University Utrecht
Master Neuropsychology

Thesis

Obstacle avoidance

The influence of position and identity of obstacles on the reach trajectory and reaction time.

Supervision:
Dr. H.C. Dijkerman
Dr. S. van der Stigchel

Janneke Knol
01-07-2010
Student number: 3054853

Abstract. Current research suggests that obstacles can change the path of a reaching movement. So far, mainly spatial parameters such as the object's position and width have been assessed. This experiment investigated the influence of identity of an obstacle on both the reach trajectory and reaction time. The influence of identity was examined in order to assess whether the identity of an obstacle could have a larger influence on obstacle avoidance than suspected by previous research. If this is the case, this could be regarded as evidence for cooperation between the dorsal and ventral stream. Another aim of this experiment was to find out which inhibition or attention model could better explain obstacle avoidance. All models predict the deviation of the hand as a function of the saliency of the obstacle. The saliency was varied by using proprioceptive information for one obstacle, but not for the other. Either the own hand of the participant, an imitation hand or a wooden block was used as an obstacle. The obstacle could be placed on two possible locations. Analyses revealed a significant influence of the position on the reach trajectory. In addition, evidence was found that suggests an influence of the identity of an obstacle on the reach trajectory. Neither position, nor identity displayed an effect on reaction time. This experiment confirmed the influence of the position of an obstacle on the reach trajectory. In addition, it provided evidence for a greater role of the identity in obstacle avoidance, but further research is required to strengthen support for this hypothesis. Support could be found for the response activation model, but it was unclear whether this model was the best explanation for the deviation towards the obstacles.

Introduction

In everyday life, a lot of interaction between a person and his or her surroundings occurs. People are able to manipulate their surroundings and they can move around without colliding with objects (Ouelette et al, 2009). One of the basic manipulations is grasping an object. People grasp objects many times a day, in order to move or use them. Although this might seem like a very simple action, this movement is coordinated by a complex neural network. This one simple movement of grasping an object is influenced by the position of the object, as well as by its characteristics (Meegan & Tipper, 1998, Carr et al, 2008). In addition, people have to account for the position of the hand and arm as well.

Two cortical routes play a central role in processing visual information for the guidance of grasping movements, the ventral and dorsal streams. The difference between these streams is described by a model of Milner and Goodale (Milner & Goodale, 1992, Milner & Goodale, 2007). According to their model there is a clear distinction between the functions of the dorsal and ventral streams and the underlying neural structures.

The *ventral* stream projects from the occipital lobe to the temporal lobe and processes visual input into representations about characteristics of the objects and their spatial relations. The most important task of the ventral stream is the identification of objects. In addition, the ventral stream can also influence the process of grasping in certain circumstances. Research shows that people who can not use binocular information about the object they are going to grasp, will use monocular information like texture, colour and perspective**.** This monocular information is processed in the ventral stream and is used for the control of the grasping movement (Mon-Williams et al., 2001, Verhagen et al., 2008). Another process which is subserved by the ventral stream, is the delayed grasping of an object. In this case the movement has to be controlled by visual information from memory, which is stored by the ventral stream (Cohen et al., 2009).

The processing of visual information for programming and controlling a grasping movement is a function of the *dorsal* stream, which terminates in the posterior parietal lobe and the intraparietal sulcus. This stream plays a major role in selecting specific movements for reaching to a goal object and the online control of these movements. To do this, the dorsal stream processes information about the size, shape and position of the goal object relative to the person.

The dorsal and ventral streams provide humans with mechanisms with which they can process visual information about the object to be grasped. Nevertheless, in daily life it often happens that other objects are positioned between the hand and the goal object. These obstacles have to be avoided in order to reach the goal without collision. Several studies have suggested that obstacle avoidance is mainly controlled by the dorsal stream (Schindler et al., 2004, Rice et al., 2006). Evidence for the importance of the dorsal stream for obstacle avoidance comes from people who have selective damage to the dorsal or ventral stream.

People with damage to the *dorsal* stream suffer from a condition called optic ataxia. These patients have trouble with the visual control of movements and they experience problems with obstacle avoidance (Schindler et al, 2004). When unimpaired people have to perform a reaching movement between two cylinders, the reach trajectory is influenced by the position and shape of the cylinders. This is in order to reduce the chances of collision with the obstacles. People with optic ataxia are incapable of taking these cylinders into account in the planning and execution of reaching movements. Their reach trajectories show no deviation in the presence of obstacles, demonstrating the role of the dorsal stream in obstacle avoidance. Despite their impairment in obstacle avoidance, people with optic ataxia are capable of bisecting the space between two cylinders, because this task depends on ventral stream processing.

The reverse is true for people with visual form agnosia. These patients have specific damage to the *ventral* stream. They are incapable of recognizing objects and show inverted results on the two tasks when compared to people suffering from optic ataxia (Rice et al, 2006). During reaching they take the position of the two cylinders into account and show a deviation of the reach trajectory in order to minimize the risk of collision. People with visual form agnosia perform in a similar way as unimpaired people on this task. Nevertheless, they are impaired when asked to bisect the space between the two cylinders. These patients show no impairment in obstacle avoidance because of their intact dorsal stream, but the damage in their ventral stream impairs the performance on the bisection task. Together these studies show the difference in the involvement of the dorsal and ventral streams in obstacle avoidance.

Despite the differences between the dorsal and ventral stream, there is a possibility that both streams cooperate in specific situations of obstacle avoidance. Milner and Goodale (2006) suggest that the ventral stream plays a role in analyzing obstacles to determine their semantic and materialistic characteristics. This function could be activated in certain cases of obstacle avoidance, for example in the presence of salient obstacles. While moving around these obstacles, the information from the ventral stream could cause the person to move his hand more carefully. The goal of this study will be to investigate Milner and Goodale’s hypothesis by examining deviations of the reach trajectory in obstacle avoidance. In this experiment, obstacles with different semantic and materialistic characteristics will be used and their effect on the reach trajectory will be studied. If each obstacle has a different effect on the reach trajectory, this could suggest an involvement of the ventral stream in obstacle avoidance.

It is clear that the dorsal and ventral streams process visual information about objects in the environment in order to be able to grasp objects and avoid obstacles. The reach trajectory can be influenced by the position and characteristics of these obstacles. Research shows that an obstacle has more effect on the reach trajectory when it is positioned close and ipsilateral to the hand (Meegan & Tipper, 1998, Carr et al, 2008). When an obstacle is positioned ipsilateral to the hand this means that it is positioned on the same side of the body as the hand that makes the reaching movement. The amount and course of the deviation can be explained by two different models.

The first model is the response vector model (Tipper et al, 1997). This model explains the deviations of the reach trajectory by means of inhibition mechanisms. When preparing a grasping movement, a movement to both the goal object and the obstacle is prepared. This preparation takes place in groups of neurons in the premotor cortex and the parietal lobe. The neuronal assemblies which prepare the movement to the goal object overlap with those that prepare the movement to the obstacle. While planning the movement, competitive groups of neurons for both the goal object and the obstacle are being activated. Because the movement to the obstacle is inhibited, the movement to the goal object is inhibited as well because the groups of neurons are overlapping. The salience of the obstacle influences the amount of inhibition. More salient obstacles cause more neural activation which in turn causes more inhibition of the movement to the obstacle. Because of the overlapping assemblies, the movement to the goal object is also more inhibited and causes the movement to steer away from the obstacle. In the case of less salient obstacles a different inhibitory mechanism is activated. The movement towards these less activating obstacles is supposed to be sufficiently inhibited by on-centre off-surround mechanisms. However, incomplete inhibition of the movement towards the obstacle could leak into the reaching movement and therefore cause a deviation of the reach trajectory towards the obstacle.

The second model which explains deviations of the reach trajectory is the response activation model by Welsh & Elliot (2004). This model also assumes that movements to both the obstacle and the goal object are prepared. After this preparation, the movement to the obstacle is inhibited. The movement to less salient obstacles is immediately inhibited, which causes the movement to deviate away from the obstacle. The movement to more salient obstacles takes longer to inhibit, which causes the movement to deviate towards the obstacle.

The difference between the response vector model and the response activation model is the direction of the deviation. The response vector model states that a movement steers away from salient obstacles but moves towards less salient obstacles. The response activation model states an opposite effect: a movement will steer away from less salient obstacles but moves towards more salient obstacles. The inhibition of more salient obstacles takes longer, which causes the hand to move towards the obstacle.

The assumption of both models that movements are prepared for both the obstacle and the goal object is supported by research of Cisek and Kalaska (2002). They implanted cortical electrodes in a monkey’s brain in order to measure the cortical activity. The monkey had to perform a reaching task with more than one possible goal object. Analysis of the data revealed that potential-response cells in the premotor cortex prepared a movement to every object in the environment. After it became evident which object was the goal object, the corresponding movement was selected and executed. This data suggests that in the case of multiple possible goal objects a movement towards every object is prepared. Afterwards, one movement is selected and the other movements are inhibited.

Besides inhibition mechanisms, there are other explanations for the deviations of the reach trajectory. Research has shown that reach deviations could be explained by the amount of attention which is attracted by the obstacles (Chang & Abrams, 2004). In this experiment, participants had to make a grasping movement to an object in the presence of two categories of obstacles. The first category consisted of obstacles that could potentially be goal objects. In this condition, multiple movements could be prepared and inhibition mechanisms could explain possible deviations of the reach trajectory. The second category contained obstacles that could never be goal objects. Preparing movements towards these obstacles is unnecessary and deviations from the reach trajectory could therefore not be explained by inhibition mechanisms. The data from this experiment showed that there were deviations from the reach trajectory in both conditions. The hand moved towards both obstacles, regardless of whether the obstacle was a potential goal object or not. This effect could not fully be explained by inhibition mechanisms, because a movement to the object in the second category was not prepared. This result could be explained by the amount of attention the obstacles attract. The salience of an obstacle could activate the spatial attention system and this could change the representation of the obstacle that is used in the planning of the reaching movement. Because the used representations are changed, the reach trajectory changes accordingly.

All the above theories claim that the salience of an obstacle influences the reach trajectory. The salience of an obstacle is, among others, dependent on its position. This is demonstrated by the proximity-to-hand effect. This effect implies that the closer an obstacle is to the start position of the hand, the more attention it will attract and therefore the more influence it will have on the reach trajectory (Meegan & Tipper, 1998, Carr et al, 2008). An obstacle will also have more influence on the reach trajectory if it is positioned ipsilateral to the moving hand instead of contralateral (Meegan & Tipper, 1998).

Apart from the reach trajectory, an obstacle can also influence reaction time, the velocity of the movement and the grip aperture of the hand. Research has shown that the hand moves slower and the grip aperture is reduced in the presence of an obstacle in order to minimize the risk of collision (Mon-Williams et al, 2001). The closer an obstacle is positioned to the hand, the longer it takes for participants to start the reaching movement (Meegan & Tipper, 1998).

Despite the research done so far, the precise influence of the identity of the obstacles on the reach trajectory is not clear. The identity of an obstacle is defined as the collective aspect of the set of characteristics by which a thing is definitively recognizable or known (The American Heritage Dictionary of the English Language, 2009). The aim of this experiment is to unravel the influence of the identity of the obstacle on the reach trajectory and reaction time. In this experiment both the position and the identity of the obstacle are manipulated. The obstacle is placed in two different locations to measure the effect of its position. In order to determine whether there is a differential influence of these obstacles dependent on its identity, the obstacle in this experiment is either an imitation hand or the own hand of the participant.

The difference between these two conditions is the amount and type of information available. One type of information is available about the imitation hand, namely visual information. In contrast, two types of information are available about the own hand of the participant, namely visual and somatosensory information. Somatosensory information is involved in determining the position of different body parts in relation to each other (Dijkerman & de Haan, 2007). The somatosensory information concerning action is processed in the posterior parietal cortex (PPC). Mainly the Brodmann area 5 is involved in this process. In the PPC 5 tactile and proprioceptive information is integrated with sensoric information about the goal object. Neurons in this area respond to somatosensory stimulation related to reaching movements (Dijkerman & de Haan, 2007). Research with monkeys reveals the participation of area PPC 5 in determining the position of the arm (Graziano, Cooke & Taylor, 2000). This ability to represent the positions of different body parts and keeping track of these positions during movement is called the body scheme. The information from this scheme is used for the spatial organisation of actions (Haggard & Wolpert, 2005). The own hand will be incorporated as a part of the body of the participant and it can be placed in the body scheme, while the imitation hand will be processed as an object apart from the body of the participant. The available information about the two obstacles will therefore be different and could have a differential effect on the reach trajectory and reaction time. The imitation hand can not be placed in the body scheme. It will therefore be less expected and might attract more attention than the own hand of the participant. If this is correct, the imitation hand will be more salient than the own hand of the participant and will have a larger effect on the reach trajectory.

The main goal of this study is to examine the role of the dorsal and ventral stream in obstacle avoidance. Information about the identity of an obstacle is processed in the ventral stream and obstacle avoidance is believed to be programmed and executed with the help of the dorsal stream. In this experiment, the influence on the reach trajectory of two obstacles with different identities is examined. If the results of this experiment show an influence of identity on the reach trajectory, this could suggest that the information from the ventral stream is used in the execution of reaching movements. This would suggest that the dorsal and ventral stream could, under certain circumstances, work together in order to avoid obstacles.

The second aim of this experiment is to discover which model better explains the deviation of the reach trajectory. According to both inhibition models (Tipper, 1997; Welsh & Elliot, 2004) more salient obstacles will have a larger effect on the reach trajectory than less salient obstacles. A salient obstacle will have to be more inhibited than a less salient obstacle and will therefore have more effect on the reach trajectory. According to the attention model (Chang & Abrams, 2004), a salient obstacle attracts more attention and will therefore affect the reach trajectory more then a less salient obstacle. The hypothesis of all aforementioned models is that the imitation hand will have a greater influence on the reach trajectory because it is more salient than the own hand of the participant. In addition, both inhibition models predict whether the hand will move towards or steer away from the obstacle. Which direction the hand deviates depends on the saliency of the obstacle. This experiment will examine the deviation of the reach trajectory to find support for one of the inhibition models.

The third objective of this experiment is to confirm the effect of the position of the obstacle on the reach trajectory. Previous studies have demonstrated that obstacles which are positioned closer to the hand, will have a larger influence on the reach trajectory (Meegan & Tipper, 1998, Carr et al, 2008).

The final objective of this experiment is to investigate the influence of both position and identity on reaction time. It is expected that the closer the obstacle is positioned to the hand, the longer it takes for participants to react (Meegan & Tipper, 1998). The effect of obstacle identity on reaction time is yet unknown. It is predicted that the imitation hand will have a larger effect on reaction time, because this obstacle is less expected and attracts more attention. Therefore, participants will react more carefully and take more time to prepare and start the reaching movement.

Methods

Participants

Twelve people participated in the experiment (four males). All participants were right handed as validated with the Handedness Questionnaire. The mean age of the participants was 24 years (SD: 2.0). The participants had normal or corrected-to-normal visual acuity and had no motoric disabilities.

Stimuli and Apparatus

The experiment took place in a lit room. The participants were seated at a white table of 122 x 61 cm. A yellow button, which served as the start position of the right hand, was positioned 8 centimeters off the side of the table closest to the participant. Forty centimeters from the start position was a grey button of 5 x 22 cm which was the target of the movement. This button was pressed by the participant by which the end of the movement could be determined.

The reaching movement was recorded by miniBIRD sensors (miniBIRD tracking system; Ascension Technology, Burlington, VT) with a frequency of 100 Hz. Underneath the right corner of the table, on the opposite side from the participant, an electromagnetic coil was attached with which the positions of the sensors could be determined. To prevent a disturbance of the magnetic field, the participant and experimenter removed all metal objects (telephones, jewellery, etc.) and placed them outside the magnetic field. During the experiment two sensors were used to determine the position of the right hand. The first sensor was attached to the nail of the index finger. The second sensor was attached to the back of the hand just below the index finger.

In this experiment, three different obstacles were used, namely the left hand of the participant, an imitation left hand and a wooden block. The imitation hand was a lifelike copy of a left hand made of rubber. It was 12.5 x 19.5 cm en had approximately the same colour as a caucasian hand. The shape of the wooden block roughly resembled the shape of the left imitation hand and was of a similar colour as the rubber hand (figure 1).

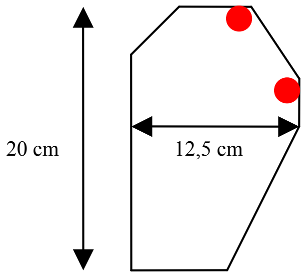

Figure 1; shape of the “left-handed” wooden block. The red dots indicate the positions of the “index finger” and “thumb” which were used to put the obstacle in the correct position.

In each trial, one obstacle was used which could be placed on two different positions to the left of the participant, position A or B. The distance between the midline (the line from start position to the centre of the goal) and the closest point of the obstacle was 12 cm at position A and 8 cm at position B (figure 2). Two dots marked the position and orientation of the obstacles at positions A and B, one dot for the index finger and one for the thumb.
A wooden block was positioned to the right of the participant. The shape of this block mirrored the wooden “left-handed” block and had the same colour. The distance between the midline and the closest point of the wooden block was 12 cm (figure 2, position A’). The block on the right of the participant was used to keep the maximum deviation during the reaching movement within limits.

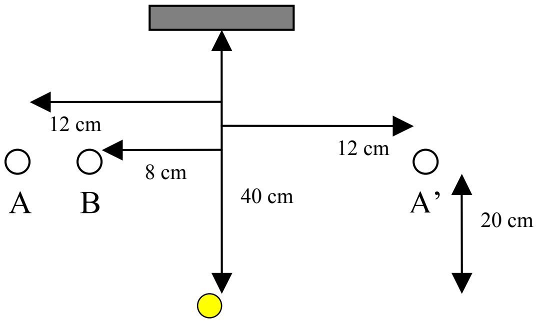

Figure 2: Composition of the experimental setup. Each white cirkel represents the position of the thumb of an obstacle.

Experimental procedure

Before starting the experiment, the participants completed an informed consent and the Handedness Questionnaire. Next, the experimental procedure was explained and the two sensors were attached. Before the actual experiment, the participant practiced the reaching movement five times.

Each trial started when the participant held the start button with his right index finger. After this, the experimenter instructed the participant which obstacle had to be placed at which position. The experimenter removed the previous obstacle and handed over the new one. The participant took the obstacle with his left hand and placed it in the correct position (A or B). After positioning the obstacle, he put his left hand in his lap (except for the trials in which the own left hand was the obstacle) so that it would not influence the reach trajectory. The experimenter checked the position of the obstacle and whether the participant removed his left hand from the table. If everything was correct, the experimenter pushed a button after which a sound was produced. This was the sign for the participant to start the reaching movement towards the grey button**.** After reaching the goal, the participant returned his right hand to the start position, ready for the next trial.

In the experiment, 3 obstacles were used which could be placed at 2 positions, resulting in 6 different conditions. All conditions were performed 30 times, which resulted in 180 trials. After every 30 trials the participant was given the opportunity to take a short break (without removing the sensors). The sequence of the trials was randomised and presented on a laptop by the Presentation program (version 11; Neurobehavioral Systems, San Francisco, CA). Two to four seconds after the experimenter pushed a button to indicate that the obstacle was in the correct position, this program also produced a sound which was the sign for the participant to start the reaching movement. This variation in time between the push of the button and the sound was introduced to maintain the attention of the participant.

Data analysis

The data of the miniBIRD sensors was analysed in a self-made script run in the program MatLab. The starting point of every trial was defined as the moment that the sound was produced by the Presentation program. The endpoint of the movement was defined as the moment at which the goal button was pressed. The amount of sample points per trial was calculated to determine the total length of the trial. All trials in which the movement time took longer than 4 seconds and all trials in which the hand moved less than 2 cm were deleted. The remaining trials were checked manually for the amount of noise**.** A graphic drawing was made of each trial with which could be determined whether it showed an unambiguous movement. If this was not the case because of too much noise, the trial was deleted. The average percentage of deleted trials per participant was 1.76 %. After deleting these trials at least 170 trials per participant remained.

Using these remaining trials, three types of data were produced: the maximum deviation of the hand, the deviation at the point of passing the obstacle and reaction time. The maximum deviation of the hand was defined as the largest deviation from the midline (Tresilian, 2004). The deviation at the point of passing the obstacle was defined as the average deviation from the midline while passing the area from 1 cm before until 1 cm after the thumb of an obstacle (Schindler et al, 2004). The average deviation was calculated by dividing the sum of all the deviation values in this area by the number of sample points made in that same area. Reaction time was the time it took participants to react to the sound which was the sign that they could start the movement. It was defined as the time in milliseconds between this sound and the first movement of the hand (Meegan & Tipper, 1998).

Two graphic drawings were made for each type of data. The first graphic drawing showed the results from the first half of the experiment and the second drawing showed the results from the second half of the experiment. Comparisons of the two graphic drawings revealed a learning effect. The data of the second half of the experiment showed a greatly reduced effect of the obstacles (see figure 3). Therefore, the data was split in two and the data of the first half of the experiment was analysed further.

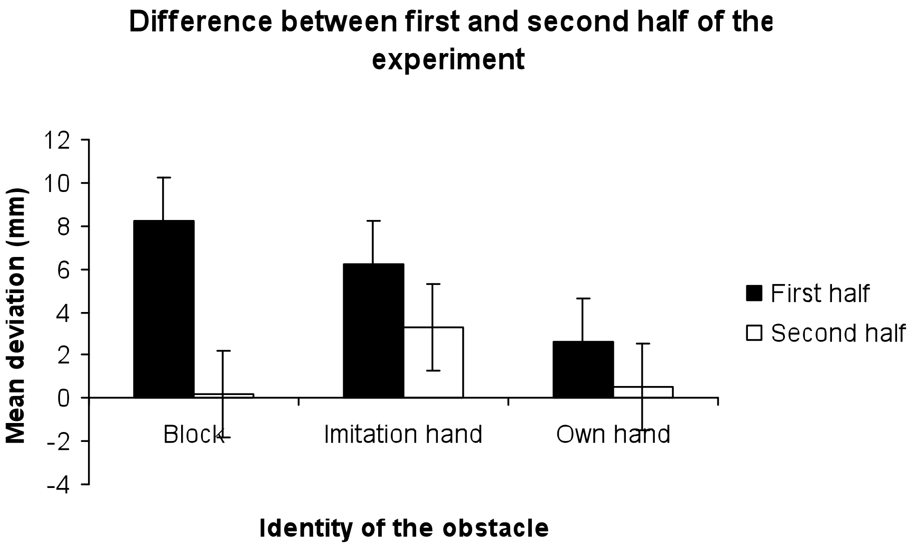

Figure 3: The mean deviation of the hand while passing the obstacle in the first and second half of the experiment.

The data was organized using the program Excel. For every participant the mean values of the maximum deviation of the hand, the deviation at the point of passing the obstacle and reaction time were entered. The average of all participants was calculated for every condition.

This data was analysed by the program Statistical Package for the Social Sciences 16.0 (SPSS). A repeated measures analysis with factors ‘position’ and ‘identity’ was accomplished for each dependent variable. The factor ‘position’ had two levels: position A and position B. The factor ‘identity’ had 3 levels: own hand of the participant, imitation hand and wooden block.

Results

Analysis of the data revealed that participants moved towards the obstacle. An example of the path of the reach trajectory is shown in figure 4.

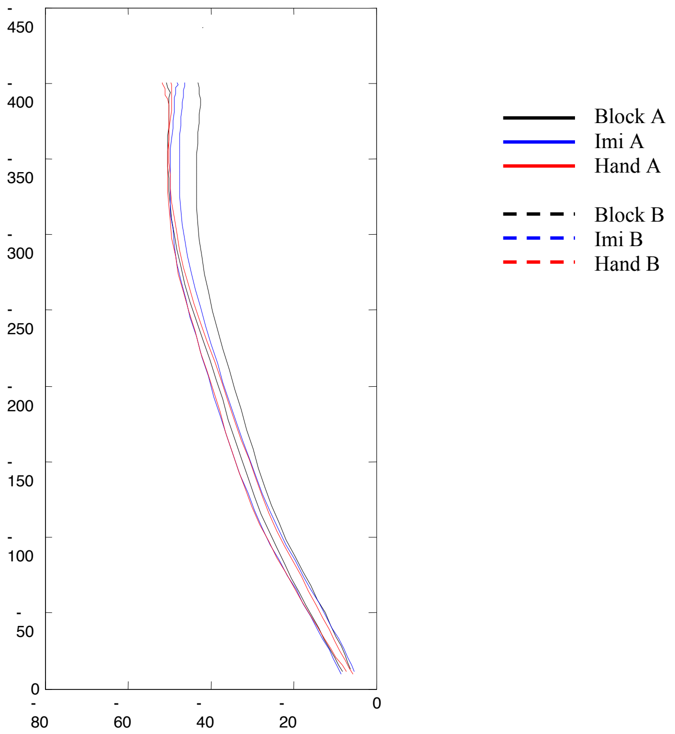

Figure 4: Deviation from the midline in mm (zoom) for all positions (A and B) and identities (Imitation hand (Imi), Own hand (Hand) and wooden block (Block)).
The obstacle is positioned to the left of the reach trajectory.

Maximum deviation of the hand

A repeated measures ANOVA with factors position and identity showed a significant effect of position on the maximum deviation of the hand ($F_{(1,11)} = 5.758$, $p = .035$). This means that participants showed a larger maximum deviation of the midline when the obstacle was positioned on position A compared to when the obstacle was positioned on position B. (Position A: mean deviation (cm) = 5.1; std = 2.6 , Position B: m = 1.1; std = 1.1) The mean maximum deviation for the different conditions is shown in figure 5.
The identity of the obstacle had no significant effect on the maximum deviation of the hand ($F_{(2,22)} = 1.63$, $p = .219$). No significant interaction effect was found ($F_{(2,22)} = 1.527$, $p = .239$).

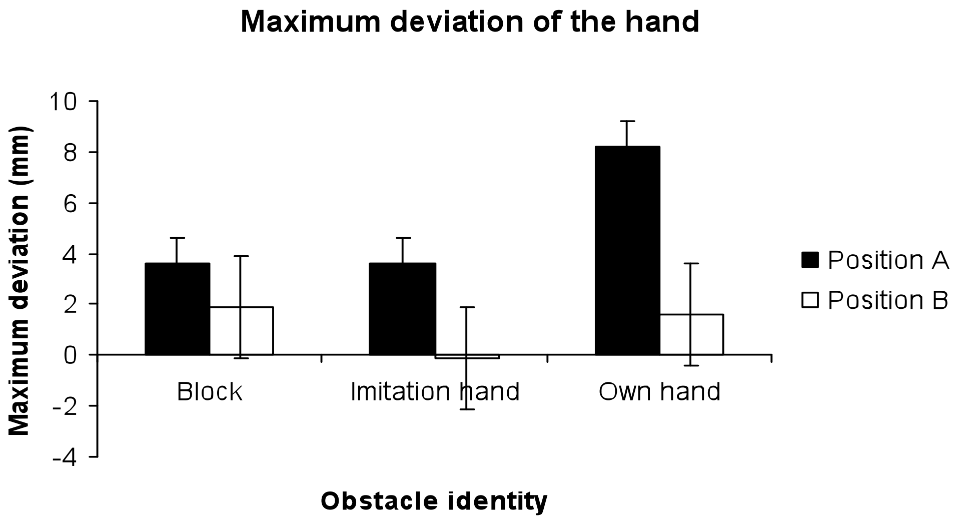

Figure 5: Mean maximum deviation of the hand.

Deviation of the hand at the point of passing the obstacle

A repeated measures ANOVA with factors position and identity revealed a significant effect of position on the deviation of the hand at the point of passing the obstacle ($F_{(1,11)} = 6.88$, $p = .024$). This means that participants displayed a larger deviation of the midline while they were passing the obstacle when it was placed on position A compared to position B. (Position A: m = 3.9; std = 1.9, Position B: m = 1.1; std = 0.6) The mean deviation of the hand while passing the obstacle is shown in figure 6 for all conditions.

No significant effect of the identity of the obstacle was found ($F_{(2,22)} = 1.983, p = .161$). No significant interaction effect was found ($F_{(2,22)} = 2.535, p = .102$). However, a graphic display of the data did indicate an interaction effect between position A and the identity of the obstacle. Therefore, a repeated measures ANOVA with factor identity was performed to see whether the identity of the obstacle had a significant effect on the reach trajectory while passing the obstacle when it was placed on position A. The results showed a significant effect of identity ($F_{(2,22)} = 3.518, p < .05$). A paired samples T-test showed a significant difference in influence on the reach trajectory between the wooden block and the own hand of the participant ($t = 2.353, p < .05$). This means that participants showed a larger deviation of the midline, at the point of passing the obstacle, when the obstacle was their own hand in comparison to the wooden block. No significant differences were found between the imitation hand and the own hand ($t = 2.142, p = .055$) and between the wooden block and the imitation hand ($t = .691, p = .504$).

A repeated measures ANOVA with factor identity was performed to see whether the identity of the obstacle had a significant effect on the reach trajectory while passing the obstacle when it was placed on position B. The results showed no significant effect of identity ($F_{(2,22)} = .446$, $p = .646$).

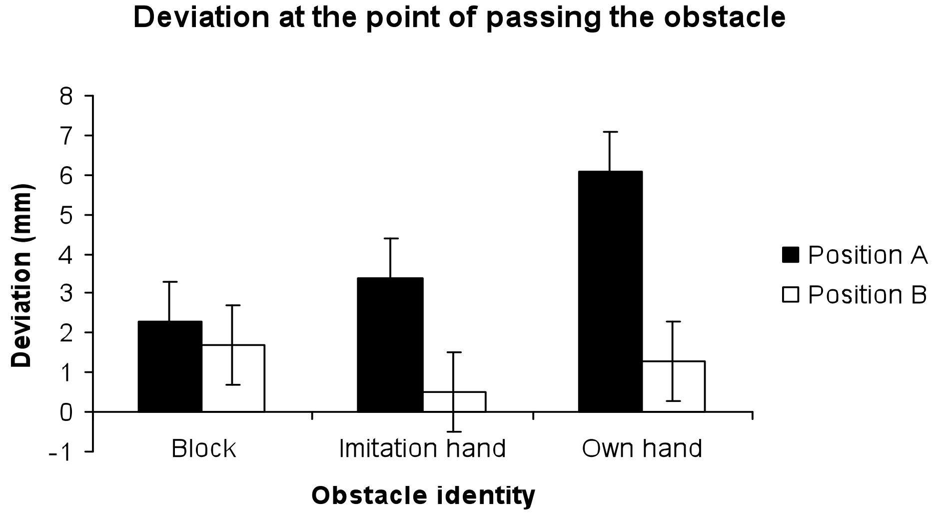

Figure 6: The mean deviation of the hand at the point of passing the obstacle.

Reaction time of the hand

A repeated measures ANOVA with factors position and identity revealed no significant effect of position on the reaction time of the hand ($F_{(1,11)} = 1.922$, $p = .193$). No significant effect of the identity of the obstacle was found ($F_{(2,22)} = 3.139$, $p = .063$). No significant interaction effect was found ($F_{(2,22)} = 1.312$, $p = .290$). The mean reaction time of the hand for the different conditions is shown in figure 7.

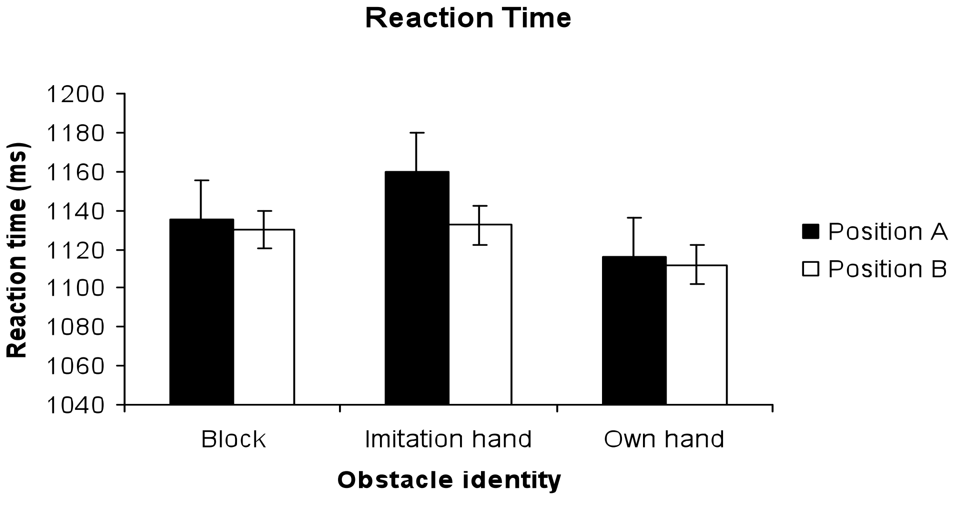

Figure 7: The mean reaction time of the hand.

Discussion

The main goal of this experiment was to investigate whether the object identity could have a larger influence on obstacle avoidance than suggested by previous research. The secondary goals of this experiment were to confirm the influence of position of the obstacle on the reach trajectory and to get more clarity about which model better explains the influence of position and identity on both the reach trajectory and reaction time. Current theories suggest that obstacle avoidance could be explained by inhibition or attention models. The expected results were that both the identity and position of an obstacle would have a significant effect on the reach trajectory and reaction time. In order to minimize a collision with the object the hand is predicted to veer away from the obstacle. The assumption was that the closer an obstacle is positioned to the hand, the more influence it will have on the reach trajectory (Meegan & Tipper, 1998). In case of the identity of the obstacle, it was assumed that an imitation hand would have a larger effect than the own hand of the participant. This was because participants had less information about the imitation hand, which would therefore be less expected and thus attract more attention than their own hand. The imitation hand would therefore be more salient than the own hand and was supposed to have a larger effect on the reach trajectory. It was also predicted that the reaction time would be influenced by the position of the obstacle. Previous research suggests that obstacles slow down the reaction time of the hand when they are positioned ipsilateral and close to the participant (Meegan & Tipper, 1998).

The results showed a significant effect of identity on the deviation while passing the obstacle when it was placed twelve centimetres away from the participant. Further analysis revealed a significant difference in effect between the own hand of the participant and the wooden block. This result supports the hypothesis that the identity of an obstacle could have a larger influence on obstacle avoidance than suggested by previous research. Graphic drawings did also suggest a difference in effect between the own hand of the participant and the imitation hand when it was positioned twelve centimetres from the participant, but this could not be supported by analysis of the data. It could be that the difference between these two identities was not significant because the sample size in this experiment was too small. It could also be that the difference in available information about the own hand and the imitation hand is too small to exert a different effect on the reach trajectory. Analysis of the other conditions in this experiment did not reveal a significant effect of identity on both reaction time and the reach trajectory. This could be because the sample size was too small, but another explanation is that the influence of the identity of an obstacle is related to the position of the obstacle. This means that the obstacle has to be placed on a certain position to reveal an effect of identity.

Analysis of the data revealed that participants moved towards the obstacle instead of veering away from them. This could be explained in several ways as both inhibition models have an explanation for reach trajectories which move towards an obstacle. According to the response vector model (Tipper et al., 1997) a hand moves towards less salient obstacles. It could therefore be suggested that the obstacles in this experiment did not attract enough attention. This explanation is not very likely. In each trial the obstacle changed in both position and identity and participants placed the obstacles themselves. These two factors made sure that the participants noticed the obstacles and took them into account in the planning and execution of the reach trajectory. The results of the present study therefore do not support the response vector model.

According to the response activation model (Welsh & Elliot, 2004) a hand moves towards more salient obstacles and steers away from less salient obstacles. As mentioned above, it is assumed that the obstacles used in this study attracted the attention of the participant. Because the reach trajectories showed a deviation towards the obstacles, this study could support the response activation model.

Another way to explain the unexpected direction of the deviation is the experimental setup. In order to keep the deviation within limits a wooden block was positioned to the right of the participant. This object could have influenced the reach trajectory more than intended. The block on the right was on the ipsilateral side of the participant in contrast to the obstacles which were placed on the contralateral side. Obstacles are expected to have a larger influence when they are positioned on the ipsilateral side (Meegan & Tipper, 1998). Because the wooden block was being a constant factor, it was not expected to have a significant effect on the reach trajectory. However, it could be that the movement towards the obstacles was actually a movement away from the ipsilateral positioned and therefore most ‘threatening’ object: the block on the right.

Analysis of the data showed that the position of the obstacle had an influence on both the maximum deviation and the deviation at the point of passing the obstacle. This outcome is in accordance with earlier research (Meegan & Tipper, 1998; Carr et al, 2008). The results showed that when the position of an obstacle changes, the reach trajectory changes accordingly. The further away the obstacle was, the more the reach trajectory moved towards the obstacle. When the obstacle was positioned closer to the participant, the hand showed less deviation from the midline. These results do not support the attention model (Chang &

Abrams, 2004). This model suggests that obstacles which attract more attention will have a larger influence on the reach trajectory. Current results revealed that the obstacle which was positioned closest to the participant and therefore attracted the most attention exerted less influence on the reach trajectory than the obstacle positioned further away. This experiment therefore does not support the attention model.

The effect of the position of the obstacle on the reach trajectory can be explained by the experimental setup of this study. The block on the right might be the most threatening object. Participants moved away from this object in order to minimize the chance of collision. However, the participant also had to take into account the obstacle on the left side. The more to the left this obstacle was positioned, the more space the participant had to move away from the block on the right.

Analysis also showed that the position and identity of the obstacles did not have an effect on the reaction time of the participants. This finding is not in accordance with previous research (Mon-Williams et al, 2001), but it might also be explained by the experimental setup. An object which is positioned ipsilateral to the hand has more influence on reaction time (Meegan & Tipper, 1998). It could be that the block on the right had a substantially bigger influence on reaction time than the obstacles on the left because it was positioned ipsilateral to the hand. The combined effect of the left and right objects on reaction time consists therefore mostly of the effect of the right object on reaction time. Variations in position and identity of the left obstacle were therefore relatively unsubstantial and did not produce a significantly different effect on reaction time.

This experiment provides support for the hypothesis that obstacle identity has a larger effect on the planning and execution of obstacle avoidance than suggested by current theories. Most conditions of this experiment did not show a significant effect of identity on obstacle avoidance, perhaps because the sample size was too small or because the influence of the identity is related to the position of the obstacle. It could therefore be interesting to increase the sample size to discover whether a significant effect of identity can be found in all conditions. It could also be interesting to introduce a wider range of obstacle identities and positions to examine the interaction between the identity and position of the obstacle.

Another situation in which the identity of an obstacle could influence the reach trajectory is when the obstacles are dangerous of life-threatening and when it is absolutely necessary to avoid them. Therefore, an interesting future experiment would be to investigate obstacle avoidance again, only now with obstacles which participants would absolutely have to avoid. Examples of these are repulsive or possibly instable obstacles.

Another interesting experiment would be to repeat this experiment with an adjusted setup. The right block should be made less prominent to reduce its influence on the movement. Other manipulations of this experiment could also be interesting. For example, using a hand as an obstacle has an interesting social component which is not investigated in this experiment. A hand suggests that another person is nearby. It could be that people with social fobia react more strongly to this obstacle than healthy persons. Besides, there could be a gender difference in avoiding social obstacles, because of differences in personal space regulations.

This experiment sheds a new light on obstacle avoidance. Untill now, research mostly examined the influence of the position of the obstacle on the reach trajectory. This experiment confirmed past findings on the influence of the position, but also found evidence for the influence of another characteristic of the obstacle, namely its identity. This experiment therefore sheds a new light on obstacle avoidance and it constitutes a basis for future research.

References

Carr M., Phillips J.G., Meehan J.W. (2008). Non-target flanker effects on movement in a virtual action centred reference frame. *Exp Brain Research* 184, 95-103.

Chang S.W.C., Abrams R.A. (2004). Hand movements deviate toward distracters in the absence of response competition. *The Journal of General Psychology* 4, 328 – 344.

Cisek P., Kalaska J.F. (2002). Simultaneous Encoding of Multiple Potential Reach Directions in Dorsal Premotor Cortex. *Journal of Neurophysiology* 87, 1149 – 1154.

Cohen N.R., Cross E.S., Tunik E., Grafton S.T., Culham J.C. (2009). Ventral and dorsal stream contributions to the online control of immediate and delayed grasping: A TMS approach. *Neuropsychologia* 47 (6): 1553-1562.

Dijkerman C.H., de Haan H.F. (2007). Somatosensory processes subserving perception and action. *Behavioral and brain sciences* 30, 189-239.

Goodale M.A., Milner A.D. (1992), Separate visual pathways for perception and action, *Trends in Neurosciences* 15, 20–25.

Graziano M.S.A., Cooke D.F., Taylor C.S.R. (2000). Coding the Location of the Arm by Sight. *Science* 290, 1782 – 1786.

Haggard P., Wolpert D.M. (2005). Disorders of Body Scheme. *Higher-Order Motor Disorders*, Oxford University Press.

Houghton Mifflin Company (2009), The American Heritage Dictionary of the English Language, *Fourth Edition*.

Meegan D.V., Tipper S.P. (1998). Reaching into cluttered visual environments: spatial and temporal influences of distracting objects. *The Quarterly Journal of Experimental Psychology* 51 A, 225 – 249.

Milner A.D., Goodale M.A. (2006). The visual brain in action (2nd ed.), Oxford University Press, Oxford.

Milner A.D., Goodale, M.A., (2007). Two visual systems re-viewed. *Neuropsychologia* 46, 774-785.

Mon-Williams M., Tresilian J.R., Coppard V., Carson R.G. (2001). The effect of obstacle position on reach-to-grasp movements. *Experimental Brain Research* 137 :497-501.

Mon-Williams M., Tresilian J.R., McIntosh R.D., Milner A.D. (2001). Monocular and binocular distance cues: insights from visual form agnosia, *Experimental Brain Research* 139 : 127 – 136.

Ouellette M., Chagnon M., Stat P., Faubert J. (2009). Evaluation of Human Behavior in Collision Avoidance: A Study inside Immersive Virtual Reality. *CyberPsychology and Behavior* 12.

Rice J., McIntosh R.D., Schindler I., Mon-Williams M., Démonet J., Milner A.D. (2006). Intact automatic avoidance of obstacles in patients with visual form agnosia. *Experimental Brain Research* 174, 176-188.

Schindler I., Rice N.J., McIntosh R.D., Rossetti Y., Vighetto A., Milner D.A. (2004). Automatic avoidance of obstacles is a dorsal stream function: evidence from optic ataxia. *Nature Neuroscience* 7.

Tipper S.P., Howard L.A., Jackson S.R. (1997). Selective reaching to grasp: evidence for distractor interference effects. *Visual cognition* 4 (1), 1-38.

Tresilian J.R. (2004). Attention in action or obstruction of movement? A kinematic analysis of avoidance behavior in prehension. *Experimental Brain Research* 120, 352 – 368.

Verhagen L., Dijkerman C.H., Grol M.J., Toni I. (2008). Perceptuo-Motor interactions during prehension movements. *The Journal of Neuroscience 2*8 (18), 4726-4735.

Welsh T.N., Elliot D. (2004). Movement trajectories in the presence of a distracting stimulus: Evidence for a response activation model of selective reaching. *The Quarterly Journal of Experimental Psychology* 57A (6), 1031-1057.