Manipulating haptic spatial reference frame preference by blindfolding sighted participants

Bachelor thesis Liberal Arts & Sciences

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Abstract

Research done by Struiksma, Noordzij & Postma in 2011 has shown a discrepancy between reference frame preferences in blind, low-vision, and sighted subjects on the horizontal, but not the vertical plane. In the horizontal plane sighted and low-vision participants did not differ in their reference frame preferences, but the blind showed a clear preference for the intrinsic frame in favor of the absolute/relative frame. The question remains whether this differences is caused by the blindness in the latter participants or from the fact that the first two groups could use concurrent visual inputs on the environmental background.: noninformative vision. Non-informative vision can be influential on reference frame preference and could explain the discrepancy between the preferences of blind and sighted subjects. This research aimed to determine whether manipulating non-informative vision has an influential role on the reference frame preference. Participants were told to haptically explore three identical sets of seven boxes. For each box a response was provided. Responses were measured on a 7-point Likert scale. Results indicate that participants either blindfolded or with non-informative vision show almost similar results without any significant interaction between conditions. This refutes the hypothesis that removing visual information from sighted participants influences reference frame preference.

Introduction

Whether we navigate our world physically or mentally, a spatial template of the objects perceived is constructed with a central point of origin (Carlson-Radvansky & Logan, 1997). These so called reference frames help us understand our place in the world around us and how to interact with our environment. Reference frames can be seen as a spatial construct consisting of elements like object, subject and target. Imagine a visitor asking somebody where his car was parked and the response is 'in front of that building over there'. Even though you just established that your car still exists and was parked, 'in front' could still be quite ambiguous. 'In front' only gets its meaning from the experience we have with the word and the typical layout of a building. If the building has a design or features that don't resemble anything heard of before, 'in front' can still get the tourist to walk around the entire building. Reference frames help interpret and represent spatial relations.

Three types of reference frames are used when researching mental representations; the absolute, relative and intrinsic frame (Carlson-Radvansky & Logan, 1997; Struiksma, Noordzij, & Postma, 2011). The most dominant one is the vertically aligned, i.e. *y*-axis, *absolute* reference frame. Sitting behind a desk or walking down a street there are always powerful elements presents like buildings, walls and even gravity. As long as the people or objects discussed are in a normal orientation items can easily be ordered in a top-bottom sequence. However, when lying down, looking at people who are tilted, or objects in an atypical orientation, this frame can still be manipulated, following the axis of the object. The relative frame is in the eye of the beholder, using the perceiver as the central point of orientation. When a person is standing up or walking, the absolute (A) and relative (R) frames align with the world and are perceive as lining up. The top end of the vertical axis can easily be related to the head when the bottom end can easily be related to the earth itself. The intrinsic frame is the most flexible one. The intrinsic (I) frame places the perspective as originating from within an external item, like the car owned by the visitor.

Reference frames form a core aspect of spatial mental representations, which are of key importance to human perception and cognition (Struiksma, Noordzij, & Postma, 2011). Research into reference frame preference usually involves ambiguous targets prompting the participants to form a judgment (Alloway, Corley, & Ramscar, 2006; Carlson-Radvansky & Radvansky, 1996; Levelt, 1984; Struiksma, Noordzij, & Postma, 2011; Yamamoto & Philbeck, 2013). The preference of reference frames can be influenced, or even primed, by variation of situational context, functionality or linguistic input. Manipulation of situational context can be achieved by methods like blindfolding (Shelton & McNamara, 2001; Yamamoto & Philbeck, 2013), engaging the subjects with virtual environments (Alloway et al., 2006) or adjusting the physical orientation of the observer (Franklin & Tversky, 1990). Functionality relies on the relationship inherent to objects observed, like *postman-mailbox or shoe-ball.* When a functional relationship is present the intrinsic reference frame is preferred in comparison to a non-functional relationship where the absolute/relative reference frames are preferred. When a functional relationship is displayed, the intrinsic reference frame and terminology is preferred (Carlson-Radvansky & Radvansky, 1996). However, linguistic information can also be considered as perceptual information during task performance (Wilson & Golonka, 2013). This implies that linguistic information has an influence on spatial representation.

Following a supramodal model of mental representations this influence might be expressed even more in the blind (Struiksma, Noordzij, Neggers, Bosker, & Postma, 2011). Mental representation is said to be a supramodal function that works almost identically for the blind and the sighted (Struiksma, Noordzij, & Postma, 2009). A combination of (spatial) tasks and imaging-research has revealed that supramodal brain regions produce abstract representations from the modalities that provide data. The processing of spatial perception and object-form takes place in the same neurological pathways in a similar fashion for both blind and sighted subjects. Even the timing of tactile object recognition seems to be on par with the timeframe of visual object recognition (reviewed in Ricciardi, Bonino, Pellegrini, & Pietrini, 2014). Even though a perceptual visual image is not available to the blindthey do experience similar spatial representations as sighted people. Relying on the support of other modalities seems to be key in the production of accurate spatial representations, supporting a supramodal view of mental representations (Struiksma et al., 2009). Important to note is the bidirectional connection between the supramodal representation and the different modalities. Disrupted vision is compensated by other modalities, and the same might work for loss of hearing. This simultaneously discards vision as a fundamental prerequisite for a normal cognitive development. As the supramodal organization remains intact, lesions in the occipital cortex, physical or virtual, is shown to have a significant impact on the linguistic and spatial skills of the blind to the extent that some lose their ability to read Braille (reviewed in Ricciardi et al., 2014; Struiksma, Noordzij, Neggers, et al., 2011). It seems the human brain is quite efficient at redistributing its resources to compensate for missing modalities but also still depends on every available resource.

Research into the inner workings of reference frames gives us an insight into human cognition, mainly on the aspect of mental representations. The fact that the mental representations of blind and sighted subjects are not to different from each other supports a supramodal view of mental representations and suggests the blind brain can proficiently adjust to missing modalities. However, a lot of research into reference frame preference has been solely performed with sighted participants. In a recent research, Struiksma, Noordzij & Postma (2011) compared reference frame preferences of blind, low-vision and sighted participants. They established that all participant groups have access to all three reference frames. How they interact with these frames differed. Participants were asked to judge the truth value of the sentences “The ball is above the shoe” (Dutch: De bal is boven de schoen) and “The ball is in front of the shoe” (Dutch: De bal is voor de schoen) while haptically exploring five and seven corresponding configurations respectively, represented inside a total of twelve boxes. A differentiation was created between canonical and non-canonical, which can be seen as typical of a-typical. The experiment was held at an annually held blind- and low-vision conference in the Netherlands. The response applied to a certain configuration which dissociates the reference frames. Participants responded identically in the ‘above’ condition, but a difference between sighted and blind subjects emerged when using ‘in front’. An overview of the configurations and their corresponding frames are provided in the results section.

In the vertical plane the use of 'above' consistently evoked a preference for the absolute/relative frame in sighted, low-vision, and blind participants. The general preference for the absolute/relative frame in the ‘above’ condition corresponded with earlier research (Struiksma, Noordzij, & Postma, 2011). ‘Above’ suggest a vertical absolute/relative arrangement as supported by the results. The strongest argument for the preference of ‘above’ is the world, gravity and our body itself as stated earlier. Vertical relations are relatively strong and readily available, as we navigate our environment in an upright fashion. Adjusting the physical orientation, e.g. diagonally instead of vertically, has been shown to influence the orientation of reference frames (Franklin & Tversky, 1990).

On the horizontal axis a different pattern emerged. A significant difference was recorded on the horizontal plane with the use of the ambiguous spatial term 'front'. Sighted and low-vision participants matched the ambiguous properties of 'front' and showed an almost 50/50 preference for absolute/relative compared to intrinsic reference frames on the horizontal plane, as expected. These results might be explained by the inherent ambiguity of ‘front’, established in sighted participants in a different research (Alloway et al., 2006). In contrast, blind subjects rejected (about 20% acceptance) the absolute/relative reference frame in comparison to the intrinsic reference frame (about 80% acceptance; Struiksma et al., 2011). This was remarkable since one might think that the blind would either prefer an absolute/relative frame, i.e. perception from oneself is dominant, or a response pattern similar to ‘above’, i.e. the blind and sighted process the semantics of ‘front’ in a similar fashion.

While the results discussed above give way to some interesting thoughts, the aspect that influences the shift in preference on the horizontal frame is yet to be identified. One aspect besides the long term visual deprivation differentiating between the early-blind and sighted participants was the availability of non-informative vision. Firstly, research by Zuidhoek (Zuidhoek, Visser, Bredero, & Postma, 2004) showed that the availability of non-informative vision influenced processing speed and reduced deviation within results. Secondly, in an elaborate study consisting of seven experiments a preference arose for egocentric (relative) perspectives when these were aligned with an external reference system in the environment, i.e. non-informative vision (Shelton & McNamara, 2001). Removing any visual information might influence the amount of relative frame preference or even any other spatial reference frame. In the Struiksma study the participants that did have at least some degree of visual input were not blindfolded and might have used environmental information to align reference frames. Hence, some of the results might have been influenced by environmental information. This can be tested by blindfolding the participants and testing whether residual visual information might influence reference frame preference.

The goal of this research was therefore to determine whether blocking non-informative vision has an influential role on the reference frame preference. If a response curve comparable to that of the blind participants in the original experiment appears, a lack of visual information might explain the difference in response curves between the blind and sighted. When no significant influence can be found and response curves are similar to the original research, a lack of visual information might not be influential on reference frame preference.

If non-informative visual information influences the reference frame preference, then blocking visual information in sighted participants evokes response curves similar to those of blind participants

Materials and methods

By creating a set-up of 13 boxes, participants were subtly forced to choose between reference frames, measuring preference. The task of the current research was mostly identical to the task described in the paper by Struiksma (2011), while the participants were healthy sighted individuals. There were three distinct differences compared to previous executions on participant input and research location. First, the participant input provided more information. To assess whether appropriateness is consistent on each participant each response was given on a seven-point scale for appropriateness. Second, the research was executed at the Utrecht University in a suitable environment. And third, only the ‘in front’ condition was tested, as no differences were found in the ‘above’ condition.

Participants

Participants were recruited on campus using flyers or through personal information. The group consisted of 30 subjects, 15 men and 15 women. All subjects were native Dutch speakers and had normal (or corrected to normal) vision. Subjects had a mean age of 22.97 with a standard deviation of 2.498 and a range of 12. There where some outliers in age (minimum 20 years, maximum 32 years). Between blindfolded (56% male) and non-informative vision (46% male) the gender ratio was skewed. Overall there was a 50/50 gender ratio between subjects. Participants had the possibility of asking questions during the signing of the informed consent form before the actual research. While some started speculating on the goal of the research, these questions weren’t answered until after the three rounds of research. Participants either received credits for participating in this research or were paid based on a €6 hourly fee.

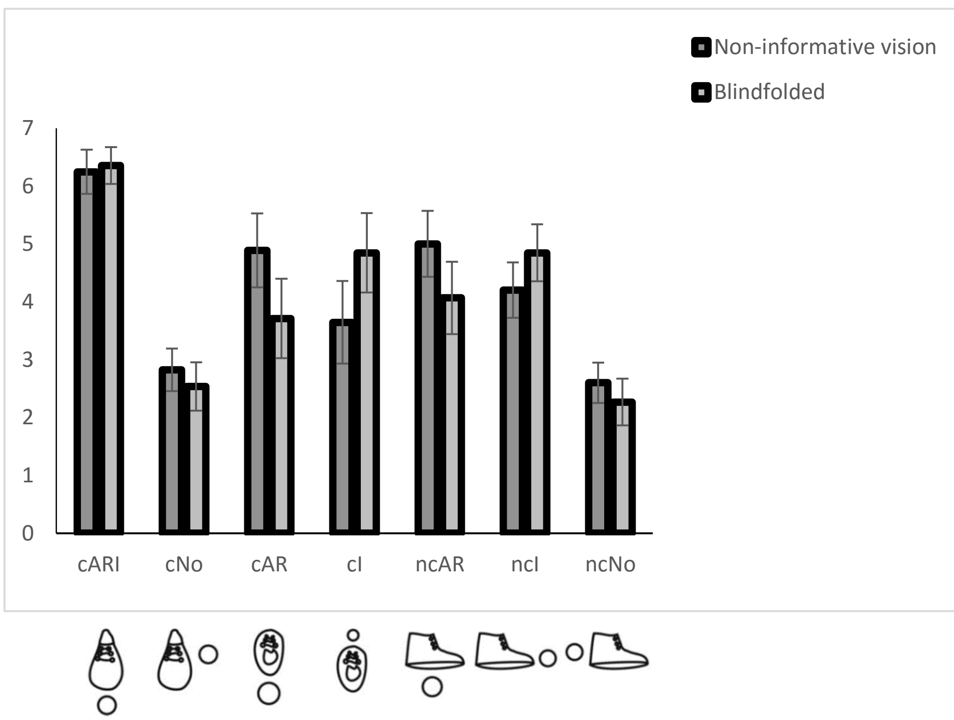
Materials and procedure

The seven configurations as designed by Struiksma (2011) were replicated using three kinds of balls and shoes. Standard IKEA storage boxes measuring 33cm x 33cm x 33cm were modified for this experiment. The shoes and balls were glued to the removable bottom in one of the previously designed spatial configurations. The ball and the shoe were always 5 cm apart. Each box was marked to the spatial configuration and the opening and the front were directed horizontally and covered by a cloth attached to the lid. Three sets of seven boxes, each consisting of a set-specific type shoe and ball, were used during the research. All seven boxes and corresponding configurations were reproduced according to the data and schematics offered in the research paper by Struiksma (2011).

Participants were informed that each box contained a ball and a shoe, but were not presented with any examples or with the layout of the lab. Outside of the lab the participants were blindfolded, brought into the lab and disoriented. Participants were instructed to place their hand inside a box and feel both stimuli, following the sequence from left to right. After perception, participants judged the sentence “The ball is in front of the shoe” (De bal is voor de schoen) by replying with a response fitting to a 7-point Likert-scale. After finishing each set, a short intermezzo was held to change the set. This meant each participant took part in three rounds, executing the same task three times, but with slightly different materials. The order within-set (box 1-7) was altered every five participants, and the order between sets (set 1/2/3) was also changed every five participants to counter order effects. After finishing the tasks, the participants filled in a questionnaire asking for age, education, gender and visual capabilities.

Results

In the following table the mean is represented per condition per box. The means (M) show that there does not appear to be much difference between non-informative vision and blindfolded participants. The relatively high standard deviation makes the results more suited for drawing conclusions.



Means per frame per condition. Error bars +/- 1SEM

The graph clearly illustrates how there does not seem to be a preference for neither the absolute/relative nor the intrinsic frame. The results were analyzed using a repeated-measures ANOVA. The within-subjects variable of reference frame had seven levels, each corresponding to one specific spatial configuration. The between-subject variable of condition contained two levels, non-informative vision and blindfolded. Given the difference in content between the 7 reference frames, a significant effect was found for this within-subjects variable ($F(1.836, 51.409)=11.772$, $p=<.001$)[1]. Considering the fact that some boxes were aligned withall the frames and some with none of the frames, an effect was

[1] Due to the significance of Maulchy’s test of Sphericity (W=0.003, p=<.001), the Greenhouse-Geisser correction was used

to be expected.

Between the frame and the condition, there was no significant difference between the conditions for the different reference frames (F(1.836, 51.409)=1.239, p=.296). The between-subjects effect of condition was also not significant (F(1,28)=0.183, p=.672). A pairwise comparison of NIV and blindfolded participants has also shown that none of the different spatial configurations had significant differences. The results as stated above show that generally there is no effect from blindfolding or non-informative vision on reference frame preference in sighted individuals. However, the relatively high number of participants with a range >2, shows that responses were relatively inconsistent. A range above 2 might indicate a change in strategy or support the ambiguity suggested by 'front'.

Condition	Frame	M	SD	Subjects with >2 range
Non-informative vision	cARI	6,2444	1,47716	2
	cNo	2,8222	1,43021	1
N=15	cAR	4,8889	2,47421	4
	cI	3,6444	2,76735	3
	ncAR	5,0000	2,20749	4
	ncI	4,2000	1,85934	5
	ncNo	2,6000	1,34636	3
Blindfolded	cARI	6,3556	1,23099	1
	cNo	2,5333	1,61737	2
	cAR	3,7111	2,65732	2
N=15	cI	4,8444	2,65434	2
	ncAR	4,0667	2,42409	2
	ncI	4,8444	1,90182	5
	ncNo	2,2667	1,56955	2

Figure 1. Results per condition per frame

When zooming in on the canonical and non-canonical absolute/relative and intrinsic configuration in a 2 x 2 x 2 MANOVA with canonicity, reference frame (absolute/relative vs. intrinisic) and condition as factor, no significant effect has been found of canonicity (F(1,28)=1.430, p=.242) between canonicity and tcondition (F(1,28)=.132, p=.719). This means that typicality doesn't influence reference frame preference in both the sighted and blindfolded participants. Also no effects have been found of reference frame (F(1,28)=.002, p=.965) nor of the reference frame and condition interaction (F(1,28)=1.703, p=.203). No interaction between reference frame, canonicity and conditions has either been found (F(1,28)=.839, p=.368).

Discussion

The goal of this research was to determine the role of non-informative vision in spatial reference frame preference. Following the research done by Struiksma et al. (2011) the current research used seven boxes containing distinct spatial configurations of a ball and a shoe. Half of the participants were blindfolded and had to perform a haptic perception task three successive times. Responses were measured on a 7-point Likert scale and data were analyzed using MANOVA's and comparing between and within subjects. Results show no significant effects between non-informative vision and blindfolded participants on the haptic tasks. The fact that a significant effect has only been found between the different boxes and similarity of the response curve to the one produced by Struiksma (2011), supports the research method applied. Nonetheless, the availability of non-informative vision seems to have had no influence on reference frame preference in sighted subjects.

When looking at the results, no significant differences between sighted participants with or without blindfold become apparent. However, visual information is not the only influential factor of mental representations. The preference of reference frames can be influenced, or even primed, by variation of functionality or linguistic input. It is possible the term 'front' evokes a less ambiguous response in the blind. In a supramodal model the blind rely more on linguistic and tactile information for mental representations, which might evoke a response stronger than the ambiguity experienced by the seeing and low-vision participants. The intrinsic functional relationship between 'shoe' and 'ball' might have primed the preference of the intrinsic reference frame (Carlson-Radvansky & Radvansky, 1996). Even though actual visual perception is absent for the blind, there seem to be remarkable similarities and differences between the mental representations of both groups. I suggest further research manipulating the conditions as stated above. Since both functionality and speech do not depend on sight, the results of the current research encourage further exploration through different modalities.

There are some points in which the current research could be improved. Firstly, the sample size is quite small, it might even be insufficient. Some participants chose a clear strategy before starting the task, and some might even be confused as they showed a large response range in some cases. The short duration of the 'blindness' in blindfolded participants might explain why the response patterns between groups was so similar. Maybe extended training to being blindfolded might alter the preferred mental representations. For some configurations, as many as five participants had a range larger than two, which is one fifth of the group. A larger group could have provided more accurate results. Secondly, stimuli serving as noise might be added. Each response clearly contributed to the test and the repetition might have given something away. Adding non-relevant additional stimuli might counter this.

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