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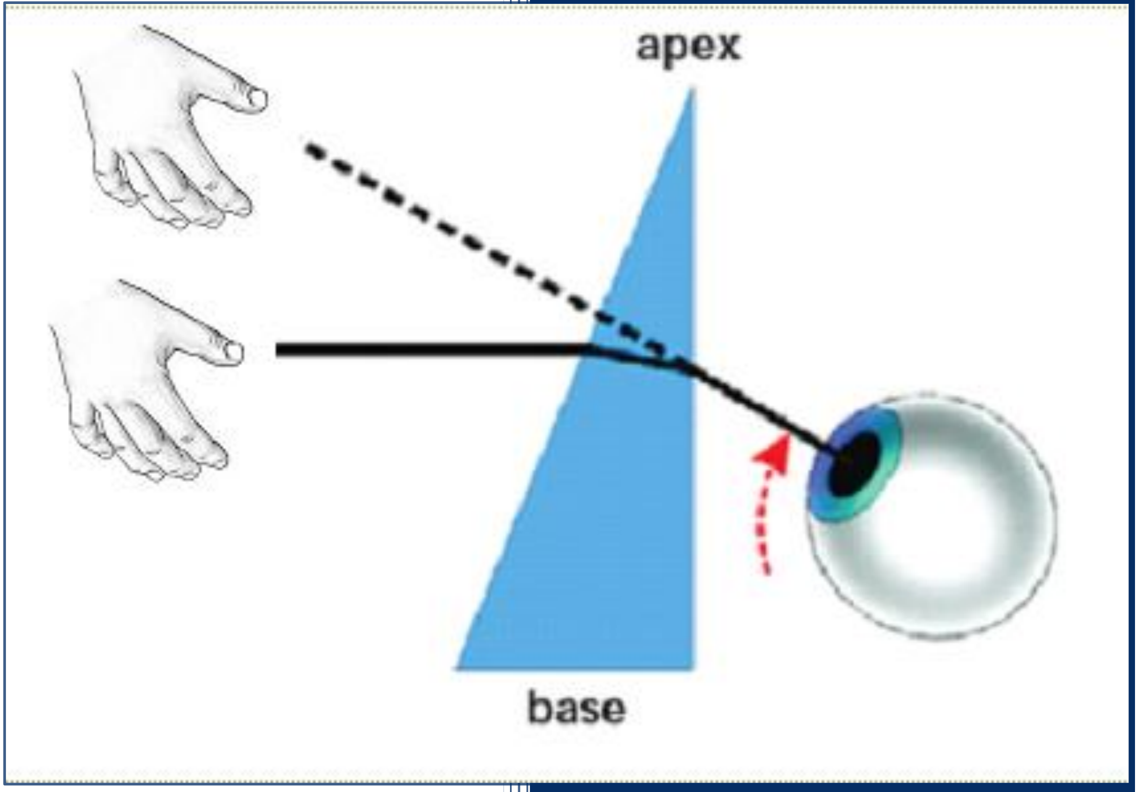
A prismatic view of the hand

The influence of verbal and tactile feedback on visuotactile predictions



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Thesis

A Prismatic view of the hand:

The influence of verbal and tactile feedback on visuotactile predictions.

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Abstract

We interact all the time with our environment. In order to do this efficiently we persistently make visuotactile predictions. However, certain patient groups, such as patients with unilateral neglect, show deficits in their interaction with their environment. Unilateral neglect is a disorder in which patients are unaware of the contralesional space (Danckert & Ferber, 2006). One technique often used in rehabilitation programs for unilateral neglect is prism adaptation. Prism adaptation could be of beneficial influence on neglect symptoms. What stands in the way of usage is that the actual method of reaching prism adaptation (with motor execution or motor imagery) may pose a problem for neglect patients, because of the usage of movements. This because patients with severe unilateral neglect have problems during movement initiation and execution. In this study healthy subjects were used to assess if it is possible to obtain a prism adaptation without the usage of movement. When in real life visuotactile predictions are made, feedback from different sensory modalities will follow, so in this research where assessing the influence of different types of feedback (no-, verbal- and tactile-feedback). In the current study, participants had to make visuotactile predictions before, during and after prism exposure. After each block of visuotactile predictions the participants had to indicate their body-midline, to assess proprioception. The results show that prism adaptation occurred in all three conditions (no-, verbal- and tactile-feedback) during the visuotactile prediction task, as is revealed by an after-effect. The observation of an after-effect in the "no-feedback" condition indicates that the participants must have had some kind feedback. Therefore the "no-feedback" condition was excluded from further analyses. Also an after-effect is shown in the proprioception task. Both after-effects are not the result of different amounts or various sizes of wrong given answers. Hereby can we conclude that it is possible to obtain a prism adaptation without the usage of movement, for both types of feedback (verbal and tactile).

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1. Introduction

Unilateral neglect is a disorder in which patients are unaware of the contralesional space (Danckert & Ferber, 2006). Neglect patients fail to report, respond to or orient towards stimuli in the contralesional space. It seems therefore as if for them, one half of their world stopped to exist. Behavioral symptoms that patients with unilateral neglect show are a shift in in their posture, gait and gaze towards the side of the lesion. What may stand out for example is that they have turned their head away from their body-midpoint towards the side of the lesion. Other behavioral signs you can see in neglect patients are the disregard of personal care for their contralesional side (for instance not shaving their left side) and they may bump into people and objects that are present in their contralesional space. Unilateral neglect patients usually have a brain lesion in the right-hemisphere in the dorsal stream, which has as a result that they show neglect on their left side of the body and the left side of space. More specifically, according to the research from Mort et al. (2003) there are two posterior regions where damage is associated with neglect. They indicate that in the territory of the middle cerebral artery (MCA) the critical region for neglect is the angular gyrus (ANG) on the lateral surface of the inferior parietal lobe (IPL). And that the parahippocampal region is the critical area in the territory perfused by the posterior cerebral artery (PCA), on the medial surface of the brain. Damage to these regions can lead in the acute post stroke phase to neglect. According to the research from Farnè et al. (2004) around 9% of the patients with neglect in the acute post stroke stages recover spontaneously and in a two-week period another 43% will show some improvement. This means that a large group of patients continues to have debilitating symptoms after two weeks and need rehabilitation.

One technique often used in these rehabilitation programs is prism adaptation. Prism adaptation is an example of adaptive perceptual-motor control. The conventional procedure that is used during prism adaptation consists of wearing prismatic goggles during repeated active movements towards a visual target (Kornheiser, 1976). Prismatic goggles create a shift in your view. In the rehabilitation programs, this shift will be towards the non-neglected, right side. When pointing, initially there will be a pointing error towards the deviation of the prism goggles. Gradually the pointing error will be corrected as a manifestation of adaptation to the lateral shift caused by the prism. Finally, when the prismatic goggles are removed, subjects show a shift in their movement endpoint, away from the deviation, so this will be towards the neglected left side (after-effect). During this part of the procedure the participant has to point again towards several targets (Kornheiser, 1976). During the test, visual guidance is avoided by covering the arm en hand while participants are making the arm movements. The idea behind the use of prism adaptation in rehabilitation is that neglect patients learn to focus their attention also to the left side of space. This may also result in their body-midline shifting more towards their actual body-midline.

Rossetti, Rode, Pisella, farné, Li, Boisson and Perenin (1998) showed that after a period of prism adaptation neglect patients display remarkable changes in their overt behavior. Their research consisted of two parts. In the first experiment they aimed at measuring the adaptability of neglect patients to a lateral shift of the visual field. Their experiment shows that neglect patients can adapt to a lateral shift of the visual field to the left (Rossetti, Rode, Pisella, farné, Li, Boisson and Perenin, 1998). This implies that prism adaptation had a compensatory effect for the left hemispatial neglect for these patients. In the second part of their experiment they wanted to examine if the main clinical manifestations of neglect could also be improved by prism adaptation. The second experiment indicated that in neglect patients, impairments in the organization of higher levels of spatial representations can be affected by the process of prism adaptation (Rosetti, et al., Prism adaptation to a rightward optical deviation rehabilitates left hemispatieel neglect., 1998). Also Rode, Rosetti and Boisson (2001) investigated the effects of prism adaptation on neglect symptoms. They tested two neglect patients at three different levels: the sensory-motor level, the intermediate level and on cognitive level. The test they used were a pointing task, drawing a daisy from memory and a mental imagery task in which they had to name within 2 minute as many French towns as they could. The conclusion they drew from these results was that not only sensory-motor levels but also higher cognitive levels of mental space representation and/or exploration were improved by prism adaptation. In a review article, Newport and Schenk (2012) examined studies that tested the effect of prism adaptation on neglect, and in concordance with the studies discussed above, their conclusion was that a positive effect of prism adaptation on neglect symptoms is assessed in more than 90% of the studies. These improvements last between two hours and one week after the prism adaptation. The amelioration of neglect after prism adaptation involves sensory-motor tasks, cognitive tasks and non-visual components of neglect (Redding & Wallace, 2006). This is interesting because it means that the ameliorating effects on neglect from prism adaptation go beyond specific sensory-motor tasks, which are applied in general during prism exposure. So neglect patients profit in a broad spectrum of neglect components from prism adaptation. The non-invasive nature of prism adaptation makes it an attractive procedure, just as its acceptability to patients and its ease of use (Rossetti, et al., 1998). Also, it seems that in some cases, the effects of prism adaptation can be quite long-lasting (up to two weeks).

However, a possible downside of prism adaptation as a treatment option is the requirement of movements during the procedure. Movement of the contralesional arm and hand may be disrupted in neglect patients, and additionally, many neglect patients show directional hypokinesia, which is reflected in slower initiation of the ipsilesional arm, unaffected arm, toward the contralesional space (Sapir, Kaplan, He, & Corbetta, 2007). Because of the requirement of a motor response in the neglected hemisphere during most standard tests of neglect, it is difficult to distinguish between motor and perceptual components of neglect. Mattingley, Phillips and Bradshaw (1994) showed that patients with mild unilateral neglect performed comparable to controls on goal-directed movements. But patients with severe unilateral neglect performed significantly worse than their matched controls. The patients showed a slowness in the initiation of movements towards the contralesional side (directional hypokinesia), and through slowness in the execution of movement towards the contralesional side, directional bradykinesia (Mattingley, Phillips, & Bradshaw, 1994). These problems during movement execution can be of influence on the effects from prism adaptation therapy. During the classical procedure for prism adaptation, the patient has to perform a target-pointing task. Patients that have directional hypokinesia or/and directional bradykinesia cannot perform optimal during the target-pointing task. But good performance during the target-pointing task is a necessity for the traditional method of prismatic adaptation to obtain an optimal result.

The question is, if it is possible to obtain prism adaptation without movement because prism adaptation and movement are often regarded as strongly linked. Goodale and Milner (1992) proposed that there are two visual pathways. One for perceptual identification of objects, the ventral stream, projecting from the striate cortex to the inferotemporal cortex. The other one is used for visual guided actions towards an object, the dorsal stream, projecting from the striate cortex to the posterior parietal cortex. Striemer and Danckert (2010) have suggested that prisms influence neglect by acting on dorsal stream circuits subserving visuomotor control. This would explain why prisms affect tasks requiring overt motor responses. However, effects of prism adaptation have been found on non-motor tasks, such as the drawing of a daisy from memory and enumerating French cities used in the research from Rode, Rosetti and Boisson (2001) as those used in the research from Rosetti et al. (2004) whom tested two neglect patients with the number bisection tasks. They used the number bisection task because it is a nonexplicitly spatial task, which has no visual or manual components so that the functional link between number and space representation directly could be investigated. (Rossetti, Jacquin-Courtois, Rode, Ota, Michel, & Boisson, 2004). In the sham adaptation procedure, with neutral goggles, no effect was found in the bias during the number-bisection task. After prism adaptation, in contrast, a sudden change in performance was noted. There was a great improvement in the two patients' bias in the number-bisection task. (Rossetti, Jacquin-Courtois, Rode, Ota, Michel, & Boisson, 2004). The patient who had the largest improvement on the number-bisection task had also a larger adaptation affect. Rosetti, Jacquin-Courtois, Rode, Michel and Boisson (2004) indicate with these results that not only proprioceptive, visual and motor framing of space is altered by prismatic adaptation. Also cognitive levels of space representation, bottom-up process, can be reorganized by prismatic adaptation.

Moreover, recent research from Michel, Gaveau, Pozze and Papaxanthis (2013) showed that actual motor responses might not be necessary for prism adaptation. Their experiment consisted of a comparison between six possible conditions, which differed in whether the participant wore prisms, if there is a sensorimotor conflict (with respect to the target location between the actual en predicted hand position), if there is an intersensory conflict (between proprioceptive-non-shifted and visual-shifted hand condition) and if they had to make a pointing movement to the target. During the pre-test and the post-test the participants had to make the target-pointing task, which consists in their research of 12 visuo-manual open loop pointing movement towards a visual target (Michel, Gaveau, Pozzo, & Papaxanthis, 2013). The results show that also during imagined movements participants adapted to the prismatic deviation. A second result was that a significant difference was found for both groups on the pre- and post-test for straight-ahead estimation. This reaffirms that under prism exposure the adaptation during mental practice was due to sensory realignment (Michel, Gaveau, Pozzo, & Papaxanthis, 2013). This reveals that movement of the limb is not a necessity for prism adaptation, imagining that you move it may be enough. However, motor imagery activates the motor network (de Lange, Roelofs, & Toni, 2008), which is one of the structures associated with neglect after damage (Halligan, Fink, Marshall, & Vallar, 2003). This has as an implication that this method, imaging the movement, probably still cannot be used in neglect rehabilitation therapy.

A possible way to let neglect patients whom show disruptions in their motor control benefit from prism adaptation is to let to them make visuotactile predictions. In order to interact in an efficiently way with the world we continuously make visuotactile predictions in our daily life (Legrand, Brozolli, Rossetti, & Farnè, 2007). The visuotactile predictions make it possible to avoid or interact with objects in our peripersonal space. The peripersonal space is represented through integrated sensory inputs in a body-centered manner (Legrand, Brozolli, Rossetti, & Farnè, 2007). Graziano (1999) showed with his research on monkeys that by means of a convergence of visual cues and proprioceptive cues onto the same neurons the arm position is presented in the premotor cortex of the monkey. Brozzoli, Cardinali, Pavani and Farnè (2010) investigated if differential modulations of peripersonal space are involved whether different actions are performed towards the same object. They conclude that as a function of on-line sensory-motor requirements a continuous remapping of the multisensory peripersonal space is induced by performing actions. Only there is a problem with letting neglect patients make visuotactile predictions. This because they are unaware of the contralesional space. So they fail to report, respond to or orient towards stimuli in the contralesional space, which is in most cases the left side. This need not be a problem for my experiment, because the visual stimulus can be showed in the ipsilateral space, which would be in most cases the right side. This ensures that neglect patients can view the stimulus and so use it for their predictions. Visuotactile predictions could work as a rehabilitation program because it may cause an attentional shift. This shift in attention is brought about as a result of the alignment of the multisensory system. In our daily life we get information from several modalities, whit all the information we try to make one corresponding perception. The information from several modalities is integrated into one perception. Because of the strong links between vision and touch during information processing. Driver and Spence (1998) studied possible cross-modal links in attention. They showed that within touch, audition or vision the presentation of an irrelevant but salient event can attract covert spatial attention in the other modalities. The results of their research show that a preceding visual flash on the right side of space will lead to a faster tactile discrimination on the right side of space. Regardless of whether the hands are crossed or un-crossed. When the hands adopt a different posture the spatial mapping from retinal activation in vision to somatotopic activation in touch will be updated. This remapping is under the influence of proprioceptive signals which determine the current hand position. So, the attentional interactions between two modalities (vision and touch) are influence by a third modality (proprioception). These findings where confirmed by the revived research of Kennett, Spence and Driver (2002). Whose research was in line with the research of Driver and Spence (1998).

Gray and Tan (2002) continued the research investigating a dynamic link in the spatial mapping between vision and touch. They were mostly interested in the influence of stimulated motion on the dynamic link between vision and touch. During the first experiment they used a series of vibrations to stimulate motion along the forearm of the participant. They found that the reaction times where faster, as the interstimulus interval increased, for when the visual target was offset in the same direction as the stimulated tactile motion. This shows that there is a dynamic updated for moving objects in the crossmodal links between vision and touch. Another conclusion they made was that information from vision, direction and time, can be utilized to reorient attention in our tactile map of external space. Neppe-mòdona, Auclair, Sirigu and Duhamel (2004) went a step further with their research and investigated the influence of the eye, head and trunk orientation on the predictions of the impact location on the face from an approaching stimulus. The main finding is that when the target originated from a straight-ahead location predictions about the impact-point where most accurate. But also that when the stimuli originated from an off-centered location a systematic bias is introduced. This means that when an approaching stimulus starts at the right side and is aimed at the midline or left side of the face, participants perceive it as directed towards the tight side of their face. They concluded that the predictions about the point of impact from an approaching stimulus do not solely depend on visual factors, but the visual information is combined with postural information. All in all, the results demonstrate a strong link between vision and touch, which makes visuotactile predictions a good approach for obtaining prism adaptation.

When in real life visuotactile predictions are made, feedback from different sensory modalities will follow. Therefore, to further investigate the prism adaptation process, this study will include different types of feedback on visuotactile predictions. Participants will receive -in different sessions on different days- either no feedback on the visuotactile predictions, tactile or verbal feedback. The tactile feedback consists of touching the correct finger with a rubber pointer and the verbal feedback consists of telling the participant the correct finger. The usage of verbal and tactile feedback gives the participants the opportunity to adjust their predictions toward the introduced shift. Both types of feedback will thus influence the visuotactile predictions made by the participant.

At the beginning there will be a bias toward the same side as the optical deviation, but during the conditions with verbal- or tactile feedback a correction will follow. When a body part is touched, sensory information is detected by touch receptors. This information will be together with other fibers, subsurving other somatosensory modalities in the same body part such as those for proprioception, be conveyed to the central nervous system (Gardner, 2010). Information of touch and proprioception are strongly linked during their information processing (Blanchard C. , Roll, Roll, & Kavounoudias, 2011). Therefore, we expect the tactile feedback to have a larger influence, a better adaptation to the visual shift, than verbal feedback has on the prism adaptation. No correction towards the optical deviation is expected when no feedback is giving. Additionally, we will investigate whether the perceived midline shifts due to the prism goggle exposure, which is an indication for an effect on proprioception. This because according to Driver and Spence (1998) proprioception acts as a mediator (third modality) between the modalities of vision and touch when they interact. The expectation is that a shift in proprioception will take place when adaptation occurs (Fortis, Goedert, & Barrett, 2011). The shift in proprioception has an effect on the performance of tasks that are often taken as a marker for neglect. Taken everything together we hypothesize that it is possible to obtain prism adaptation without movement by means of visuotactile predictions when feedback is supplied.

In the current experiment we let healthy subject make visuotactile predictions and straight-ahead estimations. During the visuotactile prediction task subject have to make predictions about which finger of the left hand would be touched by an approaching stimulus, while their hands are covered. Summarizing, prism adaptation could be of beneficial influence on neglect symptoms. What stands in the way of usage is that the actual method of reaching prism adaptation (with motor execution or motor imagery) may pose a problem for neglect patients. In this research we want to pursue this matter further. During the set-up we used, instead of requiring arm or hand movements, we ask healthy participants to make visuotactile predictions. The participant will see a small stick approaching their hand and has to make a prediction about which finger shall be touched. The hand and arm of the participant will be blocked from view. In line with the work from Michel, Gaveau, Pozze and Papaxanthis (2013), the expectation is that it is possible to have prism adaptation without the patient having to move. In their experiment, an intersensory conflict and the participant imagining the movement was enough to evoke prism adaptation. We therefore expect that it is possible to obtain a prism adaptation by means of visuotactile predictions.

2. Methods

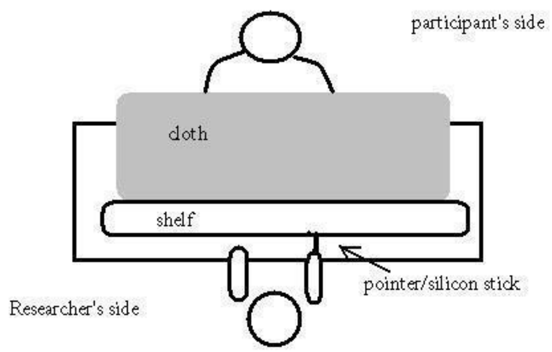
2.1 Participants

Eighteen, healthy volunteers, twelve females and six males, with mean age of 22.94 years [SD: 1.95; range: 19-26] are recruited. All the volunteers are recruited at the University of Utrecht. All participants have normal or corrected to normal vision and normal tactile acuity by self-report.

2.3 Task and Stimuli

Prismatic goggles with a leftwards deviation of 15 degrees have been used in this experiment. The prismatic goggles introduce a shift in the view of the participant so that the natural midpoint of the participant viewed through the prismatic goggles is deviated towards the left with 15 degrees. Participants have been seated at a table, with both hands facing downwards under a wooden shelf (90 x 45 cm), which blocks the view of the hand. The table has been covered with a black cloth so that the texture of the table cannot be used as a reference point. Additionally, a dark cloth blocked vision of the arm. On the shelf, a measuring tape is taped at the experimenters' side, outside the view of the participant. A wooden, bright neon green coloured pencil was used as a visual stimulus (the approaching pointer).

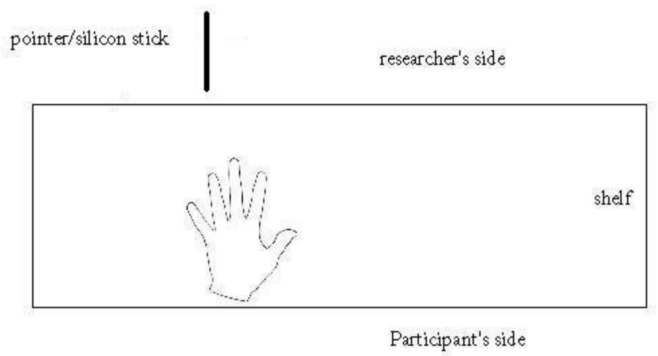
This study has been conducted in three sessions, each on a different day. During each session the same procedure has been applied, only the type of feedback differed (either tactile, verbal or no feedback, see below). The test that was applied during each session consisted of two parts, a visuotactile task followed by a proprioceptive task. A proprioceptive task was conducted at the end of each block (before, during and after prism exposure). Each block consisted of a visuotactile prediction task, in which the participant had to make a prediction about the end state of visual stimulus, a pointer with a rubber tip.



2.3 Procedure

In each session, participants performed the visuotactile prediction task before, during ("prismatic") and after prism exposure. At the end of each block, the visuotactile prediction task was followed by a proprioception task

The participants were asked to put their left hand under the shelf and to sit still during the visuotactile prediction task. Also their arms were covered so they had no reference point about their hand position. The experimenter had placed the participant's hands on a marked spot under the shelf: 15 cm from the midline and with the tip of the middle finger 10 cm from the experimenter's edge of the shelf. At first, a baseline block was completed, without prism goggles. During each trial, the experimenter moved the stimulus from the centre of her chest towards one of the fingers of the participant or towards the space next to the hand. The experimenter has moved every 5 trials, to prevent participants from using the experimenter's body as a fixed reference point to make a prediction. About twenty cm of the trajectory of the experimenter's pointing movement was visible for the subjects. Depending on which of the fingers of the participant is pointed at, the last 7 till 10 cm of the trajectory could not be seen by the participant. When the tip of the pointer has reached ~ 5 cm under the edge of the shelf, the experimenter asked the subject to predict which finger the visual stimulus will touch the skin or if it would be the space next to the hand. The seven answering conditions are: The Dutch names of the fingers (pink, ringvinger, middelvinger, wijsvinger and duim) and the space left and right next to the hand, which has been indicated with "miss/naast". After the prediction, depending on the feedback condition that day, the participant received no-feedback, verbal feedback or tactile feedback. The "no-feedback" condition was used as a baseline measurement throughout the research to see if the participants actually receive any feedback and do not adjust their answers. In the verbal condition the participant was told what the correct answer was. In the tactile feedback the finger was been touched or the movement ended up in the space next to the hand.



In line with Redding and Wallace (2006), each block has consisted of 35 trials (5 more than for instance Redding and Wallace (2006), to ensure an equal usage of every position.) The positions within a block has been random.

Then during the first proprioception task, participants were asked to close their eyes and to point with their index finger of their right hand to their body-midline. The position of the finger was measured with the measuring tape. Afterwards the participant moved their right hand back to the start position and opened their eyes.

After the "before" phase the experimenter has helped the participant put on the prismatic goggles (participants were not allowed to move their hands). During the "prismatic" phase the same procedure was used as in the "before" phase. After the "prismatic" phase the experimenter asked the participant to keep their left hand in the same position and not to move it during the second proprioception task. The right hand was removed from under the cloth. Again the participants were asked to close their eyes and to point towards their body-midline. Again the position of the finger was measured with the measuring tape. Afterwards the participant moved their right hand to the start position and opened their eyes. Their right hand was placed back underneath the shelf and the right arm was covered with the dark cloth. Before the "after" phase of the visuotactile prediction task the experimenter had removed the prismatic goggles. Then, during this phase the participants again has received the same procedure as in the "before" and "prismatic" phase. This last phase has been done to determine if there are "aftereffects" present. Thus, participants completed three blocks of 35 trials sequentially, first without prism goggles (baseline), then with prism goggles, and finally after taking the prism goggles off again, to test the after effect. At the end of each session, the proprioceptive task was repeated. The participants were asked to close their eyes and point with their finger to the position of their body-midline. Also this position was measured.

2.4 Data Analysis

The order of the three sessions (with different feedback types) was counterbalanced across participants. The sessions were administered on different days, because prism adaptation can have a long lasting effect.

Prediction

A zero was assigned to a correct prediction. For incorrect predictions to the left a negative value was assigned. Indicated with -1, is an incorrect prediction of one finger to the left of the target finger. For incorrect predictions to the right a positive value was assigned. Indicated with 1, is an incorrect prediction of one finger to the right of the target finger. The averaged deviation of predictions where used to measure the accuracy of the predictions made during the visuotactile prediction task.

Proprioception

Participant's midline drift was measured with a tape-measure when they pointed straight ahead, after each block of visuotactile predictions. The body-midline was scored, ascending in size number, from right to left. So a body-midline more to the left has a higher score.

Statistics

A within Subject Repeated Measured Design has been used for this study. A repeated measure ANOVA has been used with the independent variables, type of feedback and moment of measurement. To see if the after-effects differed significantly between the three feedback conditions, three Paired Sample T-test with Bonferoni-correction were performed. When the criterion of sphericity is not met a Greenhouse-Geisser correction was applied.

3. Results

3.1 The visuotactile prediction task

The number of fingers deviating from the target finger where counted during all the visuotactile prediction trials. If the deviation is to the right of the target finger, a positive value based on the number of fingers to the right, was assigned. A negative value was assigned to a deviation to the left of the target finger.

Figure 3.1 shows the average deviation from the prediction in fingers on the last six trials of the "before prism expose" condition and the first six trials of the "after prism exposure" condition. Our expectation was that it is possible to obtain prism adaptation by means of visuotactile predictions, leading to an after effect in the first trials after adaptation, which would be reflected by positive (rightwards) deviations. This after-effect was analyzed with a 3x2 repeated measures ANOVA, with the factors type of feedback (no-feedback, verbal-feedback and tactile-feedback) and measurement (before, after). The criterion of sphericity is not met for type of feedback [$X^2(2)$ = 8.182, p = .017], so a Greenhouse-Geisser correction was applied [$\varepsilon = .714$]. There was a main effect from moment of measurement on the average deviation of the prediction in fingers [F (1,17) = 7.454, p = .014], with predictions deviating more to the right after prism exposure. No effect of type of feedback was shown.

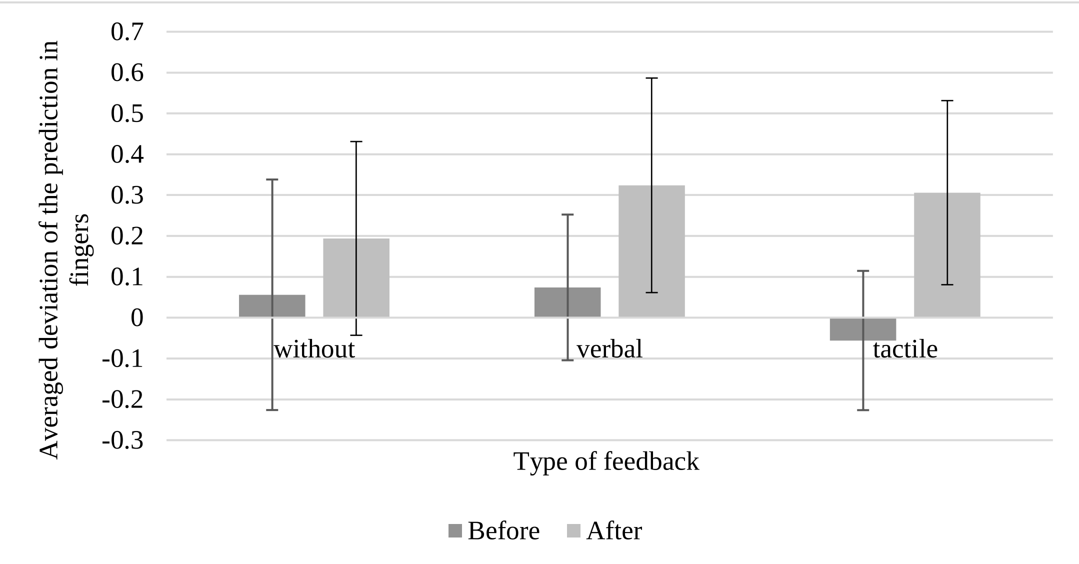
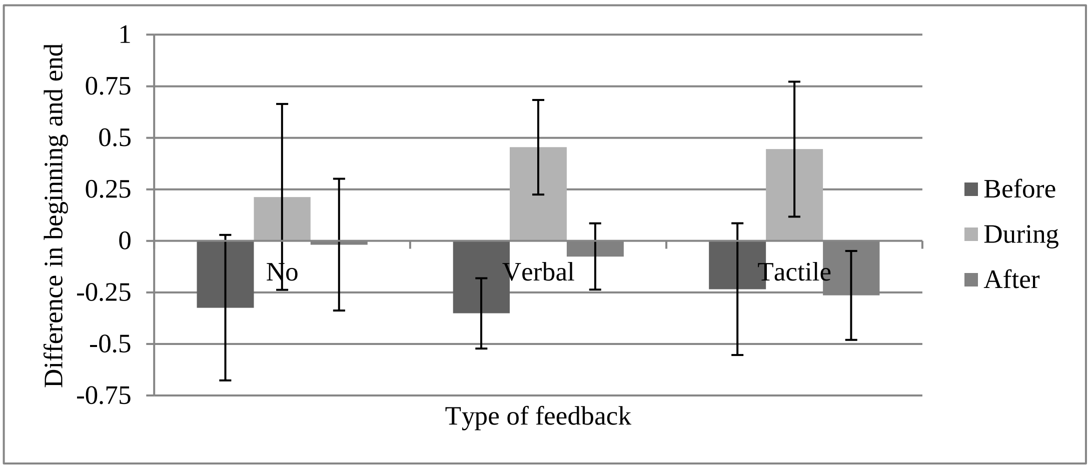


Figure 3.1. Average deviation from the prediction in fingers on the last six trials of the "before prism expose" condition and the first six trials of the "after prism exposure" condition. The deviation is achieved by averaging the prediction in fingers away from the target finger in the six trials. The error bars represent one standard deviation.

3.2 Adaptation during the prism block

One of our expectations is that the performance during each block of visuotactile predictions changes, because participants adjust their answers by means of feedback. To assess whether this is the case, a 2x3x3 repeated measures ANOVA was applied with the dependent variable mean deviation of the prediction in fingers away from the target finger, for six trials, at the beginning of a block and at the end of a block. Independent variables are type of feedback (no-, verbal- and tactile-feedback) and measurement (before, during and after prism exposure). For the latter, the criterion of sphericity [$X^2(2)$ = 17.732, p = .000] is not met, so a Greenhouse-Geisser correction [$\varepsilon = .599$] has been applied. There was a main effect of type of feedback [F(2,34) = 3.402, p =

.045] on the difference in performance in the visuotactile prediction task, as well as for moment of measurement [$F(1.198,20.361) = 33.575$, $p = .000$]. Furthermore, an interaction between type of feedback and moment of measurement is found [$F(4,68) = 3.030$, $p = .023$] and between moment of measurement and end of a block [$F(2,34) = 18.746$, $p = .000$]. Figure 3.2 shows the "during prism exposure" condition is of most influence on the difference between the end of each block for the feedback types. Another separate repeated measures ANOVA was performed to assess the



factor of influence on the interaction between the factors moment of measurement and end of a block. In the "before prism exposure" condition a significant difference is found between the first [M =.336 , SE = .081] and last six trail [M = .033, SE = .088, $t(17) = 3.065$, $p = .007$]. For the "after prism exposure" no significant difference has been found between the beginning and the end of the block of trials.

Figure 3.2. The chart shows the influence of moment of measurement for each type of feedback. The difference between the beginning and end of a block is filtered-out, by means of the subtraction of the averaged deviation of the first six trials of the block from the last six trials of the block. The error bars represents one standard deviation.

3.3 The proprioception task

Participant's midline drift was measured with a tape-measure when they pointed straight ahead, after each block of visuotactile predictions. A 3x3 repeated measures ANOVA was carried out on the indicated midline, to assess the effect of prism adaptation in the different feedback conditions. The body-midline was scored from right to left. So a body-midline more to the left has a higher score. The main factors were type of feedback (no-, verbal- and tactile-feedback) and moment of measurement (before, during and after prism exposure).

For the interaction, between type of feedback and moment of measurement, the criterion of sphericity was not met[$X^2(9) = 22.694$, $p = .007$], and so a Greenhouse-Geisser correction was applied [$\varepsilon = .649$]. There was a main effect for type of feedback on the body-midline drift feedback [$F(2,34) = 5.341$, $p = .01$]. The Pairwise Comparisons revealed that verbal feedback significantly differs from tactile feedback [p = .01].

To look further into the body-midline drift only the first measurement is compared with the last measurement, by means of paired sampled t-tests. Figure 3.3 shows the indicated body-midlines at the beginning and end of the research. There was an effect for the comparison between the first measurement [M=44.389, SE= .9467] and the last measurement [M = 42.667, SE =.9359, $t(17)$ = 2.710, $p = .015$] within the verbal feedback, as well as between the first [M=42.722, SE=.7131] and last measurement [M = 40.944, SE =.8687, $t(17)$ =3.637, p =.002] within the tactile feedback condition. To see if there was a difference in the body-midline drift between tactile and verbal feedback condition a t-test was applied. There was no significant difference for the body-midline drift, shown by the after-effect, for the comparison of verbal- with tactile feedback.

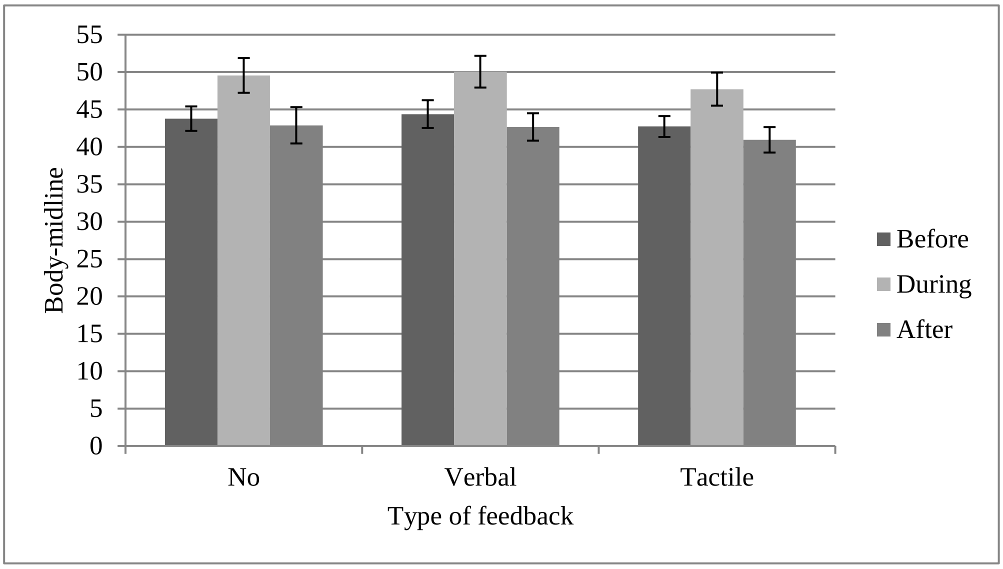


Figure 3.3. The chart shows the drift in participants' body-midline for each feedback condition. The body-midline was scored, ascending in size number, from right to left. Represented by the error bars is one standard deviation.

3.4 The number of wrong answer during the visuotactile prediction task

We were also very interested to see if there would be a difference in de number of wrong answers made during the visuotactile prediction task. So a repeated measures ANOVA was carried out to explore differences in the number of wrong answers. The main factors where type of feedback (no-, verbal- and tactile-feedback) and moment of measurement (before, during and after prism exposure).

A significant main effect from type of feedback on the number of wrong answers was found [$F(2,34)$ = 9.602, p =.000]. The Pairwise Comparison reveals that the no-feedback condition significantly differs from the verbal-feedback condition, as well as from the tactile-feedback condition in the amount of wrong given answers. In the condition with no feedback the number of wrong answers is higher than for the other two conditions. Also a significant effect has been found for moment of measurement on the amount of wrong given answers [$F(2,34)$ = 45.844, p = .000]. The number of wrong answers is highest in the block with prism exposure as shown by figure 3.4.

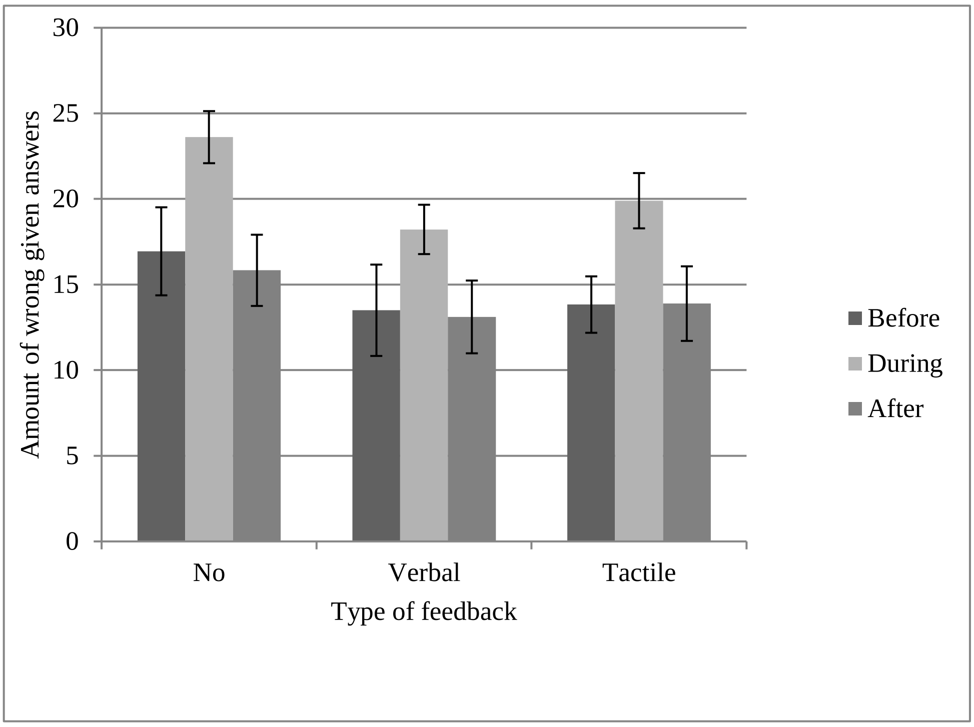


Figure 3.4 shows the average number of wrong answers in blocks before, during and after prism exposure in the visuotactile prediction task for each type of feedback. The error bars represent one standard deviation.

Discussion

4.1 Discussion

Our goal in the present study was to gain more insight in the possibility to obtain a prism adaptation without movement by means of the visuotactile prediction task. To see if prism adaptation was obtained during this experiment, we looked at the deviation in the visuotactile prediction task. To see if prism adaptation has taken place the deviations for whether the participant was wearing the prism goggles or not were compared. Comparing the deviation in predictions during the visuotactile prediction task for whether the participant was wearing prism goggles or not shows that the prism goggles had an effect on the deviation in predictions. Looking at the corrections made during prism exposure, more leftward, and after prism exposure, more rightward, a drift in the corrections made is shown. To look further into the corrections made, a comparison is made between the last six trials of the “before prism exposure” condition and the first six trials of the “after prism exposure” condition. The first six predictions of the “after prism exposure” condition were significantly more to the right than the last six predictions of the “before prism exposure” condition, which is a requirement in this study to see that an after-effect was obtained. This after-effect shows that it is possible to obtain prism adaptation without movement.

Additionally, it was evaluated whether a possible prism adaptation was of influence on proprioception. This proprioceptive measure is a different measurement to see if prism adaptation has taken place. By means of comparing the before prism exposure measurement with the after prism exposure measurement it is possible to see if prism adaptation has taken place. In addition, it is possible to explore if the influence of prism adaptation is the same on proprioception as it is in the classical application. Participants had to indicate their body-midline three times, after each block (before, during and after prism exposure), to measure if there was a difference in indicated body-midline. The results show a significant difference between the indicated body-midline at the beginning of the test and at the end of the test. As shown by figure 3.7 the indicated body-midline is more rightward at the end of the test, which is in line with our expectations. As with the visuotactile prediction task, this implies that there is an after-effect.

Previous research shows that it is possible to obtain prism adaptation in healthy subjects (Michel, et al., 2003).The after-effects shown in the present study closely resembles the after effects seen in classic prism adaptation. An after-effect of prism adaptation is shown by an initial misreach in the opposite direction of the prismatic shift after prism adaptation, which shows the persistence of the obtained prism adaptation in the previous phase (Newport & Schenk, 2012). This misreaching was reflected by a bias in visuotactile predictions and indicated body-midlines in the current study, which suggests that in the present study prism adaptation was obtained. The present study differs from the more classical prism adaptation studies, in the fact that prism adaptation is obtained without movements performed by the subject. The results indicate that it is possible to obtain prism adaptation without the necessity of moving a limb. During the classical prism adaptation studies a target pointing test is applied, as for example is done in the research from Kornheiser (1976). A different approach is applied in the research from Michel, Gaveau, Pozze and Papaxanthis (2013). They showed with their research that movement of a limb is not a necessity for prism adaptation. The research revealed that mental practice, imagining that you move, had prism adaptation as a result due to sensory realignment. This is in line with the present study, because both conclude that movement is not a necessity for prism adaptation. The present study adds to the current series of research that it shows that visuotactile predictions are a good manner to obtain prism adaptation without movement of a limb

Goodale and milner (1992) made a proposition about the involved brain regions during prism adaptation. Goodale and Milner (1992) proposed that there are two visual pathways. One for perceptual identification of objects, the ventral stream, projecting from the striate cortex to the inferotemporal cortex. The other one is used for visual guided actions towards an object, the dorsal stream, projecting from the striate cortex to the posterior parietal cortex. Striemer and Danckert (2010) have suggested that prisms influence neglect by acting on dorsal stream circuits subserving visuomotor control. This would explain why prisms affect tasks requiring overt motor responses. Striemer and Danckert (2010[1]) examined the effect of prism adaptation on motor and perceptual performance. They conclude that prisms influence is limited to the circuits in the dorsal visual stream, which controls motor behavior and spatial attention (Striemer & Danckert, 2010)[2]. The dorsal visual stream consists of the superior parietal lobule (SPL) and the anterior intraparietal sulcus (IPS), which are undamaged in many neglect patients. Crucial lesions sites in neglect patients are the inferior parietal lobule and the superior temporal gyrus, which represent a multimodal association area, which is thought of to be important for the linkage of the ventral stream with the dorsal stream (Striemer & Danckert, 2010). So there is no linking of visual information with motor outputs, which makes it unlikely that after prisms adaptation there will be a change in the perceptual bias. However, effects of prism adaptation have been found on non-motor tasks, the number bisection task, such as those used in the research from Rosetti et al. (2004). Rosetti, Jacquin-Courtois, Rode, Michel and Boisson (2004) indicate with their results that not only proprioceptive, visual and motor framing of space is altered by prismatic adaptation. Also cognitive levels of space representation, bottom-up process, can be reorganized by prismatic adaptation. Moreover, recent research from Michel, Gaveau, Pozze and Papaxanthis (2013) showed that actual motor responses might not be necessary for prism adaptation, imaging making a movement is enough to cause prism adaptation. Their results reaffirm that under prism exposure the adaptation during mental practice was due to sensory realignment (Michel, Gaveau, Pozzo, & Papaxanthis, 2013). However, motor imagery activates the motor network (de Lange, Roelofs, & Toni, 2008), which is one of the structures associated with neglect after damage (Halligan, Fink, Marshall, & Vallar, 2003). The visuotactile prediction in the current research does not make usage of mental imagery and thereby the motor network is not used. Because it does not make usage of the motor network, this could be a better method to apply during prism adaptation therapy for neglect patients.

We expected to find an after-effect for the condition with verbal feedback, as well as for the condition with tactile feedback for both tasks. That an after-effect also present is in the no-feedback condition is not what we expected. This is not in line with Bultitude and Woods (2010) and Michel, Gaveau, Pozze and Papaxanthis (2013) who showed that in case of conflicting input a generalized adaptation of the multisensory system follows. This is needed to obtain prism adaptation. In the baseline condition no feedback was given, so there was no conflicting input, so you would expect no generalized adaptation of the multisensory system and subsequent after-effect. The after-effect in the no-feedback condition therefore is not in line with our expectations and it indicates that the participants got some kind of feedback during this condition. We tried to diminish the feedback participants could get by removing the restrictions on response a prediction which finger is pointed at by supplying the option of open space at both sides, no finger. A possibility is that participants noticed the shift in vision of other elements in the room when the goggles where put on, and responded to that change. Or that they had an expectation about what was going to happen, and adapted their response to fit their expectations. An option in further research is to further limit the feedback participants can get from the testing environment by means of visible cues, like a grain socket on a black background, or auditory cues, like ambient sounds. This makes it an inadequate baseline measurement. So, for the rest of the discussion no interpretations will be drawn from the no feedback condition.

For both types of feedback conditions (verbal and tactile) the results remain suitable for analysis. However, a comparison with a true baseline condition is not possible. So instead of making a comparison between the baseline and both possible feedback conditions to see the influence of feedback on the possibility to obtain prism adaptation by means of visuotactile predictions, a comparison was made between both feedback conditions. The supplied feedback, verbal as well as tactile feedback, gives the subject the possibility to adjust their predictions during the visuotactile prediction task, which is in accordance with the expectations. It is the Central nervous System (CNS), more specific the basal ganglia and cerebellum (Hikosaka, Nakamura, Sakai, & Nakahara, 2002), that maintains the accuracy of motor behavior in humans. Responsible for the compensatory changes in various sensorimotor systems, in response to internal and external alterations, is the plasticity of the CNS. The plasticity of the CNS during prism adaptation studies has mainly tested the influence of visual feedback on the target pointing test. So it is not baffling that the main cue leading to sensorimotor adaptation is considered vision (Bernier, Chua & Franks, 2005; Bordin, Gauthier, Blouin & Vercher, 2001), and proprioception is considered to be the second best cue. In the present study we did not find the expected difference between verbal and tactile (proprioceptive) feedback on the obtained after-effect during the visuotactile prediction task. Both types of feedback showed an equal after-effect during the visuotactile prediction task, and no difference was found between the obtained body-midline drift in after-effects between the two types of feedback which is in conflict with our expectations, because it was expected that both types of feedback had an effect, but the effect as a result of tactile feedback was expected to be larger than that from verbal feedback. This indifference is not in accordance with a series of studies that show within the peripersonal space a strong link between vision and touch (Spence, Nicholls, Gillespie, & Driver, 1998; Legrand, Brozzoli, Rossetti, & Farnè, 2007). Type of feedback was not of influence, when was looked at the difference in deviation during visuotactile perditions as a total for both types of feedback. This indicates that it is possible to obtain prism adaptation without movement by means of both types of feedback. It suggests that adaptation during the trails is not restricted to visuotactile integration.

A possible explanation for the indifference is drawn from the research from Buekers and Magill (1995), which showed that verbal knowledge of results is an important cue, which provides spatial information that increases the motor performance. This provision of spatial information by means of verbal knowledge is used in the present study, but instead of an increased motor performance it has an improvement in predictions during the visuotactile prediction task as a result. Also, the research from Blanchard, Roll, Roll and Kanvounoudias (2011) shows that information obtained from two different modalities may be intergraded complementarily, depending on their respective relevance to the task. In their study they created an illusion of hand movement by scrolling a texturized disk underneath the hand of the participants. To create an illusion of arm movement vibrations where applied to the wrist. By means of this study design they could study the contribution of tactile and proprioceptive feedback on hand movement. Their results show that the proprioceptive effects increased by adding a consistent proprioceptive stimulus, whereas the tactile illusion was decreased by adding a conflicting proprioceptive stimulus. An important finding was that the gain of the illusion was only affected by strong proprioceptive stimulation in both conditions, consistent and conflicting stimulation. Their conclusion that information from two different modalities may be integrated complementarily, depending on their relevance to the task, is in accordance with "modality Appropriateness" model developed by Welch and Warren (as sited in Calvert, Spence and Stein 2004). According to this model the behavioral relevance in a given context alters the sensory weighting of a given modality. The ability of our brain to anticipate efficiently on the stimuli in the peripersonal space by means of the adaptation of the modalities is an interesting competence. In the present study made use of the ability of the modalities to anticipate on the stimuli in the peripersonal space by means of tactile feedback.

However, for the proprioceptive task an interaction effect was found between type of feedback and moment of measurement, before during and after prism exposure. So type of feedback has a different influence on the indicated body-midline at different moments of measurement. This indicates that type of feedback is of influence of body-midline drift. The pairwise comparisons revealed that verbal and tactile feedback significantly differed from each other for moment of measurement. To look further into the body-midline drift, only the first measurement is compared with the last measurement, to get a better view on the after-effect. The results show an after-effect for the verbal as well as for the tactile feedback condition. No difference is found between the obtained body-midline drift in after-effects between the two types of feedback. This is in line with Bultitude and Woods (2010) and Michel, Gaveau, Pozze and Papaxanthis (2013) whom declare that in case of conflicting input a generalized adaptation of the multisensory system follows. The shown after-effects in the proprioception task for both type of feedback indicate that a proprioceptive shift is obtained by means of verbal as well as by means of tactile feedback. This indifference between verbal and tactile feedback on the after-effect is not in line with the assumption that proprioception and information of touch are strongly linked during their information processing (Blanchard C. , Roll, Roll, & Kavounoudias, 2011). Sensory information induced by a touch is detected by touch receptors. The information provided by the touch receptors will be together with other fibers, subserving other somatosensory modalities in the same body part such as those for proprioception, be conveyed to the Central Nervous System (Gardner, 2010). This is supported by the literature about peripersonal space (Cardinali, Brozzoli, & Farnè, 2009; Brozzoli, Cardinali, Pavani, & Farnè, 2010) which assigns a specific role to visuotactile integration. It seems that in the present study, both types of feedback, verbal and tactile feedback, provided enough information to give the subject the possibility to adjust their predictions during the visuotactile prediction task. Both types of feedback provide conflicting input, with the visual shift, and a generalized adaptation of the multisensory system has followed. If the observed similarities in after-effect between the current study and classical prism adaptation studies means that in the present study prism adaptation is obtained, we would expect the obtained prism adaptation also shows on the battery of tests typically administered in neglect patients. So the next step in the research on obtaining prism adaptation by means of visuotactile predictions without movement of a limb would be to administer a battery of test after a period of prism adaptation.

4.2 Conclusion

This study emphasizes that movement is not a necessity to obtain prism adaptation. This is in line with research that applies different research methods, like imagining the movement. The sensory modalities are able to adapt to the visual shift, induced by the prism goggles, to obtain a matching perceptual representation. This adaptation is achieved by the possibility to adjust to the induced shift by means of feedback. The adaptation induced by feedback is seen over the trials, as well as in an after-effect. This adaptation towards the visual information and the shown after-effect are in line with the results obtained from classical prism adaptation procedures. It is shown that type of feedback is not of influence on the possibility to adapt to the visual shift. It seems that both types of feedback (verbal and tactile) are sufficient to obtain a prism adaptation.

This research shows that prism adaptation without movement is an option that could be used in the rehabilitation of neglect patients whose movement of the contralesional arm and hand is disrupted, and/or who have directional hypokinesia, which is reflected in a slower initiation of the ipsilateral arm towards the contralesional space.

Further investigations to determine which type of feedback possibly gives rise to a better prism adaptation would be of great theoretical importance and may shed some light as to which modality is better able to adapt to the visual shift induced by the prism goggles, and therefore be a better type of feedback to applicate during a prism adaptation period.

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