difference was neither found for main effect of groups, $F_{(3,36)}$=1.68, p>0.05, nor for main effect of KR types $F_{(3,36)}$=1.59, p>0.05. These results imply that both the blind and blindfolded-sighted children from two KR types performed the transfer task with the same precision. However, the blind group who took 100% frequency feedback performed the task significantly less accurate than the other groups.

TABLE 1
|CE| AND VE FOR TRANSFER TEST

	KR Types	$\bar{X}$	SD
|CE|	100 % Frequency Blind	15.77	8.48
	10 % Bandwidth Blind	8.56	7.70
	100 % Frequency Sighted	7.57	7.37
	10 % Bandwidth Sighted	4.65	6.34
VE	100 % Frequency Blind	5.06	1.72
	10 % Bandwidth Blind	3.36	1.99
	100 % Frequency Sighted	3.41	1.66
	10 % Bandwidth Sighted	3.34	1.12
	100 % Frequency Blind	3.79	1.75

|CE| – absolute constant error, VE – variable error, KR Types – types of knowledge of results provided to participants, $\bar{X}$ – mean, SD – standard deviation

Discussion and Conclusion

One of the aims of this study was to investigate the effect of different types of knowledge of results (KR) between the blind and blindfolded-sighted children on a spatial memory task. Moreover, we also aimed to find whether there is a difference between groups from two KR types in terms of accuracy and precision when they transfer this spatially memorized location into a different location. Initially, we have looked to see if the blind and blindfolded-sighted 10% bandwidth groups were taken different amount of corrective feedback. Even though the amount of 10% bandwidth feedback provided to the blind seems to be less than blindfolded-sighted group (see Figure 2) for the first two blocks, this was not found to be significantly different. As the number of bandwidth feedback provided to the blind and blindfolded-sighted participants are the same across acquisition blocks, we can expect to see the same accuracy performance between two groups. In fact, the results of the |CE| and VE among the four blocks showed the same performance between two-groups taken bandwidth KR.

According to the results for the acquisition blocks, no statistically significant differences were found in KR types among the groups of the blind and blindfolded-sighted participants in terms of accuracy and precision. Only significant difference was found in VE for the main effect of blocks. As one may expect, participants overall were more consistent in the last acquisition block than first two blocks. Therefore, types of KR manipulation during acquisition did not result in performance of accuracy and precision differences on acquisition blocks for the blind and blindfolded-sighted participants. Furthermore, types of KR manipulation also did not make performance differences between two groups. Similar to the acquisition blocks, the blind and blindfolded-sighted participants from two types of KR group performed the task with same accuracy and precision in the immediate and delayed retention tests. Participants overall had higher |CE| in the delayed retention test than in the immediate retention test. However, both groups with respect to their KR types performed the task with the equal accuracy in the retention tests. Thus, providing different types of KR on acquisition blocks did not make any performance difference in their learning on either immediate or delayed retention tests. Some researchers have examined the effect of bandwidth KR in constant practice[30,31] and found that bandwidth KR did not improve learning under constant practice among blindfolded-sighted participants. The results of this study are in agreement with the previous findings. In addition, we have also found that the blind and blindfolded-sighted participants performed this spatial memory task with the same accuracy and precision level. The task employed in this study was required to find the target point with the sensory information mainly from proprioception. The performance of the blind population was expected to be better than the sighted participants because of their reliance on auditory, proprioception, and tactile information as a result of lack of visual information. As both the groups performances were not different, lack of vision for the blind group does not seem to be enhancing their target location capability by using proprioceptive system. In their study, Gaunet and Rossetti[14] used pointing spatial task to compare blind and blindfolded-sighted people and found that both groups performed similarly. The results of our study also indicated same conclusion. To shed light to our findings, Gaunet and Thinus-Blanc[16] found that the alteration of places between two objects was equally well searched out by blind and blindfolded-sighted people, whereas the alteration of an object in centimeters was not searched out well enough by the congenitally blind.

One of the aims of the study was to examine the effect of KR types on transfer of learning, ANOVA was conducted and a significant interaction between groups and KR types was found. Further analysis revealed that 100% frequency KR blind group performed less accurate than the other three groups.

The variety in the KR types may have positively affected the performance of the 10% bandwidth KR blind group than the 100% frequency KR blind group. According to the guidance hypothesis, too much KR has a detrimental effect on learning motor skills[32,33], hence, the result of our study indicated that receiving less amount of feedback during skill practice transfers positively to a new condition for the blind group. However, the same effect was not observed in the blindfolded-sighted group. It might be speculated that a sighted person has broader movement repertoire and has more movement experiences. The conditions created in this experiment were not enough to yield a difference in transfer condition for the blindfolded-sighted group.

Information processing by using interoceptive and exteroceptive sources is vital for human movement performance and learning. Vision, tactile, vestibular, and proprioception are some of the information we use for movement execution. The lack of visual system for the blind people forces them to use other sources predominantly. The studies indicated that there is an increase usage of vestibular system[13], tactile information[12] but our study failed to indicate enhanced usage of proprioceptive information for acquisition of a target location. In addition, it can be inferred from this study that different KR types have the same effect in the learning process and retention tests to a spatial memory skill. It may also be suggested that the blind and blindfolded-sighted children share similar degree of skill acquisition in spatial memory. Because reduced frequency of KR in the blind was found to be more effective in applying skill in a different way, an implication of this study may be that exercises developing spatial memory should be beneficial for the blind. The data indicates that future research needs to be conducted to examine whether proprioceptive system is more enhanced as a result of lack of vision.

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TRANSFER UČENJA U RJEŠAVANJU ZADATKA PROSTORNE MEMORIJE IZMEĐU SLIJEPIH I SUDIONIKA SA POVEZOM PREKO OČIJU

SAŽETAK

Osnovni cilj ove studije je bio da se ispita uticaj dva različita tipa povratnih informacija na rješavanje zadataka prostorne memorije između slijepih i sudionika sa povezom preko očiju. Sudionici u ovoj studiji su imali zadatak da procijene unaprijed određenu razdaljinu koristeći se svojom dominantnom rukom. Svaka od grupa je bila podijeljena na dvije podgrupe, a sudionici su nasumično svrstavani u jednu od njih kao »100% frequency« i »10% bandwidth«. Postignuti rezultat je sudionicima saopštavan usmjeno u smislu poznavanja rezultata (KR). Meta je bila postavljena na udaljenosti od 60 cm. Šestdeset akvizicijskih opita su izvedeni u četiri seta a svaki je uključio 15 ponavljanja, nakon čega su primijenjeni testovi neposredne i odgođene retencije. Povrh toga, ispitanici su sporveli 15 ne-KR opita kao test transfera (tada je meta bila postavljena na udaljenosti od 30 cm). Rezultati dobijeni statističkom analizom su pokazali da nije bilo značajne razlike kod oba opita, akvizicijskog opita i opita retencije. Međutim, značajna razlika se pojavila kod testa transfera. »100 frequency« podgrupa kod slijepih sudionika je bila značajno nepreciznija u poređenju sa svim ostalim sudionicima. Prema tome, može se zaključiti da različiti tipovi povratnih informacija imaju sličan uticaj na zadatke prostorne memorije koji su korišćeni u ovoj studiji. Međutim, tipovi povratnih informacija mogu promijeniti izvedbu točnosti kada je transfer ove sposobnosti u pitanju kod slijepih sudionika.