The congruency of visual and proprioceptive afferents influences the orientation of spatial attention

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The congruency of visual and proprioceptive afferents influences the orientation of spatial attention

Attention and sensorimotor adaptation using virtual reality

INTEGRATIVE CLINICAL PSYCHOLOGY

COGNITIVE PSYCHOLOGY

A thesis submitted for the degree Master of Science in Psychology

by

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Abstract

Converging evidence suggests that body parts and peripersonal space are represented based on multisensory constructions. Few studies have examined the distinct contributions of different sensory modalities to the construction and dynamics of peripersonal space. This study aims to investigate the influence of visual and proprioceptive afferents on spatial attention using virtual reality. We measured vocal reaction times of healthy participants reacting to spatially lateralized visual targets following non-predictive peripheral cues presented close to their hand. Half of the participants were examined with their right hand, and the other half with their left hand. The crucial manipulation was the position of the image of a virtual hand (positioned in left or right visual space) versus the position of the participants' own hand conveyed through proprioceptive input (positioned in left or right space). Mutually exclusive hypotheses were that spatial attention (defined as the benefit of spatially valid cues) was a) only affected by visual input, b) only affected by proprioceptive input or c) affected by a combination of visual-proprioceptive inputs. Our results demonstrated attentional modulation only for the group of participants tested with the right hand compared to the group using their left hand. Specifically, participants showed significant validity effects only when both real and virtual hands had congruent positions and the target appeared on the right. Together, our results indicate that while visual-proprioceptive congruency seems the main factor affecting the construction of peripersonal space, it is significantly modulated by hemispheric differences in the deployment of attention.

Keywords: Peripersonal space, hand, attention, visual, proprioceptive, congruency, virtual reality

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Déclaration sur l'honneur

Je déclare que les conditions de réalisation de ce travail de mémoire respectent la charte d'éthique et de déontologie de l'Université de Genève. Je suis bien l'auteur-e de ce texte et atteste que toute affirmation qu'il contient et qui n'est pas le fruit de ma réflexion personnelle est attribuée à sa source ; tout passage recopié d'une autre source est en outre placé entre guillemets.

Genève, le 18 août 2021

Emilie Marti

Signature : 

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1. Introduction

In order to interact daily with our environment and to be able to control our actions in space, humans need to perceive the location and posture of their limbs and the relevant visual information surrounding them (Ehrsson, 2012). We usually rely on where and in what position we see and feel our hands to guide our actions efficiently (Limanowski & Friston, 2020). However, what seems a simple act such as grasping a cup of coffee, is a complex mechanism that requires the brain to integrate multiple information about hand position. Indeed, the way we explore a visual environment and the spatial representation that we construct are modulated by multiple sensory cues, in particular vision and proprioception (Holmes & Spence, 2004).

One way to investigate this multisensory integration is to experimentally create a conflict between the two modalities. For instance, behavioural studies have investigated this process in experiments in which participants view their hands through optical prisms (van Beers, Sittig, & Gon, 1999). Prisms create a conflict between visual and proprioceptive cues about the hand position by displacing the visual field. This experimental setting offers an estimate of the influence of each sensory information and their combination. For instance, after adapting to prisms, participants change their pointing, showing an adaptation to a modality, generally with vision dominating proprioception (Redding & Wallace, 1996). Another well-known example to study this sensory integration is the rubber hand illusion (RHI) (Botvinick & Cohen, 1998). This study focused on operating a multisensory integration in a hand-centred spatial reference frame. By watching a rubber hand being touched in a synchronous way with their own hidden hand, participants reported feeling that the rubber hand was part of their own bodies. The attribution was measured by the drift observed in judging and perceiving position of their own hand as closer to the rubber hand than it really was. According to the authors' interpretation, RHI reflects an interaction between vision, touch, and proprioception where visual information overrides touch. This effect results in a mislocalization of tactile perception in reference to the spatial localization of visual perception. The illusion is only observed when both hands are congruently positioned (Ehrsson, Spence, & Passingham, 2004). This implies that the space around the hand can be modulated by intermodal congruency. However, human experiments on RHI rely on additional visuo-tactile interaction and therefore cannot completely isolate these visual and proprioceptive afferents. More recent studies have manipulated sensory information independently by using virtual reality technology. Limanowski & Blankenburg (2016) presented a virtual 3D arm that could be in a congruent or incongruent position with the real arm of the participant. Through the VR setting, the authors were able to manipulate independently visual information and proprioceptive information by changing position of the real arm of participants. Using functional MRI they showed that parietal, premotor and selective posterior visual brain areas of the human body respond preferentially to a virtual arm seen in a position corresponding to the unseen, real arm (i.e., congruent positions). Hence, the brain seems to integrate visuo-proprioceptive estimates mostly when there is cross-modal congruency between tactile, proprioceptive, and visual information (i.e., between the real position of the limbs and the visual-proprioceptive information of their position).

Animal studies have shown that sensory modalities converge also at the single cell level. A visuo-proprioceptive representation of limb position has been found in the posterior parietal and ventral premotor areas of macaque monkeys (Graziano, Cooke, & Taylor, 2000). The neurons involved in spatial coding of limb location based on visuo-tactile integration are called bimodal cells (Graziano, 1999). Human studies have found that the putamen, parietal and frontal lobes are involved in the integration of bodily-relevant stimuli appearing within a close and restricted space surrounding the body (Làvadas, 2002; Maravita, Spence, & Driver, 2003). This hand-centred representation of nearby space is called peripersonal space, and is defined as space located within reaching distance. More specifically, it represents the space wherein the individual manipulates external stimuli and is thus related to direct action towards the environment (Salomon et al., 2017). For this reason, it is mainly influenced by the sources of sensory information involved in estimating the position of body parts such as upper limbs.

Solid evidence in favour of the construction of a special representation of the space near the body comes from neuropsychological studies. Several studies have revealed that some hemispatial neglect patients exhibit a selectively altered representation of space near the body (Halligan & Marshall, 1991) or far from the body (Cowey, Small, & Ellis 1994). This implies that patients have a specific deficit in awareness of and attention to near vs far space of the visual field. This suggests that body-part-centred representations of space and representations of far space are coded by different brain structures and processed differently. This idea is also illustrated with studies showing that the use of a tool enlarges the representation of the space around the hand. Berti & Frassinetti (2000) asked a neglect patient to perform a line bisection task to assess the pathological rightward bias characterizing neglect. The rightward bias was observed for the near space but not for the far space. When she was asked to bisect lines in the far space with a laser pointer, her result was comparable to healthy participants. However, when she had to use a stick, the bias was present for the near and the far space. This finding shows that an artificial extension of peripersonal space with a tool such as a stick modifies the limits of peripersonal space. Thus, multisensory interactions appear to delimit and eventually extend the space surrounding body.

One hypothesis emerging from these observations is that peripersonal space is defined by visual information around the hands, its reference frame being centred on the acting limb (Brozzoli, Ehrsson, & Farnè, 2014). An important interplay has been observed between attention to objects in peripersonal space and the proximity of the hand. The idea being that more attentional resources must be allocated to events occurring near the body to allow us, for example, to track or avoid objects of potential harm (Graziano & Cooke, 2006; Lloyd, Morrison, & Roberts, 2006). Substantial evidence has shown that visual stimuli near the hand draw attention to tactile stimuli presented close to the hand (Kennett, Spence, & Driver, 2002) or that hand position influences visual target detection. Reed, Grubb, & Steel (2006) investigated whether the location of a static hand affects spatial attention. One hand was placed next to a visual target while participants had to detect targets based on predictive visual cues. Results showed that the detection of the visual target was better closer to the hand, which supports the idea that hand position affects the allocation of attention in visual space. Regarding multisensory integration, some studies using spatial attention tasks have demonstrated facilitation of stimulus processing when its location matches with a stimulus in a different modality (Spence & Driver, 1994). For instance, participants detected a visual target faster and more accurately when it was presented in spatial proximity to a task-irrelevant sound (Spence & Driver, 1997) or touch (Spence, Nicholls, Gillespie, & Driver, 1998) compared to when the stimulus appeared further away from the target. However, while multisensory interactions have been well characterized, the distinct effects of visual and proprioceptive limb coordinates on spatial allocation of attention are less well known.

We focused in this study on the role of visual and proprioceptive afferents and their effects on spatial attention. We aimed at a better understanding of the influence of each type of sensory afferent on the construction of the representation of stimuli presented in peripersonal space. We reasoned that if spatial attention in near space is modulated by the positioning of body parts (here, the hands), shifts of attention should either be affected by the visual coordinates of the hand, its proprioceptive coordinates, or both. Given previous work our hypothesis was that shifts of attention, expressed as validity effects of a peripheral cue (Jonides, 1981) would be affected by the interaction between the two types of sensory afferents similarly for participants tested with their left hand or right hand.

2. Method

2.1 Participants

Twenty-four healthy right-handed participants (12 women, mean age 25.2 years, range 20 – 29 years) with normal or corrected-to-normal vision and no history of neurological or psychiatric disorders took part in this study. Hand preference was verified with the Edinburgh Handedness Inventory scores (Oldfield, 1971). All volunteers gave informed consent, and the study was approved by the Ethical committee of the Faculty of Psychology and Educational Sciences, University of Geneva.

Participants were randomly assigned to one of two experimental groups composed of 12 subjects each defined by the real hand tested. One group performed all the experimental task with their right hand, while the other group performed the task with their left hand. They were neither informed about group affiliation nor of the purpose of the study.

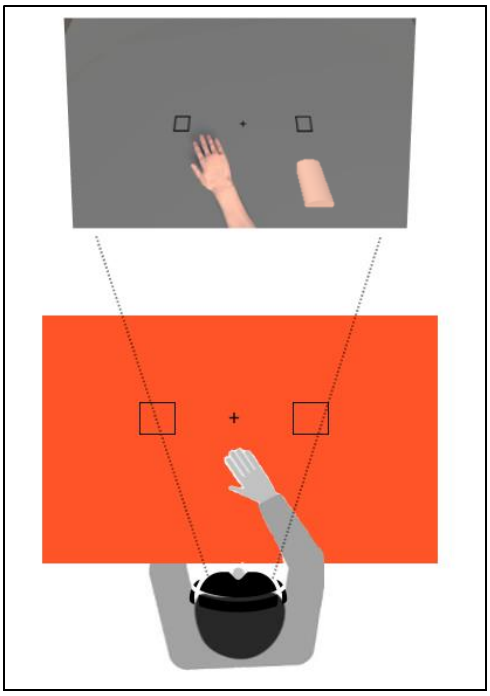
2.2 Apparatus, stimuli, and procedure

A spatial cueing task (Posner, 1980) adapted in virtual reality (VR) was used to assess spatial attention. The experiment was programmed using Unity 3D software. A Vive VR system (HTC Corp., Taoyuan, Taiwan) was used to present all stimuli and for data collection. The VR headset has a 110-degree field of view at a refresh rate of 90 Hz. A microphone served to record vocal response times of participants. Volunteers sat in a chair in front of a table which had a working surface of 100 x 60 cm and was at 78 cm from the floor. On the table, a black central fixation cross (2,5° of visual angle) was drawn together with two black squares (7,3° of visual angle) positioned 0.15 cm to the left or to the right of the fixation cross. This display was exactly reproduced within the VR (see Fig. 2). In order to superimpose the real table with the experimental display reproduced in the VR, the VR system was calibrated according to the position of the participant's body. More precisely, the midsagittal line of the volunteer was centred on the centre of the table and on the calibration point of the room. To this aim, we recorded within the VR system the position of the centre of the table, of the corners of the table and of the fixation cross.

To experimentally dissociate the contribution of visual and proprioceptive afferents in spatial orienting, a photorealistic virtual 3D hand was created. To make the virtual display as precise as possible, positions of volunteers' elbow and middle finger pointing at either the left square or the right square on the table were calibrated. The virtual hand was also adjusted in size and skin colour to make it the most realistic. Finally, to visually balance the experimental display, a rectangular block adjusted in size and colour to the hand was placed in the hemispace contralateral to the virtual hand. Participants were asked to maintain their posture during the entire experiment and to avoid moving their arms or hands. The passive real hand tested was manipulated at the beginning of each block of trials by the experimenter so that it would correspond to the experimental condition, while the other hand, the one that was not selected for the task, was instructed to be kept on their lap throughout the whole trial.

Figure 1

Experimental setup

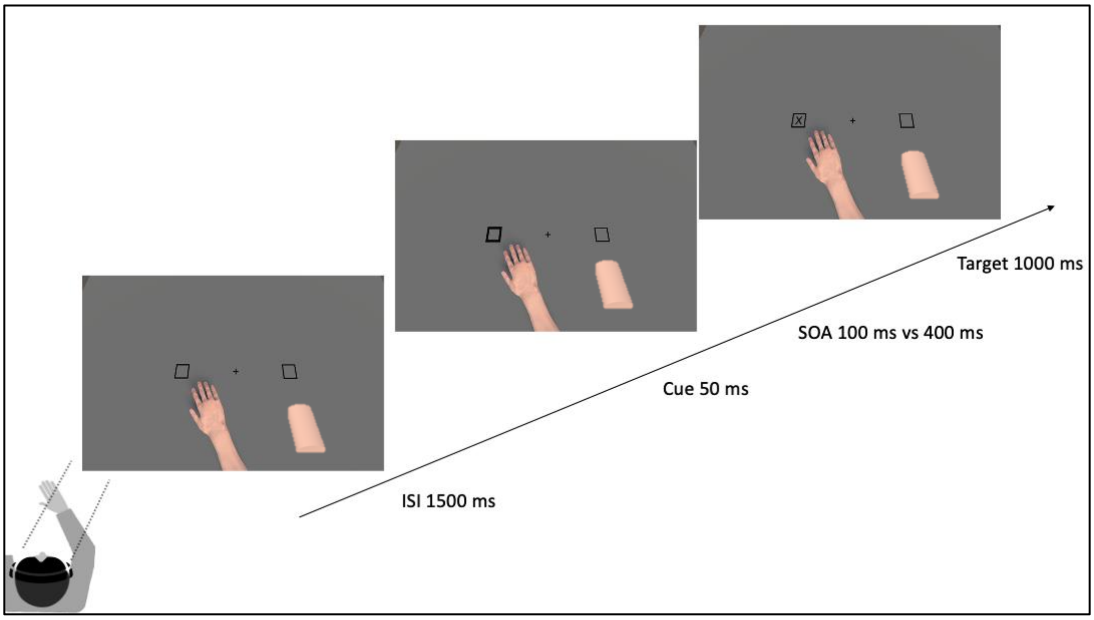


Note. The arrangement of the table (represented in orange) and the VR display seen through the headset (represented in grey) relative to the participant. Example of participant of the experimental group tested with the right hand. Real hand positioned towards the left hemispace (towards the left square). Virtual hand positioned towards the left hemispace as well. Example of the congruent condition where the real hand and the virtual hand have the same position.

The display of the spatial cueing task was presented in the VR on a medium grey background and remained visible throughout the whole trial. The peripheral cue was represented by a fast thickening (50 ms) of one of the two squares. The cue indicated the correct location of the upcoming target (valid cue) in 50% of the trials. Invalid trials (i.e., when the target was presented on the other side indicated by the cue) represented another 50% of the trials. A target was then presented after a stimulus onset asynchrony (SOA) of 100 ms in 75% of the trials and of 400 ms in another 25%. The manipulation of the SOA was randomized across trials in order to avoid habituation and anticipation. The target, represented by an "X" (3° of visual angle) could be presented either in the left square in 50% of the trials or in the right square in another 50% during 1000ms. Participants were asked to detect the target stimulus X as quickly as possible by saying orally "top" (Fig. 3).

Figure 2

Sequence of events and timing of the experimental design

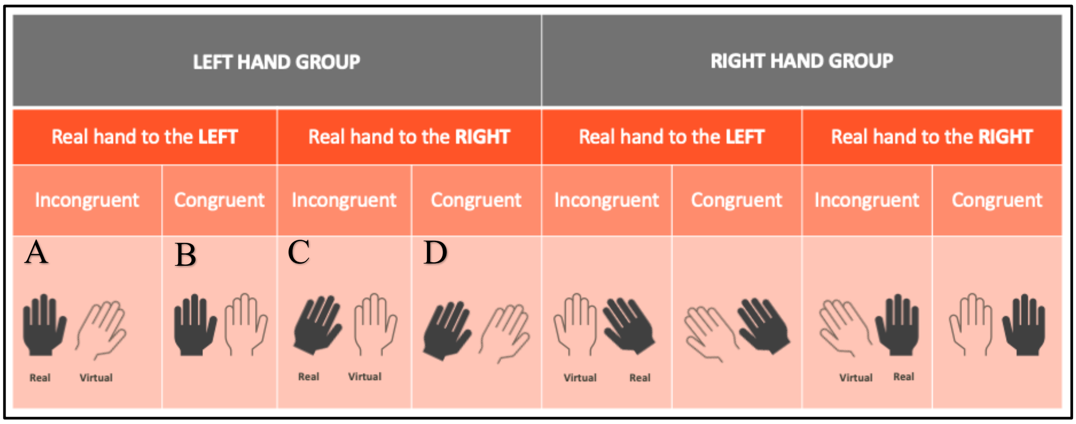


Note. Visual display visible throughout the whole trial. Valid cue appearing on the left hemispace for 50 ms and indicating the correct position of the upcoming target. Target appearing on the left hemispace during 1000 ms. Participant gives vocal response by saying "top".

The experiment used a 2 – position of the real hand (left vs right) x 2 – position of the virtual hand (left vs right) x 2 – validity of the cue (valid vs invalid) x 2 – position of the target (left vs right) within-subject design. The total of 16 experimental conditions were randomized in four blocks and completed for each participant with a total of 128 trials/block. One block lasted 5 minutes. Therefore, 512 trials were completed by a participant (32 repetitions x 16 randomized permutations of the variables) over approximately 30 minutes. Validity of the cue and target position were varied randomly trial to trial, whereas real and virtual hand position were alternated between blocks depending on the experimental condition tested. Thus, the positions of the real and the virtual hand could be congruent (both arms were placed towards the left square or towards the right square) or incongruent (i.e., the virtual arm was positioned towards the left square while the real arm was positioned towards the right square) (see Fig. 4). The order of hand positions was counterbalanced across subjects.

Figure 3

Summary of the Congruency conditions



Note. **A.** Incongruent condition with the left real hand positioned towards the left hemispace while virtual hand positioned to the right hemispace. **B.** Congruent condition with the left real and virtual hands positioned to the left hemispace. **C.** Incongruent condition with the left real hand positioned towards the right hemispace while virtual hand positioned to the left hemispace. **D.** Congruent condition with the left real and virtual hands positioned to the right hemispace. For the group using their right hand, same patterns but mirror inversed.

2.3 Data analysis

The onset of each vocal response time measured in seconds was recorded by the headset and extracted with a custom-made MATLAB script. Each onset was then visually verified. RTs equal to 0 or outside a 2 SD interval of the mean of each experimental condition were excluded from statistical analyses (4.45% of total trials). As a measure of attentional orienting, validity effects based on the difference between the mean of invalid minus valid RTs were calculated.

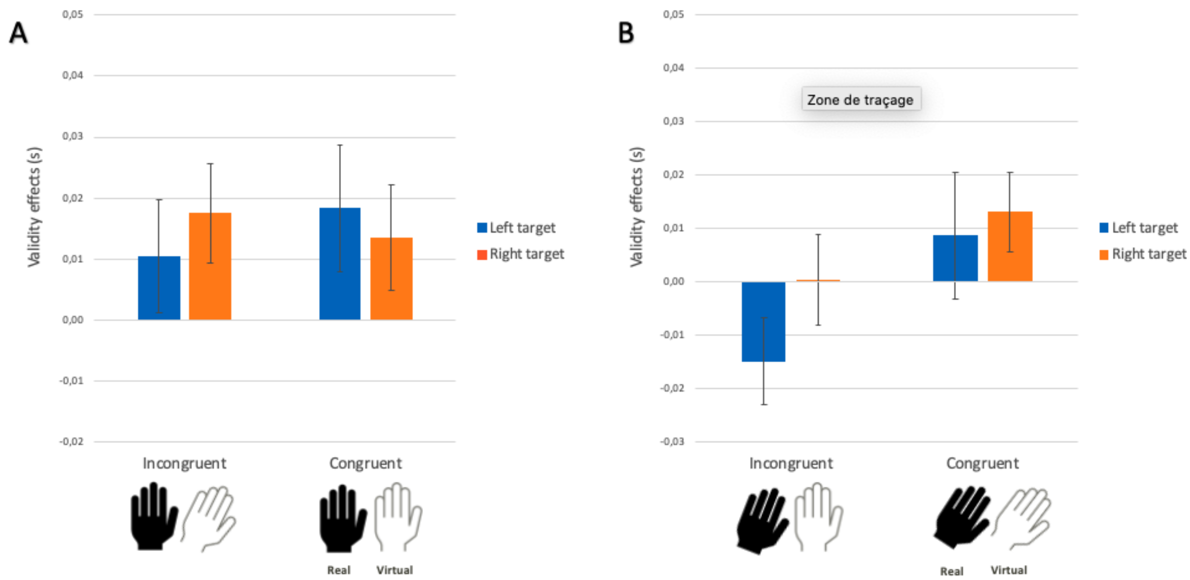
3. Results

Validity effects were submitted to a repeated-measure analysis of variance (rANOVA) with Group (left hand vs right hand) as between-subject factor and Target position (left vs right), Proprioceptive position (left vs right) and Congruency between the position of the real hand and the virtual hand (incongruent vs congruent) as within-subject factors. Over all trials, there was a significant main effect of Target position ($F(1,22) = 5.522$, $p = .028$), a significant two-way interaction between Proprioceptive position and Group ($F(1,22) = 6.511$, $p = .018$) and a three-way interaction between Group, Target position and Congruency ($F(1,22) = 9.153$, $p = .006$). In order to follow up this triple interaction, ANOVAs were performed for each group separately.

For the left-hand group the ANOVA only revealed a main effect of Proprioceptive position ($F(1,11) = 8.513$, $p = .014$; Figure 5). This effect was due to differences in time responses of participants depending on their left hand positioned towards the left hemispace versus the right hemispace.

Figure 5

Validity effects (s) for the group tested with the left hand based on the real hand position



Note. None of the validity effects were significant for the group using their left hand only. **A.** Experimental condition when the left hand of participants was positioned towards the left hemispace. **B.** Experimental condition when the left hand of participants was positioned towards the right hemispace.

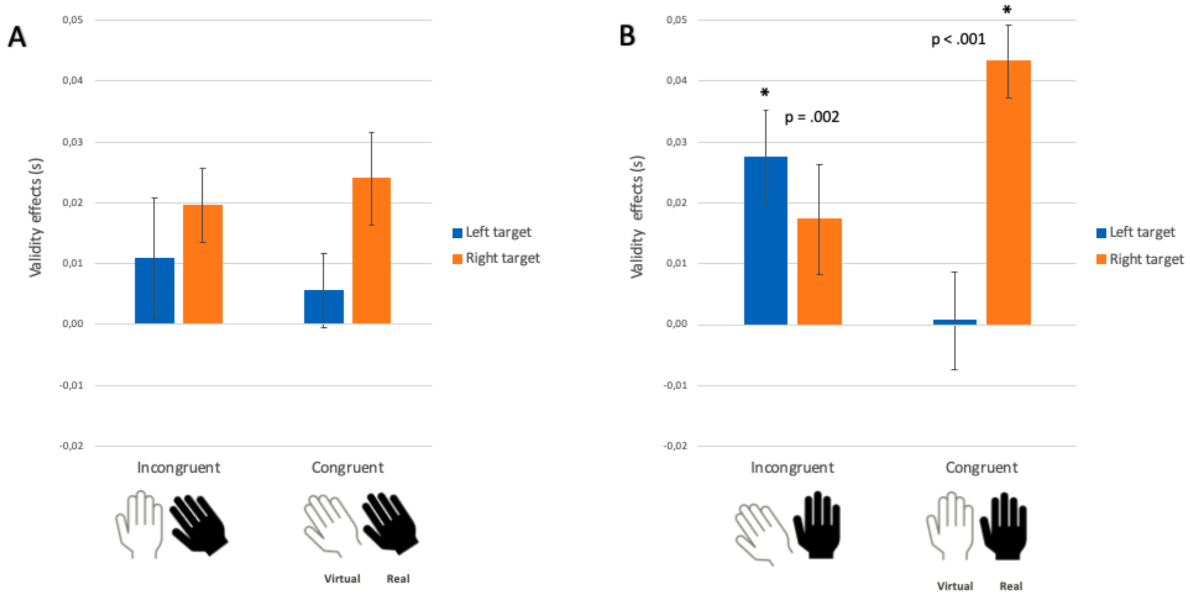
For the right-hand group, the analysis showed a main effect of Target position ($F(1,11) = 6.624$, $p = .026$) and a significant interaction between Target position and Congruency ($F(1,11) = 10.690$, $p = .007$; Fig. 6). In addition, there was a trend toward significance for the triple interaction between Target position, Proprioceptive position and Congruency ($F(1,11) = 4.194$, $p = .065$). In order to understand this triple interaction, we followed up with two-way

ANOVAs comparing Congruency effects and Target position depending on each Proprioceptive positions.

The results indicated no main or interaction effects were observed when the real hand was positioned in left hemispace (all ps > .127) (see Fig. 6a). However, a significant main effect of Target position was observed when the real hand was positioned in right hemispace ($F(1,11) = 10.635$, $p = .007$). More importantly there was also a significant interaction between Target position and Congruency ($F(1,11) = 17.065$, $p = .002$) when the participants' hand was located in right hemispace. T-tests against 0 revealed a significant validity effect in the incongruent condition (real hand positioned towards the right hemispace and the virtual hand positioned towards the left hemispace) when the target was shown in left space ($p = .002$). This result indicates that participants were slower to respond to invalid trials compared to valid trials when real and virtual hands were incongruent and when a target was presented in left hemispace. In contrast, in the congruent condition (real hand and virtual hand positioned towards the right hemispace), a significant effect of validity was found when a right target was presented ($p < .001$). This also shows that participants were much slower to respond to the target when the cue was invalid rather than when it was valid (see Fig. 6b).

Figure 6

Validity effects (s) for the group tested with the right hand based on the real hand position

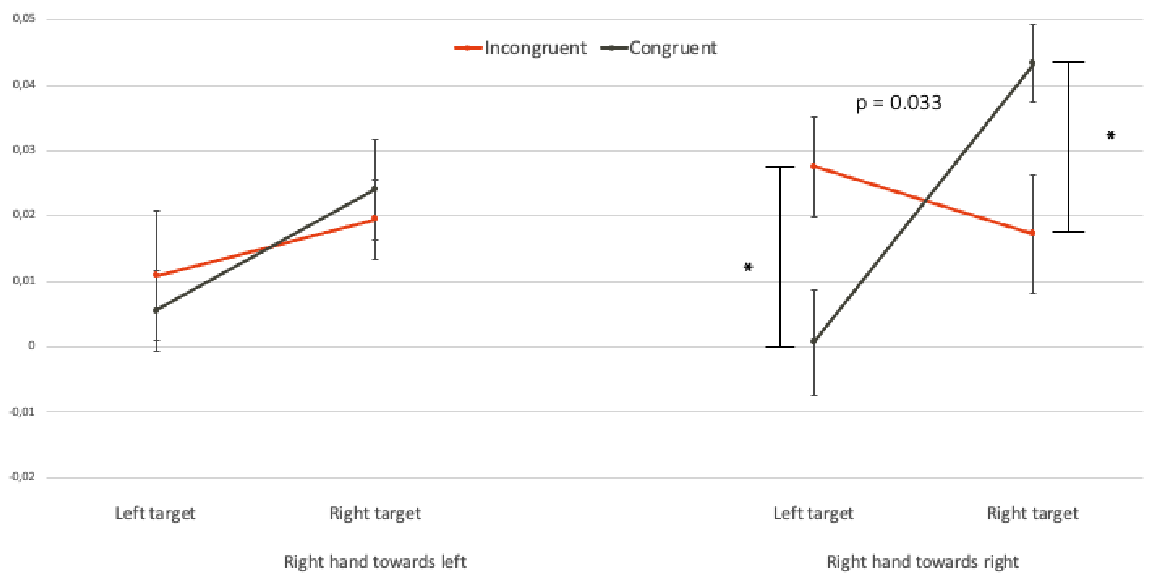


Note. **A.** Experimental condition when the right hand of participants was positioned towards the left hemispace. No significant validity effects were observed for both incongruent and congruent conditions (p > .127). **B.** Experimental condition when the right hand of participants was positioned towards the right hemispace. Validity effect found with incongruent position of the hands (the real one positioned towards the right hemispace but the virtual one towards the left hemispace) when the target appears on the left hemispace but not when it appears on the right hemispace. Validity effect also observed in congruent position of the hands (both real and virtual hands positioned towards the right hemispace) when the target appears on the right hemispace only.

Planned comparison analyses showed significative effects of Target position and Congruency ($p = .033$). These results demonstrate that the comparison between the condition where the target appears on the left and the condition where the target appears on the right when the hands are congruent shows a significant difference. (see Fig. 7).

Figure 7

Planned comparison for the group tested with the right hand based on the real hand position



4. Discussion

The closer objects get to the body, the more attentional resources are allocated to evaluate and respond efficiently to them (Losier & Klein, 2004). Studies have shown that participants process differently targets that are presented in space near the hands compared to far from the hands (Brown, Marlin, & Morrow, 2015). The source of these effects and the role of vision and proprioception in processing visual targets in peripersonal space is still being debated. Some demonstrations of this spatial bias in visual attention suggest that people need to see their hand nearby the target (di Pellegrino & Frassinetti, 2000) while others suggest that vision of the hand isn't necessarily required (Brown et al., 2008, 2009). In this study we reasoned that if spatial attention in near space is modulated by the positioning of the hands, shifts of attention should either be influenced by the visual input, by the proprioceptive one, or both. Considering previous evidence, we expected that shifts of attention (expressed as validity effects of a peripheral cue) would be affected by the interaction between the two types of sensory afferents similarly for participants tested with their left hand or right hand.

Surprisingly, our results revealed significant attentional modulation only for the group of participants tested with the right hand compared to the group using their left hand. Our results confirm the known effect of validity (Jonides, 1981; Posner, 1980) where the cue has either facilitated or impaired the perception of the target by indicating the correct or false upcoming location but only for the right group. They also support the idea that attention in peripersonal space is influenced by the position of our limbs (Jackson, Miall, & Balsley, 2010). Our results demonstrate that participants using their right hand which is positioned in the right hemispace show stronger influence on the modulation of their attention than when their hand is positioned in the left hemispace (see Fig. 6). Indeed, we notice higher validity effects for participants whose real hand was positioned towards the right hemispace (Fig. 6b) compared to the left hemispace (Fig. 6a). Even though, there were no significant results for the group tested with the left hand, we can also observe that attentional modulation was stronger when the position of their hand matched the laterality of the hand they were using (see Fig. 5). Participants show higher validity effects when their left hand was positioned towards the left hemispace (see Fig. 5a) compared to when it was placed towards the right hemispace (see Fig. 5b).

However, we cannot strictly conclude here on the unique effect of proprioception as the virtual hand position was also manipulated. On the contrary, our results suggest that the allocation of attention in peripersonal space is modulated by the visuo-proprioceptive congruency about hands position (see Fig. 6b). Evidence showed that visual stimuli appearing near the hand seem to benefit from bimodal representations that influence the allocation of visual attention (Reed et al., 2006) and that bimodal neural representations of hand position allow attention to interact with visual perceptual representations (Cosman & Vecera, 2010). One explanation is that participants associate proprioceptive and visual information from the close hands to create a specific peripersonal space frame of reference within which they map the target location. Hence, participants may better localize the target when it appears in this near-hand framework because it represents its position as both a visual location and as a potential posture (Brown et al., 2015). However if visual stimuli, such as peripheral cues, appear outside of it, participants show greater negative impacts on their attentional modulation with an inhibition of return to a previous referential location expressed with slower time reactions. Globally, our results match evidence showing that participants are slower to disengage their attention from visual cues to near-hand targets in peripersonal space (Abrams et al., 2008). We found these negative effects of peripheral cues for participants mobilizing their right hand. When both real and virtual right hands had congruent positions towards the right hemispace, we observed no validity effects for a target presented on the left hemispace but an important cost for invalid trials for right-sided targets. Therefore, participants of the right group were slower to detect the target on the right hemispace when the cue flashed on the left hemispace (i.e., invalid cue). One hypothesis could be that the congruency between the real and virtual right hands positioned towards the right hemispace creates this near-hand space that drives the attention of the participant on the right hemispace. We can hypothesize that when a cue appears on the left hemispace, an important attentional shift is due to the strong effect of the cue as a distractor. Participants might be more penalized in engaging their attention to the left-sided cue that is outside this near-hand reference frame but more importantly, they take more time to disengage their attention from it when they must detect the right-sided target. Hence, we observe an important attentional cost which results in much slower time responses for right-sided target detection.

We found the inverse pattern of results for the incongruent condition characterized by the virtual hand positioned towards the left hemispace (i.e., while the real hand is still pointing at the right hemispace). In this condition, a significant validity effect only for left-sided targets was found. Hence, participants were much slower to detect the target appearing on the left when the cue previously flashed on the right hemispace. Here, we can hypothesize that this near-hand spatial reference framework is based on the virtual right hand position more than the real right hand. Indeed, validity effects are observed when the target position spatially matches the virtual hand position. Classically, the estimate of hand position has been presented as relying more on vision than proprioception (Welch & Warren., 1986). However, van Beers et al., (2002) showed that the weighting of visual and proprioceptive afferents about hand localization is highly dependent on experimental conditions. For instance, evidence shows that the passive positioning of the hand by an experimenter can reduce the participant’s proprioceptive feeling (Mon-Williams et al., 1997) which could have influenced our results as well. We could also explain this pattern of results with the optimal integration model (van Beers et al., 1999). It suggests that the brain weights the sensory information of each modality in a way to reduce the uncertainty of perceived position. We can hypothesize that when the virtual and the real hands have different positions, uncertainty is more important due to the incongruency. For this reason, as found in literature, if sensory modalities are in conflict, visual information about the hand location could dominate proprioception due to the greater precision and spatial acuity of vision (Maravita, Spence, & Driver, 2003). Hence, our participants could have here used the virtual hand as point of reference for their spatial near-hand framework.

While our results indicate that visual-proprioceptive congruency seems the main factor affecting the construction of peripersonal space, we also observe that it is significantly modulated by hemispheric differences in the deployment of attention. Indeed, results might also be explained by a right attentional hemispheric dominance, which is strengthen when the right hand is mobilized. Extensive literature has demonstrated a greater degree of engagement of the right hemisphere in spatial processing and visual attention, mostly based on studies of patients with spatial neglect (Heilman & Van Den, 1980; Mesulam, 1981) as well as in healthy adults (Hämäläinen & Takio, 2010, for a review). The right-hemisphere specialization model proposed by Mesulam (1981) suggests that the left hemisphere controls shift of attention in the rightward direction, while the right hemisphere controls shift of attention in both direction. This rightward attentional bias was supported by neuroimaging evidence reporting right hemisphere dominance in tasks involving a cued shift of spatial attention and target detection (Nobre et al., 1997; Gitelman et al., 1999). As found in our results, evidence has shown a more pronounced multisensory effect in right than left hemispace (Chen & Spence, 2017, for a review). Another possible explanation of why a visual stimulus close to the right hand especially is greater to influence shifts of spatial attention is based on how people interact with their environment (Bridgeman & Tseng, 2011). Some studies have proposed that the effect of near-hand space is limited to the space around the right hand, especially in right-handers. More specifically, it seems that right-handers use their right hand more frequently which makes the space around their dominant hand a more functional one (Le Bigot & Grosjean, 2012) resulting in enhanced visual processing at locations where action is more likely to occur (Bridgeman & Tseng, 2011). For instance, greater spatial cueing effects have been found for targets appearing on the right side of a screen, closest to a static right hand, but not for a left hand (Llyod, Azanon, & Poliakoff, 2010). The authors suggested that the right hand can influence the shifting of attention towards visual cues and targets occurring in peripersonal space surrounding the right hand especially. The fact that we chose only right-handed participants for this study, makes it possible that attentional effects we observed happened only for the dominant hand that they use the most to interact with the world (Rubichi & Nicoletti, 2006).

In conclusion, the current study provides evidence that the congruency between visual and proprioceptive information about the right hand position induces to a greater or lesser extent a cost in the re-orientation of the attention depending on the target position in the near-hand space.

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