The effect of lateralized pointing on processing tactile stimuli

Master thesis Neuropsychology

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Date: September, 2014

Abstract

Prism adaptation is a well-known sensori-motor conflict/adaptation paradigm, which induces an adaptation to a visual shift and can improve spatial bias in neglect patients. However, recent research indicates that the prism induced visual shift during pointing movements is not necessary for spatial perception to be affected, lateralized sensori-motor experiences alone are sufficient to influence spatial processing. Different studies have shown that PA and LP induce quite similar results, both are capable to induce a spatial bias and all these results are in accordance with the idea that the working-mechanism of LP and PA are quite similar. The current study examines if LP could produce a supramodal effect and bias processing in the tactile modality, similar to PA. It was hypothesized that participants who stimulated one hemisphere by lateralized pointing to the contralateral half of space would process tactile stimuli to the contralateral hand faster compared to baseline. Participants performed a tactile temporal order judgements (TOJ) task both before and after LP. The results provide no evidence that lateralized pointing has an effect on tactile processing. A possible explanation for the incongruence between PA and LP could hence be that LP is capable to affect processes involved in space perception, but is not capable to sufficient affect high level multimodal representations the ensure a supramodal effect. The results of the current study could also indicate that LP has no effect on (several) lateralized functions, including tactile processing. However, current limitations could have affected the results. Further research redeemed from the current limitations would be helpful in order to draw a more definite conclusion.

Keywords: Prism adaptation, lateralized pointing, tactile temporal order judgement, tactile spatial representations, personal space.

Introduction

Prism adaptation is a well-known sensori-motor conflict/adaptation paradigm which induces an adaptation to a visual shift and can improve spatial bias in neglect patients (Rossetti, Rode, Pisella, Farné, Li, Boisson & Perenin, 1998). In normal controls prism adaptation results in an induced spatial perceptual bias (Berberovic & Mattingley, 2003; Michel, Pisella, Halligan, Luaute, Rodem Boisson & Rossetti (2003); Rosetti et al., 1998). This suggests that there is a link between space perception and sensori-motor experiences (Dupierrix, Alleysson, Ohlmann & Chokron, 2008). The underlying assumption is that sensori-motor adaption induced by prism adaptation is not just involved in recalibration of visuo-motor coordination but also has an effect on cognitive processes that are involved in spatial representation (Rosetti et al., 1998; Dupierrix et al., 2008).

However, recent research has shown that the prism induced visual shift during pointing movements is not necessary for spatial perception to be affected. Dupierrix et al. (2008) were the first to hypothesize that lateralized sensori-motor experiences alone would be sufficient to influence spatial processing. This hypothesis was based on the research of Glover and Castiello (2006). Glover and Castiello (2006) tested left visual neglect patients following right hemisphere stroke on their sensory (report the location at which the object appeared) and motor responses (reach out and grasp the object) to the left, middle and right side of space in a real environment, with particular interest in their ability to respond to targets presented in neglected left visual field. The baseline assessment was followed by a training phase using the Virtual Reality (VR) technique in which the participants were not able to look at their actual grasping movement; instead they had to look at a virtual grasping movement on a computer screen located in front of them. During the training phase the position of the real and virtual targets could be manipulated, with the critical training condition being the left-incongruent trials, in which the real object was placed in the left hemispace (the previously neglected left side of space), but straight ahead or in the right hemispace in the virtual space. The training phase was followed by a reassessment of their ability to respond to targets presented in the previously neglected left visual field. The result showed a significant improvement in the ability of the neglect patients to respond to the real environment targets in the left visual field. Therefore Glover and Castiello (2006) hypothesized that that movement to the previously neglected left side of space was responsible for the recovery of space perception. The hypothesized involvement of asymmetric sensori-motor activity in the inducement of spatial bias formed the fundamentals of Dupierrix et al. (2008) hypothesis.

Dupierrix et al. (2008) tested their hypothesis using a lateralized pointing (LP) task, a low-order lateralized sensori-motor task with no perceptual or motor conflict. Participants have to point as quickly and as accurately as possible with their right index finger to a target randomly presented on one side of space (left or right) on a computer screen in front of them (Dupierrix et al., 2008). The duration of a LP task had to be approximately 5 minutes to be effective. Dupierrix et al. (2008) showed that LP is indeed able to induce subsequent biases in space perception as assessed with a visuo-motor and a perceptual bisection task. In the visuo-motor bisection task participants had to place a cross-mark at the centre of a horizontal line (Dupierrix et al., 2008). In the perceptual bisection task identical lines were presented, but were pre-transacted. Participants had to judge if the lines were transacted leftward or rightward of the center (Dupierrix et al., 2008). The significant biases induced by LP in both bisection tasks were in the direction of the previous pointing hemispace. It seems that LP affects higher level processes involved in space perception because simple motor biases cannot be accountable for the induced deviation given the deprivation of any motor components in the perceptual bisection task (Dupierrix et al., 2008). These findings are similar to the findings of a prism adaptation studies (Michel et al., 2003).

Therefore LP can elicit a short-term spatial bias in line bisection task similar to PA. Hatada, Miall and Rossetti (2006) have demonstrated that prism adaptation can also induce a long-lasting aftereffect in straight ahead (SA) task. In a follow-up study Dupierrix, Gresty, Ohlmann and Chokron (2009) were interested if LP was able to induce similar long-lasting aftereffects. Participants had to perform a Straight-Ahead (SA) task in which they had to attempt to point straight ahead with either their left or their right index finger. There were five different starting positions ranging from -30˚ to +30˚. The SA task had to be performed at three sessions, prior to, immediately after and one day after the LP task (Dupierrix et al., 2009). The LP task design was identical to the LP task design used in their previous study. The results showed long lasting lateral deviations, which indicate that a simple low-order lateralized sensori-motor task is able to produce a long-lasting modulation in a SA task, which suggests that LP can affect proprioceptive personal space (Dupierrix et al., 2009).

The mechanism that enables LP to affect the underlying cognitive processes remains largely unknown. It has been previously hypothesized that the mechanism of PA works by restoring or disrupting the balance between the two hemispheres (Herlihey, Black, & Ferber, 2013). Given that PA and LP induce quite similar results, this hypothesis could also be an explanation for the LP induced bias. It could be that pointing to the left side of space increases activation in the right hemisphere and vice versa (Herlihey, Black, & Ferber, 2013). This increased activation in a hemisphere results in enhanced attention oriented (attentional bias) to the sensory hemispace contralateral to the activated hemisphere (Querné, Eustache & Faure, 2000; Kinsbourne, 1970). The attentional bias, in turn, results in more efficiently processed stimuli (Jaśkowski & Verleger, 2000). The attended stimuli are perceived earlier than the unattended stimuli, known as the prior entry effect (Yates & Nicholls, 2011). Kinsbourne (1970) proposed that both hemispheres play a part in shifting the attention in the contralateral direction. Consequently if one hemisphere is activated the orienting tendency of the other will be inhibited to achieve unified performance which enables unified performance instead of potentially conflicting outputs (Chiarelle, & Maxfield, 1996; Kinsbourne, 1970).

So far, Dupierrix and colleagues only used tasks with a directional component (line bisection and SA). Herlihey et al. (2013) wondered if it would be possible to achieve comparable results when using task without a directional component, and if the results still would be in accordance with the proposed hypothesis. They used the modified hierarchical figure task version of Bultitude and Woods (2010), which participants had to complete before and after the LP task. They focused on the processing of global and local features because of its lateralization in the two hemispheres, with global features preferential processed in the right hemisphere and local features in the left hemisphere (Bultitude & Woods, 2010; Delis, Robertson & Efron, 1986). The results showed reaction time (RT) differences as a function of LP direction. Left LP resulted in longer RTs when responding in local trials and right LP resulted in faster RTs when responding in local trials. The longer RTs were caused by an increase in interference from incongruent global information and faster RTs were caused by a decrease in interference (Bultitude & Woods, 2010). And indeed, given that the right hemisphere is dominant in processing global information, these results are congruent with the previous mentioned hypothesis (Bultitude & Woods, 2010). Similar results have been found using PA (Bultitude & Woods, 2010).

The effects of PA are not restricted to the visual modality. McIntosh, Rossetti, and Milner (2002) have shown that PA can produce changes in haptic performance in a neglect patient. PA is able to improve proprioception and pressure sensitivity in neglect as well (Dijkerman, Webeling, ter Wal, Groet & van Zandvoort, 2004). Maravita, McNeil, Malhotra, Greenwood, Husain and Driver (2003) also have shown that PA can improve the tactile extinction in neglect patients with right hemisphere strokes. Moreover, PA also can affect haptic performance in healthy participants (Girardi, McIntosh, Michel, Valler & Rossetti, 2004). Given that LP and PA have showed quite similar results so far, it would be interesting to examine if LP could also produce a supramodal effect and bias processing in the tactile modality. Given that the temporal order judgements (TOJ) task is a successful paradigm to establish a spatial bias of attention in neglect patients and normal participants, this paradigm will be used in the present study (Berberovic, Pisella, Morris and Mattingley 2004; Rorden, Mattingley, Karnath and Driver, 1997).

The TOJ task is a paradigm that can be used to measure perceptual latency, as well as revealing the point of subjective equality and the just noticeable difference of an individual (Davis, Christie & Rorden, 2009; Jaśkowski, Jaroszyk & Hojan-Jezierska, 1990). It places minimal demands on motor processes (Berberovic et al. 2004). Participants receive two stimuli in temporal succession and have to judge the temporal order of the stimuli correctly by indicating which of the stimuli occurs first (Yamamoto and Kitazawa, 2001). In the current study participants have to indicate the temporal order by means of foot pedals, placed side by side. Extensive research has shown that participants are able to successful judge the temporal order if the interval between the two stimuli is 30 ms or more (Heed, Backhaus and Röder, 2012; Hirsh and Sherrick, 1961; Pöppel, 1997).

As previously mentioned, TOJ is a successful paradigm to establish a spatial bias of attention (Yates & Nicholls, 2009; Yates & Nicholls, 2011). They investigated the effect of attention manipulation in the somatosensory modality. Their results indicate that attention manipulation, by directing tactile attention to a particular location using a somatosensory exogenous cue, affects the point of subjective equality compared to the baseline (Yates & Nicholls, 2011). The magnitude of the prior entry effect, the average shift in point of subjective equality, was 31 ms (Yates & Nicholls, 2011). Directing tactile attention to a particular location using a somatosensory endogenous cue could also affect the point of subjective equality (Yates & Nicholls, 2009). If Herlihey, Black & Ferber (2013) hypothesis is correct, pointing to the left side of space increases activation in the right hemisphere and vice versa, perhaps the subsequent shift in attention orientation to the contralateral hemisphere could also induce a shift in point of subjective equality similar to shifts induced by exogenous or endogenous cues.

The purpose of the present study is to investigate the influence of LP on tactile processing accessed by a TOJ task. The primary hypothesis is that participants who stimulated their right hemisphere by lateralized pointing to the left will process tactile stimuli to the contralateral hand faster compared to the baseline. The second hypothesis is that interhemispheric inhibition leads to an increased processing time for tactile stimulation ipsilateral to the activated hemisphere. This will be assessed with a TOJ task and the LP design of Dupierrix et al (2008).

Method

Participants

For this study, 39 healthy volunteers were tested, 9 males and 30 females. Inclusion criteria of the study were: (1) right handedness indicated by the Edinburgh Handedness Inventory (Oldfield, 1971) with a cut-off criteria of >40 (appendix 2), (2) able to read and communicate in the Dutch Language, (3) normal or corrected-to-normal visual acuity and (4) no somatosensory deficits. The data from two participants had to be excluded due to their handedness scores (<40). Eight participants had to be excluded due to undefined numerical results in Matlab as a result of SOA conditions which did not meet the pre-determined requirements (>100 ms and <3000ms) in either the pre-test, post-test or both. This resulted in a participant group consisting of 5 males and 24 females, with a mean age of 22.28, a range of 10.00 and a standard deviation of 2.42. Their handedness score had a mean of 79.55, a range of 60.00 and a standard deviation of 17.09.

Participants received course credit as compensation for their time. All participants were naïve with regard to the purpose of the study and had to read and sign an informed consent form prior to the study, in which they were informed that they could leave the study at all times without consequences and that the data was going to be used for scientific purposes (appendix 1).

Design and Procedure

Participants were tested in a lab of the van Langeveld building of the University of Utrecht. When the participant entered the lab he or she were given a brief explanation about the course of the experiment and had to read and sign the informed consent and fill in the Edinburgh Handedness Inventory and two additional questions concerning their age and gender.

The current task was performed in combination with another task, which investigated the effects of lateralized pointing on coordinate and categorical judgements. The results of this task are reported elsewhere. The participant would either start with a baseline assessment of the temporal order judgement task with the instruction to indicate which stimulus they perceived first, by means of the response box operated by their feet and then followed by the baseline assessment of the visual task (either the categorical task or the coordinate task) or vice versa. The order of the tasks was counterbalanced (Table 1).

Table 1. During the test administration participants had to complete the visual experiments as well, since it was a combined experiment which investigated the effect on LP on categorical and coordinated tasks given the lateralization in the hemispheres.

Participant nr.	Left/Right pointing	Start with
1	Left	Visual
2	Right	Visual
3	Left	Visual
4	Right	Visual
5	Left	Tactile
6	Right	Tactile
7	Left	Tactile
8	Right	Tactile

Before the actual baseline experiment, participants were given 10 practice trials.
After the baseline assessment participants performed the lateralized pointing task. The participants were given the instruction to point as quickly and as accurately as possible to the target on the computer screen with their right index finger. With the additional instruction to maintain the pointing position as long as the target was visible on the screen. Before the TOJ task, following the lateralized pointing, participants were given 5 practice trials. The post-measurement consisted of the same temporal order judgement task and visual tasks as performed at the baseline assessment, with the same instructions.

Temporal order judgement

The task that was used for temporal order judgements was based on the design of de Haan, Anema, & Dijkerman (2012). The tactile stimuli that were used consisted of a metallic pin and were applied by the use of computer controlled solenoid tappers (MSTC3 M&E Solve, Rochester, UK). The pin had a diameter of 2 mm and all taps had a duration of 6 ms. Participants were seated behind a desk in a dimly lit room, with both hands in front of them, 30 cm apart (Soto-Faraco, & Azanon, 2013). Two wooden bars were attached to the desk to which the participants had to place their hands against to assure that the distant between their hands remand 30 cm. One tactile stimulus was attached to the left index finger, another to the right index finger. The two tactile stimuli were presented at different stimulus onset asynchronies (SOA) with either the left or the right stimulus being presented first. The different SOAs were set at -700, -400, -150, -90, -60, -30, -15, 15, 30, 60, 90, 150, 400 and 700ms (de Haan et al., 2012). Negative SOAs denote that the left hand stimulus was presented first. Each SOA was repeated 20 times, divided in 5 blocks of 56 stimuli. The TOJ task lasted for 15 minutes, with each block lasting approximately 3 minutes. The SOA's and direction were randomised within the 5 blocks and the inter-trial interval was variable (between 1000 and 3000 ms) to ensure focus during the entire experiment (de Haan et al., 2012). The participants were instructed to indicate by means of a response box operated by their feet which stimulus they perceived first (Craig, 2003).

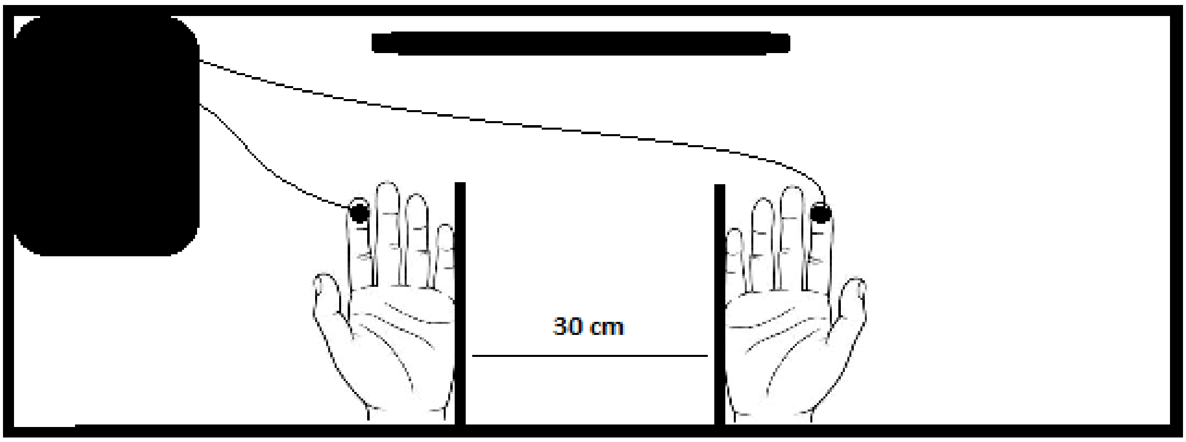

Figure 1. A schematic view of the TOJ set up. The hands are positioned 30 cm apart and the solenoid tappers were attached to the left and right index finger.

Lateralized pointing (LP) task

The design of Dupierrix et al. (2009) was replicated for the lateralized pointing task. Participants had to point to a target presented on a computer screen. The target consisted of a black dot with a 6 mm diameter (0.6°x 0.6°, 20 pixels) and was presented on the right or on the left side of the computer screen (337 x 302 mm, 1280 x 1024 pixels) on a white background, depending on the condition that the participant was in (left of right lateralized pointing) (Dupierrix et al., 2008; Dupierrix et al., 2009; Herlihey et al., 2013;). The target was presented a total of 153 times, since there were 9 target positions and participants had to point 17 times towards each target position. For the left group that meant a range of 0° to x -13.6° along the horizontal axis and for the right group it meant a range of 0° to +13.6° (Herlihey et al., 2013). The distant between the 9 target positions was 1.72° (11.8 mm). The target was presented for 1500 ms, immediately followed by a mask of 300 ms to erase the preceding target (Dupierrix et al., 2008). The mask (36.9°x 24.9 mm) consisted of random black and white pixels. Participants were given the instruction to point as quickly and as accurately as possible to each target as soon as they perceived the target, with the additional instruction to maintain the pointing position as long as the target was visible on the screen (Herlihey, 2013). After each presentation the participant had to bring their index finger back to the starting point indicated on the desk by a round piece fabric placed in the middle off and 6 cm off the edge of the table. The participants sat at a 600 mm distance from the computer screen and had to keep their head in a chinrest during the entire lateralized pointing task.

A path-like device was attached to their right index finger to supposedly record the movement and accuracy of their pointing. We were not interested in the pointing accuracy or speed, but in the effect of the pointing task on the performance on the post-measurement temporal order judgement task (Dupierrix et al., 2008).

The duration of the task was approximately 5 minutes (Dupierrix et al., 2008; Dupierrix et al., 2008; Herlihey et al., 2013).

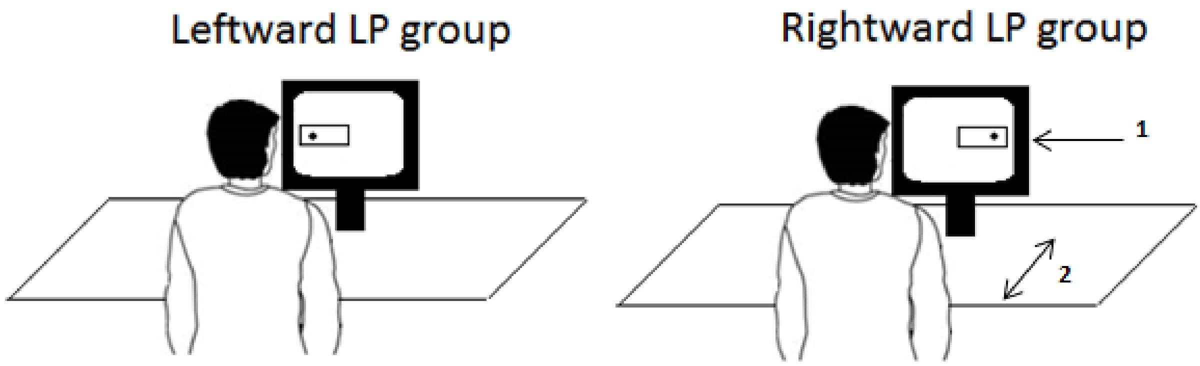

Figure 2. A schematic view of the LP set up. 1= Range of the 9 target position for the right LP group. 2 = Distance of 600 mm between participant and computer screen.

Data Analyses

Trials with reaction times under 100 ms and longer than 3000 ms were excluded from further analysis. The directional judgements and the reaction times were both recorded per SOA in the pre and post condition. The reaction time was recorded with respect to the second tap. The proportion of rightward directional judgements was calculated and analysed in Matlab. The proportion of rightward directional judgements is the most relevant dependent measure given that it is a measure that reflects the bias in temporal processing. If lateralized pointing has no effect on tactile information processing, no interference from the pointing task would be expected and the point of subjective equality (PSE) in the post- and pre-test should be comparable. A discrepancy in the PSE between the pre- and post-test would be expected if lateralized pointing indeed has an effect on tactile information processing. The PSE is the critical moment at which the responses of the participant were 50% rightwards and 50% leftwards (de Haan et al.,2012). The shift in the point of subjective equality was investigated with a logistic function fitting algorithm previously used by de Haan et al. (2012) (Ezyfit Matlab toolbox, logistic model:

$$y = floor + (ceiling - floor) * (\frac{1}{1 + e^{-(a+bx)}})$$

in which 'y' is the probability of a response rightwards, 'a' the point of subjective equality and 'b' the slope which reflects the performance). This algorithm was applied to the single subject data and for the leftward- and rightward LP average group data. The point of subjective equality data and the slope data obtained from the logistic function fitting algorithm for each participant were compared with a mixed-design ANOVA with a between-subject factor of pointing (left or right) and with a within-subject factor of pre-/post-test (2). Median reaction times were also analysed with a mixed-design ANOVA with a between-subject factor of pointing (left or right) and with three within-subject factors of pre-/post-test (2) x stimulus direction (2) x SOA (7).

Results:

The data of 10 of the 39 participants had to be excluded and for the remaining 29 participants the proportion of rightward directional judgements at the 14 different SOA's (-700, -400, -150, -90, -60, -30, -15, 15, 30, 60, 90, 150, 400, 700) were analysed in Matlab. The average results of the left- and rightward LP group in the pre- and post-test are shown in figure 3 (the leftward LP group) and figure 4 (the rightward LP group). Both in the pre- and post-test measurements there was a strong positive correlation between SOA and proportion of rightward directional judgements (pre-leftward LP: R = .998; post-leftward LP: R = .999; pre-rightward LP: R = .998; post-rightward LP: R = .997) and fitted well to a logistic curve (pre-leftward LP: R^2 = .996; post-leftward LP: R^2 = .998; pre-rightward LP: R^2 = .996; post-rightward LP: R^2 = .994). All the individual data of the leftward LP group (pre-leftward LP all $R > 0.94$; post-leftward LP all $R > 0.90$) and the rightward LP group (pre-rightward LP all $R > 0.95$; post-rightward LP all $R > 0.95$) also had a strong linear correlation between SOA and proportion of rightward directional judgements and fitted well to a logistic curve (pre-leftward LP all $R^2 > 0.88$; post-leftward LP all $R^2 > 0.81$; pre-rightward LP all $R^2 > 0.90$; post-rightward LP all $R^2 > 0.90$). The average data of both the left- and rightward LP group suggest that there is not a substantial shift in PSE among the pre- and post-test.

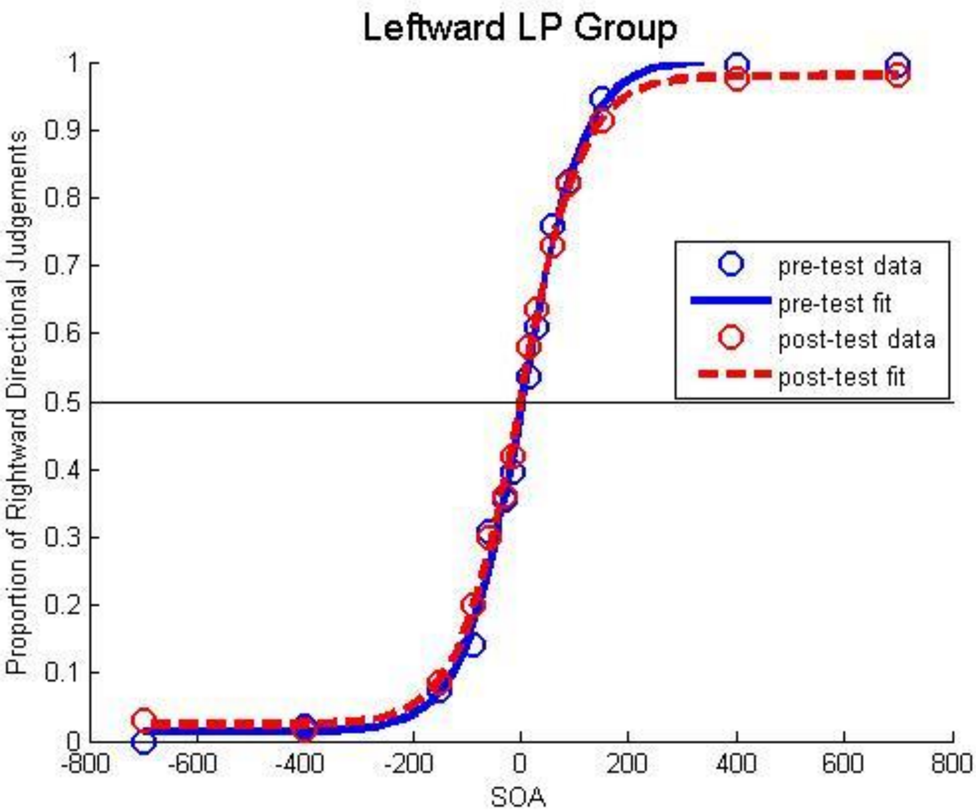

Figure 3. The proportion of rightward directional judgements at the different SOA's for the leftward LP group. *The blue open circles depict the average proportion of leftward directional judgements in the pre-test condition at the different SOA's and the red open circles depict the average proportion of leftward directional judgements in the post-test condition. The logistic function fitting algorithm was plotted for the pre-test condition (red dashed line) and the post-test condition (blue line). Negative SOA's indicate that the stimuli was presented to the left first, and positive SOA's indicate first right presented stimuli. The floor, ceiling, slope and PSE of the pre-test condition were .014, .989, .018 and -.087, respectively. The floor, ceiling, slope and PSE of the post-test condition were .024, .956, .017 and .013, respectively.*

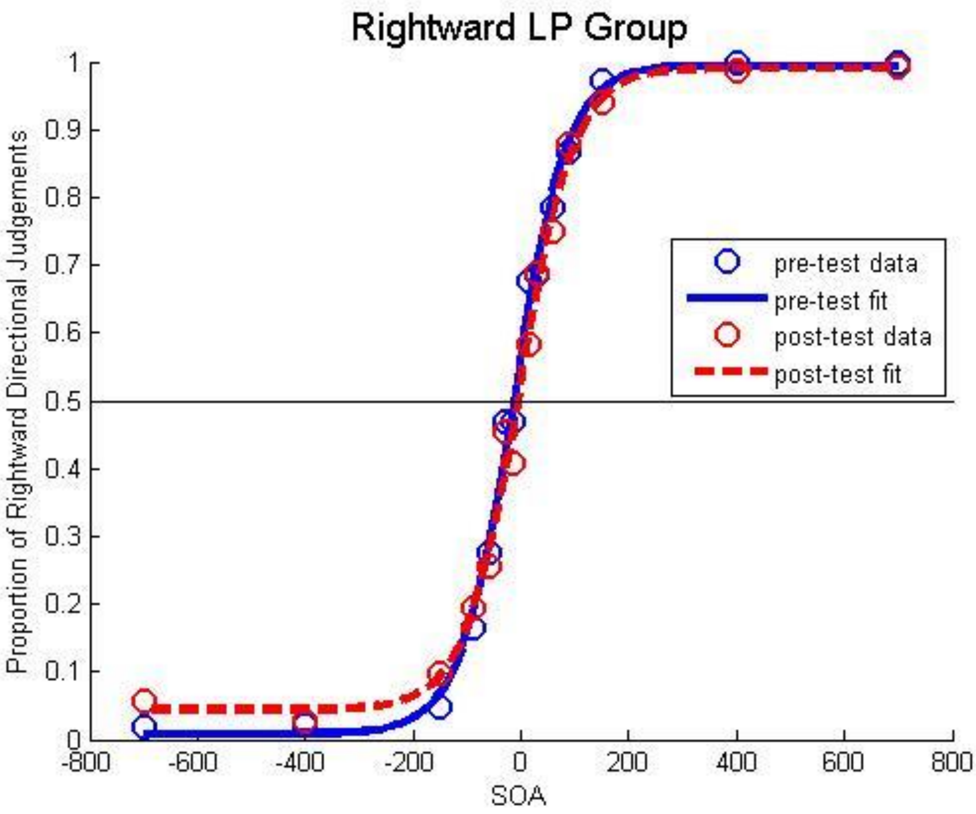

Figure 4. The proportion of rightward directional judgements at the different SOA's for the rightward LP group. *The blue open circles depict the average proportion of rightward directional judgements in the pre-test condition at the different SOA's and the red open circles depict the average proportion of rightward directional judgements in the post-test condition. The logistic function fitting algorithm was plotted for the pre-test condition (red dashed line) and the post-test condition (blue line). Negative SOA's indicate that the stimuli was presented to the left first, and positive SOA's indicate first right presented stimuli. The floor, ceiling, slope and PSE of the pre-test condition were .008, .987, 0.020 and 0.265, respectively. The floor, ceiling, slope and PSE of the post-test condition were .044, .947, .019 and .048, respectively.*

Shift in PSE

To further examine the shift in PSE ('a' in the model), a mixed-design ANOVA with a between-subject factor of pointing (left or right) and with a within-subject factor of pre-/post-test (2). The results indicated no significant main effect for pre-/post-test on the shift in PSE, $F(1,27) = 1.397$, $\rho = .247$, $\eta_p^2 = .049$, which suggests no difference on the shift in PSE in the pre- and post-test regardless of the assigned pointing direction. There was no significant interaction effect of pre-/post-test*pointing on shift in PSE, $F(1,27) = .332$, $\rho = .569$, $\eta_p^2 = .012$. This indicated that the shift in PSE in the left or right pointing group did not differ in the pre- and post-test. In both the leftward and rightward LP group one participant could potential affect the results (PSE differed > 3 SD from the mean). The removal of both the outliers did not affected the results. The results still indicated no significant main effect for pre-/post-test on the shift in PSE, $F(1,25) = 1.666$, $\rho = .209$, $\eta_p^2 = .062$, and no significant interaction effect of pre-/post-test*pointing on shift in PSE, $F(1,25) = 1.904$, $\rho = .180$, $\eta_p^2 = .071$. The results indicate that both the leftward LP and rightward LP did not significant influenced the PSE.

Performance

The slope data ('b' in de model) of each participant was analysed to check if there was a difference in performance between the pre- and post-test. The two participants who affected the results of the PSE mixed design ANOVA were excluded from this analysis. The results indicated no significant main effect for pre-/post-test on the performance, $F(1,25) = 1.117$, $\rho = .301$, $\eta_p^2 = .043$, which suggests no difference on performance in the pre- and post-test regardless of the assigned pointing direction. There was no significant interaction effect of pre-/post-test*pointing on performance, $F(1,25) = .291$, $\rho = .594$, $\eta_p^2 = .012$. This indicated that the performance in the left or right pointing group did not differ in the pre- and post-test, therefore the non-significant results of the PSE mixed design ANOVA could not be explained by performance.

Reaction time

For each SOA the median reaction time (RT) was calculated in the pre-test and post-test. The median reaction time was used because the RT were not normally distributed, the RT for a number of SOA's were skewed to the right. The median RTs were analysed with a mixed-design ANOVA with a between-subject factor of pointing (left or right) and with three within-subjects factors of pre-/post-test (2) x stimulus direction (2) x SOA (7)

The Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated for the main effect of SOA, $\chi^2(20) = 159.81$, $\rho < .000$, the interaction effect of pre-/post-test*SOA, $\chi^2(20) = 57.53$, $\rho < .00$, direction*SOA, $\chi^2(20) = 50.16$, $\rho < .00$, and pre-/post-test*direction*SOA, $\chi^2(20) = 58.33$, $\rho < .00$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .27$ for the main effect of SOA, .60 for interaction effect of pre-/post-test*SOA, .52 for the interaction effect of direction*SOA and .50 for the interaction effect of pre-/post-test*direction*SOA).

The results indicated a significant main effect for pre-/post-test on reaction time, $F(1,25) = 22.373$, $\rho = .000$, $\eta_p^2 = .472$, which suggests a difference in response times in the pre- and post-test regardless of the SOA condition and direction condition. The response times in the pre-test (*M* = 619.76, *SD* = 24.17) were slower than the response times in the post-test (*M* = 543.57, *SD* = 20.59). Furthermore there was a significant main effect for SOA on reaction time, $F(1.60, 40.09) = 162.656$, $\rho = .000$, $\eta_p^2 = .867$, which suggests a difference in response time to different SOAs regardless of the pre-/post-test condition and direction condition. Simple contrast revealed that response time increases when SOAs decreases (Table 2).

Table 2. The simple contrasts of the seven different SOAs regardless of the pre-/post-test condition.

SOA	Mean	SD
700 ms	365.66	17.59
400 ms	363.16	17.83
150 ms	510.87	19.94
90 ms	604.53	22.06
60 ms	658.29	23.39
30 ms	752.73	31.39
15 ms	816.39	34.65

There was no significant effect of pointing on reaction time, $F(1, 25) = 1.016$, $\rho = .323$, $\eta_p^2 = .039$, indicating that ratings from pointing to the left or right were in general the same. There was a significant interaction effect of pre-/post-test*SOA on reaction time, $F(3.62, 90.50) = 8.817$, $\rho = .000$, $\eta_p^2 = .261$. This indicated that the response time of different SOAs differed in the pre- and post-test. To break down and assess the source and direction of the interaction, paired sample t-tests were conducted. The results showed no significant difference for the 700 ms SOA between the pre-test (*M* = 362.99, *SD* =122.92) and the post-test (*M* = 368.12, *SD* = 106.82) condition, $t(26) = -.18$, $\rho = .86$. There were significant differences between the pre-test and the post-test condition for the 6 other SOAs (the 400 ms SOA pre-test (*M* = 388.482, *SD* = 106.149) and post-test (*M* = 332.48, *SD* = 88.54), $t(26)= 5.17$, $\rho = .00$; the 150 ms SOA pre-test (*M* = 538.54, *SD* = 104.14) and post-test (*M* = 481.20, *SD* = 114.48), $t(26)= 3.61$, $\rho = .00$; the 90 ms SOA pre-test (*M* = 636.78, *SD* = 124.62) and post-test (*M* = 570.06, *SD* = 117.39), $t(26) = 3.81$, $\rho = .00$; the 60 ms SOA pre-test (*M* = 702.23, *SD* = 138.74 and post-test (*M* = 611.72, *SD* = 122.49), *t*(26 = 4.33, $\rho = .00$; the 30 ms SOA pre-test (*M* = 811.44, *SD* = 199.26) and post-test (*M* = 684.26, *SD* = 154.65), $t(26) = 4.88$, $\rho = .00$; and the 15 ms pre-test *(M* = 882.92, *SD* = 212.02) and post-test (*M* = 739.26, *SD* = 182.08), $t(26) = 4.84$, $\rho = .00$). These results again indicate that the reaction time of the participants decreases in the post-test condition for all the SOA's (except for 700 ms) and that the response time increases when SOAs decrease.

Discussion

The aim of the present study was to investigate whether lateralized pointing had an effect on tactile processing as assessed by a temporal order judgements task. The hypotheses were that participants who stimulated one hemisphere by lateralized pointing to the contralateral half of space would process tactile stimuli to the contralateral hand faster compared to baseline and that interhemispheric inhibition would lead to an increased processing time for tactile stimulation ipsilateral to the activated hemisphere. If lateralized pointing indeed has an effect on tactile information processing, there would be a discrepancy in the point of subjective equality between the pre- and post-test. However, the results show no significant shift in PSE after either rightward or leftward lateralized pointing and therefore were not in accordance with the hypotheses. The results suggest that lateralized pointing has no effect on tactile processing. The slope of each participant was also analysed and the results showed a non-significant difference between the pre- and post-test. Given that the slope resembles the performance of the participant, the non-existing shift in PSE could not be attributed to a difference in performance. This indicates that the participants were presumably not less motivated or less accurate during the pre-test versus the post-test. The median reaction time data per SOA were analysed and the results were in accordance with the result of a previous study (de Haan et al., 2012). The results showed a main effect of SOA reflecting an increase in response time when the SOA decreases. The results also showed a significant difference between the pre- and post-test, reflecting faster response time in the post-test condition. This could presumably be attributed to a learning effect.

The hypotheses of the present study were based on the proposed hypothesis that the mechanism of PA works by restoring or disrupting the balance between the two hemispheres (Herlihey, Black, & Ferber, 2013). Different studies have shown that PA and LP induce quite similar results, both are capable to induce a spatial bias. Dupierrix et al. 2008 showed that LP is able to induce a subsequent bias in space perception, assessed with a visuo-motor and a perceptual bisection task. These findings resemble the results of a prism adaptation study of Michel et al. 2003. Subsequently, Dupierrix et al. 2009 showed that LP is able to produce a long-lasting modulation in a SA task and can affect proprioceptive personal space. These findings again resemble the results of a prism adaptation study in which PA could induce a long-lasting aftereffect in a SA-task (Hatada, Miall and Rossetti, 2006). And finally, Herlihey et al. (2013) showed that LP can induce similar results to PA when using a task without a directional component. All these results are in accordance with the idea that the working-mechanism of LP could be quite similar to the working-mechanism of PA, given that LP and PA produce similar results. Unfortunately, it seems that the resemblance between LP and PA does not apply to tactile processing.

The results of the current study imply that LP is not able to affect tactile processing in the personal space, whilst several studies showed that PA is able to reduce somatosensory deficits in personal space. Maravita et al. (2003) for example showed that PA could improve the perception of contralesional tactile stimuli in neglect patients and Dijkerman et al. (2004) showed in a single case study that PA could result in improved pressure sensitivity. Girardi et al. (2004) showed that PA could affect haptic space representations in normal subjects, by influencing the central cognitive processes. And Serino, Bonifazi, Pierfederici and Ladavas (2007) observed an improvement of tactile attention after PA in left hemispatieel neglect patients. Their results indicate an improvement in accuracy for bilateral stimuli in a tactile extinction test (Serino et al., 2007). All these studies showed an evident effect of PA on somatosensory processing in neglect patients and in healthy participants. With respect to the underlying mechanism, Maravita et al. (2003) hinted that PA could influence high-level multimodal representations associated with spatial attention, since PA is able to activate the parietal lobe, which is important for multimodal integration. An possible explanation for the incongruence between PA and LP could hence be that LP is capable to affect processes involved in space perception, but is not capable to sufficient affect high level multimodal representations to ensure a supramodal effect. Further research with for example using fMRI to assess whether multimodal neural areas are influenced by LP would be necessary to further investigate this claim.

The results of the current study could also indicate that LP merely has no effect on tactile spatial representations. Tactile spatial representation is not the only lateralized function that could not be influenced by LP. The thesis research of Brummelman (2014) provides evidence that LP has no influence on spatial relation processing, by comparing categorical processing, which is lateralized in the left hemisphere, with coordinate processing, which is lateralized in the right hemisphere. The results showed an improvement in reaction times in the categorical condition regardless of the pointing direction and no significant effect in the coordinate condition regardless of the pointing direction. This supports the idea that motor action instead of attentional processes could be accountable for the results, given that LP is performed with only the right hand, which would lead to activation in the left hemisphere, which is involved in categorical processing (Brummelman ,2014). The hypothesis of the involvement of motor action seems improbable in the present study, given that there is no shift in either directing. If motor action would be involved, a shift to the right would be expected.

It would be premature to say that LP has no effect on all lateralized functions. Previous research of Herlihey et al. (2013) indicate that LP has an effect on the processing of global and local features, with global features lateralized in the right hemisphere and local features in the left hemisphere. Left LP resulted in increased reaction time on local processing task and right LP resulted in decreased reaction time on the local processing (Herlihey et al, 2013). In this case motor activation alone could not account for the results, the pointing direction did influence the results, which in turn suggest that attention processes could play a role. The exact working mechanism of LP though remains unclear and further research would be necessary to determine it and thence determine why LP is not capable to affect tactile processing.

An alternative explanation for the incongruence between PA and LP in the tactile modality could be that the limitations of the study distorted the results. It could be that participants unwittingly used their hearing instead of tactile sensation to determine the first stimuli, given that there were no earplugs or headphones (with random noise played on it) to suppress the sounds produced by the computer controlled solenoid tappers. This could indicate that the effect of LP on auditory information processing was measured instead of tactile processing. The sound was not predominant, but it could be that the participants were able to hear the sounds produced by the stimulator and subsequently tried to distinguish the first and second stimuli by means of it. The results of the current study could therefore also indicate that lateralized auditory processing was not affected by LP, whilst the intention was to measure the effect of LP on lateralized tactile processing.

A second limitation of the present study was the clarity of the TOJ task instructions. When analysing the data with Matlab it became evident in the 700 ms SOA condition most participants reacted to the first stimuli, rather than to the second stimuli, which resulted in many unusable trials. Eight participants had to be entirely removed from the study given that there were no usable trials left in the 700 ms SOA condition. This removal resulted in a smaller participant sample size.

To conclude, the present study does not provide evidence that LP has an effect on tactile processing. This result is not in accordance with the hypotheses of the study. It could be that LP has no effect on (several) lateralized functions, including tactile processing. However, current limitations could have distorted the results. Further research redeemed from the current limitations would be helpful in order to draw a more definite conclusion.

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Appendix 1

Toestemmingsformulier "point!"

Proefpersoonnummer: ….

Je staat op het punt om deel te nemen aan een onderzoek van Universiteit Utrecht genaamd "point!". Voordat je gaat beginnen, willen we je vragen om onderstaande informatie goed door te lezen en deze te ondertekenen als je het hiermee eens bent.

Je zult zo een aantal visuele en tactiele taken uit voeren en een korte vragenlijst invullen. Het doel van het onderzoek is om de relatie tussen motoriek en visuele en tactiele waarneming in kaart te brengen. In totaal zal het ongeveer anderhalf uur duren.

Alle data die gedurende het onderzoek verzameld wordt, zal anoniem worden verwerkt en enkel voor wetenschappelijke doeleinden worden gebruikt.

Tijdens het onderzoek mag je altijd vragen stellen en ben je te allen tijde vrij om te stoppen met het onderzoek.

Voor deelname aan dit onderzoek wordt **1,5**? proefpersoonuur toegekend.

Datum: …………………………………..
Naam deelnemer: ……………………….
Studentnummer: ……………………….
Handtekening:
……………………………………………

Datum: …………………………..
Naam onderzoeksleider:
…………………………………
Handtekening:
…………………………………

Appendix 2

Edinburgh Handedness Inventory[1]

Your Initials:_______________

Please indicate with a check (✓) your preference in using your left or right hand in the following tasks.

Where the preference is so strong you would never use the other hand, unless absolutely forced to, put two checks (✓✓).

If you are indifferent, put one check in each column (✓ | ✓).

Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in parentheses.

Task / Object	Left Hand	Right Hand
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking a Match (match)		
10. Opening a Box (lid)		
Total checks:	LH =	RH =
Cumulative Total	CT = LH + RH =	
Difference	D = RH – LH =	
Result	R = (D / CT) × 100 =	
Interpretation: (Left Handed: R < -40) (Ambidextrous: -40 ≤ R ≤ +40) (Right Handed: R > +40)		

[1] Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychololgia*, *9*, 97-113.